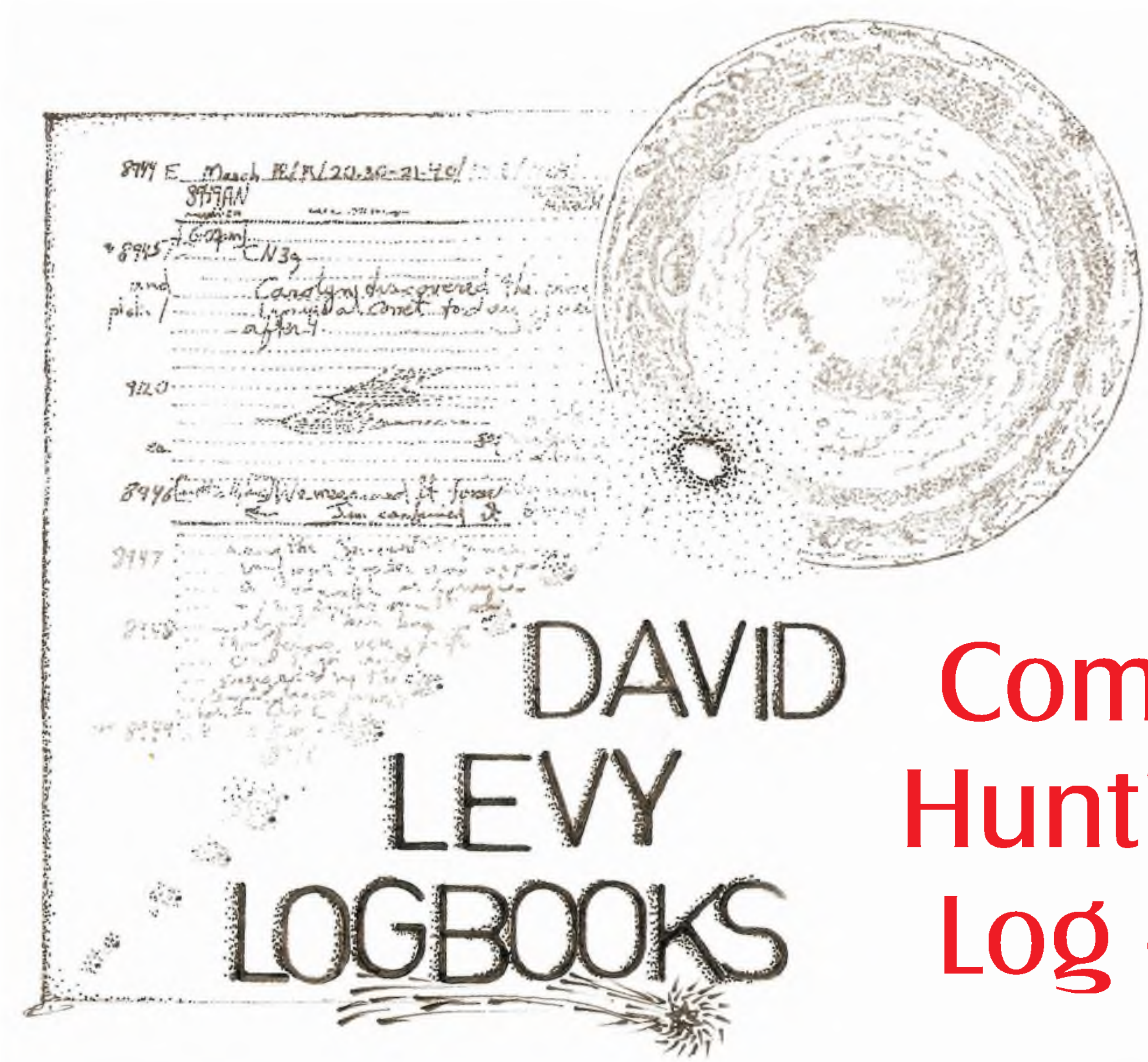

Comet Hunting Log #1

Prepared 2016 by David H. Levy

CN 3

Research on Comets and Novae

CN3 ~~2~~ – the Ph.D.

The Sky in Early Modern English Literature:

A study of how celestial events between 1572 and 1610 were interpreted in Elizabethan and Jacobean writing

A Doctoral Dissertation by

David H. Levy

for the Department of English, The Hebrew University

"I have the greatest admiration for a man or woman who discovers
because I know of the hard and thorough work which the success impli

--W. R. Brooks, quoted in Mary Proctor, (1926) The Romance of Come

"(~If you hunt long enough, sooner or later you will someda
comet.) Keep hunting and stay away from Virgo."

--Robert Burnham Jr., conversation, June 6, 1967.

To the comet hunters,
past, present and future

--Dedication to Peter L. Brown, (1973) Comets, Meteorites and Me

Here is a message for you:

David and Steve:

I'm glad you liked the minor planets "Levy" and "Larson"! I rath
you might have had an inkling that they were in the works at th
"Asteroids II" but didn't feel I should say anything! Actually,
several other participants there who now have minor planets, so Ric
viewgraph already needs substantial updating. It's OK, we can h
more things called "Levy" in the sky: get out there looking again!

Brian, Apr. 5, 12 45 UT

--Brian Marsden, 1988

Comet Search Codes.

CN3 original comet search program. December 17, 1965.

CN3a added Edmund wide field finder telescope. October 7, 1970.

CN3b used larger 12-inch telescope RASC. March 1973. Other borrowed instruments.

CN3c Catalogue of masqueraders. Fall 1977.

CN3d Miranda used for search. September 11, 1981.

CN3e TV Corvi, and other variable magnitude objects like P/S-W 1. December 17, 1986.

CN3f Photographic and electronic searching. December 17, 1988.

CN3g Joining with other group searches, December 17, 1988. (CN3fg responsible for Periodic comet Shoemaker-Levy 9 discovery.)

CN3h Automated searching, Esther. Also Project Hope. December 17, 2001.

CN3i formerly CN3nb11. Search with Joshua Cole.

CN3j Kreutz comet search. December 17, 2001.

CN3k11. Electronic search with Clyde. December 17, 2002.

CN3L11. Comet hunting with Lothar and Paula's Minnowbrook lens. January 19, 2006.

CN3-40m. Comet hunting with Flaire! December 17, 2005.

CN3n. Comet unting with Ulysses. December 17, 2005.

CN3o11. Formerly CN3nll. Secondary camera with Esther. December 17, 2005.

CN3p. 1977-2015 and ongoing. Comet research in the Victorian era–Tennyson

Aims:

① To become "very" familiar with the sky through searching for comets and/or novae.

② To discover either a comet or a nova.

③ To learn as much as possible about comets and/or novae through a research program.

(As of Dec. 17, 1965, the main interest area is in the field of comets.)

④ To observe other comets too! (Dec '84) CN3S

Comet Notes

By VAN BIESBROECK

COMET VAN GENT-PELTIER. This comet has gone through a short-lived period of brightness. We mentioned last month that this object, which in the beginning of December was located too far south for observers on this side of the equator, would probably soon become an evening object. It was, indeed, independently discovered by Leslie C. Peltier of Delphos (Ohio), who has already so many comet discoveries to his credit. He swept it up in his 6-inch telescope in the evening of December 17, and gave the rough position as $23^h 20^m$, $-16°$, with the indication "moving slowly westward." He called the brightness equivalent to a 7^m star.

COMET VAN GENT-PELTIER
(Drawing from a photograph taken December 24 with the 24-inch reflector of the Yerkes Observatory.

Comet Van Gent-Peltier-Daimaca was found by Leslie Peltier on December 17, 1943, 22 years before CN3 began.

C/1944 I = C/1943W1

C/1943 W1 1944 I van Gent-Peltier-Daimaca
1944 01 12.250 27 Nov, Johannesburg (vG). 3 Dec, Giclas (Flagstaff).
16 Dec Targul Jiu, Rumania (D). 17 Dec, Delphos OH (P).
http://pds-smallbodies.astro.umd.edu/comet_data/comet.catalog

CN3s.

Comets seen (Dec 30 1984) (visual)

1. 1965F Ikeya-Seki Oct 29 1965.
5. 1968c Honda.
2. 1966d Kilston 9. 1973- Kohoutek
3. 1966 Barbon (d) (1632 EM-12) 10. 1974- Bradfield (March 28)
4. 1967n Ikeya-Seki 2 **2019EM2.
6. 1969 Tago-Sato-Kosaka
7. 1970 Bennett
8. 1970 Abe 1973 f Kohoutek 11. 1975 Kobayashi-Berger-Milon
12. 1976 West 51. *3462E C/Kohler 1977m. Diffuse ...,
13. 1980 Bradfield. 4458 Ez Feb 10. 1979 l
14. 1980 (4850AN2) P/Stephan-Otterma 1867-I.
15. P/Encke 1786-I
16. P/Tuttle 1790-II.
17. 1980 φ Meier 1980 φ
18. 1980 Panther 5117EM
19. 1982 Austin *5948E2. 20. *5860E. Bowell.
21. 1982f P/Churyumov-Gerasimenko. *6066EM3
22. 1982e d'Arrest, definitely now, 6051E. possibly also 7yrs earlier, *2298EM.
23. 1983d *6280M2 Iras-Araki-Alcock.
24. 1983. *6291AN Kopff.
25. 1983 **6340M P/Tempel-2. Ind. disc.
26. 1983e Also ⊕ approacher; Sugano-Saigusa-Fujikawa 28. 1984. Crommelin.
27. 1983v. Hartley-IRAS. ⊕⊕6456E, ind. disc. 29. 1984. Austin.
30. 1984t. Levy-Rudenko. ⊕⊕⊕6684E.
31. 1984s. Shoemaker. *6701AN.
32. 1984k. Arend-Rigaux.
33. 1984m. Schaumasse
34. 1984p. Tsuchinshan I.
35. 1984f. Shoemaker.
36. 6817M Machholz 1985e.
37. 6833E P/Giacobini-Zinner.
38. *6879AN P/Halley. 1982i.
39. *6883AN P/Maury 1985k. $m_v = -16$
40. *6885EM Hartley-Good 1985l.
41. *6921E Thiele. 1985m. moved in real time
42. 6957AN P/Grigg
43. *6961AN P/Ciffreo 1985p
44. 6960AN P/Boethin

CN3s.

Comets seen (visual)

45. 7120M P/Machholz 1986e
46. 7198 E Churyumov-Solodovnikov
47. 7129EM Wilson. (Wilson B on 7657AN)
48. 7270E Sorrells
49. 7276AN P/Schwassmann-Wachmann II
50. 7277AN C/Urata-Niijima
52. 7310AN P/Comas Sola
1987 53. 7314M Levy. (1987a)
54. 7327E. Nishikawa-Takamizawa-Tago. (1987c)
55. 7328EM2 P/Wiseman-Skiff (1987b)
56. 7336AN Terasako (1987d) (sunward feature)
57. *7468M P/Schwassmann-Wachmann I
58. *7445AN Shoemaker 1987o.
59. *7445AN P/Klemola
60. *7463AN P/Grigg-Skjellerup
61. *74643 AN Torres 1987j.
62. *7476 M2 P/Brooks 2. (again on ** 7552AN2)
63. *7478M2 P/Howell
64. *7482M P/Reinmuth 2
65. *7507E Bradfield 1987s.
66. *7513E Rudenko 1987u. seen through discovery t
67. *** 7536E Levy 1987y.
68. ** 7552 AN2 P/Harrington.
69. " P/Kohoutek 1986k.
70. " P/Gehrels 1.
71. " P/Borrelly
72. *7565AN P/Shoemaker-Holt 1987z.
73. *7566AN P/Mueller 1987a,
74. " P/Helin
75. *7569M Ichimura 1987d,
76. *** 7570AN Furuyama 1987F. confirmation observat
77. 7583 5EM Jensen-Shoemaker
78. 7585AN2 P/Reinmuth I ~~179~~ 178 Bradfield.
79. " P/Longmore
80. " P/West-Kohoutek-Ikemura 28 on 198
88 81. 7600EM Liller
82. 7602AN McNaught
83. 7659AN Shoemak
84. " MAURY-PHINN 88c.
85. 7675AN P/Hartley 3 1988d

CN3s.

Comets seen (visual).

86. 7684M2 Levy 1988e.
87 7715AN P/Gunn.
88. 7727AM2 Shoemaker-Holt 1988g
89. 7761AN Shoemaker-Holt-Rodriquez 1988h
90 7772M Machholz 1988j
91 7907AN Ge-Wang 88o.
92 7925M2 Yanaka 88r
93 7931AN Helin-Roman-Crockett 89b ~~178) Yanaka 88~~
94 7931AN Yanaka 89a
95. 7963AN Shoemaker 89e
96. " Shoemaker 89f
97 " P/Parker-Hartley 89i
98. P/Clark 89h
99. Shoemaker-Holt 89j
100. 7994AN P/Pons-Winnecke
101. 8049EM P/Brorsen-Metcalf
102 8061AN Okazaki-Levy-Rudenko 1989r
103. 8104AN Helin-Roman-Alu 1989v
104 8104AN Helin-Roman-Alu 1989w
105 8139AN Comet ~~P/Kowal 3,~~ better known as 2060 Chiron
106 8193AN Comet McKenzie-Russell
107 8194AN Comet P/Wild 4 1990a
108 8197E Comet Austin. 1989c,
109 8156AN Comet Skorichenko-George
110 8263AN Comet Cernis-Kiuchi,-Nakamura 1990b
111 8270M2 Comet Levy 1990c
112 8279M P/SW-III.
113 8372- ~~P/Shoemaker-Levy 1991d~~ Aarseth-Brewington
114. Nov 1990 8432EM Shoemaker-Levy 1991d
115. P/Metcalf-Brewington.
116. ~~Shoemaker-Levy 1991e~~,. (177 July C/Tsuchiya-Kiuchi,
117. P/Levy 1991f (174 P/Wolf-Harrington
118 Zanotta-Brewington. (134) 8759E - Comet Mueller
119 Machholz. Independent find,
120, 9104E. Mueller 1993a.
121 9184E. McNaught-Russell
122 Shoemaker-Levy 6
123 9202M2 Takamizawa-Levy

CN39.

124. P/Swift-Tuttle.
125. Periodic Comet Shoemaker-Levy 9
126. P/Machholz 2.
127. 9255AN. Nakimura-Nishimura-Machholz.
128. 9528M De Vico
129. 9535M2 Bradfield
130 9636E Szczepanski
131. Hyakutake 1995 Y1
132. Hyakutake 1996 B
[illegible] Hale-Bopp
134 Comet Mueller - see opposite, 21 Feb-1992
135 ~~Sw~~ P/Tempel-Tuttle.
136. P/Harrington - Abell. 10,806E2. 18 Dec 1998.
137 Aug 11 1999 Lee. (2nd. Disc)
138. C/Linear 1999 J3 (2nd. Disc)
139. C/Linear near Polaris.
140 C/Linear 2000 July 2. (2nd disc.)
141. C/Linear C/2001A2 12129SE2.
142. C/Batters 2001W2 *12554E2
143 C/Linear 2000 WM1 *12554E2.
144 C/Ikeya-Zhang.
145. C/Petriew Canadian Discovery.
146. C/Snyder-Murakami
147. C/ ~~Ust~~ Utsunomiya 12756M3.
148 C/2002T1 Linear.
149 C/2001 O4 Neat
150 8 17P/ ~~Holmes~~. (2002) "Swan" near Pollux, fast motion no tail
151 8P/Tuttle.
152 Machholz C/2004 Q2
153. Hoenig C/2002 O4.
154. Swan. C/2006.
155 P/Levy 2006 T1.

CN3s.

192. P/Lovas I. August 23, 1989. 61"
193 C/Catalina. December 17, 2015. Obadiah vessel.

Date	Times Start–Finish (very approx)	Total (exact)	
1965			
(1) Dec. 17, 1965	23:55-~~00~~:05	00:10	Between Pollux + Castor
(2) 19	20:45-20:55	00:20	Between γ + β Arietis; among 3 stars of Orion's belt.
~~3. 26~~			
(3) 26	20:00-20:40 21:20-21:30 21:35-21:40 21:55-22:05	01:25	7h 50m to 6h. +28°
1966			
(4) Jan. 1	19:00-21:30	01:55	~~7 hours 50m~~ 7h 50m to 4hrs +28° to ~~to~~ +40° along an
(5) 3	23:10-23:15	02:00	~~+12°30'~~ +11° to +12° 10h 7m to 9h.
(6) 15	17:40-18:05	02:10	5h 15m to 3h 40m; +46° to +47° - along an arc
	18:45-19:15	02:40	5h 50m to 1h. +8° to +10°.
	22:45-23:10	03:00	~~10h 20m to~~ 11h 30m to 4h 45 +12° to +15°.
(7) Feb. 12/13	00:45-01:00	03:15	5h to 10h } along an arc. +45° to +60° }
(8) June 24/25	00:00-0300	↓	14h 15m +20° 2h 40m +45° } along 14h 30m +40° 2h +60° } within
	03:00-0330	2¼h. 05:30	2h 15m +15° 1h +15° } al 23h +45° 22h +30° } t
(9) June 30/31	00:50-0115	¼h. 05:45	~~in~~ roughly in vicinity of Pegasus
(10) July 4/5	2200-0430	2h. 07:45	(1) { 13½h -10° — 1h +75° along certain areas wit { 13h +10° 0h 90° these blocks. (2) { 16h -5° 1h +60° { 19h +15° 2h +60° (3) Pegasus & Cassiopea area & vi (Twilight horizon)
July 7/8	0045-0100	¼h. 0800	16½h +25° to 0h 90°. along an arc

2

DATE.	START	FINISH	ACCUMULATED TOTAL	
(12) July 11/12	0030 ~~0137~~	0137	0840	15h 80° to 0h 90° / 16h 80° to 19h 70° } along arcs in above block, plus in region of Pegasus' Square
(13) July 12/13	0045	0148	0918	15h +25° 12h +75° / 16h 07 -29° 18h +30° } along certain arcs in bl
(14) July 13/14	0140	0347	10 41	(1) ~~Polaris~~ 0h 90° to 10h + 60° (2) 0h 90° to 14h + 20° along arcs around her
(15) July 14/15	0035	0400	13 04	12h +55° to 18h +50° / 14h +40° to 19h +32° } along cert arcs in
(16) July 15/16	0025	0120	13 15	
(17) July 16/17	0019	0325	14 39	Polaris — N horizon.
(18) July 17/18	0005	0020	14 47	Pegasus + region.
(19) JULY 18/19	0205	0238	15h 17m	Pegasus, UMi, Draco, Lyr + vcn.
(20) JULY 20/21 ~~19/20~~	0042	0355	17h 38m	Polaris to N horizon.
(21) July 30/31	0300	0307	17h 43m	Pegasus + region.
(22) Aug 3/4	2155	2255	18h 26m	UMi, Boo - Region.
(23) Aug 5/6	2234	0004	19h 33m	UMa, Boo, Sco Region
(24) Aug 6/7	2220	2245	19h 45m	UMa, Dra, Region | Surveyor 40
(25) 10/11	2313	2318	19h 50m	Hercules
(26) 13/14	2129	2151	} 21h 55m	UMa - TWT HZN.
	0029	0250	}	Aries, Pegasus.
	0335	0437	22h 40m	Taurus - TWT Hzn
(27) 14/15	~~002~~ 2145	2150	22h 45m	UMa - TWT Hzn.
↓	0023	0245	24h 43m	(Cyg, Pg, Aries) area.
(28) ~~15~~	0344	0408	25h 02m	Andromeda - ~~Tr~~

	DATE	START	FINISH	TOTAL	
28	17-18	0112	0130	25h 19m	Andromeda, Aries, Taurus.
		0202	0430	27h 10m	
		0443	0456	27h 20m	Twilight Horizon.
29	19-20	2210	2215	27h 25m	U Ma
		2245	2327	28h 07m	U Ma
30	20-21	2050	2140	28h 42m	Bootes, Hercules
		2350	0014	29h 01m	
		0058	0200	29h 56m	Draco, Ursa Major
		0235	0251	30h 12m	Pg, Aries
31)	23-24	0027	0435	32h 34m	Pg, Aqr, Cet, + region. Twilight horiz
32)	27-28	0230	0530	34h 34m	Pg, Aries, Orion-region. Twilight H
33)	28-29	0200	0500	36h 07m	Pg, Aries, Taurus, Andromeda region.
34)	31-32	0200	0300	36h 12m	UMi, Cam + region.
35) Sept.	5/6	2145	0410	38h 23m	Pg, Aries, Andromeda, Gemini & a CrB, U Ma, Dra, Boo
36)	7-8	2045	0459	4h 54m 43h 17m	UMa, CrB, Her, Lyr, + vcn; UMi, Dra + Pg, And, Aqr + vcn; Ori, Gem; CMi
37)	8-9	2230	0210	46h 08m 2h 51m	Aql, Pg, And, Ari, Per + vcn.
38)	9/10	0230	0400	46h 18m	Pg
39)	10/11	2300	0115		
		0235	0530	48h 39m	Pg, Ar, Psc, Ori + vicinity —; Psc Aus
40) Oct.	21/22	0525	0625	49h 34m	Leo + vcn.
41)	24/25	0530	0625	50h 25m	Leo, Cancer
42)	Nov 12/13	0450	0600	50h 45m	Leo + vicinity, Bootes, Virgo
43)		1730	1805	51h 15m	U Ma, UMi, Dra
	Nov 13/14	1930	2100	52h 19m	Peg, Tau + vcn.
44)	Nov 18/19	2240	2330	53h 00m	Peg, Taurus + vcn.

DATE	START	FINISH	TOTAL		AREA SEARCHED
45) Nov. 19/20	1750	0005	55h	27m	Peg, Ori, Tau, And + vcn.
	0455	0605	56h	25m	Leo, + vcn; Bootes, ~~Co~~ Co[illegible]
46) Nov. 20/21	1725	1755	56h	52m	~~P~~ Her, Boo + region.
~~46~~ 46) Nov. 20/21 also	0440	0620	58h	04m	Leo, Boo, Com & vcn
47) ~~1~~ Nov. 21/22	0450	0605	59h	05m.	Leo, Boo, Com + vcn.
48) ~~1~~ Dec. 18/19	0535	0600	59h	10m	Bootes + vcn; Leo
49) Dec. 27/28.	0430	0630	60h	25m	Bootes + vcn.
50) Dec. 30/31	~~0530~~ 1730	2000	60h	45m	Peg, And, Aur + vcn
51) 1967 January 15/16	1919	2050	62h	05m	~~Pea~~ Gem, Aur + vcn.
January 17/18	1850	1910	62h	21m	Aur, Per + vcn.
52)	0516	0620	63h	21m	~~B~~ Hercules + vcn. (Ten below zero
January 18/19 53)	2250	2325	63h	51m	Orion. (Cosmos)
January 30/31 54)	1900	1930 ~~2200~~	64h	03m	Auriga; Taurus; general vicinity.
January 31/32 55)	2000	2100	64h	38m	Aur; Tau; vcn.
February 3/4 ~~56~~ 56)	2100	2200	65h	20m	Gemini, Leo + vcn.
February 6/7 57)	~~200~~ ~~1400~~ 1915	2010	65h	58m	Gemini, Leo – vcn.
February 7/8	1940	1955	66h	10m	Gemini, vcn.
58)	0500	0615	67h	11m	Hercules, Summer Δ area (Five below
59) 11/12	2300	0025	68h	06m	~~A~~ vcn. Auriga
60) 12/13	0500	0610	68h	54m	Hercules, Lyra + vcn. (Cyg.) (2 radio stations:- Ten below; 16 below)
61) 13/14	1850	2030	70h	01m	Orion. (Cosmos)
62) ✓ 17/18	0100	0300	71h	05m	Hercules, Bootes, vcn. (Pegas

No.	Date	Start	Finish	Total	Instrument	Area Searched
46)	18/19	1850 2340	2005 0045	72h 05m 73h 00m	Pegasus Cosmos	Gemini and east vcn. Leo
64 ~~47)~~	19/20	1955	2120	74h 02m	Pegasus	Gemini Cancer Leo
65 ~~48)~~	21/22	0510	0605	74h 47m	Pegasus	Hercules, Lyra, vcn.
66 ~~49)~~	26/27	~~0400~~ 2100 0450	2130 0600	75h 04m 76h 04m	Cosmos Pegasus	vcn. Orion Oph, Her, vcn.
67 ~~50)~~	March 1/2	1835 0515	2105 0555	78h 05m 78h 35m	Cosmos Pegasus	Pers, And; Ori (2h vcn Lyr–Cyg (avoided Milk
68 ~~51)~~	3/4	2215	0615	5 hours 0m. 83h 35m	Cosmos	Leo, Boo, vcn; Her, vcn.
69 ~~52)~~	11/12	2100	2150	84h 20m	Cosmos	Cancer, vcn.
70 ~~53)~~	24/25	2200	2230	84h 30m	4" Townsend	Gemini, Cancer
71 ~~54)~~	31/32	2100	2330	86h 30m	~~6" R~~ Cosmos	Leo, vcn.
~~55)~~ 72	April 20/21	2330	0030	87h 00m	Pegasus	Her, Lyr, vcn.
73 ~~56)~~	25/26	2200	0410	91h 40m	Pegasus	~~Arcturus,~~ Bootes ~~Lyr~~, Lyr, Her, vcn
74 ~~57)~~	26/27	2300	0400	95h 40m	Pegasus	Bootes, Lyr, Her, vc
75 ~~58)~~	MAY 3/4 1967	2100 EDT	2200	96h 00m	Cosmos	vcn. of "upper" Virgo (away from galaxies)
~~59~~ 76)	May 5/6	2030	0300	99h 00m	Pegasus	Bootes, Lyr, Hercules, Cep, Cass, UMi, vcn.
77)	May 6/7	2100	0500	104h 00m (5 hrs)	Pegasus	Bootes, Lyr, Herc, vcn. & UMi, vcn. Boo, Oph., ~~vc~~ Sag, vcr
78)	May 19/20	0230	0420	105h 30m	Little Joe	Pegasus, Cyg (West), vcn.
79)	May 21/22	~~03~~ 2200	2300	106h 30m	Little Joe, Pegasus	Polar region
80)	May 26/27	2300	0405	110h 35m	Little Joe, Pegasus	Her, Lyr, Cyg, (not m.w Pegasus
81)	~~J~~ 30/31	2200	0500	113h 20m	Moonwatch	(Tucson)

No.	Date	Start	Finish	Total	Inst	Area
82)	~~3~~ May 31/32	2015	0300	117h 30m	4" Moonwatch	(Tucson)
83)	June 1/2	~~21~~ 2030	0530	↓	Moonwatch	(Tucson)
84)	June 2/3	2000	2300	122h ↓	Moonwatch	(Tucson)
85)	3/4	2200	~~23~~ 0400	124h 00m	Moonwatch	(Tucson)
86)	July 3/4	2200	0310	127h 35m	Little Joe, Maksutov	(Skycrest)
87)	8/9	2200	2300	128h 30m	Little Joe	(Skycrest)
88)	24/25	0030	0130	128h 45m	Little Joe	(Skycrest)
89)	25/26	0000	0500	131h 00m	Little Joe, Peg Maks.	(UMi, Peg)
90)	26/27	2200	2330	131h 25m	Little Joe	Bootes
91)	30/31	2300	0030	132h 05m	Little Joe	Boo + vcn.
92)	Aug 1/2	2100	0500	136h 15m ✓	Little Joe, Mak.	Boo, Her, vcn. UMi, vc Taurus, vcn.
93)	6/7	2300	0100	137h 20m	Midas	~~UMi~~ Her + vcn.
94)	8/9	2100	0100	138h 35m	Midas	Her + vcn.
95)	10/11	2300	0330	141h 10m	Midas	Her, UMa, UMi, vcn.
96)	11/12	2330	0030	141h 45m	Midas	~~Her~~ Her
97)	31/32	2200	2300	142h 05m	Little Joe	Peg
98)	Sept. 1/2	2100	0515	147h 35m (5h 30m record)	Little Joe	Peg, vcn. E. - mainly East sky all night.
99)	4/5	2100	2300	148h 55m	Little Joe	Peg
100) ✓	5/6	0100	0215	149h 40m	Little Joe	E. sky.

No. - Date		Start-Finish	Total	Inst.	Area Searched
			7h 30m	Little Joe	
101) Sep	6/7	2020-0540	157h 10m	Pegasus - 1hr.	general sky — !
102)	10/11	2100-0500	163h 10m	Little Joe	Peg, Taur, Aqr, CMi, Gem,
103)	12/13	2100-0545	169h 50m (6h 40m)	(Pegasus) - 1hr. Little Joe	Peg, Taur, Cet, vcn. Gem, vcn.
104)	13/14	2000-0605	178h 00m (Record 8h 10m)	Peg - 4½ about L. Joe - 4½ about.	Peg, And, Taur, vcn.; Cet, vcn; Gemini, vcn;
105)	14/15	2100-0130	180h 00m	Peg - about ½ hr. Litt. Joe	Peg, Taur, vcn.
106)	15/16	2100-2300	180h 40m	Pegasus	Pegasus + vicinity
107)	16/17	2300-2340	181h 00m	Lit. J.	Pegasus
108)	20/21	2200-2210	181h 10m	Cosmos	vcn. Peg.
109) Oct.	1/2	2200-2330	182h 15m	Little Joe	Peg, vcn.
		0550-0615	182h 35m	Little Joe	Gem, Cancer, vcn.
110)	2/3	0430-0615	184h 00m	Little Joe	Gem, Cancer, vcn.
111)	7/8	2000-0300	187h 02m	Little Joe	Ursa Minor, vcn; And, Psc, vc
112)	23/24	0115-0225	188h 07m	Little Joe	Vcn. of Pollux - Castor side of
113)	30/31	0105-0210	189h 10m	Little Joe	Cancer & vcn.
114) Nov.	1/2	0505-0520	189h 12m	Little Joe	
115)	3/4	0050-0215	190h 15m	Little Joe	Aur, Gem, vcn.
116)	10/11	2100-2330	192h 00m	Little Joe	vcn Peg, And.
117)	15/16	0050-0205	193h 00m	Little Joe	Orion + vcn (mostly); Auriga.
118)	24/25	2300-0015	193h 21m	Little Joe	Gem + vcn.
119)	28/29	0100-0130	193h 36m	Little Joe	Gem + vcn.

No.	Date	Start-Finish	Total	Inst.	Area Searched
120)	Dec. 1/2	1700-0245	198h 06m (4h 30m)	Little Joe	Aqr + vcn; Eastern sky
21)	3/4 20:10 approx 200th hr	1700-2100 — 0100-0230 concluded	200h 20m / 201h 13m	Little Joe / Little Joe	And, Aries + vcn. Taurus + vcn. Cancer, Leo, vcn,
122)	5/6	0330-0445	202h 15m	Little Joe	UMa
23)	9/10	1900-2030	205h 02m	Little Joe	Aur, Tau, UMa, vcn.
24)	15/16	0020-0135	206h 02m	Little Joe	UMa, Leo, vcn.
25)	16/17	0155-0310	207h 02m	Little Joe	UMa
26)	20/21	1730-0150	210h 12m	Little Joe	Peg, And; Orion, vcn; UMa
27)	23/24	1900-0400	214h 02m	~~Little Joe~~ Elmer	Peg, And, vcn, Gem + vcn, UMa, UMi + vcn.
28)	24/25	1805 - 0330	218h 02m	~~Little Joe~~ Elmer	Ori, UMa, UMi + vcn.
29)	26/27	17:15-0315	222h 02m	Elmer	UMa, UMi, vcn; Ori. (Temp in teens)
130)	29/30	23:00-00:30	223h 15m	Elmer	Orion
131)	1968 Jan. 1/2	2100-2300	224h 15m	Echo	Gem, Cancer
32)	Jan. 5/6	1730-2350	225h 15m	Little Joe	Gem, Can, UMa, vcn.
133)	7/8	1730-1805 / 2245-2310	225h 45m / 226h 00m	Little Joe / Little Joe,	Aur, vcn. ~~Can, vcn.~~ Can, vcn. —12°F and w
134)	8/9	1730-1935	226h 30m	Little Joe	Peg. vcn. Gem.
135)	10/11	2230-0145	228h 00m (1½ hrs - temp -6°F)	Little Joe	Cncr + vcn; UMi
136)	15/16	0000-0115	229h 00m	Little Joe	UMa, vcn.
137)	Feb 7/8	0030-0135	230h 00m	Little Joe	UMa, CVn
138)	Feb 23/24	2000-0000	232h 00m	Peg, L. Joe	Cancr, UMa, vcn

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No	Date	Start-Finish	Total	Inst.	Area Searched
139)	24/25	2030-0130	235h00m	Peg, Lit.Joe Echo	U Ma and vcn.
140)	25/26	0145-0305	236h00m	Little Joe	Eastern sky, Her + vcn.
141)	26/27	~~0~~2330-0035	237h00m	Little Joe	Boo + vcn.
142)	March 1/2	2100-0200	240h03m	Little Joe	Boo + vcn. (E. Sky)
143)	2/3	0430-0540	241h04m	Little Joe	Aquila + vcn.
144)	5/6	2345-0100	242h05m	Little Joe	Boo + vcn.
145)	6/7	0100-0215	243h06m	Little Joe	Oph, Her, vcn.
146)	8/9	2000-0230	246h34m	Little Joe	Leo, vcn., Cancer, vcn, Her, vcn.
147)	11/12	2345-0020 0100-0215	247h09m 248h09	Little Joe Little Joe	E. sky (Boo, vcn) Her + vcn.
148)	13/14	0000-0115	249h09	Little Joe	Boo, Her, vcn.
149)	14/15	0000-0110	250 02	Little Joe	Her, vcn.
150)	24/25	~~0~~2315-0025	251 02	Little Joe	Boo, vcn.
151)	27/28	0030-0145	252 03	Little Joe	~~Boo~~, Her, vcn.
152	29/30	2130-0005	254 00	Little Joe	~~Oph, vcn.~~ Boo, CBr, vcn.
153	30/31	1930-0100	256 00	Little Joe	Boo, vcn. Her, vcn.
154	April 1/2	0015-0120	257 00	Little Joe	Her + vcn.
155	2/3	2350-0045	257 40	Little Joe	Her + vcn.
156	6/7	0015-0050	258 00	Little Joe	Her, vcn.
157)	7/8	2050-2215	259 00	Little Joe	-Eastern sky-

No.	Date	Start-Finish	Total	Instrument	Area Searched and Comments
158	12/13	2330-0010	259h30	Little Joe	vcn. moon - during total eclipse
159	14/15	0400-0435	260h00m	Little Joe	East. sky
160	16/17	0000-0110	261 00	Little Joe	Lyra, vcn.
161	27/28	0000-0440	264 20	Little Joe. Pegasus	Boo, Oph, vcn., E. sky
162	28/29	2030-0550	270 35	Pegasus Lit. Joe	Boo, Oph, C Br, Peg, Her, vcn.
163	29/30	2100-0100	272 25	Little Joe	Gem, vcn. Her, vcn.
164	MAY 1/2/3	2055-0430	277 49	Pegasus 1, LJ 4½	Cancr, vcn; UMi, vcn;, Boo, vcn, Peg
165	5/6	2055-2330 0315-0430	279 39 280 35	Peg .40, Lit. J. 1 Little Joe	UMi, Boo, vcn. C Br Peg + vcn, Boo, vcn.
166	6/7	2050-0415	286 10	Little Joe, 6" Dynascope (5min)	UMi, vcn; Aur, vcn; Boo, vcn.
167	7/8	2330-0430	290 10	Little Joe	Boo, vcn. Peg vcn.
168	10/11	2030-0200	291 00	Little Joe	UMi, vcn. Boo, vcn.
169	12/13	0200-0330	292 00	Little Joe	~~H~~ Peg, vcn.
170	13/14	~~030~~ 2130-0130	295 00	Little Joe - 1 Peg - 2	UMi, ~~P~~ Boo, Her, Peg
171	15/16	0030-0200	295 55	Little Joe	~~H~~ UMi
172	19/20	2100-2300	296 30	Little Joe	UMi
173	20/21	0130-0230	296 50	Little Joe	Peg, vcn. (E. sky)
174	22/23	0230-0330	297 15	Little Joe	Peg, vcn.
175	23/24	2340-0400	301 30	Pegasus	Her, Peg. (3h 34m without stopping)
176	26/27	2130-0100	303 20	Little Joe Pegasus	UMi, vcn. Her

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No	Date	Start-Finish	TOTAL	INSTRUMENTS	AREA SEARCHED & COMMENTS
177	27/28	~~3??~~ 2100 - 0030	305 00	Pegasus Little Joe	Hercules + vcn.
178	31/32	2100 - 0430	309 40	~~Peg~~ Arcturus	Hercules, Ophiuchus, Ursa Min Ursa Major
179	June 3/4	2330-0300	311 40	Arcturus	Draco, Ursa Minor
180	4/5	2130-0420	315 50	Arcturus.	Dra, UMi, Peg.
181	5/6	2130-0420	319 50	Arcturus	Dra, UMi, Cep, Peg, vcns.
182	16/17	2200-0100	321 10	Little Joe	UMa, Oph, vcn.
183	July 3/4	0000-0030	321 15	LJ	Cass vcn
184	4/5	0000-0345	324 19	LJ	Cass vcn
185	6/7	0000 - 0345	327 24	LJ	Cass - Per, vcn. not Milky Way.
186	8/9	2350-0115	328 24	Spica	UMi
187	10/11	~~0~~ 2300 2330	328 40	LJ	UMi, vcn
188	17/18	2300 0000	329 15	LJ	Her, vcn.
189	23/24	2300 0230	331 20	LJ	Oph, vcn.
190	26/27	2230- 0230	333 42	LJ	Oph, Aqr, vcn,
191	28/29	2330-0130	335 12	LJ	Sco, vcn.
192	August 2/3	2230-2330	335 50	LJ	UMa, UMi, vcn.
193	13/14	0130-0330	336 30	LJ	U Ma vcn
194	14/15	2230-0130	338 05	LJ	U Ma, vcn.
195	[illegible]	[illegible]	[illegible]	LJ	UMa, vcn.

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196	~~12/13~~ 17/18	2200-0130	342 35	Little Joe	UMa vcn.
197	20/21	2200-0300	343 20	LJ	UMa, Ssky.
198	21/22	2200-0130	344 50	LJ	UMa, Peg
199	30/31	2300-0110	345 13	LJ	UMa, vcn. ~~Oph~~ Peg, vcn.
200	31/32	2000-0510	350 38	LJ	UMi, Peg, vcns.
201	Sep 7/8	2000-0530	357 18	Peg	Dra, Vcn. ~~Cn~~ Gem, vcn-
	Independent discovery of comet 1968c (Honda)				
202	8/9	0000-0130	357 53	Peg	Tau, vcn.
203	12/13	2300-2345	358 18	~~Pe~~ LJ	Peg, Her, Sag vcn (t)
204	15/16	2030-0100	362 00	LJ	UMa UMi Boo Peg Aqu Psc Aus
205	16/17	2030-2330	364 00	LJ	UMa, UMi
206	17/18	2030-2245	366 00	LJ	Boo, UMa UMi Her
207	18/19	2025-2305	368 00	LJ	Boo, vcn; UMa, UMi, Dra, Her, CrB
208	19/20	2025-2335	371 00	LJ	Boo vcn; ~~UMa~~, Dra, Her, CrB, Aqr-
209	20/21	2035-2240	373 00	LJ	Boo, vcn; Dra, UMa, UMi
210	21/22	2015-0615	382 20 Record 4h20m	LJ	Boo; vcn; Dra, UMi; Cet, vcn Ori; Cancr, vcn; UMa.
211	22/23	2100-2145	383 00	LJ	And, vcn.
212	29/30	2000-2205	385 00	LJ	~~LJ~~ Boo, vcn, Her, Dra
213	~~3~~ 1/2 Oct	2000-2100	386 00	LJ	Boo, vcn. Her, CB
214	6/7	2130-2300	387 00	LJ	UMi, vcn.

215	10/11	2000-2105	388 00	LJ	Boo, vcn; UMi, vcn.
216	Nov 4/5	1900-1945	388 20	LJ	UMi, vcn.
217	6/7	2000-2035	388 30	LJ	UMi, UMa
218	17/18	1945 2015	389 00	LJ	UMi, vcn.
219	26/27	1945 2020	389 30	LJ	UMi, vcn.
220	27/28	1830-1910 2230-2330	390 00 391 00	LJ LJ	~~UMi, vc~~ W. horizon UMi, vcn.
221	30/31	1945-2110	392 00	LJ	UMi, vcn., Draco
222	December 10/11	2230-2305	392 30	LJ	Ori
223	11/12	1730-1815	393 00	LJ	W. sky, UMi.
224	1969 Jan 21/22	1900-2005	394 05	LJ	Aqr, vcn, Ori
225	22/23	2105-2210	395 05	LJ	Ori, vcn, UMa, vcn, Lepus
226	23/24	1945-2045	396 00	LJ	Aqr, vcn.
227	Feb. 7/8	2100-2205	397 05	LJ	Aqr, Cet, UMi, vcn.
228	8/9	1900-2230	**400 00**	LJ	UMa, vcn.
2 nights 229 230	Summer '69		401 10	LJ, Pgs.	
231	Sept 2/3	2100-0300	405 00	LJ, Pgs.	E sky.
232	3/4	2300-0000	406 00	Pgs	E sky.
233	1970 Feb 25/26	0000-0115	407 05	LJ	Bootes, vcn.
234	May 4/5	2200-2230	407 15	LJ	Gem, vcn

May 235	May 23/24	23/24	2130-0100	409	00	LJ	Gem, Leo, Cancer.
236		28/29	2330-0030	409	55	LJ	Leo, UMa, UMi
237		29/30	~~2000-0~~ 2300-0000	410	40	LJ	Leo, Cnc, vcn.
238	June	~~5/6~~	2~~1~~30-2330	411	40	LJ	Leo, UMa, UMi, Cass,
239	June	13/14	0130-0230	412	40	LJ	UMa, UMi, Cass, vcn.
240		14/15	0030-0110	413	00	LJ	UMa, UMi, Cass, vcn.
241		15/16	0000-0030	413	20	LJ	"
242		16/17	0000-0030	413	40	LJ	"
243		17/18	~~000~~ 2300-0000	414	40	~~L~~ 5" RFT	"
244		~~20~~/21	0245-0315	415	00	LJ	UMi, vcn, Cyg.
245		23/24	2330-0100	416	00	LJ	Her, vcn; Aqr, vcn.
246		25/26	2350-0100	417	00	LJ	" "
247	July	17/18	2215-2315	417	45	LJ	~~H~~. UMa, vcn.
248		23/24	0015-0035	418	00	Spica	UMa, Vcn.
249	Aug	2/3	2300-2355	418	45	Spica	UMa, vcn.
250		4/5	2300-0030	419	00	Spica	Hercules.
251		5/6	2200-0000	420	40	Spica	Boo, UMa, Her
252		6/7	2130-0000	421	00	Spica	Boo, UMa.
253		7/8	2130-0000	422	00	Spica, Apollo, Antares	Boo, UMa.

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254)	8/9	2300-0000	422 51	Spica	UMa, Boo, vcn.
255)	9/10	0930-0515	425 22	Spica, Apollo, Antares, Echo	UMa; Her, vcn.; Tau, Aur, vcn UMi
256)	10/11	~~0~~2330-2330	426 08	Apollo	UMi, UMa, Dra, vcn.
257)	12/13	2115-2310	427 00	Echo	UMa, vcn. Boo
258)	14/15	2130-2330	427 20	Spica	UMa, UMi, vcn.
259)	15/16	2130-2330	427 25	Spica	UMi, vcn.
260)	18/19	2130-0130	429 30	Spica, Apollo, Antares	UMi, UMa, Her, Boo, v Apt - 1st hr. Ant + Spica - end
261)	19/20	2240-0200	430 30	Spica,	UMi, etc. Cloud hop.
262)	27/28	2330-0230	432 30	Pegasus	Peg, Aries, Taurus, vcn.
263)	29/30	2030-0530~	438 35	Pegasus, 6" F/4	Echo, 8" F/4.5 Lossing] Peg, Aqr, Houston[UMi, UMa, Boo, Her,
264)	31/32	2030-0030	440 06	Pegasus	Pegasus, Aquarius; UMa, vcn.
265)	Sept. 2/3	2100-0030	442 00	Pegasus	Aqr, Peg, vcn.
266)	5/6	~~2200~~ 000-0230	443 00	Pegasus	Peg, vcn.
267)	8/9	~~01~~ 2100-2230	443 22	Echo	Peg, vcn.
268)	11/12	2100-0430	446 52	Little Joe	Peg, And, vcn. UMi, UMa, vc
269	12/13	2030-0615	454 32 (7h 40m)	Little Joe	~~UMa~~, Boo, vcn., Her, Oph, vcn.; ~~Pe~~. And, vcn; UMa, vcn.
270	~~13~~14/15	2050-2150	455 32	Little Joe	W. sky - Bootes, vcn. bright full moo
271	19/20	0200-0320	456 22	Little Joe	U Mi, vcn.
272 ✓	20/21	2100-2320	458 32	Little Joe	uma, u mi, vcn; her, vcn: independent find of comet ...

No	date	time	acc. total	inst	area
273	23/24	~~2200~~ 2040-2205	459 49	little joe	her, vcn; uma, vcn; umi, vcn.
274	24/25	2200-2205	459 50	little joe	her; independent fin of comet abe
275	29/30	0035-0205	460 45	little joe	Peg, vcn; delph, vcn.
276	october 2/3	2100-2215	461 45	little joe	oph, ~~or~~ her, vcn. (lcp-ac212)
277	5/6	2350-0117	463 02	little joe	peg, and, aqr, vcn.
278	6/7	0210-0320	464 05	little joe	ori, tau, psc, peg, vcn.
279	7/8	2345-0135	464 58	little joe	tau, psc, peg, vcn.
280	8/9	2350-0130	465 39	little joe	~~t~~ peg
281	21/22	0120-0130	465 49	little joe	peg
282	30/31	0200-0300	466 39	little joe	ori
282	31/32	2100-2230	467 39	little joe	peg, vcn.
283	1971 jan 18/19	0200-0250	468 04	little joe	leo
284	24/25	0200-0235	468 29	little joe	~~te~~ umi, vcn.
285	27/28	0125-0145	468 48	little joe	umi, vcn. cloud hopping
286	29/30	~~0130~~ 0200-0217	469 03	little joe	leo
	July '72	485 h	485 00		
	Dec 31 '72	~~489~~	489 00		

* under country sky

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	date	time	acc. ttl.	inst.	area
1973 Jan	2/3	2200-0205	490 30	12½-inch, Peg, LJ	and, gem, leo, boo, vcn.
	3/4	1740-1810 1900-2000	491 10	LJ	evening ~~two~~ eastern sky
	4/5	0300-0330	491 15	LJ	bootes
	5/6	~~0000~~ 2355-0135	492 15	Peg, LJ	LMi, vcn; east sky.
	6/7	1730-0130	494 00	Peg, 8-in. Clarkson, LJ.	Gem, Ori, LMi, vcn., etc
	7/8	0040-0140	495 00	LJ	eastern sky from wini – seeing quite good
	8/9	1730-2300	497 00	LJ	e. sky.
	11/12	0020-0130	498 00	LJ	Boo, + vcn; vcn, etc etc.
	12/13	0210-0320	499 00	LJ	Bootes, vcn.
	15/16	0200-0215	499 05	LJ	Vcn. Bootes.
	20/21	1930-2100	500 00	Peg	UMi, vcn.
	29/30	after midnight	500 40	LJ	E. sky.
March	24/25	2215-2245	500 55	12½-inch.	N. sky, etc.
June	2/3	2145-2245	501 55	LJ (?) ?Peg	east. near overhead sk Boo, vcn. - eastward
July *	5/6	0000-0130	502 55	LJ	Bootes, vcn., etc.
*	6/7	~~0~~2330-0100	503 30	LJ	Bootes, vcn. - etc.
	9/10	2200-0000	504 30	~~L~~ Peg	Hercules, vcn, etc.
	22/23	~~00~~ 2340-0045	505 30	Peg	UMi, vcn.
	23/24	2230-0000	506 30	LJ	Her; vcn.

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	Date	Time	acc. ttl.		inst.	area
	29/30	0050-0115	506	45	Peg	UMi, vcn.
Aug	28/29	2200-2300	507	00	LJ	(Farmington, Me.) NW S... CrB, v...
	29/30	2200-2300	507	10	LJ	(Sussex, NB). NW Sky.
1975. Oct.	4/5	~0230-0245	507	25	LJ	Pegasus, vcn.
	5/6	~0145-0200	507	40	LJ	Peg, vcn.
	6/7	0145-0200	507	55	LJ	UMi, vcn.
	7/8	0145-0200	508	10	LJ	Ori, vcn.
	8/9	~~0~~2300-2330	508	25	LJ	Aqr, vcn.
	9/10	01:30-02:15	508	55	LJ	UMi, vcn.
Nov	23/24	0100-0130	509	10	LJ	UMi, vcn.
1976 Feb	24/25	~~010~~ ~~0~~2310-2325	509	15	Pegasus	U Mi, vcn.
March	23/24.	0120-0140	509	30	Pegasus	"
	24/25	~~01~~ 22~~30~~20-2240	509	45	Celestron	Gemini (non milky way) + vc...
	25/26	0020-0040	510	00	Pegasus	U Mi, vcn.
	28/29	2325-0025	511	00	Pegasus	UMi, vcn.
July	3/4	0255-0315	511	20	LJ	And, vcn.
	9/10	0140-0150	511	30	Pegasus	hunt for Comet d'Arrest
Aug	24/25	0347-0450	512	32	Pegasus	Aur, Tau, Gem vcn.
Dec	24/25	2300-2315	512	47	LJ	Orion + vcn
1977 ~~Jan~~ Feb	4/5	2015-2030	513	02	LJ	W. Sky

19	Date	Time	Acc. Total	Instrument	Area
	26/27	2300-2325	513h 02m	Little Joe	Orion, vcn.
	27/28	2210-2220	513h 07m	LJ	Orion, vcn.
	29/30	0000-0025	513 22	LJ	UMa, vcn. *
1977	11/12	2148-2205	513 37	LJ	Ori, Eri, Lep
January (? Feb)	16/17	0015-0200	513 47	LJ	UMa, CVn, vc
	19/20	0003-0016	513 57	LJ	Ori, vcn.
	21/22	2255-2315	514 12	LJ	Ori, vcn → Tau,
	22/23	2320-2345 0005-0010	514 37	LJ	Ori, Tau, vcn,
	23/24	2323-0000 0005-0025	515 02 515 12	LJ	Cam, UMa, vcn. *
	24/25	0000-0040	515 42	LJ	UMa, Cam, vcn
	25/26	2240-2350	515 52	LJ (16.3)	UMa, Cam, vcn
	26/27	2355-0000	515 57	LJ	Cam + vcn.
March	~~27~~ 10/11	2317-2325	516 02	LJ	UMi, vcn.
	18/19	2353-0010	516 17	LJ	Cam, Her, UM
April	13/14	2200-2215	516 32	LJ	UMa, vcn *
	15/16	2050-2300	516 47	LJ	Cor, Vir, Boo,
	16/17	2205-2230	517 02	LJ	UMa, Boo, vcn.
	20/21	2245-2315	517 22	LJ	UMa, vcn.

20	Date	Time	Acc. Total	Inst.	Area
June	6/7	0210 - 0305	517 52	Little Joe	UMa, UMi, Dra cloud hopping
July	25/26	0030-0055	518 13	Little Joe	Peg, region to N + NW.
Oct.	7/8	2050-2055 2220-2310	519 03	Little Joe	UMa, UMi vcn.
1978 June	5	0040-0240	519 08	Pegasus	UMi
	15	~~0115-0230~~ 0230-0340	520 18	Pegasus	Peg, And.
	22	2205-2315	520 43	Pegasus (Mira)	Leo (Cyg)
	24	2200-0020	521 13	Pegasus	Leo, CBr, CVn *
	27/28	0130-0215	521 43	Pegasus	SW sky.
	~~2~~28/29	2215-2355	522 58	Little Joe	Leo, Boo, vcn
	29/30	~~24~~ 0200-0340	523 18	Pegasus	Peg, Agr *
July	1/2	2255-2335	523 48	Little Joe	N Sky *
	2/3	0230-0300	523 55	Little Joe	
	4/5	2200-2300	524 10	Little Joe	Lyra + vcn
August	4/5	2215-2300	524 40	Little Joe	N.
	22/23	2355-0020	524 55	LJ (on Procyon)	Pegasus
	29/30	0210-0250	525 25	Apollo	Pg + vcn.
	31/32	0030-0230	526 25	Pegasus Apollo	Peg + vcn E sky
Sept	1/2	2210 - 0300	527 55	Cosmos	Pg + vcn
	2/3	2100 - 0430	530 45	Pegasus	Oph, Peg, Cet, vcn

	Date	Time	Acc Total	Inst.	Area
	3/4	2100-0510	532 55	Pegasus? + Apollo	sky
	4/5	2145-0335	533 00	Spica-Cosmos	Psc + vcn.
	9/10	~0320-0335~	533 10	Mira	e. sky
	12/13	0125-0200	533 25	Little Joe	Independent discov of Nova Cygni made just before
	28/29	1950-2135	533 50	Mira	SW sky
1978 Oct.	1/2	0040-0130	534 05	Mira 3	sky
	2/3	0130-0215	534 20	Mira 3	"
	4/5	2000-2050	534-50	Apollo	Her
	23/24	1930-0030	535 20	Spica?	Peg + vcn
Nov	2/3	1730-1910	535 50	Little Joe	W Sky
	7/8	0000-0215	536 05	Pegasus?	Cancer + vcn.
		0445-0605	536 45	Little Joe	Hydra + vcn.
	19/20	1800-1935	537 00	Little Joe	W Sky
	20/21	2050-2130	537 05	Spica	N Sky
	30/31	1750-1830	537 30	Pegasus	W Sky.
Dec	2/3	1740-1845	538 00	Mira	W+N
	17/18	~~1750~~ 1810-1850	538 30	Little Joe	13th anniv. ...
		2045-2300	538 40	Pgs?	

some sessions at
NW amherstview
comet hunt site

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	Date	Time	Acc Total	Inst	Area
	18/19	1850-1940	539 10	Little Joe	W Sky
	19/20	1755-1915	540 10	Little Joe	Her + vcn
	21/22	1750-1850	540 45	Little Joe	Her + vcn.
	23/24	1815-1845	540 55	Mira Ceti 3	W + N
1979: January	9/10	2215-2235	541 00	Mira 3	N
Feb	2/3	1815-1915	541 30	Little Joe	W
Mar	10/11	0030-0150	541 35	Propus	N Sky
	18/19	1940-2045	542 05	Pegasus	W Sky
	19/20	2000-2100	542 20	?	SW Sky
	20/21	1915-2040	542 50	Little Joe	W Sky
	21/22	1925-2030	543 20	Little Joe	W Sky
April	20/21	0300-0345	543 50	? Pegasus	E, SE
	22/23	1945-0130	544 20	Little Joe	W
	23/24	0000-0150	544 50	Pegasus	Her + vcn.
May	5/6	0340-0420	545 05	Little Joe	Pgs + vcn.
	8/9	2110-2230	545 35	Little Joe	W
June	18/19	2150-2310	546 05	Rigel	W

	Date	Time	Acc Total	Inst	Area	23
	24/25	0200-0400	547 05	?Apollo	E	
July	13/14	2230-0300	547 30	? Pegasus		
	14/15	2230-0200	548 35	Pegasus?		
400	24/25	2330-0030	548 45	Mintaka	Lyr + ucn?	
Aug	11/12	~~00~~ 2130-0440	549 15	Jarnac II		
		— Tucson —				
Oct.	6/7	1900-1950	549 45	~~P~~ Spica	W	
	7/8	1900-2000	~~54~~ 550 15	Spica	W	
	9/10	1900-2040	551 15	Pegasus?	W	
	10/11	1845-2100	552 15	Pegasus	W.	
	11/12	1920-2100	552 45	Pegasus.	Cloud hopp	
		0010-1330	553 15	Pegasus	Lep, + ucn.	
	12/13	evening	554 15	Pegasus?	W.	
		0500-0540	554 55	Pegasus?	E.	
	13/14	0005-0350	556 15	Pegasus		
	14/15	1810-2000	557 25	Rigel + Pegasus.		
	15/16??	(4114EM2) 1835-2100	558 35	Rigel + Pegasus		
	16/17	~~180~~ 0000-0340	558 40	Pgs?		
		0430-0600	559 45	Pegasus + Rigel		

	Date	Time	Acc Total	Inst	Area
	17/18	1830-2210	561h 15m	Pegasus	W
	18/19	1830-2030	562h 20m	Pegasus, Rigel	W
	19/20	1835-0155	563h 30m	Rigel, Pegasus, Mercury	W+S
	20/21	~~18~~ 0320-0400	563h 32m	Spica	E?
	22/23	1830-2005	564h 32m	Rigel+Pegasus	W.
		2030-2100	564h 40m	Pegasus?	
	24/25	~~2~~ 1820-2010	565h 40m	Pegasus, Rigel	
			565h 50m	(1h 10m total tonight in session 4147E2) ✓	
	25/26	1800-1910	566h 20m	Rigel + Pegasus.	W.
		2330-0115	566h 50m	Pegasus.	S.
	26/27	1800-0600	567h 20m	~~Peg~~, Rigel	W.
			567h 50m	Pegasus	SW.
			568h 50m	Pegasus	
			569h 30m	Pegasus	E.
	28/29	1815-1915	570h 00m	Spica?	W.
	29/30	1820-2000	570h 10m	Rigel	W.
			570h 15m	Rigel	~~W~~S. See * 4162M
	31/32	1800-1900	570h 45m	Rigel, Pegasus	W
Nov.	4/5	1810-1900	571h 15m	Rigel	W.
	5/6	1830-1935	571h 45m	Rigel, Pegasus	SW, NW
	8/9	1815-1900	572h 15m	Jarnac II.	W.
	10/11	1815-2030	573h 15m	Pegasus,	W.
	11/12	1820-2025	574h 45m!	Rigel and Pegasus,	W and S

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Date	Time	Acc Total	Inst	area
13/14	0030-0225	575h 00m	Pegasus	S.
	0500-0600	575h 30m	Pegasus	E.
14/15	0000-0325	576h 05m	Pegasus	S.
15/16	1830-2030	577h 05m	Pegasus, Rigel	W.
	0000-0245	577h 50m	Pegasus	NE.
16/17	2355-0110	578h 50m	Little Joe	S. (W. of Orio
19/20	1815-1900	579h 00m	Rigel, (Pgs?)	W.
	2345-0245	579h 35m	Pegasus?	
~~23/24~~ 22/23	1800-1820	579h 40m	Ganymede	W.
23/24	0450-0610	580h 25m	Pegasus	E.
24/25	00450-0630	581h 35m	Pegasus	S, E.
25/26	1815-2000	582h 10m	Pegasus	W.
26/27	1830-2000	582h 40m	Pegasus	W.
	2200-0205	582h 55m	Pegasus	Cnc
27/28	1750-1900	583h 25m	Pegasus	W.
Dec 1/2	1810-1900	583h 35m	Rigel	W.
2/3	1820-1840	583h 45m	Rigel	W.
8/9	1820-2300	584h 45m	Pegasus	W & NW
	(1 hr may be missing here. See 4296E2)			
10/11	1820-2000	585h 45m	Pegasus, Rigel	SW.
13/14	1820-[illegible]	58[illegible]	P[illegible]	

	Date	Time	Acc Total	Inst	Area
	14/15	1830-2000	587h 45m	Pegasus	SW.
	15/16	1850-2025	588h 45m	Pegasus	SW.
	17/18	1815-0630	591h 45m	Pegasus, Rigel	SW, SE, E.
				CN III's Fourteenth anniversary.	
	23/24	1830-2035	592h 15m	Pegasus.	W.
	27/28	1815-1930	592h 45m	Pegasus	W.
	28/29	1825-1930	593h 05m	Pegasus	SW.
	29/30	0450-0635	594h 25m	Pegasus	E+NE.
1980 January	4/5	1830-2015	595h 25m	Pegasus	W.
	12/13	1820-2230	597h 25m	Syncom 3	W
	13/14	~1900-2000~	598h 25m	Syncom 3?	W.
	15/16	~~19~~2230-0100	599h 25m	Syncom 3	W.
	16/17	1830-2000	600h 25m	Syncom 3	W.
		0500-0610	601h 15m	Syncom 3	E.
				(from S. remote site)	
	22/23	0500-0620	602h 15m	Syncom 3	E.
	24/25	0500-0620	603h 10m	Syncom 3	E.
	25/26	1900-2000	603h 45m	Syncom 3	W.
		0500-0630	604h 45m	~~Syncom~~ Pegasus	E

26/27 time unlogged?

27	Date	Time	Acc. Total		Inst.	Area.
	26/27	0455-0530	604h 55m		Syncom 3	E
	27/28	0500-0620	605h 45m		Pegasus?	E
Feb.	~~28~~ 1/2	1900-2025	606h 15m		Syncom 3	W
	9/10	1850-2200	606h 55m		Syncom 3	~~E~~ W
	10/11	~~1~~ 2300-2345	607h 55m		Syncom 3	
	11/12	1850-2100	608h 40m		Syncom 3.	W
	21/22	0500-0620	609h 40m		Syncom 3.	E
	24/25	0540-0600	609h 55m		Syncom 3	E
	26/27	0500-0615	610h 40m		Syncom 3	E
March	12/13	1900-2100	611h 10m		Syncom 3	W
	17/18	0430-0600	612h 00m		Syncom 3	E.
	23/24	0230-0530	613h 30m	1h 30m	Syncom 3	E
April	2/3	1930-2000	613h 35m		Syncom 3	E.
	— (4545EM4)	1930-0210	614h 15m		Pegasus	~~E~~ W.
	** 4549 EM4	1820-0220	616h 00m	1h 45m	Pegasus	W, E.
	9/10?	1930-2115	616h 15m		Pegasus	
	13/14	1830-0605	617h 50m	1:35	Pegasus,	W, E

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	Date	Time	Acc Total	Inst	Area
	15/16	0400-0500	621h 20m	Syncom 3	~~0430~~ E.
	18/19	0400-0500	622h 10m	Syncom 3	E.
	21/22	0430-0435	622h 15m	Syncom II	E.
May	5/6	1930-2040	622h 35m	Syncom 3	W.
	7/8	1900-0200	623h ~~00~~ 35m 1:00	Syncom 3	W.
	8/9		62~~3~~4h ~~30~~ 05m	Syncom 3	W.
	9/10	0350-0420	624h 35m	·? Syn. 3?	E.
	11/12		624h 55m	Syncom 3	W.
	12/13		626h 05m	Syncom 3	W
		0345-0500	626h 35m	Syncom 3	E.
	~~13~~/14/15:		~~6~~627h 15m	Syncom 3	W.
	17/18	0400-0430	627h ~~15~~ 30m	Syncom 3	E
	21/22	0300 0430	628h 30m	Syncom 3	E.
	22/23	0400 0420	628h 35m	Syncom 3	E
June	3/4	2000-21~~45~~ 35	629h 20m	Syncom 3	W
July	19/20	0230-0330	630h ~~3~~20m	Syncom 3	~~W~~. E.
Aug	12/13	0100-0400	631h 00m	Syncom 4.	
	16/17	2105-0100	631h 30m	Syncom 4.	

	Date	Time	Acc. Total	Inst	Area
Sept	15/16	0000-0100	633h00m	4"f/4 (? Cassiopeia)	
	16/17	0415-0515	633h35m	? Cassiopeia	E
	18/19	0430-0515	633h50m	Cassiopeia	E.
	20/21	0330-0540	634h40m	Cassiopeia	E
(500)	21/22	0440-0525	635h10m	Cassiopeia	E
	22/23	0455-0515	635h20m	~~Cassiope~~ Antares	E
	27/28	1900-2130	636h25m	Syncom 3	W
	28/29	1910-1950	636h 5~~0~~5m	Virgo	W
	29/30	1900-1955	637h 2~~0~~5m	Syncom 3	W
Oct	1/2	1910-2050	638h25m	Syncom 3	W.
	7/8	1845-(0545)	639h25m	Syncom 3	W. evening
		-0545	640h10m	~~Sy~~ Little Joe	E.
	8 9/10	1850-2330	642h50m 2:40	Syncom 3	E.
		0445-0600	643h25m	Virgo	E.
	10/11	~~---~~ ~0400-0610	644h10m	"	E.
	11/12	1930-0230	645h40m 1:30		~~E~~ W.
	12/13	0315-0415	645h45m	Cassiopeia?	S.
	14/15	0430-0530	646h30m	Cassiopeia	E.
	17/18	predawn 0325-0600	647h30m	? Spica	E.
	25/26	1900-1930	647h45m	Syncom 3	W

	Date	Time	Acc Total	Inst	Area Searched
	29/30	1850-2000	648h 15m	Syncom 3	W
Nov.	7/8	0430-0600	649h 15m	Cassiopeia ~~Syncom 3~~	E.
	12/13	0430-0600	649h 50m	Virgo	E.
	20/21	0500-0545	650h 05m	Virgo	E.
	[22/23	2000-20130	20 min	Isis	N. Do not tot
	24/25	1830-1930	650h 40m	Syncom 3	W.
	26/27	~~20~~ 1830-1930	650h 55m	Syncom 3	W..
	27/28	1825-1915	651h 20m	Syncom 3	W.
Dec.	1/2	1820-1920	651h 50m	Syncom 3	W - new S
	2/3	1900-2000	652h 30m	Pegasus	W.
	3/4	0605-0625	652h 35m	~~Pegas~~ Maia	E. (TH)
	5/6	0540-0610	652h 55m	Cassiopeia	E.
	17/18	15th anniversary.			
1981 Jan	1/2	1900-~~2100~~50	653h 30m	Pegasus	W. ?
		Rolf Meier did 2h hunting, also w. Peg.			
	21/22	1830-1930	654h 00m	Pegasus	W.
February	20/21	1930-2215	654h 30m	Pegasus	W.
	23/24?	(5139E3)	654h 40m	Pegasus	E.?
	24/25	·	654h 55m	? Pegasus	E.

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	Date	Time	Acc Total	Inst.	Area Searched
Mar	10/11	0130-0600	655h 15m	Pegasus	E
	13/14	0500-0530	655h 35m	Pegasus	E.
	25/26	1800-0030	656h 05m	Pegasus.	
	26/27	~2300-~0100	656h 20m	Pegasus?	E.
	30/31	~0030-~0145	657h 20m	Pegasus	E.
	31/32	0130-0230	657h 40m	Pegasus? + Cassiopeia?	E
April	1/2	2000-2300	658h 00m	–	E.
	3/4	0100-0330	658h 40m	Pegasus	E.
	6/7	2330-0200	659h 20m	Pegasus	
	7/8	0000~-0100~	659h 40m	Pegasus.	
	8/9	~0000-0100	659h 55m	Pegasus	
May	5/6	0330-0430	660h 20m	Pegasus.	
	6/7	0330-0430	660h 55m	Pegasus.	
June	early	three ~~pa~~ consecutive predawn sessions; 5255,6,7m.	660h 05m 661h 15m 661h 25m	Pegasus Pegasos Pegasus.	
	11/12	0300-0400	662h 05m	Pegasus.	
	12/13	0300-0400	662h 55m	Pegasus.	
	13/14	~~0140~~ 0400-0430	663h 10m	Pegasus.	

Lunation 32

Mo	Date	Time	Acc. Total	Inst.	Area Search
July	11/12	0230-0310	663h 30m	Little Joe	East
August	27/28	2030-0500	666h 50m 3:20	Little Joe	W, S, E.
Sept.	9/10	0030-0130	667h 00m	Pegasus, (JM4)	
	10/11	0200-0300	667h 10m	Pegasus	Tau-region
I	~~11/12~~				
	11/12	0430-0505	667h 40m	Jupiter	Between Pollux and Castor, then East hunt
II					
	17/18	1900-2000	667h 45m	Jupiter	W.
	~~18~~/19/20.	1900-2300	2h05m 669h 50m	Jupiter	W.
	20/21.	~~1~~ 2300-0000	670h 20m	Jupiter	E.
	23/24	2300-0130	672h 20m	Jupiter.	
	27/28, 5423M2	0000-0100	672h 40m	Jupiter	E.
	28/29, 5424EM.	2330-0030	673h 00m	Jupiter	
October	~~1~~2/3, 5426M2.	0330-0530 ~~1900-2100.~~	673h 30m	Jupiter	E.
	3/4, 5427M	0000-0100	674h 00m.	Jupiter.	
	5/6 5429M.	0000-0020	674h 10m	Jupiter.	
	6/7 5431M2	0230-0520	675h 45m	Jupiter.	
III	19/20 5447E	~~0~~0100-0300	676h 45m	Jupiter.	
	21/22 5448E	0015-0100	677h 15m	Jupiter.	

Lunation/Mo.	Date	Session	Time	Total	Acc. Total	Inst.	Area
Dec	26/27	**5566EM2.	0200-0210	0.05	696h55m	Jupiter	Pollux-Castor
		– 2nd Light Ceremony					
	28/29	5573M4	0600-0620.	0.05	697h00m	Jupiter	E.
	29/30	5578M4.	0430-0530	0.20	697h20m	Jupiter	E.
1982 Jan.	2/3	5589M.	0500-0630	1.00	698h20m	Jupiter Maia	E.
VI	13/14	5606E	1855-1935	0.30	698h50m	Jupiter	W.
	20/21	5615E	1900-2000	0.30	699h20m	Jupiter	W.
	25/26	5622E2	1900-1930	0.20	699h40m	Jupiter	W.
		5624M4	0430-0615	1.25	701h05m	Jupiter	E.
	26/27	5625M	0430-0600	1.10	702h15m	Jupiter	E.
	31/32	5636M3	0445-0600	0.30	702h45m	Jupiter	E.
Feb.	1/2	5639M3	0440-0620	1.10	703h55m	Jupiter Europa	E.
	2/3	5640M	0440-0620	1.05	705h00m	Jup/Eur	E.
	3/4	5642M2	0500-0610	0.45	705h45m	Jup/Eur	E.
VII	25/26	5674M.	0430-0600	1.15	707h00m	Jupiter/E	E
(600~)	26/27	*5676M2	0315-0600	2.00	709h00m	J/Eur/Call	E.
Mar.	3/4	5685M2	0430-0615	0.45	709h45m	Jupiter	E.
VIII	15/16	**5705E	2030-2330	0.05	709h50m	Minerva	Pollux-Castor
			Little Joe is now known as Minerva.				
	22/23	5720M5	0430-0500	0.20	710h10m	Jupiter	E.
	23/24	5723M3	0425-0530	0.50	711h00m	Jup, Eur	E
	27/28	5730AM2	0500-0600	0.30	711h30m	Jupiter	E.
Apr.	1/2	5738M2	0315-0500	0.35	712h05m	Jupiter	E
IX	19/20	5768M	0330-0450	1.00	713h05m	Jupiter	E.

Lunation + Mo.	Date	Session	Time	Total	Acc Total	Inst	Area
Oct	22/23	5449EM	1900-0230	1h20m	678h35m	Jupiter	
	23/24	5451M2	0030-~0300	30m	679h05m	~~Jupiter~~ Pegasus	S.
	25/26	5456M2	0400-0535	1·10	680m15m	Jupiter	E.
	26/27	5457M	0400-0535	0·50	681h05m	Jupiter	E.
Nov.	2/3?	5460EM		2·10	683h15m	Jupiter	W.
		5461M2		0·50	684h05m	Jupiter	E.
	3/4?	5462M		0·30	684h35m	Jupiter	E.
	4/5?	5463M.		0·15	684h50m	Jupiter	E.
IV	16/17	5485E.	1930-2100	1·00	685h50m	Jupiter	W, E
	18/19	5488E.	1830-2100	1·00	686h50m	Jupiter	W.
	20/21.	5491M2	0100-0200	0·30	687h20m	Jupiter	E.
	23/24	5498E.	1830-2000	1·00	688h20m	Jupiter	W.
		5499M2	~0100-~0230	1.00	689h20m	Jupiter.	
	24/25	5502M3	0400-0600	1·15	690h35m	Jupiter	E.
	25/26	5503E	1850-2000	0·30	691h05m	Jupiter	W.
		5504M2	0415-0600	0·50	691h55m	Jupiter	E.
	28/29	**5506EM2	1825-1900	0·05	692h00m	Jupiter-W.	Official First
	30/31	5513E2	1835-1900	0·05	692·05	Jupiter-W	W.
Dec.	1/2	5517E2	2200-2230	0·10	692·15	Jupiter	W.
		5518M3	0030-0200	0·35	692h50m	Jupiter	SE.
	7/8	5533M	0425-0600	1h 05m	693h55m	Jupiter	E.
V	17/18 16th Anniv.	*5545EM	2340-0200	1·00	694h55m	Jupiter	
	23/24	5559E2	1845-2000	0·40	695h35m	Jupiter	W

Lunation/No.	Date	Session. Time		Total	Acc. Total	Inst.	Area
Dec	26/27		0200-0210	0.05	696h55m	Jupiter	Pollux-Castor
		**5566EM2.	– 2nd Light Ceremony.				
	28/29	5573M4	0600-0620.	0.05	697h00m	Jupiter	E.
	29/30	5578M4.	0430-0530	0.20	697h20m	Jupiter	E.
1982 Jan.	2/3	5589M.	0500-0630	1.00	698h20m	Jupiter Main	E.
VI	13/14	5606E	1855-1935	0.30	698h50m	Jupiter	W.
	20/21	5615E	1900-2000	0.30	699h20m	Jupiter	W.
	25/26	5622E2	1900-1930	0.20	699h40m	Jupiter	W.
		5624M4	0430-0615	1.25	701h05m	Jupiter	E.
	26/27	5625M	0430-0600	1.10	702h15m	Jupiter	E.
	31/32	5636M3	0445-0600	0.30	702h45m	Jupiter	E.
Feb.	1/2	5639M3	0440-0620	1.10	703h55m	Jupiter Europa.	E.
	2/3	5640M	0440-0620	1.05	705h00m	Jup/Eur	E.
	3/4	5642M2	0500-0610	0.45	705h45m	Jup/Eur	E.
VII	25/26	5674M.	0430-0600	1.15	707h00m	Jupiter/E	E
(600-)	26/27	*5676M2	0315-0600	2.00	709h00m	J/Eur/Call	E.
Mar.	3/4	5685M2	0430-0615	0.45	709h45m	Jupiter	E.
VIII	15/16	**5705E	2030-2330	0.05	709h50m	Minerva	Pollux-Castor
			Little Joe is now known as Minerva.				
	22/23	5720M5	0430-0500	0.20	710h10m	Jupiter	E.
	23/24	5723M3	0425-0530	0.50	711h00m	Jup, Eur	E
	27/28	5730AM2	0500-0600	0.30	711h30m	Jupiter	E.
Apr.	1/2	5738M2	0315-0500	0.35	712h05m	Jupiter	E
IX	19/20	5768M	0330-0450	1.00	713h05m	Jupiter	E.

Lunation 9 = 5h 15m (6h 10m)

Lunation No.	Date	Session	Time	Total	Acc Total	Inst	Area
		5770M	0350-0450	0.40	714h 20m	Jupiter	E
		5771M	0230-0400	1.00	715h 20m	Jupiter	E
	27/28	5782M	0130-0245	1.00	716h 20m	Jupiter	E
	28/29	5784M2	0400-0440	0.25	716h 45m	Jupiter	E.
May	2/3	5787M2	0400-0445	0.35	717h 20m	Jupiter	E.
X	10/11	5795E	2030-2045	0.15	717h 35m	Syncom 3	NW.
	~~11/12~~	5805M	0300-0500	0.30	718h 05m	Jupiter?	E.
		5806M	0300-0500	0.50	718h 55m	Jupiter?	E.
	21/22	5807M	0100-0200	0h 40	719h 35m	Jupiter	E?
	24/25	5812M	0200-0315	1h 00	720h 35m	Jupiter	E
XI June	18/19	5859M3	0230-0400	0h 50m	721h 25m	Jupiter	E.
	19/20	5861M2	0230-0400	0.30	721h 55m	Jupiter	E.
	20/21	5866M	0200-0220	0.10	722h 05m	Jupiter	E
	22/23	5867M	0230-0315	0.30	722h 35m	Jupiter	E.
	23/24	5868E	2000-2130	1.00	723h 35m	Jupiter	W.
	" "	5870M3	0300-0430	1.00	724h 35m	Jupiter	W.
	24/25	5871M	0100-0230	1.00	725h 35m	Jupiter	E.
	25/26	5873M2	0300-0400	0.40	726h 15m	Jupiter	~~W~~ E.
	26/27	5876M3	0210-0300	0.20	726h 35m	Jupiter	E.
	27/28	5880M4	0330-0415	0.20	726h 55m	Jupiter	E.
	30/31	5885M3	0315-0430	0.40	727h 35m	Jupiter	E.
July	2/3	5890M2	0300-0400	0.20	727h 55m	Jupiter	E.
		Good work!	Total Lunation 11 =			7h 20m.	
		July 5 –	Total Lunar Eclipse.			Saturn's party.	
XII	6/7	5896E	2100-2200	0.30	728h 25m	~~Ju~~ Syncom3	NW.
	11/12	5899M2	0400-0415	0.05	728h 30m	Maia	E.
	12/13	*5901M2	0330-0415	0.05	728h 35m	Virgo	E.
					– first light for	Virgo in Station 3	
	20/21 (~~13/14~~)	5907M	0400-0415	0.10	728h 45m	Virgo	E.
	22/23	5908M	0335-0415	0.20	729h 05m	Jupiter	E.
	25/26	5914M5	0200-0400	1.05	730h 10m	Jupiter	E.
	26/27	5919M3	0315-0415	1.00	731h 10m	Jupiter	E.
Aug	1/2	5930M2	0350-0420	0.15	731h 25m	Jupiter	E.
				Total 12 =	3h 30m		
XIII	6/7	5939E	2030-2200	0h 30	731h 55m	Minerva	W.
	17/18	5948E2	2215-2315	1.00	732h 55m	Minerva	SW.
		5949M3	0405-0505	1.00	733h 55m	Minerva	E.
	18/19	5951M2	0325-0430	0.45m	734h 40m	Minerva	E.

Lunation	Date	Session	Time	Total	Acc Total	Inst	Area
Aug mo. ~~20~~	20/21	*5954AN2	2130-010	1·00	735h 40m	Minerva	W
			0300-0430	1·30	737h 10m	Minerva	E.
	21/22	5955E.	2120-2230	0·30	737h 40m	Minerva	NW.
		5957M3	0215-0315	0·30	738h 10m	Minerva	E.
	31/32	5965M2	0315-0520	1·05	739h 15m	Minerva	E. and
		Ttl for 13 =		7h 50m.	Good work!		
Sept. XIV	4/5	*5966E	~~04~~2015-2100	0·15	739h 30m	Minerva	W
	11/12	*5975E.	2015-2315	1·30	741h 00m	Minerva	W, NW
			Total for 14 = 1h 45m				
Oct. XV	13/14	6005M	0000-0100	0·20	741h 20m	Jupiter	E
	16/17	*6011AN2	0300-0445	1·10	742h 30m	Jupiter	E
			0445-0515	0·30	743h 00m	Pegasus	E.
	19/20	6015M	0400-0530	1·10	744h 10m	Jupiter	E.
	21/22	6017M	0430-0530	0·40	744h 50m	Jupiter	E
	24/25	6021M2	0300-0530	2h 05m	746h 55m	Jupiter	E.
	25/26	6024M3	0240-0315	0h 15m	747h 10m	Jupiter	E.
	27/28	6026M2	0400-0545	1h 30m	748h 40m	Jupiter	E.
	28/29.	6028M2	0430-0515	0h 45m	749h 25m	Jupiter	E.
		Total 15 = 8h 25m.					
XVI Nov.	1/2	6032E	~~0~~1830-1915	0h 20m	749h 45m	Jupiter	W.
	~~2/3~~ 2/3	6033E.	1830-1900	0h 15m	750h 00m	Jupiter	W
	5/6	*6041E	1820-2230	1h 40m	751h 40m	Jupiter	W.
	9/10	6045E	1830-1835	0h 05m	751h 45m	Mercury	W.
	10/11	6049E	1830-1910	0h 25m	752h 10m	Jupiter	W.
	11/12	6050M.	0300-0510	1h 00m	753h 10m	Jupiter	~~W~~ E.
	12/13	6051E.	1830-2200	2h 00m	755h 10m	Jupiter	W.
	18/19	6060M2	0430-0530	0·15	755h 25m	Jupiter	E
	19/20	6064M	0415-0630	1·00	756h 25m	Jupiter	E.
	20/21	6066M3	~~2115~~ 0200-0400	1·30	757h 55m	Jupiter	E.
	21/22	6073M6	~~2~~ 0430-0600	1·00	758h 55m	Jupiter	E.
	✓28/29	6081M.	0530-0600	0·15	759h 10m	Jupiter	E.
		Total 16: 9:45✓					
Dec. XVII	3/4	6084E.	1930-2130	0·30	~~760h~~ 759h 40m	Jupiter	E.
	5/6	*6089E.	1830-2330	3h 10m.	762h 50m	Jupiter	E.
	6/7	6090EM	2130-0030	2h 20m.	765h 10m	Jupiter	E.
	11/12	6094EM	1920-2000	0h 30m	765h 40m	Jupiter	W.
	12/13.	60					
	13/14	6096E.	1835-1930	0h 05m	765h 45m	Jupiter	W.

Lunation	Date	Session	Time	Total	Acc Total	Inst	
	18/19	*6103AN2	1740-0715	7h30m	773h15m	Jupiter	
	20/21	6106M	0610-0030	0h10m	773h25m	Jupiter	
	22/23	6108M2	0500-0545	0h05m	773h30m	Jupiter	
	23/24	6109M	0500-0640	1h05m	774h35m	Jupiter	
	24/25	6111M2	0500-0650	1h00m	775h35m	Jupiter	
	26/27	6113M.	0500-0700	1h00m	776h35m	Jupiter	
XVIII						Total 17=17h25	
	31/32	6118E	1830-1915	0h15m	776h50m	Jupiter	
1983 January	1/2	6121E2	1800-2035	1h30m	778h20m	Jupiter	W
	7/8	6129E2	2000-2130	1h00m	779h20m	Jupiter	W
	8/9	6130EM	1800-2000	1h00m	780h20m	Jupiter	W
	9/10	6133M2	0445-0535	0h25m	780h45m	Jupiter	
	10/11	6134M2	0520-0630	0h40m	781h25m	Jupiter	E
			(was NGC 6364;36) - strange obj. in Hercu				
	11/12	6135E	1830-2130	1h15m	782h40m	Jupiter	W
		6136M2	0410-0615	1h20m	784h00m	Jupiter	E
	12/13	6139M2	0450-0620	0h50m	784h50m	Jupiter	E
	13/14	6142M3	0320-0710	1h30m	786h20m	Jupiter	E
	20/21	6150M	0450-0700	1h00m	787h20m	Jupiter	E
	21/22	6151M	0450-0700	1h00m	788h20m	Jupiter	E
(19)	23/24	6153M2	0300-0445	1h00m	789h20m	Jupiter	E
Feb	1/2	6166E2	1900-2100	1h00m	790h20m	Jupiter	W
	8/9	6169M2	0230-0410	1h00m	791h20m	Jupiter	E
	9/10	6184M	0500-0620	1h05m	792h25m	"	"
	10/11	6170M	0445-0620	1h05m	793h30m	"	"
	12/13	6173M.	430-620	1h00m	794h30m	"	E
	14/15	6175M		1h00m	795h30m	"	NW
(20)		6176M		0h35m	796h05m	"	E
March	9/10	6201M2		0h35m	796h40m	"	E
	12/13	6204M		0h50m	797h30m	"	E
	13/14	6205E		1h00m	798h30m		W
	16/17	6208M		0h25m	798h55m	"	E
	20/21	6212M		0h50m	799h45m	"	E

Location	Session	Date of Session	Total	Acc Total	Inst	Area
XXI Apr 2nd	6233E	2/3	1h 00m	800h 45m	Jupiter	W
	6234E	3/4	1h 00m	800/1h 45m	"	W
	6240E2	·	(at least) 20m	802h 05m	"	W
	6243M3		~ 40m	802 45	"	E
	6244E	10/11	2h 00m	804 45	"	W
	6245E	·	10	804 55	" ?	W.
(710)	6246M2		1 15	806 10	"	E
	*6247M		0 30	806 40	"	E
	6248M		#1 00	807 40	Jupiter	E
	6249M	15/16	1 40	809 20		E
	6252M3	16/17	1 35	810 55		E
	6253M	17/18	1 50	812 45		E
	6254M	18/19	2 00	814 45		E
	6255M	19/20	2 15	816/817 00		E
	6259M2	22/23	0 30	817 30		E
XXII May	6275E	1/2	1 30	819 00		W.
	6276E		2 00	821 00		W
	6279E		#1 00	822 00		W
	6283M	5/6	0 00	–		view of comet
	6284E	6/7	1 00	823 00		W.
	6285M2	·	30	823 30		E
	6288M3		0 15	823 15		E
	6290M2		1 30	824 45		E
	*6291AM		1 05	825 50		E
	6295M2		0 40	826 30		E
	6297M2		0 35	827 05		E
	6300M3	13/14	1 00	828 05		E
	6301M	14/15	30	828 35		E
	6305M4	15	15	828 50		E
XXIII	6321E	31	1 00	829 50		E
June	6322E	2?	0 40	830 30		W
	6324E2	3/4	1 30	832 00		W
	6326M	5/6	0 40	832 40		E
	6331EM2	9/10	0 45	833 25		W
	6338M	15	0 45	834 10		E
	6339M	16	20	834 30		E
**	6340M	17	10	834 40		E Indepen[illegible]

discovery of Tempel 2.

Lunation/No.	Session	Date	Total	Acc. Total	Inst	Ar
	6342M	19	0h 25m	835h 05m	Jupiter	E.
	6343M	20	20	835 25	"	"
XXIV July	6360E	3/4	1 00	836 25	"	W
	6361E	4	0 40	837 05	"	W
	6365M	9	0 15	837 20	"	E
	6367	12	1 00	838 20	Jupiter/Obs. B	E
XXV Aug	6387MS	13/14	1 05	839 25	Minerva	E
	6389MB	~~13/14~~ 15/16	1 40	841 05	"	E
	6391M	18/19	1 40	842 45	"	E
	6392M	19/20	1 00	843 45	"	E
	*6393AM	20/21	1 00	844 45	"	E
XXVI	6396E	24/25	0 20	845 05	"	W
	6397E	25/26	0 30	845 35	"	W
Sept	6402M	3/4	1 00	846 35	"	W
XXVII	6409E	11/12	0 15	846 50	"	W
XXIX Oct	6418M	5/6	0 30	847 20	Jupiter	E
	6419E	7/8	1 00	848 20	"	E
	6420AM	8/9	0 20	848 40	"	E
	6421E	9/10	1 15	849 55	"	W
	6430E	23/24	0 30	850 25	"	E
XXX	6432M	2 28	0 30	850 55		W
Nov	6433M	4/5	0 30	851 25		E
	6434M	5/6	2 00	853 25		~~W~~
	6436E	6/7	2 00	855 25		W
	6437M	6/7	1 00	856 25		E
	6438M	7/8	0 10	856 35		E
	6440M	8/9	0 30	857 05		E
	6441M	9/10	0 30	857 35		E
	6448M	16/17	1 00	858 35		E
XXI	6453E	~~17~~ 26/27	0 30	859 05		W
	6454E	27/28	1 00	860 05		W
	6455E	28/29	2 00	862 05		W
⊕⊕	6456E	Nov 29/30	1h 07m	863 12		W

~ independent discovery of Comet 1983v, Hartley-IRAS ~

Lunation	Month	Session	Date	Total	Acc Total	Inst	Area
		6457E ~~JAN 25 1973~~	30/31	1h 00m	864h 12m	Jupiter	W
	Dec	6459M2	3/4	1h 00m	865 12	"	E
		6463M	8/9	0h 30m	865 42	"	E.
		6465M	9/10	0h 30m	866 12	"	E.
32		6469E	21/22	0h 18m	866 30	"	W.
		6470E	22/23	0h 40m	867 10	"	W.
		6471E	27/28	0h 40m	867h 50m	"	W.
		6473M	28/29	0h 05	867h 55m	"	E.
		6476M2	31/32	1 40	869h 35m	"	E.
1984	January	6477E	3/4	0 10	869 45	"	W.
		6480M2	5/6	0 15	870 00	"	E.
		6485EM2	8/9	0 30	870 30	"	E.
33		6491E	20/21	0 20	870 50	"	W.
		6492E	22/23	0 15	871 05	"	W.
34	(Feb)/MAR	6508M	2/3	0 10	871 15	"	E.
		6510M	4/5	1 45	873 00	"	E.
		6512M2	5/6	0 35	873 35	"	E
		6513M	6/7	0 35	874 10	"	E
		6514M	7/8	1 05	875 15	"	E
		6516M	8/9	1 00	876 15	"	E
		6517M	9/10	1 00	877 15	"	E.
		6518M	10/11	0 30	877 45	Jupiter	E
		6519M	11/12	0 45	878 30	Jupiter	E.
		6520M	12/13	0 05	878 35	Jupiter	E.
35		6527E	20/21	0 15	878 50	Mercury	W.
		6528E	21/22	0 15	879 05	Jupiter	W.
	(900h)	6530EM	22/23	2 00	881 05	Jupiter	W.
		6532E	27/28	3 20	884 25	Jupiter	W
		6533M2	"	0 35	885 00	Jupiter	E
		6534E	28/29	1 00	886 00	"	W
		6535E	29/30	1 00	887 00	Pegasus	W
		6539M3	31/32	0 45	887 45	Jupiter	E
	Apr	6541M2	1/2	0 15	888 00	"	E
		6542E	2/3	0 45	888 45	"	W
		6543M2	"	0 30	889 15	"	E
		6547M3	5/6	0 30	889 45	"	E
36		6559E	20/21	1 00	890 45	"	W
		6560E	21/22	1 00	891 45	"	W
		6563E2	23/24	2 10	893 55	"	W
		6564M3	"	0 25	894 20	"	E

Lun.	Mo	Session	Date	Total	Acc Total	Inst	Area
		6567M	27/28	$0^h 20^m$	$894^h 40^m$	Jupiter	E
		6568M	28/29	$0^h 10^m$	894 50	"	E
		6569M	29/30	1 00	895 50	"	E
		6570M	30/31	0 20	896 10	"	E
	May	6572E	2/3	1 25	897 35	"	W
		6573M2	"	0 10	897 45	"	E
		6574M	3/4	0 40	898 25	"	E.
37		6588E	22/23	2 00	900 25	"	W
		6589M2	"	0 15	900 40	"	E
		6593M	28?	0 45	901 25	"	E
	Jun	6596M	3/4	0 15	901 40	"	E.
38		6603EM	16/17	2 00	903 40	"	W
		6604E	18/19	0 30	904 10	"	W
39	Aug	6623EM2	21/22	0 35	904 45	Minerva	W
		6624M2	"	0 25	905 10	"	E
		6626EM	22/23?	0 15	905 25	"	W
		6629AN	30/31	1 00	906 25	"	W
		"	"	0 30	906 55	"	E
40	Sep	6651M	22/23	0 50	907 45	Jupiter	E.
		6652M	23/24	0 30	908 15	"	E
		6653M	24/25?	0 50	909 05	"	E
		6654M	29/30	0 30	909 35	"	E
		6658M	30/31	0 30	910 05	"	E
	Oct	6659M	1/2	1 05	911 10	"	E.
		6660M	3/4	1 20	912 30	"	E
41		6667M	27/28	0 45	913 15	"	E
		6668M	28/29	1 10	914 25	"	E.
	Nov	6669M	1/2	0 20	914 45	"	E
		6670M	2/3	0 35	915 20	"	E
		6672M	3/4	0 15	915 35	"	E
42		6680E	10/11	0 20	915 55	"	W
		6683E	12/13	0 30	916 25	"	W

***6684E Nov 13/14 1h 03m 917h 28m Jupiter W

Discovered Comet
1984t
LEVY-RUDENKO

~850 nights 41	6693M	Nov 22/23	0h 40m	0h 40m	Jupiter	E.
	6694M	23/24	0 20	1 00	"	E.
Dec	*6701AN	1/2	0 30	1 30	"	E.
	6704M	4/5	0 30	2 00	"	E
43	6708E	12/13?	0 10	2 10	"	W, S.
	6716EM	22/23	0 20	2 30	"	S
	6719M	23/24?	0 10	2 40	"	S
	6719M	28/29	0 10	2 50	"	E.
	6720AN	29/30	1 50	4 40	"	E.
	6722M2	30/31	0 40	5 20	"	E
1985 Jan	6725M2	1/2	1 30	6 50	"	E.
	**6727M	2/3	0 10	7 00	"	E
	6728M	3/4	0 20	7 20	"	E.
44	6733AN2	18/19	0 30	7 50	KPNO finder	E
	6736M	19/20	0 30	8 20	Jupiter	E
	6738M2	26/27	0 45	9 05	Pegasus	E.
45 Mar	6750E	12/13	2 00	11 05	Jupiter	W.
	6751E	13/14	2 00	13 05	"	W
	6752E	15/16	1 15	14 20	"	W
	6753E	17/18	2 00	16 20	"	W
	6754M2		1 45	18 05	"	E
	6756E	20/21	2 00	20 05	"	W
	6758M3	20/21	1 00	21 05	"	E
	6759M	21/22	0 45	21 50	"	E
	6760E	22/23	0 25	22 15	"	W
	6761M2	22/23	0 30	22 45	"	E
	6763EM2	23/24	0 30	23 15	"	E.

Lun Mo	Sess	Date	Total		Acc. Ttl		Instrument	Area	
	6764M3	23/24	0	15?	23	30	Jupiter	E	
46 April	6766M	~~1/2~~ 31/1	0	50	24	20	"	E	
	6768E	7/8	0	45	25	05	"	W.	
11/12	6772E	11/12	2h	45m	27	50	"	W.	
12/13	6773E	12/13	2	00	29	50	"	W.	
	6774A		1	00	30	50	"	E.	
	6775E	13/14	2	00	32	50	Pegasus	W.	Pegasus
	6776M2		0	30	33	20	Jupiter	E	Jupiter.
	6777M	14/15	1	15	34	35	"	E.	
	6780M2	17/18	1	00	35	35	"	E	
	6781M	18/19	0	45	36	20	"	E	
	6782M	19/20	1	30	37	50	"	E	
	6783E	20/21	0	30	38	20	Pegasus	W	
	6784M	22/23	0	20	38	40	Jupiter	W	
	6785M	23/24	~~0~~1	05	39	45	"	E	
	6786M	24/25	0	15	40	00	"	E	
	6792M	28/29	0	40	40	40	"	E	NGC 7753
	6793M	29/30	0	10	40	50	"	E.	
47 May	6798E	5/6	0	20	41	10	"	W.	
	6799E	6/7	0	40	41	50	"	W.	
	6800E	7/8	1	05	42	55	"	W	
	*6801EM	10/11	4	20	47	15	"	W, E.	
	6802EM	11/12	3	45	51	00	Pegasus	W, N, E.	
	6803E	12/13	1	20	52	20	Jupiter	W.	
	6805AM	17/18	1	25	53	45	Pegasus	E	
	6808M	20/21	1	15	55	00	Jupiter	E	
	6809M	21/22	0	20	55	20	"	E	
	6811M2	22/23	0	40	56	00	"	E	
48 June	6821E	~~2~~5/6	1	50	57	50	"	W.	
	6822E	6/7	2	15	60	05	"	W	
	*6823EM	7/8	~~2~~ 0	~~45~~ 30	60	35	PEGASUS	W.	
	6825M	9/10	0	15	60	50	JUPITER	E.	
	6826E	10/11 ✓	0	45	61	35	"	E ✓.	

Lun Mo	Sess	Date	Total	Acc. Ttl	Instrument	Area	
	6764M3	23/24	0 15?	23 30	Jupiter	E	
April	6766M	~~1/2~~ 31/1	0 50	24 20	"	E	
46	6768E	7/8	0 45	25 05	"	W.	
11/12	6772E	11/12	2h 45m	27 50	"	W.	
12/13	6773E	12/13	2 00	29 50	"	W.	
	6774M		1 00	30 50	"	E.	
	6775E	13/14	2 00	32 50	Pegasus	W.	Pegasus
	6776M2		0 30	33 20	Jupiter	E	Jupiter.
	6777M	14/15	1 15	34 35	"	E.	
	6780M2	17/18	1 00	35 35	"	E	
	6781M	18/19	0 45	36 20	"	E	
	6782M	19/20	1 30	37 50	"	E	
	6783E	20/21	0 30	38 20	Pegasus	W	
	6784M	22/23	0 20	38 40	Jupiter	W	
	6785M	23/24	1 05	39 45	"	E	
	6786M	24/25	0 15	40 00	"	E	
	6792M	28/29	0 40	40 40	"	E	NGC 7753
	6793M	29/30	0 10	40 50	"	E.	
47 May	6798E	5/6	0 20	41 10	"	W.	
	6799E	6/7	0 40	41 50	"	W.	
	6800E	7/8	1 05	42 55	"	W	
	*6801EM	10/11	4 20	47 15	"	W, E.	
	6802EM	11/12	3 45	51 00	Pegasus	W, N, E.	
	6803E	12/13	1 20	52 20	Jupiter	W.	
	6805AM	17/18	1 25	53 45	Pegasus	E	
	6808M	20/21	1 15	55 00	Jupiter	E	
	6809M	21/22	0 20	55 20	"	E	
	6811M2	22/23	0 40	56 00	"	E	
48 June	6821E	~~23~~ 5/6	1 50	57 50	"	W.	
	6822E	6/7	2 15	60 05	"	W	
	*6823EM	7/8	~~2 45~~ 0 30	60 35	PEGASUS	W.	
	6825M	9/10	0 15	60 50	JUPITER	E.	
	6826E	10/11	0 45	61 35	"	E✓.	

Lunation	Month	Session	Date	Ttl	Acc Ttl	Inst.	Area
		6828M	11/12	0 35	62 40	Jupiter	E
		6829E	12/13	1 00	63 40	"	W
		6830M2		0 30	64 10	"	E
		6831M	13/14	0 30	64 40	"	E
		6832M	14/15	0 30	65 10	"	E
49	~~6845~~ July	6845E	3/4	0 15	65 25	"	W.
		6851M	26/27	1 05	66 30	"	E.
50	Aug	6855E	3/4	0 45	67 15	MINERVA	W.
		6856E	4/5	0 50	68 35	"	W
		6857E	5/6	0 40	69 ~~0~~15	"	W
		6858E	8/9	1 00	70 15	"	W.
		*6863M	15/16	1 15	71 30	"	E Jarnac!
		*6864AN	16/17	1 15	72 45	"	E.
		6866AN2	17/18	2 25	75 10	"	E
51	Sep	6876E	4/5	1 20	76 30	Jupiter	W
		6877E	5/6	2 20	78 50	"	W
		68~~80L~~ 81AN	9/10	0 15	79 05	Minerva	W, N.
		6882AN	10/11	0 15	79 20	"	W, N.
		6883AN	11/12	0 15	79 35	"	E.
		6884M	12/13	1 00	80 35	Jupiter	E.
		6887M	~~13~~ 16/17	0 30	81 05	"	E
		6888AN	17/18	1 30	82 35	"	E
		6889M	21/22	0 30	83 05	"	E,
		6891M	23/24	1 00	84 05	"	E
52	Oct	6898E	3/4	0 20	84 25	"	W
		6899E	5/6	2 30	87 05	"	W
		6906M	18/19	0 45	87 50	"	E
		*6910M2	~~19~~/20/21	1 00	88 50	"	E
		6911M	22/23	0 30	89 20	"	E
		6912M	23/24	0 30	89 50	"	E
		6913M	24/25	0 30	90 20	"	E
53	Nov	6919E	1/2	~~1 2~~ 1 30	91 50	"	W.
		6920E	2/3	1 20	93 20	"	W
		6921E	3/4	1 15	94 35	"	W

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Session	Date	Begin	End	Time todecimal hr.	Scope	Area	Comment
1000	07/12/86	0	0	95.50			Accumulated total
6924M	11/10/85	2100	2359	.25	Miranda	W	First computer entry
6928E	11/15/85	1900	2030	.50	Miranda	W	Jupiter - Miranda
6930AN	11/17/85	0500	0600	.25	Minerva	E	KUAT night
6931AN	11/19/85	0500	0600	.25	Minerva	E	
6941E2	11/29/85	1900	2100	1.00	Miranda	W	
6943E	11/30/85	1830	1900	.33	Miranda	W	
6956M2	12/12/85	0515	0600	.50	Miranda	E	
6957AN	12/13/85	0500	0600	.25	Minerva	E	
6960AN	12/16/85	0430	0600	1.00	Minerva	E	
6961AN	12/17/85	0500	0600	.50	Minerva	E	20th Anniversary CN3
6963M2	12/19/85	0500	0600	.33	Miranda	E	date uncertain
6966M3	12/19/85	0500	0600	.50	Miranda	E	
6981AN	01/03/86	0500	0600	.60	Minerva	E	
6984E6	01/06/86	1800	2000	2.00	Miranda	W	
6987M2	01/08/86	0500	0610	.80	Miranda	E	
6989M2	01/09/86	0535	0635	.80	Miranda	E	date uncertain
6991M2	01/09/86	0530	0610	.33	Miranda	E	
6994M3	01/10/86	0530	0615	.80	Miranda	E	
6996M2	01/11/86	0530	0615	.33	Miranda	E	
6998AN	01/15/86	0300	0430	.33	Miranda	E	lots of driving!
7014M2	02/06/86	0530	0630	.75	Miranda	E	after Las Cruces
7016M	02/08/86	0300	0330	.17	Minerva	E	Flagstaff- cold.
7017M	02/12/86	0300	0500	1.50	Miranda	E	
7018M	02/16/86	0500	0600	.80	Miranda	E	
7019M	02/17/86	0500	0615	1.17	Miranda	E	
7025E	02/25/86	1930	2000	.33	Miranda	W	Miranda official
7026E	02/26/86	1900	2100	1.00	Miranda	W	

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Session	Date	Begin	End	Time	Scope	Area	Comment
7030E2	02/28/86	1930	0000	3.00	Miranda	W	
7032SAN	03/01/86	1900	1915	.10	Miranda	W	Miranda first light
7035M	03/03/86	0500	0600	.50	Miranda	E	
7036M	03/04/86	0500	0600	.50	Miranda	E	
7046M2	03/14/86	0400	0615	.66	Miranda	E	Miranda first light
7047M	03/15/86	0200	0630	1.33	Miranda	E	
7049M2	03/18/86	0405	0430	.25	Miranda	E	Miranda first light
7067E2	03/29/86	2045	2300	1.00	Miranda	W	Miranda first light
7071E	04/01/86	2000	2320	1.00	Miranda	W	Miranda first light
7091M	04/18/86	0430	0450	.25	Miranda	E	
7093M2	04/19/86	0340	0440	.66	Miranda	E	
7099E	04/25/86	2025	2100	.25	Miranda	W	
7105EM	05/03/86	2000	2200	1.50	Pegasus	W	TAAA star party
7109E2	05/05/86	2030	2130	.80	Miranda	W	
7113EM	05/09/86	2200	0000	1.00	Pegasus	W	Texas Star Party
7118M2	05/14/86	0300	0415	.50	Miranda	E	
7119M	05/15/86	0230	0415	.80	Miranda	E	
7120M	05/16/86	0300	0430	1.00	Miranda	E	
7121M	05/18/86	0300	0430	1.00	Miranda	E	
7122M	05/19/86	0230	0405	.66	Miranda	E	
7128E	05/27/86	2000	2200	1.00	Miranda	W	
7145M2	06/07/86	0310	0400	.75	Miranda	E	
7146AN	06/07/86	0245	0410	.75	Miranda	E	
7147AN	06/08/86	0200	0410	1.25	Miranda	E	
7150M3	06/09/86	0320	0410	.40	Miranda	E	
7151AN	06/10/86	0000	0400	1.10	Minerva	S-E	Jarnac and KPNO
7153M2	06/11/86	0245	0400	1.00	Miranda	E	
7161M2	06/18/86	0300	0430	.25	Miranda	E	

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Session	Date	Begin	End	Time	Scope	Area	Comment
7164M3	06/19/86	0330	0410	.25	Miranda	E	new galaxy!
7170EM	06/28/86	2300	0030	.50	10 rfl	N	RASC GA Winnipeg 86
7175M	07/08/86	0200	0300	.25	Miranda	E	
7176M	07/09/86	0130	0430	2.45	Miranda	E	
7177M	07/10/86	0330	0405	.33	M/Rigel	E	
7178M	07/11/86	0245	0405	1.10	Miranda	E	
7179M	07/12/86	0320	0400	.66	Minerva	ENE	Very close to horizo
7180E	07/13/86	2030	2120	.25	Minerva	WNW	Pima Mine Road
7181M	07/15/86	0230	0335	.33	Miranda	E-S	UT DATE FROM NOW ON
				142.25			

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Session	Date	Begin	End	Time	Scope	Area	Comment
1000	07/16/86			142.25			Accumulated total
7182M	07/17/86	0300	0340	.20	Miranda	E	
7189E	07/25/86	2015	2200	1.50	Miranda	W	Clear summer sky!
7193E	07/26/86	2015	2200	1.13	Miranda	SW S	Clear evening agai
7194E	07/28/86	2030	2130	.50	Miranda	E	suspect
7195E	07/27/86	2000	2200	1.00	Miranda	E	Some clouds
7197E	07/30/86	2230	0030	1.00	Miranda	E S	nice night
7198E	07/31/86	0030	0130	.25	Miranda	S	
7206AN	08/12/86	0200	0500	2.00	Minerva	E	Jarnac Dock
7207AN	08/13/86	0330	0445	1.14	Minerva	E	Jarnac Dock
7218M2	08/31/86	0300	0400	.20	Miranda	E	
7220AN	09/02/86	0100	0520	3.00	61finder	E	
7221AN	09/03/86	0350	0500	1.00	Minerva	E	
7222E	09/04/86	2000	0000	1.00	Miranda	W	
7224M	09/05/86	0100	0500	3.00	Miranda	E NE	
7225EM	09/06/86	2230	0500	2.33	Miranda	E NE	
7228M	09/09/86	0350	0430	.30	Miranda	E	
7229M	09/11/86	0350	0450	.60	Miranda	E	
7231M2	09/12/86	0300	0500	1.50	Miranda	E SE	
7233M2	09/13/86	0345	0445	.50	Miranda	E S	
				164.40			

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Session	Date	Begin	End	Time	Scope	Area	Comment
1000	11/23/86			164.40			Accumulated Total
7234M	09/14/86	0330	0430	.50	Pegasus	E	
7235E	09/17/86	1900	2000	.50	Maia	W	hunt from car.
7236E	09/18/86	1930	2100	.50	Ophelia	W	from car;Gates pass
7237E	09/19/86	1935	2000	.25	Ophelia	W	
7239E2	09/23/86	1930	2030	.66	Miranda	W	
7240E	09/25/86	1930	2100	1.00	Minerva	W	KPNO-Marsden&Gehrels
7241E	09/26/86	1930	2200	2.00	Miranda	W	
7242E	09/27/86	1930	2100	.80	Miranda	W	
7243M2	09/27/86	0000	0015	.15	Miranda	W	
7244E2	09/28/86	2300	0100	1.10	Miranda	E	
7246E	09/29/86	1930	2330	2.00	Miranda	W	
7248AN	10/01/86	1900	2100	.25	Minerva	W-E	Mt Bigelow
7249M	10/02/86	0300	0500	2.00	Miranda	E	
7250M	10/04/86	0300	0500	2.00	Miranda	E	
7251E	10/05/86	1930	2345	2.33	Pegasus	W	
7252M2	10/05/86	0430	0530	.25	Miranda	E	
7257E	10/20/86	1900	2000	.25			
7258E	10/21/86	1900	1945	.80			
7267E	11/20/86	1830	1940	1.00	Pegasus	W	South site
7268E	11/21/86	1830	2000	1.00	Miranda	West	
7269E	11/22/86	1845	2200	2.00	Miranda	W	
7270E	11/23/86	1815	2300	2.33	Miranda	W	
				188.07			

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ssion	Date	Begin	End	Time	Scope	Area	Comment
1000	12/09/86			188.07			
7271E	11/24/86	1830	0000	1.00	Miranda	W	
7272E	11/25/86	1900	1915	.25	Ophelia	W	
7273E2	11/25/86	2000	2030	.25	Miranda	W	
7274M	11/26/86	0100	0200	.25	Miranda	E	
7275M	11/27/86	0230	0300	.25	Miranda	E	
7276AN	11/28/86	1800	0600	.12	Pegasus	S	
7277AN	11/29/86	1800	0600	.12	Pegasus	E	
7278E	11/30/86	1845	1925	.25	Pegasus	W	near Buckeye AZ
7281M	12/02/86	0340	0540	.75	Pegasus	E	Morgan Site
7282E	12/03/86	2000	2130	1.20	Pegasus	W N	Polaris Observatory
7283M2	12/03/86	0330	0530	1.00	Pegasus	E	Little Rock Site
7286M	12/09/86	0430	0600	1.00	Miranda	E	
7287M	12/11/86	0330	0600	2.00	Miranda	E	
7288M	12/12/86	0430	0600	.80	Miranda	E	
7292E	12/13/86	1840	1940	.50	Pegasus	West	Start of CNIIIe
7293M2	12/18/86	0000	0230	.60	Pegasus	South	Start of Sungrazer s
7294E	12/20/86	1845	2030	1.00	Miranda	West	
7295E2	12/22/86	1900	2200	1.00	Miranda	West	after day w/Richard
7297E	12/24/86	2300	0000	.33	Miranda	South	
7304M	12/29/86	0430	0630	1.20	Miranda	East	
7305M	12/30/86	0300	0415	1.00	Miranda	East	
7306M	12/31/86	0000	0100	1.00	Miranda	south	during vs book
7311M	01/04/87	0540	0610	.20	Ophelia	East	South site
12M	01/05/87	0515	0630	.66	Miranda	East	possible comet
7314M	01/07/87	0430	0700	.25	Miranda	East	New Comet Confirmed
				205.05			

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ssion	Date	Begin	End	Time	Scope	Area	Comment
7318M2	01/09/87	0400	0630	.25	Miranda	E	
7319M	01/10/87	0400	0630	.60	Miranda	E	
7325E	01/19/87	1900	2000	1.00	Miranda	W	
7326E	01/21/87	1900	2000	1.00	Miranda	W	
7330EM2	01/23/87	2230	0100	.75	Miranda		
7331M	01/24/87	0000	0200	1.00	Miranda	S E	
7333EM2	01/25/87	1930	0230	1.33	Miranda	W S E	
7335EM2	01/26/87	2330	0530	.50	Miranda	S E	
7336AN	01/27/87	1800	0630	6.10	Miranda	W E	Good session
7337M	01/29/87	0300	0630	2.00	Miranda	E	
7339EM	02/01/87	2300	0800	3.00	Miranda	E	
7344AN	02/06/87	0500	0515	.10	Minerva	SE	
7347E	02/17/87	1900	2300	.50	Min Mir	W	
7349M	02/24/87	0300	0400	.50	Miranda	E	
7351E	02/28/87	1900	2000	.50	Minerva	W	Tumamoc
7352M2	02/28/87	0400	0600	.50	Miranda	E	
7361M	03/12/87	0430	0530	.50	Miranda	E	
7362M	03/13/87	0000	0530	.25	Miranda	E	New 20mm Nagler
7369EM	03/23/87	1930	0130	3.60	Miranda	W E	
7370M	03/23/87	0300	0530	2.50	Miranda	E	
7371E	03/25/87	1930	2015	.50	Ophelia	W	W of Deming New Mex
7372M2	03/25/87	0200	0300	5.00	Miranda	E	
7373AN	03/26/87	2000	0515	4.40	Miranda	W E	
7374AN2	03/27/87	0500	0530	.25	Pegasus	NE	P/Halley Phase 9
[illegible]5AN	03/28/87	0430	0530	.66	Pegasus	E	Mt. Bigelow
7376AN	03/29/87	0430	0530	.33	Pegasus	E	Very cold
7380M3	03/30/87	0430	0530	.33	Pegasus	E	Mt Lemmon
7382M2	03/31/87	0425	0515	.60	Pegasus	E	

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ssion	Date	Begin	End	Time	Scope	Area	Comment
7385AN2	04/02/87	0415	0455	.60	Pegasus	E	
7388M2	04/06/87	0400	0500	.75	Miranda	E	
7390M2	04/07/87	0430	0500	.33	Miranda	E	
7391M	04/08/87	0430	0500	.25	Miranda	E	
7392M	04/09/87	0330	0500	.75	Miranda	E	
7393M	04/10/87	0430	0500	.25	Miranda	E	
7394M	04/11/87	0430	0500	.25	Miranda	E	
				41.73			

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Session	Date	Begin	End	Time	Scope	Area	Comment
1000	05/03/87			41.73			
7403E	04/17/87	1930	2245	2.50	Miranda	W	
7412M2	04/22/87	0125	0320	1.06	Miranda	E	
7420M2	04/26/87	0430	0445	.12	Miranda	E	
7424M3	04/29/87	0345	0415	.25	Miranda	E	
7428EM2	04/02/87	0345	0430	.33	Miranda	E	
7430M2	05/03/87	0345	0420	.60	Miranda	E	
7434AN	05/04/87	0430	0530	.90	Pegasus	E	Mt Lemmon near 60-in
7435AN	05/05/87	0400	0520	1.10	Pegasus	E	near 60-inch
7440M	05/19/87	0000	0200	.60	4-in L	N	Oso Observatory
7444EM	05/25/87	2200	2300	.50	4-in SCT	W	John Griese's scope
7449AN	05/30/87	2200	0600	4.00	Minerva	W E	with Clyde Tombaugh
7453M	06/09/87	0330	0415	.50	Miranda	E	
7454M	06/10/87	0330	0415	.50	Miranda	E	
7455E	06/14/87	2000	2200	.12	Miranda	W	clouds
7458AN	06/17/87	2000	2200	.25	Minerva	W	KPNO near 2-36
7459AN	06/18/87	2000	2200	1.00	Minerva	W	near 2-36 KPNO
7464EM	06/25/87	2000	0300	2.75	Minerva	W E	
7465M	06/26/87	0245	0400	1.00	Miranda	E	
7467M2	06/27/87	0230	0405	.50	Miranda	E	possible P/DenningFu
				60.31			

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Session	Date	Begin	End	Time	Scope	Area	Comment
1000	06/27/87			60.31			
7469M	06/28/87	0200	0400	.33	Miranda	E	
7470AN	06/29/87	2000	0430	5.50	Miranda	W E	
7471M	06/30/87	0000	0430	2.12	Miranda	E	
7472M	07/01/87	0100	0430	1.00	Miranda	E	
7473M	07/02/87	0200	0430	1.00	Miranda	E	
7474M	07/03/87	0000	0430	.50	Md-Pegas	S E	
7476M2	07/04/87	0130	0400	.66	Pegasus	E	
7478M2	07/05/87	0035	0400	1.60	Miranda	W E	
7480M2	07/06/87	0100	0415	2.33	Miranda	W N E	
7481M	07/07/87	0200	0405	1.50	Miranda	S E	
7482M	07/08/87	0200	0415	.50	Miranda	E	
7487E	07/13/87	2030	2130	.25	Minerva	W	Pomona Calif
7488E	07/14/87	1955	2300	1.00	Minerva	W	Mount Peltier
7490E	07/15/87	2100	2215	1.00	Minerva	W NW	Mt Baldy Calif
7492E	07/17/87	2100	2215	1.00	Minerva	W	OCA site
7493E	07/19/87	2045	0130	3.50	Minerva	W N	Polaris site
7496M	07/21/87	0100	0300	1.00	Miranda	E	
7497M	07/22/87	0000	0430	.25	Oph Min	W E	South site - JMF
7498E	07/23/87	2100	2130	.25	Ophelia	W	
7499M2	07/23/87	0000	0430	2.00	Miranda	NE E	
				87.60			

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Session	Date	Begin	End	Time	Scope	Area	Comment
1000	07/23/87			87.60			
7500M	07/24/87	0300	0400	.25	Miranda	E	
7501E	07/28/87	2000	0000	.50	Minerva	W	JOCR
7502M	07/29/87	0300	0400	.25	Miranda	E	
7503M	08/02/87	0245	0415	1.20	Miranda	E	
7504E	18/12/87	1940	2300	.20	Minerva	W	
7507E	08/14/87	1950	2300	1.00	Pegasus	W	new JM3 site on roof
7508M2	08/14/87	0400	0420	1.75	Mir Peg		
7509EM	08/16/87	1930	0030	2.00	Peg Mir	W	
7511M2	08/22/87	0200	0430	2.00	Mir Peg	E	
7512M	08/23/87	0300	0440	.33	Miranda		
7515M2	08/30/87	0230	0500	2.00	Minerva	E	last Jarnac Pond sn
7518M	09/04/87	0330	0430	1.00	Mir Peg	E	
7519M	09/06/87	0420	0450	.50	Pegasus	E	
7521E	09/09/87	2000	2100	.25	Pegasus	W	
7522E	09/11/87	1930	2130	.40	Pegasus	W	
7523E	09/87/87	1930	2130	.80	Pegasus	W	
7524EM	09/13/87	2000	2100	.25	Mir Peg	W	
7525M	09/18/87	0300	0400	.25	Pegasus	E	
7529M	09/30/87	0300	0515	1.00	Miranda	E	
7530M	10/02/87	0430	0515	.50	Pegasus	E	
7531M	10/03/87	0300	0515	1.25	Miranda		
7532M	10/04/87	0400	0515	.50	Miranda	E	
7534E	10/08/87	1900	1940	.50	Pegasus	W	Ind. find 1987S
7536E	10/11/87	1900	2030	1.25	Pegasus	W	possible comet
7537E	10/12/87	1900	2200	.10	Pegasus	W	new comet confirmed

				107.63			

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Session	Date	Begin	End	Time	Scope	Area	Comment
7539E	10/15/87	1830	2330	3.00	Peg Mir	W	
7540EM	10/16/87	1815	0030	4.00	Peg Mir	W	
7542EM	10/19/87	2300	0230	3.00	Miranda	E	Galaxies near Ca
7544M2	10/20/87	2200	0530	2.25	Mir Peg	W E	
7546M2	10/21/87	1900	0540	3.00	Miranda	W E	
7553M	10/30/87	0200	0430	2.00	Miranda	E	
7555M2	11/01/87	0400	0500	.33	Pegasus	E	
7558M3	11/02/87	0400	0540	1.25	Miranda	E	
7559E	11/09/87	1800	1900	.25	Mir Peg	W	
7560E	11/10/87	1830	2000	1.00	Minerva	W	Whitaker Peak C
7561E	11/11/87	1800	2000	1.00	Minerva	W	
7562E	11/14/87	1730	1930	1.00	Minerva	W	Pt Reyes Calif.
7563E	11/17/87	1830	2300	3.00	Miranda	W	
7567AN	11/22/87	0300	0500	1.50	Minerva	E	Polaris Observa
7568E	11/23/87	1800	1930	1.00	Minerva	W	Whitaker Peak
7570AN	11/25/87	1800	0630	2.50	Miranda	W E	
7572AN	11/27/87	1800	0600	1.33	Min Mir	E	
7573AN	11/28/87	1815	0650	3.75	Min Mir	W E	
7575E	12/09/87	1800	1900	.50	Minerva	W	
7576E	12/10/87	1800	2200	2.20	Min Mir	W	
7577E	12/11/87	1800	2100	2.25	Min Mir	W	
7578E	12/12/87	1900	2330	3.40	Miranda	W	
7580E	12/14/87	1840	1900	.17	Minerva	W	
7581M2	12/19/87	0000	0215	.33	Miranda	NW	
7582E	12/15/87	1800	1900	.17	Minerva	W	Mt Bigelow
7584M	12/17/87	0500	0610	1.00	Miranda	E	Cloud hopping
				45.18			
7585AN	12/21/87	~~1730~~ 0530	0700	.75	Minerva	E	
7587M2	12/22	0430	0600	1.25	Mir/Min	E	
7588AN	12/23	1830	0630	6.50	Mir Min	W N E	
7589M	12/26	0500	0630	0.66	Minerv.	E	
7591E	12/28	1800	1845	0.25	Minerv	W	Gage, NM
7593M3		0400	0630	1.00	Miranda	E	
			1988				
7595E	Jan 7	1830	1930	1.00	Minerva	W	
7596E	9	1930	2200	3.00	Minerva	W	
7597EM	10	~~1400~~	0300	3.00	Min Mir	W	
7598SE	11	~~1430~~ 1930	2330	3.00	Min Mir	W	
7599M	12	0100	0200	0.50	Minerva	W	
*7600EM	13	1840	0130	1.50	Min Mir	W	

↗

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Session	Date	Begin	End	Time	Scope	Area	Comment
7629E	01/31/88	1830	1910	.25	Minerva	W	
7632M3	01/31/88	0605	0620	.10	Minerva	E	
7634E	02/06/88	1900	2045	1.50	Minerva	W	
7636E	02/07/88	1900	2200	2.00	Minerva	W	
7637E	02/08/88	1900	2300	2.50	Minerva	W	
7638E	02/09/88	1920	2330	3.50	Miranda	W	
7639M2	02/09/88	0540	0620	.33	Minerva	E	
7640EM	02/10/88	1915	0040	4.00	Mir Min	W E	
7641EM	02/11/88	1925	0150	3.50	Min Mir	W	
7642AN	02/12/88	1830	0630	6.50	Min Mir	W E	
7645M3	02/13/88	0530	0615	2.50	Minerva	E	
7647M2	02/14/88	1830	0630	4.50	Min Mir	W E	
7648AN	02/15/88	1830	0630	10.25	Min Mir	W S E	record!!
7649AN	02/16/88	1830	0620	4.25	Min M ir	W S E	
7650E	02/17/88	1830	0415	3.00	Miranda	W E	
7653M2	02/18/88	0130	0245	1.60	Minerva	W E	
7655M	02/21/88	0200	0645	1.80	13 refl	E	
7656M	02/22/88	0200	0630	.60	Minerva	E	
7659M	02/25/88	0500	0600	.50	Minerva	E	
7661M	02/27/88	0530	0610	.20	Minerva	E	
7662E	02/28/88	1920	1935	.20	Minerva	W	
7663M2	02/28/88	0530	0600	.20	Minerva	E	
7664E	02/29/88	1900	1930	.25	Minerva	W	
7665E	03/04/88	1915	1945	.25	Minerva	W	
7666E	03/05/88	1915	2030	1.00	Minerva	W	
7667E	03/07/88	1930	2100	.50	Miranda	W	
7668E	03/09/88	1900	2330	3.20	Min Mir	W	
7669E	03/10/88	1900	2245	2.00	Minerva	W	24mm eyepiece!

↗ 7602AN	Jan 15	1800	1830	0.25	Minerva	W	
		0430	0530	0.50	"	E	
7606E2	20	1830	2205	1.00	"	W	
7607M3	"	550	630	0.50	"	E	"Ind disc." McNaught 87b,
7608E	21	1830	2300	2.8	"	W	
7609M2		0445	0630	1.50	"	E	
7610E	22	1830	-2000	0.50	"	W	
7611M2	"	450	-630	1.20	"	E.	"Ind dis." McNaught 87b,
7612AN	23	1845	-0630	4.25	Min Mir	W, E.	"Ind. dis." P/Borrelly. KF
7615M3	24	510	-635	1.00	Mirande	E	
7618E2	25	1850	-1930	0.50	Minerva	W	
7620M4	25	0000	-0700	1.50	Miranda, Min	~~W~~ E.	Heavy gusts ~40m
7622M2	26	430	-630	1.33	Mirande	E	
7623E	27	1830	-1930	0.50	Minerva	W.	
7624E	29	1830	-1930	0.50	Minerva	W.	
7628M2	30	0500	-0515	0.10	Mirande	E.	Cirrus

13

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-hr, tenths

Session	Date	Begin	End	Time	Scope	Area	Comment
7671E	03/12/88	1930	2050	1.00	Minerva	W	
7672E	03/13/88	1930	0000	2.50	Minerva	W	
7673E	03/14/88	1930	2155	2.00	Miranda	W	
7674AN	03/15/88	1900	0630	.75	Minerva	W E	
7675AN	03/16/88	1830	0630	.75	Minerva	W E	
7677E	03/18/88	1930	2030	1.00	Min Mir	W	
7678E	03/18/88	0415	0530	1.00	Miranda	E	
7679E	03/19/88	1930	2130	1.50	Min Mir	W	
7680M2	03/19/88	0340	0600	1.50	Mir Min	E	2 suspects in Pegas.
7681E	03/20/88	1930	2130	1.25	Min Mir	W	
7682M2	03/20/88	0430	0550	1.25	Mir Min	E	suspect in Pegasus
7683E	03/21/88	1915	1935	.25	Minerva	W	
7684M2	03/21/88	0345	0500	1.00	Miranda	E	Confirmed 1988e!!
				162.25			

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hr, min.

Session	Date 1988	Begin	End	Time	Total	Scope	Area	Comment
7686E	23/24	1915-	1940	45	45	Minerva	W	
7687		0445-	0615	50	1 35	Mir Min	E	
7688	24/25	1930-	1950	15	1 50	Minerva	E	
7689		0410-	0615	1 20	3 10	Min Mir	E	
7690M	25/26	0130	0600	1	4 10	Miranda	E	
7691M	28/29	450	535	10	4 20	Miranda	E	
7692	APR 3	1930	2000	15	4 35	Minerva	W	
7694E	4	1940	2040	25	5	Minerva	W	
7695E	5	1940	2000	2 45	7 45	Miranda	W	
7697AM	9			1	8 45	Minerva	WE	
7698AM	12	0500	630	10	8 55	Minerva	E	
7700M	17	140	500	1 10	10 05	Miranda	E	
7701AM	19	2000	440	5 40	15 45	Mir Min	WE	
7702EM	20	2230	500	3	18 45	Mir Min	E	
7703	21	1930	2035	5	18 50	Minerva	E	Ind. disc. Liller
7705AM	23	1930	1950	10	19		W	
				35	35	/	E	
7706AM	24	1930	2020	10	45		W	
7707	25	1900	515	30	20 15	Minerva	E	
7708M	26	3	430	1	21 15	Miranda	E	
7709	29	1900	130	15	30	Minerva	W	
7710M		4	440	30	22	Miranda	W	
7712E	MAY 4	2000	2020	15	22 15	Minerva	W	Tack Room!
7713E	5	2015	2300	1 35	23 50	Min Mir	W	
7714E	6	2000	0000	2 45	26 35	Miranda	W	
7716E	8	2030	2330	3 10	29 45	Miranda	WE	
7717EM	9	2130	0230	1 50	31 35	Miranda	W	
7718E	10	2000	2200	1 05	32 40	Miranda	W	
7720AM	11	2200	0630	2 15	34 55	Minerva	W	
7721AM		2200	0610	4 05	39 00	Minerva, 13	W, E, N	Texas Star Party
7722AM	14	2115	630	5 05	44 05	Minerva, 13	W, E, N	" " "
7723E	15	2130	200	2	46 05	Minerva, 13		
7724M		330	6	1 15	47 20	Minerva	E	
7727M	19	2	4	1	48 20	Miranda	E	
7728	20	2030	420	2 40	51 00	Miranda		
7730	24	330	410	3 10	54 10	Minerva	W	
7731	28	22	01	15	54 25	Minerva		
7733E	30	22	23	10	54 35	Minerva	W	
7734E	JUNE 2	2030	2230	1 15	55 50	Miranda	W	
7735	7	2030	2240	2	57 50	Minerva	W	
7736EM		2350	130	45	58 35	Miranda	W	
7737E	8	2030	2230	1 35	60 10	Minerva	W	
7738		330	4	15	60 25	Minerva	E	

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Session	Date 1988	Begin End	Time	Total	Scope	Area	Comment
7739	Jun 9		3 15	63 40	Minerva	WE	
7740	10		50	64 30	Miranda	E	
7743AN	12		1 00	65 30	Mi	W	
7744	13		1 30	67	Minerva	NE	} reverse order
			0 30	67 30	Minerva	E	}
7745E	14		2 40	70 10	Miranda	WE	
7748M			1	71 10	Miranda	E	
7749	16		1	72 10	Miranda	E	
7750	24		2 20	74 30	Miranda	E	
7751	25		15	74 45	Minerva	E	
7752	26		1	75 45	Miranda	E	
7753	27		0 30	76 15	Miranda	E	
		"Thurs"	40	76 55	M ?		} I did these sometime
		"Wed"	1 25	78 20			} around here - they
		"Tues"	15	78 35			} are recorded this
		"Mon"	1 40	80 15			} way. But when ??
7758M	July 9		15	80 30	Miranda	E	
7764	15		3 15	83 45	Minerva	W,	NE
7765	17		30	84 15	Minerva	W	
7771	Aug 4		30	84 45	Minerva	W	OFF I-10, hot + buggy
7773M	8		1	85 45		E	
7774AN	9		5 30	91 15	Min Mir	WNE	
7776M	10		20	91 35	Minerva	EN	
7777M			15	91 50	Miranda	E	
7778AN	11		4	95 50	Miner Mir	WNE	
7779	13		2	97 50	Minerva	WN	
7781M	18		50	98 40	Minerva	E	
7782M	19		2	100 40	Minerva	W	
7785M2	22		50	101 30	"	E	
7787AN	31		3	104 30	Mir Min	WE	
7789E	Sept 1		2	106 30	Minerva	W	
7790	2		15	106 45	Minerva	W	
7792			5	106 50	Miranda	E	clouds
7793M			10	107	Minerva		
7794AN	6		4 45	111 45	Mir Min	WE	
7795AN	7		1 15	113	Minerva	W, E	+ North in sweep around
7796AN	8		5	118	Miranda	WE	
7797, 7798AN	9		2	120	Miranda	WE	
7799EM	10		30	120 30	Minerva	W	
7800	11		15	120 45	Min	W	
7804	14		1 15	122	Min	E	"Camping Squalour"
7805	15		15	122 15	Min	E	
7806	16		2	124 15	Miranda	W	

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	Session	Date	Begin End	Time	Total	Scope	Area	Comment
	7807	16		0 40	124 55	Miranda	E	
	7810	17		45	125 40	"	E	
	7811	18		15	55		W	
	7813			2 45	128 40		W, E	
	7814	19		15	55	Minerva	W	
	7815			1 45	130 40	MirMin	E	
	7816	20		2 15	132 55		WE	
	7819	23		1	133 55		E	
	7823E	27		15	134 10	Minerva	W	
	7824E	28		30	134 40		W	
	7825	29		1	135 40		W	
	7826	30		1	136 40		W	
OCT 88	7827	6		05	136 45		E	
	7828	7		1	137 45	MirMin	E	
	7829	8		4 45	142 30	MinMin	WE	
	7830MN	9		6	148 30	Minerva	WNE	
	7831M	13		4 45	153 15	Miranda	E	
	7832	14		45	154	Miranda	E	
	7833M	15		10	154 10	Minerva	E	RAINING during hunt
	7834E	16		1	155 10	Minerva	W	(E clear)
	7836EM3	16		25	155 35	Miranda	W	
	7837M4	[illegible] 16		1 [illegible]	15[illegible] 5[illegible]		E	156 35
	7838M	17		15	156 50	Minerva	W	
	7839	18		1	157 50	Mir Min	E	
	7841	21		25	158 15	Minerva	E	
	7842	22		1	159 15		E	
	7843	23		10	159 25		W	
	7844	·		30	159 55	Miranda	E	
	7845	24		5	160	Minerva	W	
	7846	25		5	160 05	?Minerva	E	
	7848	27		20	160 25	Minerva	W	
	7849	28	1830-1945	40	161 05	Minerva	W	
	7852E	29	1900-2040	1	162 05	Min Mir	W	
	7854	31		4 10	166 15	Miranda	W	
Nov	7855	·		45	167	Miranda	S	
	7856	Nov 1		4 30	171 30	Minerva	W	
	7857	2		45	172 15	Miranda	W	
	7858	·		35	172 50		W	
	7859			4 45	177 35		WN	
	7860	4		4 30	182 05		WN	
	7861	5		45	182 50	Minerva	W	
	7862	5		35	183 25		N	
	7864E2	6		20	183 45		W	

"Galactic wind", origin (2) 38.

DATE SESSION	TIMES DATE	TOTAL		ACC. TOTAL		SCOPE	AREA	
7865	NOV 6		25	184	10	Miranda	E	
7866	7		30	184	40	Minerva	N	
7868	9	3	20	188	00	Min Mir	E	
7869	10	6	15	194	15	Miranda	W E	
7870	11		5	194	20	Miranda	E	
7872	11	1		195	20	Miranda	E	
7874	13	7		202	20	Minerva	WNE	
7875,6	14	4	40	207	00	Mir Min	W E	
7878	15	1		208	00	Miranda	E	
7879	16		35	208	35	Minerva	SE	
7881	17	2	15	210	50	Miranda	N SE	
7883	18	1	30	212	20	Miranda	E	
7885	19	1	10	213	30	Miranda	N	
7886M3	19		5	213	35	Penelope	E	
7887	20		15	213	50	Miranda	E	
7888	20		40	214	30	Miranda	E	
7889	21		35	215	05		E	
7890	22		5	215	10	Miranda	E	
7891	28	2	35	217	45	Minerva	W	
7892	29	3	15	221	00	Miranda	W	
7893	30	4		235	00	Miranda	W	
7894E	1 DEC	4		229	00	Miranda	W	
7895	2	4		232	00	Miranda	W/N	
7896	4	1		233	00	Minerva	SW	with Clyde
7897	5	0	15	233	15	Minerva	W	
7900	6		20	233	35	Minerva	E	
7901	7		30	234	05	Miranda	E	
7903	8		30	234	35	Miranda	E	
7904	11	4	20	238	55	Mir/Min	WE	
7910AN	17/18	Start of		CN3F+3G,		Record will be kept in observ		
7911	19		30	239	25	Minerva	E	
7912M	20		15	239	40	Minerva	E	
7913M	21	1		240	40	M Miranda	E	
7915	24		10	240	50	Minerva	W	

"Galactic wind", origin (2) 38.

DATE SESSION	TIMES DATE	TOTAL		ACC. TOTAL		SCOPE	AREA	
7865	NOV 6		25	184	10	Miranda	E	
7866	7		30	184	40	Minerva	N	
7868	9	3	20	188	00	Min Mir	E	
7869	10	6	15	194	15	Miranda	W E	
7870	11		5	194	20	Miranda	E	
7872	11	1		195	20	Miranda	E	
7874	13	7		202	20	Minerva	WNE	
7875,6	14	4	40	207	00	Mir Min	W E	
7878	15	1		208	00	Miranda	E	
7879	16		35	208	35	Minerva	SE	
7881	17	2	15	210	50	Miranda	N SE	
7883	18	1	30	212	20	Miranda	E	
7885	19	1	10	213	30	Miranda	N	
7886B	19		5	213	35	Penelope	E	
7887	20		15	213	50	Miranda	E	
7888	20		40	214	30	Miranda	E	
7889	21		35	215	05		E	
7890	22		5	215	10	Miranda	E	
7891	28	2	35	217	45	Minerva	W	
7892	29	3	15	221	00	Miranda	W	
7893	30	4		225	00	Miranda	W	
7894E	1 DEC	4		229	00	Miranda	W	
7895	2	4		232	00	Miranda	W/N	
7896	4	1		233	00	Minerva	SW	with Clyde
7897	5	0	15	233	15	Minerva	W	
7900	6		20	233	35	Minerva	E	
7901	7		30	234	05	Miranda	E	
7903	8		30	234	35	Miranda	E	
7904	11	4	20	238	55	Mir/Min	WE	
7910AN	~~19~~ 17/18	Start of	CN3F+3G.			Record will be kept in observ		
7911	19		30	239	25	Minerva	E	
7912M	20		15	239	40	Minerva	E	
7913M	21	1		240	40	Miranda	E	
7915	24		10	240	50	Minerva	W	

SESSION	DATE	TOTAL		ACC. TOTAL		SCOPE	AREA	COMMENTS
7917E	27	2	00	242	50	Minerva	W	w/Steve
7918	28		30	243	20	"	W	
7922	29	1	45	245	05	Miranda	W	
7924	30	2	30	247	35	Miranda	W	
7925	30		5	247	40	Miranda	E	Confirmed 1988r Yanaka
7928	JAN	1		248	40	Miranda	W	
7929	8	3	30	252	10	Miranda	W E	
7930	9	3		255	10	Miranda	W N E	
7932M	15		15	255	25	~~A~~	E	Calgary
7934E	29	1	15	256	40	Minerva	W	
7935			15	256	55		E	
7936E	30	2	30	259	25	Miranda	E	
7937	1 FEB		30	259	55	Miranda	W	
7938	2		20	260	15	Miranda	E	
7939	3	2		262	15	Miranda	W	
7940	4	1		263	15		E	
after 7933 { 7943	23/24 Jan	0	20	263	35	Minerva	W	suspect
7944	25/26	0	5	263	40		W	*was NGC 7793.
7941		1		264	40	Miranda	E	
7942		1		265	40	Miranda	E	
7946	21/22		15	265	55	Minerva	W	
7947	22/23		30	266	25		W	
7948	23/24	1	40	268	05	Miranda	W	
7950	26/27	2		270	05	Miranda	W	
7952	3/4 MAR		20	270	25	Minerva	E	
7953EM	4/5		40	271	05	Min Mir	E	
7954AN	5/6	4		275	05	Miranda	WE	
7955		4	10	279	15	Mir	W	
7957	7/8	4		283	15	Miranda	W E	
7959	8/9	2		285	15	Miranda	~~W~~ E	
7960AN	9/10	5		290	15	Mir Min	W, E	
7961AN	10/11		30	290	45	Minerva	E	
7965	15/16		45	291	30	Miranda	E	
7966	16/17		10	291	40	Minerva	E	
7968	26/27		10	291	50	Minerva	W	
7969	26/27/28		30	292	20	Min	W	
7970	27/28	5		297	20	Min Mer	W, E	
7971	28/29	5		[illegible]	20	Min Mir	W E	

Hyperbola-①5-Orbits.
hydromagnetic waves, Origin②37.

horror + comet pp 13-13.56720

SESSION	DATE	TOTAL		ACC TOTAL		SCOPE	AREA	COMMENTS
7972	29/30	2		304	20	Miranda	W, E	
~~APR~~ 7974	31/32		10	304	30	~~Min~~ spyglass	E.	
APR 7975	4/5		30	305	00	Minerva	W	
7976		1		306		Mir Min	E	
7977			15	306	15	Minerva	W	
7978			20	306	35	Minerva	W	(before 7968)
7980	5/6	2		308	35	Miranda	E	
7981	6/7	1		309	35	Miranda	E	
7982	7/8	1		310	35	Miranda	E	
7985	2/9	1		311	35	Miranda	E	
7986/7992	7992/29/30		10	311	45	Minerva	E	
7988	2/3	1		312	45	Miranda	W	
MAY 7989			45	313	30	Miranda	E	
7991	3/4		50	314	20	Miranda	E	
7992	4/5		20	314	40	Minerva	E	
7995	8/9	2		316	40	Miranda	W E	
7996	9/10	1	35	318	15	Miranda	E	
7997	10/11		10	318	25	Minerva	W	
7999			20	318	45	Minerva	E	
8000	26/27		30	319	15	Minerva	NW	
8001	27/28		30	319/318	45	Minerva	NW	
8003	29/30		05	319	50	Minerva	W	
JUNE 8005	1/2		30	320	20	13" Minerva	W	
8006	2/3	3		323	20	13", Min	~~W~~, N, E	
8009	3/4		5	323	25	Minerva	E	
8011	5/6		10	323	35	Minerva	E	
8012	7/8		15	323	50	Miranda	E	
8013	8/9/10		30	324	20	Miranda	E	
8014	10/11	2	15	326	35	Min Mir	W, E	
8015	11/12		30	327	05	Miranda	E	
8016E	12/13		30	327	35	Miranda	E	
8017			40	328	15	Miranda	E	
8020	15/16		45	329		Miranda	E	

Summer 1989

SESSION	DATE	TOTAL		Acc TOTAL		SCOPE	AREA	COMMENT
8021	21/22	1	10	330	10	Minerva	N, W	
8022	22/23	0	45	330	55	Miranda	W	
8023	23/24	2		332	55	Miranda	W, E.	
8024	24/25/26	2		334	55	Miranda	E	
8025	25/26/27	1	40	336	35	Miranda	W, E	
8026	26/27		35	337	10	Miranda	E	
8027	27/28		30	337	40	"	E	For P/BrM
July 8030	1/2		15	337	55	Minerva	W	
8031			40	338	35	Minerva	E	
8032	2/3		30	339	05	"	E	
8033	11/12		20	339	25	"	E	
8034	12/13		40	340	05	Miranda	E	
8036	13/14	1		341	05	"	E	
8039	20		5	341	10	Minerva	E	
8041	23		5	341	15	"	NW	
8042	26	1		342	15	"	W	
8043	28	2		344	15	"	W	
8047	31		30	344	45	"	W	
Aug 8049	6		5	344	50	"	E	
8051	9	1		345	50	Miranda	E	
8052	10		40	346	30	"	E	
8055	20		40	347	10	"	W	
8056	21		45	347	50	"	W	
8060	25	1	15	349	05	"	W	Suspect
8061	26	1	15	350	20	"	W	Discovery
8062				0	10			
8066					55			
8067				2	55			
8069				5				
8070				7	20			
8071				7	40			
8072				8	00			
8079				8	30			
8080				10				
8082				12				
8087				13				
8088				13	20			
8089				13	25			

SESSION	DATE	TOTAL	ACC TOTAL	SCOPE	AREA	COMMENTS
8090	26/27-Aug		14 25			
8091			14 40			
8094			15 40			
8096			15 55			
8097			16 55			
8098			18 30			
8101			20			
8102			22 30			
8105			23 30			
8106			24 30			
8107			25 30			
8109			25 50			
8108✓			26 35			
8119			26 50			
8120			27 05			
8131			27 15			
8133			27 20			
8139			27 25			
8143			27 30			
8144			28 30			
8155			28 45			confirmed SK-Geo
8157EM			30 45			
8158			31 45			
8162			32 05			
8162			32 40			
8170			33 20			
8172	1990		33 45			
8173			35 15			
8174			35 405			
8175			35 450			
8176			36 10			
8185			38 10			
8188			39 10			
8190			840 25			
8192			40 40			
8195			41 20			
8196			42 25			
8197			43 25			

SESSION	DATE	TOTAL	Acc TOTAL	SCOPE	AREA	COMMENTS
8200			44 30			
8201			45 45			
8204			46 15			
8207			46 25			
8210			47 25			
8211			48 45			
8220		3h	51 45			
8221		15'	52 00			
8222			52 40			
8223			53 30			
8227	1990 Mar 13/14	0 40	54 10	Miranda	W	
8237		2 35	56 45			
8239		35	57 20			
8246	April	10	57 30			
8250	"	45	58 15			
8261	May 11/12	1	59 15			
8264	15	1	60 15			
8265		15	60 30			
8270	20	40	61 10	Miranda	E	Discovered 1990c
8273	22	2	2	Minerva	W	
8276	24	1 45	3 45	13" rl	E.	
8281		15	4	Miranda		
8282		1 20	5 20	Miranda	E	
8287		35	5 55	Mir ~~Min~~	W	
8288		35	6 30	Miranda	W	
8289		1	7 30	Mir/Min	W	
8291		1	8 30	Miranda	W	
8306			10			
8314			10 30			
8315			10 50			
8326			11 50			
8327			12 30			
8359			12 40			
8361			13 50			
8362			14 10			
8364			14 40			
8366			15 10			
8368			15 40			
8369			16 25			

SESS	DATE	TOTAL	Acc TOTAL	SCOPE	AREA	COMMENTS
	Law of Univ. Grav (1)-4 Hist					
	Correct light erratic fluctuations of Origin (2) 37					
8373			16 55			
8375			17 30			
8376			18 00			
8378			19 00			
8380			19 30			
8384			19 40			
8392			20 55			
8393			22 55			
8394			25 55			
8395			27 25			
8399			28 10			
8400			29 10			
8402			30 10			
8406			32 10			
8414			33 10	independent find of 1990i		
8418			33 50			
8419			35 20			
8420			35 55			
8431			36 25			
8437			37 40			
8438			38 25			
8439			41 55			
8442			44 10			
8448			44 30			
8449			45 15			
+			46 35			
8458			46 50			
8461			48 50			
8471			49 20			
8474			49 35			
8475			50 20			
8476			51 10			
8477			54 00			
8479			55 30			
8480			56 30			
8482			57 40			
8494			59 25			

Law of Univ. Grav ① -4 Hist
Comet light, erratic fluctuations of Origin ② 37

SESS	DATE	TOTAL	Acc TOTAL	SCOPE	AREA	COMMENTS
8373			16 55			
8375			17 30			
8376			18 00			
8378			19 00			
8380			19 30			
8384			19 40			
8392			20 55			
8393			22 55			
8394			25 55			
8395			27 25			
8399			28 10			
8400			29 10			
8402			30 10			
8406			32 10			
8414			33 10	independent find of 1990;		
8418			33 50			
8419			35 20			
8420			35 55			
8431			36 25			
8437			37 40			
8438			38 25			
8439			41 55			
8442			44 10			
8448			44 30			
8449			45 15			
+			46 35			
8458			46 50			
8461			48 50			
8471			49 20			
8474			49 35			
8475			50 20			
8476			51 10			
8477			54 00			
8479			55 30			
8480			56 30			
8482			57 10			
8494			59 25			

SESSION	DATE	TOTAL	BEAcc TOTAL	SCOPE AREA	COMMENT
8617			8 15		
8618			8 25		
8620			89 05		
8622			9 10		
8624			9 20		
8626			10 05		
8627			11 20.		
8628			11 30		
8631			12 5		
8633			12 35		
8634			13 5		
8635			13 25		
8636			14 5		
8638			14 55		
8642			15 25		
868			16 25		
869			18 25		
8661			18 50		
8662			19 15		
8663			19 40		
8664			20 05		
8665			20 ~~25~~ 30		
8668			21 15		
8669			22 15		
8670			23 30		
8671			24 50		
8672			25 25		
8676			26 45		
8677			27 00		
8678			28 00		
8679			29 00		
8680			30 00		
8681			30 25		
8686			30 35		
8687			31 20		
8688			32 00		
8690			32 05		
8691			32 10		
8694			32 40		

ISESSON	DATE	TOTAL	ACC TOTAL	SCOPE	AREA	COMMENTS
8697			32 55			
8699			33 00			
8706			33 15			
8705			33 20			
8713			33 25			
8715			33 405			
8716			33 35.			
8717			34 05			
8718			34 10			
8726	1992		34 15			
8728			34 20			
8729			34 30			
8731			35 35			
8732			36 35			
8733			36 40			
8735			36 45			
8738			38 30			
8740			40 15			
8742			40 20			
8743			41 35			
8744			43 20			
8745			44 35			
8746			45 25			
8749			45 50			
8750			45 55			
8751			46 15			
8752			46 20			
8758			46 35			
8759			49 15			
8760			50 15			
8761			51 15			
8763			51 20			
8764			51 25			
8767			51 30			
8770			51 35			
8771			52 40 50			
8772			54 15			
8773			55 00			
8775			56 45			

SESS	DATE	TOTAL	ACC TOTAL	SCOPE	AREA	COMMENT
Cort's Theory, Origin ③38.						
2776			57 30			
2777			58 45			
2778			59 35			
2779			60 10			
2780			62 10			
2781			63 40			
2784			64 10			
2786			65 10			
2787			66 10			
2791			66 15			
2792			66 25			
2793			66 35			
[illegible]			667 00			
[illegible]			67 05			
2798			67 45			
2802			68 00			
[illegible]			68 30			
[illegible]			69 30			
[illegible]			72 30			
[illegible]			74 00			
[illegible]			74 15			
[illegible]			74 20			
[illegible]			74 35			
[illegible]			74 50			
[illegible]			74 55			
[illegible]			75 00			
[illegible]			75 20			
[illegible]			75 50			
[illegible]			76 20			
[illegible]			76 45			
[illegible]			77 45			
[illegible]			77 55			
[illegible]			78 55			
[illegible]			80 00			
[illegible]			81 00			
[illegible]			81 05			

SESSION	DATE	TOTAL	ACC TOTAL	SCOPE	AREA	COMMENT
8831			81 10			
√8832			81 15			
√8832			81 20			Comet Tanaka-Machholz at < 2°
8833			81 35			$M_1 = 11$
8834			81 45			
8836			82 20			
8837			82 25			
8838			83 10			
8839			83 15			
8843			83 50			
8844			84 20			
8845			84 55			
8846			85 15			
8847			87 45			
8849			88 15			
8850			88 40			
8851			88 50			
8852			89 10			
8855			90 10			
8857			91 08			
8859			91 10			
8861			92 10			
8863			94 10			
8866			95 10			
8867			96 10			
8868			98 10			
8870			98 30			
8871			98 50			
8872			99 05			
8873			99 45			
8874			101 45			
8875			104 45			
8876			107 45			
8877			108 05			
8878			108 50			
8883			109 20			
8884			~~109~~ 110 05			
8888			110 35			
8889			111 05			

SESSION	DATE	TOTAL	ACC. TOTAL	SCOPE	AREA	COMMENTS
	Parabola (1) - ~~#~~7 - Orbits, Prominences, Origin (3) - 38 Plasma - Origin (2).					
8890			113 05			
8891			115 05			
8892			116 45			
8893			118 00			
8895			119 00			
8898			120 15			
8899			120 30			
8900			120 45			
8901			121 00			
8902			121 20			
8903			121 25			
8904			121 33			
8906			123 33			
8907			124 33			
8911			125 15	(-2 min)	see 8455)	
8912			126 00			
8913			127 05			
		1993				
8916			127 35			
8918			128 10			
8920			129 10			
8922			130 20			
8932			131 10			
8933			132 30			
*8934			133 35			Wilmot Fed.
8935			135 35			
8936			137 00			
8937			13~~8~~7 30			
8940			138 30			
8941			138 40			
8942			138 50			
8944			139 50			
✓9120			141 15			
✓8946			141 45			
8947			142 45			

SESSION	DATE	TOTAL	ACC TOTAL	SCOPE	AREA	COMMENT
8948			—			
8949			—			
			CN3g: Discovery of Periodic Comet Shoemaker-Levy 9 (see special book}- CN3; II)			
8953			143 45			
8954 }			144 45			
8955 }		(see 8911) (2 min)	obs. of 1993e. P/S-L 9.			
8962			145 45			
8963			~~146 45~~ (147 05)			
8964			147 50			
8965			148 30			
8966			148 50			
8967			150 10			
8968			151 10			
8969			151 55			
8970			152 40			
8971			153 00			
8972			153 30			
8974			155 10			
8975			156 10			
8981			156 20			
8982			157 00			
8983			157 20			
8984			158 20			
8985			159 00			
8989 —			CN3g: Discovery of Comet Shoemaker-Levy 199[illegible]			
9001/12			159 15			
9006			160 15			
9007			161 15			
9008			162 50			
9010			163 20			
9011			163 25			
9012			164 00			
9014			164 30			
9016			164 35			
9017			165 10			
9018			165 25			

SESSION	DATE	TOTAL	ACC TOTAL	SCOPE	AREA	COMMENT
9019			165 40			
9020			165 45			
9021			166 50			
*9024 M2			168 20	Comet-like		White Sands launc
9026 M2			168 35			
9027			168 50			
9028			169 25			
9028/9029			169 50			
9032/9038			170 15			
9039			170 40			
9041			171 105			
9042			172 10			
9043			172 15			
9044			172 30			
9045			172 45			
9046			173 00			
9047			173 10			
9048			173 20			
9049			173 35			
9050			173 50			
9052			174 25			
9059			174 50			
9060			174 55			
9061			175 06			
9062			175 13			
9063			175 19			
9067			175 35			
9068			177 ~~176~~ 05			
9070			178 35			
9071			180 05			
9073/9075			180 50			
9082/9072			181 30			
9091			181 35			
√9103			181 40			
√9099			181 45			
9100			181 50			
9102			181 55			
√9116			182 55			in memory of Lima Ba
9117			183 55			

1994

SESSION	DATE	TOTAL	ACC TOTAL	SCOPE	AREA	COMMENT
9129M		45m	184 40			
9131M		1h	185 40			
9133M2		1 20	187 00			
9136E		05	187 05			
9137E		30	187 35			
9141AN		30	188 05			
9143EM		1 00	189 05			
9142EM		2 00	191 05			
9145M		25	191 30			
9146M		1 00	192 30			
9152E		2 20	194 50			
9156AN		1 15	196 05			
9156AN again		30	196 35			
9157E		2 00	198 35			
9159EM2		1 00	199 35			
9163E2		05	199 40			
*9164M3		1 00	200 40			
9166M2		15	200 55			
						CN3g: Carolyn finds fast moving comet on films taken Mar 13/14 1994
9178M		5	201 00			
9184E		1 00	202 00			
9186E		1 30	203 30			
						CN3g: Carolyn recovers that new comet: Shoemaker-Levy 1994d April 1/2, 1994
9197 ~~9196M~~2		05	203 35			
9199E2						CN3F: films to search for 1994d.
[illegible] 9202M2	Apr 14/15	0 30	204 05			– after 10 minutes, found Takamizawa-Levy 1994F,
9203M	15/16	0 40	0 40			
9212E		0 15	0 55			
9217AN		0 15	1 10			
9218AN		0 25	1 35			
9219AN		0 05	1 40			
9222M		30	2 10			
9229AN		40	2 50			
9230AN		1 10	4 00			

1994

SESSION	DATE	TOTAL	ACC TOTAL	SCOPE	AREA	COMMENT
9129M		45m	184 40			
9131M		1h	185 40			
9133M2		1 20	187 00			
9136E		05	187 05			
9137E		30	187 35			
9141AN		30	188 05			
9143EM		1 00	189 05			
9142EM		2 00	191 05			
9145M		25	191 30			
9146M		1 00	192 30			
9152E		2 20	194 50			
9156AN		1 15	196 05			
9156AN again		30	196 35			
9157E		2 00	198 35			
9159EM2		1 00	199 35			
9163E2		05	199 40			
*9164M3		1 00	200 40			
9166M2		15	200 55			
			CN3g: Carolyn finds fast moving comet on films taken Mar 13/14 1994			
9178M		5	201 00			
9184E		1 00	202 00			
9186E		1 30	203 30			
			CN3g: Carolyn recovers that new comet: Shoemaker-Levy 1994d April 1/2, 1994			
9197 ~~9196~~M2		05	203 35			
9199E2	CN3F: films to search for 1994d.					
9202M2	Apr 14/15	0 30	204 05			– after 10 minutes, found Takamizawa-Levy 1994F.
9203M	15/16	0 40	0 40			
9212E		0 15	0 55			
9217AN		0 15	1 10			
9218AN		0 25	1 35			
9219AN		0 05	1 40			
9222M		30	2 10			
[illegible]AN		40	2 50			

SESSION DATE	TOTAL	ACC TOTAL	SCOPE	AREA	COMMENT
9232AN Robey's Theory, Origin (2)	0 35	4 35			
9255AN	2 00	6 35			
9271AN	0 15	6 50			
9273AN	5	6 55			
9274AN	5	7 00			
9284AN	15	7 15			
9285AN	1 30	8 45			
9289M	1	9 45			
9303EM	15	10 00			
9304AN	5	10 05			
9305AN	10	10 15			
9306AN	10	10 25			
9308AN2	10	10 35			
9332E 1995	1 05	11 40			
9333M2	30	12 10			
9339M2	45	12 55			
9341M	1	13 55			
9346M	30	14 25			
9348M2	15	14 40			
9357EM	2	16 40			
9358EM	1	17 40			
9359EM	1 30	19 10			
9361M	5	19 15			
9362M	25	19 40			
9367M3S	25	20 05			
9373E	40	20 45			
9374M	25	21 10			
9377E	1 20	22 30			
9380E	30	23 00			
9381E2	35	23 35			
9385M2	1	24 35			
9387M2	50	25 25			
9388M	30	25 55			TV Crv 13.0
9391M3	1	26 55			
9393M2	35	27 30			
9394M	1	28 30			
9398M2	30	29 00			
9412E	1	30 00			
9422M3	1	31 02			

SESSION	DATE	TOTAL		ACC TOTAL	SCOPE	AREA	COMMENT
9434E		1		32 00			
9443M			40	32 40			
9446E			45	33 25			
9454M			50	34 15			
9449M3			45	35 00			
9450M		1		36 00			
9453E			15	36 15			
9461E			45	37 00			
9462M2		1		38 00			
9463M			35	38 35			
9482M		1	10	39 45			
9481M		1		40 45			
9471M2		1		41 45			
9477M			50	42 35			
9480M			40	43 15			
9485M2			45	44 00			
9488AN		1		45 00			
9503M			45	45 45			
9505M			45	46 30			
9509M			20	46 50			
9510M		1		47 50			
9511M			5	47 55			
9518E		1	40	49 35			
9519M			40	50 15			
9520M			30	50 45			
9534E			50	51 35			
9554E		4	00	55 35			
9556E		4	00	59 35			
9561M			45	60 10			
9562M		1		61 10			
9583M		2	00	63 10			
9588E			45	63 55			
9589E			30	64 25			
9586M			30	64 55			
9587M			15	65 10			
9605E	1996	3	00	68 10			
9607E		1		69 10			
9608M2		1		70 10			
[illegible]			45	70 55			

SESSION	DATE	TOTAL	ACC TOTAL	SCOPE	AREA	COMMENT
	Solar wind, Origin ② 38					
	~~S~~ Sweets Mechanism, Origin ② 40.					
9622E		1 00	71 55			
9623E		3 00	74 55			
9626M		45	75 40			
9627M		1	76 40			
9628M		1	77 40			
9629M		1 45	79 25			
9657M3		30	79 55			
*9663AN		45	80 40			Last session a[t] for comet hun[ting]
	*9701E was final session at JM4.					
9708AN		10	80 50			
9709AN		10	81 00			
*9750M		20	81 20			First Vail/Jarna[…] comet hunting
9757E		30	81 50			
9759E		1	82 50			
9760E		35	83 25			
9766E		1 10	84 35			
9767M2		30	85 05			
9770EM3		10	85 15			
9788M		30	85 45			
9789M		30	86 15			
9790M		35	86 50			
9796M		30	87 15			
9798M2		1	88 15			
9799M		30	88 45			
9802EM2		45	89 30			
9804M2		30	90 00			
9805E		30	90 30			
9806M2		45	91 15			
9807M		55	92 10			
9815E		30	92 40			
9816E		15	92 55			
9817E		1 30	94 25			
9818E		1 50	96 15			
9820E		40	96 55			
9821E		1 15	98 10			
9822M		40	98 50			
9823E		1 15	100 05			

SESSION	DATE	TOTAL	ACC TOTAL	SCOPE	AREA	COMMENT
9824M2		0 50	100 55			
9825E		0 35	101 30			
9826E		1 05	102 35			
9828E		1	103 35			
9838E		45	104 20			
9839E		1	105 20			
9840M2		40	106 00			
9847M2		1	107 00			
9848E		1 30	108 30			
9849E		35	109 05			
9854M2		1	110 05			
9858M2		1 05	111 10			
9870E		15	111 25			
9871E		30	111 55			
9876E		2	113 55			
9877E		1	114 55			
9878E		1 30	116 25			
9880M2		1 35	118 05			
9881E		1	119 05			
9883M2		1 35	120 45			
9884M		1 30	122 15			
9891M2		40	122 55			
9893M2		1 20	124 15			
9898SE		10	124 25			
9900M3		40	125 05			
9903M3		10	125 15			
** 9907EM2	17 Dec	5	125 20	MineralX	S.	31st anniversa[illegible]
9908M2		20	125 40			
9909E		10	125 50			
9911M2		5	125 55			
9912E		10	126 05			
9916E		15	126 20			
9919E2		10	126 30			
9923E		10	126 40			
9926E2		30	127 10			
9933E		2	129 10			
9940E3	1997	1 15	130 25			
9945E		20	130 45			
99[illegible]M		25	131 10			

SESSION DATE	TOTAL	ACC TOTAL	SCOPE	AREA	COMMENTS
9946M	0 30	131 40			
9947M	10	131 50			
*9949M3	30	132 20			In memory of Clyde T.
9951M2	45	133 05			
9954M	15	133 20			
9955E	10	133 30			
9964M	10	133 ~~35~~ 40			
9967E2	1 30	135 10			
9968E	5	135 15			
9971E3	30	135 45			
9979E2	40	136 25			
9980M2	15	136 40			
9981E	2 05	138 45			
9983M	1 30	140 15			
9986E2	5	140 20			
9988M4	1 35	141 55			
9991E	10	142 05			
9993M3	1 25	143 30			
*9996M3	1	144 30			
9998M2	40	145 10			
10001M3	1 15	146 25			
10003M	20	146 45			
10016E	1	147 45			
10017M3	15	148 00			
10018E	1 25	149 25			
10019M2	15	149 40			
10022E3M4	35	150 15			
10026M2	25	150 40			
10029E3	10	150 50			
10030M4	25	151 15			
10033E	30	151 45			
10034E	25	152 10			
10035M2	30	152 40			
10046M3S	25	153 05			
10047E	30	153 35			
10048/M2	20	153 55			
10049E	20	154 15			
10050M2	20	154 35			
10054E2	5	154 40			

SESSION DATE	TOTAL	ACC. TOTAL	SCOPE	SESS AREA	COMMENT
10056M	0 30	155 10			
10069M2	5	155 15			
10072E3	30	155 45			
10073E	30	156 15			
10074M	20	156 35			
App 10076E 4/97	5	156 40			
10084E	15	156 55			
10086M3	5	157 00			
10087E	40	157 40			
10094E	50	158 30			
10096E	1 00	159 30			
10097M2	25	159 55			
10100M3	50	160 45			
10105E	15	161 00			
10110E2	15	161 15			
10121E	10	161 25			
10124M3	45	162 05			
10130M2	50	162 55			
10135M3	30	163 25			
10137AN	1 40	165 05			
* 10138AN	4 20	169 25			
10145M	40	170 05			
10146M	30	170 35			
* 10158M	40	171 15			
* 10159AN	4 40	175 55			
10160E	1	176 55			
* 10162AN	5	181 55			
10163E	1	182 55			
10164M2	35	183 30			
10167E	5	183 35			
* 10171SAN2	4 10	187 45	Min, Mir	Miranda: secondary	
* 10173SAN2	6 05	193 50	Min, Mir.		
10178M3	1	194 50	Min, Mir.		
* 10180M3	1	195 50	Miranda		
10181M3	1 15	197 05	Miranda		? comet ?
10183M2	50	197 55	Miranda		Comet- [illegible]
10192SE2	1	198 55	Miranda		
10194E2	1	199 55	Miranda		
10195E	1	200 55	Min, Mir		

SESSION DATE	TOTAL	ACC TOTAL	SCOPE	AREA	COMMENT
10196E	1 05	202 00	MinMin		
10200E	1	203 00	Miranda		
10205E2	25	203 25	Miranda		
10206M	1	204 25	"		
10209M2	20	204 45	Munerva		
10210M	1	205 45			
*10211AN	6 30	212 15	MinMin		
*10214AN3	6 10	218 25	MrMin		
10232M	1 5	219 30			
10242M2	30	220 00			
10244M2	30	220 30			
	– prostate cancer surgery –				
*10252E2	15	220 45			
10253E	5	220 50			
10254E	2	222 50			
10259E	30	223 20			
10261M	35	223 55			
10264E	35	224 30			
10274E	30	225 00			
10275E	30	225 30			
10276E	35	226 05			
10279E	1 50	227 55			
10280E	30	228 25			
	– kidney cancer surgery –				
10286E	25	228 50			
10287E	30	229 20			
10296E	20	229 40			
10297E	30	230 10			
10319M2	40	230 50			
10332E2	10	231 00			
10335E2	1	232 00			
10337E2	1 10	233 10			
10346E2	1	234 10			
*10348EM2	45	234 55			
10350E2	10	235 05			
10353M2	1	236 05			
10353M2	1	237 05			
10355E2	10	237 15			
10356M3	1	238 15			

# Session Date	Total	Acc Total	Scope	Area	Comments
10359E2	0 20	238 35			
10360M3	20	238 55			
10367M3	25	239 20			
10378E	30	239 50			
10390E2	1	240 50	Ind. disc. P/Tempel-Tut		
10418E2	5	240 55			
10420E2	1	241 55			
10444M2	1 15	243 10			
10446E2	15	243 25			
10448E2	15	243 40			
10,456E2	30	244 10			
10,458E2	1 20	245 30			
10461E2	15	245 45			
10463 E2	1	246 45			
10465E2	10	246 55			
10468E2	5	247 00			
10476M2	10	247 10			
10478M2	35	247 45			
10480E2	1 10	248 55			
10481 M3	~~1 4~~35	249 30			
*10483E2	20	249 50			
10484M3	35	250 25			
10488M4	1	251 25			
10501E2	10	251 35			
10503M	30	252 05			
10507E2	1	253 05			
10511E	15	253 20			
10513M	5	253 25			
10514M	5	253 30			
10517M2	30	254 00			
10520M	1	255 00			
*10527M	1 15	256 15			
105[illegible]9M	35	256 50			
*10[illegible]56SANS	6 05	262 55			
*10557AN	5	267 55			
*[illegible]	1	[illegible]			

SESSION

?? ?

DATE	TOTAL	ACC TOTAL	SCOPE	AREA	COMMENT
10,578E2	0h 20m	270h 00m			
10,579E	20	270 20			
10,581E2	20	270 40			
10,582E2	1 05	271 45			
10,586E3	1 10	272 55			
10,591E	1 10	274 05			
10,593M	0 25	274 30			
10,596M2	10	274 40			
10,598E2	1	275 40			
10,599M3	55	276 35			
10,604M3	10	276 45			
10,615E	30	277 15			
10,621M	45	278 00			
10,623M	30	278 30			
10,625M2	1 ·	279 30			
10,631E2	10	279 40			
10,634ANS	1 30	281 10			
~~10,634M4~~ "	10	281 15			
10,638M4	30	281 45			
10,646E	15	282 00			
10,669M2	45	282 45			
10,671M3	45	283 30			
10,674M3	55	284 25			
10,677M3	10	284 35			
10678E	1 05	285 40			
10679M2	45	286 25			
10 682M3	35	287 00			
10 685M3	1 35	288 35			
10 688M3	1 45	290 20			
10692M4	1 30	291 50			
10,704E2	30	292 20			
10,713E	30	292 50			
10 737M2	50	293 40			
10,736M2	20	294 00			
10 738M	15	294 15			
10,745M2	20	294 35			
* 10,748AN2	1	295 35			Hawaii - Leo
10,756 M2	30	296 05			
10,763 M2	40	~~29?~~ 296 45			

SESSION	DATE		TOTAL	ACC TOTAL	SCOPE	AREA	COMMENTS
10,766M			40	297h 25m			
10,777E2			35	297 55			
10779E2			30	298 25			
10800M4		1	30	299 55			
10802E2			20	300 15			
10804M4		1	30	301 45			
10808E2			15	302 00			
10811E2			15	302 15			
10,812M3		1	10	303 25			
10,815M3			15	303 40			
10,818M3			50	304 30			
10,820E2			30	305 00			
10821M3		1		306 00			
10,825M4			40	306 40			
10828M3		1	05	307 45			
10830E2			25	308 10			
10832M4		1		309 10			
10837M5		1		310 10			
	1999						
10,847E2			15	310 25			
10872M2			55	311 20			
10874E2			20	311 40			
10875M3		1	15	312 55			
10881M4		1		313 55			Miranda + add
10885M4		1		314 55			
10888M3		1		315 55			
10900E2			10	316 05			
10901M3		1	15	317 20			
10904M3		1		318 20			
10,911E2			20	318 40			
10916E2			20	319 00			
10924M3			35	319 35			
10926M2		1		320 35			
10938M3			15	320 50			
10944M2			45	321 35			
10948M3			50	322 25			
10951M2			55	323 20			
10956M4			45	324 05			

SESSION	TOTAL	Acc. Total	COMMENTS
10960E	0 30	324 35	
10962E	30	325 05	
10977M2	1 15	326 20	
10980M3	1 30	327 50	
10983M4	45	328 35	
10985M2	1 15	329 55	
10987M2	1 05	331 00	
10990M2	25	331 25	
10994E2	2	333 25	
10996E2	30	333 55	
11105M3	35	334 30	
11008M	20	334 50	
11010M3	20	335 10	
11014M3	20	335 30	
11016M2	50	336 20	
11018M2	50	337 10	
11020M3	30	337 40	
11048AN2	4 50	342 30	TSP
11049AN	3 00	345 30	TSP
11051AN2	3 45	349 15	TSP
11052AN	3 05	352 20	TSP
11053EM	1 05	353 25	TSP.
11055M2	45	354 10	
11057M2	45	354 55	
11058M	45	355 40	
11063M	1	356 40	
11070E	25	357 05	
11073E2	45	357 50	
11074E	5	357 55	
11089SAN	3 35	361 30	
11091M	50	362 20	
11099M5	50	363 10	
11100M	35	363 45	
11104M2	35	364 20	
11114E2	10	364 30	
11134M2	1 05	365 35	
11136M2	1	366 35	NGC 1491 cat. obj. 86
11144M3	30	367 05	

SESSION	TOTAL	ACC. TOTAL	COMMENTS
11149M3	30	367h 35m	
*** 11177SANS	20	367 55	Ind. dis. c/Lee
11190M2	20	368 15	
11195M	30	368 45	
11214M4.	50	369 35	
11217M3.	1	370 35	
11222M4.	30	371 05	
11223M	50	371 55	
11224M	50	372 45	Ind. disc. c/Linear 9
11227M3	40	373 25	
11228M	50	374 15	
11230M2.	30	374 45	
11233M.	1	375 45.	
11235M.	45	376 30	
11259E	30	377 05	
11258M2	40	378 45	
11259E	1	378 45	
11263M2	50	379 35	
11266M3	30	380 05	
11271AN	1	381 05	
11275M2	1	382 05	
11280M3	1	383 05	
11286E2	35	383 40	
11297M3	10	383 50	Patsy's house.
11298E	15	384 05	
11300M3	1 10	385 15	
11302M2	1	386 15	
11306M3	50	387 05	
11309M3	50	387 55	
11312M3	1	388 55	
11327E	15	389 10	
11328E2	05	389 15	
11329M3	05	389 20	
11331M	1 10	390 25	
11334M3	1	391 25	
11336M2	1	392 25	
11339M3	1	393 25	
11343M4	1	394 25	
[illegible] M3	1m	39[illegible] 25	

SESSION	TOTAL	ACC. TOTAL	COMMENTS
11348M2	1h 10m	396h 45m	
11352AN2	2	398 45	
11358M4	1 05	399 55	
* 11361EM3	05.	400 00	Dec 17, 1999, 34th anniv and first light party for Sarnac Observato
11362M4	1 15	401 15	
11372E2	1	402 15	
11377M	15	402 30.	
11385M5	1 20	403 50.	
11388M3	1 15	405 05.	{ 11390E2 CN3F-Levy-Wallach
11391M3	1	406 05	{ J2204.4+4509 "Wendee's R
11394M	0 55	407 00	
11397M3	1 05	408 00	
11400 M3	1 15	409 15	
11403M3	1	410 15	
11405M2	1 20	411 35.	
11407AN2	2 30	414 05.	
11410M3	1 10	415 15.	
11412M2	1 05	(416) ~~418~~ 20	
11416M3	1 00	417 20	
11419M3	1 05	418 25	
11424M2	1 20	419 45.	
11426M2	2	421 45	
11428E2	15	422 00	
11429M	25	422 25	
11451M2	20	422 45	
11453AN2	1	423 45	
11456M3	1 15	425 00	
11457SE	25	425 25	
11458M2	1	426 25	
11461M3	1 05	427 30	
11464E3	20	427 50	
11465M4	1	428 50	
11467E2	20	429 10	
11468M3	1	430 10	
+ 11475M5	1 25	431 35	San Salvador; 1625.8-711
+ 11476M	1	432 35	San Salvador
11478E2	1	433 35	San Salvador

SESSION	TOTAL		ACC TOTAL		COMMENTS
11479M	2	30	436	05	~~So~~ El Salvador, 20"
11482M3		20	436	35	San Salvador
11484M2		20	436	55	
11488M3	1	10	438	05	
11491M2	1		439	05	
11510M2	1	20	440	25	
11513M3	1	20	441	45	
11517M4	1	20	443	05	
11520M3	1	30	444	35	
11526M2	1	05	445	40	
11530M4	1	20	447	00	
11532M2	1	05	448	05	
11534M2	1	15	449	20	
11537M3	1		450	20	
11539M	1	05	451	25	
11541E2		15	451	40	
11542M3	1	05	452	45	
1154[illegible]E2.		15	453	00	
11549M4.		20	453	20	
11557E	1		454	20	
11576M		45	455	05	
11578M2		40	455	45	
11581M3.	1	15	457	00	
11584M3	1	05	458	05	
11587M3	1	10	459	15	
*11592AN2	6	15	465	30	
11604M2	1	05	466	35	
11607M3	1		467	35	
11609M2	1		468	35	
*11612AN	5		473	35	
11613AN	3	30	477	05	
11615M2	1		478	05	
11616AN	5	20	483	25	
11617EM		02	483	27	
11618M2		58	484	25	
11621M	1		485	25	
11623M2	1		486	25	
11629M4		45	487	10	

SESSION	TOTAL		ACC TOTAL		COMMENTS
11636E2		35	487	45	
11638E2	1	30	489	15	
*11654SAN2	2	30	491	45	
11657M3	1		492	45	
11661 M3	1	10	493	55	
11662 M3	1		494	55	
11669 M3	1	05	495	00	
11678 M2		50	496	50	
*11690SAN	1		497	50	
11695M		50	498	40	
* 11696SAN	2	35	501	15	Ind. disc. bright c/Line
11699M3	1		502	15	
11702M3	1		503	15	
11705M3		20	503	35	
11708M3		45	504	20	
11710M2	1		505	20	
11713M3	1	10	506	30	
11718M2		35	507	05	
11729E2		30	507	35	
11740M2		10	507	45	with Pegasus.
11747M3	1		508	45	with Minerva
** 11753M2		50	509	35	with Miranda's newly aluminized optics.

Independent Discovery of Comet Encke - M_v 10, in Gemini, close to horizon.

History: Jan 17, 1786 Pierre Mechain 5th mag.
2, Nov 7, 1795 Caroline Herschel 5.5
3. Oct. 20, 1805 J.-L. Pons 5.5 (also Huth & Bouvard)
- Encke calculated 12.12 yr. period
4. Nov 26, 1818 J.-L. Pons 8
- Encke calculated 3.3 yrs & connected earlier comets.
5. June 2, 1822 Rumker (Australia) 4.5 recovery
August 9, 2000 Levy "recovery" 10 mag.
Comet moving rapidly southeast.

SESSION	TOTAL		ACC TOTAL		COMMENTS
11755M2		40	510	15	
11763M3		20	510	35	
11770E2		15	510	50	
11787M3	1	30	512	20	

	SESSION	TOTAL	ACC. TOTAL	COMMENTS
#7	11796M3	1h	513 20	
	11798E2	15m	513 35	
	11799M3	1 15	514 50	
	*11803M2	35	515 25	
	11804M2	1	516 25	
	11806M2	35	517 00	
	11810M2	1 10	518 10	
	11819E2	30	518 40	
	11831E3	35	519 15	
	11833E2	30	519 45	
	*11838SAN	3 30	523 15	
	11841M	35	523 50	
	11844M3	1 10	525 00	
	11848EM2	30	525 30	
	11849E	05	525 35	
	11850m	30	526 05	
	11851M	35	526 40.	
	11853M2	1 10	527 50	
	11861E.	50	528 40.	
	11884M.	45	529 25.	
	11886E.	25	529 50.	
	11895M.	45	530 35.	
	11899m2	50	531 25.	
	11901M2	35	532 00	
	11904M3	2	534 00	
	*11905SE	40	534 40.	
	*11906M2	1 20	536 00	Ind. Disc. McNaught-Hart.
	11909M3	35	536 635	
	11911E2	1	537 35	
	11912M3	1 15	538 50	
	11916M4	50	539 40	
	11917M	35	5340 15	
	11922M4	1	541 15	
	11925M2	1	542 15	
	11928E.	5	542 20	
	**11929M2	3 10	545 30	
	11931M	1 00	546 30	
	+11935E	30	547 00	December 17, 2000

SESSION	TOTAL	ACC TOTAL	COMMENTS
11948 M3	1 h 15 m	548 15	
11951 M2	1 10	549 25	
11955 M3	25	549 50	
11956 M2	1 10	551 00	
11959 M3	15	551 15	
11972 E2	1	552 15	
11975 E2	1	553 15	
11977 E2	20	553 35	
11986 M3	10	553 45	
11987 M2	40	554 25	
11993 M2	1 05	555 30	
11998 M2	0 25	555 55	
12003 M3	1	556 55	
12005 M2	1	557 55	
12042 M3	1	558 55	
12043 M2	40	559 35	
12044 M	40	560 05	
12047 M3	50	560 55	
12058 M3	35	561 30	
* 12074 E2	10	561 40	First hunt with Cupid
12083 E	05	561 45	
12084 M3	40	562 25	
12092 M3	40	563 05	
12095 M.	45	563 50	
* 12099 M4	45	564 35	
12105 M3	20	564 55	
* 12136 AN2	15	565 05	
12140 M3	30	565 35	
12144 AN2	20	565 55	
12146 E2	30	566 25	
12149 M.	1	567 25	
12150 M	30	567 55	
12154 M4	40	568 35	
* 12156 AN2	1 30	570 05	
12158 AN2	1 10	571 15	
12163 M2	25	571 40	Manette's River.
12180 M2	20	572 00	E 2344.5 + 5612
* 12183 AN2	1 10	573 10	W 2336.2 + 5615

SESSION	TOTAL	ACC TOTAL	COMMENTS
12186M3	0^h 35^m	$573^h 45^m$	
12189M3	1	574 45	
12192m3	1	575 45	
12196E2	1	576 45	
12201M2	20	577 05	
12204 m3	1	578 05	
12206M2	1	579 05	
12208M2	20	579 25	
12210M2	1	580 25	
12223~~M~~E	30	580 55	
12232~~EM~~2 SAN	45	581 ~~35~~ 40	
12242MS3	30	582 10	Africa.
12244MS2	1 10	583 20	Africa.
12249E2	10	583 30	Africa.
12250 m3	25	583 55	Africa.
12254M4	30	584 25	Africa.
12280E2	30	584 55.	
12283E2	20	585 15	
12292E2	30	585 45.	
12293M3	1	586 45.	
12296M3	30	587 15	
12302 M.	1 15	588 30	Cat 49 + 50.
12312M2	15	588 45.	
*12315M3	1 30	590 15.	
12326E2	0 25	590 40	
12346M2	40	591 20	
12367M4	1 20	592 40	
12375E2	30	593 10	
12377E2	45	593 55	
12379E2	55	594 50	
12381EM2	1 20	596 10	
12394M.	45	596 50	
12396M2	40	597 30	
12435M2	5	597 35	
12443M2	5	597 40	
*12446M3	45	598 25	CN3Fg at same time,
*12449M3	1 00	599 25	ated;
*12451E2	1 40	601 05	

SESSION	TOTAL	ACC TOTAL	COMMENTS
12452M3	0h30m	601 35	Arp 321, L, M, + C.
12454SE2	1 35	603 10	
12455M3	0 30	603 40	
12457E2	1	604 40	
**12458M3	35	605 15	Spindle, Arp321, 1851.
12461M3	1	606 15	
12465M4	25	606 40	
12468M3	25	607 05	
*12471M3	35	607 40	
12476M	1 10	608 50	
12479M3	30	609 20	
12482M3	50	610 10	
12485M3	30	610 40	
12490M5	45	611 25	
12494M4	45	612 10	
12547E2	30	612 40.	
*12565EM3	30	613 10	
*12572AN2	3 00	616 10	
12576E2	5	616 15	
12577MS3	1	617 15	Centaurus A.
12581M3	45	618 00	
12584M3	45	618 45	
12590M3	1 05	619 50	
12593M2	1 15	621 05	
12594E	05	621 10	
12610M4	05	621 15	2002
12628M3	40	621 55	
12631M3	1	622 55	
12634M3	15	623 10	
12638M3	1 25	624 35	
12641M3	1 15	625 50	
12644M3	50	626 40	
12647M3	05	626 45	
12651MS2	35	627 20	
12662SEM2	30	627 50	
*12682M3	1	628 50	Star chain 1934.3 +2
12684M2	40	629 30	
12686M2	1	630 30	

Session	Total	Acc. Total	Comments
12696M3	1h 20m	631h 50m	
12699M3	30	632 20	
12705MS4	40	633 00	
12716~~EM2~~SE2	1	634 00	
12733M2	35	634 35	
*12736M3	35	635 10	Comet Snyder-Murak
12739M3	50	636 00	
12748M2	30	636 30	
12756M3	05	636 35	Comet ~~Ut~~ Utsunomiya
12769E3	1	637 35	
12771E2	1	638 35	
12791M2	2 20	640 55	
12794M2	3 05	644 00	
12801M4	0 25	644 25	
12803AN	45	645 10	
12807m3	1	646 10	
12812M	30	646 40	
*12814SAN2	1 05	647 45	
12829EM	30	648 15	
12836EM2	1 05	649 20	
*12839AN2	3	652 20	
12864M~~A4~~3	30	652 50	
12867M2	1	653 50	
12878EM2	30	654 20	
*12880EM2	1	655 20	TV Cru in outburst.
*12893AN2	0 50	656 10	
*12898AN2	3 05	659 15	
12904M2	1 25	660 40	
12908M4.	1 05	661 45.	
12912M3	0 50	662 35	with Pegasus.
12915M2	15	662 50	with Miranda.
12919M3	1 10	664 00	
12922MS3	1	665 00	
12923AN	1	666 00	
12925M3	10	666 10	
12936E2	1	667 10	Peter Jedicke over phone Wa
12940SE2	45	667 55	Wendee. I searched Tu
12945AN2	3 15	671 10	

Session	Total	Acc.T.	Comments
12954 SAN	1 00	672 10	Catalog No. 86 : NGC
12962 M2	1	673 10	No. ~~107, 108~~ 2 new obj. L110, 111
12964 M2	1	674 10	
* 12977 E2	10	674 20	Σ1604, Triple in Crv
* 12998 E2	5	674 25	Comet Hoenig. Coma, no tail
12999 M3	35	675 00	Comet Swan quickly N. no ta
* 13001 M2	3 20	678 20	~~Session misnumber~~
13004 M2	1 15	679 35	115: NGC 1788, 2071, 2064 ~~in cata log~~
13006 M2	1	680 35	L116 NGC 2158.
13008 M	40	681 15	
13018 E2	40	681 55	L117 = M80 L118 = GSSC + NGC 652
* 13020 E2	15	682 10	L118, L119 = M24, L120 = 6451, L121 = 5846.
13022 EM2	1	683 10	
13026 M2	30	683 40	L118 NGC 2392, L122 = 6826. L77 = R
* 13035 M3	3 15	686 55	L115 = 1788 L123 = 1600 L124 = 2174 L125 = 202
13038 M3	10	687 05	
* 13045 M3	30	687 35	
13054 E2	30	688 05	
13057 E2	1 05	689 10	
13068 M3	3 —	692 10	L93 = 2683, L126 = ,
13070 MS	20	692 30	
13072 E	1	693 30	
13073 M2	1	694 30	
* 13075 EM2	4 45	699 15	L127 16/17 Dra,
* 13080 M2	45	700 00	L129 = UGC 5373 Sex B; *L130 3198; *L131 = 2964
13082 M2	1 05	701 05	L132 = 3432.
* 13084 M	35	701 40	L133
13085 M	0 30	702 10	*L135 *L136, *L137, *L138.
* 13089 M2	0 20	702 30	L139 L140 L141 *L142 *L143 *L144 *L14
13095 M	05	702 35	
13101 E	1	703 35	
* 13111 AN2	9	712 35	Deep South Regional Star Gaze,
13112 E	1 10	713 45	
* 13116 AN2	10 00	723 45	*L149 – *L181
13128 M2	1 10	724 55	L182 – L185
13130 M2	45	725 40	*L186 – *188
13132 M2	50	726 30	*L189 – *L193
13134 M2	45	727 15	*L210 – *L215
[illegible]	30	[illegible]	[illegible] L218

Session	Total	Acc. T.	Comments
13141 M	10	727 55	Cat. Obj. Hydra Clusters
13154 M2	30	728 25	
13158 M	10	728 35	
*** 13166 MS3	45	729 20	On Marco Polo, before total eclipse
13178 M2	10	729 30	
13188 E2	1 00	730 30	
13193 E2	30	731 00	
13195 E2	15	731 15	
13198 E3	15	731 45	Session misnumbering from 1320
*** 13009 AN2	11 00	742 45	An all-time record for me 2221-
13014 M4	1 10	743 55	
13017 M2	1 15	745 10	
13025 M2	1	746 10	
13028 M3	1 15	747 25	
13031 M3	55	748 20	
13035 M2	1 05	749 25	
13037	1	750 25	
13039 M2	1 15	751 40	
13054 E2	1h	752 40	
13070 M3	3 30	756 10	
13072 M3	10	756 20	
13077 M3	1	757 20	
13080 M3	1	758 20	
13090 M2	30	758 50	
13092 M	40	759 30	
13095 M2	1	760 30	
13126 M2	3	763 30	
13129 M2	1	764 30	
13133 M4	20	764 50	
13136 M3	1	765 50	
13140 M	50	766 40	
13144 M2	1	767 40	6780 M91 D6.3 Agl GC
13164 SAN	3	770 40	Windy
13171 M2	30	771 10	
13177 M3	1	772 10	
13180 M3	1	773 10	
13182 E2	10	773 20	
13183 M3	2	775 20	

Session	Total	Acc. T.	Comments
13190M	1 00	776 20	
13196M	1	777 20	Owl Cluster.
13220AN	3	780 20	L245 V460 Cyg L246 7217
13227AN2	2	782 20	L247 Hockey Stick.
13233M2	15	782 35	
*13238E2	5	782 40	JARNACCOTTAGE.
13247E	30	783 10	
13249E2	1	784 10	
13251E2	1	785 10	L248 2986 L249 457
13256SAN2	30	785 40	
13259M3	3	788 40	
13262AN2	2	790 40	
13267EM3	1 10	791 50	
13273M2	1 05	792 55	
13282M3	20	793 15	
13295AN2	3 30	796 45	
13306M2	15	797 00	
13308M2	1 10	798 10	
13313M3	1 15	799 25	
13325AN2	3 20	802 45	
13335M2	1	803 45	
13338M2	1	804 45	
13341M3	1	805 45	
13360AN	3	808 45	Through Cupid at Starfest.
13361SEM	30	809 15	
13365M2	40	809 55	
13367M2	1 ~~20~~	810 55	
13369M2	20	811 15	
13374M	45	812 00	
13377M3	45	812 45	
13382M2	1	813 45	
13384M	1	814 45	
13392SEM	1	815 45	
13393SEM	1	816 45	
*13394SEM	1	817 45	
13397EM	1	818 45	
13399AN2	3	~~81~~821 45	
13411M2	1	822 45	

Session	Total	Acc. T.	Comments
13417M2	0 45	823 30	
13433M2	05	823 35	
13435M2	30	824 05	
13437E	30	824 35	Apollo's First comet search
13439AN	3	827 35	Windy
13443M3	1 05	828 40	
13452	1	829 40	
13655M3	0 30	830 10	(Session miscount from 13001)
13664M4	5	830 15	
*13688M2	3 00	833 15	Cat *L257, L258, L259
13690M2	1 00	834 15	
13692M	1 00	835 15	
13695M2	1 00	836 15	
*13719AN2	4 00	840 15	Cat * L185
13723M2	1 05	841 20	Catalogue L260
13725E2	1 00	842 20	
13727M4	1 00	843 20	
13732M2	1 30	844 50	Cat L261
13748M2	1	845 50	
13755EM2	1	846 50	
13759E2	1	847 50	
*13764AN2	3 30	851 20	
*13775M3	2	853 20	L119, L270, *L271
13781M3	1 40	855 00	L39
13784M2	1	856 00	
*13786AN2	1 30	857 30	
13799E2	30	858 00	
13801EM2	5	858 05	
*13821M4	3 20	861 25	
13833M3	1	862 25	
13868AN2	3	865 25	
13870SEM	10	865 35	
13874M2	45	866 20	
13877E3	10	866 30	
*13884SAN	3	869 30	
13887	1	870 30	
*13909E2	1	871 30	
*13930M3	1	872 30	Ind. disc C/2002 T7 Linear in brig

Session	Total	Acc. T.	Comments
13936AN2	1h 00m	873 30	
13943M4	45	874 15	
13949M3	30	874 45	
* 13977AN2	3	877 45	
13984SAN	1 05	878 50	
* 13986AN2	2 45	881 35	
* 13988AN2	4 30	886 05	
13994M4	0 30	886 35	
13997M3	30	887 05	
* 14000M3	30	887 35	
14002M2	1	888 35	
14005M3	1	889 35	
* 14029AN2	3 00	892 35	
14032M3	1	893 35	
14035M3	1	894 35	
14037E2	15	894 50	
14038M3	25	895 15	
14041E	15	895 30	
14043E2	35	896 05	
14045AN2	2 40	898 45	
14046AN	3 05	901 50	
14049E3	05	901 55	
14056EM	1 30	903 25	
14066EM3	45	904 05	
14087M3	1 30	905 35	
* 14089AN2	4 40	909 15	
* 14091AN2	5 45	916 00	
14106AN	60	917 00	
14109M	1 15	918 15	More time hunting for a single
14111M2	15	918 30	comet than ever. EVER.
* 14135AN3	2 40	921 10	Even my first one.
14142E2	1	922 10	→ ADIRONDACK SCIENCE CAMP
14148M4	3	925 10	
14151M3	2 45	927 55	
14159M3	1 05	929 00	
14161AN2	35	929 35	
14175EM2	1	930 35	

Session	Total	Acc.T.	Comments
14183E2	2 25	934 15	
14184M3	1 20	935 35	
14185EM	2 10	937 45	
* 14195AN2	3 00	940 45	
14211M2	1 05	941 50	
14225E2	30	942 20	
14212M2	1	943 20	
14228E	1	944 20	
14236EM2	1	945 20	
14239AN3	4 05	949 25	
14247SE	1	950 25	
14251E	1	951 25	
14255M3	15	951 40	
14257M2	1 15	952 55	
14279E2	30	953 25	
14284E3	30	953 55	
* 14296M3	30	954 25	Coyhaique, Chile.
14308EM4	30	954 55	near Vicuna, Chile.
14312EM	30	955 25	IC 4499 near S. Pole.
14322M3	30	955 55	
14332E	15	956 10	
14334M2	25	956 35	
14337E2	15	956 50	
* 14346M3	3 05	959 55	
14350SAN	3 00	962 55	
14356M	20	963 15	
14380M	05	963 20	
14387EM3	3 00	966 20	
14391EM	0 05	966 25	
14393SEM2	15	966 40	
14404M4	1 05	967 45	
14405	1	968 45	
14426AN	30	969 90	
14461SAN2	3 05	972 10	
14475AN	15	972 25	
14477M2	40	973 05	
14483E4	15	973 20	
14484EM	50	974 10	

Session	Total		Acc. T.		Comments
14486E2	0	30	974	40	
14488E2		15	974	55	
14489M3		15	975	10	
14496E		20	975	30	M/S Galapagos Legend.
14499M2	1	20	976	50	" "
14501E2		50	977	40	"
14507M2		15	977	55	"
14512M2		15	978	05	"
14516M4		15	978	20	"
14523M2		40	979	00	
14555E		15	979	15	
14556M2		40	979	55	
14560M3	1	00	980	55	
14563E		05	981	00	The Adirondack Scenic Camp.
14586E2		30	981	30	
14588E	1		982.30.		
14595EM3	3	35	986	05	
14592E		10	986	15	
14597SE2	1		987	15	
14598M3	1	05	988	20	
14599EM		40	989	00	
14604M3		40	989	40	

Telegram
Sent to IAU CBAT
on August 31, 1975.

92 - 1428 Satellite CAM | 185 ALEWIFE BROOK CAMBRIDGE MASS

D LEVY, FIRST OBSERVED AT 01:50 U.T., AUG 31 | 1975, NOVA | R.A. | 21 H | 10.5 M | DEC 48 deg N | MAG 1.6 | OR 1.7 AT 03:05 | U.T.

DAVID LEVY

45/23

45
15 350
30 315
10.5 sec 3
315 665
54
719

30-3

NOVA CYGNI 1975

21:50 - Beverley and me, Phil, Debbie and a friend, ~~and~~ get out of car at ~~his~~ Bev's house. In the driveway I look up to see that Cygnus has an extra star. My initial reaction is that it is a slow moving satellite. The others go in. As I am go in I look again and note that the star hasn't moved at all.

21:53 Yes it's a nova all right - almost as bright as Deneb. I show it to the others. Beverley still isn't feeling well, so she decides not to go with me to the observatory

~22:40. Arrival at observatory. The others hadn't realized. Leo and Gordon had wondered, then dismissed it. Everybody runs up or out to look at the nova.

23:05 Mag. estimate 1.6 or 1.7. Telegram written out by Nora.

00:00 Nora, Leo + I arrive at telex office and send wire to IAU.

00:30 at home, I show mother the nova. Two people have phoned (while I was out) about it. Mag. est. 1.7.

02:15 At observatory again. Mag. est 1.7. Photographed nova; camera on tripod, then piggyback on Celestron.

04:08 finished snack at Harvey's, taking Nora home. Mag est ~~≈~~ 1.6. Once home, I observe alone with camera, telescope (6") and binoculars for over an hour. At 4:50 I estimate nova again at 1.7, send letter to IAU

The feeling was puzzled at first, then shocked and disbelief. There, just five degrees North of Deneb, was a new star. Surely thousands have already seen this nova but I was late - if it were visible last night I couldn't have seen it through the clouds + rain. Tonight the sky was dark for about an hour, before I casually looked up to be surprised by this celestial newcomer.

The first people I saw at the observatory parking lot were Boyd, Gordon + his brother. I told them there's a bright nova in Cygnus, and they dashed up the stairs to the ob field to see it. Leo + Nora simply didn't believe me until I said that there is a nova in Cygnus of about first magnitude.

Yesterday I carefully bought Beverly a get-well present - a jade ring. Tonight the sky sent her a get-well present too.

A real nova!!! Not 5 degrees from Deneb is a bright star!!

Session * 3689M2. September 12, 1978/0125-0200/9-f (Moon)/ Pine Trees Campground, Lewis, NY/ Little Joe/M31. CN3. VSO-I. Independent discovery of Nova Cygni 1978.

Comets and other discoveries by David Levy

Comet Levy-Rudenko, 1984t, C/1984 V1, Nov 14, 1984
Comet Levy, 1987a, C/1987 A1, January 5, 1987
Comet Levy, 1987y, C/1987 T1, October 11, 1987
Comet Levy, 1988e, C/1988 F1, March 19, 1988
Comet Okazaki-Levy-Rudenko, 1989r, C/1989 Q1, August 25, 1989
Comet Levy, 1990c, C/1990 K1, May 20, 1990
Periodic Comet Levy, P/1991 L3, June 14, 1991
Comet Takamizawa-Levy, C/1994 G1, April 15, 1994
Periodic Comet Levy, P/2006 T1, October 2, 2006

Photographically, as part of team of Eugene and Carolyn Shoemaker and David Levy:
Periodic Comet Shoemaker-Levy 1, 1990o, P/1990 V1
Periodic Comet Shoemaker-Levy 2, 1990p, 137 P/1990 UL3
Comet Shoemaker-Levy, 1991d C/1991 B1
Periodic Comet Shoemaker-Levy 3, 1991e, 129P/1991 C1
Periodic Comet Shoemaker-Levy 4, 1991f, 118P/1991 C2
Periodic Comet Shoemaker-Levy 5, 1991z, 145P/1991 T1
Comet Shoemaker-Levy, 1991a1, C/1991 T2
Periodic Comet Shoemaker-Levy 6, 1991b1, P/1991 V1
Periodic Comet Shoemaker-Levy 7, 1991d1, 138P/1991 V2
Periodic Comet Shoemaker-Levy 8, 1992f, 135P/1992 G2
Periodic Comet Shoemaker-Levy 9, 1993e, D/1993 F2 (This comet crashed into Jupiter in 1994, resulting in the most dramatic events ever seen on another world)
Comet Shoemaker-Levy, 1993h, C/1993 K1
Comet Shoemaker-Levy, 1994d C/1994 E2
Comet Jarnac, P/2010 E2 (David Levy, Wendee Levy, Tom Glinos)

Other discoveries
Nova Cygni 1975, August 30, 1975 (independent discovery)
Nova Cygni 1978, September 12, 1978 (independent discovery)
Comet Hartley-IRAS (P/1983 V1), November 30, 1983 (independent discovery)
Comet Shoemaker 1992y, C/1992 U1 (aided in discovery)
Periodic Comet Shoemaker 4, 1994k, P/1994 J3 (aided in discovery)
Discovered Asteroid 5261 Eureka, the first Martian Trojan asteroid (shares Mars's orbit), with Henry Holt, June 1990
With Tom Glinos and Wendee, discovered more than 150 asteroids
Established the cataclysmically recurring nature of 1215-17 TV Corvi (Tombaugh's Star), August 1987

THE UNIVERSITY OF ARIZONA
TUCSON, ARIZONA 85721

OFFICE OF THE PRESIDENT (602) 621-5511

April 1, 1988

Mr. David Levy
Lunar and Planetary
Laboratory
Campus

Dear Mr. Levy:

This is just a brief note to congratulate you on your latest find, which furthermore distinguishes you as the official U.S. amateur record-holding comet discoverer. Through your private efforts, as with your work at the Lunar and Planetary Laboratory, you bring deserved recognition to yourself--and to the University of Arizona.

You have my best wishes for continued success.

Cordially,

Henry Koffler
President

HK/kp

Written during the latter part of November, 1966.

CN3
Research on Comets.
Volume 2

Comets and Comet Hunting

plagiarised by
David H. Levy (B.Sc.I)
CN3
818 Upper Belmont Avenue
Montreal, 6, P.Q.

CN-III

from
for McGill Science Journal

1 9 6 6

Feb/Mar 1968
Denver Observer

1981
ALPO Journal.

Asteroid - Comet - Meteor - II
1991 - Flagstaff
Comet 1990c papers
Friday June 27 1991
Sue Hoban Comet Levy etc.

No? [first 3.4 μm feature in any comet
The first 3.4 micron feature, found in Comet Levy]
This feature always present, changes from comet to comet, and night to night
observed at 3.36, 3.1, 3.65 μm
Linearly interpolate to find the emission
big difference between Levy and Halley

Giotto - no pictures will be possible
optical path is blocked.
retargeted to go to Grigg-Skjellerup.
will be unhibernated in May 1992
July 10 1992 encounter

→ Rosetta - Comet Nucleus Sample return
needs a large perihelion distance
Jupiter family comet OK
spacecraft will talk with the comet to find a landing site
90% of nucleus mapped

→ CRAF - Paul Weissman.
New start 1989. Joint Cassini
study a nucleus for 2½ - 3 yrs
2003 arrive at P/Tempel 2.
Congress: might be delayed a year,
touch spacecraft down on nucleus at very end to know where nucleus stuff is.
Sen. Mikulski + Garn

May 8 1978. With feeling!!

On September 18, 1965, Kaoru Ikeya, a piano-factory worker, was peering through the eyepiece of his home-made eight-inch reflector when he spotted a little spot of haze in the field of view. Now Ikeya knew the sky and he was fairly sure that that object was not supposed to be where it was. His star atlas showed nothing in that position, and a look through the eyepiece a short while later convinced him that he really was looking at something new, for the fuzzy patch had moved.

This new object was doubtlessly a comet, and Ikeya lost little time in sending a wire to the Tokyo Observatory. Just one hour later, Tsutomu Seki, a guitar instructor, found the same object. Hence the discovery of new Comet Ikeya-Seki was made known to the astronomical world.

When this comet was found its brightness was only that of eighth magnitude (about six times fainter than the faintest object that can be seen with an unaided eye.) It resembled all faint comets — a hazy patch, with perhaps a small bright centre, or nucleus, that moved ever so slightly in the period of an hour. A telescope with a mirror eight inches in diameter could show it clearly.

8" telescope -

The comet's motion gave the first clue of what was to come. It was moving in the sun's direction, which meant that it would probably become brighter. Eight days after discovery of the comet a tail was noticed and its brightness began to increase rapidly. Within two months, this visitor from space had rounded the sun, become brighter than the full moon, displayed a beautiful tail seventy million miles long, and started to move away toward the dark void of interplanetary space from where it came.

<u>What is a comet?</u> A comet, when away from the sun, exists as an icy nucleus that may be as small as a few hundred yards, or as large as three miles, across

Embedded in the ice(frozen water, methane and ammonia) are meteoric particles ~~much~~ which contain calcium, iron, nickel and other elements.

As the comet nears the sun a coma, of evaporated ice with meteoric particles, forms. The hazy spot you see in your telescope is this coma. If the comet is close by and is fairly large, you might see the nucleus as a faint, starlike object. NO

The material in the coma is very thin and is subject to movement at the slightest provocation. There exists a very mild but constant stream of ~~particles~~ plasma coming forth from the sun, the "solar wind" which causes the gas in the coma to stream out in one direction, away from the sun, forming a tail. Comets' tails can be extremely long. In 1843 one grew a tail that stretched for two hundred million miles, longer than the distance between the sun and Mars So little matter is involved in this part of a comet, however, that ~~gum~~ one million miles of tail can possibly be squeezed into your briefcase. prop? Show b

Origin of Comets. The question of how comets came to be has been puzzling astronomers for a long time. Two theories, one by Dr. J.H.Oort and the other by Dr. Donald Robey, suggest different solutions to this facinating problem.

Dr. Oort proposes that comets were formed at the same time as the asteroids (thousands of little objects that lie between Mars and Jupiter). While the asteroids remained where they were, the cometary material was moved into a "clou about two light years away from the sun. By gravitational pull of stars, some comets were drawn from this "cloud" and headed towards the sun. This "cloud" surrounded the solar system in spherical fashion.

Dr. Donald Robey rejected this theory on the grounds that it was based on the asumption that orbits of comets ~~were~~ are distributed at random, in any plane.

He found from studying a computer analysis of over five hundred comets that their orbits clustered in a pattern around a single axis which passes through the sun.

The solar wind, already mentioned, blows away from the sun at hundreds of miles per second. A stronger wind, the "galactic wind", generated by all the stars in our galaxy, blows in the direction of the pattern formed by the comet orbits.

Dr. Robey concluded that comets are formed from the interaction of the galactic wind and the solar wind.

Near the sun is an area or "cavity" in which the force of the outward-blowing solar wind equals that of the inward-blowing "galactic wind." This cavity moves toward the sun(to Jupiter) and away from the sun (beyond Pluto) in a cycle of eleven years. This very rapid vibration (about five billion mil in eleven years) causes blobs of plasma to tear away from the cavity. If the escape at a certain small angle to the axis of the galactic wind, they will go into orbits to become comets. These plasmic comets capture a very small bi of cosmic dust and their nuclei are formed.

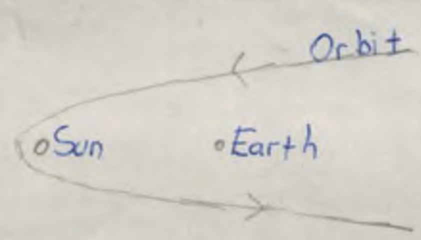
If this theory is true, we need never worry about running out of comets, as the solar and "galactic" winds will forever provide our supply.

<u>Orbits of Comets.</u> Comets are peculiar in the solar system in that their orbits are much more eccentric than those of the planets, asteroids and meteors. In fact, most comets have orbits that can be considered to be, for practical purposes, parabolic. If we say that a circle has an eccentricity of zero, and that a parabola has an eccentricity of one, then an ellipse is anywhere between zero and one, and a hyperbola is greater than one. Most come

have estimated eccentricities of about one. (Even in a single comet estimates may differ. One source uses three observed positions and assigns an eccentrici value of 0.9997; another has three different positions of the comet and arrives at a value of 1.0002. Obviously, with this comet, and with most, it is safe to assume that its orbit is parabolic.)

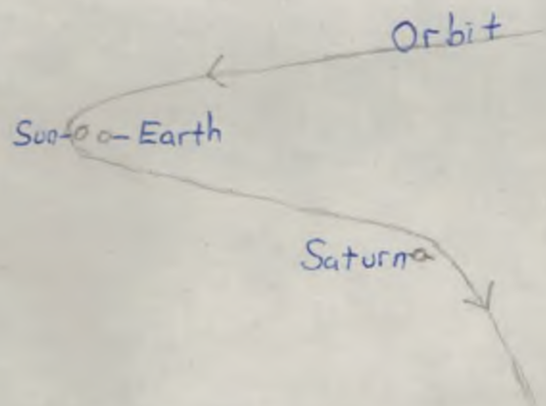
This whole discussion can be thrown away when we consider an orbit at a great distance from the sun. The planets, and even the nearest stars, can easily affect the orbit of a comet. Witness:

Figure 1.



The orbit of this comet here seems to be parabolic. But watch what happen when the comet moves farther out into space and happens to approach a planet like Saturn:

Figure 2.

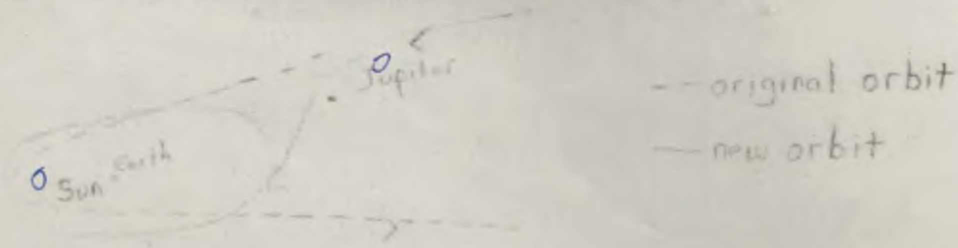


That takes care of any simple discussion on comet orbits.

Special types of comets.

<u>Families of Comets.</u> The term "family of comets" refers to comets which or, Periodic Comets (most.) were captured by one planet. Here is figure 2, changed in that the planet involved captures the comet instead of kicking it into deep space.

Figure 3.



This comet has just become a member of Jupiter's family and will revolve around the sun for ages hence in its new short-period orbit. Jupiter has captured sixty-one comets in this way, Saturn five, Uranus three, Neptune ten (including Halley's Comet), and Pluto one. We can tell to what family a comet belongs by calculating where its aphelion (farthest point from the sun) is. Comet Halley's aphelion exists near the orbit of Neptune. It happens that there are five comets whose aphelia lie at approximately equal distances from the sun but beyond the orbit of Pluto, the outermost known planet. This may indicate that there exists in the depths of interplanetary space, another planet.

<u>Sungrazing Comets.</u> Millions of years ago a comet of enormous size (as far as comets go) came too close to the sun, grew too hot for its own good and exploded. The pieces, of varying sizes, moved away. The larger each piece was, the more the sun's gravity affected it, so that the orbits were not of equal size and the pieces would return at different times. However, the paths of these comets while in the sun's vicinity are practically identical, causing each comet to make a dangerously sharp U-turn around the sun. Members of this group of sungrazers appeared in 1882("The Great Comet of 1882"), 1945, 1963(Comet Pereyra) and 1965(Comet Ikeya-Seki). It must be mentioned that the "one big comet" idea

is but an unproved theory.

Halley's Comet. Edmund Halley observed in 1682 the passage of a brilliant comet and found, after calculating its orbit, that its period was approximate seventy-six years. He noted that in 1607 and in 1531, bright comets appeare Concluding that these three objects were really the same comet, he predicted return in 1758. Halley died shortly before that year, but his comet returne as scheduled and was named after him. This monument to Halley's genius came back again in 1835 and in 1910, and will probably visit us in 1986. But this comet, like all comets, loses some of itself each time it approaches the sun. At one time a spectacular object, in 1910 is was only as bright as the North star. Comet Ikeya-Seki was many times brighter.

Death of Comets. Like everything else, comets must die, though admittedly, their lifetimes are far shorter than those of other objects in the solar system. At every return a comet loses some of its mass (usually one or two percent, but occasionally much more, depending on how close the comet approach the sun), and consequently becomes much weaker. After a long while, it disintegrates completely, leaving only a shower of meteors as a memorial.

Comets and Meteors. Every comet leaves in its wake a stream of meteors, and a large portion of the meteors we see belonged once to a comet. The meteors spread out along the orbit of the comet to form something like an oval "ring". Once a year, if the Earth's orbit intersects that of the comet, we witness a shower of meteors. The most impressive annual shower is that of t Perseids, occuring around the twelfth of August.

It is easily seen that meteors, although stream along an orbit, will tend to concentrate around the comet(or around where the now-deceased comet was). The Leonid shower recurs annually but every thirty-three years the earth crosses this concentration and a spectacular shower sometimes results. This event happened just last month (November 17, 1966), when, for a few hours, thousands of meteors were observed.

With this discussion we close our treatment of comets in a pure sense, and turn to a more practical side on how comets are named, and how they are found.

Designation of Comets. The naming process for comets, while apparently simple, is really quite complex. When a comet is found, it is named after its discoverer and assigned a temporary designation. Comet Ikeya-Seki-1965f implies that this was the sixth comet to be discovered in 1965.

Because some faint comets are observed only on photographs which are not analysed for a long time, the permanent naming of the comets must wait until about three years after the year in question. At that time the comets are designated in chronological order of closest approach to the sun (i.e., perihelion passage). Since the Great Comet of 1882 was the second comet that year to round the sun, it is called "Comet 1882-II."

Once in a long while a comet will become very bright and will create great excitement. An unofficial "Great Comet" title may then be bestowed upon it. Comets deserving of this distinguished designation came along in 1843, 1882, and 1965.

Finding Comets. Now that we are aware of what a comet is (or, rather, what it might be), and of how it moves around the sun, and of how it came to be a comet in the first place, and of what will happen to it after it has finished being a comet, we can discuss the means of how a comet is found.

Letter to Levy

Submitted by WMacDonald on Mon, 2012-09-03 12:45

Posted in 1967 barograph levy Messier List montreal tfmorris Williamson

All's Well That Ends Well

In 1967 the nineteen-year-old David Levy was an enthusiastic observer, and an observationally active member of the Montreal Centre, pursuing his life-long quest for comets, and an ever deeper familiarity with the night sky (activities which he knowledgably, imaginatively, and fruitfully pursues to this day).

All organizations have politically hidden shoals, lee shores, and mines, which are not always obvious or, alas, avoidable. The RAS throughout its history has been no exception, and David unknowingly sailed into troubled waters. The episode is best narrated in h own words:

> I had just suffered through the first phase of what is now known as the "observatory crisis," during which Isabel K. Williamson, then director of observational activities for the Montreal Centre, had threatened to cancel my membership because she thought I had broken the observatory barograph. Anyway, I was so excited about finding the nebula (NGC 6207, a faint galaxy near M13, or NGC 6402 [M14], placed low in the sky and appearing comet-like) that I resolved that no matter what, all would be well on my return to Montreal.

> It wasn't. The following Wednesday I was yelled at and physically pushed out of the building. I decided that day to resign my entire interest in astronomy, comets and all. But that morbid feeling didn't last long. Instead I quickly resumed all my activities, and some ten years later, while working on my master's degree at Queen's, I wrote to Isabel Williamson to ask how she was doing. She replied that she was fine, and invited me to call on her on my next visit to Montreal. Although she never apologized to me, these visits became a staple of all my Montreal trips for the next two decades, and her indication that all was well, until her death in 2000. We did become good friends at last, and I successfully nominated her to receive the Royal Astronomical Society of Canada's Service Award, and successfully proposed that the Centre's Observatory be named after her. To close this interesting chapter of my life, during a recent visit the Montreal Centre decided to give me the precious barograph, which stands atop my bookcase in a place of honour at Jarnac Observatory.

The letter reproduced in facsimile here is from Theodore F. Morris, a professor of theoretical physics at McGill (1949-1987), and th second person to complete the Montreal Centre's Messier list (and one of the first people in the world to do so as a member of Messier club, as was David himself - the Club's creation was due to Ms Williamson). The letter resulted directly from Davi misunderstanding with Ms Williamson, and was part of the strategy of the Montreal Centre's establishment to control the situation. Other measures included a formal meeting at which the "observatory crisis" was discussed, and an attempt made to expel David from the RASC. Saner heads spoke up in favour of not forcing him to walk the plank. (On May 18, 1967, just two days after the Board meeting during which he was almost expelled, David received a brand-new 6-inch reflector he'd earlier ordered, and its timely arrival served to buoy his astronomical spirits. That telescope, subsequently named Minerva, is numbered among those still in service at Jarnac).

Fortunately for the RASC, amateur astronomy, and the world of astronomy in general, David weathered the storm, continued to observe, and went on to a successful career of scientific discovery, astronomical writing, and effective education and public outreach. It's astonishing that in the end no souls were lost overboard during and after the "observatory crisis" - but that fact speaks to the qualities of the characters involved, in particular the extraordinary patience and persistence of a nineteen-year-old observer. Time heals, and there is much to be said for reconciliation if the parties are amenable to it. It hardly need be observed that institutional factionalism is never a positive thing.

If there is a lesson here, it is that organizations ought to think carefully before eating their young, and devouring their future. Not every analogous story has such a fortunate ending.

- R.A. Rosenfeld

Attachment	Size
Letter2Levy-1967.pdf	3.67 MB
Letter2Levy-1967.djvu	226.51 KB

Year: 1967
Pages:
2

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ROYAL ASTRONOMICAL SOCIETY
OF CANADA

MONTREAL CENTRE

WITHOUT PREJUDICE

MONTREAL, May 25, 1967.

Mr. David Levy,
618 Upper Belmont Ave,
Westmount.

Dear Mr. Levy:

At a recent meeting of the Board of Directors of the Montreal Centre of the R.A.S.C. I was delegated by a unanimous decision to write to you. Within the past few months, a number of incidents have occurred in which apparently you have had differences of opinion with various officers of the executive. The responsibilities and powers of these officers are clearly defined in the constitution and are designed to facilitate the work of the Centre. Normally, the spirit of cooperation for the good of the Centre is expected to prevail. If this fails, the officers are entitled to use their judgment in order to deal with specific cases.

The principle is quite simple. An officer is accountable to the Board of Directors for his actions, or for his lack of action. The authority to act for the interest of the Centre is delegated to those who bear the burden of responsibility; e.g. the Director of Observations is responsible for the observational program and may appoint <u>or dismiss</u> assistants, even though the power to dismiss is not mentioned in the Constitution.

Also, the Director of the Observatory is responsible for the Observatory and for the equipment which belongs to the Centre. Concomitant with this, he or his representative has the authority to request a member to leave the Observatory for reasons considered to be sufficient. Such action on his part does not constitute a denial of the rights of membership as guaranteed by the Constitution. The meetings on Wednesdays and Saturdays of each week are informal meetings. Participation in these meetings is based on the traditional cooperation and acceptable conduct which the Centre has the right to expect from its members.

In almost any group of people, one is apt to encounter differences of opinion. In this event there are acceptable and unacceptable ways of registering a contrary opinion. Generally speaking, a descent to the level of derogatory personal remarks is not likely to be rewarding. Once adopted, it is very difficult to return from such a position. If personal communication fails, a better way to register dissent would be to write a quiet letter to the Secretary. In due course, such a letter would be read and discussed by the Board of Directors, and you would receive a written reply. This procedure requires patience, but it is acceptable and traditional.

At present, the Board of Directors contemplates no further action, other than to review the situation at a later date. Of course, another meeting can be held for sufficient cause. In the meantime, I suggest that you should cooperate, in every way possible, with the officers of the Centre. In particular, it would be considered to be a gesture of good will on your part if you were to return, by the next mail, those reports of the Comet and Nova Section which you still retain. Any reports which you may receive subsequently should also be returned promptly.

Yours sincerely,

T. F. Morris

T.F. Morris,
114 Dobie Ave,
Montreal 16.

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PERIODIC COMET SCHWASSMANN-WACHMANN 1

Further precise positions have been reported as follows:

1976/77 UT	R. A. (1950)	Decl.	m1	Observer
Nov. 24.64219	2 59 49.09	+28 31 20.9	12.5	Furuta
Dec. 27.16492	2 48 04.18	+27 03 25.8		Schwartz
Jan. 14.02887	2 46 47.89	+26 25 29.1		"
Feb. 17.01318	2 55 15.93	+25 58 17.2		Shao

T. Furuta (Tokai, Japan). 31-cm reflector. From Orient. Astron. Assoc. Comet Bull. No. 141.
G. Schwartz and C. Y. Shao (Harvard College Observatory, Agassiz Station). 155-cm reflector. Measurer: Shao.

K. Kane and T. P. Roark, Perkins Observatory, provide the following total magnitude estimates (IIa-D emulsion, GG14 filter): 1976 Nov. 16.09, 12.4; 17.07, 12.8; 20.13, 13.5; 1977 Feb. 11.07, 12.3.

R CrB VARIABLES

R CrB. Further visual magnitude estimates suggest that this decline is particularly rapid: Feb. 27.9 UT, 7.2 (C. Henshaw, Cheadle, Cheshire, England); Mar. 1.3, 7.1 (D. Levy, New Orleans, Louisiana); 3.49, 7.6 (L. Hiett, Arlington, Virginia); 5.51, 7.9 (J. Morgan, Prescott, Arizona); 7.89, 8.1 (R. Lukas, Wilhelm Foerster Observatory); 9.11, 9.6 (J. Bortle, Brooks Observatory); 11.33, 10.0 (P. L. Collins, Harvard College Observatory); 12.27, 10.4 (Collins); 12.49, 10.2 (Morgan); 14.52, 11.1 (Morgan).

SU Tau. Visual magnitude estimates: Feb. 21.31, 11.8 (C. E. Spratt, Victoria, British Columbia); Mar. 1.10, 12.2 (C. Hurless, Lima, Ohio); 7.02, 12.0 (Bortle); 13.15, 11.7 (Morgan).

NOVAE

V1500 Cyg. Visual estimate: Mar. 3.40 UT, 12.5 (Collins).

NQ Vul. Visual estimates: Mar. 1.41, 11.3 (Collins); 3.39, 11.5 (Collins); 9.53, 11.4 (Morgan); 14.54, 11.4 (Morgan).

Nova Sge 1977. Visual estimates: Feb. 17.43, 10.4 (Collins); 23.42, 11.5 (Collins); 26.41, 11.5 (Collins); Mar. 5.51, 11.2 (Morgan); 10.55, 10.5 (Morgan); 14.52, 11.2 (Morgan).

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PERSEID METEORS AND PERIODIC COMET SWIFT-TUTTLE

D. Levy and P. Jedicke report that their observations from Springfield, VT, through clouds, showed what was obviously a rather intense display of Perseids on Aug. 12.3 UT, with 15 meteors, one as bright as mag -8, being noticed in an interval of 40 min. Yamamoto Circ. No. 2170 quotes a report from Y. Taguchi, Osaka, to the effect that observations by a group at an altitude of 1720 m near the Kiso Observatory gave the following individual hourly rates for the midtimes specified: Aug. 12.62 UT, 64; 12.66, 352; 12.70, 62; the corrected ZHR for the middle hour (Lsun = 138.86, equinox 1950.0) was more than 400. P. Aneca, B. de Pontieu, J. Deweerdt and J. Vanwassenhove, Vereniging voor Steerenkunde, Brussels, observing in very good conditions (limiting mag 6.2-6.5) at Haute Provence, individually recorded between 280 and 320 meteors during two hours surrounding Aug. 13.08 UT; correction only for the radiant height yields a ZHR of up to 200. Observations by Levy and Jedicke on Aug. 13.3 UT, this time under clear skies south of Montreal, showed far fewer meteors than the night before.

Although it is generally presumed that the associated comet, P/Swift-Tuttle (1862 III), passed perihelion unobserved around 1981 +/- 2, the possibility that P/Swift-Tuttle was identical with comet 1737 II (Kegler) and that it may therefore return in late 1992 is perhaps enhanced by this year's very strong Perseid display. The nominal prediction (Marsden 1973, A.J. 78, 662) is T = 1992

Nov. 25.85 ET, Peri = 153.05, Node = 138.74, i = 113.45 (equinox 1950.0), q = 0.9582 AU, e = 0.9633. Because of nongravitational effects, the uncertainty in T could be as much as +/- 2 months, and this affects the ephemeris (below) through mid-October by +/- 2 degrees, mainly in declination. The predicted magnitude is little more than a guess.

1991 ET	R.A. (1950)	Decl.	Delta	r	m2
Sept.11	9 36.73	+31 22.6			
21	9 43.10	+31 32.2	6.022	5.324	21.2
Oct. 1	9 49.23	+31 48.5			
11	9 55.01	+32 13.2	5.589	5.143	20.8
21	10 00.26	+32 47.7			
31	10 04.83	+33 33.9	5.101	4.960	20.5
Nov. 10	10 08.51	+34 33.7			
20	10 11.03	+35 48.8	4.591	4.774	20.1
30	10 12.10	+37 20.9			
Dec. 10	10 11.33	+39 11.0	4.097	4.584	19.7

1991 August 28 **(5330)** **Brian G. Marsden**

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1991 August 28 **(5330)** **Brian G. Marsden**

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COMET LEVY-RUDENKO (1984t)

Independent reports of the discovery of a new comet have been received from David Levy (0.40-m f/5 reflector) and Michael Rudenko (0.15-m refractor, 30 x). Available observations follow:

1984 UT	R.A. (1950.0)	Decl.	mQ	Observer
Nov. 14.12	18 47	+ 9 50	8.5	Levy
14.96	18 47.4	+10 10		Schwartz
15.00	18 47.4	+10 10	9.5	Meier
15.05	18 47.5	+10 15	10.5	Rudenko
15.08	18 47.4	+10 13	9.5	Levy

D. H. Levy (Tucson, AZ). Diffuse; no condensation; no tail.
G. Schwartz (Oak Ridge Observatory). 0.40-m astrograph. Faint image not detected until Meier and Rudenko observations known.
R. Meier (Nepean, ON). 0.44-m reflector, 62 x. Some condensation.
M. Rudenko (Amherst, MA). Very diffuse, diameter < 2'; no tail.

COMET SHOEMAKER (1984r)

Precise positions obtained by J. Gibson at Palomar, with the 1.2-m Schmidt on Nov. 2-3, with the 1.5-m reflector on Nov. 4-5:

1984 UT	R.A. (1950.0)	Decl.
Nov. 2.17120	3 11 30.86	+17 39 56.2
2.47606	3 11 05.05	+17 38 12.6
3.34377	3 09 52.06	+17 33 16.0
4.32147	3 08 29.59	+17 27 37.1
5.34222	3 07 03.33	+17 21 42.1

New parabolic elements from 11 observations Oct. 23-Nov. 5:

T = 1984 Sept.22.953 ET   Peri. = 185.196
                           Node = 237.871   1950.0
q = 5.49985 AU   Incl. = 179.203

SUPERNOVA IN IC 4839

B. J. Jarvis and M. M. Phillips, Cerro Tololo Interamerican Observatory, report that an SIT-vidicon spectrum obtained with the 4-m telescope on Oct. 28.04 UT shows the supernova to be of type I, approximately 1-3 weeks past maximum.

1984 November 15   (4007)   Brian G. Marsden

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PERIODIC COMET SHOEMAKER-LEVY 9 (1993e)

Almost 200 precise positions of this comet have now been reported, about a quarter of them during the past month, notably from CCD images by S. Nakano and by T. Kobayashi in Japan and by E. Meyer, E. Obermair and H. Raab in Austria. These observations are mainly of the "center" of
the nuclear train, and this point continues to be the most relevant for orbit computations. Orbit solutions from positions of the brighter individual nuclei will be useful later on, but probably not until the best data can be collected together after the current opposition period.
At the end of April, computations by both Nakano and the undersigned were
beginning to indicate that the presumed encounter with Jupiter (cf. IAUC 5726, 5744) occurred during the first half of July 1992, and that there will be another close encounter with Jupiter around the end of July 1994. Computations from the May data confirm this conclusion, and the following result was derived by Nakano from 104 observations extending to May

Epoch = 1993 June 22.0 TT

T = 1998 Apr. 5.7514 TT	Peri. = 22.9373	
e = 0.065832	Node = 321.5182	2000.0
q = 4.822184 AU	Incl. = 1.3498	
a = 5.162007 AU	n = 0.0840381	P = 11.728 years

This particular computation indicates that the comet's minimum distance Delta_J from the center of Jupiter was 0.0008 AU (i.e., within the Roche
limit) on 1992 July 8.8 UT and that Delta_J will be only 0.0003 AU (Jupiter's radius being 0.0005 AU) on 1994 July 25.4.

As noted on IAUC 5726, the positions of the ends of the nuclear train can be satisfied by varying the place in orbit at the time of the 1992 encounter and considering the subsequent differential perturbations. Using the above orbital elements, the undersigned notes that the train as reported on IAUC 5730 corresponds to a variation of +/- 1.2 seconds. Separation can be regarded as an impulse along the orbit at that time,although the velocity of separation (or the variation along the orbit)depends strongly on the actual value of Delta_J. At the large heliocentric distances involved any differential nongravitational acceleration must be very small, as Z. Sekanina, Jet Propulsion Laboratory, has also noted. Extrapolation to shortly before the 1994 encounter indicates that the train will then be about 20' long and oriented in p.a. 61-241 deg, whereas during the days before encounter the center of the train will be approaching Jupiter from p.a. about 238 deg.

1993 May 22 (5800) Brian G. Marsden

From: quai@eps.harvard.edu
To: OBSERVE@jarnac.org
Subject: CBET 3342: 20121213 : COMET P/2012 WX_32 = 1931 AN = 2003 WZ_141 (TOMBAUGH-TENAGRA)

Electronic Telegram No. 3342

Central Bureau for Astronomical Telegrams
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e-mail: cbatiau@eps.harvard.edu (alternate cbat@iau.org)
URL http://www.cbat.eps.harvard.edu/index.html
Prepared using the Tamkin Foundation Computer Network

COMET P/2012 WX_32 = 1931 AN = 2003 WZ_141 (TOMBAUGH-TENAGRA)

Syuichi Nakano, Sumoto, Japan, has identified comet P/2012 WX_32 (cf. CBET 3329) with an apparently asteroidal object discovered by the LINEAR survey on 2003 Nov. 21 and 23 (and given the minor-planet designation 2003 WZ_141; cf. MPS 92135) and with the comet found belatedly by Clyde Tombaugh at Lowell Observatory in 1932 from plates exposed on January 1931 (discovery observations tabulated below; see also IAUC 6161, and MPC 24423 and 24544), as outlined by D. H. Levy et al. (1995, Int. Comet Q. 17, 52); Levy et al. noted the comet to be diffuse with strong condensation with a tail at least 2' long in p.a. about 270 deg on those 1931 plates. Spacewatch astrometry of 2003 WZ_141 from 2003 Dec. 18 gave magnitude 17-18.

1931 UT	R.A. (2000)	Decl.	Mag.	Observer
Jan. 11.25903	8 34 50.84	+33 42 38.1	12.5	Tombaugh
12.28750	8 34 15.36	+33 53 20.8		"
13.28681	8 33 38.39	+34 04 04.6		"

The following orbital elements by G. V. Williams (from 125 observations spanning 1931 Jan. 12-2012 Dec. 13; mean residual 0".53), along with residuals and an ephemeris, appear on MPEC 2012-X79.

```
            Epoch = 1931 Jan. 19.0 TT
   T = 1931 Jan. 15.24391 TT      Peri. =  34.47426
   e = 0.4387011               Node  =  85.67590 2000.0
   q = 2.4368809 AU              Incl. =  16.19522
    a =  4.3415034 AU   n = 0.10895417   P =   9.05 years

            Epoch = 2004 Mar. 16.0 TT
   T = 2004 Mar.  9.83331 TT      Peri. =  39.52546
```

e = 0.4350130 Node = 83.57298 2000.0
q = 2.4669499 AU Incl. = 16.05033
a = 4.3663836 AU n = 0.10802425 P = 9.12 years

Epoch = 2013 Mar. 9.0 TT
T = 2013 Feb. 23.35003 TT Peri. = 38.45834
e = 0.4400716 Node = 81.36298 2000.0
q = 2.4418922 AU Incl. = 15.83852
a = 4.3610795 AU n = 0.10822138 P = 9.11 years

NOTE: These 'Central Bureau Electronic Telegrams' are sometimes superseded by text appearing later in the printed IAU Circulars.

2012 December 13 (CBET 3342) Daniel W. E. Green

(4) Everything conspires to make comets standout
-241 as something special.
Men have always tended to view them with terror, especially in the middle ages, and e[ven] today they still do in primitive Societies.
... we find accounts, which, though often naive or even incorrect, do capture the essential spirit of comets.
Nicetus 1182: "a comet appeared in the heavens like a twisting serpent; now writhing [and] coiling back upon itself, now it would terrif[y] people with its gaping mouth; as if lust[ing] for human blood, it seemed about to slake its thirst."
Paré 1528: "So ~~terrible~~ horrible was it, so ter[r]ible, so great a fright did it engender in t[he] populace, that some died of fear; others fell sick... this comet was the color of blood; at its extremity we saw the shape of an arm hol[d]ing a great sword as if about to strike us do[wn]. At the end of the blade there were three stars. [On] either side of the rays of this comet were seen great numbers of axes, knives, bloody swords, amongst which were a great number of hideous human fa[ces] with beards and hair all awry..."
Shakespeare (Julius Caesar) When beggars di[e] there are no comets seen;
The heavens themselves blaze forth the death of princ[es]

Comets were transformed by work of ~~Paul~~ Newton and Halley into astronomical bodies that fo[llow] laws of gravitation.

Bk p. 12
↓ ↓
1-2 Early Notions.
Earliest ideas inaccurate.
① Anaxagoras and Democritus — comets attributed to "combined splendor of a concourse of planets"
② Aristotle — some kind of exhalations from the ⊕ that had reached the upper part of the atmosphere and there, became inflamed and were luminous.
& Foundations
① Comets generally brightest when nearest sun; hence visible only in twilight; tails would appear more or less upright in atmosphere;
~~Support~~
③ Ptolemy - did not regard comets as among heavenly bodies.
④ Seneca - was in minority - did not favor Aristotle's v

3 Ideas change.
① Carden concluded that comets must lie far beyond the moon.
② first definite demonst. of their celestial character given by Tycho Brahe — found that apparent position of daylight comet of 1577 as seen from Hven in Baltic sea was indistinguishable from its direction as seen fr Prague — 400 mi. South.
∴ The moon did show considerable apparent difference of position.
∴ Comet was far more distant from ⊕ than moon.
③ How comets move with reference to Sun,
ⓐ Tycho — comet of 1577 moved in ☉ circle som outside orbit of Venus
ⓑ Kepler - Comets move in straight lines.
did not extend Planetary Laws to Com
ⓒ Hevelius - comets in parabolic orbits.
departure from rectilinear motion due to resistance by the ether.

Newton - Law of Universal Gravitation.
Halley then solved the problem of cometary orbits
- showed from a discussion of 24
comets observed between 1337 and
1698 ~~that~~ ~~so~~ these moved in
accordance with Law of Grav.

<u>Tails.</u>

Tycho - optical illusions, - formed by
passage of Sunlight through
comet itself.
4 Hooke - impulsion of solar rays on
comet drove of material not subject
to solar attraction by Sun but to
repulsion.
Bessel + Olbers - electric + magnetic actions.

Roche - comet consists of a homogeneous
gaseous atmosphere retained by a ~~gravitational~~
gravitating nucleus.

Discovery

July 13, 1874. G M Hopkins sees "The Comet - I
seen it ~~Comet~~' at bedtime in the west, with head to
the ground, white, a soft well-shaped
tail, not big: I felt a certain awe and
instress, a feeling of strangeness, flight (it
hangs like a shuttlecock at the height, before it f
+ of threatening —
What comet was this?

COGGIA

or 1874-III

from New Handbook of
Heavens, p. 97.

also in Ash + Grant,
Comets p. 42.

1874 III - no special comments
about it.

Aristotle: "Meteoroliga" has
3 comets - 427/6 (BC)?
341/0
373/2

on pages 345 a1 343b5 343b1 + ff.

From Sheldon Cohen of Tennesee - (Address 72140,327)
to Gary Kronk (76615, 3054)
written both Oct/88.

discovered ~~[illegible]~~ BM ORI on his 70th
(Hartwig: started at Bamberg, did much work on variable stars.)

BAMBERG, FR GERMANY, APRIL 1989.

Bamberg - First Paper. April 24 1989.
Roberta JM Olson and Jay Pasachoff.
I have to run the slides.
Nuremberg Chronicle (1493) is a record of noteworthy events
There are 13 comet illustrations, including
P/Halley 684 AD, 471, 1472 but were not
necessarily intended for accurate description of comets
Comet 1577 drawn by Jiri Daschitzky -
shows comet & possible self-portrait
of artist drawing it!
1580 Hans Rogel broadside - shows
path in heavens & celestial context indicated
by constellations.

THE COMET PAIR 1988e AND 1988g

BRIAN G. MARSDEN
Harvard-Smithsonian Center for Astrophysics

As everybody knows, Edmond Halley recognized the periodicity of the comet that bears his name by noting that three of the 24 cometary orbits he calculated bore a strong resemblance to each other. What is perhaps not quite so well known is the fact that he and other early orbit computers suggested other cometary identities that did not work out. Soon after the ignominious failure of widespread predictions that a stupendous comet with a 300-year period would return in the mid-nineteenth century, Martin Hoek introduced the concept that there were cases where several different comets existed in essentially the same nearly-parabolic orbit. This idea gained currency with the appearance during the 1880s of comets with sungrazing orbits that were practically identical with that of the great comet of 1843, and at least a qualitative explanation of how such comet groups might be formed was provided by the appearance of the 1882 member, which evidently split into four or perhaps more fragments. Comet splitting was not of course a new phenomenon, for duplicity of the celebrated Biela's comet had been observed in 1846; and the two components, separated in the sky by about half a degree, were again present when the comet returned to perihelion 6½ years later.

The study of comet groups had become quite fashionable around the turn of the century, the most avid practitioner being W. H. Pickering, whose related study of clusterings of cometary aphelia led to his infamous predictions for what he called planets *O*, *P*, *Q*, *R*, *S*, *T* and *U*. However, like the predictions for unknown planets, the concept of pervasive comet groups eventually ran its course, and in 1977 Fred Whipple concluded that, except for the sungrazing comets that had been examined in great detail by Heinrich Kreutz, all the alleged comet groups and at least some of the comet pairs were entirely due to chance.
1 In 1984 Bertil-Anders Lindblad suggested that *all* the comet pairs were also due to chance.

But if comets are observed to split, is it not entirely reasonable that comet groups and pairs should exist? The point here is that the smaller fragments of a split comet clearly have a very poor survival rate. In the case of Biela's comet, neither component has shown up since

1852; and as I demonstrated some 20 years ago, one needs to kill off most of the fragments of the Kreutz sungrazers at successive splittings in order to produce the essentially bimodal distribution in the nodal longitudes of the best observed members.

Since the orbits of the members of the Kreutz group, and indeed the orbits of the components of any split comet, obviously differ principally by actual position in the orbit and by revolution period, the orbital semimajor axis a (or its reciprocal in the case of comets of long period) is clearly an important quantity that distinguishes one component from another. Since the two-body energy integral relates differences in this quantity to differences in orbital velocity, it seems quite reasonable to study the motions of the lesser fragments in terms of impulsive separations—basically along the orbit—from the primary body. In general, however, this approach to the problem has not led to particularly successful results.

Closer inspection of the energy integral indicates that one can consider a difference in a in terms of a difference either in velocity or in the product of the gravitational constant and combined masses of the system (or both). This may not make too much sense if one were dealing with rigid bodies, but one should remember that all comets are subject to accelerations of a nongravitational nature that in large measure seem to vary as the inverse square of heliocentric distance. It would in fact be very surprising if the nongravitational accelerations on the components of a comet that has split were identical. Some 12 years ago Zdenek Sekanina hit upon the idea of explaining the splitting process in terms of a relative radial acceleration of the components at an initial relative velocity of zero. He applied this model to the 14 well-observed cases of cometary splitting known at that time (five of them involving three or four components) and in all but one case obtained an excellent representation. He subsequently handled this troublesome case (comet 1957 VI, which had a perihelion distance $q = 4.4$ AU) by also including a velocity component normal to the orbit plane. He also refined some of the other cases by including velocity terms and extended the application to the ten or so other known cases of split comets, or for a total of about 2 percent of all the cometary apparitions for which orbits have been computed.

Sekanina found that the minimum separation acceleration γ was $\sim 10^{-5}$ that of the solar attraction, or 0.06 μm/s^2. This amount is therefore a convenient unit for measuring γ and corresponds to a value of the standard radial nongravitational parameter $A_1 = 0.3$ (measured in units of AU and 10^4 days). A typical comet of radius 1 km and density that of water has an escape velocity (at its surface) of 0.8 m/s, and a nongravitational acceleration of the order we are considering could typically allow a companion at the earth's distance from the sun to escape from it after about 2 weeks. One should not take this figure too seriously, however, and in a few of the cases where Sekanina considered an initial separation velocity this was already on the order of the escape velocity.

By studying the process of cometary splitting in this manner, Sekanina was able to come to some important conclusions. Splitting takes place with comparable probability out to heliocentric distances $r = 4$ AU and in the case of comet 1957 VI occurred at $r = 9$ AU. Smaller components are found to accelerate away from the sun at a greater rate than larger ones, and components with large accelerations are short lived. Fragments with $\gamma > 100$ units do not survive for more than about a month. For a value of γ an order of magnitude smaller, the equivalent survival time is at least half an order of magnitude and perhaps more than one order of magnitude greater. A single comet with a radial nongravitational parameter corresponding to $\gamma = 100$ ($A_1 = 30$) would almost certainly not be under observation long enough to have its nongravitational parameters determined, but there is at least one known comet (1944 I, which does seem to have fizzled out shortly after it passed perihelion) for which one needs to postulate a nongravitational parameter of at least half this amount in order to ensure that its original orbit about the barycenter of the solar system was not hyperbolic.

With this extensive but necessary preamble, I discuss now the recent comets 1988e and 1988g. The first was discovered visually by David Levy near Tucson on March 19 of this year and the second by Carolyn Shoemaker on films taken by Gene Shoemaker, Henry Holt and herself with the 0.46-m Palomar Schmidt on May 13. Shortly after the initial parabolic orbit determination for the second comet (from observations on three consecutive nights), Conrad Bardwell noticed the strong resemblance of the two orbits, which were inclined at $\sim 63°$ to the ecliptic. Comet 1988e had passed perihelion at $q \sim 1.2$ AU on T = 1987 Nov. 29 and comet 1988g on T = 1988 Feb. 13. Except for the Kreutz sungrazers, this was the first clear case of two long-period comets that had to be genetically related. At its discovery 1988g was located in the sky some 17° to the north of 1988e. (Actually, the Palomar observers had been planning to photograph 1988e but mis-set the telescope and accidentally picked up 1988g.) Sekanina's application of his theory caused him to conclude that the comets' mutual separation must have taken place far from the sun, a lower limit of $r \sim 25$ AU after the last perihelion passage being derived if the eccentricity $e \sim 0.99$, the smallest value that was reasonably consistent with the observations; he obtained the most satisfactory result for orbits that were actually slightly hyperbolic, leading him tentatively to suggest that the comets had come in from the Oort Cloud and that this was the site of their separation. The 76-day difference in T was clearly *too long* for separation in the inner part of the solar system during the past few years, and it really seemed to be too *short* for the separation to have occurred at the previous perihelion passage—whenever that may have been.

By late May the available observations of 1988g still spanned only three days, while those of 1988e were confined to five days in March, four days in mid-April and a single point on May 15, by which time this comet had become very faint. Although e for even 1988e was therefore still very indeterminate, it occurred to me that one might be able to establish what it was (specifically, whether or not the objects were Oort Cloud comets) by assuming that the two comets had identical orbits (except for the difference in T) when traced back out beyond the orbit of Neptune and reckoned with respect to the solar system's barycenter. Starting with a near-sun heliocentric parabolic orbit for 1988e, for example, we find that the original barycentric orbit would have $e = 1.00022$. To make 1988g have the same original orbit then yields a near-sun heliocentric orbit with $e = 1.00008$. However, if one tries, with only T permitted as a free parameter, to fit this orbit to the observations, he finds that the (O-C) residuals $\Delta\alpha \cos\delta$ of the observations in right ascension are systematically in the range from +31 to +36 arcsec. Starting from the heliocentric orbit that seemed to be indicated (but that satisfied the observations equally well) if one were unwise enough to attempt a general solution for 1988e, namely, one with $e = 0.99672$, one then obtains an original orbit with $e = 0.99694$ and a near-sun heliocentric orbit for 1988g having $e = 0.99680$. This time, however, the values of $\Delta\alpha \cos\delta$ for 1988g were in the range −47 to −42 arcsec. This suggested that one could interpolate (iteratively, if necessary) between these solutions to derive a result that satisfied the observations of both comets. The resulting values were as shown in the Abstract, namely, $e = 0.99876$ for 1988e, $e = 0.99898$ for the barycentric orbit and $e = 0.99884$ for 1988g. I repeated the process in mid-June, when the observed arcs for the comets covered $2\frac{1}{2}$ months and 1 month, respectively, and refined these figures to $e = 0.99820$ for 1988e, $e = 0.99842$ for the barycentric orbit and $e = 0.99828$ for 1988g.

The possibility that the pair had just come in from the Oort Cloud seemed therefore to have been ruled out, and with an aphelion distance of only 1500 AU the original barycentric orbit should have been essentially free from gravitational perturbations (at least by the known planets) since the pair, then presumably in very close proximity to each other, crossed Neptune's orbit following their common perihelion passage about 20 300 years ago. Beyond

Neptune's orbit there are good reasons to believe that comets should be free from nongravitational perturbations too, for although these may go as an inverse-square law near the sun, where the cometary ice is vaporizing, the activity should stop at some distance, depending on the volatility of the ice. Many studies have indicated that this distance is about 3 AU, which would be *expected* of a comet made of water. For a comet made of carbon dioxide, however, this critical distance would be about 11 AU, and the fact that comet 1957 VI seems to have split at 9 AU suggests that some credence should be given to this possibility. It is also not impossible, though perhaps rather unlikely, that the presence of significant amounts of highly volatile substances such as methane, carbon monoxide, nitrogen, perhaps even hydrogen, would permit the relative nongravitational acceleration on the comets to have some effect at large distances from the sun.

So although Sekanina's model did not seem to permit it, let us consider the consequences of a separation of 1988g from 1988e at their previous perihelion passage. To produce a difference in period of 76 days in 20 300 years requires a change of just 10^{-8} AU^{-1} in $1/a$. In a paper relating the ice-vaporization law to differences $\Delta(1/a)$ (in AU^{-1}), Sekanina, Yeomans and I developed the expression

$$\Delta(1/a) = A_1 \alpha r_0 [0.00005877(r/r_0)^{-1.15} - 0.00009726 + 0.00007909(r/r_0)^{3.943}],$$

valid for heliocentric distances $r \ll r_0$, and where for water $r_0 = 2.808$ AU and the normalizing constant $\alpha = 0.1113$. Adopting for r the perihelion distance $q = 1.17$ AU, we find that the required change in $1/a$ implies a differential force of only $A_1 = 0.0005$ or $\gamma = 0.0017 = 0.1$ nm/s^2. With its longer revolution period, the component that returned as 1988g would be accelerated outward from what became 1988e, the primary nucleus. This time the simple-minded calculation suggests that escape velocity might not be achieved for several years. Description of the separation in terms of impulse along the orbit instead of radial acceleration yields a velocity difference of only 0.1 mm/s.

Except that the value of γ is well over two orders of magnitude smaller than the cases considered by Sekanina, this all seems quite plausible. Given that such small values of γ occur, one would expect the fragments to be long lived, certainly long enough that they could both survive a second passage through perihelion. In terms of survival time, if there are to be comet pairs of genetic significance, those separated by only a few months would in fact be those we should most expect to exist.

Why, therefore, are there not more of them? Why did Sekanina's model apparently fail? Was it possible that the parent comet just cracked as it passed perihelion and actually separated later? Possibly some thermal and rotational effect would be sufficient to complete the job. Or how about some unexpected perturbations from planet X? I think the answer is that the split really did occur near perihelion and that Sekanina's model does not in fact consider what the two fragments were doing before their relative velocity exceeded that of escape. Obviously they were orbiting around each other, a complex circumstance with many free parameters that renders meaningless any actual attempt to compute the time taken for the secondary component to escape. In any case, a frequent consequence of a very small separational acceleration is undoubtedly the establishment of the secondary on a track that soon causes it to collide with the primary. If a collision does not occur, there would seem to be a good chance that the fragments would still be orbiting each other when they had receded far enough from the sun that the nongravitational accelerations switch off, leaving the secondary as a permanent satellite of the primary—at least until the next perihelion passage. Van Flandern once discussed the possibility that comets may have satellites, and after all the flak he had received from me about asteroidal satellites, I think he was rather surprised when I actually agreed with him on this. Whipple has also made use of the concept in explaining some of the observed outbursts in cometary brightness. And after all, with the recent discovery of an extensive atmosphere extending from Pluto in the direction of its satellite, there is a even more reason to regard Pluto and Charon as a pair of large comets (as opposed to an asteroid and the satellite an asteroid is not supposed to have). As for comets 1988e and 1988g, if the timing is about right, could it not be that they reached the point where the nongravitational acceleration switches off when the secondary had just spiraled out to the point where it could escape? It might in any case be that the comets had existed as a bound pair during the whole of their previous revolution around the sun. We are dealing, I think, with a rather unusual circumstance, and this presumably explains why the phenomenon of a genetic pair of long-period comets should be so rare.

Rare, but not, now, it seems, unique. At about same time that these comets were discovered the Solar Maximum Mission (SMM) coronagraph made the discovery of a pair of sungrazing comets. This instrument and the coronagraph on the SOLWIND satellite before it have found a total of eight sungrazing comets during about as many years. Although the astrometic data are lacking in both quality and quantity, none of the eight comets is incompatible with membership in the Kreutz group. The point about the two comets that

JULY 3RD

→→1996

EIFFEL

TOWER

THE TOP!!!

Meudon 1996

FROM: David Levy, 70721,1706
TO: Brian Marsden,
>INTERNET:brian%cfaps1.DECNET@cfa.harvard.edu
DATE: 03/25/93 at 17:59

SUBJECT: New comet

Hi Brian,

We got cut off on our last message to you (the one we logged directly to your computer service) so we are resending with more details.

The strange comet is located as follows:

1993 03 24.35503 12 26.7 (2000.0) -04 04 M= 14

The motion is west-northwest (not southeast as in the previous message) at about 7 arcminutes per day. The image is most unusual in that it appears as a dense, linear bar very close to 1 arcminute long, oriented roughly east-west. No central condensation is observable in either of the two images. A fainter, wispy "tail" extends north of the bar and to the west. Either we have captured a most unusual eruption on the comet or we are looking at a dense tail edge-on.

Right now we are sitting in the middle of a cloud with no hope of observing tonight, and we had very poor observing last night. Observers are Eugene and Carolyn Shoemaker, David Levy, and Philip Bendjoya. The comet was found by Carolyn; assuming that this is our discovery, the discoverers should be Shoemaker and Levy.

Gene

FROM: INTERNET:jscotti@lpl.arizona.edu,
INTERNET:jscotti@lpl.arizona.edu
TO: David Levy, 70721,1706
DATE: 03/26/93 at 6:38

SUBJECT: Shoemaker object.

Sender: jscotti@lpl.arizona.edu
Received: from hindmost.lpl.arizona.EDU by iha.compuserve.com (5.65/5.930129sam)
id AA00195; Fri, 26 Mar 93 09:22:55 -0500
Received: by lpl.arizona.edu (4.1/hindmost-MX-1.4)
id AA12283; Fri, 26 Mar 93 07:22:08 MST

Date: Fri, 26 Mar 93 07:22:08 MST
From: jscotti@lpl.arizona.edu (Jim Scotti)
Message-Id: <9303261422.AA12283@lpl.arizona.edu>
To: brian%cfaps1.DECNET@harvard.harvard.edu
Subject: Shoemaker object.
Cc: 70721.1706@compuserve.com, jscotti@lpl.arizona.edu

Brian,

Here are my measurements of this remarkable object which the Shoemakers and David Levy have found. It is indeed a unique object, different from any cometary form I have yet witnessed. In general, it has the appearance of a string of nuclear fragments spread out along the orbit with tails extending from the entire nuclear train as well as what looks like a sheet of debris spread out in the orbit plane in both directions. The southern boundary is very sharp while the northern boundary spreads out away from the debris trails.

Perhaps we can make arrangements to have Gareth download a screen- dump later today. It looks like the weather here is deteriorating with rain predicted for later in the day. I hope the system will clear out quickly, with only a night or two lost at most. Tom found an object on his last night (Wed. night) and I got a pair of epochs on it tonight which I will upload once I finish their reductions.

```
Shoe-Obj.     1C1993 03 26.29531 12 25 42.24 -03 57 55.7
13.9 T       691
Shoe-Obj.      C1993 03 26.30479 12 25 42.09 -03 57 53.7
16.7 N       691
Shoe-Obj.      C1993 03 26.31448 12 25 41.63 -03 57 53.7
          691
Shoe-Obj.     2C1993 03 26.41291 12 25 38.70 -03 57 34.8
          691
```

Note 1: Nuclear region is a long narrow train about 47" in length and about 11" in width aligned along p.a. 260 - 80 degrees. At least 5 discernable condensations are visible within the train with the brightest being about 14" from the SW end of the trail. Dust trails extend 4.20' in p.a. 74 degrees and 6.89' in p.a. 260 degrees, roughly aligned with the ends of the trail, measured from the midpoint of the train. A tail extending more than 1' from the nuclear train with the brightest component extending from the brightest condensation in the train to 1.34' in p.a. 286 degrees. The midpoint of the train was used for the astrometric measures. Note 2: Observations through cirrus.

Time for bed!

Jim, Mar. 26, 14:17 UT.

FROM: INTERNET:brian%cfaps1.span%cfa.BITNET@mitvma.mit.edu,
INTERNET:brian%cfaps1.span%cfa.BITNET@mitvma.mit.edu
TO: David Levy, 70721,1706
DATE: 03/26/93 at 14:19

SUBJECT: IAUC 5725: 1993e, 1993E

Sender: brian%cfaps1.span@cfa.bitnet
Received: from MITVMA.MIT.EDU by iha.compuserve.com
(5.65/5.930129sam)
id AA29750; Fri, 26 Mar 93 17:01:08 -0500
Received: from MITVMA.MIT.EDU by mitvma.mit.edu (IBM VM SMTP
V2R2)
with BSMTP id 4977; Fri, 26 Mar 93 17:00:15 EST
X-Delivery-Notice: SMTP MAIL FROM does not correspond to sender.
Received: from cfa.bitnet (MAILER@CFAPS2) by MITVMA.MIT.EDU
(Mailer R2.10
ptf000) with BSMTP id 9688; Fri, 26 Mar 93 17:00:14 EST
Received: from cfaps1.Span by cfaps2 with VMSmail ;
Fri, 26 Mar 93 16:52:21 EST
Date: Fri, 26 Mar 93 16:52:21 EST
From: brian%cfaps1.span%cfa.BITNET@mitvma.mit.edu
Message-Id: <930326165221.12t@cfaps2>
Subject: IAUC 5725: 1993e, 1993E
To: quai%cfa.BITNET@mitvma.mit.edu
X-St-Vmsmail-To: ST%QUAI,ST%QUAJ,ST%QUAK

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MARSDEN@CFA or GREEN@CFA (.SPAN, .BITNET or .HARVARD.EDU)

COMET SHOEMAKER-LEVY (1993e)

Cometary images have been discovered by C. S. Shoemaker, E. M. Shoemaker and D. H. Levy on films obtained with the 0.46-m Schmidt telescope at Palomar. The appearance was most unusual in that the comet appeared as a dense, linear bar about 1′ long and oriented roughly east-west; no central condensation was observable, but a fainter, wispy 'tail' extended north of the bar and to the west. The object was confirmed two nights later in Spacewatch CCD scans by J. V. Scotti, who described the nuclear region as a long, narrow train about 47" in length and about 11" in width, aligned along p.a. 80-260 deg. At least five discernible condensations were visible within the train, the brightest being about 14" from the southwestern end. Dust trails extended 4'.20 in p.a. 74 deg and 6'.89 in p.a. 260 deg, roughly aligned with the ends of the train and measured from the midpoint of the train. Tails extended more than 1' from the nuclear train, the brightest component extending from the brightest condensation to 1'.34 in p.a. 286 deg. The measurements below refer to the midpoint of the bar or train.

1993 UT		R.A. (2000)	Decl.	m1	Observer
Mar.	24.35503	12 26 39.27	- 4 03 32.9	14	Shoemaker
	24.43072	12 26 37.21	- 4 03 23.0		"
	26.29531	12 25 42.24	- 3 57 55.7	13.9	Scotti
	26.30479	12 25 42.09	- 3 57 53.7	16.7	"
	26.31448	12 25 41.63	- 3 57 53.7		"
	26.41291	12 25 38.70	- 3 57 34.8		"

C. S. Shoemaker, E. M. Shoemaker, D. H. Levy and P. Bendjoya (Palomar).
Measurers D. H. Levy, J. Mueller, P. Bendjoya and E. M. Shoemaker.
J. V. Scotti (Kitt Peak). Last observation made through cirrus.

The comet is located some 4 deg from Jupiter, and the motion suggests that it may be near Jupiter's distance.

SUPERNOVA 1993E IN KUG 0940+495

D. D. Balam and G. C. L. Aikman report a measurement of V = 20.3 +/- 0.1 and B-V = +0.51 on Feb. 26.28 UT, using the 1.85-m reflector (+ CCD) at the Dominion Astrophysical Observatory.

1993 March 26 (5725) Brian G. Marsden

FROM: INTERNET:brian%cfaps1.DECNET@cfa.harvard.edu, INTERNET:brian%cfaps1.DECNET@cfa.harvard.edu
TO: David Levy, 70721,1706
DATE: 03/26/93 at 15:52

SUBJECT: RE- Thank you

Sender: brian%cfaps1.DECNET@cfa.harvard.edu
Received: from cfa.harvard.edu by ihc.compuserve.com (5.65/5.930129sam)
id AA23159; Fri, 26 Mar 93 18:51:48 -0500
Return-Path: <brian%cfaps1.DECNET@cfa.harvard.edu>
Received: from CFAPS1.DECnet MAIL11D_V3 by cfa.harvard.edu; Fri,

26 Mar 93 18:45:54 -0500
Date: Fri, 26 Mar 93 18:45:53 -0500
Message-Id: <9303262345.AA05804@cfa.harvard.edu>
From: brian%cfaps1.DECNET@cfa.harvard.edu
To: compuserve.com::70721.1706%cfa.DECNET@cfa.harvard.edu
Cc: BRIAN@compuserve.com
Subject: RE- Thank you

Well, of course, my computation was only one possibility (but yes, the Palomar and the Kitt Peak observations DO seem to be mutually consistent), but with Jupiter and the comet separated now by more than 4 degrees, it is hard to arrange for a very close encounter to be TOO recent. Some time in 1992 therefore seemed reasonable, also to allow for separation along a 47" arc, and perhaps not too close to the end of the year. I put the encounter just eight months ago and since then, of course, the comet has been too close to the sun for observation or at least pretty far over in the morning sky (or did you search this regic last month?). We shall see what happens when we get a longer arc!

FROM: INTERNET:brian%cfaps1.DECNET@cfa.harvard.edu,
INTERNET:brian%cfaps1.DECNET@cfa.harvard.edu
TO: David Levy, 70721,1706
DATE: 03/27/93 at 10:19

SUBJECT: I hope this does not go too far overboard!

Sender: brian%cfaps1.DECNET@cfa.harvard.edu
Received: from cfa.harvard.edu by ihc.compuserve.com (5.65/5.930129sam)
id AA24546; Sat, 27 Mar 93 13:18:15 -0500
Return-Path: <brian%cfaps1.DECNET@cfa.harvard.edu>
Received: from CFAPS1.DECnet MAIL11D_V3 by cfa.harvard.edu; Sat, 27 Mar 93 13:17:57 -0500
Date: Sat, 27 Mar 93 13:17:57 -0500
Message-Id: <9303271817.AA19677@cfa.harvard.edu>
From: brian%cfaps1.DECNET@cfa.harvard.edu
To: compuserve.com::70721.1706%cfa.DECNET@cfa.harvard.edu
Subject: I hope this does not go too far overboard!

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Telephone 617-495-7244/7440/7444 (for emergency use only)
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Circular No. 5800

Central Bureau for Astronomical Telegrams
INTERNATIONAL ASTRONOMICAL UNION
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PERIODIC COMET SHOEMAKER-LEVY 9 (1993e)

Almost 200 precise positions of this comet have now been reported, about a quarter of them during the past month, notably from CCD images by S. Nakano and by T. Kobayashi in Japan and by E. Meyer, E. Obermair and H. Raab in Austria. These observations are mainly of the "center" of the nuclear train, and this point continues to be the most relevant for orbit computations. Orbit solutions from positions of the brighter individual nuclei will be useful later on, but probably not until the best data can be collected together after the current opposition period. At the end of April, computations by both Nakano and the undersigned were beginning to indicate that the presumed encounter with Jupiter (cf. IAUC 5726, 5744) occurred during the first half of July 1992, and that there will be another close encounter with Jupiter around the end of July 1994. Computations from the May data confirm this conclusion, and the following result was derived by Nakano from 104 observations extending to May 18:

```
                 Epoch = 1993 June 22.0 TT
    T = 1998 Apr. 5.7514 TT            Peri. =  22.9373
    e = 0.065832                       Node  = 321.5182  2000.0
    q = 4.822184 AU                    Incl. =   1.3498
      a =  5.162007 AU    n = 0.0840381     P =  11.728 years
```

This particular computation indicates that the comet's minimum distance Delta_J from the center of Jupiter was 0.0008 AU (i.e., within the Roche limit) on 1992 July 8.8 UT and that Delta_J will be only 0.0003 AU (Jupiter's radius being 0.0005 AU) on 1994 July 25.4.

As noted on IAUC 5726, the positions of the ends of the nuclear train can be satisfied by varying the place in orbit at the time of the 1992 encounter and considering the subsequent differential perturbations. Using the above orbital elements, the undersigned notes that the train as reported on IAUC 5730 corresponds to a variation of +/- 1.2 seconds. Separation can be regarded as an impulse along the orbit at that time, although the velocity of separation (or the variation along the orbit) depends strongly on the actual value of Delta_J. At the large heliocentric distances involved any differential nongravitational acceleration must be very small, as Z. Sekanina, Jet Propulsion Laboratory, has also noted. Extrapolation to shortly before the 1994 encounter indicates that the train will then be about 20' long and oriented in p.a. 61-241 deg, whereas during the days before encounter the center of the train will be approaching Jupiter from p.a. about 238 deg.

FROM: David Levy, 70721,1706
TO: David Levy, 70721,1706
DATE: 02/05/94 at 17:11

SUBJECT: IAUC 5801: 1993e

Circular No. 5801

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PERIODIC COMET SHOEMAKER-LEVY 9 (1993e)

Following the remarks on IAUC 5800 concerning the encounter with Jupiter in July 1994, it should be noted that the 3-deg difference in p.a. between the comet's direction of approach and the orientation of the nuclear train should increase immediately before encounter, and the undersigned's initial estimate is that more than half of the nuclear train could collide with Jupiter--over an interval approaching three days. Preliminary computations by A. Carusi, Rome University, show that surviving nuclei are likely to remain as satellites of Jupiter or be thrown closer to the sun on short-period heliocentric orbits (depending on which side of Jupiter they pass). It must be emphasized that a 1994 collision of the train center with Jupiter is not assured, and in the case of a miss, the 3-deg difference in p.a. would minimize the chance of collision with any part of the train.

1993 TT		R. A. (2000)	Decl.	Delta	r	Elong.	Phase	m1
May	13	12 07.45	- 2 04.0	4.755	5.462	130.2	8.1	13.5
	23	12 06.15	- 1 54.9	4.880	5.460	120.2	9.2	13.6
June	2	12 05.98	- 1 52.8	5.019	5.458	110.5	10.0	13.7
	12	12 06.92	- 1 57.8	5.166	5.455	101.2	10.5	13.8
	22	12 08.92	- 2 09.4	5.318	5.453	92.2	10.7	13.8
July	2	12 11.92	- 2 27.5	5.471	5.451	83.5	10.7	13.9
	12	12 15.82	- 2 51.4	5.622	5.448	75.0	10.4	13.9
	22	12 20.53	- 3 20.5	5.766	5.445	66.7	9.9	14.0
Aug.	1	12 25.96	- 3 54.2	5.901	5.443	58.7	9.2	14.0
	11	12 32.03	- 4 31.9	6.025	5.440	50.7	8.3	14.0

The orbit on IAUC 5800 indicates that the comet was already in jovicentric orbit before 1992, but this conclusion is very uncertain. Nevertheless, the following ephemeris may be useful for 1992 searches; the magnitude is, of course, a pure guess.

1992 TT		R. A. (2000)	Decl.	Delta	r	Elong.	Phase	m2
Feb.	8	10 48.10	+ 6 54.3	4.572	5.498	157.8	3.9	22.4
	18	10 43.94	+ 7 22.5	4.522	5.496	169.0	2.0	22.2
	28	10 39.47	+ 7 53.1	4.503	5.493	179.4	0.1	22.0
Mar.	9	10 35.02	+ 8 24.0	4.515	5.491	168.4	2.1	22.2
	19	10 30.92	+ 8 53.1	4.556	5.489	157.4	4.0	22.4
	29	10 27.48	+ 9 18.7	4.625	5.486	146.5	5.8	22.5
Apr.	8	10 24.92	+ 9 39.3	4.719	5.483	135.9	7.3	22.6

1993 May 22 (5801) Brian G. Marsden

FROM: INTERNET:brian%cfaps1.DECNET@cfa.harvard.edu, INTERNET:brian%cfaps1.
NET@cfa.harvard.edu

Brian's 1st reply

Date: Sat, 28 Aug 93 13:06:59 -0400
From: brian%cfaps1.DECNET@cfa.harvard.edu
To: acadiau.ca.dnet!roy.bishop%cfa.DECNET@cfa.harvard.edu
Cc: BRIAN@cfa.harvard.edu
Subject: RE- Re: Will this do?

Dear Roy,

As I think you will understand, I tried to be extraordinarily careful in what I wrote about 1993e, in order to give credit where it is due. It is not correct to call the observations by Helin and Lindgren "prediscovery images". Helin and Lindgren both noticed these images before the Shoemaker-Levy discovery, and both Helin and Lindgren did in fact get images on a second night, again before the Shoemaker-Levy discovery. On the other hand, Shoemaker and Levy only had one night on the comet before it was announced. What Helin and Lindgren did NOT do was immediately realize that they had images of the comet on two nights. On the second night the field was just taken to ensure follow-up when the plates were fully analyzed. Helin was at the time preoccupied with getting a NASA proposal completed, and Lindgren was too inexperienced to appreciate what the image was. Scientifically, Shoemaker did the right thing by having Scotti get a CCD image, for not only did this knowingly confirm the comet, but it immediately showed what had happened to make the photographic images so peculiar.

You will appreciate that there is tremendous competition and animosity between Helin and Shoemaker. Whichever way one states the situation the other will complain. I said it like it was, and it is my job to try to report and credit discoveries properly and fairly. When all is said and done, the real problem is that comets are actually named for the earliest reporting discoverers, and asteroid discoveries are credited only to the first reporting discoverer. Maybe we should all appreciate that the discovery/confirmation process is collective, with generally no single person doing it on his or her own. Photographic/CCD discoveries are themselves made by teams--with some people taking the exposures and others developing and/or examining them. The astrometry may be done by someone else--and the follow-up necessary to get an orbit invariably is. And those who compute the orbits are involved too. I have just done a review of asteroid discoveries. In the case of the visual discoveries I credited the individuals who actually found the objects, and in many cases they did much of the necessary micrometric astrometry (and even orbit computation). For the photographic discoveries I credited only the institutions. Right at the start, when Wolf pioneered photographic discoveries at Heidelberg in 1891, he stated that astrometry would not be possible from the short-focus plates. So what did Wolf do? He got others to do micrometric astrometry. Who was his principal micrometric collaborator? None other than Palisa in Vienna, who with remarkable total of 121 visual discoveries, and who at the time of the introduction of photography had made 25 percent of all of the discoveries, set records that can never be beaten. Heidelberg is still in first place for discoveries, and if you want to speak of an individual one would have to put Reinmuth down as the record holder. But the Crimean Astrophysical Observatory in Nauchnyj will surpass Heidelberg (for numbered minor planets, that is) in the next year, and Palomar will move into first place a couple of years later. Chernykh, one of the Crimean observers, will soon surpass Reinmuth as the individual leader, but he Chernykh will first be surpassed by Ted Bowell--most of whose discoveries are from fourth-place Flagstaff, although many are from films obtained at Palomar: films that are taken, in fact, by the Shoemakers and Levy!

In short, Carolyn Shoemaker is indeed great at finding and reporting comets on the Palomar films. But others do a pretty good job at finding

2

comets too. Bill Bradfield's feat of 16 visual discoveries, all by himself, is at least as remarkable. And what David Levy has done with regard to even 7 visual comets is an excellent record for a living North American.

He also did this all by himself (although neither he nor Bradfield has done the micrometric follow-up of some of the nineteenth-century discoverers). Carolyn finds the comets but is dependent on the team that includes her husband and a third person who is often David Levy. Collaboration and cooperation: those are the words we should be using. Competition may be fine up to a point, but to stress it in a case like 1993e is unnecessary, unproductive and largely meaningless.

My response (Sept. 1)

Dear Brian,
Thank you for your detailed & candid comments re the discovery of 1993e.

One item is not clear to me in your first paragraph.
You write: "Helin and Lindgren both noticed these images before the Shoemaker-Levy discovery, . . ."
Yet you also state that Helin and Lindgren did not "immediately realize that they had images of the comet on two nights."

The second statement appears to contradict the first, but it may be I am misunderstanding something. The further comments about Helin being "preoccupied" and Lindgren "inexperienced" suggest that the Shoemaker-Levy team were the first discoverers, and this is, of course, the point that bothers me about your Handbook text.

I feel very much that I am in an awkward position. My "bottom line" (as I mentioned earlier) is that the Observer's Handbook be accurate. Also I apologize for bothering you again about this touchy topic!

If you wish to make any change in your Handbook article, I must hear from you tomorrow (Sept. 2) (Handbook proofs arrived while I was composing this reply)!

Regards, Roy

Brian 2nd

Date: Wed, 1 Sep 93 13:03:58 -0400
From: brian%cfaps1.DECNET@cfa.harvard.edu
To: acadiau.ca.dnet!roy.bishop%cfa.DECNET@cfa.harvard.edu
Cc: BRIAN@cfa.harvard.edu
Subject: RE: Re: RE- Re: Will this do?

Dear Roy,

I'm sorry this is all so complicated and sensitive! The trouble is that there is no really clear notion of what constitutes a discovery. As I say, Shoemaker and Levy did the right thing: they immediately recognized that they had something interesting and contacted the best person to get the necessary confirmation quickly--although one could argue that they themselves had the responsibility to confirm the object on a second night themselves. But in this peculiar case a second photographic night would not have shown how interesting the comet was. Helin and Lindgren had their programs organized so that the second-night photographs were taken, essentially automatically. But they did not look at their second-night data, and their preoccupation and inexperience (respectively) did not let them consciously follow up their first-night detections, even to the extent of telling us about those detections at the time. If Eleanor Helin had told me, for example, about the peculiar image at any time on March 19, 20, 21, 22, 23 or 24, I should have immediately recalled this when the Shoemaker report came on the 25th (at the same time as Shoemaker alerted Scotti). Then the comet would have become Helin-Shoemaker (probably no Levy and no mention of Helin's assistants); the observations would have been entirely on a par with each other, with one image reported by each. If, then, on the evening of the 25th, I had announced the comet as Helin-Shoemaker, Helin would undoubtedly have realized she had the other night's film, and we could well have had an orbit out before Scotti looked on the 26th. Inexperienced astronomers do sometimes get credited with discoveries! They make their reports, and subsequent action by others confirms that they really had something. When it comes to asteroids, we do insist that observers produce observations from two nights--and we further insist that they measure the positions accurately on those nights. I tend to feel that the same should apply even to unusual earth-approaching asteroids and comets that are found by professionals, although the wily observer may instead get some other astronomer to do the second night for him (viz. Shoemaker here). Anyway, as for the bottom line, I think that what I stated in what I originally wrote is correct. Helin, Lindgren, Shoemaker and Naranjo all independently noticed an image of the comet without otherwise knowing of its existence. And this was, as far as I can tell, the chronological order in which they noticed the image. A prediscovery image is something one notices AFTER one is alerted by others to the discovery, and in this case the term should only apply to the observations by the Japanese amateurs (I suppose it is not out of the question that they, too, noticed the image first, but they have not claimed to me that they did so; anyway, it seems as though they had only single-night detections).

Does this help? In short, I think the item should stay as I wrote it. Shoemaker may object, but nothing is incorrectly stated, and he is given full credit for the important step of alerting Scotti. The perspicacious reader may wonder why Lindgren and Helin did no conscious follow up: that's OK. On the other hand, if one says that Helin had "a prediscovery image", you can guarantee to get a nasty letter from her!

I indicated in my last message that I thought we should credit visual discoveries to individuals and non-visual discoveries to institutions/teams. Every time a case like 1993e comes along, I am more and more inclined to get this instituted as official IAU policy!

Regards

Brian

4 Dear Brian,

My 2nd response

°Thanks for your prompt reply. I shall use your article as
°provided.
°
°I must say that I am still bothered by the definition of
°"discovery". Regarding 1993e, I conclude that Helin noted
°"something" on her first photograph but did not pursue it
°or tell anyone about it. This, to me, does NOT amount to a
°"discovery".
°
°I note that on Circular #5738 you cite Helin as having
°made a "prediscovery observation", along with a note that
°"The Mar, 19 images were actually noted at the time."
°I assume this must have generated "a nasty letter from her"!
°
° I 1:1
ûááÇ
° F1-Help F2-Local user lists F3-Address books F6-Distribution lists
° F7-File attachments F9-More options Ctrl-Enter-Send the message
ááì

Öááááááááááááááááááááááááá Send Message: Editing Screen áááááááááááááááááááááááááá¢
° To : brian%cfaps1.DECNET@cfa.harvard.edu,BRIAN@cfa.harvard.edu
° Subj : RE: Re: RE- Re: Will this do?
ûááÇ
°"something" on her first photograph but did not pursue it
°or tell anyone about it. This, to me, does NOT amount to a
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°made a "prediscovery observation", along with a note that
°"The Mar, 19 images were actually noted at the time."
°I assume this must have generated "a nasty letter from her"!
°
°I have promised David Levy that I would report back to him
°regarding your article on 1993e. Do you mind if I pass your comments
°on to him, or would you prefer that I not do this? (Given the
°sensitive nature of this topic, you may have intended your
°replies to be confidential).
°
°With best regards, Roy
° I 23:24
ûááÇ
° F1-Help F2-Local user lists F3-Address books F6-Distribution lists
° F7-File attachments F9-More options Ctrl-Enter-Send the message
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Öááááááááááááááááááááááááá Send Message: Editing Screen áááááááááááááááááááááááááá¢
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°made a "prediscovery observation", along with a note that
°"The Mar, 19 images were actually noted at the time."
°I assume this must have generated "a nasty letter from her"!
°
°I have promised David Levy that I would report back to him

Brian 3rd & last reply

Date: Thu, 2 Sep 93 13:36:01 -0400
From: brian%cfaps1.DECNET@cfa.harvard.edu
To: acadiau.ca.dnet!roy.bishop%cfa.DECNET@cfa.harvard.edu
Cc: BRIAN@cfa.harvard.edu
Subject: RE- RE: Re: RE- Re: Will this do?

Dear Roy,

I agree that it ought to be a requirement of discoverers to report things properly, and it ought to be completely clear that they did not know of any other detections of the object at the time. But some would-be discoverers are more inclined to report very tentative discoveries than others would be, which is why we have tried to introduce some minimal requirements for what is wanted. This problem will clearly become greater in the future, as we deal more with automated discoveries and team effort, and I really think we need to draw some distinction between the such teams and the "rugged amateur", who goes about his thing alone, usually making only visual observations.

I had been thinking of discussing the 1993e business with David Levy myself. I am actually on very good terms with him. You could bring the matter up with him if you wish, although it occurs to me that there would be one potentially upsetting point for him. This is when I said we might have called the comet "Helin-Shoemaker", without acknowledging him. The point is that there would also have been one of Helin's assistants to mention, and we cannot have four names. What we want, of course, are unique names, and in this connection I cannot help but think that "P/Helin-Shoemaker" is simpler to deal with than "P/Shoemaker-Levy 9".

Regards
Brian

From brian%cfaps1.DECNET@cfa.h, with 0 attachment(s) áááááááááááá 6 of 23 á¢

°Dear Roy,
° I agree that it ought to be a requirement of discoverers to report
°things properly, and it ought to be completely clear that they did not
°know of any other detections of the object at the time. But some would-be
°discoverers are more inclined to report very tentative discoveries than
°others would be, which is why we have tried to introduce some minimal
°requirements for what is wanted. This problem will clearly become greater
°in the future, as we deal more with automated discoveries and team effort,
°and I really think we need to draw some distinction between the such teams
°and the "rugged amateur", who goes about his thing alone, usually making
°only visual observations.
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°myself. I am actually on very good terms with him. You could bring the
°matter up with him if you wish, although it occurs to me that there would
°be one potentially upsetting point for him. This is when I said we might
°have called the comet "Helin-Shoemaker", without acknowledging him. The
°point is that there would also have been one of Helin's assistants to
°mention, and we cannot have four names. What we want, of course, are
°unique names, and in this connection I cannot help but think that
°"P/Helin-Shoemaker" is simpler to deal with than "P/Shoemaker-Levy 9".
°Regards
°Brian

áá +/- <F5>-mark <Del> Copy Forward Headers Move Print Reply eXtract áááááá 93%

Öá From brian%cfaps1.DECNET@cfa.h, with 0 attachment(s) áááááááááááá 6 of 23 á¢

°Dear Roy,
° I agree that it ought to be a requirement of discoverers to report

6.

Öááááááááááááááááááááááááá Send Message: Editing Screen áááááááááááááááááááááááá¢
° To : [dhlevy@lpl.arizona.edu (David H. Levy),] °
° Subj : Re: Brian °
ûááÇ
°Dear David, (Sept. 20) '93 °
° °
°Thanks for the message. I had not forgotten that I said I °
°would reply to you, but for two reasons I have delayed doing °
°so. (1)The university year has begun and I am busy. (2) Brian °
°wishes to stick to his original text. He and I had some °
°moderately extensive correspondence (by e-mail) and I have °
°been wondering how best to respond to you. °
° °
°As I mentioned to you, Brian's text states that 1993e was °
°discovered independently by Lindgren and Helin, and by the °
°Shoemakers and Levy. Yet he admits that Lindgren and Helin °
°did not report the comet at the time they obtained images, nor °
°did they realize that they had images of the comet on two nights. °
° °
°Brian stated to me that "It is not correct to call the observations °
° I 1:1 °
ûááÇ
° F1-Help F2-Local user lists F3-Address books F6-Distribution lists °
° F7-File attachments F9-More options Ctrl-Enter-Send the message °
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Öááááááááááááááááááááááááá Send Message: Editing Screen áááááááááááááááááááááááá¢
° To : dhlevy@lpl.arizona.edu (David H. Levy), °
° Subj : Re: Brian °
ûááÇ
°by Helin and Lindgren 'prediscovery images'". Yet he himself did °
°so on IAU Circular #5738: he used the term "prediscovery °
°observations", but added in a footnote the curious comment: "The °
°Mar. 19 images were actually noted at the time." °
° °
°In short, Brian says that the first report of 1993e was by °
°the Shoemakers and Levy, yet he is also saying that Helin °
°made an independent (and earlier?) discovery --- even though °
°she did not report it and even though Brian does not state °
°clearly that Helin realized that she had a comet prior to its °
°actual announcement. °
° °
°In one of my replies to Brian I stated: "I am still bothered by the °
°definition of "discovery". Regarding 1993e, I conclude that Helin °
°noted "something" on her first photograph but did not pursue it °
°or tell anyone about it. This, to me, does NOT amount to a °
° I 32:1 °
ûááÇ
° F1-Help F2-Local user lists F3-Address books F6-Distribution lists °
° F7-File attachments F9-More options Ctrl-Enter-Send the message °
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Öááááááááááááááááááááááááá Send Message: Editing Screen áááááááááááááááááááááááá¢
° To : dhlevy@lpl.arizona.edu (David H. Levy), °
° Subj : Re: Brian °
ûááÇ
°"discovery"." Brian replied (in part): "I agree that it ought °
°to be a requirement of discoverers to report things properly, °
°and it ought to be completely clear that they did not know of °

°any other detections of the object at the time." I am not happy
°with his response.
°

°I suspect that Brian has received "flak" from Helin, and he
°is trying to steer a middle course. He did say "I had been
°thinking of discussing the 1993e business with David Levy
°myself." Thus, I think you should feel free to contact
°Brian about the whole matter.
°

°I told Brian that my "bottom line" is that the OBSERVER'S
°HANDBOOK be accurate. Unfortunately, it will say that Helin
°made an independent discovery, and I am unconvinced that this
°was so. Since Brian wishes to say this (and told me that "I
°   I 48:1 °

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° F1-Help F2-Local user lists F3-Address books F6-Distribution lists °

° F7-File attachments F9-More options Ctrl-Enter-Send the message °

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Õáááááááááááááááááááááááá Send Message: Editing Screen áááááááááááááááááááááááá¢

° To : dhlevy@lpl.arizona.edu (David H. Levy),

° Subj : Re: Brian

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°

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°made an independent discovery, and I am unconvinced that this
°was so. Since Brian wishes to say this (and told me that "I
°tried to be extraordinarily careful in what I wrote about 1993e")
°I have followed his wishes.
°

°This is a rather long message, but the correspondence I have
°had is longer!
°

°Best wishes, Roy
°

°PS: That was a nice write-up on you in MERCURY.
° Ferris expressed some of my thoughts very well.
°
°   I 59:1 °

ûááÇ

° F1-Help F2-Local user lists F3-Address books F6-Distribution lists °

° F7-File attachments F9-More options Ctrl-Enter-Send the message °

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Õáááááááááááááááááááááááá Send Message: Editing Screen áááááááááááááááááááááááá¢

° To : dhlevy@lpl.arizona.edu (David H. Levy),

° Subj : Re: Brian

ûááÇ

°

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°HANDBOOK be accurate. Unfortunately, it will say that Helin
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°tried to be extraordinarily careful in what I wrote about 1993e")
°I have followed his wishes.
°

°This is a rather long message, but the correspondence I have
°had is longer!
°

P/Shoemaker-Levy 9 : Fragment Q

Positions of 1993e - Q

Feb 11	14	39.17	-16	17.9
12	14	39.39	-16	18.7
13	14	39.59	-16	19.5
14	14	39.78	-16	20.2
15	14	39.96	-16	20.9
16	14	40.13	-16	21.5
17	14	40.28	-16	22.0
18	14	40.43	-16	22.5
19	14	40.56	-16	22.9
20	14	40.68	-16	23.3
21	14	40.78	-16	23.6
22	14	40.88	-16	23.8
23	14	40.96	-16	24.0
24	14	41.03	-16	24.1
25	14	41.09	-16	24.1
26	14	41.14	-16	24.1
27	14	41.17	-16	24.1
28	14	41.20	-16	23.9
Mar ~~29~~ 1	14	41.21	-16	23.8
2	14	41.20	-16	23.5
3	14	41.19	-16	23.2
4	14	41.16	-16	22.8
5	14	41.12	-16	22.4
6	14	41.07	-16	21.9
7	14	41.01	-16	21.3
8	14	40.94	-16	20.7
9	14	40.85	-16	20.0
10	14	40.75	-16	19.3
11	14	40.64	-16	18.5
12	14	40.51	-16	17.6
13	14	40.38	-16	16.7
14	14	40.23	-16	15.7
15	14	40.08	-16	14.7
16	14	39.91	-16	13.6
17	14	39.73	-16	12.4
18	14	39.53	-16	11.2
19	14	39.33	-16	09.9

Jupiter Watch

Cam Vickery
Jay

July 21st 22nd 23rd

26th 27th

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March 27th Passover

2-3 pm

October 18, 1993

Mr. David Levy
120 William Carey Street
Tucson, AZ 85747

Dear Mr. Levy,

I am following up on a letter I wrote to you last month asking if you could participate in a special series of sessions by The Planetary Society at the National Science Teachers Association Convention in Anaheim next year. Our session block is on Friday, April 1 in the Marriott Hotel, adjacent to the Convention Center.

We have scheduled a session with the working title of "When Worlds Collide: Comet Shoemaker-Levy 9 and Jupiter." Dr. David Morrison has already agreed to be one of the two speakers, and we hope that you can join him. I need to confirm our speakers by next week so that the information can be included in NSTA's advance program.

Please let me know if you will be able to participate. The Planetary Society will cover your travel expenses. + single hotel room.

By the way, if you can join us, please let me know what title and affiliation we should use when naming you in the advance program.

Give me a call if you have any questions.

Sincerely,

Susan Lendroth
Manager of Events and Communications

COMETS IN COLLISION

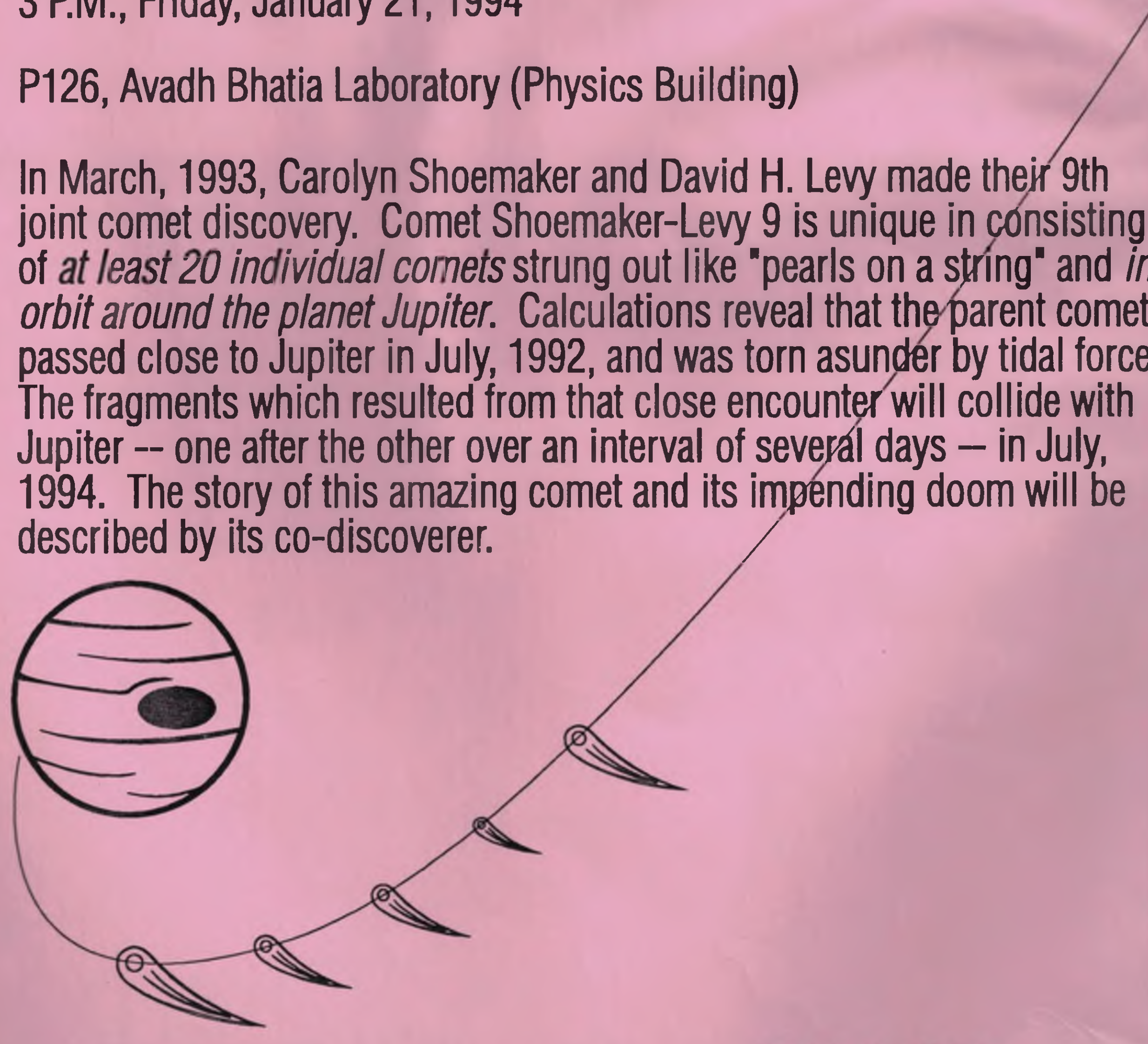
A Special Colloquium
of the
Department of Physics, University of Alberta

Speaker: David H. Levy. Flandrau Planetarium and Palomar Observatory. Canadian-born writer, popularizer of science, and one of the most successful comet hunters of all time.

Time: 3 P.M., Friday, January 21, 1994

Place: P126, Avadh Bhatia Laboratory (Physics Building)

Abstract: In March, 1993, Carolyn Shoemaker and David H. Levy made their 9th joint comet discovery. Comet Shoemaker-Levy 9 is unique in consisting of *at least 20 individual comets* strung out like "pearls on a string" and *in orbit around the planet Jupiter.* Calculations reveal that the parent comet passed close to Jupiter in July, 1992, and was torn asunder by tidal forces The fragments which resulted from that close encounter will collide with Jupiter -- one after the other over an interval of several days -- in July, 1994. The story of this amazing comet and its impending doom will be described by its co-discoverer.



NOTE: David Levy will speak at the Edmonton Space and Science Centre at 7:30 P.M. on Sunday, January 23, 1994. A limited number of tickets will be available for purchase in advance. Phone 452-9100 for information.

PLEASE ANNOUNCE TO STUDENTS

SLH 94

2 weeks March ... Decouvert Sundays 6:10 Canada-wide
Fr, Switzerland, Belgium Tues 11:30 pm

En dix-neuf cent$ soixante dix-neuf J'ai demenagé à Tu
pour miex vivre la vie d'un astronome.

Je suis un auteur, né ... né a Montreal

myself

Mon diplome est en litérature anglaise, dans laquelle j'ai etudié les poems, especialement ceux de Hopkins, qui mentionnait une comete dans l'année dix-huit cent soixante quatre.

La Comete est une boule de neige, avec des roches et de la boue

Rare qu'on peut suivre le processus d'un destruction d'un comete en rentrant ~~d'ar~~ dans l'atmosphere de la grande planete Jupiter. (Jupee-t

~~J'ai decouvr~~ ~~sur~~ sur

Discovery

Les Shoemakers, Gene et Carolyn, et moi-meme l'ont decouv sur la pellicule photographique pendant la cherc pour les cometes et les astéroïdes.

Aussi, J'ai decouvrit 7 comètes avec ~~le~~ un telescope am l'oeil (Oy) dans mon arrière-cour.

Après une inspection plus détailé, on aperçu quelle était realement veignt-et-une pièces. En plus, ~~nous avons~~ les astronomes ont ~~de~~ calculé que la comète etait en orbi autour de Jupitaire depuis les année mille ~~huit~~ hu(t) cent soixante. En dix neuf cent quatre-veignt douze, la comete a rapproché les nuages du Jupiter et brisé en plusieur pièces. ~~Le~~ Juillet prochaine chaque pièce va plonger dans l'atmosphere de Jupiter, laissant un tunnel de feu.

(lèe-ain)

K/T Ce phenomène à ces ~~lignes~~ liens à ~~une~~ l'epoque de dinosaurs ~~de~~ la Terre. La plupart des geologistes ~~croiente~~ sur croient (croit) qu'une comete ou une astéroide de la meme grandeur approximativement s'est pulverizé dans la region de la Yucatan en Mexique. Un cratère de deux cents kilometères s'est ~~gaitte~~ taillé dans une minute ou deux, le resultat etait la destruction ~~de~~ quatre-veignt dix percent des e vivants
~~La force de ces impacts~~

Les impacts ~~de chaque~~ de toutes les pièces cometaire auront une energie très grande si on explosait toutes les bombes atomique que possedait l'Union Sovietique et les Etats Unis pendant la guerre froide.

La force serait peut-être une millième de la comete. C'est assez incroyable!!!

La plupart des teleccopes a travers le monde vont surveiller c'est évenments rare et speciale.

CN 3

Research on Comets

and Novae

CN3 — the Ph.D.

The Sky in Early Modern English Literature:

A study of how celestial events between 1572 and 1610 were interpreted

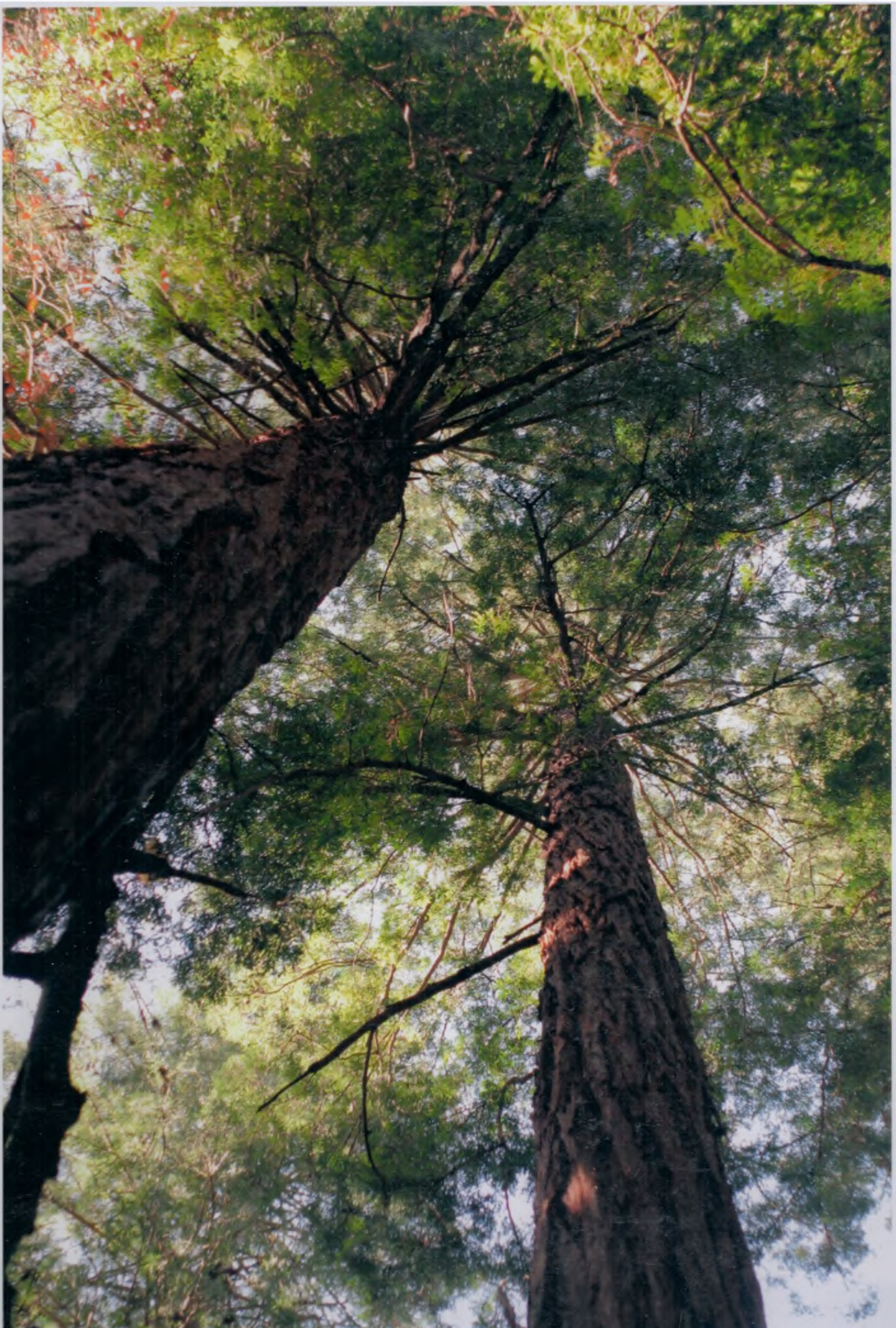
in Elizabethan and Jacobean writing

A Doctoral Dissertation by

David H. Levy

for the Department of English, The Hebrew University


Daily Schedule
1. Thesis
2. CN3 last night
3. Sharing the Sky
4. Jarnac Observatory
5. Articles
6. Eclipse book
7. Meteor book



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Research on Comets and Novae.

David H. Levy
CN-3
December 17, 200
Started on Decem
1965

I am aware that the author of this dissertation may not have set out to answer the particular questions that I have raised. This dissertation, after all, is Mr. Levy's, not mine. He might answer my questions by saying: "But I accomplished what I set out to do: namely, to document the celestial phenomena of Shakespeare's time and the references to those phenomena in his drama." And this is just what he has done. Perhaps the most expeditious way of addressing my concerns would be to temper the claims about "cultural significance" early in the dissertation. The New Historical dimension is the least satisfactory aspect of the dissertation.

If my comments have been more negative than positive, it is because I can best serve Mr. Levy by alerting him to potential pitfalls. Should he want to turn this dissertation into a book, he will need to anticipate the skepticism of book reviewers, who will surely raise the same issues that I have highlighted.

Despite my reservations, I want to emphasize that I enjoyed reading this dissertation and believe that it represents a real contribution to knowledge: no one has previously documented in such detail the fascination with the sky that characterized Shakespeare's age. And I was pleased to learn about such works as Thomas Nashe's *A Wonderful, strange, and miraculous, Astrological Prognostication for this the year of our Lord God, 1591.* Therefore, I believe that Mr. Levy's work merits acceptance as a doctoral dissertation and meets the requirements for such.

I suggest that Mr. Levy consider the concerns I have articulated above and make whatever changes he may deem appropriate. He is a man of considerable learning and experience. I trust his good judgment and that of his dissertation director.

24.9.09

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Reference > Cambridge History > The Drama to 1642, Part One > The Plays of the University Wits > Peele's poetry

‹ Beginnings of dramatic criticism | Robert Greene ›

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The Cambridge History of English and American Literature in 18 Volumes (1907–21).
Volume V. The Drama to 1642, Part One.

VI. The Plays of the University Wits.

§ 12. Peele's poetry.

George Peele.

Though Peele's life may have had its unseemly sides, he had a real vision of literature as an art: *primus verborum artifex,* Thomas Nashe called him; nor, for the phrasing of the time were the words exaggerated. Reading his songs, such as that of Paris and Oenone in *The Araygnement of Paris,* or the lines at the opening of *King David and Fair Bethsabe,* one must recognise that he had an exquisite feeling for the musical value of words; that he had the power to attain a perfect accord between words and musical accompaniment. One can hear the tinkling lute in certain lines in which the single word counts for little; but the total collocation produces something exquisitely delicate. Yet Peele is far more than a mere manipulator of words for musical effect. He shows a real love of nature, which, breaking free from much purely conventional reference to the nature gods of mythology, is phrased as the real poet phrases. The seven lines of the little song in *The Old Wives Tale* beginning, "Whenas the rye reach to the chin," are gracefully pictorial; but the following lines from *The Araygnement of Paris* show Peele at his best, as he breaks through the fetters of conventionalism into finely poetic expression of his own sensitive observation: 18

Not Iris, in her pride and bravery,
Adorns her arch with such variety;
Nor doth the milk-white way, in frosty night,
Appear so fair and beautiful in sight,
As done these fields, and groves, and sweetest bowers,
Bestrew'd and deck'd with parti-colour'd flowers.
Along the bubbling brooks and silver glide,
That at the bottom do in silence slide;
The water-flowers and lilies on the banks,
Like blazing comets, burgeen all in ranks;
Under the hawthorn and the poplar-tree,
Where sacred Phoebe may delight to be,
The primrose, and the purple hyacinth,
The dainty violet, and the wholesome minth,

1585

The double daisy, and the cowslip, queen
Of summer flowers, do overpeer the green;
And round about the valley as ye pass,
Ye may ne see for peeping flowers the grass: …

Is there not in the italicised lines something of that peculiar ability which reached its full development in the mature Shakespeare—the power of flashing before us in a line or two something definitive both as a picture and in beauty of phrase?

One suspects that Peele, in the later years of his life, gave his time more to pageants *19*
than to writing plays, and not unwillingly. He certainly wrote lord mayors' pageants—in 1585, for Woolstone Dixie, and, in 1591, his *Discursus Astraeae* for William Webbe. Moreover, all his plays except *The Old Wives Tale* were in print by 1594, and even that in 1595. One of the *Merrie Conceited Jests of George Peele,* those rather dubious bits of biography, tells us "George was of a poetical disposition never to write so long as his money lasted." Whether the *Jests* be authentic or not, those words probably state the whole case for Peele. 8 He was primarily a poet, with no real inborn gift for the drama, and he never developed any great skill as a playwright. This may have been because he could not; the reason may, probably, be sought in the mood which finds expression in *The Old Wives Tale*—a mood partly amused by the popular crude forms of art, partly contemptuous towards them. Consequently, as he went on with his work without artistic conscience, without deep interest in the form, he could not lift it; he could merely try to give an imperfectly educated public what he deemed it wanted. But even this compromise with circumstance could not keep the poet from breaking through occasionally. And in his feeling for pure beauty—both as seen in nature and as felt in words—he is genuinely of the renascence.

Note 8. As to the *Merrie Conceited Jests,* cf. *ante,* Vol. IV, Chap. XVI, p. 411. [back]

the laſt quarter to the change, for olde age only, according to the verſe,

Luna vetus veteres, iuuenes noualuna requiris.

The Moone in age, the ancient ſort,
Their veynes may open beſt:
The younger ſort tyll Moone be newe,
Muſt let their veynes haue reſt.

Laſt, the age of the partie to be let blood is much to be conſidered: for none before. xiiii. or after. lxx. yeeres, ought to be let blood: the firſt, for ſlendernes of the veynes: the later, for debilitie of nature, vnles the olde men be fleſhy, full of blood, and ſtrong.

For Bathing.

The Moone in { Libra or Piſces, for clenlynes. / Aries, Leo, or Sagittarius, for groſſe bodyes. / Cancer, Scorpio, or Piſces, for dry bodyes. }

For ſweatyng, vſe the ſame conſideration which is in bathing.

Cut heare, the Moone in Libra, Sagittarius, Aquarius, or Piſces, and in the encreaſe.

Sow Seedes which you woulde haue to yeelde fruite the ſame yeere, the Moone being in moueable ſignes, as Aries, Cancer, Libra, or Capricorne: it wyll be beſt when ſhe is in Virgo, Capricorne, or Cancer, if ſhe be increaſing in number. The like is to be ſayd of Piſces.

But to plant Trees for continuance, let it be whyleſt ſhe is in Taurus, Leo, or Aquarius.

Fell Tymber from S. Barnabies day in Iune, tyll the firſt Kalendes of Ianuarie, in the wane of the Moone.

Fell fire wood, that the ſtocke may ſoone ſpring, from the change to the firſt quarter.

To remooue Graffes, or young Trees, at the laſt quarter of the Moone.

Good to gelde or libbe Cattle, in Sagittarius, Capricornus, or Piſces, the Moone encreaſing.

Of

Of the Eclipſe of the Moone.

The Moone this yeere ſhalbe Eclipſed the. xx. day of December, at. iii. of the clocke in the morning, and almoſt a quarter, ſhe being then in her proper manſion Cancer, almoſt corporally conioyned with the malignant planet Saturne, and within two degrees of her Dragons head in the ſeconde houſe, the houſe of ſubſtaunce and riches: which what it may preſage, I leaue it to others to diſcuſſe. My meanyng is not to vſe long and tedious diſcourſing in a matter not very neceſſary, and familiar to euery one, conſideryng the yeerely paſſions which happen to theſe great lyghtes: and therefore with prayer to God, to auert the euyll threatned thereby, I ceaſe for this poynt.

The beginning of the foure *Quarters of this yeere:*

And fyrſt of the Spring.

The Spring taketh his commencement and beginning the. xi. day of March, at two of the clocke. l. minutes after noone, at ſuch tyme as the Sunne entreth into the firſt ſcruple of Aries, making the day and nyght then equall, and the æquinoctium vernum, whereby I gather that the yeere is lyke to proue indifferent fruiteful, and temperate, neither ſubiect to many ſtormes nor ſhewers, neyther hindered by too exceeding drought, ſo that there is no want, penurie, or ſcarcitie, by Gods permiſſion to be feared.

Of the Sommer.

The Sommer beginneth the. xii. day of Iune, at. xi. of the clocke and. xxxiii. ſcruples in the forenoone, when the Sunne entreth into the fyrſt minute of Cancer, making his ſolſtitium eſtiuum, longeſt day, and returneth againe Southward from whence he came. This ſeaſon wyll proue ſomething remiſſe in heate.

A iiii. Of

from ⓐ Soundest evidence of S rejection of judicial. No play's resolution or catastrophe is determined by the stars. Events originate in character

14. Gary Jay Williams. Our Moonlight Reveals. Iowa City: U of Iowa P, 1997.

even when they think they're acting under control of stars.

I have additional individual corrections, notes, and suggestions on my hard copy of the proposal, and will gladly forward them at your request. Most are minor to typographical in substance--some are more substantial.

3 types of astrol. refs. ⓐ rhetorical or or to express mood ⓑ symbols of happiness or misfortune ⓒ direct affirmation or negation of power of stars.

There is also attached a more-or-less up-to-date CV. If the MicrosoftWord format is problematic, please let me know. Thanks again for the opportunity. I look forward to hearing from you.

Frederick (Rick) Williams
Associate Prof. of Classics
Director, University Honors Program
Southern Illinois University Carbondale

ⓐ 1 Henry 4. Comets, importing
ⓑ Sonnet 25: Those who are in favour with their stars
RJ *-crossed lovers. *xd lovers.
ⓒ Titus (4,3) Titus shoots at the planets w petitions to the gods fixed on ends of arrows
2 Hen 6. ONLY one where horoscope faithfully predicts some event "4.1" (4,1) A cunning man did calculate my birth, and told me that by water I should die (then killed by WALTER)

At 11:18 AM 12/17/2003 -0700, David H. Levy wrote:

Dear Rick,

In comedies, astrol. is used by characters to make j... (AW ...)

I am enclosing the proposal as an attachment. If you could write a one or two paragraph assessment of the proposal, along with your CV, and send it to Larry Besserman (he my supervisor at HU, and the only one really enthusiastic about the proposal there!) with a copy to me, I would appreciate it! The idea would be that you might be my co-supervisor with him and a member of my committee. I would be so honored if you would agree to serve.

Thank you so much!

Cannot attribute to Sh. the sentiments of his characters without taking their personalities into account.

Finally, in addition to the classical reference that already exists in the proposal, I found the following last fall: (These are just preliminary notes):

Cumberland Clark: Sh populated his plays w/ what the audiences wanted: fairies, witches + Sh made concessions. ∴ he has his bad characters pronounce the scientific opinions. (p257)

Maphaeus Vegius and his Thirteenth Book of the Aeneid
Stanford U P, 1930

It contains two translations, one completed in 1513; the other in 1583. The translation of 1583 (just a few years after the great supernova of 1572) is far more specific about "starre" in several places.

(See C. Clark, Sh. + Science 1929, p. 59).

Riht great, when they the Ocean have passed, shall convay
To heaven on high: whom virtues fayne great actes for to assay,
And to atchieve, through virtue them as Gods shall lift to skies.
As for tis flame, thy noble Nations prayse before thyne eyes
For future time it showes, by starry fire God gave this signe.
(86)
(Sidereo dedit is Latin)

Conclusions (p258-9) Sh. believed in influence of ☉, ☾, + * on 4 elements. But he did not adhere to belief in judicial + rejected science of horoscopy. Did believe in providence. Natural astrology no longer has any meaning for us.

My great Aeneas to advance unto the loftie skie,
And him of due desert to place among the starres on hie. (89)
Thou what in him is mortall take away, and make him free,
And ad him to the mighty sytarres that shine in lofty skies. (91)

Kent believes in astrol (KL 4 3)
astrologia naturalis – influence of heavenly bodies on weath[er] physical matter, & bo[dies]
" judicialis → human destiny dea[th]

To: msbesser@mscc.huji.ac.il
From: Frederick Williams <rickw@siu.edu>
Subject: Levy dissertation proposal
Cc: david@jarnac.org

Helena in All's Well: the fated sky gi[ves] us free scope (i,i) also Cassius, JC (1,2) will itself free.
age of S. had no specific astrological belief

Dear Dr. Besserman:

Comedy of ALBOMAZAR (John Tomkis) 1614 – astrologer con[...] with

I am happy to serve on David Levy's dissertation committee. I find his topic fresh and exciting, and its interdisciplinary character should be seen as quite common in the market of today's dissertations.

Dodsley's Collection of Old Plays Vol. 2 (1825) 291 ff
PR 13 C28X

There are drawbacks to my service, of course: the most obvious are that 1) I am a classicist; and 2) I am located in southern Illinois. There may be many others.

... Discover more new stars & unfam[iliar] plane[ts]

David says [paragraph "C)"] that although general discussions on his topic appear "from time to time," he "can find no investigation . . . that emphasizes the literary reaction to actual events in the sky." As a friend, I'm willing to take his word for it. As a thesis committeeman, however, I must insist on evidence. That means either 1) that he will have to actually FIND such an investigation; or 2) demonstrate satisfactorily that he has read everything written on the topic. No selectivity. Tough job, I know; but to persuade an already skeptical community, his ground work will have to be exhaustive.

Green (Cathcart) Apology of the sacred scien[ce] astro[logy]
Sidney – confession of faith in the stars in a sonnet → 26

Nashe, Jonson, and the others are of passing interest, but the world will turn its laser-focus upon Shakespeare. For that reason, Levy should consider doing the same with his thesis. As I said, I am excited about David's project, but I suspect it will need much more digging than an astronomer is used to. Let's hope he has a good supply of work gloves and hand salve; our job is to supply him the tools. I've only just begun to investigate, but it seems to me that there are several sources that need to be tapped, if only to reject them. And if I've found several, there are likely more--presumably fewer than there are stars, but who knows? Among them:

Sonnet XV belief in natural astrology.

1. C. G. Abbot. "Astronomy in Shakespeare's time and in ours." Smithsonian Institution, 3405 (1937) — Also David DeV mentioned it.
2. David Ball. Backwards and Forwards Carbondale: Southern Illinois UP, 1983. PN 1661. B3
3. Cumberland Clark. Astronomy in the Poets. 1922. Folcraft: Folcraft Press, 1969. PR 3053
4. ------------------. Shakespeare and Science.1929. New York: Haskell House Pub.,1970.
5. Keir Elam. Shakespeare's Universe of Discourse: Language-Games in the Comedies. Cambridge: Cambridge UP, 1984. PR 298 E4
6. Eugenio Garin. Astrology in the Renaissance: The Zodiac of Life.Trans. Carolyn Jackson, June Allen, and Clare Robertson. London: Routledge & Kegan Paul, 1983. BF 1[...] G37
7. Grant, Edward. Planets, Stars and Orbs: The Medieval Cosmos, 1200-1687. Cambridge: Cambridge UP, 1994. SCIENCE QB 981 G 664
8. Tom McAlindon, Shakespeare's Tragic Cosmos. Cambridge: Cambridge UP, 1991. PR 298[...]
9. A.J. Meadows. The High Firmament: A Survey of Astronomy in English Literature. Leicester: Leicester UP, 1969.
10. John L. Russell. "The Copernican System in Great Britain." The Reception of Copernicus' Heliocentric Theory. Ed. Jerzy Dobrzycki. Dordrecht: D. Reidel Pub.Co., 1972.
11. Dee Scoggins. Searching the Stars for God: Divine Semiotics in Dante, Rabelais, Shakespeare, and Milton. Austin: U of Texas at Austin P, 1997.
12. Moritz Sondheim. "Shakespeare and the Astrology of his time." Journal of the Warburg and Cortauld Institutes 2 (1939): 243-59. AS 122 L 5915. see all around this page
13. Alan Scott Weber. Shakespeare's Cosmology. Diss. State University NY, 1996.

His sense in line 2: "It is not from the stars that I take my prophecies tho' I think I know astrology."

W. Wilson thinks that S. himself is the sectary astronomical. Sond[heim] disagrees. all astrol. refs never go into detail. → See

Shakespeare's Last Act: The Starry Messenger and the Galilean Book in *Cymbeline*

Scott Maisano
University of Massachusetts at Boston

Ye men of Galilee, why stand ye gazing into heaven?

Acts 1:11, *King James Bible,* London 1611

In the novel *2010: Odyssey Two,* Arthur C. Clarke presents a spectacle of sheer sublimity rather obviously designed to whet his fans' appetites for a cinematic sequel to his 1969 collaboration with director Stanley Kubrick. As a spaceship prepares for its destined landing on the planet Jupiter, the narrator expresses the unspoken awe of the anxious crew by allowing us to see through their eyes:

> Jupiter was already larger than the Moon in the skies of Earth, and the giant inner satellites could be clearly seen moving around it . . . . The eternal ballet they performed—disappearing behind Jupiter, reappearing to transit the daylight face with their accompanying shadows—was an endlessly engaging spectacle. It was one that astronomers had watched ever since Galileo had first glimpsed it almost exactly four centuries ago; but the crew of the *Leonov* were the only living men and women to have seen it with their unaided eyes.[1]

Clarke's narrator, however, may have overestimated just how "endlessly engaging" this interstellar spectacle would prove for earthly audiences; for, truth be told, "almost exactly four centuries" ahead of Clarke's fictional cosmonauts were Shakespeare's real-life groundlings, who saw something strikingly similar but probably just shook their heads in disbelief at the playwright's own outlandish Vision of Jupiter.

1. Arthur C. Clarke, *2010: Odyssey Two* (New York: Del Rey, 1982), p. 84.

Configurations, 2004, 12: 401–434 © 2007 by The Johns Hopkins University Press and the Society for Literature, Science, and the Arts.

> Had Shakespeare's prime writing years ended a decade later, his plays might have reflected a vastly different situation. After Galileo's crucial observations of Jupiter, Venus, the moon and the sun, philosophers and writers had to contend with the mounting evidence for the new philosophy of a universe in which the Earth circles the Sun rather than one in which the Sun orbits the Earth . . . . Even if Shakespeare had believed in the new cosmology, it would not have served his purpose well, for the old system, with its emphasis on the Earth and mankind at the center of the universe, is more sound for the purpose of drama. After all, why would the heavens have blazed forth the death of princes in Calpurnia's dream, if the princes had not been at the center of the universe?[9]

The mistake that Levy makes is to assume that Shakespeare's "prime writing years" had ended by 1600, leaving him to look for allusions to Galileo's observations in *Julius Caesar,* written while the young Galileo was still rolling cannonballs off the Leaning Tower of Pisa, but not in a much later Roman play, featuring a character named Pisanio, *Cymbeline.*[10]

One explanation for why Levy, Nicolson, Guthke, and countless others have not considered this "last act" of *Cymbeline* as a possible response by Shakespeare to Galileo's discoveries is that for nearly three hundred years most readers felt that this "theophany" was not such stuff as Shakespeare's dreams are typically made on. At once a theatrical debacle and an authorial anticlimax, the fifth act of this final play in the First Folio left in its wake a theatrical "tradition of omission" as well as an archive of editorial dismay and disavowal. From 1683, the year of *Cymbeline*'s first post-Restoration revival (or rather "revisal," in Thomas Durfy's *The Injured Princess*), to 1946, when George Bernard Shaw published the text to his aptly named adaptation, *Cymbeline Refinished,* the descent of Jupiter within the dream of Posthumus was rarely, if ever, present.[11] Not only was the Jupiter scene cut in its entirety, but all references to his intervention—and to the book that he leaves behind for the characters to decipher—

9. David H. Levy, *Starry Night: Astronomers and Poets Read the Sky* (Amherst, NY: Prometheus Books, 2001), pp. 67–69.

10. Actually, I've taken a bit of poetic license in my response to Levy: for, even supposing that Galileo did conduct his own experiments at the Leaning Tower, he would have concluded them by 1592, when he accepted the chair of mathematics at the University of Padua. For a very detailed, if at times conjectural, account of what experiments Galileo performed and when, the best resource remains Stillman Drake, *Galileo at Work: His Scientific Biography* (Chicago: University of Chicago Press, 1978).

11. John Pitcher, "The Play in Performance," in *Cymbeline* (London: Penguin UK, 2005), pp. lxxxiii–lxxxviii.

From: "Dr. Roger C. Lewis" <saigai@netidea.com>
To: <msbesser@mscc.huji.ac.il>
Cc: "David H. Levy" <david@jarnac.org>
Subject: proposal

Dear Lawrence Besserman,

David Levy has asked me to read over his proposal for a doctoral dissertation and send you an assessment.

This proposal I found very exciting. It is the most ambitious project yet in David's entirely laudable effort to combine literature and science in advanced scholarly studies. Although it was aimed at the general reader, I thoroughly admired his *More Things In Heaven and Earth* for the way it demonstrated the effect the night sky had on widely differing poets. Like the present proposal, it juxtaposed expert literary analysis with empirical observation about the heavens derived from many hours of stargazing and from intensive readings in relevant scientific literature. I also admire David's biographies of astronomers and other books of commentary on astronomy.

I do recognize that there are academic objections to a proposal at the Ph.D. level of this scope and cross-disciplinary breadth. Nevertheless I think such objections can be met. During my lifelong work on the painter-poet D.G. Rossetti, I have been forced to deal simultaneously with the disciplines of painting as one of the fine arts, art history and literary criticism. At first, my proposal for a doctoral dissertation on Rossetti was turned down because certain professors held that a Ph.D. student could not be expert in both painting and poetry. Perhaps not, I agreed, and I postponed scholarly writing about DGR as a painter/poet until later, simplifying my thesis to satisfy the demands of these academic specialists. However, I am presently the Editor-in-Chief of the 10-volume *Correspondence of Dante Gabriel Rossetti* (Cambridge: Boydell&Brewer) and I must say it now strikes me as infantile to make such an arbitrary separation between Rossetti's work as an artist and as a poet.

Because of David's wide reading in literature and science, his ability to write clear expository prose and his fundamental intelligence, I am confident that he can carry out his proposal at a high level of academic excellence. His bringing together of Milton and Galileo should provide an intellectual climax to his study - these two giants of the Renaissance belong together in the history of ideas.

I have not addressed minor points in the proposal - it does need some tidying up and tightening - as I think you need an overall appraisal from me at this point. I would be very happy to be of further assistance if needed. I attach a short CV which can be expanded to include courses taught, theses supervised, papers read, membership on committees etc. if this sort of information is required.

Sincerely,
Roger C. Lewis

CV for Roger C. Lewis.doc

David:

Thanks for sending me a copy of your thesis prospectus, which I have now read hastily, but with interest. I do not have a clue as to what standards the Hebrew University Department of English has for dissertations, so I will employ the usual criteria one finds in a mainstream history department in the United States (oh god no!), with my apologies of course, but that is the only way I can provide you with anything useful. Since your proposal has a strong historical element, it is likely that you will find at least one historian on your review panel, depending upon the insularity (or lack thereof) of the departments at HU.

A history department will always expect to see a review of extant literature on the subject, as a preamble. How will your work add to, deter from, or differ with, for instance, that of A J Meadows (The High Firmament: A Survey of Astronomy in English Literature. Leicester U P 1969) or from the broader literature that seeks to show cultural or scientific impact on literary forms (Marjorie Hope Nicolson's work, in any genre), or, more pointedly, how your study will add to an appreciation of how events in history (wars, famine, politics, intrigue, love triangles, floods, volcanoes, murders) have been recorded or reflected in literature or even scientific milestones (Einstein on literature and art, for instance). At the least, in a history department, you would need to demonstrate in your preamble to your prospectus that you know where your work will fit into the larger field of cultural influences on literature. Historians will only be convinced that you know something when you identify cogently, with explicit citation, just what has been done to date, and why it is insufficient to convince you of something that you feel, and can argue, is worth knowing to the extent you expect a reader to know it once he/she finishes reading and absorbing your dissertation.

The next thing those pesky historians would expect to see is a delineation of the analytical tools you will bring to the table to interpret the data you represent – in this case, the data are astronomical events and passages in literature relating to them. Sure, you can provide a narrative, linking one to the other in time, frequency, etc (your chapter on comets will be of great interest to many readers outside the litcrit field) but this will be regarded as an anecdotal narrative only (by historians, of course) and worthy only of popular or maybe specialist consumption – not as an addition to historiography, per se. Tools may include letters, diaries, contemporary critiques, as well as (far more difficult) statistical and structural studies of the texts involved. For example, take event "X" which introduces a new idea into the world "Y" – how can you demonstrate that, indeed, Y stems from X? One way would be to read all literature in a particular field in the years following event "X" and do a word analysis – how many times does "Y" appear as a theme, character, metaphor, allegory, or in satire? Then, for historians, you would have to show that indeed any trends you found in the number and nature of occurrences of "Y" indeed stand out from the general trend of all literature of that time (This is why grad students as research assistants are so valuable), so that the behavior of your "Y" is in fact an indicator that "X" made a difference. Then you have to describe that difference in your conclusions, rather than just restate your intentions.

I'll now change gears:

I get the sense that what really motivates you to this work is your infectious fascination with experiencing things happen in the sky. You want to share this fascination with others (you have done this better than anyone I know) and now you want to find a way to relive the fascination that historical figures in literature must have experienced in their days with the passage of comets, novae, meteors, and other natural phenomena, and how that experience aided the introduction of new ideas into the broader culture. Here, I would imagine, an English Department would want you to explore how such a motivation through experience results in new literature. What stimulates writing about something, or using something new in your writing? At the least I would expect there to be studies of this question, and criteria offered to help try and answer it. What indicators or factors have been identified by literary historians that help them evaluate the importance of motivation in the creation of new literature? If such analytical or descriptive tools exist, you should find them and use them, or argue why you cannot use them, and therefore devise your own tools (your own methodology).

All these comments are predicated on the assumption that the HU English Department hold to standards common to humanities studies. Historians tend to be rather picky about context, being absolutely clear about the characters, setting, or "locating" or "situating" them, as we historians say, properly within their times, not ascribing present-day knowledge, insight or standards, upon historical characters, etc. It all depends upon how historical your English Profs at HU tend to be.

Finally, there are a few things worthy of comment from your prospectus, again, the plight of the pesky historian:

p. 8 – we need explicit discussion of the extant literature on Shakespeare and astronomy. Is there not a work called "Astronomy in Shakespeare" ?? I know that C. G. Abbot published Astronomy In Shakespeare's Time And In Ours 1937, but doubt that it is the one I have in mind.

p. 9: You have switched the Tychonic Universe with the Digges Universe. Tycho's still has the Sun orbiting the Earth and the Earth motionless. Check out the Rive website (the best for this stuff): Tychonic model:
http://es.rice.edu/ES/humsoc/Galileo/Images/Astro/Conceptions/tycho_univ.gif

p. 13: You are probably correct about Tycho's motivation, but I would ~~check~~ in the Thoren biography, or even the Dreyer bio. QB 36 B8 D7 1977 and T49. Sc. 3rd

p. 17 and elsewhere – thyis is where I get the feeling that your motivation is based upon personal fascination, which is certainly OK, but there will be academics who take a long hard look at this as "captive scholarship" – others call it "going native" – all depends upon the politics of the Department at HU.

Dreyer 38–41 he'd just built his sextant. (better than X staff.)
(he measured pos. of star & found it steady)

Yes Thoren 58: observed distance SN & Schedir (α Cas) always 7° 5

Christiansson 17, → able to prove that change could occur in celestial regions.

p. 31: dates of telescope seem a bit off – Dutch development circa 1608, Galileo definitely started observing in late 1609 – Jupiter was not his first target. Also, the feeling is that Lipperhey knew about the effect of combining lenses but was the first to patent it as a military/commercial device. Again, for you, trivia not related.

p. 35 – F) Conclusions – "other authors" needs historiographical treatment – who, where, when, to what effect, and why are you doing something different.

Bibliography: plenty of good secondary works here. The question will be: what have you gleaned from them, and how will your work add to them? This is the essence of a historiographical essay. Where is Usher's work? Has he not published?

D) My method for identifying astronomical references or allusions will subject them to the following criteria:

1) Can the reference be connected to:
    a) a specific event in the sky? or
    b) a kind of event in the sky with which readers would be familiar? or
    c) a more general cultural belief about the sky?
1) How can the reference help us to understand an aspect of the contemporary night sky?
2) Can the reference help us to appreciate the author's intent within a particular passage?
3) How does the reference function within the context of the writing?

CN3e

Clyde Tombaugh's star

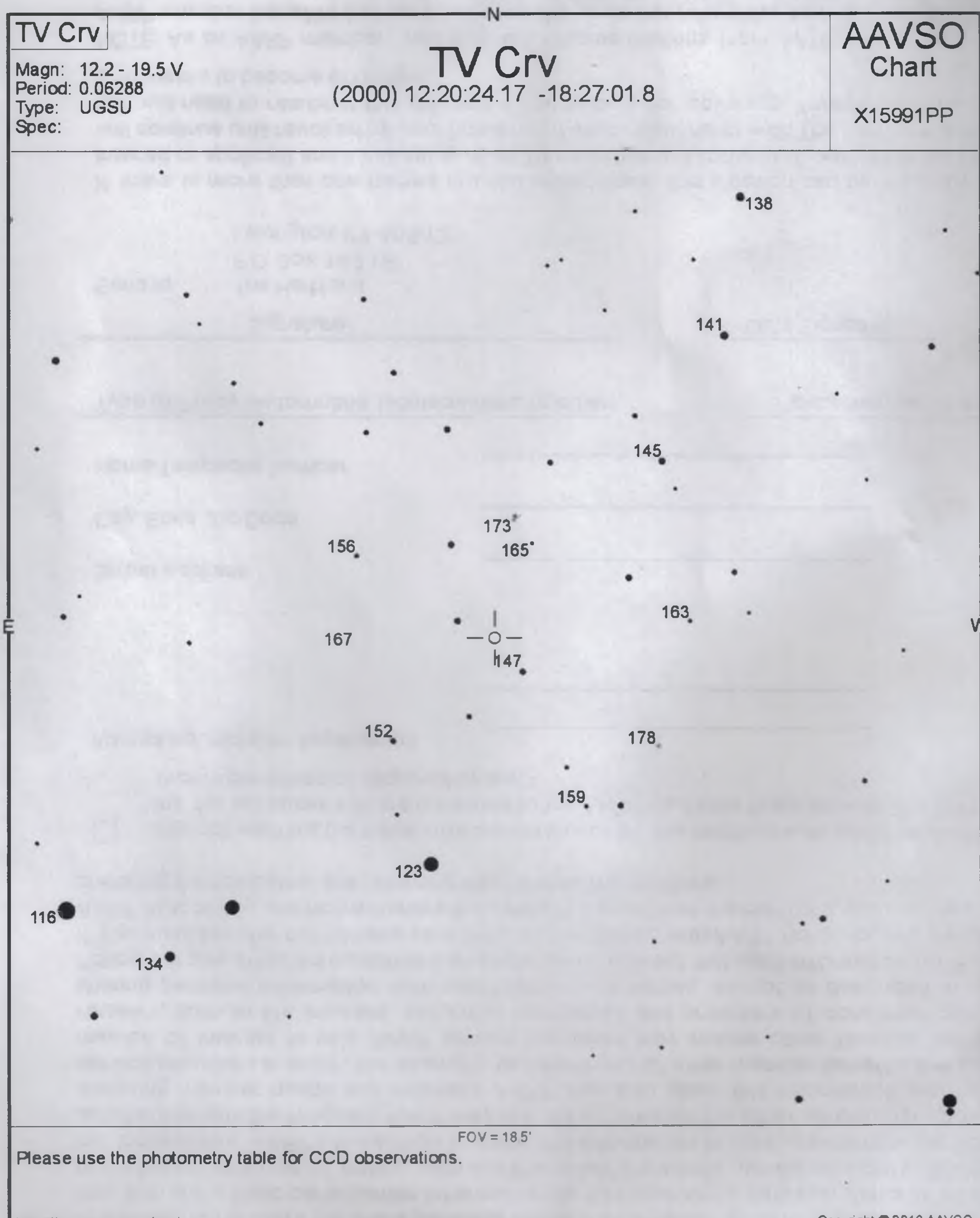
And other variable-magnitude objects

(like 29P/Schwassmann-Wachmann 1)

December 17, 1986

Variable Star Plotter

- Plot Another Chart
- Photometry Table for This Chart



To obtain a printable version of this chart, simply click on the chart.

N

TV Crv

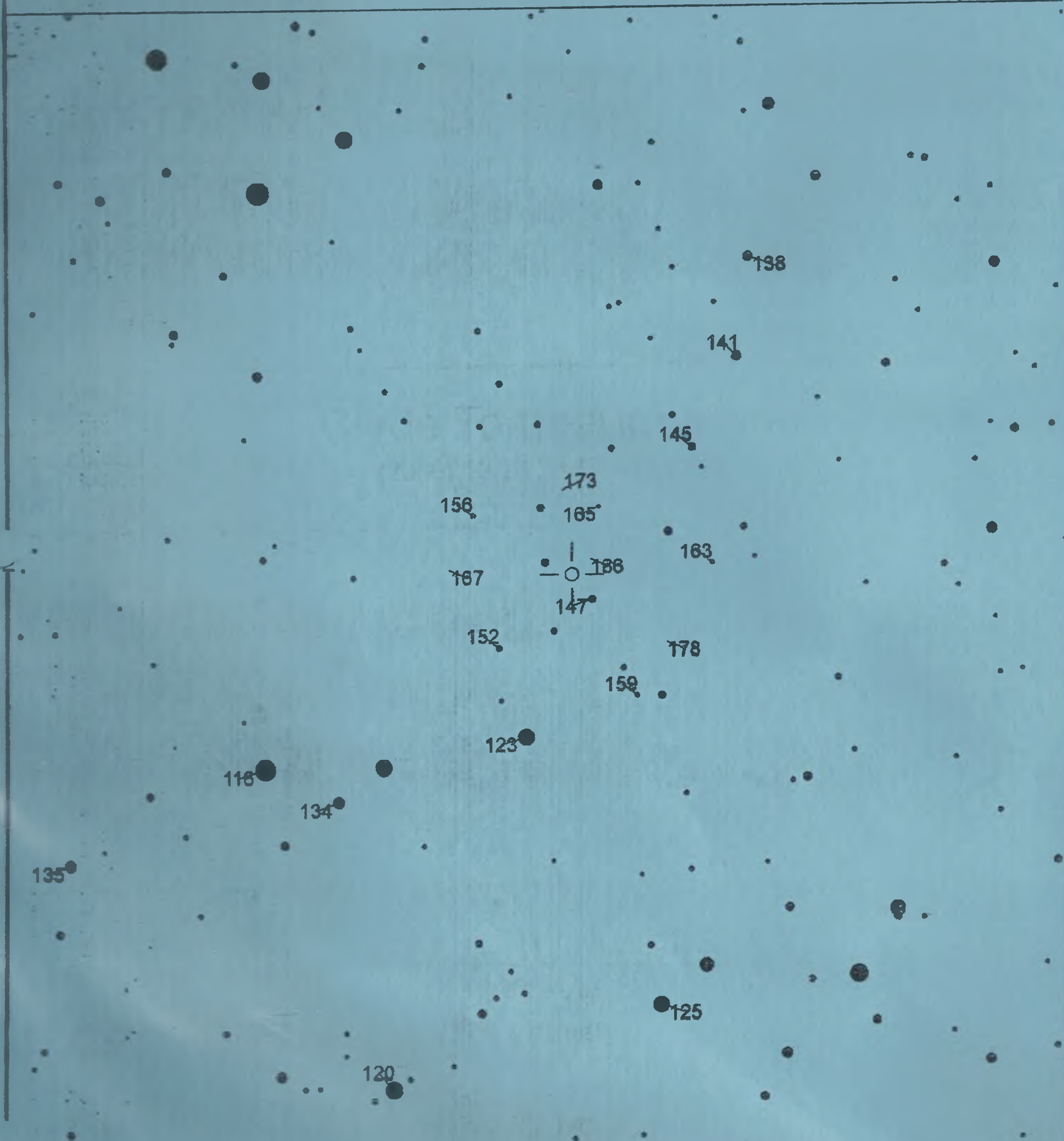
Magn: 12.2 - 19.5 V
Period: 0.06288
Type: UGSU
Spec:

Clyde Tombaugh's Star.

(2000) 12:20:24.17 -18:27:01.8

AAV
Cha

13300C

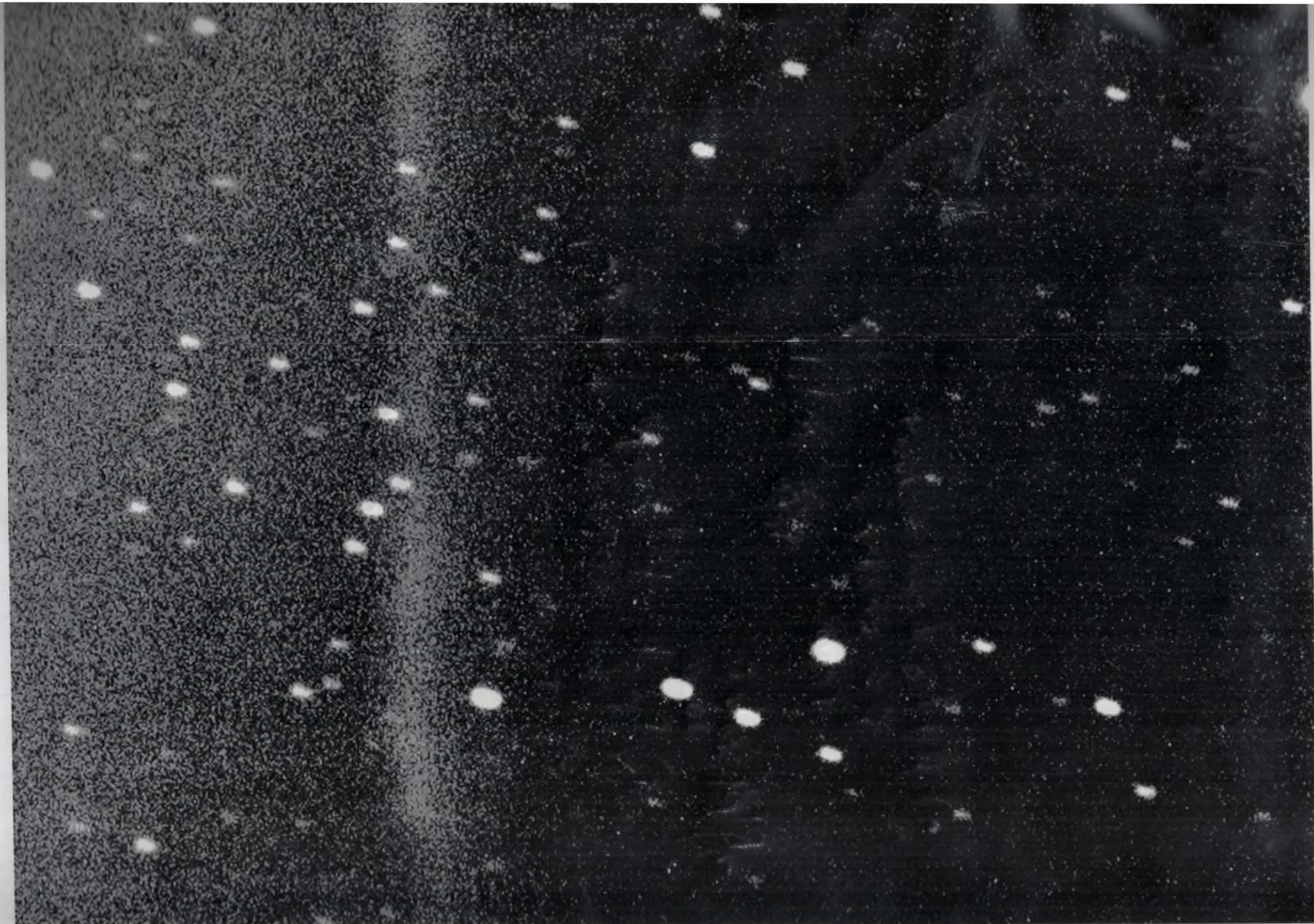


FOV = 30.0'

Please use the photometry table for CCD observations.
This is the star that Clyde Tombaugh discovered in May 1932.

CN3e
2014
March
23-Local

Early Geminid or late Leonid. December 1 2005



CN3k11 Patus CN3e Clyde 1s stay February 2013

IAU Central Bureau for Astronomical Telegrams

IAUC 4983: CATACLYSMIC Var IN Crv; 1989c1

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CATACLYSMIC VARIABLE IN CORVUS

D. H. Levy, Tucson, AZ, communicates the discovery by C. W. Tombaugh of a cataclysmic variable in Corvus on a plate taken 1931 Mar. 23 with the 0.33-m A. Lawrence Lowell astrograph at Lowell Observatory, when the star's magnitude was about 12. A search by Levy through 260 plates in Harvard College Observatory's archives revealed 9 other maxima on the following dates: 1932 Mar. 2, 1940 Feb. 12, 1941 Feb. 5, 1952 Apr. 21, 1971 Apr. 20, 1983 Feb. 22, 1985 Mar. 15, 1987 Mar. 6, and 1988 May 21. Levy reports another outburst on 1990 Mar. 23.270 UT, with the star at mv = 13.6. Precise positions measured by B. Skiff, Lowell Observatory (equinox 1950.0): discovery plate, R.A. = 12h17m48s.38, Decl. = -18 10'27".4; Palomar Sky Survey O exposure, 1954 Mar. 7, R.A. = 12h17m48s.64, Decl. = -18 10'22".7 (estimated blue mag about 17-18, red mag about 19).

COMET AUSTIN (1989c1)

D. G. Schleicher and D. J. Osip, Lowell Observatory; and P. V. Birch, Perth Observatory, report: "We have obtained gas production rates based on aperture photometry obtained on 6 nights between 1989 Dec. 19 and 1990 Mar. 7 using the Lowell-Perth 0.61-m telescope, and on Mar. 14 and 15 using the Lowell 1.07-m telescope. For mid-March, log Q(C2) = 26.6, log Q(C3) = 25.4, and log Q(CN) = 26.7 (i.e., the relative abundances are basically normal). Q(C2) varies approximately as r**2.0 over the total observational interval; however, during the first month the increase was much steeper than the mean, varying as r**4, while from mid-January to early March it varied as r**1. The March observations imply that a higher rate of increase may have resumed. It is unclear how much, if any, of these changes in slopes are due to short-term variability. The increase in the dust production has been extremely shallow, with log (A f rho) = 3.2 in mid-March (A being the albedo of the grains, f the filling factor of the grains, and rho the radius of the field of view; cf. A'Hearn et al. 1984, A.J. 89, 579), and showing variation as r**n with n < 1.0 since December. These data imply a current gas-to-dust ratio approximately 3 times higher than was observed in P/Halley at a comparable heliocentric distance."

Total visual magnitude estimates (B = binoculars): Mar. 19.11 UT, 6.1 (A. Hale, Las Cruces, NM, 10x50 B); 22.01, 6.0 (J. E. Bortle, Stormville, NY, 15x80 B); 23.13, 5.9 (C. S. Morris, Whitaker Peak, CA, 20x80 B).

1990 March 23 (4983) Daniel W. E. Green

Some Personal Thoughts on TV Corvi

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Abstract As part of the AAVSO's role in celebrating the United Nations' International Year of Light, I have been asked to prepare a brief retrospective on my interest in Clyde Tombaugh's star, TV Corvi. Because of the clever light pollution ordinances that have governed the night sky surrounding the area around Tucson, Arizona, and the International Dark Sky Association, our Jarnac Observatory has been blessed with a dark night sky that often permits observations down to 19th magnitude, the star's suspected minimum magnitude. Preparing this article has also helped me to understand that variable star observing is not just science; it is community. My own understanding of the behavior of Tombaugh's Star is gathered from my long friendship with Clyde Tombaugh, discoverer of Pluto and the scientist who opened the door to the Kuiper Belt to other AAVSO observers over many years, Steve Howell, from the Planetary Science Institute, who alerted me to the possibility that one component of TV Crv is a brown dwarf, and the pure joy of being able to observe this faint variable star under a dark sky.

1. Introduction

Recently Dr. Stella Kafka, newly appointed Director of the AAVSO, asked me to write an article for *JAAVSO* about TV Corvi, my favorite variable star. One thing I learned long ago is that when a Director, particularly of the AAVSO, asks me to write something, the best thing to do is to drop whatever it is that I am doing and fulfill her request. My own concern for this particular star dates back almost thirty years to February 9, 1986, the perihelion date of Halley's comet. Sitting in the basement of Lowell Observatory, I was studying the original photographic logs of Clyde Tombaugh in preparation for a biography I was writing about him. On the plate exposed 10 January 1931 was circled the trailed image of a comet. I spent years trying to substantiate Clyde's images, but found nothing. Even though Clyde's telescopes recorded several images of this object, the International Astronomical Union's Central Bureau for Astronomical Telegrams would not announce it unless images from other observers could be found. The comet was rediscovered in 2012 on images taken by the Tenagra Observatories, and is now known as Comet 274P/Tombaugh-Tenagra.

The search for comets did not end there, however. During the summer of 1987 I retuned to Lowell and checked every one of Clyde's planet search plates. (Although the search for trans-Neptunian planets was what the search began as, after Pluto was discovered the search was expounded to a "trans-Saturnian planet" program, and this is how Clyde always referred to it.) This time I uncovered evidence of Clyde's discovery of a single star annotated:

> Nova. 1 nova suspect "T 12" near southwest corner of plate, magnitude about 12, confirmed well on Cogshall [telescope] plates of MARCH 22. No trace of object on 13-inch plates of March 20 and 17, 1931. The image is exactly deformed, like the other star images in the neighborhood. Evidently a very remarkable star to rise from 17 or fainter to 12 in 2 days time.... This object was discovered on May 25, 1932, at 11:00 AM. (Tombaugh 1931; Levy 1991)

Sixty years after the fact, Clyde was still alive and remembered well the moment of discovery. "It was a definitely a real star," the discoverer of Pluto told me over the phone, adding that its image was slightly deformed just like the surrounding stars near the edge of the plate he had taken. He knew it was a "temporary star" as he called it, because it did not appear on either of the other plates he had exposed of the same region. Brian Skiff, a staff astronomer there, suggested that I search some plate archives for other images of this star that could confirm its existence.

2. Confirming Tombaugh's star

On September 11, 1989, therefore, I visited the famous plate stacks at Harvard College Observatory, just a long block down the road from the AAVSO's old headquarters on Concord Avenue. Over three days, I searched through 260 patrol plates, probably the entire collection that HCO had containing the position of the star Clyde had discovered 58 years earlier. The search period spanned a long period of time, from 1930 to 1988. The search yielded nine additional outbursts of what I concluded had to be an SS Cygni-type dwarf nova.

Armed with this evidence, I walked across the lawn to Brian Marsden's office in an adjoining building. He looked at the list of outbursts I presented to him, then back at me. "I agree this is interesting," he said, "but I am not going to announce it yet."

"Why not?" I asked.

"Because," Brian answered sagely but with a grin and a wink, "you are an amateur astronomer." I took a couple of deep breaths, then prepared to say something less than friendly. Brian then added, "If you were a professional astronomer, you'd have to apply for telescope time, and probably you wouldn't bother with it. But as an amateur with a beautiful 40-centimeter reflector capable of discovering comet after comet, you can keep a visual watch on the star's position every night. When you next see the star in outburst, which I don't doubt would someday occur, then I will announce it as a current item."

Thus, in November 1989 when Corvus began to make its appearance in the predawn sky after solar conjunction, I began daily observations of the field.

On March 22, 1990, after giving a lecture in Florida, I checked the region using one of Don Parker's telescopes. The following night, back home, I used my own 40-cm reflector and saw a new star of magnitude 13.6 where nothing had been before!

Since that memorable night I have seen several further outbursts of this star, which Steve Howell of the Planetary Science Institute determined to be not only a high galactic latitude cataclysmic variable star (most such stars lie near the galactic plane), but also that it consists of a white dwarf and a brown dwarf that orbit each other in an area smaller than the Sun in a period under two hours (Planetary Science Institute 2005; Wood *et al.* 2011). One outburst in 2005 deserves particular note. The star was apparently just beginning its rise to maximum when I recorded it. I decided to take repeat exposures every thirty minutes for the rest of the night. My sequence recorded a series of images showing this beautiful star on its way to maximum, and at the AAVSO spring meeting a few months later I played the animation, actually "TV Corvi: The motion picture," during the paper session. After a few showings I went to shut it off, but the audience refused to allow this. Thus I had to continue the animation for the remainder of my paper. Incidentally, this episode is one of the reasons I love going to AAVSO meetings. (Another episode, that had nothing to do with TV Crv, took place during an evening observing session during a spring meeting at our Jarnac Observatory. I casually asked if anyone would be interested in seeing my small collection of old blueprint charts; within a minute the whole crowd was gathered round, admiring the way we used to do variable stars.)

3. Tombaugh's star and the community of variable star observers

Of all the outbursts I have seen since 1990, four have occurred near the date of my first one, March 23, which was coincidentally the date of Clyde's first detection back in 1931. The one on March 23, 2000, was so special to me that I informed then-director Janet Mattei about it by telephone. It meant so much to her that I called because it brought to the forefront her wish to see the human side of variable stars. And on that particular evening, she did. I have presented a paper and co-written other short pieces about this atar, and have discussed it on countless occasions with many astronomers both amateur and professional (Levy *et al.* 1990; Levy 2000).

More important, Tombaugh's star has a unique role to play in the history of the AAVSO and in its many decades of outreach. It is important because it reminds us of one of the most important astronomical observers in the twentieth century. It is important because it suggests the existence of a stellar type that is very, very small; much smaller than our Sun and whose components might be not much larger than Jupiter. And for me, it reminds me of some interesting times that have happened in my life.

4. Superoutbursts for a super star

We now understand that TV Crv is an SU-Ursae Majoris variable: a cataclysmic variable whose outbursts come in two varieties, normal outbursts and superoutbursts, and that exhibits superhumps (small periodic variations related to the length of the orbital period) during superoutbursts. Outbursts occur when gas that is gathering in the accretion disk reaches a certain temperature, the viscosity in the disk changes, and the gas collapses onto the brown dwarf. As gravitational potential energy is released, the system brightens exponentially. This particular star's outbursts apparently result when the accretion disk surrounding the smaller star becomes unstable.

TV Crv (Figure 1) is a special type of SU UMa variable in that its superoutbursts come in two varieties—one with an uninterrupted rise to maximum, and one with a partial rise, slight decline, then full rise to maximum. This latter type is the result of a precursor normal outburst which happens to affect the disk in a way that triggers the superoutburst (Uemura *et al.* 2005).

For examples, we can revisit the superoutburst of 2001 18 February, during which the first recorded visual magnitude observation was 12.9 (Figure 2). In this event, TV Crv went into its superoutburst phase without warning; the preceding nigh the star was typically fainter than magnitude 14.6—there wa no precursor in this superouburst.

The 2004 June 4 superoutburst was associated with a precursor. It appeared to begin as a normal outburst. TV Cr brightened from its quiescent state to about magnitude 13.

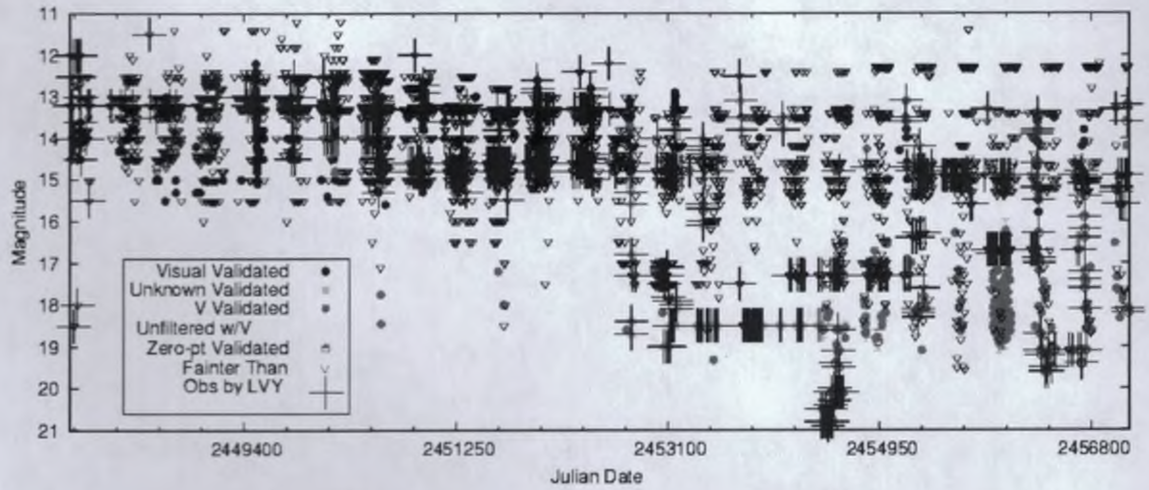

Figure 1. TV Crv, 17 November 1989–4 June 2015 (JD 2447848–2457178). Data from AAVSO International Database (AID). Earliest, historical data in A (February 1930–April 1981, not shown) were digitized by D. Levy from the Harvard College Observatory plate collection and the Palomar Observatory Sky Surv

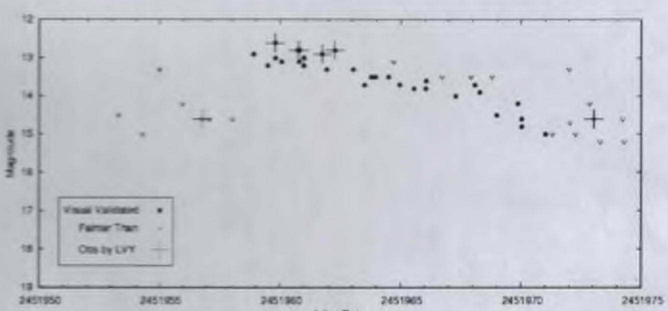

Figure 2. TV Crv, 9 February–6 March 2001 (JD 2451950–2451975). Data from AAVSO International Database.

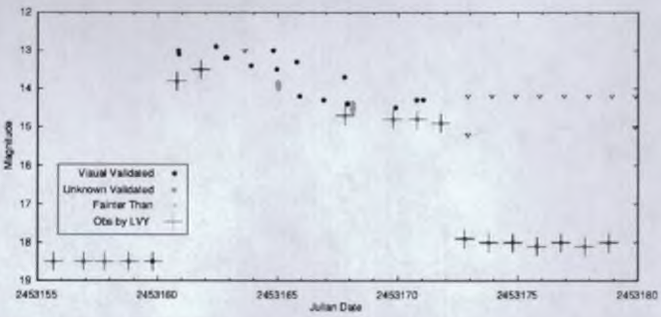

Figure 3 TV Crv, 29 May–23 June 2004 (JD 2453155–2453180). Data from AAVSO International Database.

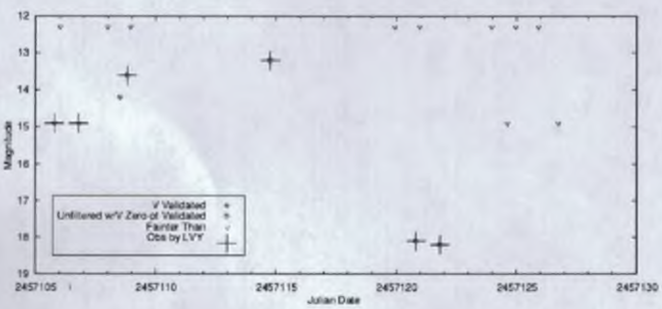

Figure 4. TV Crv, 23 March–17 April 2015 (JD 2457105–2457130). Data from AAVSO International Database.

over a few hours, and then, after a slight fading, continued brightening in a superoutburst, reaching maximum 1.7 days later (Uemura *et al.* 2005) (Figure 3).

In the superoutburst of 27 March 2015 (Figure 4), which took place as I was writing this paper, TV Crv was still at maximum when I observed it again on 2 April. It subsequently returned to minimum by May 17.

5. TV Crv: its astronomical and personal significance

Why exactly is TV Corvi, or Tombaugh's star, my favorit variable? This is not a hard question to answer. Every time observe either the star itself or its field, I am reminded of my close friendship with Clyde Tombaugh. Most people know Clyde only for his discovery of Pluto, connected today with the continuing arguments over its status. Years ago Steve Howel told me that he considered TV Corvi to be Tombaugh's mos significant discovery, far more so than his primary discoverie of the Kuiper Belt. As I was now devoting most of my observing hours to comets, it seemed appropriate to observe its field every night during its season to determine its outburst frequency Although, as a cataclysmic variable, its outbursts cannot be predicted, the outbursts have the unlikely habit of occurring roughly once each year. March appears to be the favored month and on four occasions the outbursts have taken place either on March 23, or have been in progress on that date or slightly after Besides being the date on which more than two outbursts have been detected, March 23 is also the date marking the discovery of my most important comet, Shoemaker-Levy 9 in 1993, and i is the day I married Wendee in 1997. More recently, one of the telescopes I use for my nightly comet search is named "Clyde" not for his discoveries, but for the personality of the man: hi love of science, his sense of humor, and his ubiquitous and unforgettable puns. All these things are rooted in this unusua cataclysmic variable, TV Crv. This wonderful pairing of two tiny stars has made a personal and continuing involvement in my life that I will not soon forget.

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102: 1321–1327, November 1990

THE HISTORICAL DISCOVERY AND RECENT CONFIRMATION OF A NEW CATACLYSMIC VARIABLE IN CORVUS

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ABSTRACT

During the trans-Saturnian planet search of Lowell Observatory, Clyde Tombaugh exposed and studied 362 pairs of plates during the years 1930–44. Among other discoveries he found a nova candidate that appeared on a plate taken on 1931 March 23. This star has stayed in obscurity since that time, its only record being that of Tombaugh's notes written on the plate jacket. On 1990 March 23 this star again went into outburst. Observational studies during this recent outburst and one month later during quiescence have shown this star to be a high-galactic-latitude cataclysmic variable. A total of eleven historical outbursts are now known for this object, all of which have a maximum near $V = 13.0$, 6.5 magnitudes above its current quiescent value.

Key words: cataclysmic variables–high-galactic-latitude stars

1. Introduction

Cataclysmic variables (CVs) are close binary-star systems that include the dwarf novae, novalike variables, classical novae, and related subgroups. All consist of a white-dwarf primary and a mass-transferring, late-type main-sequence secondary. They show small to dramatic changes in the brightness caused by mass transfer, orbital motion, viewing geometry, or a combination of all of these. Their properties have been reviewed recently by Wade and Ward (1985).

Recently, Howell and Szkody (1990) have presented an initial summary of their study of high-galactic-latitude CVs. These stars show some differences from the CVs that are located in the galactic disk. In particular, all the high-latitude dwarf nova systems with known orbital periods of <2 hrs show large outburst amplitudes with an average value of 7 mag. These large amplitudes are ~3 mag greater on average than the disk systems. The period distribution and period gap may also be different in these stars.

The galactic latitude of the star under study here ($b = +42°$) and the large outburst amplitudes seen (see Sections 2 and 3) appear to make this object a typical high-latitude dwarf novae, possibly with a short orbital period.

2. History

While researching a biography of Tombaugh, Levy (1991) reviewed the serendipitous discoveries that were made and noted by Tombaugh during his trans-Saturnian planet search which started in 1930 and which led to his discovery of Pluto[1]. During the 14 years of the search, Tombaugh exposed 338 pairs of 14 × 17 inch plates plus an additional 24 pairs of 8 × 10 inch plates. A review of the original notes written on the plate jackets by Tombaugh revealed that he had discovered two comets, the supercluster of galaxies in the Pegasus-Perseus region (Tombaugh 1937), five new open-star clusters, one newly identified globular-star cluster (Lampland and Tombaugh 1932), many new variable stars and asteroids, and what appeared to be a nova.

The "nova" was seen by Tombaugh on a plate taken on 1931 March 22 (civil date) in the constellation Corvus. Tombaugh's jacket notes read:

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[1]Although the initial aim was to find a trans-Neptunian planet, Tombaugh eventually planned the search with sufficient plate overlap that any object brighter than 17th magnitude and equal to or greater than the distance of Saturn would be discovered.

1 nova suspect. "T12" near southwest corner of plate, magnitude about 12, confirmed well on 5" Cogshall plate of March 22. No trace of object on 13" plates of [local date] March 20 and 17, 1931. The image is exactly deformed, like the other star images in its neighborhood. Evidently a very remarkable star to rise from 17 or fainter to 12 in 2 days time. Position: Epoch 1855 RA 12^h13^m Dec $-17°40'$, Epoch 1930 RA $12^h16^m.9$ Dec $-18°5'$. This object was discovered on May 25, 1932, at 11:00 AM.

The object was plainly visible on the plate of 1931 March 23 UT (limiting magnitude $m_{pg} \sim 17$) as well as on a plate taken simultaneously with the 5-inch (12.7-cm) Cogshall "witness" camera. It did not appear on plates taken on 1931 March 18 and 21 UT, each of which also had a limiting blue magnitude of about 17. The Palomar Observatory Sky Survey (POSS) plates were examined and a star of magnitude ~19 (O plate) and ~20 (E plate) does appear at the position of the nova. Figure 1 shows a finding chart for the object and a CCD image taken recently.

The position of the object on the discovery outburst plate was measured recently by Skiff, using the Lowell PDS microdensitometer. A net of 35 SAO stars was used to define the reference frame. Despite the relatively dense net, strongly comatic images led to a position several arc seconds from that determined later. Nevertheless, it provided unambiguous identification on the POSS prints centered near 12^h30^m and $-18°$. Comparison of the two prints showed the candidate to be blue in color. The position of the star and a 20-star SAO reference net were measured on the O "blue" print using the PDS machine as a visual measuring engine (i.e., not in a scanning mode). The mean rms residuals of the reference stars were $0''.6$, leading to a position of R.A. = $12^h17^m48^s.64$ Dec. = $-18°10'22''.7$ (1950.0). R. McNaught (1990) obtained positions within 0.5 arc second of this based on measures of a UK Schmidt plate during the March 1990 outburst.

The Harvard College Observatory patrol plates were examined by Levy in an attempt to find other outbursts of this star. Two-hundred sixty-two plates spanning the years 1930 to 1988 were searched. Nine additional confirmed outbursts were discovered and we have listed these dates in Table 1. Plates from dates earlier than 1930 were also studied, but the limiting magnitude was near 12, which is not deep enough to see the star even at outburst. Eleven other doubtful outbursts were also detected on the Harvard plates very near the plate limit (see Table 1).

Based on the many observed outbursts (and evidence given in later sections), we believe that the "nova" Tombaugh found is actually a cataclysmic variable, probably of the dwarf nova subclass. Using the mean absolute value for a dwarf novae (i.e., 7.5), this star would have a z distance of ~2 kpc.

3. Recent Observations

With the commencement of the 1989–90 observing season, Levy began a visual check of the field of the star, observing it on 64 clear nights from December 1989 through March 1990. On March 21 UT the object was fainter than 14.0, and the following night poor conditions allowed only an observation that the star was fainter than 12.0. On 1990 March 23 UT, 59 years to the day after Tombaugh's initial discovery plate, Levy (1990) discovered that once again this object was in outburst. Table 2 lists the observations made during this outburst.

3.1 *Spectroscopy at Outburst*

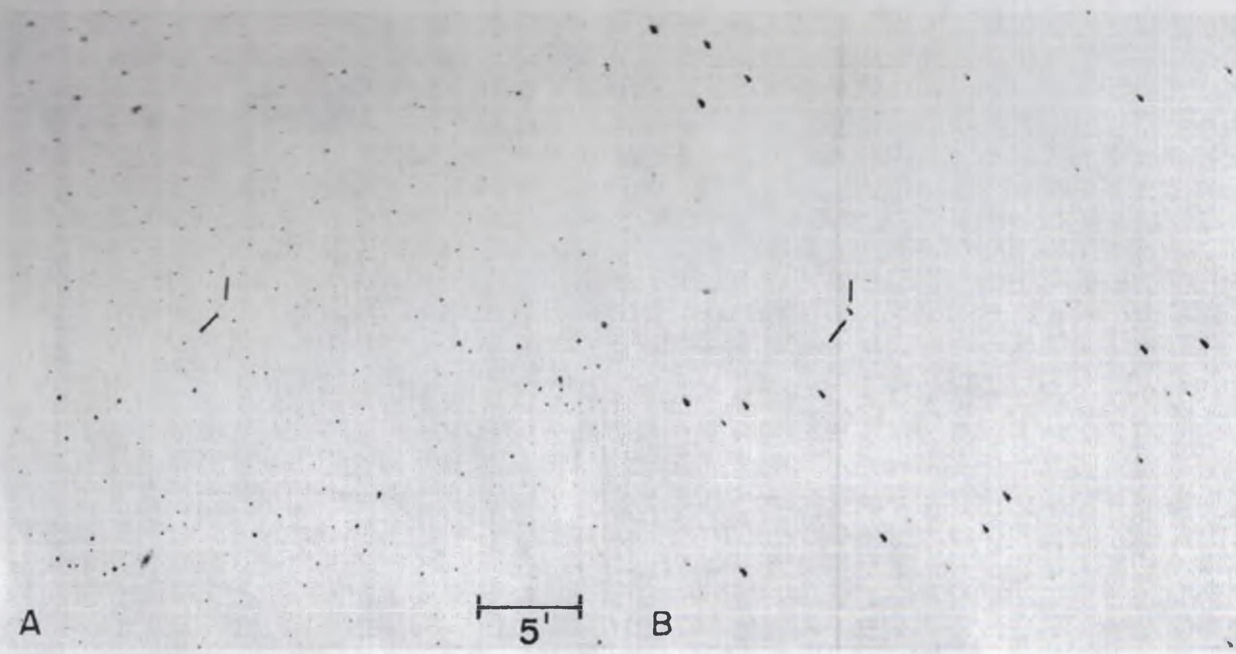
Two spectra were obtained at the 2.1-m telescope on Kitt Peak on 1990 March 23 and 24 UT. These two spectra were taken as target-of-opportunity observations using the Goldcam with grating No. 400. The central wavelength was 7500 Å with a resolution of 14 Å. The spectra were reduced using the IRAF[2] software and standard spectral reduction techniques of bias and flat corrections, spectral extraction via maximum entropy from 2-D to 1-D, wavelength calibration using He-Ne-Ar images taken close in time to the data, and, finally, flux calibration using Kitt Peak IIDS standard stars. Figure 2 shows the reduced spectra. An initial description of the raw spectra was given in *IAU Circ.* No. 4987.

The spectra show that Hα is clearly in emission on both nights, with the overall continuum flux being ~2.4 times greater on the 23rd of March. The strength of Hα above the continuum increases as the continuum level drops (i.e., the outburst declines), as is typical in dwarf novae. There are some very weak indications that He I λλ5876, 6678, and 7065 may be present in emission on the second night and that Hα may be double peaked on the 23rd.

3.2 *Photometry at Outburst*

CCD photometry was obtained at the 1.07-m Hall telescope on 1990 March 24 and 25 UT. *B* and *V* measurements were made once on each night and compared with established comparison stars near the object OJ 287. The measurements were corrected for extinction using mean values for Anderson Mesa (Lowell Observatory). Note that the star faded very quickly from its maximum value observed by Levy on the 23rd. The nights of these *B* and *V* observations were not photometric, hence the large error in the absolute magnitude values. The ΔB and ΔV values between the two nights, however, are based on differences between the same comparison stars on each *B* and *V* frame and are good to ±0.03 mag. While the *V* magnitude faded by 0.48 mag, the star dimmed in *B* by

[2]IRAF is distributed by National Optical Astronomy Observatories, which is operated by the Association of Universities for Research in Astronomy, Inc., under contract to the National Science Foundation.



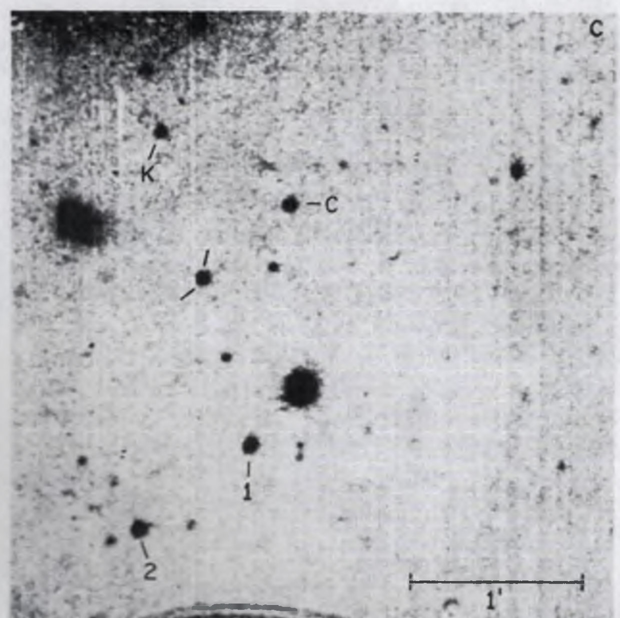


FIG. 1–(a) A portion of the POSS "O" plate centered on the star. It appears here in quiescence at magnitude ~19. (b) A copy of the original discovery plate taken by Tombaugh. The "nova" is clearly visible and shows the coma due to being near the plate corner. (c) A CCD image taken in the WR filter during April 1990. It clearly shows the variable and the comparisons used in our analysis. The position measured on the discovery plate is R.A. $12^h17^m48\overset{s}{.}38$, Dec. $-18°10'27\overset{''}{.}4$ (1950) and on the POSS R.A. $12^h17^m48\overset{s}{.}64$, Dec. $-18°10'22\overset{''}{.}7$. North is up and east is left in all three images.

1.55 mag, a factor of ~2.5. Therefore, while the outburst was ending, light from the blue part of the spectrum decreased much more rapidly.

3.3 *Time-Series Photometry at Minimum*

About one month after outburst, Howell and Kreidl obtained CCD time-series photometry using the 1.8-m Perkins telescope of the Ohio Wesleyan and Ohio State Universities at Lowell Observatory. The data are shown in Figure 3 and summarized in Table 3. The *V* magnitudes were determined from nightly observations of photometric standard stars. The *V* frames were obtained immediately before the wide-R (WR) time series of each night. No corrections were made for color terms and/or air-mass differences, but these were small. The errors in the *V* magnitude are $1\sigma = \pm 0.3$ mag. The WR time-series data were obtained as described in Howell, Mitchell, and Warnock (1988) and have a 1σ error of ± 0.01 mag, calculated from their equation (4). The star showed a slight increase of ~0.4 mag in mean magnitude on the second night as well as a "quieter" light curve. The *V* magnitudes agree quite well with that found on the POSS. Both data sets were searched independently and together for periodicities using the PDM analysis technique of Stellingwerf (1978). Both data sets show 0.1 to 0.2 magnitude variations but no significant periodic modulations were present with confidence levels of >60%. The two time series do, however, show the typical flickering behavior usually associated with a dwarf nova. Further study of this system to determine if its orbital period is indeed less than 2 hours is needed. This determination would provide another confirmation of the evidence provided by Howell and Szkody (1990).

Table 1
Observed Outbursts
(1930-1990)

UT Date	Source	Magnitude[a]
1931 Mar 23	Tombaugh plates	12
1932 Mar 2	Harvard plates	12
1940 Feb 12	"	12
1941 Feb 5	"	12
1952 Apr 21	"	12.5
1971 Apr 20	"	13.5
1983 Feb 22	"	13.0
1985 Mar 15	"	13.0
1987 Mar 6	"	13.0
1988 May 21	"	13.0
1990 Mar 23	Levy - visual	13.6

Dates of Doubtful Outbursts[b]
(1930-1990)

1933 Jul 11	---
1946 Apr 8	13?
1947 Jun 19	---
1947 Jul 22	---
1948 Feb 19	13?
1971 Mar 1	---
1983 Feb 10	---
1987 Feb 24	---
1987 Mar 24	---
1987 Jun 17	---
1988 Jan 21	---

a) Tombaugh plate magnitude derived from comparison with POSS plate plus HST guide star photometric sequence field S716 (Lasker *et al.* 1988). The estimated error of ±0.5 is due to star being located at a plate corner and affected by coma. Magnitudes from the Harvard plate archive films used the nearby AAVSO R Corvi comparison field. The error in each measurement is ~±0.5 mag with a zero point offset occurring between the years 1952 and 1972. This offset of ~1 mag apparently is due to the fact that the photographic emulsion changed after the 20-year moratorium on the patrol plates ended.

b) These dates represent Harvard plate observations in which something was seen at the star's position but was very close to the plate limit of m_{pg} ~13-14 and probably represent plate defects.

4. Discussion

The initial study of this new high-galactic-latitude dwarf novae has revealed some interesting results concerning large-amplitude outbursts. The magnitude of this star at minimum of $V \sim 19$ combined with that of $V \sim 13$ during the March 1990 outburst gives an outburst amplitude of 6 magnitudes. We see from the historical record presented in Table 1 and the POSS measurements that this large amplitude (usually associated with recurrent or classical novae) is not a rare event for this star. The outburst in March 1990 was seen to be quite short, with maximum light (i.e., $V > 15$), lasting for only two days.

Howell and Szkody (1990) have shown that it is likely, although not absolutely necessary, that this star will have a short (<2 hrs) orbital period. If this is true then the star should belong to the SU Ursae Majoris subclass of dwarf novae and show both outbursts and superoutbursts (see review by Warner 1985). The superoutbursts have brighter maxima and longer (~weeks) duration. Thus, if the orbital period is 2 hrs or less, then the March 1990 outburst was not a superoutburst and we would expect to see brighter, longer-duration outbursts from this star at times.

The time-series photometry obtained during minimum light one month after the March 1990 outburst failed to reveal any clear indication of modulations that might be associated with the orbital period. Further photometric and spectroscopic studies aimed at determining this period are planned.

The *B* and *V* photometry obtained during the recent outburst shows some interesting properties. It confirms the rapid decline of the outburst both in *B* and *V* but

Table 2
Observations made during March 1990 outburst

UT Date	Type	Magnitude	Telescope	Observer
1990 Mar 23.27	Visual	13.6 ±0.5	0.4m	D. Levy
1990 Mar 24.25	Visual	14.5 ±0.5	0.4m	D. Levy
1990 Mar 23.37	Spect.	---	2.1m	R. Henry
1990 Mar 24.35	Spect.	---	2.1m	R. Henry
1990 Mar 24.312	Phot.	V = 14.59 ±0.04	1.07m	A. Sadun & J. Hayes
1990 Mar 24.318		B = 14.46 ±0.15		
		B-V = -.013[a]		
1990 Mar 25.286	Phot.	V = 15.07 ±0.04	1.07m	A. Sadun & J. Hayes
1990 mar 25.294		B = 16.01 ±0.15		
		B-V = +0.94[a]		

a) These values are only approximate as the nights were not photometric.

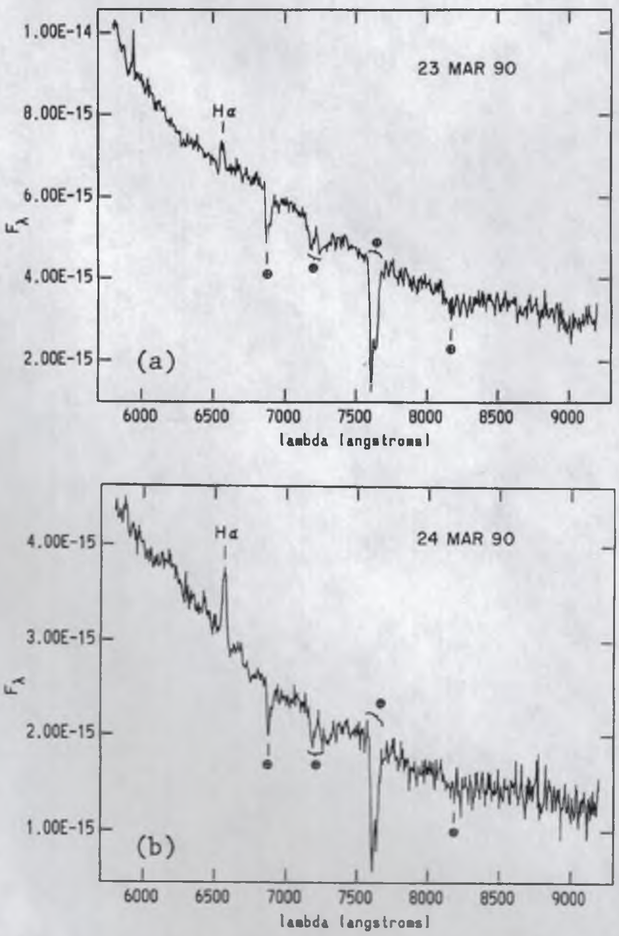


FIG. 2–Outburst spectra taken on UT 1990 March 23rd (a) and 24th (b). The presence of Hα on both nights and the lower continuum level on the 24th are both evident.

shows that the *B* light, approximately equal to *V* on 1990 March 24, dropped by an additional factor of ~2.5 by the 25th. This may be an indication that whatever produced the large outburst is very hot (blue) initially and cools (reddens) rapidly.

Study of this star is also important in terms of understanding its outburst frequency. This object has a detailed historical outburst record available and is the faintest (furthest) high-galactic-latitude dwarf nova with such a record. It would also be important to determine if this star is indeed a SU UMa star and to understand the color changes observed during outburst. The data presented in Table 1 and the associated null results from the other Harvard plates search can give us a hint at an outburst frequency for this star. If we assume that the star would be visible (on any given plate) for only two nights, that the observing season for the Corvus region was from January to July each year, and that a plate was taken only once during a month with equal sampling, then we arrive at an outburst time scale of about once every 28 days! The real situation is not as ideal as that described above and the derived frequency can only be taken as a very rough estimate. It does, however, provide us with evidence that these large-amplitude outbursts seen in this dwarf novae may occur fairly often. Maybe they occur frequently as well in all dwarf novae at high galactic latitudes.

Amateur astronomers have successfully monitored dwarf novae for outbursts since the detection of SS Cygni before the turn of the century. Even so, many of the faint and/or high-latitude CVs are essentially unstudied and, therefore, we know very little of their long-term behavior. These particular stars are usually not followed by amateurs because the time that they stay at maximum light, i.e., within the range of visibility of most amateurs, seems to be very short, about two days; most of the time there would be only a null result as the star would be invisible. These stars do, however, represent an area where valuable contributions by amateurs could be made. In order for this to occur, regular nightly observations of the fields of these stars and timely reports of any outbursts would be needed. Moreover, amateurs should understand that the *negative* observations they make are statistically valuable as well and help determine the length of time between outbursts.

We believe this paper reaffirms the importance of having historical plate collections available to the community as well as the great value of monitoring by amateurs. We are thankful for the efforts of the persons involved both now and in the past and hope that such synoptic programs will continue well into the future. The relatively small expense (as compared to plates) and availability of large-format film should allow photographic archives to continue without prohibitive cost.

We would especially like to thank the following people for interrupting their regularly scheduled programs to make observations of this star while at outburst: Richard

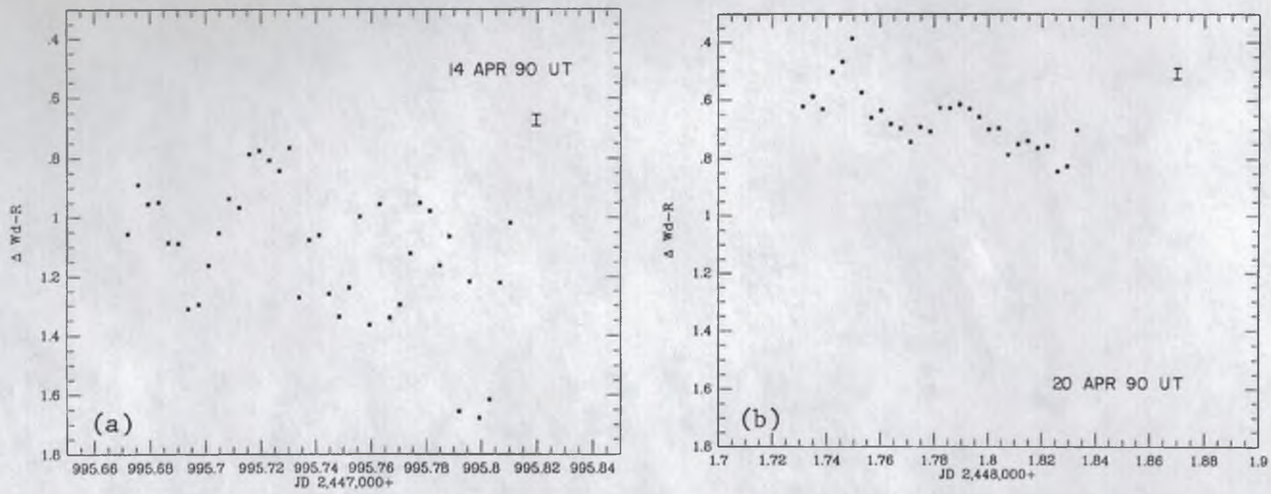


FIG. 3–CCD time-resolved differential photometry taken at quiescence on UT 1990 April 14th (a) and 20th (b). Stars 1 and 2 in Figure 1(c) were used in the analysis presented here. The *y* axis is differential magnitude (variable−star 1) in the WR filter and has the same scale and offset in both (a) and (b). One-sigma error bars are shown.

Table 3

Photometric Observations at Minimum

UT Date	UT[a] Start	N[b] Obs	t[b] sec	dt[b] sec	T[b] hrs	CCD[c]	Filter[d]	Mag[e]
1990 Apr 14	4:07:42	36	300	18	3.2	RCA	WR	19.5
				18		RCA	V	19.0
1990 Apr 20	5:32:57	29	300	18	2.6	RCA	WR	18.9
				18		RCA	V	18.6

a) Time is for midpoint of first exposure in series.

b) N = number of integrations, t = integration time, dt = dead time between integrations (varies between computers and sometimes with number of frames stored on disk), T = total observation interval (including any gaps).

c) RCA = Lowell RCA CCD; Format 256X256, Read noise = 60e-, Gain = 10e-/ADU.

d) V is a standard Johnson filter; WR (wide R) has a λ_c = 7009Å and FWHM = 2601Å.

e) V magnitudes have 1σ = ±0.3; time series errors are 1σ = ±0.01. See text for details.

Henry for his observations with the 2.1-m reflector at Kitt Peak; Alberto Sadun and Jeffrey Hayes for their *B* and *V* measurements; Raylee Stathakis, Rob McNaught, G. Rosenbaum, R. Kennicutt, D. Zaritsky, and A. Pearce. Without their kind help we would not have obtained all the data presented here on this star during its most recent outburst. We also thank R. Mark Wagner for his help with some of the spectral reductions, Brian Marsden for his support of this project, and Martha Hazen for her assistance in providing access to the Harvard College Observatory Plate Archives. T. J. Kreidl acknowledges support from the Lowell Observatory Endowment. S. B. Howell acknowledges support from NSF grant AST 89-15445 and a grant from NASA administered by the American Astronomical Society. Planetary Science Institute is a nonprofit division of SAIC. This is PSI Contribution No. 285.

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TOMBAUGH'S STAR: A HISTORICAL TALE OF THE CATACLYSMIC VARIABLE TV CORVI

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Abstract

While doing research for my 1991 biography of Clyde Tombaugh, discoverer of Pluto, I found evidence that he had discovered a probable nova in Corvus. Since this was an unusually high galactic latitude for a nova, I tried to find confirming evidence for his 1931 observation. Although my results were negative for 1931, I did find nine additional outbursts in my search through several hundred Harvard patrol plates. I observed the variable, now called TV Corvi, in outburst for the first time visually on March 23, 1990, and several times since then.

1. Introduction

When Clyde Tombaugh began blinking his two photographic plates he had exposed on March 23, 1931, he had no idea what discovery awaited him. He was on the trail of Trans-Neptunian planets, but was on the alert for anything unusual.

At 11:00 on the morning of May 25, 1932, more than two years after he discovered Pluto, Tombaugh's scan revealed a bright 12th magnitude star on one of his two plates; none appeared on the other. It appeared to be a nova at a high galactic latitude. Although the astronomer reported the discovery to his superior, Carl Lampland, there is no evidence that the announcement of the nova was ever forwarded beyond Lowell Observatory.

2. Reconfirming Tombaugh's discovery

In 1988, while writing a biography of Tombaugh, I visited Lowell to inspect the notes he had written on the back of each plate envelope. I found the notes he had made on that plate envelope from long ago: "One nova suspect," his plate notes read, " T 12 [meaning Temporary object No. 12] near southwest corner of plate, magnitude about 12.... No trace of object on plates of March 20 and 17, 1931.... Evidently a very remarkable star to rise from 17 or fainter to 12 in 2 days time. This object was discovered on May 25, 1932, at 11:00 AM."

Since the nova appeared on only one photographic plate, I needed to confirm it, but time constraints kept me from doing so until the summer of 1989. Visiting the massive photographic plate collection at the Harvard-Smithsonian Center for Astrophysics, I checked for plates near the time of the Tombaugh observation. There was a plate, but it did not record stars as faint as the nova was at the time. I then looked at other sample Corvus plates from different times. As I expected, nothing unusual appeared. But on the tenth plate was Tombaugh's star, as bright as it was in 1931. That plate was exposed in the late 1970s, decades after the original discovery.

With mounting excitement I decided to check every one of the more than 260 patrol plates of Corvus in the Harvard collection. After three days of searching, I had evidence of nine outbursts in addition to Tombaugh's find. The final confirmation was a visual one. For nearly 70 nights I checked the star, either visually with my 16-inch reflector, photographically through a Schmidt telescope, or with a CCD system. The long search and wait finally ended on March 23, 1990, 59 years to the day after the first Tombaugh plate. I pointed my telescope toward Corvus, not far from R Corvi, and saw Tombaugh's star in outburst.

3. Conclusion

Although the star is now officially known as TV Corvi, I propose that we call it Tombaugh's star in honor and memory of the man who first detected it. On its next observed outburst in June 1991, astronomer Steve Howell and others observed it using the International Ultraviolet Explorer satellite. Based on a long series of observations they conducted, they suspect that the system consists of two stars, a small white dwarf and a larger star. They also conclude that the stars rotate around each other in just two hours (Howell *et al.* 1995).

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(DOI: will be inserted by hand later)

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TV Corvi Revisited: Precursor and Superhump Period Derivative Linked to the Disk Instability Model

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Abstract. We report optical photometric observations of four superoutbursts of the short-period dwarf nova TV Crv. This object experiences two types of superoutbursts; one with a precursor and the other without. The superhump period and period excess of TV Crv are accurately determined to be 0.065028 ± 0.000008 d and 0.0342 ± 0.0021, respectively. This large excess implies a relatively large mass ratio of the binary components (M_2/M_1), though it has a short orbital period. The two types of superoutbursts can be explained by the thermal-tidal instability model for systems having large mass ratios. Our observations reveal that superhump period derivatives are variable in distinct superoutbursts. The variation is apparently related to the presence or absence of a precursor. We propose that the superhump period derivative depends on the maximum disk radius during outbursts. We investigate the relationship of the type of superoutbursts and the superhump period derivative for known sources. In the case of superoutbursts without a precursor, superhump period derivatives tend to be larger than those in precursor-main type superoutbursts, which is consistent with our scenario.

Key words. accretion, accretion disks—binaries: close—novae, cataclysmic variables—stars: dwarf novae—stars: individual:TV Crv

1. Introduction

SU UMa-type stars form a sub-group of dwarf novae characterized by the appearance of long and bright "superoutbursts", during which periodic modulations, "superhumps", are observed (Warner 1985). Superhumps have periods slightly longer than orbital periods, which can be explained by a beat phenomenon of a precessing tidally-distorted eccentric disk. According to the tidal instability theory, an accretion disk becomes unstable against a tidal perturbation from a secondary star when the disk reaches the 3:1 resonance radius (Whitehurst 1988). In conjunction with the thermal instability model for (normal) dwarf nova outbursts, the model for superoutbursts is called the thermal-tidal instability (TTI) model (Osaki 1989).

Superoutbursts are sometimes associated with a precursor typically lasting one or two days. This precursor phenomenon is actually expected from the TTI model. The precursor is considered to be a normal outburst leading to an expansion of the accretion disk over the 3:1 resonance radius and triggering a superoutburst. Growing superhumps have been detected during a decay phase from the precursor in T Leo (Kato 1997), V436 Cen (Semeniuk 1980), and GO Com (Imada et al. 2004). These growing superhumps provide evidence for the TTI model since a system is predicted to reach a supermaximum with the growth of an eccentric disk. On the other hand, the original TTI model cannot explain gradually growing superhumps even after supermaxima without a precursor, which are also frequently observed (Smak 1996).

Osaki & Meyer (2003) propose a refinement of the original TTI model with the idea that the accretion disk can pass the

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3:1 resonance radius and reach the tidal truncation radius. The dammed matter at the tidal truncation radius causes a gradual decay without a precursor. This refined TTI model predicts that SU UMa stars having a large mass ratio ($q = M_2/M_1$, where M_1 and M_2 are the masses of a white dwarf and a secondary star, respectively) can show both types of superoutbursts, that is, those with and without a precursor. This idea should be examined by observations of the early evolution of superoutbursts and superhumps.

The superhump period ($P_{\rm SH}$) in SU UMa stars generally decreases through a superoutburst with a period derivative of order $\dot{P}_{\rm SH}/P_{\rm SH} \sim -10^{-5}$ (Warner 1985; Patterson et al. 1993). A simple dynamical treatment for the tidal instability shows that the precession rate of the eccentricity wave is proportional to $r^{1.5}$, where r is the disk radius (Osaki 1985). The shortening of $P_{\rm SH}$ can, hence, be understood with the shrink of the disk during a superoutburst. Hydrodynamical simulations also show that the precessing eccentricity wave propagates inward, which causes the period shortening of superhumps (Lubow 1992; Whitehurst 1994).

On the other hand, several short-period SU UMa stars showing positive $\dot{P}_{\rm SH}/P_{\rm SH}$ have been discovered since mid-90's (Howell et al. 1996a; Kato et al. 2003c). WZ Sge-type stars, in particular, tend to show positive $\dot{P}_{\rm SH}/P_{\rm SH}$ (e.g. Howell et al. 1996a; Kato et al. 1997). The situation becomes more complicated because ultra-short period systems, V485 Cen and EI Psc also show positive $\dot{P}_{\rm SH}/P_{\rm SH}$ (Olech 1997; Uemura et al. 2002a). These two sources have quite large mass ratios ($q \sim 0.2$), though WZ Sge stars have quite small mass ratio ($q \sim 0.01$). Based on the discussions for ordinary negative $\dot{P}_{\rm SH}/P_{\rm SH}$, the positive $\dot{P}_{\rm SH}/P_{\rm SH}$ has been proposed to arise due to an expansion of the disk or an outward-propagation of the eccentricity wave (Baba et al. 2000; Kato et al. 2004a). It is, however, poorly understood why the outward propagation can occur only in the short-period systems regardless of their mass ratio (Ishioka et al. 2003).

TV Crv is known as an SU UMa-type dwarf nova having a short orbital period of 0.06288 ± 0.00013 d (Woudt & Warner 2003). The historical discovery of this object is summarized in Levy et al. (1990). Howell et al. (1996b) reported superhumps with a period of 0.0650 ± 0.0008 d from observations of a superoutburst in 1994 June. This $P_{\rm SH}$ provides a superhump period excess $\varepsilon = (P_{\rm SH} - P_{\rm orb})/P_{\rm orb} = 0.033 \pm 0.009$. This value of the excess implies that TV Crv may be a peculiar object regarding its possibly large period excess compared with other short period systems (Patterson 2001). The error of ε is, however, so large that the large ε is not conclusive.

Here we report observations of four superoutbursts of TV Crv. Our observations on TV Crv provide new clues to understand the superhump period evolution related to the precursor phenomenon and the TTI model. In the next section, we mention our observation systems. In Sect. 3, we report detailed behaviour of superoutbursts and superhumps of TV Crv. We then discuss the implication of our results linked to the TTI model in Sect. 4 and 5. In Sect. 6, we compare and discuss our results with those for other known systems. Finally, we summarize our findings in Sect. 7.

Table 1. Journal of observations.

ID	$T_{\rm start}$	δT	N	Site
01-01	1957.1607	4.75	361	Kyoto
01-02	1958.1373	5.28	243	Tsukuba
01-03	1958.2718	2.12	176	Kyoto
01-04	1959.0578	7.21	542	Kyoto
01-05	1960.3133	0.75	64	Kyoto
01-06	1961.1367	4.90	374	Kyoto
01-07	1961.1470	3.04	70	Tsukuba
01-08	1963.2215	1.96	138	Kyoto
01-09	1964.0792	2.78	73	Tsukuba
01-10	1965.1255	5.17	436	Kyoto
01-11	1965.1483	3.81	94	Tsukuba
01-12	1966.1710	0.56	39	Kyoto
01-13	1969.1343	4.44	303	Kyoto
02-01	2427.9767	2.18	132	Kyoto
02-02	2428.0206	1.47	119	Kyoto
02-03	2428.9583	2.23	195	Kyoto
02-04	2428.9960	1.86	51	Kyoto
02-05	2429.0071	1.56	147	Okayama
02-06	2430.9581	1.16	103	Kyoto
02-07	2430.9627	2.34	182	Kyoto
02-08	2434.9773	2.03	161	Kyoto
03-01	2769.9589	6.18	327	Craigie
03-02	2776.9232	1.34	71	Ellinbank
03-03	2777.0997	2.88	31	Kyoto
03-04	2777.8617	2.18	111	Ellinbank
03-05	2780.1247	1.35	37	Kyoto
03-06	2781.0285	1.82	86	Hida
04-01	3160.9673	2.46	237	Kyoto
04-02	3161.9689	2.05	142	Kyoto
04-03	3162.4693	5.84	210	Concepción
04-04	3163.4698	6.18	238	Concepción
04-05	3164.9970	0.70	34	Barfold
04-06	3166.5550	3.81	182	Concepción
04-07	3167.5709	3.40	195	Concepción
04-08	3168.5882	2.86	176	Concepción
04-09	3169.5472	1.67	57	Concepción
04-10	3169.9654	2.63	123	Kyoto
04-11	3170.9610	3.06	189	Kyoto

$T_{\rm start}$ =HJD−2450000.
δT =Period of observations in hours.
N=Number of images.

2. Observations

We conducted observational campaigns for four superoutbursts of TV Crv which occurred in 2001 February–March, 2002 June, 2003 May, and 2004 July, through VSNET Collaboration (Kato et al. 2004b). Photometric observations were performed with unfiltered CCD cameras attached to 30-cm class telescopes at Concepción (2004), Kyoto (2001, 2002, 2003, and 2004), Tsukuba (2001), Okayama (2002), Craigie (2003), Ellinbank (2003), Hida (2003), and Barfold Observatory (2004). Our observation log is listed in Table 1. Each image was taken with an exposure time of ~ 30 s. After correcting for the standard de-biasing and flat fielding, we performed aperture and PSF photometry, then obtained differential magnitudes of the object using a neighbor comparison star UCAC2 24840990 (14.43 mag). The constancy of

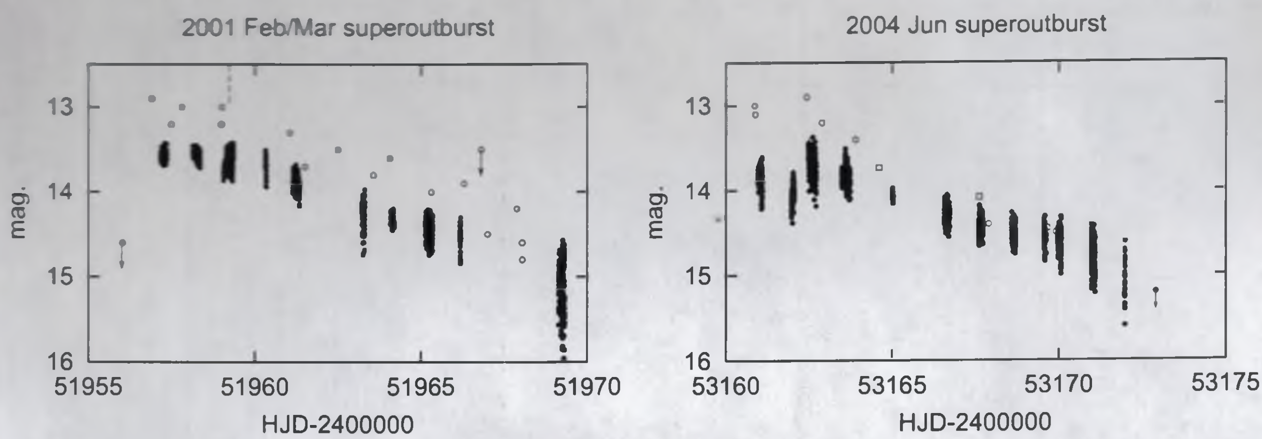

Fig. 1. Light curves of the 2001 February/March (left) and 2004 June (right) superoutbursts. The filled, open circles and open squares indicate our CCD observations, visual observations reported to VSNET, and observations by the ASAS-3 system, respectively (Pojmanski 2002). The vertical dashed lines in each panel show times when superhumps have the largest amplitude.

this comparison star was checked using another neighbor star UCAC2 24840985 (14.57 mag). In this paper, we neglect any small differences of magnitude systems between unfiltered CCD chips used by each observatory. Heliocentric time corrections were applied before the period analysis.

3. Results

Among the four superoutbursts, the evolution of superhumps was successfully detected even in early superoutburst phases during the 2001 and 2004 superoutbursts. On the other hand, the 2002 and 2003 superoutbursts were observed rather sparsely. We first report the former two superoutbursts focusing on their different features, and then shortly report the latter, poorly observed ones. Properties of all superoutbursts are summarized in Table 2. See the following sections for detailed information about the values in this table.

3.1. The 2001 and 2004 Superoutbursts

The 2001 superoutburst was detected on February 18.392 (hereafter dates refer to UT) at a visual magnitude of 12.9. Visual observations reported to VSNET indicate that the object was fainter than 14.6 mag on February 17.517 and no pre-outburst activity is seen before February 18. The outburst was, hence, detected in a very early phase within one day just after the onset of the outburst. The first time-series CCD observation initiated on February 18.654, about 6 hours after the visual detection.

The 2004 superoutburst was detected on June 4.362 (UT) at a visual magnitude of 13.0. Observations reported to VSNET indicate that it was fainter than 13.4 mag on May 28.399 (UT) and no pre-outburst activity is seen before June 4. The first time-series observation initiated on June 4.463 (UT), about 2 hours after the visual detection.

The light curves of the superoutbursts in February/March 2001 and June 2004 are shown in Fig. 1. The most noteworthy point in the light curves is their different behaviour during the first few days. While the light curve in 2001 is described with a monotonic fading, the light curve in 2004 shows a 0.4 mag rebrightening 1.7 d after the outburst detection. This observation reveals that the early outburst was actually a precursor of the late genuine supermaximum. In conjunction with the close monitoring of the object, we conclude that no precursor event was associated with the 2001 superoutburst.

We succeeded in obtaining time-series data during the early phase of the superoutbursts, which are shown in Fig. 2. We also show the observation IDs (see Table 1) and typical errors in each panel. As can be seen in Fig. 2, no superhump-like modulation appears except for the "04-02", in which a 0.3-mag hump is detected. The "04-02" run lasted 2.05 hr which well covers an orbital period of TV Crv. Throughout this run, the object is on a rapid brightening trend at a rate of 2.6 mag d^{-1}. The hump is superimposed on this brightening trend. This indicates that the temporary fading from the precursor had already been terminated, and then started brightening to the supermaximum during the "04-02" run.

The other panels of the "01-01", "01-02", and "04-01" in Fig. 2 show modulations with rather small amplitudes (~ 0.1 mag) and long timescales. No periodic signal is detected in these runs with our Fourier analysis in the period range of 10 s–0.1 d. On the other hand, we note that possible 0.1–0.2 mag amplitude short-term fluctuations with timescale of ~ 10 min can be seen in the "01-02" run.

We detected superhumps after this early phase. In the case of the 2001 superoutburst, fully grown superhumps appeared on JD 2451959 (the "01-04" run). In the case of the 2004 superoutburst, on the other hand, the supermaximum coincides with the apparition of superhumps with the largest amplitude of ~ 0.4 mag (the "04-03" run).

A period analysis with the PDM method (Stellingwerf 1978) was performed after linear trends were subtracted from the light curves. We used light curves between JD 2451959.0 and 2451966.2 for the 2001 superoutburst and between JD 2453162.4 and 2453171.1 for the 2004 superoutburst. The

Table 2. Observational properties of superoutbursts.

	2001	2002	2003	2004
Precursor	No	No?	No?	Yes
P_{SH} (day)	0.065028(0.000008)	0.064981(0.000053)	0.0674(0.0024)	0.065023(0.000013)
$\dot{P}_{SH}/P_{SH}$ (10^{-5})	7.96(0.73)	—	—	−0.32(1.20)
Fading rate (mag d^{-1})	0.12(0.01)	0.17(0.02)	0.17(0.01)	0.13(0.01)
Duration (day)	12	10	12	12
Time interval from the last superoutburst (day)	—	468	345	392

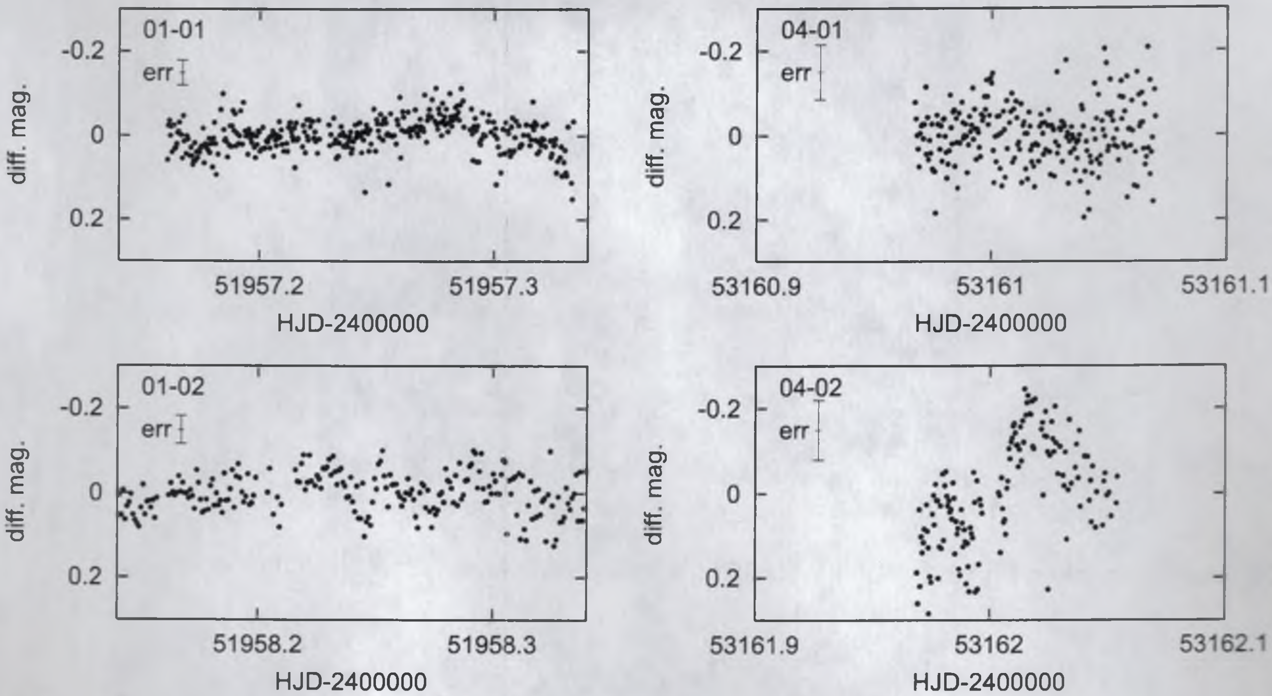

Fig. 2. Light curves during early phases of superoutbursts in 2001 and 2004. The abscissa and ordinate denote the time in HJD and the differential magnitudes, respectively. The magnitude system is normalized by subtracting average magnitudes of each panel. We indicate the run ID number (Table 1) and typical errors in each panel.

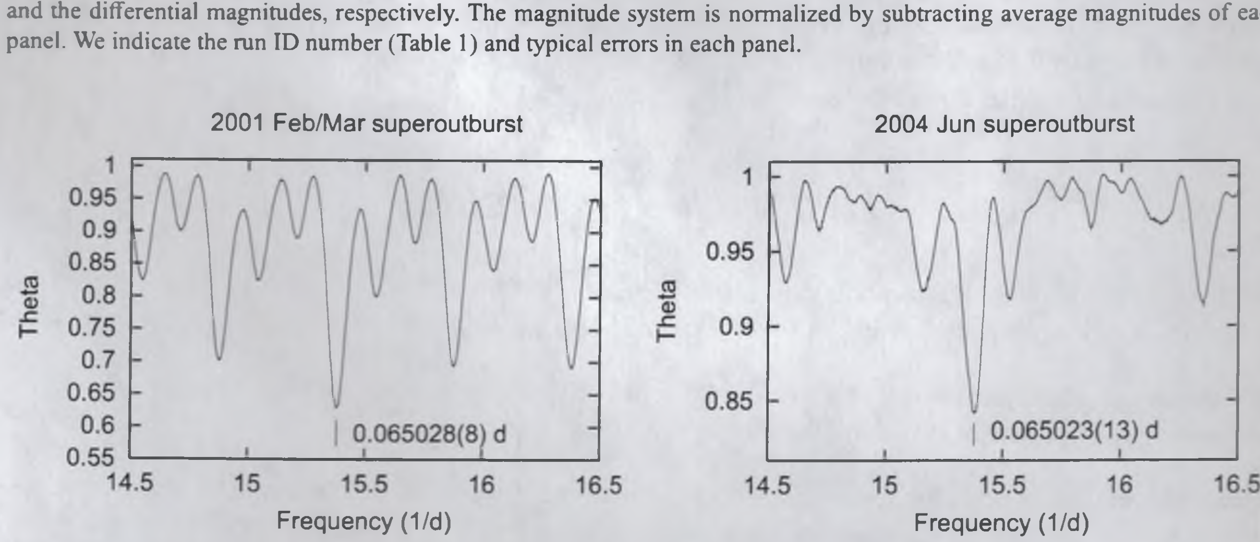

Fig. 3. Frequency-Θ diagrams for the 2001 (left) and 2004 (right) superoutbursts calculated by the PDM method.

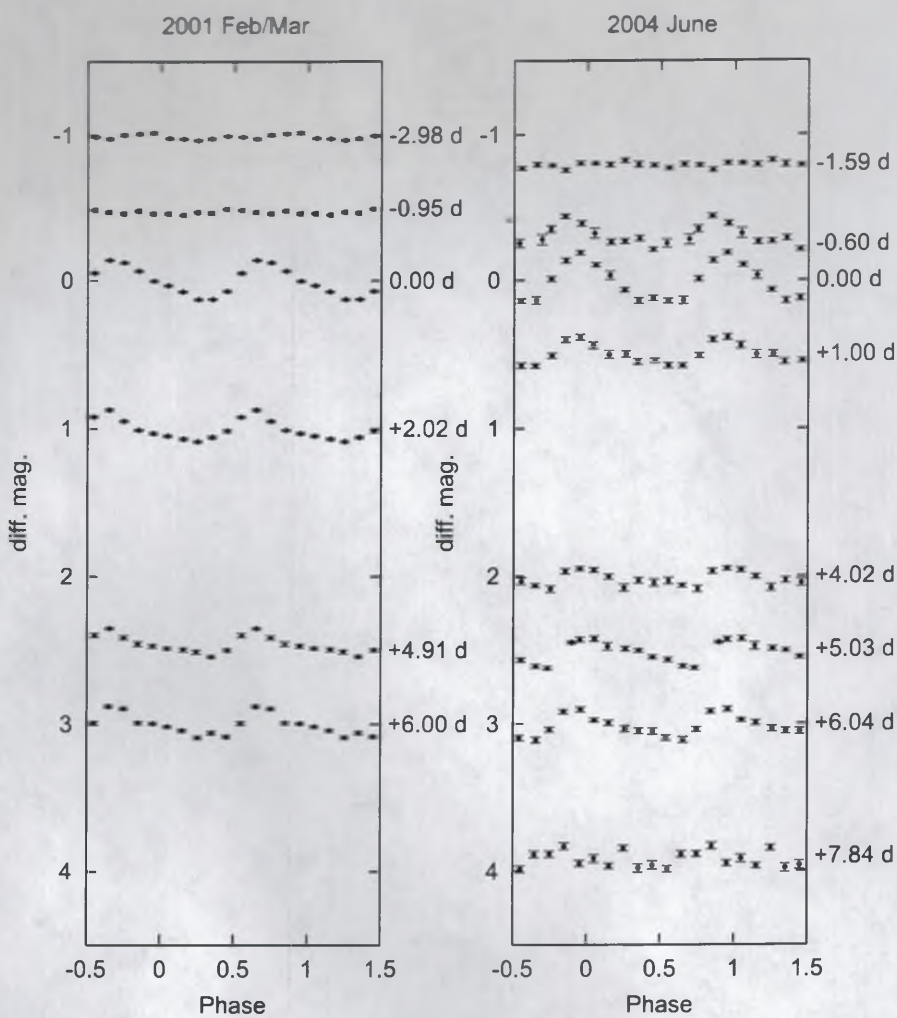

Fig. 4. Superhump evolution during the 2001 (left) and 2004 (right) superoutbursts. The abscissa and ordinate denote the superhump phase and the differential magnitude, respectively. The phase is calculated with a superhump period of 0.065028 d and an arbitrary epoch. The differential magnitudes are normalized by each average magnitude, and are sorted with observation times which are indicated on the right vertical axis of each panel. See the text for detailed information.

samples for the 2001 and 2004 superoutbursts contain 1830 and 1692 photometric points, respectively. The PDM analysis yielded the frequency–Θ diagram shown in Fig. 3. The superhump periods are calculated to be 0.065028 ± 0.000008 d (2001) and 0.065023 ± 0.000013 d (2004). These are in agreement each other and also in agreement with P_{SH} reported in Howell et al. (1996b) (0.0650 ± 0.0008 d). Since the error of P_{SH} is smaller in 2001 than that in 2004, we adopt P_{SH} of TV Crv to be 0.065028 ± 0.000008 d in this paper. According to Woudt & Warner (2003), the orbital period of TV Crv is 0.06288 ± 0.00013 d, which yields a superhump period excess $\varepsilon = 0.0342 \pm 0.0021$. The 3.4% superhump excess is relatively large for short-period SU UMa systems (Patterson et al. 2003).

Fig. 4 shows the evolution of the superhumps from the early phase including the precursor to the end of the superoutburst plateau. All light curves are folded with P_{SH} = 0.065028 d and an arbitrary epoch. The abscissa and ordinate denote the phase and the differential magnitude, respectively. We calculated center times of each run and show them in the figure. We set the origin of the times at the "01-04" and "04-03" runs, in which superhumps had the largest amplitude. The differential magnitudes are normalized by each average magnitude, and are shifted by constants proportional to the times of each run in order to clearly compare two sequences. The hump just before the supermaximum on 2004 has a peak phase roughly the same as those of later superhumps. It strongly indicates that the hump is actually a superhump, growing to the supermaximum, as observed in T Leo (Kato 1997), V436 Cen (Semeniuk 1980), and GO Com (Imada et al. 2004). As can be seen from both panels, the amplitude of superhumps decreased in a few days, then kept 0.2-mag peak-to-peak amplitudes for 6 days. The 2001 and 2004 superoutbursts, thus, have quite similar characteristics regarding the evolution of superhump amplitudes.

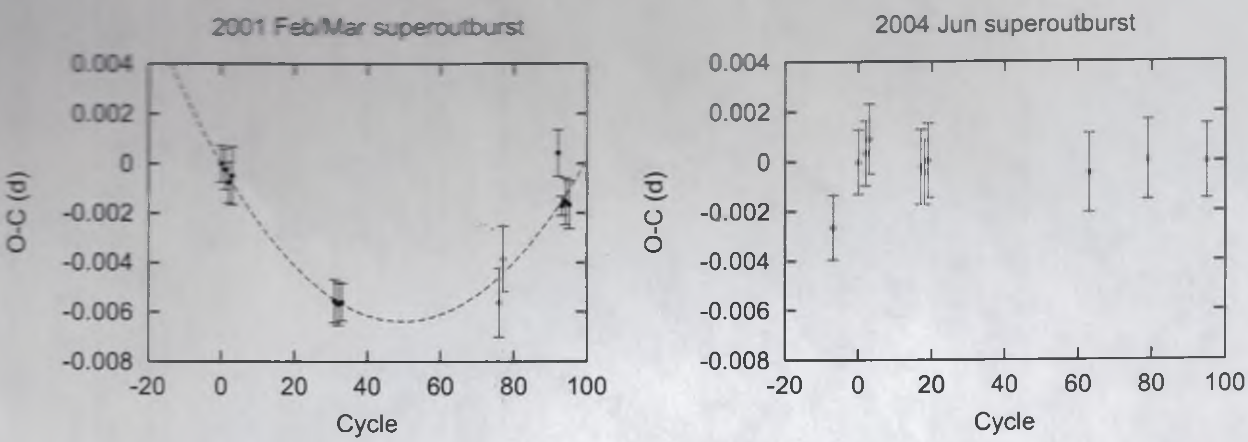

Fig. 5. $O - C$ diagrams of superhumps during the 2001 (left) and 2004 (right) superoutbursts. The abscissa and ordinate denote the cycle and the $O - C$ in day, respectively. The dashed line in the left panel is the best fitted quadratic curve for the $O - C$ in 2001.

We determined peak times of superhumps by taking cross-correlation between the light curve and average profiles of superhumps. With determined peaks and P_{SH} of 0.065028 d, we calculate the $O-C$ of the superhump maximum timings, which is shown in Fig. 5. There is an obvious difference between the $O - C$ in the 2001 and 2004 superoutbursts. The $O - C$ clearly indicates an increase of P_{SH} with time in the case of the 2001 superoutburst. A quadratic fit to the $O - C$ yields a period derivative of $\dot{P}_{SH}/P_{SH} = 7.96 \pm 0.73 \times 10^{-5}$. On the other hand, the $O - C$ is almost constant, in other words, P_{SH} was stable during the 2004 superoutburst. A quadratic fit yields $\dot{P}_{SH}/P_{SH} = -0.32 \pm 1.20 \times 10^{-6}$. This result indicates that the superhumps in 2004 superoutburst have quite small $\dot{P}_{SH}/P_{SH}$ compared with other systems (Kato et al. 2003c).

We note that there is a slight phase shift at the hump just before the supermaximum in 2004 superoutburst, as shown in the right panel of Fig. 5. The slight phase shift in the early stage implies that superhumps evolved with a rapid period change just before the supermaximum. Similar rapid period changes during very early phases are also known in T Leo (Kato 1997), V1028 Cyg (Baba et al. 2000), and XZ Eri (Uemura et al. 2004).

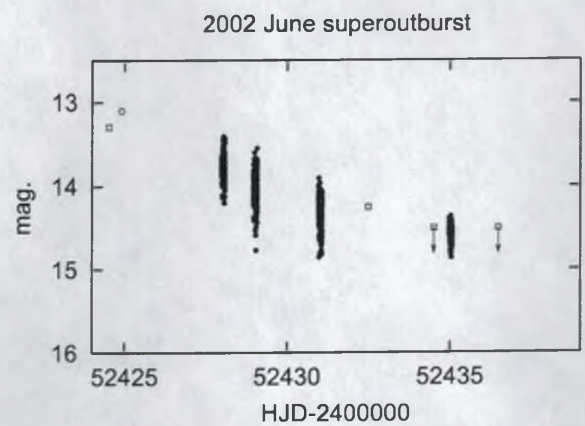

Fig. 6. Light curve of the superoutburst in 2002 June. The symbols are the same as in Fig. 1.

3.2. The 2002 Superoutburst

The 2002 superoutburst was first detected on May 30.399 (UT) at a visual magnitude of 13.1 mag. The ASAS-3 system records an earlier detection of the outburst on May 30.009 (UT) and a negative detection on May 21.048 (UT) (Pojmanski 2002). Unfortunately, there is no time-series data just after the outburst detection. The first run (the "02-01" run in Table 1) initiated at June 2.476 (UT). The light curve of the superoutburst is shown in Fig. 6. The "02-01" run detected superhumps, which establish that this outburst is a superoutburst. Profiles of superhumps during this superoutburst are shown in Fig. 7. Fig. 8 is the $O - C$ diagram of superhumps. While it contains only three points, this figure apparently implies a period increase of superhumps, as observed in the 2001 superoutburst.

3.3. The 2003 Superoutburst

The 2003 superoutburst was discovered by a visual observation on May 9.546 (UT) at 13.1 mag. The latest negative visual observation had been reported on May 6.412 (UT) (fainter than 14.6 mag), three days before the outburst detection. The first time-series observation initiated at May 10.458 (UT), about one day after the outburst detection. Considering the rapid evolution during the precursor in the 2001 superoutburst, we cannot exclude the possibility that the 2003 superoutburst had a precursor between May 6 and 9. The light curve of this outburst is shown in Fig. 9. The first run "03-01" clearly detects fully grown superhumps, as shown in Fig. 10, which reveal that it is another superoutburst. Due to the lack of enough observations, we cannot find any hints of significant period changes of superhumps.

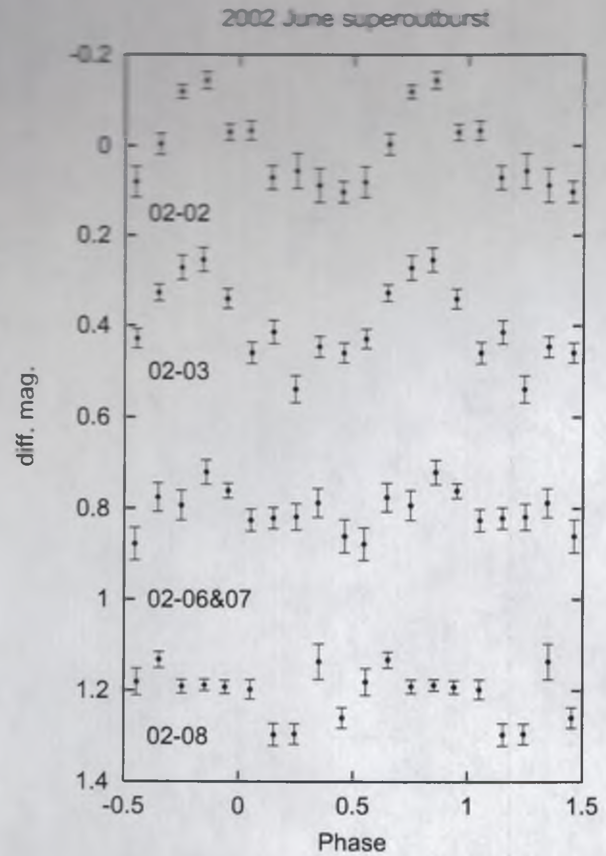

Fig. 7. Superhump evolution during the 2002 superoutburst. The symbols in the figure are the same as in Fig. 4.

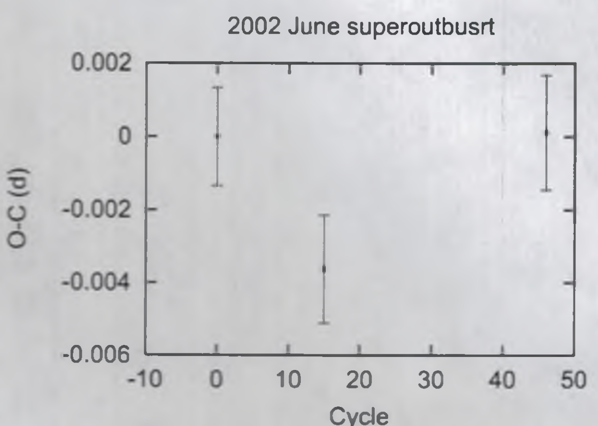

Fig. 8. $O - C$ diagram of superhumps during the 2002 superoutburst. The symbols in the figure are the same as in Fig. 5.

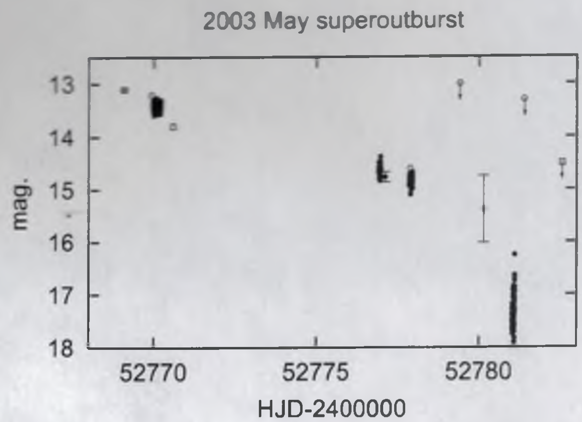

Fig. 9. Light curve of the superoutburst in 2003 May. The symbols in the figure are the same as in Fig. 1.

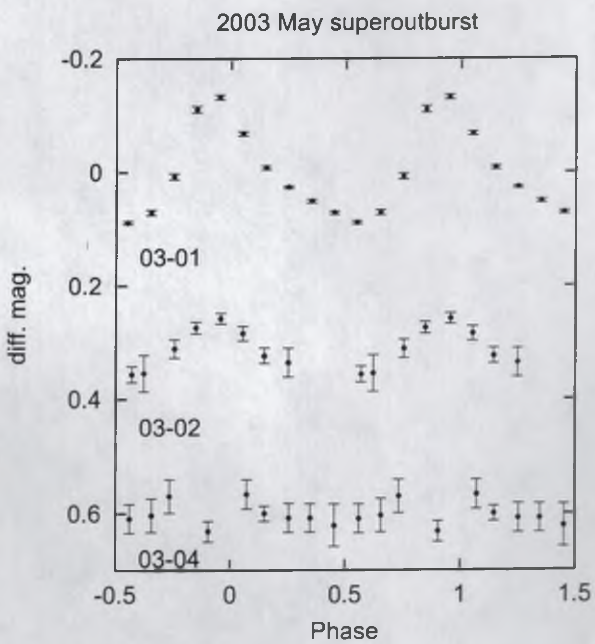

Fig. 10. Superhump evolution during the 2003 superoutburst. The symbols in the figure are the same as in Fig. 4.

4. Implication for the TTI model

The observational properties of the four superoutbursts are summarized in Table 2. TV Crv is one of the typical short orbital period SU UMa-type dwarf novae. Its supercycle is calculated to be 402 ± 51 d from the three time-intervals of superoutbursts listed in Table 2. This supercycle is also a typical value for SU UMa stars. A noteworthy feature of TV Crv is its superhump excess (3.4%), which is relatively large for short-period systems, but not extraordinary (Patterson et al. 2003). It is well known that the superhump period excess is related to the superhump period (Patterson et al. 2003). From the theoretical point of view, this can be understood since the precession velocity of the eccentric disk depends on the disk radius and the mass ratio of binary systems. The superhump period excess, ε, can be expressed as (Osaki 1985);

$$\varepsilon = \frac{3}{4}\frac{q}{\sqrt{1+q}}\left(\frac{r_{\rm d}}{a}\right)^{3/2}. \qquad (1)$$

Assuming a certain disk radius at which the tidal mode is excited, one can describe the superhump period excess as a function of the superhump period (Mineshige et al. 1992). The large superhump excess of TV Crv, therefore, implies a relatively large mass ratio among short-period SU UMa stars. The empirical relationship in Patterson (2001) yields the mass ratio to be $q = 0.16 \pm 0.01$ for TV Crv. On the other hand, it is possible that the large superhump excess is partly caused by an unusually large disk radius. The large mass ratio of TV Crv should be confirmed by spectroscopic observations in future.

Our observations reveal that TV Crv experiences two types of superoutbursts, that is, one with a precursor and the other without a precursor. Similar morphology studies of superoutburst light curves had been performed for VW Hyi, which also shows the two types of superoutbursts (Bateson 1977; Marino & Walker 1979). VW Hyi is a typical SU UMa-type dwarf novae having a relatively long orbital period of 0.074271 d (Downes et al. 2001). Our observations of TV Crv are the first to show that those two types of superoutbursts appear even in short orbital period systems.

To explain the behaviour of VW Hyi, Osaki & Meyer (2003) propose the refined TTI model, in which the types of superoutburst depend on the maximum radius of the accretion disk. When the accretion disk reaches the tidal truncation radius, the dammed matter prevents the disk from a propagation of a cooling wave, leading to a superoutburst without a precursor. In this view, a large mass ratio is required for a system to achieve the situation that the tidal truncation radius lies just beyond the 3:1 resonance radius. On the other hand, when the disk fails to reach the tidal truncation radius, a rapid fading initiates. This fading is terminated, and the object rebrightens to a supermaximum due to a growth of the tidal dissipation. In this case, a large mass ratio is also required for a rapid growth of the tidal dissipation before the object returns to quiescence. VW Hyi has a superhump excess of 3.9% (van Amerongen et al. 1987), which yields a mass ratio $q = 0.18$ from the empirical relationship in Patterson (2001). Tappert et al. (2003) reported $q \sim 0.14$ for VW Hyi based on their spectroscopic observations. The mass ratio of TV Crv is possibly close to that of VW Hyi rather than those of ordinary short period SU UMa stars (Patterson 2001).

Although TV Crv is a short period system, we propose that it has a relatively large mass ratio. According to Osaki & Meyer (2003), a system having a large mass ratio ($q \sim 0.2$) can experience the two types of superoutburst. The behaviour of TV Crv can, therefore, be explained by the refined TTI model, furthermore, it possibly provides evidence that the mass ratio plays a key role in the morphology of superoutburst light curve.

5. Presence of a precursor and superhump evolution

The most important and unforeseen finding in our observation is that the $\dot{P}_{SH}/P_{SH}$ can be variable in distinct superoutbursts in one system. This is clearly shown in Table 2; a positive $\dot{P}_{SH}/P_{SH}$ in the 2001 superoutburst and an almost constant P_{SH} in the 2004 superoutburst. Except for the difference in $\dot{P}_{SH}/P_{SH}$, another observational difference between these two superoutbursts is the presence or absence of the precursor. There was no precursor in the 2001 superoutburst, while a clear precursor was observed in 2004. Our observation hence indicates that the $\dot{P}_{SH}/P_{SH}$ is related to the precursor phenomenon.

As mentioned above, the TTI model suggests that the appearance of the precursor depends on whether the disk reaches the tidal truncation radius or not. Based on this idea, at the time when superhumps are fully grown, the disk size should be different in the two types of superoutbursts. In the case of the precursor-main type outburst, the disk size is around the 3:1 resonance radius at supermaximum. On the other hand, in the case of the superoutburst without a precursor, the hot disk can remain larger than the 3:1 resonance radius due to the dammed matter at the tidal truncation radius. The accretion disk can, hence, have a relatively large amount of gas beyond the 3:1 resonance radius even a few days after the supermaximum when superhumps are fully grown. We therefore propose that the $\dot{P}_{SH}/P_{SH}$ is related to the amount of the gas around and beyond the 3:1 resonance radius.

We now present an idea how the disk size actually affects the eccentric disk evolution. We first consider the standard picture of the eccentric disk evolution. In an early phase of outburst, the rapid excitation of the eccentric mode stops when the angular momentum removal by the tidal dissipation is balanced with the input angular momentum transfered from the inner region. In the case of the precursor-main type outburst, then, the accretion disk shrinks below the 3:1 resonance radius at that time (Whitehurst 1994). The eccentricity wave can only propagate inward, since the tidal mode is no longer excited. In the case of the superoutburst without a precursor, on the other hand, we can expect a large amount of gas over the 3:1 resonance radius at that time. We conjecture that the eccentric mode can keep excited because the disk radius presumably remains larger than the 3:1 resonance radius. The positive $\dot{P}_{SH}/P_{SH}$ can be explained by a gradual outward propagation of the eccentricity wave.

It is, however, unclear whether the outward propagation is possible only with the large disk. The outward propagation essentially requires an additional input of angular momentum from an inner region. It might be possible that the gas in an inner region may be swept up, then give additional angular momentum into the outermost area of the eccentricity wave. This additional supply of angular momentum would enable to keep the disk size large and the continuous excitation of the eccentric mode.

Olech et al. (2003) propose that the $\dot{P}_{SH}/P_{SH}$ is negative at the beginning and the end of the superoutburst, but positive in the middle phase for several SU UMa-type dwarf novae. Based on our scenario, the duration of the positive $\dot{P}_{SH}/P_{SH}$ depends on the amount of the gas which enables the continuous excitation of the eccentric mode. The transition from a positive $\dot{P}_{SH}/P_{SH}$ to a negative one may be explained by the depletion of the gas.

The above discussion is summarized in the following two ideas: i) At the time when superhumps are fully grown, the accretion disk remains larger in the superoutburst without the precursor than in the precursor-main type superoutburst. ii) Even

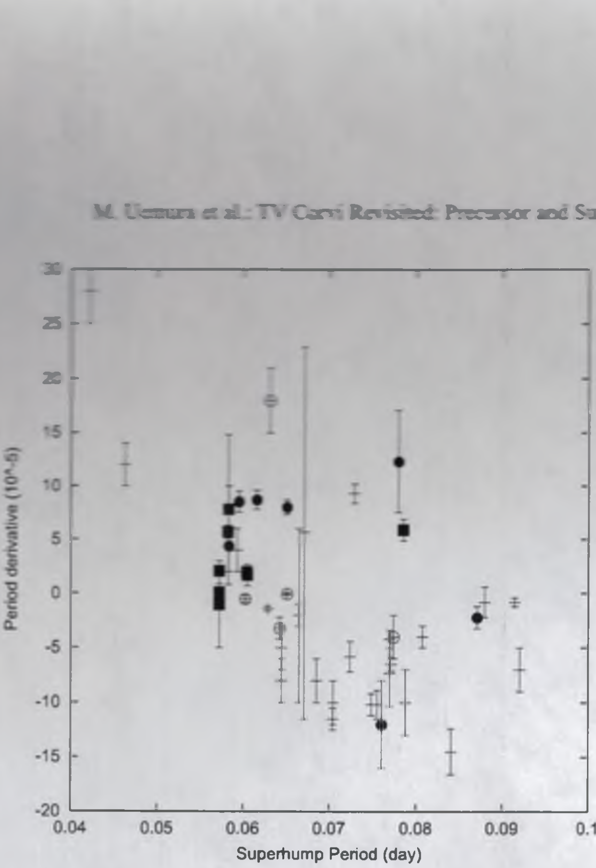

Fig. 11. The superhump period derivative against the superhump period for the SU UMa-type dwarf novae listed in Table 3. The open circles indicate type A superoutbursts which have a precursor. The filled circles indicate type B superoutbursts in which a delay of superhump growth is observed. The filled squares indicate WZ Sge-type dwarf novae. The other points indicated by the crosses are objects whose outburst types are unknown. The figure focuses on objects whose outburst types are known. We, hence, omit three unknown-type dwarf novae, KK Tel, MN Dra, (exceptionally large period derivatives) and TU Men (a long superhump period) in this figure. We only show positive values of period derivatives for KS UMa and TT Boo, in which changes of the period derivative have been observed.

after that, the eccentric mode keeps excited through a superoutburst. These ideas should be tested by hydrodynamical simulations.

6. Discussion

We revealed that the $\dot{P}_{SH}/P_{SH}$ is variable in distinct superoutbursts for TV Corvi. This result should be confirmed by observations of other sources in future because we now have no data of variations of the $\dot{P}_{SH}/P_{SH}$ against different types of superoutburst in other sources. On the other hand, it is valuable to investigate the relationship of $\dot{P}_{SH}/P_{SH}$ and the type of superoutburst in known systems. To perform this, we collected the sample of 40 dwarf novae and one X-ray binary whose $\dot{P}_{SH}/P_{SH}$ is published, as listed in Table 3. We now classify the morphology of superoutburst light curve into two types, that is, the type "A" and type "B". The type A is defined by the detection of a precursor, in other words, the precursor-main type superoutburst. On the other hand, the type B is defined by the detection of a delay of the superhump growth after a supermaximum. In our sample listed in Table 3, we find 6 and 7 cases for the type A and B, respectively. There is no system having both features. WZ Sge-type dwarf novae are indicated by "WZ" in Table 3 because their superhump evolution is peculiar; they have an early hump era followed by an ordinary superhump era (Kato et al. 1996). The sample in Table 3 has 8 cases for 5 WZ Sge stars. Types of superoutburst are unclear in the other 29 cases due to the lack of enough observations during early phases of superoutbursts. The $\dot{P}_{SH}/P_{SH}$ are shown against P_{SH} in Fig. 11.

As mentioned above, WZ Sge-type systems tend to show positive $\dot{P}_{SH}/P_{SH}$ as indicated by filled squares in Fig. 11. In these systems, their long recurrence time and the lack of normal outburst lead to a huge amount of accumulated gas compared with ordinary SU UMa systems. At the onset of their outburst, the accretion disk, hence, violently expands beyond the 3:1 resonance radius. The large disk in WZ Sge stars may partly be due to a continuous expansion of their quiescent disks, as proposed in Mineshige et al. (1998). This situation in WZ Sge systems is similar to the type B outburst in TV Crv discussed in the last section. Kato et al. (2004a) propose a scenario analogous to that described in the last section for positive $\dot{P}_{SH}/P_{SH}$ in WZ Sge-type dwarf novae. The difference between WZ Sge systems and TV Crv is the mechanism to generate a large disk over the 3:1 resonance radius. In the case of WZ Sge systems, Osaki & Meyer (2003) propose that the large disk is maintained by the strong tidal removal of angular momentum at the 2:1 resonance radius. The disk can reach the 2:1 resonance radius because of the large amount of accumulated matter. In the case of the type B outbursts of TV Crv, the large disk is maintained at the tidal truncation radius. This is due to a high mass ratio leading to the tidal truncation radius just beyond the 3:1 resonance radius.

We can therefore consider that a similar physical condition appears in the type B superoutbursts and the WZ Sge-type superoutbursts, in terms of the superhump evolution. In Fig. 11, we show these objects as filled symbols (squares for WZ Sge stars and circles for the type B) and the type A superoutburst as open circles. We can see a tendency that the B- and WZ-types generally have larger $\dot{P}_{SH}/P_{SH}$, as expected from our scenario. This figure, however, also show the presence of two exceptions breaking the tendency (GO Com and V1251 Cyg). The nature of these objects is an open issue. We need to obtain their $\dot{P}_{SH}/P_{SH}$ in another superoutburst to investigate their possible variations.

The two systems having the shortest P_{SH} in Fig. 11 are V485 Cen and EI Psc. While they have ultra-short orbital periods, their secondaries are relatively massive (Augusteijn et al. 1993; Thorstensen et al. 2002). The superhump period excess and mass ratio of EI Psc are $\varepsilon = 0.040$ and $q = 0.19$, respectively, which are actually larger than those of TV Crv and VW Hyi (Uemura et al. 2002b). According to the refined TTI model, their accretion disks can reach the tidal truncation radius and remain active in the eccentric mode through a superoutburst. Their high $\dot{P}_{SH}/P_{SH}$ can, hence, be naturally explained with our scenario. Observations of the onset of their superoutbursts are encouraged to reveal the type of them.

The only X-ray binary in table 3, XTE J1118+480, is a black hole X-ray binary (BHXB) having a quite low mass ratio

q = 0.05 (Wagner et al. 2001). This is a unique object in the point that the $\dot{P}_{SH}/P_{SH}$ is significantly determined in BHXBs. Although the low mass ratio implies a situation similar to WZ Sge-type dwarf novae, its $\dot{P}_{SH}/P_{SH}$ is slightly, but significantly negative as listed in Table 3. On the other hand, its main outburst has a precursor, which is reminiscent of the precursor-main type superoutburst in SU UMa systems (Kuulkers 2001). The accretion disk radius was probably just around the 3:1 resonance radius at the "supermaximum" of XTE J1118+480. This rather small disk may cause the inward propagation of an eccentricity wave in this low-q system.

7. Summary

Our findings through observations of four superoutbursts of TV Crv are summarized below:

i) We accurately determined the superhump period to be 0.065028 ± 0.000008 d.

ii) In conjunction with the orbital period in Woudt & Warner (2003), the superhump period yields a high superhump period excess of 0.0342 ± 0.0021. This implies that TV Crv has a relatively large mass ratio compared with other short-period SU UMa systems. Using the empirical relationship for the superhump mass ratio in Patterson (2001), the mass ratio of TV Crv is estimated to be $q = 0.16 \pm 0.01$.

iii) TV Crv experiences two types of superoutbursts; one with a precursor and the other without. This behaviour can be interpreted with the refined thermal-tidal instability model if TV Crv has a relatively large mass ratio in spite of its short orbital period.

iv) We show that the superhump period derivative is variable in distinct superoutbursts. The difference is apparently related to the presence/absence of a precursor.

v) We propose that the eccentric mode keeps excited when the accretion disk remains larger than the 3:1 resonance radius. This scenario can explain the behaviour of TV Crv, and furthermore be consistent with systematically large period derivatives in superoutbursts without a precursor.

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Table 3. Superhump period derivative and the type of superoutbursts.

Object	P_{SH} (day)	P_{SH}/P_{SH} (10^{-5})	Type	Ref.
V485 Cen	0.04216	28(3)	–	1
EI Psc	0.04627	12(2)	–	2
WZ Sge(1978)	0.05722	−1(4)	WZ	3
WZ Sge(2001)	0.05719	0.1(0.8)	WZ	4
AL Com(1995)	0.0572	2.1(0.3)	WZ	5
HV Vir	0.05820	5.7(0.6)	WZ	6
HV Vir(2002)	0.05826	7.8(7)	WZ	7
SW UMa(1991)	0.0583	6(4)	–	6
SW UMa(1996)	0.0583	4.4(0.4)	B	8
WX Cet(1996)	0.0593	4(2)	–	6
WX Cet(1998)	0.05949	8.5(1.0)	B	9
T Leo	0.0602	−0.5(0.3)	A	10
EG Cnc	0.06038	2.0(0.4)	WZ	11
EG Cnc	0.06043	1.7(1)	WZ	12
GO Com	0.06306	18(3)	A	13
V1028 Cyg	0.06154	8.7(0.9)	B	14
XZ Eri	0.06281	−1.4(0.2)	–	15
V1159 Ori	0.0642	−3.2(1)	A	16
VY Aqr	0.0644	−8(2)	–	17
OY Car	0.06443	−5(2)	–	18
TV Crv(2001)	0.06503	8.0(0.7)	B	19
TV Crv(2004)	0.06502	−0.03(0.12)	A	19
UV Per	0.06641	−2.0(1)	–	6
CT Hya	0.06643	−2(8)	–	20
DM Lyr	0.06709	5.7(17.2)	–	21
SX LMi	0.0685	−8(2)	–	22
KS UMa(2003 early)	0.07009	−21(8)	–	23
KS UMa(2003 late)	0.07009	21(12)	–	23
RZ Sge(1994)	0.07042	−10(2)	–	24
RZ Sge(1996)	0.07039	−11.5(1)	–	25
CY UMa	0.0724	−5.8(1.4)	–	26
VW Crb	0.07287	9.3(0.9)	–	27
NSV 10934	0.07485	−10.2(1.0)	–	28
CC Cnc	0.07552	−10.2(1.3)	–	29
V1251 Cyg	0.07604	−12(4)	B	30
QW Ser(2000)	0.07698	−4.2(0.8)	–	31
QW Ser(2002)	0.07697	−7.3(3.1)	–	31
VW Hyi	0.07714	−6.5(0.6)	–	32
Z Cha	0.07740	−4(2)	A	33
TT Boo(2004 early)	0.07796	−52.3(1.3)	B	34
TT Boo(2004 middle)	0.07796	12.3(4.8)	B	34
TT Boo(2004 late)	0.07796	−6.2(0.9)	B	34
RZ Leo	0.07853	5.9(1.0)	WZ	35
SU UMa	0.0788	−10(3)	–	36
HS Vir	0.08077	−4(1)	–	37
V877 Ara	0.08411	−14.5(2.1)	–	38
EF Peg(1991)	0.0871	−2.2(1)	B	39
BF Ara	0.08797	−0.8(1.4)	–	40
KK Tel	0.08801	−37(4)	–	7
V344 Lyr	0.09145	−0.8(0.4)	–	41
YZ Cnc	0.09204	−7(2)	–	42
V725 Aql	0.09909	~0	–	43
MN Dra	0.10768	−170(2)	–	44

Table 3. continued.

Object	P_{SH} (day)	$\dot{P}_{SH}/P_{SH}$ (10^{-5})	Type	Ref.
TU Men	0.1262	−9(2)	–	45
XTEJ1118+480	0.17053	−0.6(0.1)	A	46

References: 1.Olech (1997), 2.Uemura et al. (2002a), 3.Kuulkers et al. (2002), 4.Ishioka et al. (2002), 5.Nogami et al. (1997a), 6.Kato et al. (2001b), 7.Ishioka et al. (2003), 8.Nogami et al. (1998), 9.Kato et al. (2001a), 10.Kato (1997), 11.Kato et al. (1997), 12.Kato et al. (2004a), 13.Imada et al. (2004), 14.Baba et al. (2000), 15.Uemura et al. (2004), 16.Patterson et al. (1995), 17.Patterson et al. (1993), 18.Schoembs (1986), 19.this work, 20.Kato et al. (1999), 21.Nogami et al. (2003a), 22.Nogami et al. (1997b), 23.Olech et al. (2003), 24.Kato (1996), 25.Semeniuk et al. (1997), 26.Harvey & Patterson (1995), 27.Nogami et al. (2004b), 28.Kato et al. (2003b), 29.Kato et al. (2002), 30.Kato (1995), 31.Nogami et al. (2004a), 32.Haefner et al. (1979), 33.Kuulkers et al. (1991), 34.Olech et al. (2004), 35.Ishioka et al. (2001), 36.Udalski (1990), 37.Kato et al. (1998), 38.Kato et al. (2003c), 39.Kato (2002), 40.Kato et al. (2003a), 41.Kato (1993), 42.Patterson (1979), 43.Uemura et al. (2001), 44.Nogami et al. (2003b), 45.Stolz & Schoembs (1984), 46.Uemura et al. (2002c)

Table 3. continued.

Object	P_{SH} (day)	$\dot{P}_{SH}/P_{SH}$ (10^{-5})	Type	Ref.
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References: 1.Olech (1997), 2.Uemura et al. (2002a), 3.Kuulkers et al. (2002), 4.Ishioka et al. (2002), 5.Nogami et al. (1997a), 6.Kato et al. (2001b), 7.Ishioka et al. (2003), 8.Nogami et al. (1998), 9.Kato et al. (2001a), 10.Kato (1997), 11.Kato et al. (1997), 12.Kato et al. (2004a), 13.Imada et al. (2004), 14.Baba et al. (2000), 15.Uemura et al. (2004), 16.Patterson et al. (1995), 17.Patterson et al. (1993), 18.Schoembs (1986), 19.this work, 20.Kato et al. (1999), 21.Nogami et al. (2003a), 22.Nogami et al. (1997b), 23.Olech et al. (2003), 24.Kato (1996), 25.Semeniuk et al. (1997), 26.Harvey & Patterson (1995), 27.Nogami et al. (2004b), 28.Kato et al. (2003b), 29.Kato et al. (2002), 30.Kato (1995), 31.Nogami et al. (2004a), 32.Haefner et al. (1979), 33.Kuulkers et al. (1991), 34.Olech et al. (2004), 35.Ishioka et al. (2001), 36.Udalski (1990), 37.Kato et al. (1998), 38.Kato et al. (2003c), 39.Kato (2002), 40.Kato et al. (2003a), 41.Kato (1993), 42.Patterson (1979), 43.Uemura et al. (2001), 44.Nogami et al. (2003b), 45.Stolz & Schoembs (1984), 46.Uemura et al. (2002c)

1215-17 (d) TV Crv (Corvi)

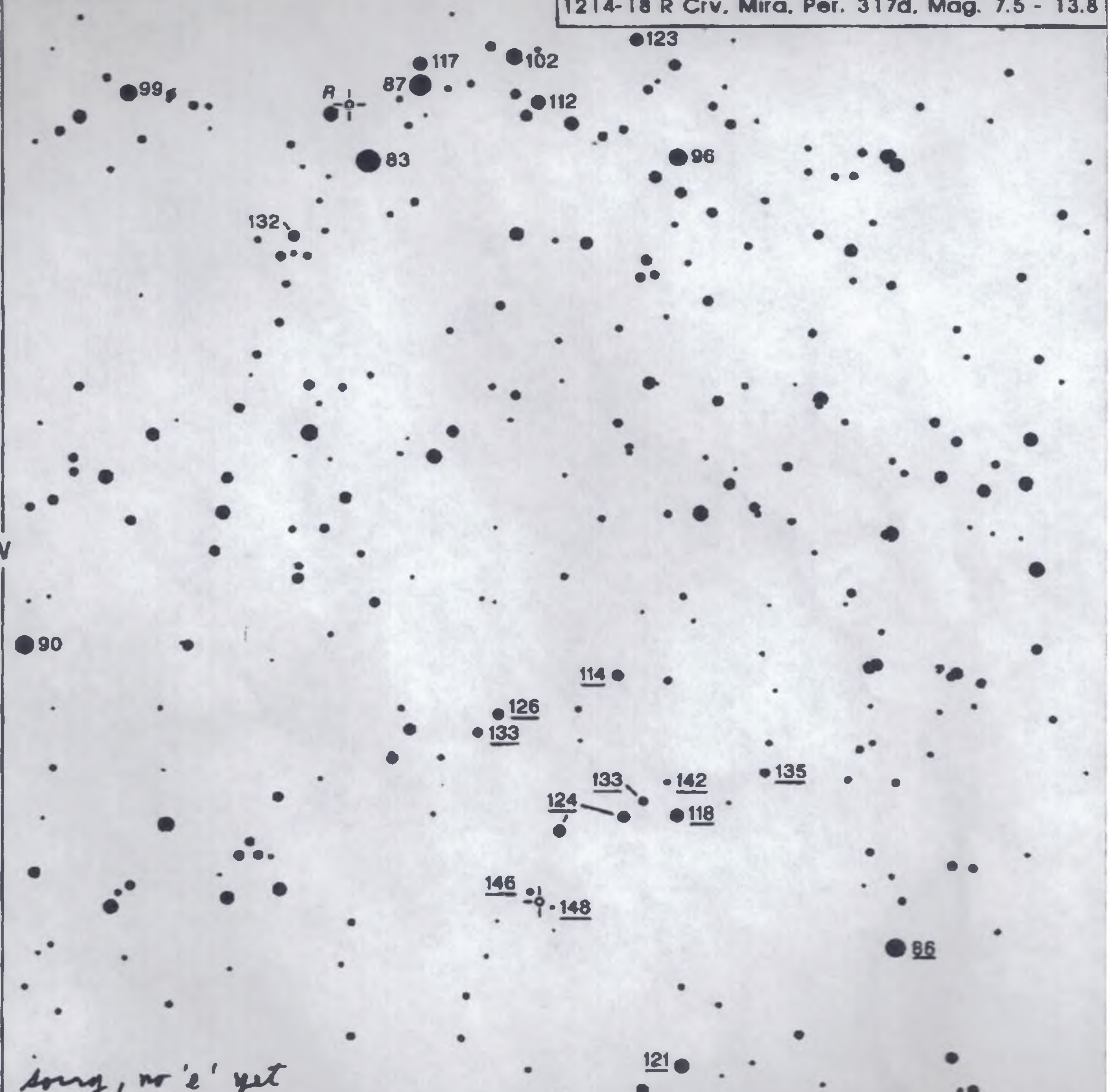
Scale 20"=1mm

Magn. - 12 - 18:p
Period -
Type -UG
Spec. -

(1900) $12^h\ 16^m\ 13^s$ $-17°\ 53'.8$
(2000) $12^h\ 20^m\ 24^s$ $-18°\ 27'.1$

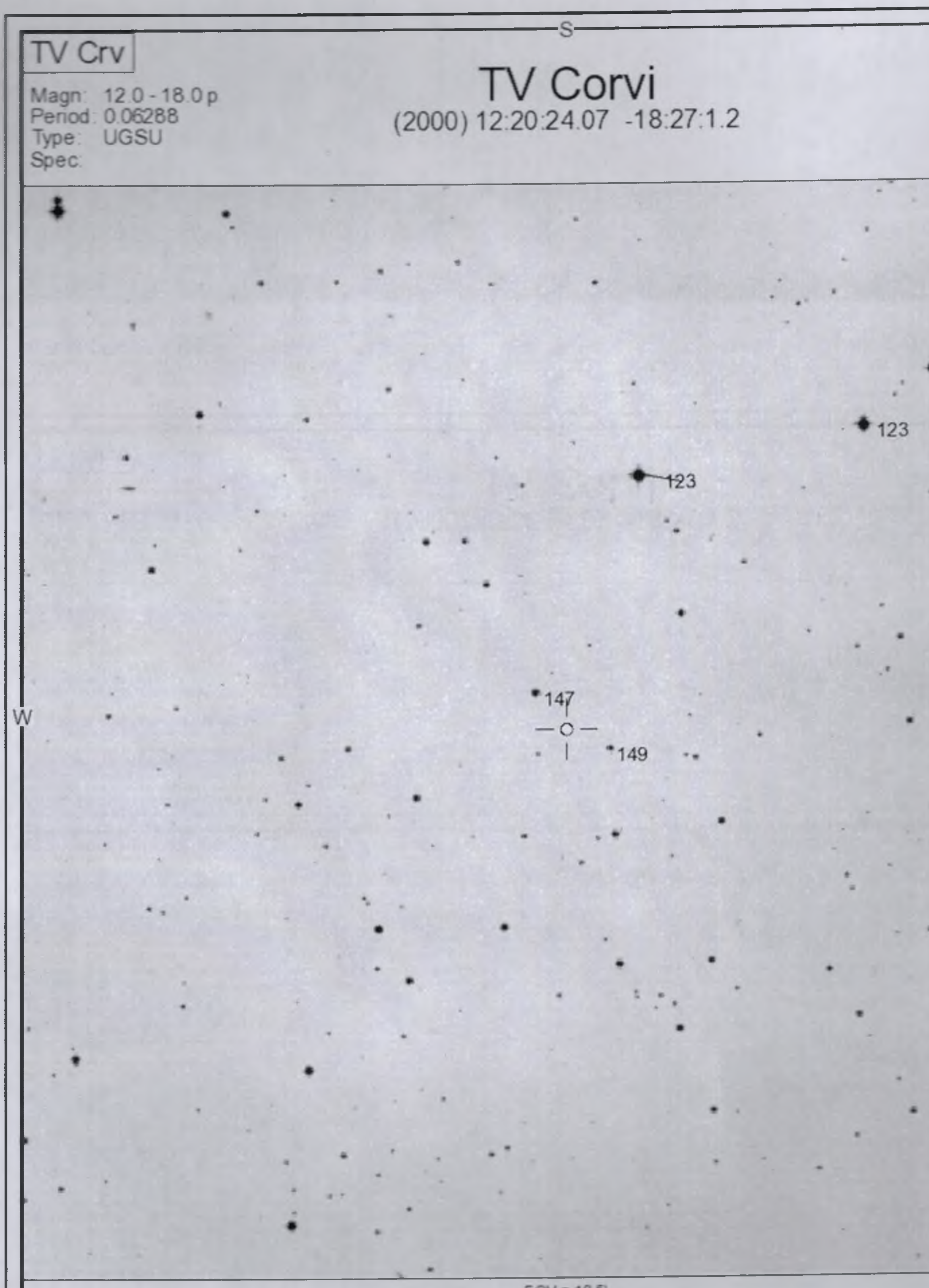
PRELIMINARY AAVSO CHART
SUBJECT TO CORRECTION

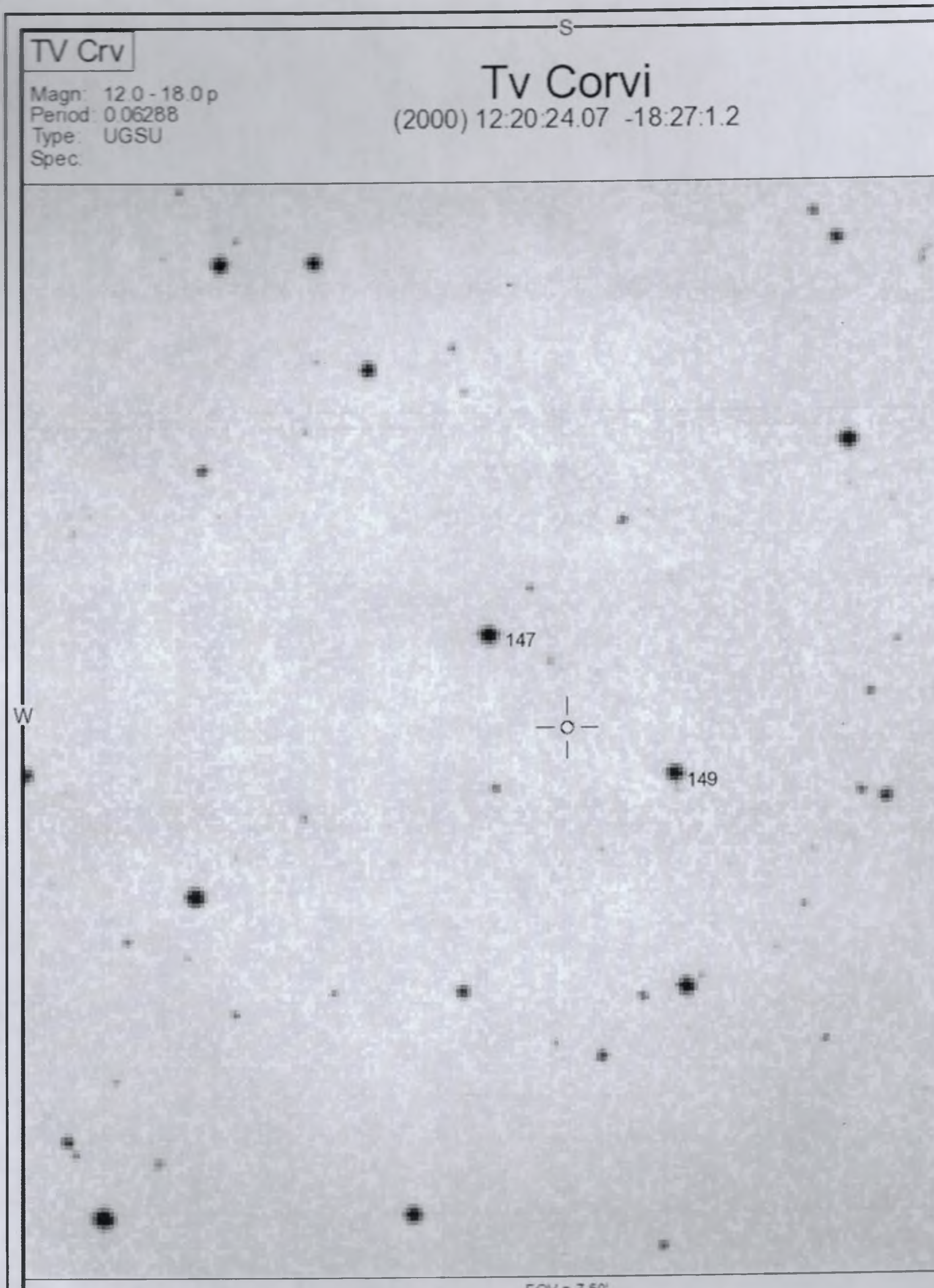
1214-18 R Crv, Mira, Per. 317d, Mag. 7.5 - 13.8



Drawn by: CES 2/93
From: Mt. Peltier photo, R Royer, & Stamford Observatory Photo
Sequence: PEP(V), R. Stanton, Geneva Obs'y, Publ. RASNZ 16; & AAVSO chart

Revision	
3	1/96
2	7/94


S
TV Crv
Magn: 12.0 - 18.0 p
Period: 0.06288
Type: UGSU
Spec:
TV Corvi
(2000) 12:20:24.07 -18:27:1.2
W
123
123
147
149


S
TV Crv
Magn: 12.0 - 18.0 p
Period: 0.06288
Type: UGSU
Spec:
Tv Corvi
(2000) 12:20:24.07 -18:27:1.2
147
W
149

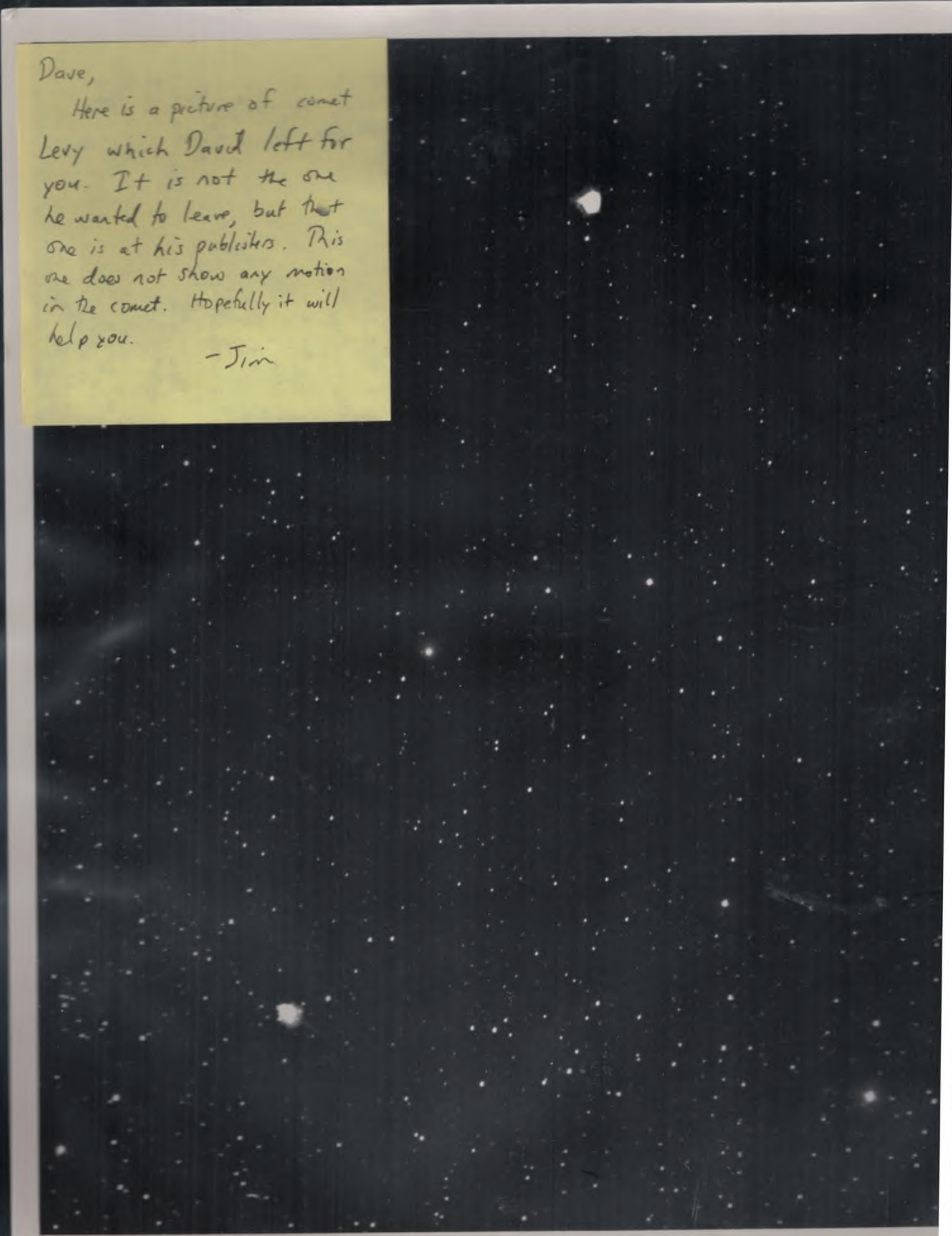
3   11 sec

CN3e TV Corvi
March 23 local date
2014

Dave,

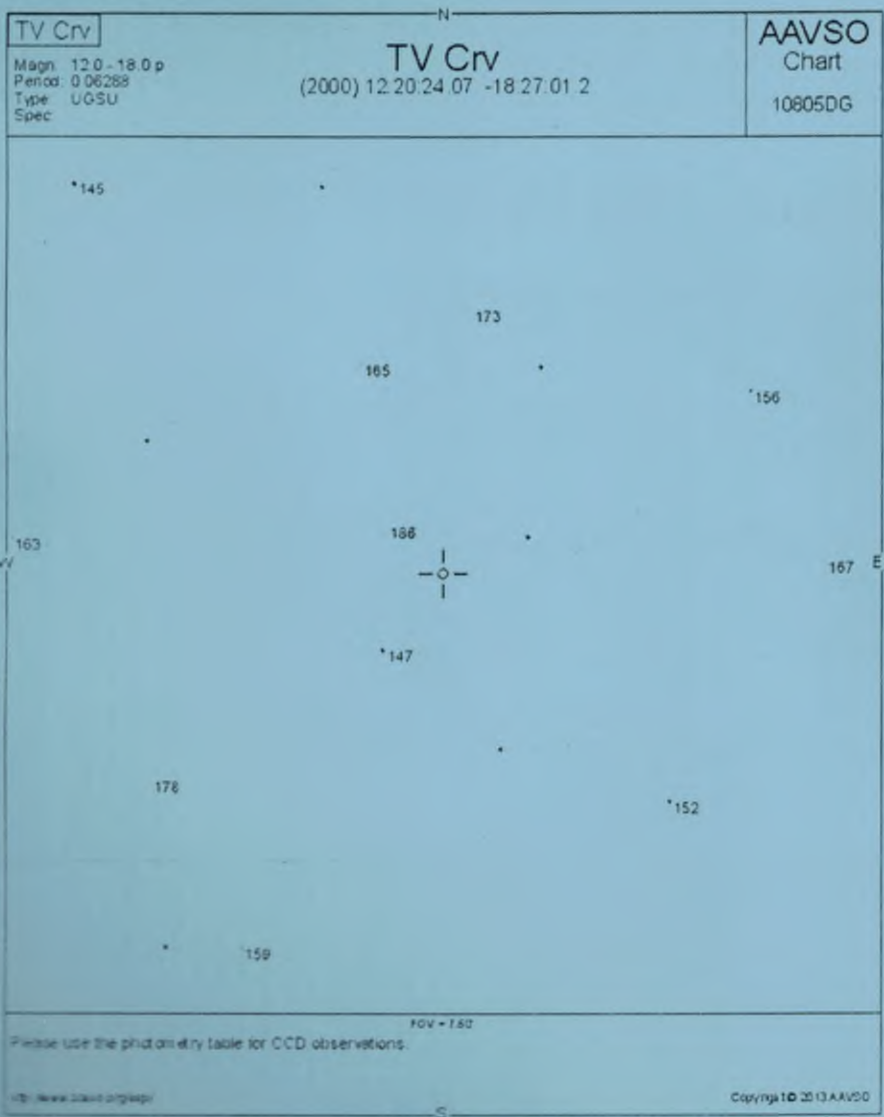
Here is a picture of comet Levy which David left for you. It is not the one he wanted to leave, but that one is at his publishers. This one does not show any motion in the comet. Hopefully it will help you.

-Jim



Variable Star Plotter (VSP)

Printable Version   Photometry Table for this Chart   Return and Replot



Click on image to view chart at full resolution/size.

N

TV Crv

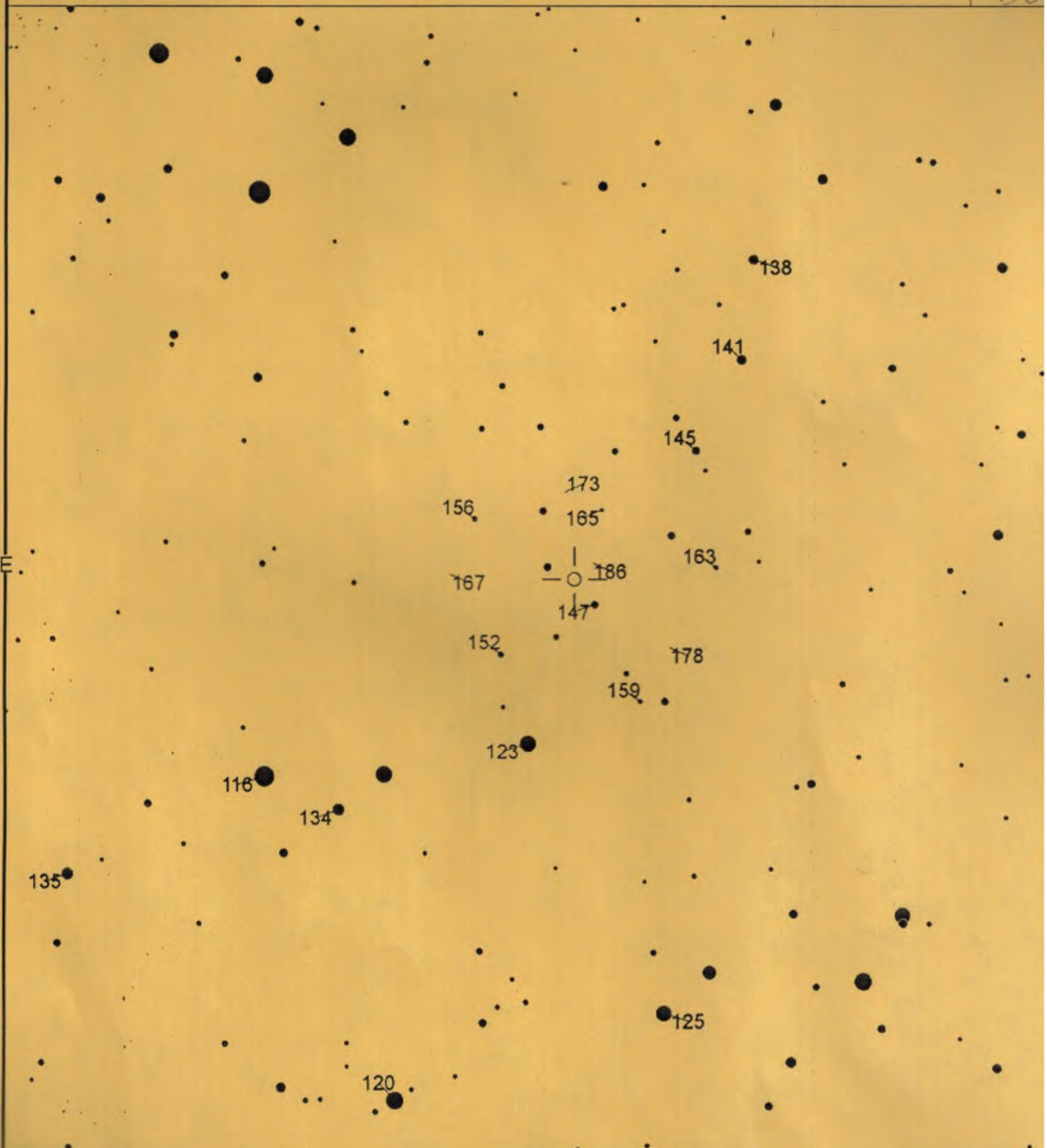
Magn: 12.2 - 19.5 V
Period: 0.06288
Type: UGSU
Spec:

Clyde Tombaughs Star.

(2000) 12:20:24.17 -18:27:01.8

AA
C

1330



FOV = 30.0'

Please use the photometry table for CCD observations.
This is the star that Clyde Tombaugh discovered in May 1932.

http://www.aavso.org/vsp/

Mon. Not. R. Astron. Soc. 282, 623–630 (1996)

Photometric superoutburst observations of the short-period dwarf nova TV Corvi

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ABSTRACT

We present photometric observations of the short-period dwarf nova TV Corvi during a superoutburst in 1994 June. Our high-speed photometric observations cover six nights and show well-defined superhumps. Using our measured superhump period, we confirm TV Crv as a short-period dwarf nova, with a likely orbital period of 1.50 h. Assuming that the cause of the superhumps is a 3:1 tidal resonance, theory allows a mass ratio of $q=0.22$ to be predicted. This in turn provides mass estimates for the two components of $M_1=0.52\ M_\odot$ and $M_2=0.12\ M_\odot$. Assigning TV Crv a probable absolute magnitude based on current work on faint, large outburst amplitude dwarf novae, we find a distance of 350 pc.

Key words: binaries: close – stars: individual: TV Crv – novae, cataclysmic variables.

1 INTRODUCTION

Cataclysmic variables (CVs) are close binaries which contain a white dwarf (WD) primary and late-type (K or M spectral class) main-sequence secondary star. In these systems, the low-mass secondary loses mass to the primary through the inner Lagrangian point of their Roche lobes. One class of CV, the dwarf novae (DN), has semiperiodic outbursts of 2–5 mag. Many, if not all, DN with orbital periods $\lesssim$2.5 h, belong to a subgroup called the SU UMa stars, named after their prototype. The SU UMa stars show fairly typical DN outbursts as well as, at times, longer and slightly brighter outbursts called superoutbursts. The time from superoutburst to superoutburst is termed the supercycle and is fairly regular in most of the SU UMa systems, but the number of normal outbursts that occur between superoutbursts can vary. Photometric observations of SU UMas during these superoutbursts reveal low-amplitude (a few tenths of a magnitude), sawtooth-like modulations called superhumps. Interestingly, these superhump modulations have periods which are approximately 1–9 per cent longer than the binary orbital period. Warner (1995a,b) review these subjects in detail.

TV Corvi, a 19th-magnitude high galactic latitude CV, was originally discovered by Clyde Tombaugh on a plate taken on 1931 March 22 during his trans-Saturnian planet search and classified as a nova (Levy et al. 1990). The orbital period of TV Crv remained unknown, although studies by Howell & Szkody (1990) suggested that TV Crv was likely to have a short orbital period, less than 2.5 h. We present here photometric observations taken during the 1994 June superoutburst of TV Corvi. This superoutburst began on 1994 May 28 and lasted over 15 d. Using photometric superoutburst observations, we have measured a superhump period and thus derived a likely orbital period. Knowing these two periods, we can determine the system mass ratio and provide a distance estimate. We discuss our observations in Section 2, and our data analysis methods and results in Section 3.

2 OBSERVATIONS

Fig. 1(a) shows the 1994 June superoutburst of TV Crv as recorded visually by members of the Royal Astronomical Society of New Zealand (RASNZ; Bateson 1994, private communication). Fig. 1(b) shows our six photoelectric data sets, placed on a magnitude scale for comparison (see Section 3 below). A summary of the details of our photoelectric observations is given in Table 1, the RASNZ visual magni-

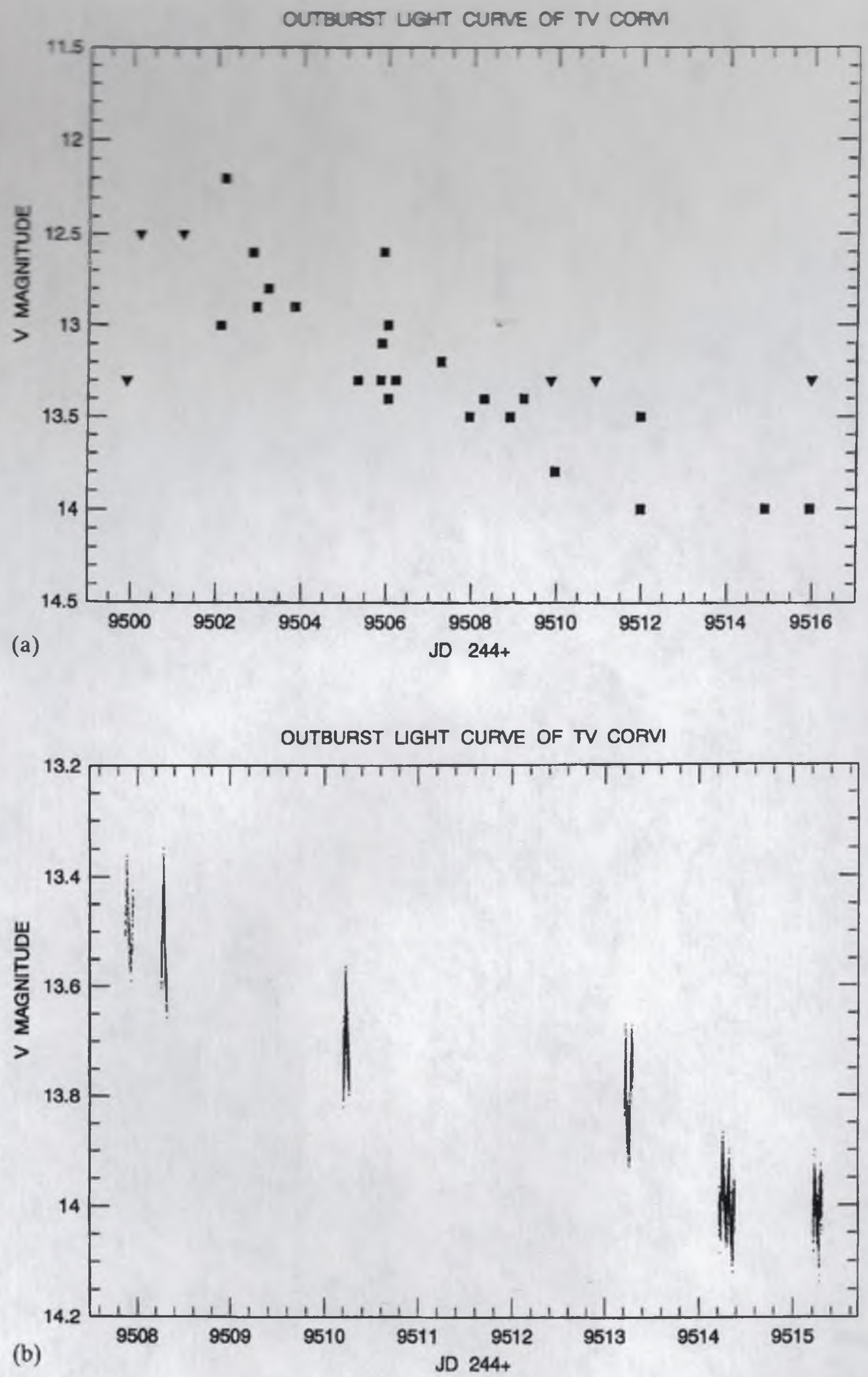

Figure 1. (a) RASNZ visual outburst observations of TV Crv. (b) Scaled photoelectric outburst light curve of TV Crv. See text for details.

tudes are listed in Table 2, and Fig. 2 presents plots of each of our individual photoelectric light curves.

High-speed photometry was obtained 7 d after the start of the outburst by A. Gilmore and P. Kilmartin on 1994 June 4 UT at Mt. John Observatory in New Zealand. The 0.6-m *f*/13 Cassegrain reflector telescope was used to obtain 30-s integrations through a Johnson *B* filter. Time-series observations covered a continuous span of 2 h, and included several sky background measurements and telescope tracking checks. The sky measures revealed that the sky was photometric during the entire TV Crv sequence, with a background count rate variation of only 3 per cent. Sky-

Table 1. Summary of photoelectric observations.

UT Date	JD Start 244+	End	Int. Time (seconds)	Filter	Observer
1994 Jun 4	9507.8710	9507.9544	30	B	A. G. and P. K.
1994 Jun 5	9508.2610	9508.3214	3	None	M. H.-A.
1994 Jun 7	9510.2037	9510.2673	3	None	M. H.-A.
1994 Jun 10	9513.2091	9513.2971	5	None	R. A.
1994 Jun 11	9514.2181	9514.3897	5	None	R. A.
1994 Jun 12	9515.2150	9515.3084	5	None	R. A.

background removal was performed, but since no standard stars were observed, extinction corrections were not applied to the data set. These extinction corrections would be quite small, considering the airmass of the observations and the short duration of the data set. The lack of these corrections does not affect our results, as we only use these data for their importance in our superhump period determination.

Five additional nights of high-speed photometry were obtained at the Sutherland observing station of the South African Astronomical Observatory (SAAO) on the nights of 1994 June 5, 7, 10, 11 and 12 UT. These observations were made with the 30-inch telescope and the University of Cape Town photomultiplier (Nather & Warner 1971). This photomultiplier has an Amperex 56DVP tube, whose S-11 response yields an effective wavelength close to that of Johnson *B*. White-light photometry was obtained on all nights with 3-s integrations on the nights of June 5 and 7, and 5-s integrations on June 10, 11 and 12. Data reduction was accomplished in the usual manner with sky-background removal and corrections for airmass and extinction performed.

3 DATA ANALYSIS AND RESULTS

The light curve in Fig. 1(b) shows our six nights of data placed on a magnitude scale as follows. The mean *V* magnitude on a given night was determined from the RASNZ light curve. This value was then used along with the standard equation, $m = -2.5 \log(\text{counts}) + C$, to derive C for each night of photoelectric observation. While the scaling is not perfect, this was done to allow comparison of the relative position within the outburst light curve at which our photoelectric measures were made. The variations seen in the nightly data in Fig. 1(b) are due to the presence of superhumps in each data set, as shown in Fig. 2. All period analysis was performed from the photoelectric data in counts and not in scaled magnitudes.

Table 2. RASNZ visual magnitude estimates for TV Crv.

JD 244+	V Magnitude[a]
9499.9000	<13.3
9500.2000	<12.5
9501.2000	<12.5
9502.0940	13.0
9502.1990	12.2
9502.8431	12.6
9502.9396	12.9
9503.2090	12.8
9503.8236	12.9
9505.2990	13.3
9505.8486	13.3
9505.8799	13.1
9505.9201	12.6
9506.0190	13.0
9506.0360	13.4
9506.2050	13.3
9507.2690	13.2
9507.9436	13.5
9508.2730	13.4
9508.8944	13.5
9509.2030	13.4
9509.8400	<13.3
9509.9474	13.8
9510.9000	<13.3
9511.9750	13.5
9511.9795	14.0
9514.8872	14.0
9515.9335	14.0
9515.9583	<13.3

[a]Magnitudes preceded by '<' are upper limits.

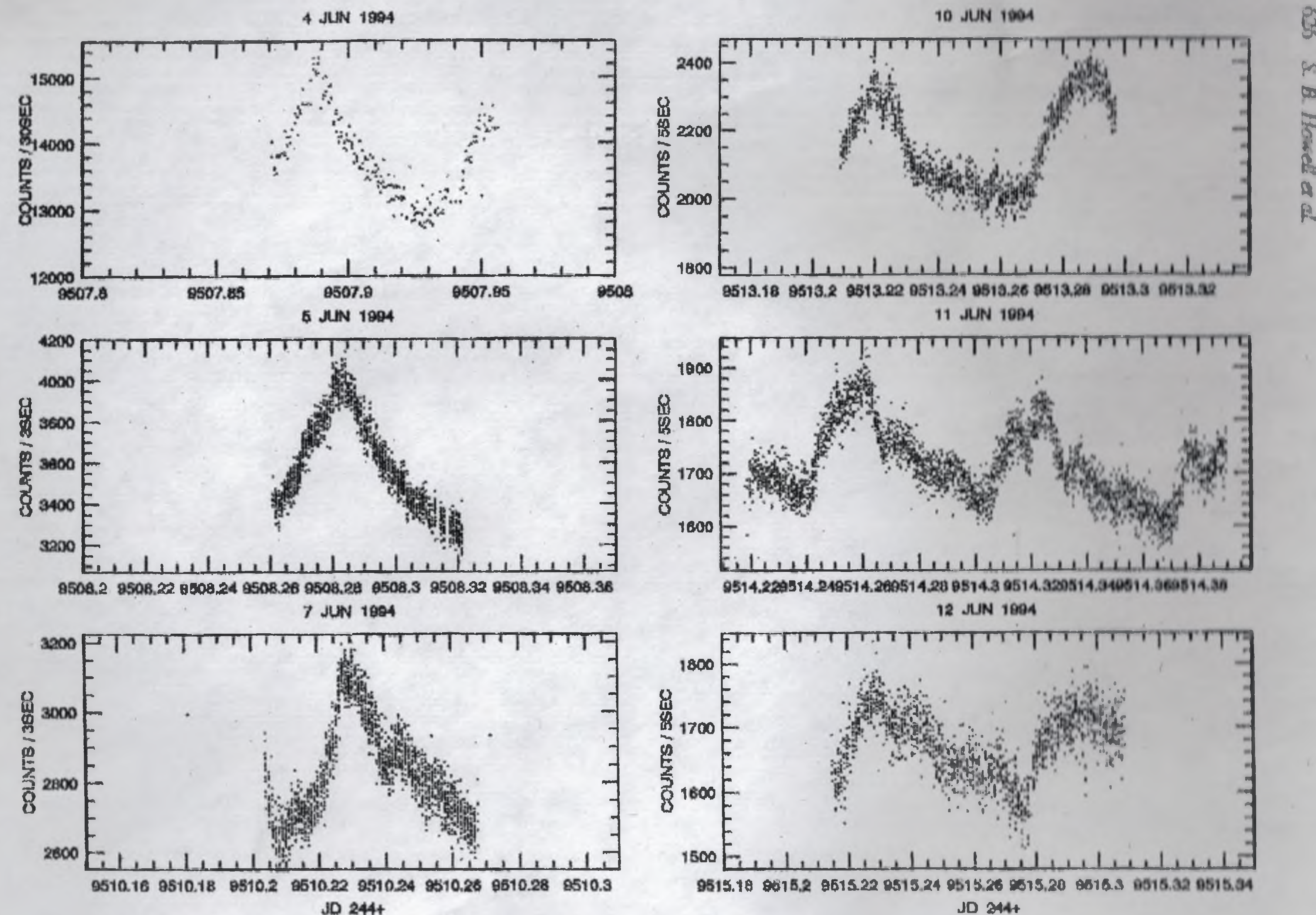

Figure 2. Photoelectric photometry of TV Crv from Mt. John Observatory in New Zealand and UCT in Sutherland South Africa. See Table 1 for observational details.

The overall TV Crv outburst light curve shown in Fig. 1 is similar to other tremendous outburst amplitude dwarf novae (TOAD) light curves showing a rapid rise, long slow phase 1 decline (0.12 mag d^{-1}), and probably the faster phase 2 decline (see Warner 1995b). Howell et al. (1995) have noted that some well-studied TOADs, in particular SW UMa, show three different types of outburst: superoutbursts, intermediate outbursts and normal outbursts. These three types of outburst vary in terms of total length and rate of each decline phase, as well as initial outburst amplitude from minimum light. With an outburst duration of over 15 d, an outburst magnitude range from 19 at minimum to 12 at maximum, a phase 1 decline rate of 0.12 mag d^{-1}, and a probable faster decline rate after 15 d (which was not visible after the star fell below 14th magnitude according to the RASNZ visual observers), this outburst of TV Crv is consistent with the Howell et al. superoutburst prescription. The phase 1 decline rate is also typical of essentially all SU UMa stars (9 ± 1 d mag^{-1}: Warner 1995a,b).

Data from each night were period-searched using a modified version of the phase dispersion minimization (PDM) technique (Stellingwerf 1978). Period searches were not attempted on the nights of June 4, 5 and 7, as these data sets in themselves do not provide long enough timebases to cover at least one superhump period. For the nights of June 10, 11 and 12, PDM provided good period estimates, which we list in Table 3. The large period error present on the three single nights is due to each night containing only about two superhumps. The three determined superhump periods are equal within the formal errors, indicating that the superhump period of TV Crv probably did not change over the course of at least these three nights.

Table 3. Superhump periods and amplitudes in TV Crv.

UT Date	Period (hrs)	1σ Errors	Amplitude (peak-to-peak)
04 June 1994	–	–	13%
05 June 1994	–	–	18%
07 June 1994	–	–	14%
10 June 1994	1.55	+0.44/-0.42	15%
11 June 1994	1.58	+0.38/-0.31	10%
12 June 1994	1.50	+0.39/-0.32	9%
All 6 nights	1.56	±0.02	---

The entire data set of all six nights was independently period-searched in order to determine a best-fitting period. A period of 1.56 ± 0.02 h was found. This period is in agreement with an average of the three independent nights and provides a good fit to all the data (see Fig. 3). The *F*-statistics associated with PDM allow us to determine that each of the three single periods, as well as the fit to the entire six nights, are all statistically significant at greater than a 99.9 per cent confidence level at their quoted 1σ errors (Table 3).

We note that on the nights of 1995 June 7, 10 and 12, there appear secondary humps sitting on the trailing side of each superhump. These are shown dramatically in Fig. 4, which is a phased, binned version of the data from 1995 June 11. Note the asymmetric shape of the peak (due to the double-hump structure apparent on this night) and the two clearly seen secondary humps. These secondary humps have orbital period phase offsets, from the peak of the superhump maximum of ~ 0.23 and ~ 0.45 respectively. Schoembs & Vogt (1980) performed a detailed study of VW Hyi during an outburst in 1978. They find 'complex structures' towards the end of the phase 1 decline and during phase 2 decline in the light curve. They make note of the fact that these secondary structures seem to grow in amplitude as the outburst progresses, and that the complexity increases as the overall outburst magnitude decreases. Their data also suggest that similar secondary humps migrate throughout the light curve, being slightly out of phase with the superhumps. While our light curve at superoutburst is not exactly like that of VW Hyi, we can make mention of some similar features. It appears that the superhump peak itself is initially single and then shows a decreasing amplitude with time, while appearing to split into multiple humps which migrate both forward and backward in the light curve. Table 4 shows the results of our measurements of the relative phases of these secondary humps in TV Crv, two other short-period dwarf novae at superoutburst (SS UMi and EF Peg), and one short-period DN (KK Tel) in quiescence, all of which show similar looking secondary humps. We see from these data that for all four stars, the two secondary humps occur between 0.2 and 0.6 in superhump phase, later than the peak of the main superhump itself, and that the phase difference between the two humps appears to be roughly constant at $\phi \approx 0.24$ (see Fig. 5).

Recently, Howell & Hurst (1994) derived a linear expression relating the superhump period and the orbital period. They extended the tabulated data of superhump periods given by Molnar & Kobulnicky (1992), and derived a relationship based solely on the observed periods and not on theory. This method provided an excellent linear fit, with a maximum error of 1.5 per cent over all known SU UMa stars. Using the equatorial fit provided by Howell & Hurst and our measured superhump period, we derive a likely orbital period for TV Crv of 1.50 h. Using our calculated period excess, $(P_s - P_o)/P_o$, for TV Crv (0.04), and interpolating it in fig. 2 of Molnar & Kobulnicky (1992), we find a corresponding $q(=M_2/M_1)$ of 0.22 for TV Crv. The equation relating orbital period and secondary mass given by Patterson (1984), and our determined value of q, allows us to calculate a mass of 0.12 $M_\odot$ for the secondary, and thus a corresponding mass of 0.52 $M_\odot$ for the primary star in TV Crv. If, however, the secondary star is indeed a degenerate star, the Patterson relations, which are based on non-degenerate main-sequence relations, will not be strictly valid, and these determined values may be in error by up to 20 per cent (Rappaport, Joss & Webbink 1982).

Having derived an orbital period for TV Crv, we can estimate a distance using the recent results of Sproats,

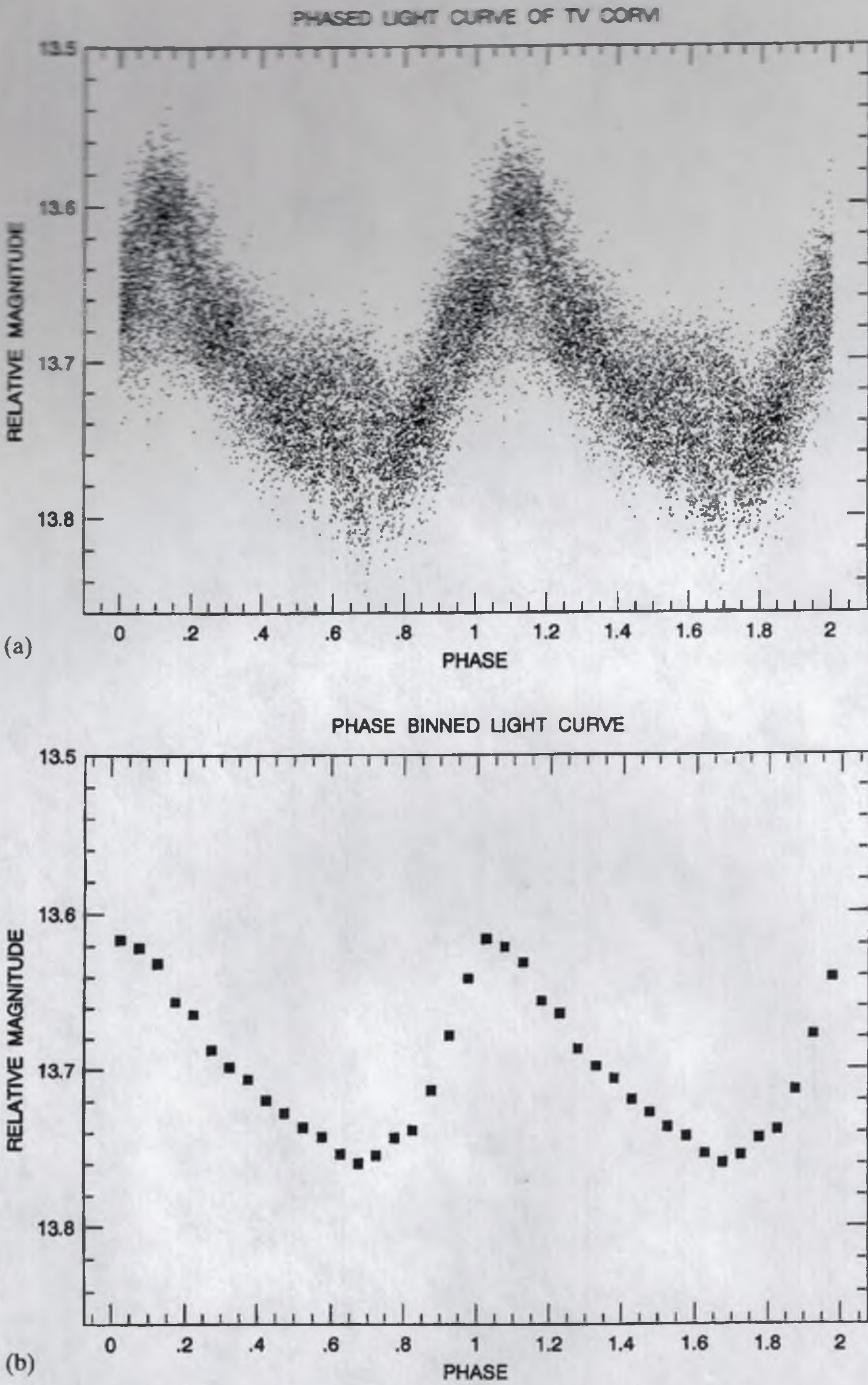

Figure 3. (a) Phase plot of the entire six nights of photoelectric data. The data have been phased on the best-fitting period of 1.56 h. Note that all six nights are fitted well by this single period. (b) Plot (a) phase binned with a bin size of $\phi = 0.05$.

Howell & Mason (1996). They show, from IR photometry of 37 faint, short-period CVs, that the mean M_v of TV Crv (based on its orbital period and outburst properties) is likely to be near $M_v = 12 \pm 2$, thus placing TV Crv at a distance of 100–600 pc.

Table 5 provides a summary of the observed and determined system parameters for TV Crv. We have seen that this observational study, along with the results presented in Levy et al. (1990), confirms that TV Crv is a short-orbital-period, large outburst amplitude DN, i.e., a TOAD. Photometric evidence presented here, along with the relations derived in Warner (1995b), lead us to consider the possibility that TV Crv may contain a degenerate secondary star. We have also noted that the superhump structures in light

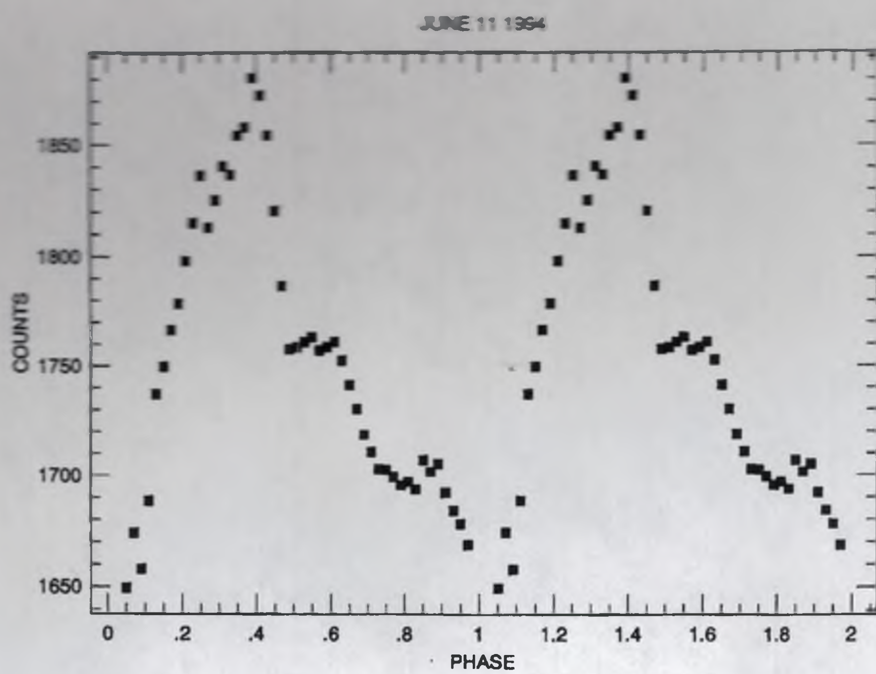

Figure 4. Phase-binned light curve of TV Crv on 1994 June 11. The bin size is $\phi = 0.05$, and the data are phased on our determined superhump period. Note the asymmetric maximum and the two clearly defined secondary humps.

Table 4. Observations of secondary humps.

UT Date	Secondary Hump 1 (ϕ)	Secondary Hump 2 (ϕ)
	SS UMi[a]	
Mar 13 1989	0.279±0.048	0.61±0.055
Sep 6 1989	0.363±0.053	0.63±0.053
Sep 10 1989	0.400±0.043	0.68±0.048
	EF Peg[b]	
Oct 23 1991	0.330±0.035	0.58±0.038
Oct 26 1991	0.391±0.033	0.62±0.037
Oct 27 1991	0.295±0.034	0.51±0.036
Oct 28 1991	0.243±0.034	0.49±0.037
Oct 30 1991	0.230±0.034	0.49±0.037
	TV Crv[c]	
Jun 7 1994	0.231±0.011	0.44±0.013
Jun 11 1994[e]	0.211±0.014	0.42±0.015
Jun 11 1994	0.246±0.016	0.51±0.017
Jun 12 1994	0.226±0.007	0.49±0.014
	KK Tel[d]	
Aug 28 1990[e]	0.38±0.045	0.59±0.0463
Aug 28 1990[f]	0.48±0.042	--
Aug 29 1990[f]	0.45±0.050	--

Notes to Table 4.
[a]Chen, Liu & Wei (1991).
[b]Howell et al. (1993).
[c]Present work (this paper).
[d]Howell et al. (1991).
[e]These nights contained more than one superhump, each of which showed secondary humps.
[f]Only one secondary hump was present.

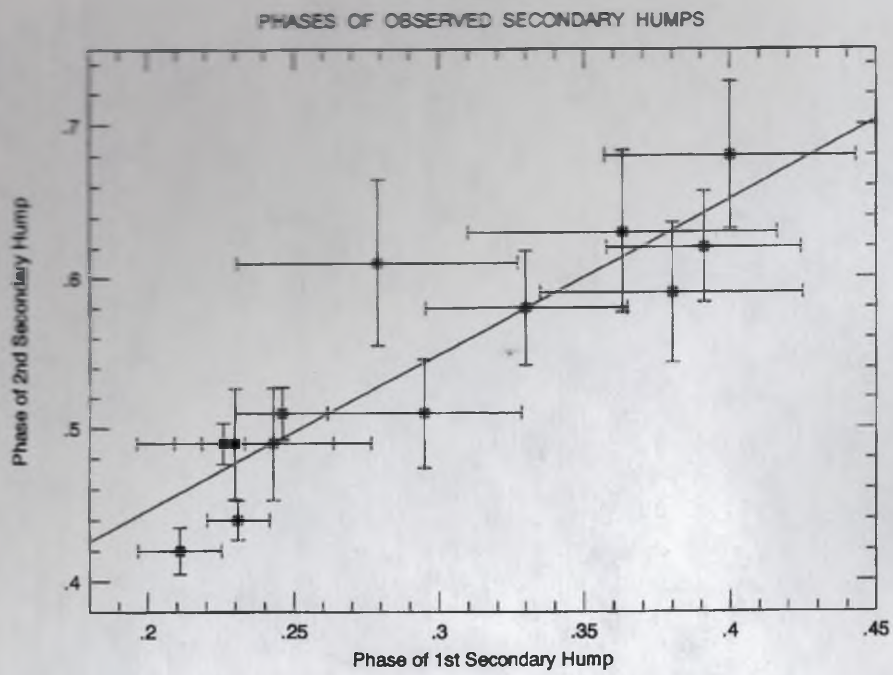

Figure 5. The phase offset of each of the two secondary humps plotted relative to the peak of the primary superhump. The straight line shows the result for a constant phase difference between the two humps of $\phi = 0.24$. See Table 4 for details.

Table 5. Determined system parameters for TV Crv.

Superhump Period (hr)	1.56±0.02
Orbital Period (hr)	1.50
Mass Ratio (M2/M1)	0.22
$M_1/M_\odot$	0.52
$M_2/M_\odot$	0.12
M_v	12±2
Distance (pc)	350±250

curves of a few short-period DN (both during superoutburst and at quiescence) can show similar secondary hump structures with roughly equal superhump phases and offsets. These interesting features are yet to be fully explained or understood.

ACKNOWLEDGMENTS

We thank Frank Bateson and the Royal Astronomical Society of New Zealand Observers for alerting us to TV Crv's outburst and providing us with the outburst light-curve visual estimates. We are also grateful to Alan Gilmore and Pat Kilmartin for responding to our vs-net plea for observations and thus providing us with their data for the night of June 4. Partial support of this work was provided by NSF Grant AST-921971 to SBH. The Planetary Science Institute is a non-profit research and educational organization, and part of the San Juan Institute.

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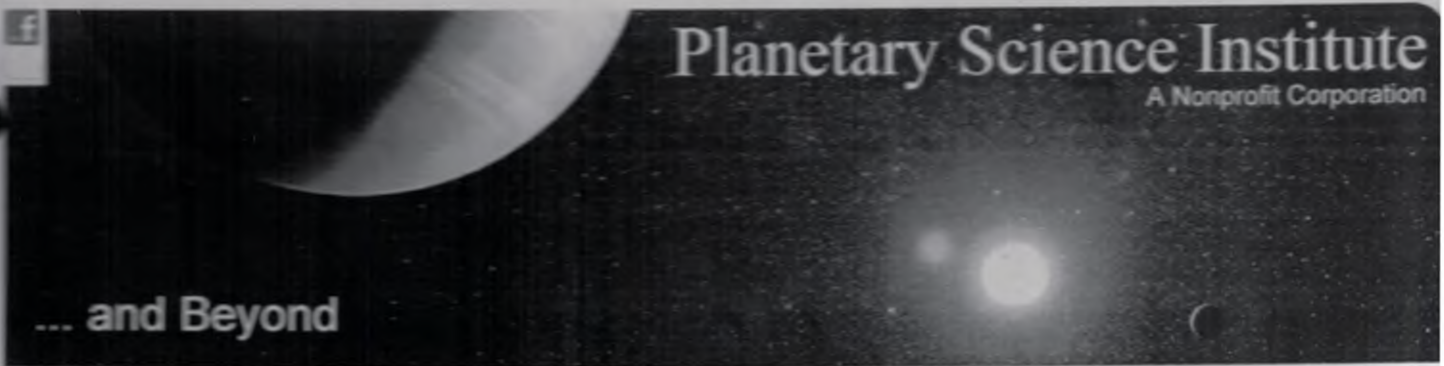

TV Corvi

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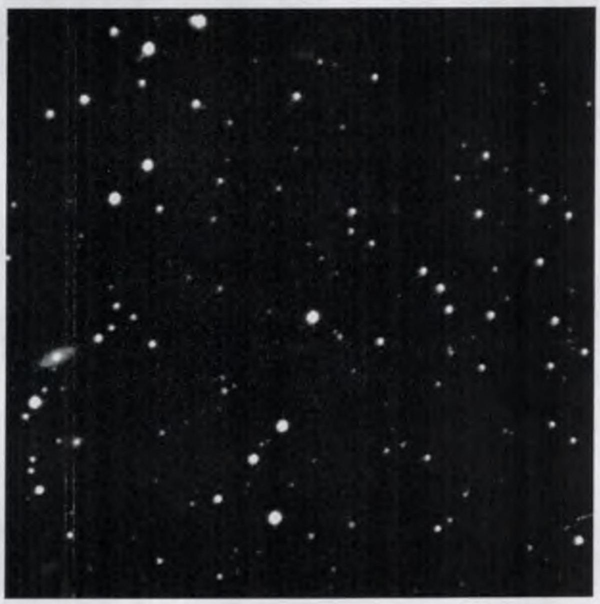

Observation: February 2, 2005

Exposure time: Seven images. First two images are 1 evening apart, last five images are each ~1 hour apart.

Description of Object:

On the night of February 2, 2005, David Levy caught the variable star TV Corvi just as it was starting one of its rare explosions. These images begin with the star barely visible as a faint speck at its normal minimimum brightness of about 1magnitude 18.5; that first image was taken the night before. At the end of the sequence, the star is brighter than the 14.8 and 14.6 magnitude stars that are on either side of it. Thus, TV Corvi increased in brightness by about 40 times.

According to research done at PSI (by Steve Howell), TV Corvi appears to be a most unusual binary star system. It is a high galactic latitude cataclysmic variable star, itself unusual since most such stars are at low galactic latitudes; i.e. near the plane of the Milky Way. According to Howell, the TV Corvi system is two small stars orbiting each other in a space smaller than our own Sun, in a period of under two hours. In this system, hydrogen leaves a brown dwarf star and travels to a spot on an accretion disk orbiting a white dwarf star. When the spot overflows with hydrogen, then a thermonuclear explosion occurs and the system brightens enormously, then fades slowly over a few days.

During his search for trans-Saturnian planets, Clyde Tombaugh discovered this star in its outburst of March 23, 1931. It was subsequently ignored until David Levy (of PSI and Jarnac Observatory) uncovered Tombaugh's observation while doing research for his book Clyde Tombaugh: Discoverer of Planet Pluto (University of Arizona Press, 1991). Levy then observed the star visually in outburst on March 23, 1990 (coincidentally 59 years to day after Tombaugh; cf. IAUC. 4983) TV Corvi was then observed by the International Ultraviolet Explorer satellite during its next outburst in June 1991. Levy has caught TV Corvi at its observed outbursts since then, including one again on a March 23, in 2000. In 2005, TV Corvi's outburst happens a day before what would have been Tombaugh's 99th birthday.

The spiral galaxy to the left is ESO573-12. It is similar to our own Milky Way but 350 million light years from us.

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Search

MEDICAL TERMINOLOGY
For the Layman

Artery - The study of fine paintings.
Barium - What you do when CPR fails.
Cesarean Section - A district in Rome.
Colic - A sheep dog.
Coma - A punctuation mark.
Congenital - Friendly.
Dilate - To live long.
Fester - Quicker.
G.I. Series - Baseball games between teams of soldiers.
Grippe - A suitcase.
Hangnail - A coat hook.
Medical Staff - A doctor's cane.
Minor Operation - Coal digging.
Morbid - A higher offer.
Nitrate - Lower than the day rate.
Node - Was aware of.
Organic - Musical.
Outpatient - A person who has fainted.
Post-operative - A letter carrier.
Protein - In favor of young people.
Secretion - Hiding anything.
Serology - Study of English knighthood.
Tablet - A small table.
Tumor - An extra pair.
Urine - Opposite of you're out.
Varicose Veins - Veins which are very close together.

-- Author Unknown

LOWELL OBSERVATORY
FLAGSTAFF, ARIZONA

December
21
19 28

Mr. Clyde W. Tombaugh,
Burdett, Kansas.

Dear Mr. Tombaugh:

Your detailed letter of December 3, and the planetary drawings have been examined with interest. Evidently you have succeeded very well, both with the telescope and with observations with it. We have been, and are still very busy with some special work and cannot write you in detail at this time.

We are obliged to you for giving us the names of some of your teachers, one of whom, Mr. Waldrip, I know quite well.

You expressed some fear that your plans for driving west might fall through and in that case you might have to search about for some other plan. If you find that you are not going to be able to drive west, please let us know and we will see if we might make some other plans. We are not able at present to make any promise of employment but we are hopeful that something might be arranged later. We expect to have soon a new photographic telescope for some special work and shall need someone to operate it. We have at present nothing planned definitely in this regard but we shall need before long to have plans perfected for carrying on that work. It is perhaps possible that you might be able after some instruction here to be able to make exposures with this instrument, so we are thinking of you as possibly developing into an assistant for that work. It would mean, as you can well imagine, long nights at the telescope during the moonless nights. Still this is something that one who undertakes astronomical observations must expect.

We shall appreciate your writing us concerning your planned trip at your early convenience.

Yours very truly,

V. M. Slipher

V.M. Slipher/LF

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ssage 1:
m systems@nova.aavso.org Fri Apr 25 15:22:14 1997
urn-Path: <systems@nova.aavso.org>
ceived: from nova.aavso.org by LPL.Arizona.EDU (4.1/SMI-4.1)
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te: Fri, 25 Apr 1997 15:28:20 -0400 (EDT)
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: aavso-newsflash@aavso.org
bject: AAVSO News Flash - No. 141
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me-Version: 1.0
ntent-Type: TEXT/PLAIN; charset=US-ASCII
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bject: TV Crv, SS Cyg, CZ Ori, DI UMa, TW Vir   No. 141
April 25, 1997

CORVI

e dwarf nova type cataclysmic variable TV Crv is in outburst, as indicted
the following observations:

UT	Mag.	AAVSO Observer Initials
R 24.1250	13.0:	LVY
R 25.1667	13.1	LVY
R 25.4014	13.5	TJN

cording to the AAVSO International Database this star is fainter than
sual magnitude 15.5 at minimum. The last outburst of TV Crv to be
corded the database was in April 1996.

CYGNI
More--

e dwarf nova type (SS Cyg subclass prototype) cataclysmic variable SS Cyg
pears to be in outburst, as indicted by the following observations:

UT	Mag.	AAVSO Observer Initials
R 22.92	12.1	GRL
R 24.090	12.0	PYG

On the Existence of Low-Luminosity Cataclysmic Variables Beyond the Orbital Period Minimum

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Accepted for *MNRAS*

Received ____________________; accepted ____________________

ABSTRACT

Models of the present-day intrinsic population of cataclysmic variables predict that 99% of these systems should be of short orbital period ($P_{orb} \lesssim 2.5$ hr). The Galaxy is old enough so that $\sim 70\%$ of these stars will have already reached their orbital period minimum (~ 80 min), and should be evolving back toward longer periods. Mass transfer rates in these highly evolved binaries are predicted to be $\lesssim 10^{-11}$ $M_{\odot}$ yr^{-1}, leading to M_V's of ~ 10 or fainter, and the secondaries would be degenerate, brown dwarf-like stars. Recent observations of a group of low-luminosity dwarf novae (TOADs) provide observational evidence for systems with very low intrinsic M_V's and possibly low-mass secondaries. We have carried out population synthesis and evolution calculations for a range of assumed ages of the Galaxy in order to study $\mathrm{P_{orb}}$ and $\dot{\mathrm{M}}$ distributions for comparison with the TOAD observations. We speculate that at least some of the TOADs are the predicted very low-luminosity post-period-minimum cataclysmic variables containing degenerate (brown dwarf-like) secondaries having masses between $0.02 - 0.06 M_{\odot}$ and radii near $0.1 R_{\odot}$. We show that these low-luminosity systems are additionally interesting in that they can be used to set a lower limit on the age of the Galaxy. The TOAD with the longest orbital period currently known (123 min), corresponds to a Galaxy age of at least 8.6×10^9 years.

Subject headings: Cataclysmic Variables, Binary Evolution, Age of Galaxy, Brown Dwarfs

1. Introduction

Cataclysmic variables (CVs) are a class of interacting close binary stars with typical orbital periods ranging from 80 min to $\sim$ 10 hrs. The two stars, a more massive white dwarf (WD) primary and a low-mass secondary, are typically separated by only a few solar radii. CVs include dwarf novae (DN), novalikes, magnetic systems (AM and DQ Hers), and classical novae. Comprehensive reviews of these systems and their evolution are given in Patterson (1984), King (1988), and Warner (1995a).

In the dwarf novae, material transferred from the secondary (via Roche lobe overflow) forms an accretion disk around the primary star that can extend all the way to the WD surface. These stars show outbursts of 2-5 mags which are widely thought to occur when material stored in the accretion disk is suddenly accreted onto the WD surface due to angular momentum loss caused by thermally unstable viscous heating (cf., Cannizzo et al. 1988). Depending on the rate of mass transfer from the secondary, which is related to the orbital period (e.g, Rappaport, Verbunt & Joss 1983 [hereafter RVJ]; Warner 1995a), the disk can be the dominant light source from high energies to the IR. Typically determined mean values of M_V for DN are 7.5 for systems with orbital periods $\gtrsim$ 3 hr, and 9.5 for systems with orbital periods $\lesssim$ 2 hr. CVs with orbital periods in the range of 2–3 hr are uncommon, and this interval has been termed the "period gap."

Warner (1995a) provides observational information on all CVs for which orbital periods and other detailed information are known. Our current observational knowledge is severely biased towards CVs with orbital periods $\gtrsim$ 2.5 hrs or those with high mass transfer rates (i.e., intrinsically bright CVs). Even surveys which covered large areas of the sky searching for UV excess or blue objects have fallen short of improving on this situation. For example, the PG survey (Green et al. 1982) covered just over 10,000 square degrees and discovered 29 CVs (Ringwald 1993), but it had a average limiting magnitude of $B_{lim} \sim 16$, so that it discovered only intrinsically bright systems, most with long ($\geq$ 3 hr) orbital periods. Our current view of CVs is thus a very skewed one, as the majority of observed CVs are not representative of the actual, or intrinsic, CV population (see Section 2).

During the past several years, Howell and collaborators (Howell & Szkody 1990; Howell, Szkody, & Cannizzo 1995; and Sproats, Howell, & Mason 1996) have provided data to help remedy the problem. They have obtained observations of CVs which are faint, including a subgroup of DN which are *intrinsically* faint, having M_V's of 10 to 14, and which show very large amplitude outbursts (6-10 magnitudes). These tremendous outburst amplitude dwarf novae, or TOADs, have the following properties: infrequent outbursts (months to decades), very low inferred mass transfer rates ($\dot{M} \lesssim 10^{-11} M_{\odot}$ yr^{-1}, implying optically thin disks), very low viscosity disk material in the quiescent state, and short orbital periods ($\lesssim$ 2.5 hrs). The TOADs consist of stars such as WZ Sge and AL Com, two of the shortest period DN known, but also contain systems such as TV Crv and EF Peg which have orbital periods near 120 min, just below the period gap (see Howell et al., 1995 for a complete listing).

Absolute magnitudes and inferred mass transfer rates have been calculated for the faint CVs mentioned above. The inferred mass transfer rates are based on Smak's (1993) relationship between M_V and $\dot{M}$ as shown in Warner (1995a; Figure 9.8) and do not represent a detailed quantitative relationship (see section 3). These faint systems are shown in Figure 1, along with those previously known and cataloged in Warner (1987; 1995a). Two previously known faint systems are now known to be TOADs (WZ Sge and T Leo; the two open squares near M_V = 11). The TOADs have calculated M_V's of 10 to 14 and inferred $\dot{M}$'s in quiescence of 10^{-11} to $10^{-13} M_{\odot}$ yr^{-1} (Sproats et al., 1996). From Fig. 1, we see that the TOADs represent an interesting set of stars which have been found to be intrinsically low-luminosity objects. Their observationally derived absolute magnitudes and low $\dot{M}$ values (see section 4) indicate that these stars represent a class of objects that are not fit well by the standard CV relations between M_V and orbital period (cf. Warner 1995a).

Several authors have discussed the existence of CVs with degenerate secondaries (e.g., Paczyński & Sienkiewicz 1981; Rappaport et al. 1982; Lamb & Melia 1987), and theoretical models of the intrinsic CV population predict that the majority of CVs contain degenerate secondaries (Kolb 1993; see also section 2). It has also been recently suggested (for observational reasons related to photometric behavior during outburst) that TOADs may contain low-mass, degenerate secondaries (Howell et al. 1995, Warner 1995b, Howell et al. 1996). Using arguments based on the standard theory of CV formation and evolution, and on the observational properties of the low-luminosity systems presented in Figure 1, we explore the possibility that at least some TOADs may indeed be the oldest cataclysmic variables in the Galaxy. If so, they *(i)* represent the first evidence of the predicted large population of very low-luminosity CVs; *(ii)* have evolved past the orbital period minimum and are evolving back to periods of $\sim$ 2 hours; *(iii)* should contain very low-mass degenerate (brown dwarf-like) secondary stars; and *(iv)* may yield a useful constraint on the age of the Galaxy.

2. The Intrinsic CV Population

The intrinsic population of CVs has been modeled in detail (e.g., Politano 1988, 1994, 1996; de Kool 1992; Kolb 1993), and a comparison with the observed population clearly illustrates the under-representation of low-luminosity systems prevalent in our current observational picture of CVs. The current percentage of observed CVs with orbital periods greater than 3 hrs is $\sim$ 55%, whereas in the intrinsic population this number is expected to be $\sim$1% (Kolb 1993), indicating a *strong* bias toward long-period (bright) systems. Also, the mean WD mass in observed CVs is $\sim 0.8 M_\odot$ (Ritter & Kolb 1995), whereas the intrinsic mean WD mass is predicted to be $\sim 0.5 M_{\odot}$ (Politano 1988, 1996). Selection effects, such as observing CVs with magnitudes of $V = 16$ or brighter, have been shown to introduce a severe bias toward systems with high-mass WDs and/or high mass transfer rates (e.g., Ritter & Burkert 1986; Dünhuber 1993; Howell et al. 1995). The remedy to the current skewed state of affairs in CVs is to reduce these selection effects by observing to fainter (apparent and absolute) magnitudes, and thereby provide a more accurate picture of the actual CV population.

The data in Figure 1 provides us with an observational sample of CVs that may possibly represent systems belonging to the intrinsic CV population, especially at short orbital periods, and therefore is a sample that can potentially provide meaningful tests of theoretical models. Theoretical models of the intrinsic, present-day CV population predict that $\sim$ 99% of all CVs have orbital periods $\lesssim$ 2.5 hrs (Kolb 1993). These systems are expected to be intrinsically faint ($M_V \gtrsim 8$), and to have low mass transfer rates $\dot{\rm M}$ $\lesssim 10^{-10} M_{\odot}$ yr^{-1}. In addition, as a typical CV evolves, it reaches a minimum orbital period near 80 min (see e.g., Paczyński & Sienkiewicz 1981; Rappaport et al. 1982). The Galaxy is old enough so that $\sim$ 70% of all CVs are predicted to have reached this period minimum and to be currently evolving towards longer orbital periods (Kolb 1993). Cataclysmic variables in this latter 70% are predicted to have very low mass transfer rates ($\dot{M} \lesssim 10^{-11} M_{\odot}$ yr^{-1}, $M_V \gtrsim 10$) and to contain very low mass ($\lesssim 0.06 M_{\odot}$), degenerate (brown dwarf-like) secondaries (e.g. Rappaport et al. 1982, RVJ, & section 3).

The systems in Figure 1, taken at face value, can be used to begin to test the validity of the above predictions. Of the 26 observed systems with orbital periods below 3 hrs, 14 of them, or 54%, have M_V's ≥ 10 and estimated values of $\dot{M} \lesssim 10^{-11} M_{\odot}$ yr^{-1}. As the sample of low-luminosity CVs is increased, and more quantitative determinations of the observed and inferred parameters can be made, we will be able to provide important (and long-awaited) constraints on theoretical models of the intrinsic CV population.

3. Secular Evolution and CVs with Degenerate Secondaries

In the conventional picture of CV evolution (see, e.g., RVJ; Hameury et al. 1988), the early phases are expected to be dominated by angular momentum losses due to magnetic braking via a magnetically constrained stellar wind from the donor star. Mass transfer rates are typically $\sim 10^{-8}$ to $10^{-9} M_\odot$ yr^{-1} for these systems and typical orbital periods range from ~ 10 hrs to ~ 3 hrs, just at the upper edge of the period gap. At some point in the evolution, the secondary becomes completely convective (at $\sim 0.3 M_\odot$) and, in the currently accepted view, magnetic braking is assumed to be greatly reduced. The near cessation of magnetic braking reduces the mass transfer rate and allows the secondary to shrink toward its thermal equilibrium radius. This causes a period of detachment (in which $\dot{M}$ drops to essentially zero) which lasts until the Roche lobe shrinks sufficiently to bring the secondary back into contact with it, at an orbital period of ~ 2 hrs. This is the commonly accepted explanation for the observed period gap between 2-3 hrs in CVs (RVJ; Spruit & Ritter 1983).

When mass transfer recommences at $P_{orb} \sim 2$ hrs, it is then driven largely by gravitational radiation losses at rates of $\sim 10^{-10} M_\odot$ yr^{-1}. As the orbit shrinks and the mass of the donor star decreases, the mass-loss timescale increases, but the thermal timescale, τ_{KH}, increases much faster, due to the $\sim M^{-3}$ dependence of τ_{KH}. Therefore, at some point the thermal timescale grows larger than the mass transfer timescale. When this occurs, the donor star is unable to adjust to the mass loss on its thermal timescale, and it therefore starts to expand upon further mass loss, in accordance with its adiabatic response; i.e., $[dln(R)/dln(M)]_{ad} < 0$. Somewhat before this point is reached, the orbital period begins to increase with further mass transfer. The orbital period at this point is typically ~ 80 min and the mass of the donor star is $\sim 0.06 M_{\odot}$. From this point on, the mass of the donor star will continue to decrease (but with longer and longer timescales), the orbital period will increase back up to periods approaching ~2 hrs (within a Hubble time), and electrons in the interior of the donor star will become increasingly degenerate.

To make some of these evolutionary descriptions somewhat more quantitative, we show in Figure 2 the secular evolution of a CV under the influence of magnetic braking and gravitational radiation. The evolution code used to generate these results is very nearly the same as was used by RVJ, except that the treatment of the secondary (donor star) has been improved. To calculate the evolution of the secondary we used a version of our code that has been used previously to follow the evolution of brown dwarfs and low-mass stars (Nelson, Rappaport, & Joss 1986; 1993). The results of these brown dwarf calculations are in excellent accord with those of Lunine, Hubbard, & Marley (1986), who utilized a more sophisticated evolution code.

The initial constituent masses of the system whose evolution is shown in Fig. 2 were $M_{WD} = 0.8 M_{\odot}$ and $M_{donor} = 0.5 M_{\odot}$. Figure 2a shows both the orbital period and the mass transfer rate as functions of evolution time, for an assumed donor star with solar composition. The calculations have been carried out beyond the oldest plausible age for such a binary. All of the evolutionary phases and features discussed above are clearly present in Fig. 2. We note that the value of P_{min} is not substantially influenced by the prior evolution either with or without magnetic braking.

As the system reaches the minimum period and evolves to longer orbital periods, $\dot{M}$ decreases from $\sim 10^{-10} M_{\odot}$ to about $\sim 10^{-12} M_{\odot}$ yr^{-1} and the orbital period increases from its minimum value of $\sim$ 80 min to $\sim$ 2 hrs within an evolution time of $\sim 10^{10}$ yrs. In Fig. 2b we show the corresponding evolution of the mass and the radius of the donor star. Note that as the donor star becomes increasingly degenerate, for masses below $\sim 0.06 M_{\odot}$, the combination of adiabatic expansion with mass loss, and the loss of thermal energy from the star, keep the radius nearly constant at about $\sim 0.1R_\odot$. This is, in fact, very close to the radius of a completely degenerate star of mass $0.01M_\odot$ with a solar composition, and only $\sim 40\%$ larger than the radius of a degenerate $0.05M_\odot$ star.

While systems with such low $\dot{M}$ may, at first glance, appear to be unobservable, in fact it appears that we may have already observed a number of such short-period systems with $\dot{M} \leq 10^{-12}M_\odot$ yr^{-1} ($M_V \sim 12-14$; see Fig. 1). The data are consistent with these systems having already reached their minimum period, evolving towards longer periods, and containing substantially degenerate secondaries.

Thus, we see that in the lowest luminosity CVs, the secondary stars are brown dwarf-like objects with masses equal to 20–60 Jupiter masses and radii that are all very close to $0.1R_\odot$, similar to "field" brown dwarfs. While they used to be normal hydrogen burning stars (i.e., red dwarfs), they should now have similar effective temperatures to field brown dwarfs. One difference, however, is that the optically thin accretion disk will *not* effectively shield the secondary, and X-ray heating is likely to be important. We also would *not* expect the presence of Li spectral features (as are expected in field brown dwarfs; e.g., Nelson, Rappaport, & Chiang 1993). The TOAD brown dwarfs will continue to lose mass, and like "field" brown dwarfs, cool down and become increasingly degenerate.

To further investigate the expected distribution and properties of the systems we are tentatively identifying with TOADs, we have carried out a population synthesis calculation of CVs, with emphasis on systems below the period gap. (For earlier population synthesis studies of CVs see, e.g., Politano 1996; de Kool 1992; Kolb 1993; Di Stefano & Rappaport 1993.) For the present study we utilized a Monte Carlo approach with most of the same input assumptions as were used in the population synthesis study of supersoft X-ray sources carried out by Rappaport, Di Stefano, & Smith (RDS; 1994). We briefly review the

procedure here, but refer the reader to RDS for more details. We start by assuming an age for the Galaxy, t_G. Then, 10^7 primordial binaries are chosen; for each, the primary mass, secondary mass, and orbital period are chosen in accordance with the 'standard model' detailed in RDS (see their Table 2 and equation 1). The time of birth for each binary, t, was chosen from a uniform random distribution in the range: $0 < t < t_G$. Each primordial binary was 'followed' (see RDS for the prescriptions used) to see if mass transfer from the primary to the secondary would occur, and if such mass transfer would result in a common envelope phase - the end product of which would be a low-mass star in orbit with a white dwarf. The assumed energetics that govern the end-point of the common envelope phase are described by equation (2) of RDS. The evolution time, up to and including the common envelope phase, was simply taken to be just the main-sequence lifetime of the primary.

If a particular primordial binary was 'successful' in evolving into a white-dwarf main-sequence binary, then the subsequent evolution was followed in detail with the same binary evolution code used to carry out the calculation shown in Figure 2. As in most other related binary evolution calculations, we made the assumption that magnetic braking is active when, and only when, the donor star has a radiative core (see RVJ; Spruit & Ritter 1983; Hameury et al. 1988). The magnetic braking was specified by the Verbunt & Zwaan (1981) model with parameter values of $\gamma = 3$ and f = 2 (see RVJ for definitions). The evolution was stopped at the current epoch, i.e., when the sum of the time to form the progenitor, the time for the binary to become a CV, and the subsequent evolutionary time as a CV equals the present age of the Galaxy, t_G. At the end of the evolution, we stored the properties of the binary for subsequent statistical analyses. Many systems, especially those with low mass main-sequence companions (potential donor stars which are completely convective), never experience mass transfer because the orbit cannot shrink sufficiently by the present epoch for the donor star to fill its Roche lobe. We find that of all the primordial binaries that we start with, only $\sim 2 \times 10^{-4}$ of them become CVs with mass transfer.

The population synthesis calculations described above were repeated for a sequence of assumed ages for the Galaxy; i.e., for $t_G = 6, 8, 10, 12, 14,$ and 16 Gyr. The results are shown in Figure 3 as a sequence of plots of $\dot{M}$ vs. P_{orb} for the simulated CVs. No observational selection effects have been included; these results are taken directly from the outputs of our population synthesis and evolution calculations, and thus describe properties of the intrinsic CV population. Note first, that there are hardly any systems (<2%) above the period gap (i.e., with $P_{orb} > 3$ hours). This is consistent with previous population studies such as those of Kolb (1993), and is due to the relatively short lifetimes that CVs are expected to have during this phase of their evolution (a result of the much higher rates of mass transfer that are experienced for systems above the period gap). The relatively large numbers of *observed* CVs above the period gap is largely due to selection effects stemming from the much higher luminosities for these systems, and hence, their greater detectability out to larger distances (Ritter & Burkert 1986; Dünhuber 1993). We also see that there are a reduced, but finite, number of systems with orbital periods within the 'gap' region (i.e., with $2 < P_{orb} < 3$ hours). Again, we have made no attempt to correct for observational selection effects in this region nor to statistically analyze the properties of the gap in our population synthesis results, as this has been well studied in earlier works (see, e.g., Kolb 1993).

Below the period gap, the population synthesis results for all Galactic ages show the same characteristic 'elbow' shaped region in the $\dot{M}$ - P_{orb} plane (see Fig. 3). The ensemble of evolutionary tracks clearly show the migration to the minimum orbital period and back up toward longer periods - with the concomitant dramatic decline in the mass transfer rates. It is important to note that the evolutionary age of any given system (time since the primordial binary was formed) in these plots is not uniquely specified by its position along the evolutionary track. This is due to (*i*) the range of main-sequence lifetimes for the progenitor primaries, (*ii*) the range of orbital separations of the systems that emerge from the common envelope phase, and (*iii*) the differences in mass of the donor star when the CV phase commences.

For each assumed age of the Galaxy, the number of CVs in our population synthesis sample is about 10^3. This is only a small fraction of the $\sim 10^6 - 10^7$ such systems that are expected in the Galaxy at the present time; however, the statistical significance of the results is sufficient to allow us to make the following statements. First, we find that for a Galactic age of 10^{10} years, the numbers of systems above the period gap, in the gap, below the gap but above orbital period minimum, and past orbital period minimum are in the ratio of 2 : 30 : 100 : 200, respectively (with substantial statistical uncertainty in the first of these). While these rates are model-dependent (especially in the choice of the initial mass ratio distribution in primordial binaries), they do provide the reader with a rough sense of the relative populations in the different phases of evolution. These numbers are in general agreement with other population synthesis studies of CVs (e.g., Kolb 1993). From these ratios, we conclude that there should be ~ 2 systems that we would associate with the TOADs for every CV with more classical properties. Second, we find that there is a clear trend in the maximum orbital period that can be attained in the post-period-minimum evolution during the history of our Galaxy, which depends on the assumed age of the Galaxy. Third, within the evolutionary sequences in Fig. 3 one can easily see two distinct sets of tracks above the period minimum, and perhaps three sets for systems below period minimum, especially among the oldest systems.

The most populous track is the one lying at the smallest values of $\dot{M}$ (for a given value of P_{orb}). These are the systems with low-mass He white dwarfs ($\lesssim 0.45\ M_\odot$)[1]. The track

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[1]The predicted existence of a significant population of CVs containing He white dwarfs is not new, and has been discussed in several previous studies (Politano 1988;1996; de Kool 1992; Kolb 1993). However, these studies did not focus on the post-minimum period systems,

with the next highest values of $\dot{M}$ are systems with CO white dwarfs ($\gtrsim$0.55 $M_\odot$) which started out with more massive donor stars ($\gtrsim$0.5 $M_\odot$) and evolved through the period gap in the manner shown in Fig. 2. Finally, the systems with the highest values of $\dot{M}$, and which reach the longest orbital periods, are systems with CO white dwarfs which started out with *less* massive donor stars ($\lesssim$0.3 $M_\odot$) in a relatively close orbit after the common envelope phase ($\lesssim$6 hours), and were thus able to form (come into Roche-lobe contact) below the period gap. These systems were thereby able to avoid the early part of the evolution shown in Fig. 2, (as were the systems with He white dwarfs). The systems which reach the longest orbital periods are therefore those (a) whose progenitor binaries were formed very early in the Galaxy's history, (b) that formed below the gap, relatively close to the orbital period minimum, and (c) that had relatively massive progenitor primaries so that both the time of white dwarf formation was short and the mass of the white dwarf is sufficient to allow gravitational radiation losses to be competitive with systems that evolved through the gap.

In order to quantify the end points of the evolution tracks shown in Fig. 3, we adopted the following statistical analysis. Our current sample of known TOADs is only $\sim$ 20. We therefore chose a random sample of 20 systems from our population synthesis results below orbital period minimum, and found both the longest orbital period and the minimum value of $\dot{M}$ in that sample. This was repeated 1000 times, and the distribution of $P_{orb,max}$ and $\dot{M}_{min}$ was constructed. From these distributions we determined the 95% confidence limits for $P_{orb,max}$ and $\dot{M}_{min}$ that are likely to be found in a sample of 20 low-luminosity CVs. (No weighting for observational selection effects was included; thus, our 95% confidence limits should be conservative, since the longest period systems should have the lowest luminosities.) We can represent how this maximum period and minimum $\dot{M}$ depend on t_G with the following simple fitting formulae:

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nor did they present $\dot{M}$-P_{orb} plots for their entire synthetic populations.

$$P_{\rm orb,max} \simeq 81 + 4.8\ (t_G/{\rm Gyr}) \qquad ({\rm min}) \tag{1}$$

$$\log_{10}(\dot{M}/M_\odot\ yr^{-1}) \simeq -11.3 - 0.080(t_G/{\rm Gyr}). \tag{2}$$

Finally, we caution that the use of equation (1) to set a constraint on the age of the Galaxy is based on the assumption that the only angular momentum loss mechanism in post-period-minimum CVs is that due to gravitational radiation. The existence of significant additional angular momentum loss mechanisms would obviously weaken the constraint set by eq. (1). In future work we plan to investigate systematically the modifications to eq. (1) that would result if, for example, magnetic braking does not cease when the donor star becomes completely convective. A preliminary set of evolution runs that we have carried out in this regard (i.e., continuous magnetic braking with parameters $\gamma = 4$ and f = 1) for a galactic age of 10 Gyr, yields a maximum orbital period of ~2.9 hours. This is to be compared with the value of 2.2 hours obtained from eq. (1). However, such continuous magnetic braking is at least inconsistent with the current conventional explanation for the period 'gap' in CVs between 2 and 3 hours. We also expect that future refinements to the population synthesis calculations described in this paper, that is, use of an improved stability criterion for rapid mass loss, inclusion of mass loss due to winds on the giant branches, and consideration of a pop II composition (in light of the extreme age of the longest period systems), may also affect the terminal values discussed here.

4. Discussion

The idea that TOADs may have very low mass transfer rates over long timescales seems fairly compelling and has motivated us to consider their association with CVs that have evolved past the orbital period minimum. However, a number of theoretical and observational uncertainties remain before such an association can be made unambiguously. We discuss the most significant of these uncertainties here.

First, we have assumed in this paper that the mass transfer rates inferred for the TOADs are a long-term phenomenon and furthermore that they represent time-averaged values of $\dot{M}$. Taking into account the high accretion rates that may occur during outburst along with the low $\dot{M}$ values that occur during the long interoutburst cycles, we recognize that the TOAD mean mass transfer rates may be different than those discussed here. Sproats et al. (1996) have shown, however, that for 3 or 4 TOADs with sufficient observational data to yield an indication of their recurrence time and outburst duration, the mean $\dot{M}$ values are not out of line with that expected for mass transfer driven by gravitational radiation alone. We emphasize here that the type of observational information used by Sproats et. al. is necessarily sparse since the needed long-term studies do not exist at all for many of the TOADs (see Howell et al. 1995). It is also possible that our limited "view" of the TOADs (i.e., during only the past 5-10 years) has indeed revealed systems with low $\dot{M}$ and low-luminosity, but these properties may be transitory and occur only on astrophysically short timescales.

Second, we also cannot be certain of the scaling of the $M_V - \dot{M}$ relations for the TOADs. As yet, no accretion disk models have been calculated for mass transfer rates lower than $\sim 10^{-11} M_\odot$ yr^{-1} and, as we mentioned above, our scaling is based only on an approximate empirical calibration. Howell et al. (1995) discussed accretion disk models which provided a good match to observational outburst data for the TOADs. However, as with all such models published to date, the lowest mass transfer rates used were $\sim 10^{-11} M_\odot$ yr^{-1}. If the M_V values of the TOADs are indeed even close to those shown in Figure 1, the mass transfer rates during minimum are much lower than 10^{-11} $M_\odot$ yr^{-1}, possibly lower than 10^{-12} $M_\odot$ yr^{-1}. At such low values of $\dot{M}$, one may consider that these systems would be permanently on the lower *stable* branch of the accretion disk limit cycle and outbursts could never occur. Cannizzo, Shafter, & Wheeler (1988), in their work on the accretion disk limit cycle and the relation between the local disk column density (Σ) and $\dot{M}$, show via analytic scaling arguments that the minimum $\dot{M}$ which can just produce outbursts is about $10^{-13}M_\odot$ yr^{-1}. Thus, while actual models at these low rates have not been produced (but are in progress), it appears that outbursts are still possible even at the low rates inferred for some of the TOADs (Cannizzo 1996). Studies of the TOADs during outburst and at minimum light are thus crucial to provide input for realistic accretion disk modeling using the very low $\dot{M}$ values.

Lastly, mass determinations of secondary stars in TOADs are essentially non-existent. This is due to the faintness of the TOADs, the existence of only one known partially eclipsing system (allowing a fair determination of the system inclination), and the fact that no spectral features from the secondary stars have been seen. Radial velocity studies using optical emission lines (from the accretion disks) have been performed for a few TOADs. However, when mass determinations have been attempted, they started with the usual assumptions of choosing a secondary radius (based on a *main-sequence* Roche-lobe filling secondary), assigning the secondary a mass (based on the same assumption), using the measured value of K_1 and guessing the orbital inclination to obtain a value for the mass ratio, and then finally solving for the primary mass. Thus, in these cases, the initial assumptions used to solve the problem nullified any efforts at determining the true secondary mass.

For the one partially eclipsing TOAD mentioned above, WZ Sge, a relatively direct determination of the secondary mass is possible. Smak (1993) found a value for M_2 of $0.06 \pm 0.02M_\odot$. WZ Sge has an orbital period of 81.6 min (near the bend in the elbow in

Fig 3), and its secondary star, if past the period minimum and degenerate, is predicted by the results presented here to have a mass near $0.06 M_{\odot}$. We note that it is also the case that the secondary star in WZ Sge would be predicted to have nearly this same mass even if still *approaching* the orbital period minimum near 80 min. We mention here that WZ Sge has been deduced to have a relatively high mass transfer rate from observations of the hot spot amplitude near the time of outbursts; however, Osaki (1994) and Howell et al. (1995) have shown that the long-term outburst behavior can be reproduced by use of a low mean mass transfer rate. WZ Sge represents a system in need of further detailed study due to its partially eclipsing nature. Further observational work is badly needed in order to determine secondary masses for the TOADs, particularly for systems with orbital periods further from the period minimum (e.g., $\gtrsim$ 100 min), where clear evidence for or against the brown dwarf-like nature of the secondary may be provided.

In spite of the above theoretical and observational uncertainties, it is nevertheless interesting to speculate about the association of TOADs with post-minimum-period CVs containing degenerate secondaries. If this idea is correct, it allows us to *(i)* confirm a number of our theoretical understandings concerning the evolution of CVs, *(ii)* augment our exploration of brown dwarfs, and *(iii)* derive an interesting constraint on the age of the Galaxy.

If the secondary stars in TOADs are indeed shown to be degenerates, then they would represent an interesting complement to studies of brown dwarfs in open clusters (where there is some age information), and those in wider binary orbits with nearby low-mass, high proper motion stars. For brown dwarfs in low-luminosity CVs, there is potentially valuable information to be gleaned about their properties: *(i)* the mass/radius relation obtained from the Roche lobe filling criterion; *(ii)* the possibility of measuring the mass directly if the system inclination and K_1 and K_2 can be determined; and *(iii)* age information (or limits thereon) that can be inferred from the evolutionary status of the binary (i.e., its orbital period).

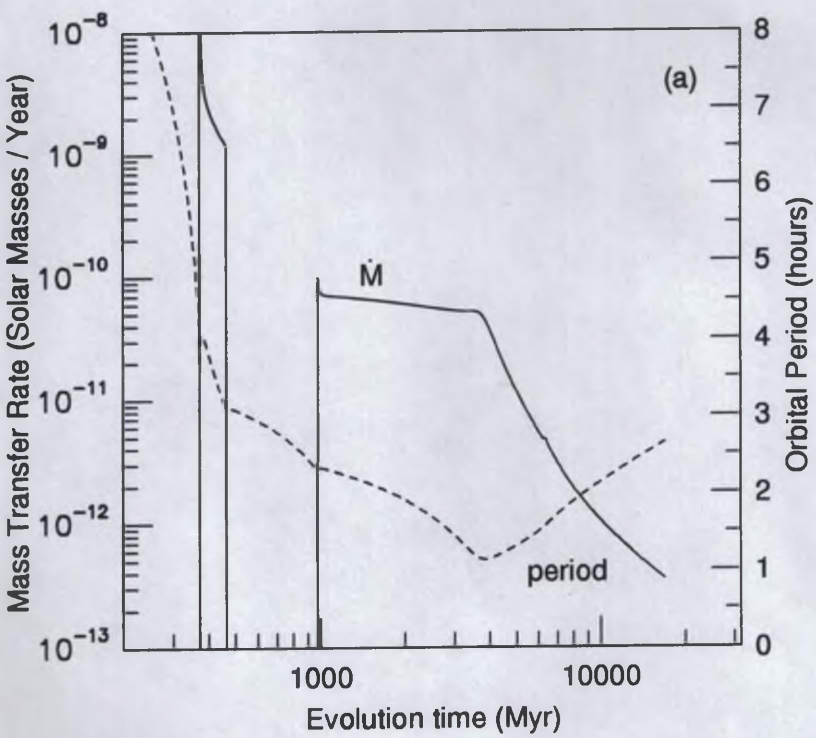
Finally, we return to the idea that the longest period TOADs may provide information about the age of the Galaxy. The TOAD with the longest known orbital period is EF Peg (P_{orb} = 123 min) and there are a number of others with periods near 110 min. The orbital period of EF Peg in conjunction with equation (1) provides a tentative lower limit to the age of the Galaxy of 8.6×10^9 yr. This corresponds to an upper limit to the Hubble constant of 76 km s^{-1} Mpc^{-1} for assumed values of the cosmological parameters $\Omega = 1$ and $\Lambda = 0$. The TOADs with orbital periods near 110 min yield less interesting limits on the age of the Galaxy of $\sim 6 \times 10^9$ yr. Clearly, a statistically enhanced orbital period distribution for TOADs would be of great interest in this regard.

5. Summary

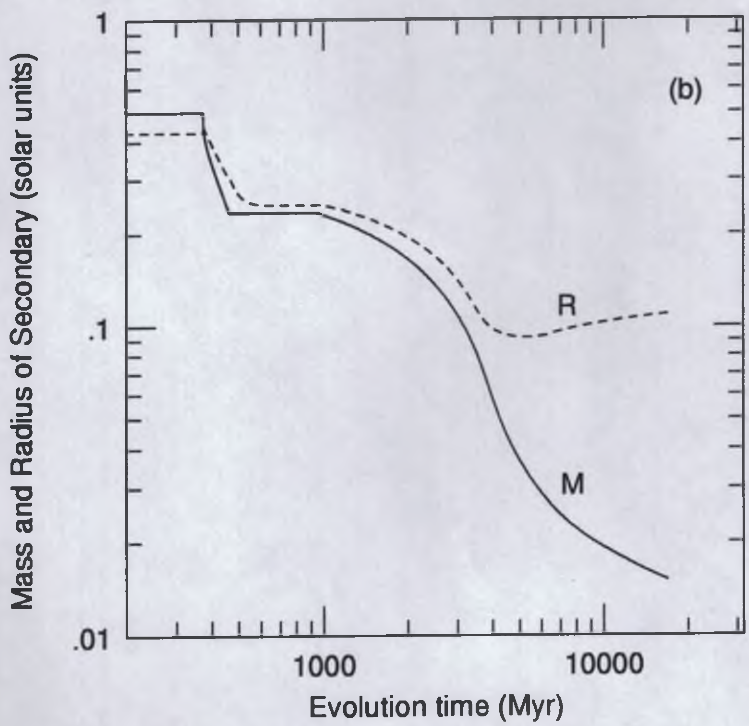
Theory predicts that, at the present epoch, $\sim$ 99% of all CVs should have orbital periods below the period gap. Of these, $\sim$ 70% should have already reached the period minimum near 80 min and be evolving back towards longer periods, the maximum of which is given by equation 1 above. These low-luminosity CVs are likely to contain degenerate secondaries of mass $\sim 0.02 - 0.06 M_\odot$ ($\sim 20 - 60$ Jupiter masses) and radii near $0.1 R_\odot$. Recognizing the uncertainties discussed above and the lack of detailed observational information for the low-luminosity dwarf novae presented in Figure 1, we have discussed the possibility that some of the TOADs may represent cataclysmic variables which are the oldest members of their class. As such, they would be the observational counterpart of the long sought after, theoretically-predicted systems containing degenerate (brown dwarf) secondaries. If this idea can be verified, the TOADs can be used to set an interesting constraint on the age of the Galaxy and provide an important complement to our knowledge of brown dwarfs.

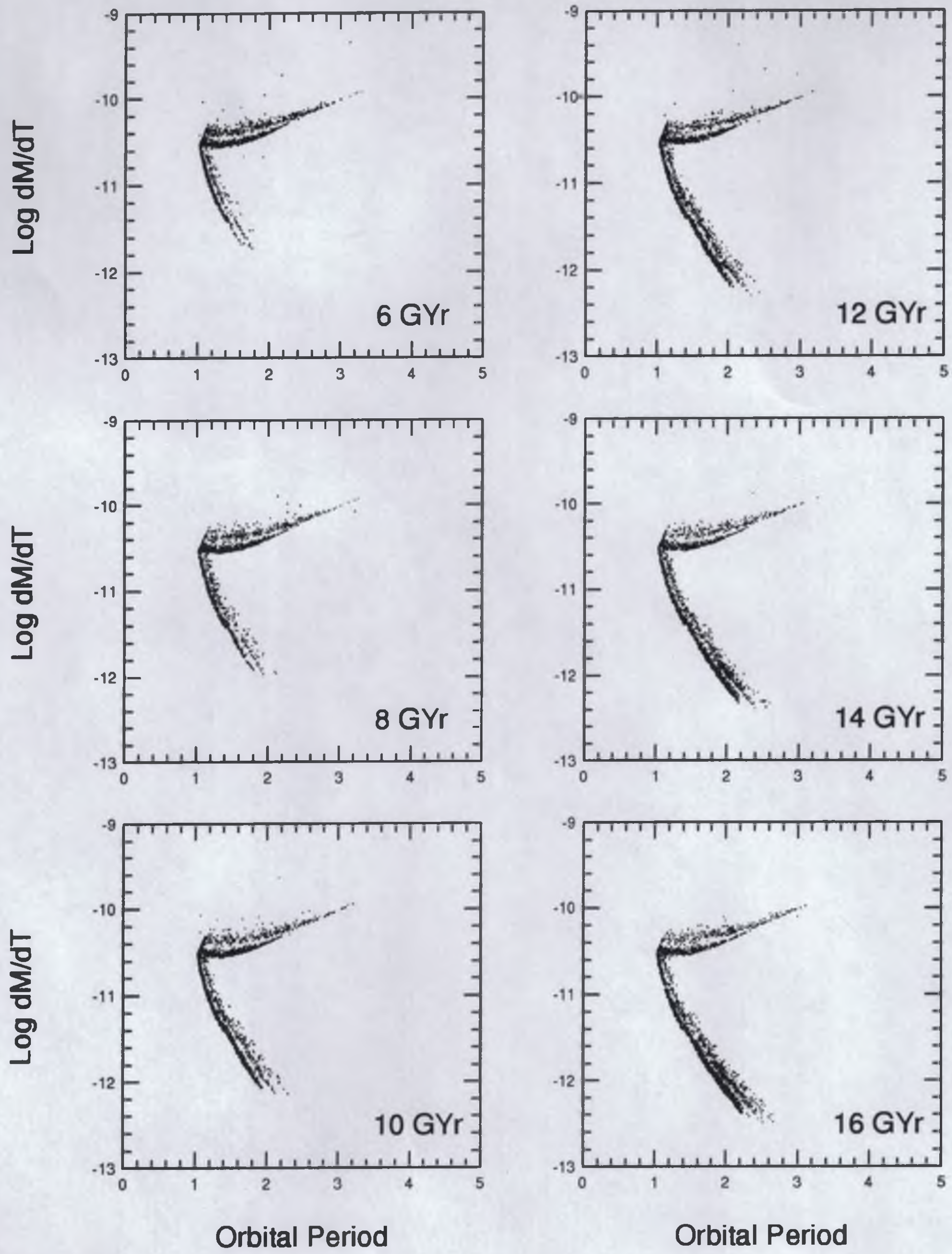
It is clear that further observations of low-luminosity CVs are needed. These should include observations at minimum light, during outburst, and over long temporal scales. The latter are needed in order to provide measures of the interoutburst timescale and the outburst durations for a much larger sample of TOADs, thus allowing better estimates of the overall $\dot{M}$ and M_V. These observations may also be expected to provide important and much needed inputs and constraints on theoretical models of the intrinsic CV population at short orbital periods.

The authors are grateful to J. Cannizzo, P. C. Joss, L. Nelson, and R. Webbink for helpful discussions. We thank C. M. Becker for invaluable assistance with the evolution code. We also wish to acknowledge the referee for several useful comments leading to an improved paper. This work was partially supported by NSF grant AST-921971 to SBH and NASA grants NAG5-2890 and NAG5-3011 to SAR.



Mass Transfer Rate (Solar Masses / Year)
Orbital Period (hours)
Evolution time (Myr)
(a)
Ṁ
period
10^−8
10^−9
10^−10
10^−11
10^−12
10^−13
1000
10000
0
1
2
3
4
5
6
7
8


1
.1
.01
1000
10000
Evolution time (Myr)
Mass and Radius of Secondary (solar units)
(b)
R
M


Log dM/dT
Orbital Period
6 GYr
8 GYr
10 GYr
12 GYr
14 GYr
16 GYr
-9
-10
-11
-12
-13
0
1
2
3
4
5

From owner-vsnet-alert@kusastro.kyoto-u.ac.jp Fri Apr 25 13:31:28 1997
From: "Rod Stubbings" <stubbo@sympac.com.au>
To: "Dr Frank Bateson" <varstar@voyager.co.nz>,
"Alert Vsnet" <vsnet-alert@kusastro.kyoto-u.ac.jp>
Subject: [vsnet-alert 861] Outbursts
Date: Sat, 26 Apr 1997 02:22:01 +1000

```
The following stars are in outburst.

TV Crv 20 April 1997 <12.8        Time(UT)     Mag.(Visual)
        25 April                    9:16            14.0
                                      9:39            13.7
                                     10:03            13.6
                                     10:26            13.6
                                     12:02            13.4
                                     12:19            13.4
                                     14.41            13.3

AG Hya 16 April 1997 <14.1
          25 April                   9:10            14.3
                                        9:36            14.3

BV Pup 20 April 1997 <14.1
          25 April                   9:30            13.7
                                        9:55            13.7

BX Pup 20 April 1997 <14.2
         25 April                    9:31            14.3
                                        9:56            14.3

CZ Ori 22 April 1997 <12.6
        25                             9:49            12.6

Rod Stubbings
Drouin,Victoria
Australia.
```

CROW JOKES AND PUNS

By Clyde W. Tombaugh

1. With whom does a crow associate?
2. Where do crows go to meet?
3. What do crows drink?
4. Who was the first man to see the crow?
5. Where does a crow keep his money?
6. What makes a crow black in color?
7. What games do crows play?
8. What kind of sewing doew Mrs. Crow do?
9. What do crows use to tell time?
10. When a crow goes beserk, what does he become?
11. What kind of flowers do they lay on a crow's coffin?
12. Where do crows hatch their eggs?
13. What do crow astronomers observe in the sun?
14. What to crows read?
15. What is the crow's most useful metal?
16. Who is the crow's favorite god?
17. What do crows like to eat?
18. To what culture does a crow belong?

ANSWERS TO CROW JOKES

1. His cronies
2. In a "crow bar"
3. Old Crow
4. Cro-magnon man
5. In escrow
6. Their chromosomes
7. Croquet
8. Crochet
9. Chronometer
10. A raven maniac
11. Crocus
12. In a crows nest
13. The chromosphere
14. The rookery chronicle
15. Chromium
16. Crocus
17. Corquettes
18. Croatian

7 April 1960

Mr. Wallace B. Alig
"The Separate"
Millbrook, Dutchess County
New York

Dear Mr. Alig:

Your letter of 15 March is in hand. I am returning the answered questionaire. Also, enclosed is a photograph of me examining planet search plates at the Blink-Microscope comparator, taken in April, 1938, when I was 32 years old. This is a typical manner in which I worked at this instrument (7000 hours of it), except that I am raising the eyepiece on the vertical transport to the next horizontal strip to view with my right hand. Then the work will be successive scanning of views along a horizontal direction for 15 minutes to an hour, and that handwheel I operated with my left hand.

You may not get much of an enthusiastic cooperation for your quest because considerable jealousy arose out of my success in finding the planet — even though it was my assigned task. This is confidential — for your own understanding of what may develop or may not develop. Such things frequently happen in small research groups of people, especially if the place of work is somewhat isolated. Then later, my own observations and interpretations of Mars clashed with Lowell's traditional views, and that did not help matters, either.

Sincerely yours,

CLYDE W. TOMBAUGH
Astronomer

Encls:
CWT/ jr

David Levy
Comet Chaser

For Patsy Tombaugh -
Here's some stuff!

Love
David + Wendee

Impeach Pluto? Say it ain't so

Halifax Chronicle-Herald Jan. 21/99

"Do I dare disturb the universe?"

T.S. Eliot posed the question in his intriguing poem, The Love Song of J. Alfred Prufrock.

And now scientists with the International Astronomical Union are answering the question — and the answer is apparently yes.

News that Pluto, the ninth rock from the sun, might be, well, impeached as an official planet is disturbing to those of us who grew up with a certain comfortable view of the solar system. Some scientists want to reclassify the erratic body as a "minor planet," take away its name and give it the number 10,000. Others want it lumped in with a new class of ice balls beyond the orbit of Neptune. Pluto, whose elliptical orbit often brings it closer to the sun than Neptune, would become Trans-Neptunian Object No. 1.

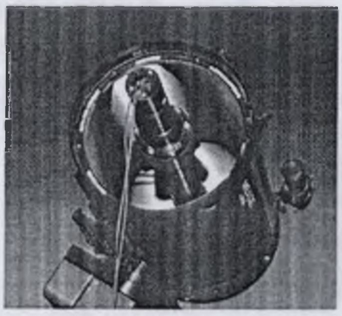
Implausibly, astronomer Brian Marsden argues that taking away Pluto's identity and issuing it a number instead is not a demotion. "It's an honour." Oh yeah? Who's he kidding? How would he like to be referred to as Astronomer #17 from now on?

Pluto — no matter its strange behaviour or small size — should be left alone. The planet, discovered in 1930, is now a part of our culture. Pluto is the god of the underworld. Pluto is Mickey's dog. Pluto is much more fun with a name. So please, folks, don't start taking the romance out of science.

N
M88
4459
4477
4473
Markarian's Chain
4461
The Eyes
4435
4438
M86
M84
M87
November 13 UT, 2005
Obadiah 30 seconds nf
David H. Levy

REMOTE SKY IMAGING INSTRUCTIONS

For Obadiah.



Mercy College has access to a moderate-sized telescope located in southern Arizona. See photo on left. Thanks to the generosity of the National Sharing the Sky Foundation and David Levy, students are able to log into this remote telescope and take pictures with it! Instructions follow.

1. **Make an appointment** with Prof. Levy. The time must be during the evening hours-- between 10 pm and 2 am Eastern Daylight Time, or between 9 pm and midnight when we go back to Eastern Standard Time. To do that you may send him a message through the course mail or write to him at observe@jarnac.org.

2. **Please be on time**. You will be assigned a "time window" during which you may take your observation.

3. **Log into the telescope's website using the following information:**

   - Type
     ~~*http://70.57.225.91:1160*~~ 70.57.225.91:1170
     into the address (URL) line of your browser

   - Enter the following login information
     login name (all lowercase letters): ~~flaire~~ obadiah.
     password: sharingthesky

The rest should be self-explanatory. Read the instructions on the website, and keep to the default values for exposure time, etc. at first. Prof. Levy will be watching and able to help. If you get into trouble, you can call him at 520-762-5685.

Please be careful not to choose objects that force the telescope to go to low. We don't want to push the poor telescope into the floor!

Good luck! And congratulations to Mercy for winning the use of this wonderful telescope!

Telescope Name: Flaire ... a Meade 14-inch Schmidt-Cassegrain fitted with a Starizona hyperstar lens which affords wide field images

THE GLOBE AND MAIL

January 20, 2012

A lifetime pressed to a telescope building an archive of epic discoveries

By INGRID PERITZ
From Saturday's Globe and Mail

David Levy, discoverer of the 20th century's most celebrated comet, is being honoured for a half century spent studying the skies, Ingrid Peritz reports.

The 11-year-old boy stood on a slope of Montreal's Mount Royal and gazed in wonder at the spectacular sight in the heavens above: The moon hovering over a sliver of the daytime sun, causing an eclipse.

Others might have just stored the memory away. But the shy boy, David Levy, decided to jot down the celestial show in his chunky schoolboy's writing.

"Partial Solar Eclipse. Just last part observed because of clouds."

The anodyne observation in 1959 became entry No. 1 and the start of a lifetime's obsession. Over the course of half a century, Mr. Levy grew from mildly autistic boy to man and followed up with more than 16,000 entries about sightings from novas to meteor storms; made discoveries of a near-record 23 comets, notably Comet Shoemaker-Levy 9 that smashed into Jupiter in 1994 in the cosmic event of the 20th century; and become one of the most famous amateur astronomers in the world.

His is a life spent pressed to a telescope eyepiece, at hours when most people are sanely asleep, in thrall to the mysteries in the darkened vault above. And now, his entire observation archive has been posted online by the Royal Astronomical Society of Canada, the first such recognition for any Canadian astronomer.

"If you don't write it down then you're not observing," Mr. Levy said from his home near Tucson this week, after coming in from his backyard observatory to prepare entry No. 16,449 in his logbook.

"This," he says of his 23-volume archive, "just gives a sense of what one man's passion has led to, session by session, night by night."

There is sweet irony in the society choosing Mr. Levy for the honour. When he was 19, he ran afoul of brass with the organization, an august group granted its royal charter by King Edward VII. There was a dispute over a piece of equipment and a senior member in Montreal chewed him out.

"He told me I was *persona non-grata* and I would never amount to anything," Mr. Levy recalls.

He thought about abandoning astronomy but changed his mind, and went on exploring and discovering and writing it all down in his logs. The scribblings shape the legacy of an explorer of the cosmos: planets, constellations, eclipses, sunspots, moon craters, rainbows and solar halos, it's all in there. There's some poetry ("stars resembling friendly beacons in a lonely night"), pencil sketches of planets, shared observations from stargazing friends like the late Clyde Tombaugh, discoverer of Pluto. Most of it, however, consists of routine and methodical annotations.

Nothing motivated Mr. Levy or gave him as much notoriety as his hunt for comets, those wisps of light in the night sky that are the "Holy Grail for amateur astronomers," he says. The pursuit began as a teenager when, searching for an easy-to-say phrase for an upcoming Grade 10 French oral at Westmount High School, he proclaimed, "*Je veux découvrir une comète*."

He succeeded, though it took him 19 years - 928 hours, 17 minutes to be exact; astronomy does not reward the impatient. Still, no comet would impact so significantly on his life than the one he co-discovered in 1993 with Eugene and Carolyn Shoemaker. Its collision with Jupiter in July the following year was dubbed "the biggest explosion ever witnessed in the solar system" by Time magazine. There were U.S. network talk shows, magazine covers, and a visit to the White House under former president Bill Clinton, though Mr. Levy says it was vice-president Al Gore who asked all the probing questions.

"It was as if the comet grabbed the three of us," he says of himself and the Shoemakers, "and took us into orbit with it for a couple of years."

It was quite a feat for someone who failed undergraduate physics at McGill University and bypassed science for degrees in English literature at Acadia and Queen's universities, evidence that astronomy remains one of the few fields of science where amateurs can make a difference.

"You can't be an amateur surgeon," the 63-year-old Mr. Levy said, "but you can be an amateur astronomer and accomplish a lot of things."

Roy Bishop, a past president of the Royal Astronomical Society of Canada who has known Mr. Levy for more than 40 years, calls him "the most remarkable amateur astronomer of the modern era."

"He's not only enthusiastic and dedicated but obviously has innate talent," said Mr. Bishop, professor emeritus of physics at Acadia.

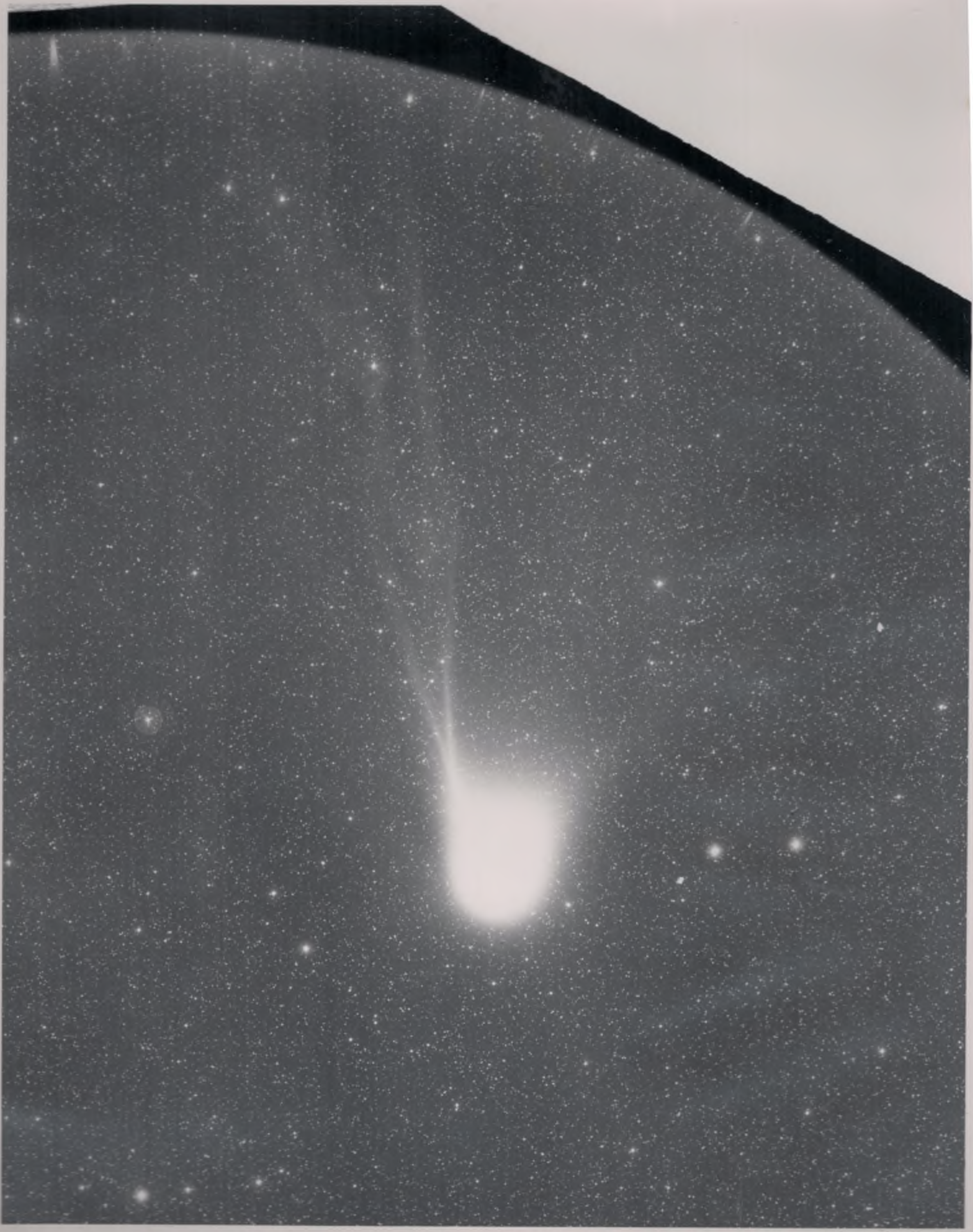
Mr. Levy, who has authored 35 books, did his PhD on "Allusions to Celestial Events" in early modern English literature, and collected honorary doctorates from five universities (including McGill, from which he dropped out after two years), still lives in anticipation of what he might find in the velvet-black sky.

In entry No. 15,489 in his logbooks, he records a stargazing session in which the Milky Way, star clusters and three meteors light up the sky. "One of the finest nights I've ever seen," he writes. "If I were to die tomorrow, I'd have not lived better because I had this night."

It's all in the logbooks, along with hundreds of pages of observations and discoveries, there to be perused by 11-year-old boys and girls who might gaze up at the sky, and wonder.

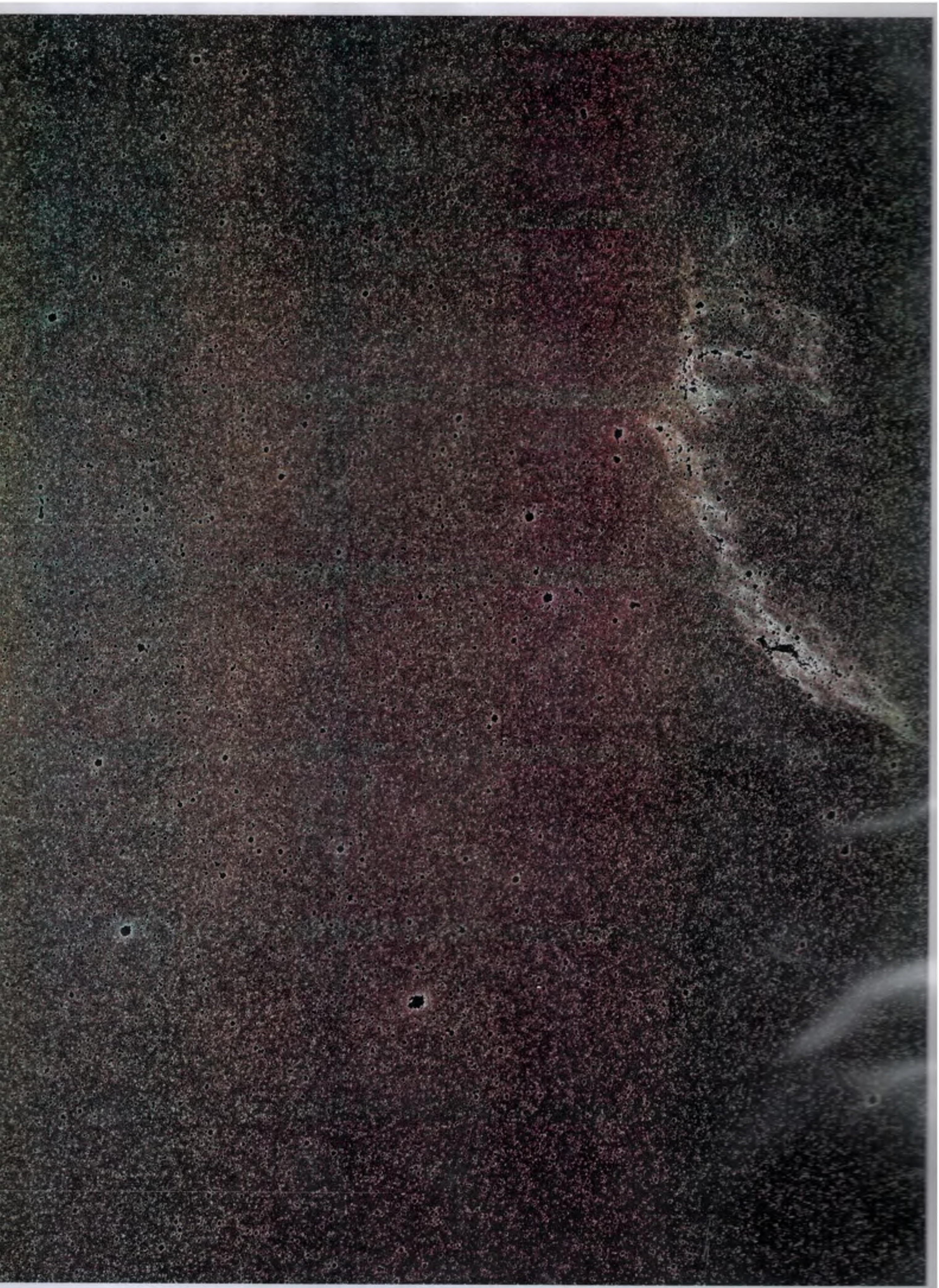
Form 1120S (2013) [redacted], INC. [redacted] Page 5

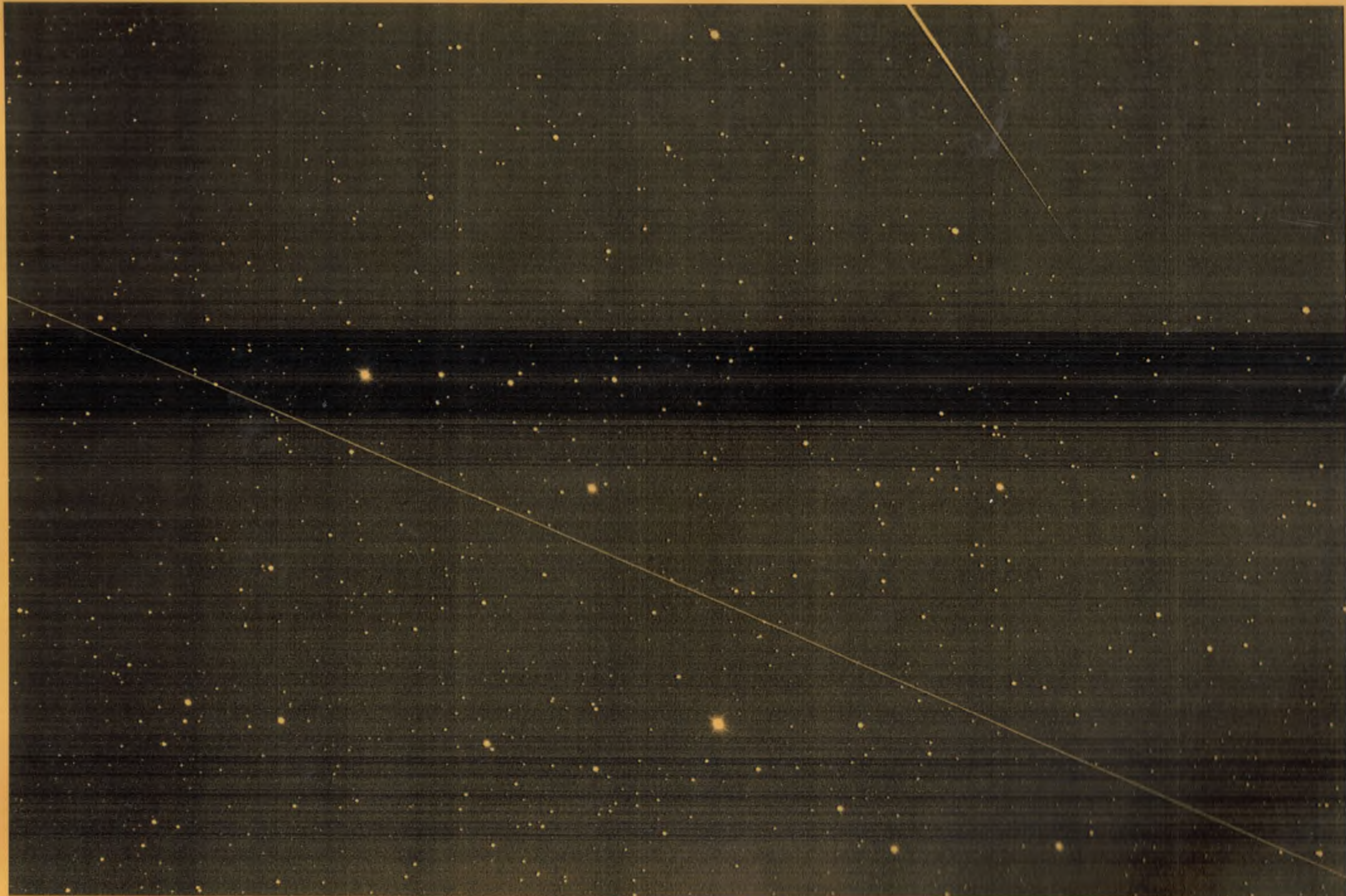
Schedule M-1 Reconciliation of Income (Loss) per Books With Income (Loss) per Return



Detail from the 13-inch Lawrence Lowell Astrograph plate of January 10, 1931. "Comet 1931 AN," discovered by Tombaugh, is in the center.

M20 CN3E 2012 01 23 Obadiah



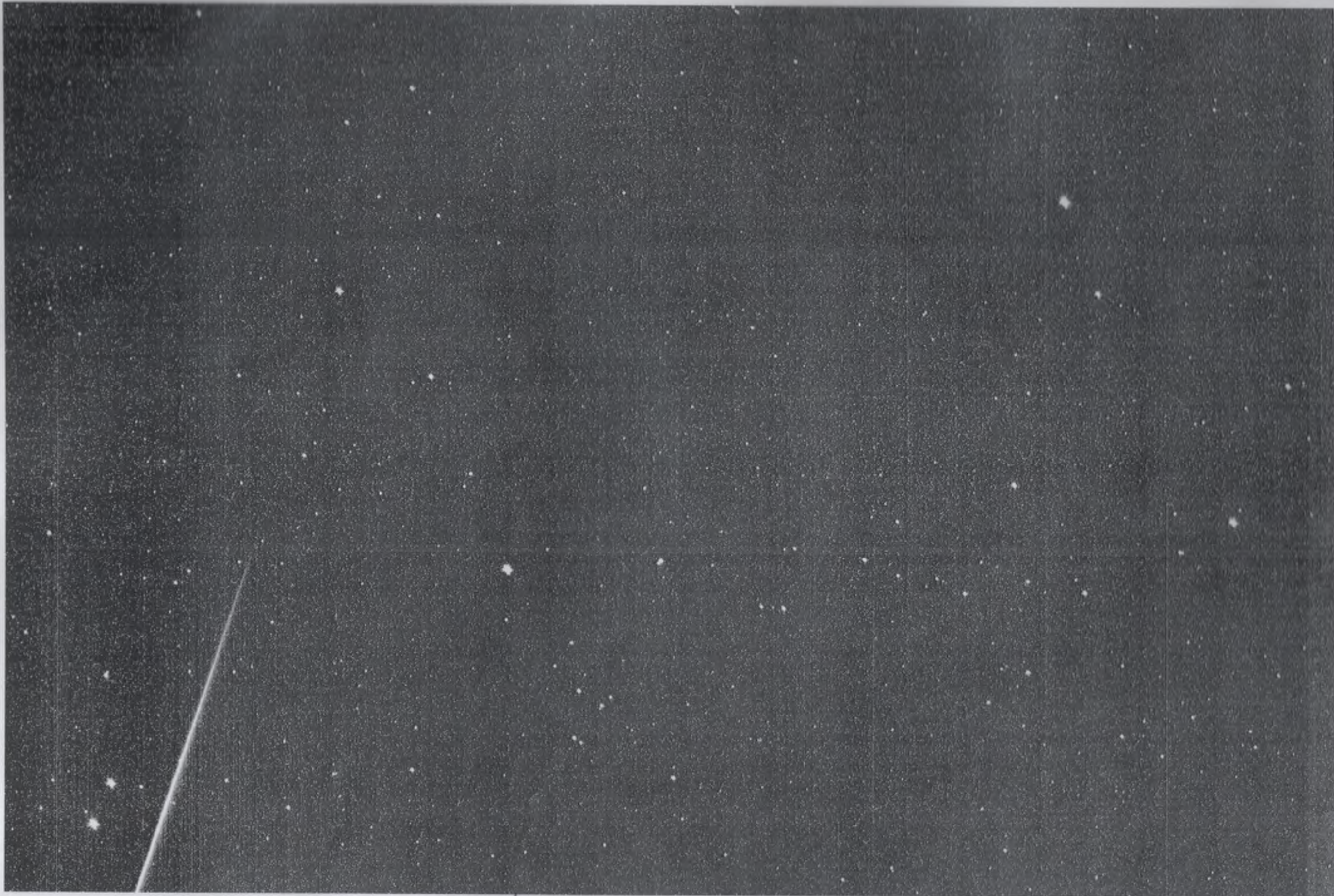


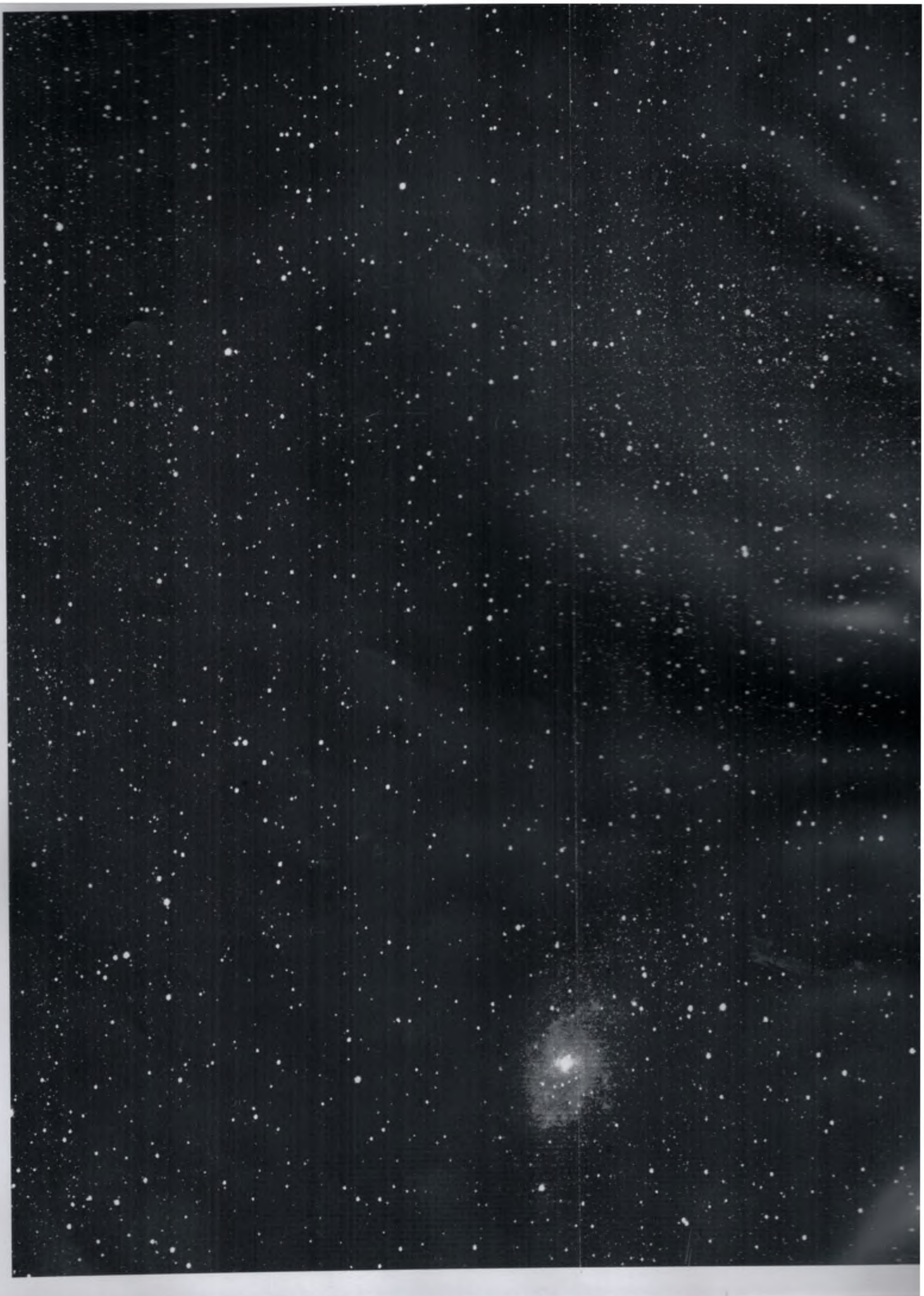
CN3F bright η Aquarid Olodich May 5 2011


CWBF
24 August 2011
Cloud

Probable Meteor upside down.

Feb2 2012 GN3F M20 ~~late~~ early February 2012





C N3F Comet Panstarrs with Olmdich 2013 04 [illegible]

AMERICAN ASTRONOMICAL SOCIETY

165th MEETING
January 13-16, 1985
Tucson, Arizona

14 January 19

To Whom It May Concern:

I am happy to introduce M
David H. Levy of Tucson, Ariz
who is writing my biograph
I have agreed with him tha
he will be my exclusive
biographer and I have offe
him full assistance in the
undertaking. I have know
him for many years and
consider him an excellent cho
for the job. My own life
been dominated with astronom
observing, which David Lev
understands well from experien
I like his style of writing
his willingness for
accuracy.

Sincerely
Clyde W. Tombaugh

The University of A
One Hundr Yea 18
1985
A Proud Beg

Search

User lo

About Us Community Variable Stars Observing Data Getting Started

Home Contact Us FAQ Donate Amazon

Home

The Trapezium, BM Orionis, and Young Stellar Objects

Don't forget about the online talk TODAY, Wednesday April 4 at 3pm eastern (19UT). Our special gues Robert Naeye, editor-in-chief of Sky & Telescope magazine.

Just over one year ago, a small spacecraft called *MOST* began a month-long observing run on one of tl spectacular objects in Earth's skies, the beautiful Trapezium region at the heart of the Orion Nebula, M collaborators and I applied for and received this observing time to survey variability in this young stellar c partly to study the eclipsing binary BM Ori (theta 01 Orionis B), but also to survey as many young stars that v able to using the unique capabilities of MOST. Since then, I along with my collaborators -- our Director Arne Bill Herbst of Wesleyan University, and Joyce Guzik of Los Alamos National Laboratory -- have been wc reduce and analyze these data to study variability in the Trapezium, and the bulk of our work is now rea conclusion. The resulting data provide a fascinating look at young stellar variability, and a tantalizing hint long-term, intensive observations might reveal. In the April 2012 Variable Star of the Season, I'll be talking a project to observe the Trapezium region and the variability of Young Stellar Objects that makes them so inter astronomers, amateur and professional alike.

Much of this article was written in January of this year, while I was on an airplane headed to the A Astronomical Society Meeting in Austin, Texas to present our work. It provided me with some much-needed f and perspective to write an overview of what we did, what we found, and most importantly, why we were look

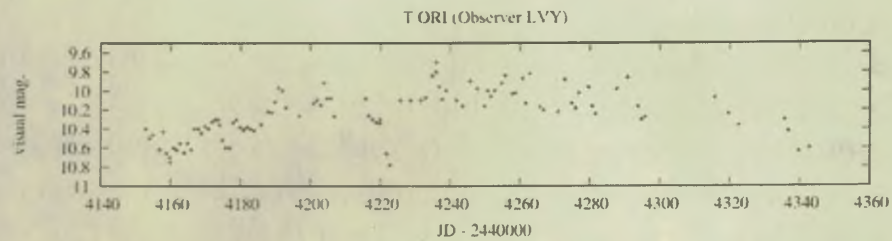
Star formation and young open clusters

Stars form in groups out of large clouds of gas and dust that fragment and collapse into individual stars. Th of how exactly this process stars and proceeds is still being disentangled, but we know that when star clust form, the objects that form have a well-defined distribution of stellar masses called an initial mass function. cluster will be made of a few very massive stars, and increasing numbers of lower-mass stars, eventually fc great many low-mass stars. Young clusters will appear very bright because of the massive, luminous, and sh stars, but as the cluster gets progressively older, these massive stars die, leaving the rest of the clust

("I" for irregular, and "N" for association with a nebula). Among the variables are several likely T Tauri star with other interesting young stars like the FU Orionis (FUOR) and UX Orionis (UXOR) variables, and young, rotating spotted stars. Stars in the process of forming -- those that are still accreting matter from surı nebulae -- are often variable because of this accretion process. Just as accretion powers variability in catε variables, so too it can lead to variability in young stars as well. In these cases, the mass donor is the star nebula itself rather than a secondary donor star. Stars can flare due to changes in the accretion rate, or ins in the accretion disk. This is the cause of the bright state in the FUORs. The T Tauri stars and the FUC powered by accretion, but the difference is the accretion rate: a T Tauri might accrete 10^{-7} solar masses per y in FUORs, this can temporarily exceed 10^{-4}, creating both the bright disk and boundary layer and a powerfı wind. Young stars can also flare because of magnetic activity, since young stars are frequently ver magnetized and have rotation rates much faster than the Sun. Rapidly changing morphology of star spots (rise to complex light curves when the star rotates. Finally, some stars also have irregular fades, due obscuration events. They're embedded in nebular material, and so are often obscured by the very same dus that they're accreting. This is how the UXORs vary. [*Note: for more on the UXOR class, read Dr. Laszlo Kis: on RR Tau.*]

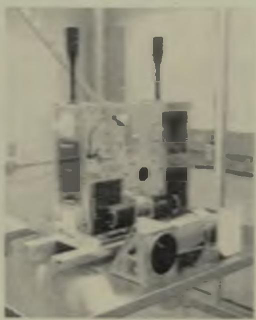
It's not a given that a star in the field is necessarily a cluster member, but past work that examined the motions of stars in the field suggested that a number of prominent named variables (like T Ori) are indeed m of the same parent population as the Trapezium. Any variable can tell you something about itself thr variability, but a bona fide cluster member will also tell you something about the cluster too. That's why var clusters are important topics of study.

Although we've recently begun requesting more intensive observations of several YSOs, young stars ha targets of the AAVSO for a long time. One of the most famous of these is T Tauri itself -- namesake of the stars, and for which we now have observations dating back to the mid 19th Century. This famous star outside the Orion nebula, but it is a part of the larger Taurus-Aurigae star forming region. Another famous s *does* lie near the Trapezium is T Orionis, a star that undergoes much more rapid variations than do typical stars. Its variations are hard to understand unless you spend a lot of time looking at them carefully, whic observers have done in the past. As an example, the light curve below shows half-day averages o observations by David Levy during the 1979-1980 observing season. It's clear that the star shows wild da variations. Understanding such variations is doubly challenging -- do you have enough data to catch al variations, and if you do, what causes them?



As with several other classes of rapidly-varying stars, the trick is to obtain as continuous a record of data possibly can, with both rapid cadence and long-time spans of coverage. That's impossible for a single-site c to do, and very challenging for even a well-organized network of observers. But, what if you had an oppor observe such targets with a single telescope 24 hours a day for days at a time?

MOST: little satellite, big light curves



MOST stands for **M**icro-**O**scillations of **ST**ars. It's a satellite about the size of a large launched into low Earth orbit in 2003 by a Canadian-led consortium of astronomers in in stellar pulsation and other kinds of stellar variability. MOST orbits the Earth abc every 91 minutes, and if the objects are in the right part of the sky given the Sun ar constraints, MOST can observe continuously, all day, every day, for months at a ti doing so, researchers can obtain a continuous span of data without having to deal daily data gaps that single-site, ground-based observations face. This can greatly a detection of weak, periodic signals as might be caused by pulsations in a distant star.

MOST was designed from the start to do continuous photometry -- and only continuous photometry. There filter wheels and there is only a single camera with a 15-cm telescope. It is, for the most part, a flying tel with only the bare minimum of onboard instrumentation required for power, flight control, and communicatio the years, MOST has observed a number of other stars, among them pulsators across the HR diagram, along number of other kinds of variable stars. Although MOST is primarily a Canadian project, the United States p some annual support and funding for the spacecraft operations in exchange for a limited amount of time spacecraft. Observing time was then awarded competitively through NASA's grant-making program.

In late 2009, we applied for time to observe BM Ori, the Trapezium, and around 50 more variables w half-degree field of view around BM Ori. Although the project was focused squarely on BM Ori, we were h learn more about variable stars in the Orion star forming region, including both young stellar objects and other variables -- especially young pulsators like delta Scuti stars. Individual variable stars can tell you something a physics behind that individual star, but a large sample of co-evolving variable stars with similar chemical comp and ages would be a really great way to expand our knowledge of this particular cluster.

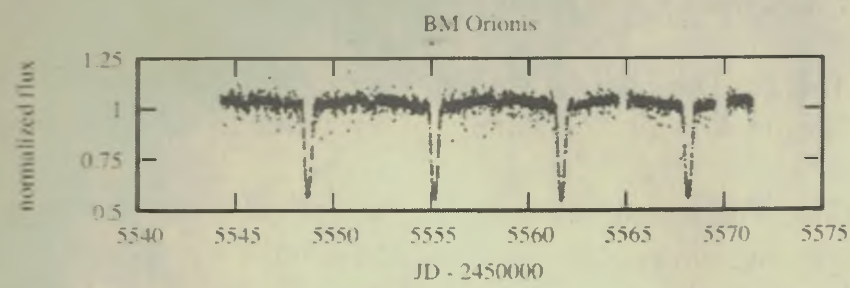
We were notified that we'd been granted time in April 2010, and the observations were made in late Dece 2010 into mid-January of 2011. We received our light curves in May 2011, and have since been working to the data and understand the variability that we see. We have data for 37 stars, measured once every 30 s **for over 27 days**. Aside from short gaps in coverage once per orbit, the light curves are nearly unbroke entire month. I show a few light curves from MOST in the next section.

The data from MOST are very exciting, but reduction of the data has been challenging, mainly because of signals from scattered light from the Earth and Moon. The spacecraft design is such that it is sensitive to light, and there are also light leaks that lead to transient signals. Further, since there are so many observat star -- over 35,000 observations per light curve -- we've been working with the automated pipeline photometr than the image frames themselves, and then working backwards to try and remove these "image defects" f photometry. Much of our upcoming paper on these observations will be devoted to how we dealt with many signals, while future papers will deal with particularly important individual stars. It's been a challenging projec the end all that work paid off, and we've succeeded in producing a wonderful new data set for these stars, some of the remarkable variations that young stars undergo. We don't think we found conclusive evidence of p (yet), but we have found more than a dozen stars showing all kinds of variability, and we hope to use this info to tell us more about star formation in M42, and the young lives of the stars that it is making.

Along with the MOST data, we also have ground-based data that we're working on, since AAVSO observers p observations for the campaign announced in Alert Notice 427. We're in the process of interpreting those dat with both the MOST photometry and photometry from AAVSOnet's Bright Star Monitor. We present some results below.

BM Ori

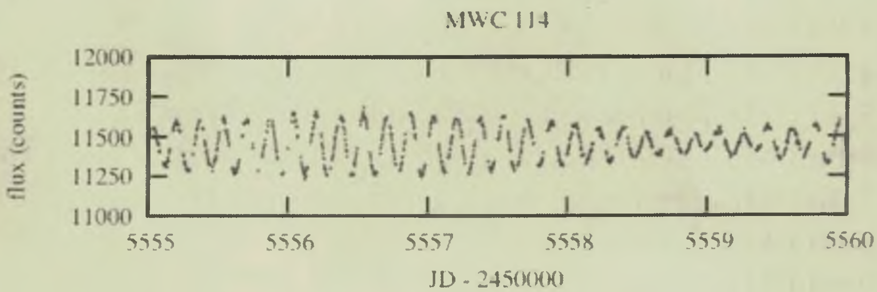
MOST provided us with four light curves of stars in the central Trapezium, theta 01 Ori A, B, C, and D. Of t only that of theta 01 Ori B, BM Orionis, shows clear evidence of intrinsic variability. Eclipses of the prim clearly visible, and a secondary eclipse is also apparent. Like many eclipsing binaries, there's also a clear r component present, where light from the primary reflects off of the secondary, meaning that the light curve va of eclipse as well as in eclipse itself. Bill Herbst at Wesleyan has been observing BM Ori and other youn objects for many years, and he and his students are leading the analysis of this star. What he's found s intriguing. The duration of totality of the primarily eclipse has changed since the last time-series observatio made nearly two decades ago. This strongly suggests that the orbit of the stars about one another is changin



While we're doing a large survey paper discussing all of the observations, we're also working on a separat just on the BM Ori results. There have been many speculations as to what BM Orionis really is -- simila speculation surrounding epsilon Aurigae -- and we're hopeful that our analysis of the light curve will clarify happening in this very, very young binary star. I'll talk more about our results on this star in a future article c work is done.

MWC 114, a rapidly-varying Be-star

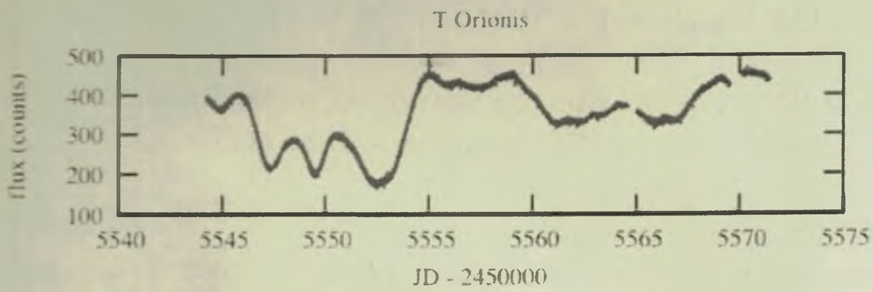
One of the most fascinating serendipitous discoveries in our data set was the detection of multiperiodicity in MWC 114. Although it was already known to be a Be-star, it was only a suspected variable until now. The light curve for this star is truly remarkable, showing clear evidence of rapid multiperiodic variations. These va are at the level of about 0.01 magnitude in brightness, with a cluster of periods around four hours. The light beautiful to look at; it shows the unmistakable signature of multiple modes, a beat pattern where the amplituc primary variation is modulated over the span of several days.



We haven't yet determined what is causing the variations. They're very reminiscent of pulsations, and B s known to pulsate. However, Be-stars are known to be rapidly rotating, very close to the breakup velocity. Th rotation is the source of the disks and mass loss that characterize these stars. Rotational frequencies of 3-(per day would yield a rotation rate near the Keplerian breakup velocity for something the size of a Be-star. frequencies come about from the star itself, or the disk, or an interaction between the two? We don't yet kr we hope to understand this beautiful light curve better very soon.

T Orionis

Earlier I highlighted past observations of the star T Ori, and showed a single season of visual data. The vis proved that T Ori is indeed highly variable, but the MOST light curve really drives the point home. It nev constant, but changes constantly, continuously, and (apparently) smoothly, at least over the 27 days that we o with MOST.



These variations are similar in both magnitude and timing to what AAVSO observers have seen over the past years that we've been monitoring this star, and it is clear that T Ori and other stars like it never stop varying, on the timescales that we observe them. There are some tantalizing hints of coherence -- perhaps sc quasiperiodic -- but during this "short" stretch of only 27 days, its clear that T Ori has a lot going on, and a s search for short period variability showed nothing periodic or quasiperiodic. It's tantalizing to think what a stretch of data might tell us about T Ori and other similar stars, but that will be a job for a network of groun observers -- like you!

Other variables and variability

One disappointment we've had thus far with the data is that there's little evidence for pulsational variability an sample. Other than MWC 114 (which is very exciting), only one star showed faint evidence for pulsation single period, and even that one star only shows a single weak period. Given the power that multiperiodic p can have for telling us about the interior structure and composition of stars, we were hoping to find more. digging more deeply into our reduced data to search for very low-amplitude pulsations in some of our consta and even without pulsators, we have a fascinating sample of young stellar variables.

There are several other stars that show irregular variations like T Ori, including MX Ori, NV Ori, V361 Ori, V V566 Ori, V2149 Ori, and NSV 2184. The data show that their variations are irregular, rapid and large, all c occurrences among YSO variables. Such stars mainly vary due to rapid changes in either the disk around the the circumstellar environment. The stars can brighten rapidly if the the accretion rate around the star increa some reason, or if the star briefly peeks through any dust clouds that orbit around it; they can fade for preci opposite reason -- often due to obscuration by dust, or by temporary decreases in the accretion rate.

Along with the irregular variables there are a handful of stars showing periodic or quasiperiodic variation eclipsing binary BM Ori and the Be-star MWC 114 are certainly the most obvious, but there are a number c amplitude variables mixed in. Most are likely to be rotating stars of some kind, with periods on the order c days. These include V1232 Ori, AN Ori, and two other stars not previously known to be variable. All four show quasiperiodic variations of between 5 and 20 percent. Their variations seem stable in period, but it's cl light curve shapes change from cycle to cycle, suggestive of rotating stars with changing starspot patterns.

periodic star is LP Ori, a star of early spectral type (B1.5) with a period around four hours but much lower a than is seen in MWC 114. It's hard to tell by looking at the data that it is varying, but both Fourier ana autocorrelation show a single, low-amplitude signal (much less than 1% in amplitude, but very coherent). Th another star that we're looking at more closely to try and understand how and why it's varying.

AAVSO participation

In Alert Notice 427, we requested observations of a number of targets in and around the Orion Nebula, some interesting variables outside of Orion, like RY Tau and RW Aurigae. We received observations of 1 MOST sample, along with an uptick in the number of observations of stars in the wider field like T Tau. instrumental observers have added these stars to their observing queues as well, and we're starting to se V-band light curves along with the visual data. Our first priority was to use the AAVSO community data t magnitudes colors and provide a basic flux-to-magnitude calibration for the MOST data, which we've now don soon be looking more deeply at the AAVSO data for these stars to see what other science is possible u community data.

We also have some Bright Star Monitor photometry that remains to be reduced -- they were already proces subsequent analysis showed that there was a stray low-amplitude variable among the comparison star en Arne Henden and I will be working together identify it and reanalyze the images; once we do, all of t photometry will enter the AID for community use. Getting a stray variable comparison star wasn't an e surprising development. Mike Simonsen had to be very careful in setting up new sequences for star Trapezium region when he did so back in early 2010, since it's very hard to find non-variable stars of app color in the field. Our sequences for this region are now better than they've ever been, but even so we ha careful with these data. All of this will need to be taken into account when the AAVSO data are analyzed in th

More Young Stellar Object Science

The past few years have brought several new campaigns and programs to AAVSO observers, and our proj MOST is just one of them. In 2010, Dr. Colin Aspin requested observations of two YSOs that entered activ that year, the stars V2492 Cyg (= VSX J205126.1+440523) and V2493 Cyg (= HBC 722), and observations stars are requested through the end of 2012 at least. More recently, Dr. Hans Moritz Guenther of Smithsonian Center for Astrophysics requested observations of SU Aur and AB Aur in support of his su XMM-Newton observing run in mid-February 2012. We're hoping that these successful campaigns will lead collaborations with the YSO research community, providing a new avenue for AAVSO observers to partic cutting-edge research. The AAVSO archives also continue to be a rich source of research projects, with Percy publishing new analyses of many long-term light curves of T Tauri stars with his students. There are so Pro-Am observing programs coming up in the next few seasons, and we look forward to announcing ther AAVSO community when their programs are finalized.

More importantly than these specific campaigns however is the new *community* initiative on these fascinating stars. Observer Michael Poxon recently launched the Young Stellar Object Section for the observer co geared to support observers interested in pursuing YSOs. The section is off to a very active start and h drawn support from the professional research community -- Drs. Colin Aspin and William Herbst (the latter a our MOST project) have been providing suggestions and scientific justifications for new observing projects, as giving important background on the astrophysics of these important stars. We're thrilled to see this new s operation, and we encourage observers looking for new and exciting ways to participate in science to conside in your observing planning. Be sure to stop by the YSO forum, too!

As for the MOST project itself, one of the clear results that is already apparent is how challenging the YSO observe, since many show little or no predictability. However, they also provide interesting new avenues for a interested in carving out a unique niche for themselves. As an example, there is little calibrated, multicolor lc photometry for many of these sources. While single-filter or visual observations are useful for learning *how* sta multicolor photometry can begin to tell you *why* they vary. We know some of the mechanisms involved, bu little knowledge of individual stars, and a surprising number of objects have little or no detailed observationa that would give a clue as to what they might be. And given that we found two new variables from a continuous monitoring, careful photometry of stars in this region may reveal more new variables.

But don't forget one of the more basic reasons to observe these stars, too. YSOs are often associat prominent nebulae and star formation regions, and are often beautiful as well as productive targets for obser The Orion Nebula is one of the lovelier sights of our nighttime skies, and one that's available to nearly all ot around the world. It's a wonderful reminder that something as bright and beautiful as Orion still holds myst explore, and can still teach us new things about the universe that we live in. The next time you're showing Ori a budding new astronomer, you can point out that astronomy has both an intellectual and aesthetic appeal. *sure to make a few estimates while you're at it!*

Further Reading

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This Variable Star of the Season article was written by Dr. Matthew Templeton. The AAVSO acknowledges for this project from the National Aeronautics and Space Administration through NASA grant NNX10AI83G.

Page Editor: Matthew Templeton
Last Updated: April 4, 2012 - 11:52am

Lovely Late Leonid
Meteoric
Meteor.

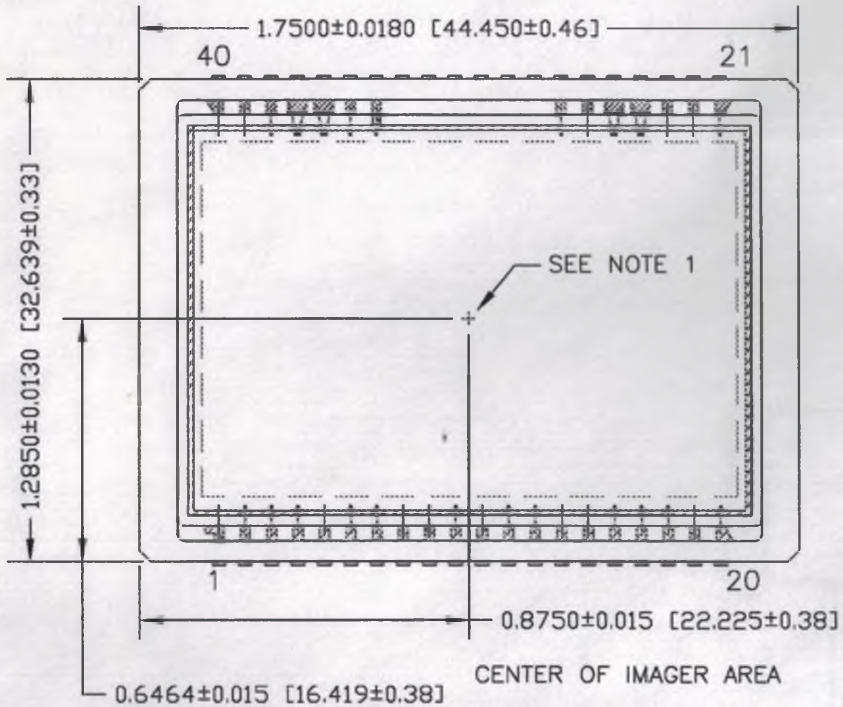
Lovely
Late
Leonid

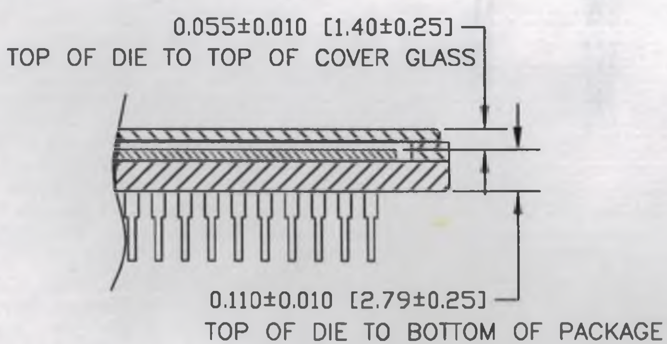
Meteo[illegible]
Mete[illegible]

19 November 2015
Obadiah

REVISION

NO.	CHANGE	ECO/PCR # DATE
2	CHANGED PARALLELISM, ADDED DEVICE	ECO #487 6/10/02
3	MODIFIED TABLE AND NOTES	ECO# 504 7/31/02
4	ADDED PEEL OFF SHIELD, CHANGED MARKING ORIENTATION	ECO# [illegible] 06/09/03





△3 NOTES:

1. CENTER OF IMAGE IS OFFSET FROM CENTER OF PACKAGE BY (0.00, 0.10)MM NOMINAL.
2. DIE IS ALIGNED WITHIN +/– 2 DEGREES OF ANY PACKAGE CAVITY EDGE.

DIMENSIONS	UNITS: INCH [MM]	EASTMAN KODAK CO. IMAGE SENSORS SOLUTIONS ROCHESTER, NEW YORK
TOLERANCE: UNLESS OTHERWISE SPECIFIED CERAMIC: ± 1% NO LESS THAN 0.005" L/F: ± 1% NO MORE THAN 0.005"		NAME: KAI–11000 / H25 ASSEMBLY
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DESIGNED BY: M.J. CIMINELLI	DATE: 5/2/2001	REV. 4
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		DWG. SIZE B

FOCAL DISTANCE	
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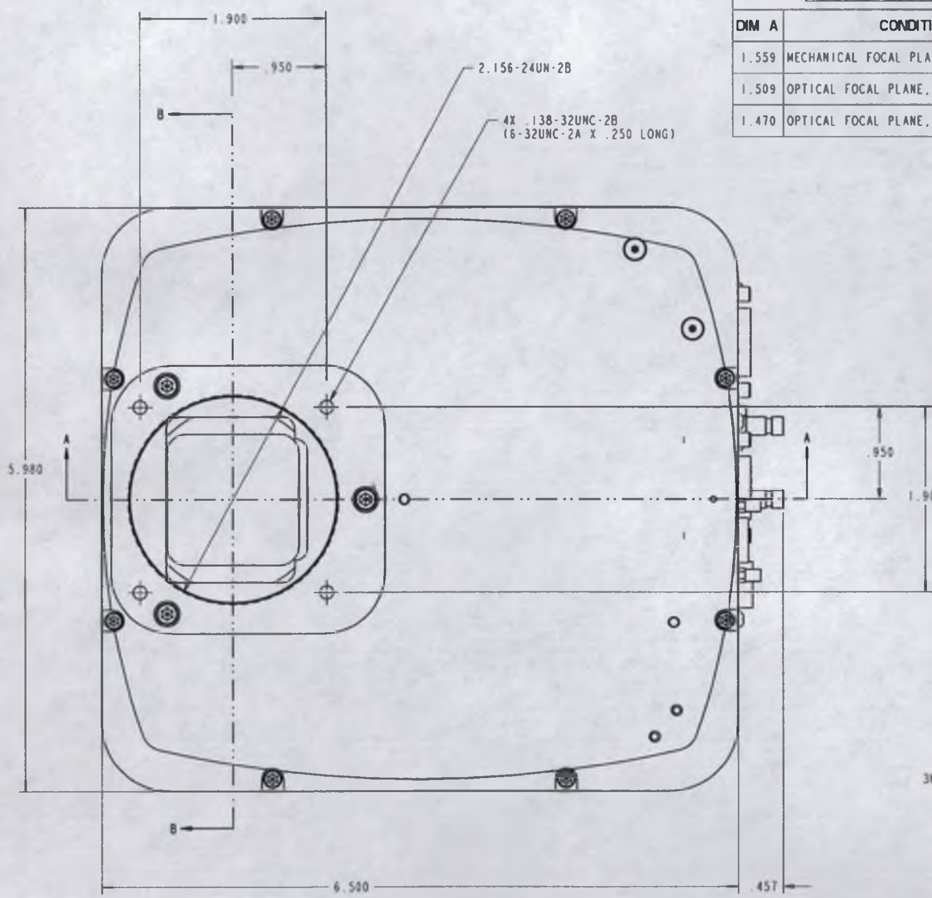
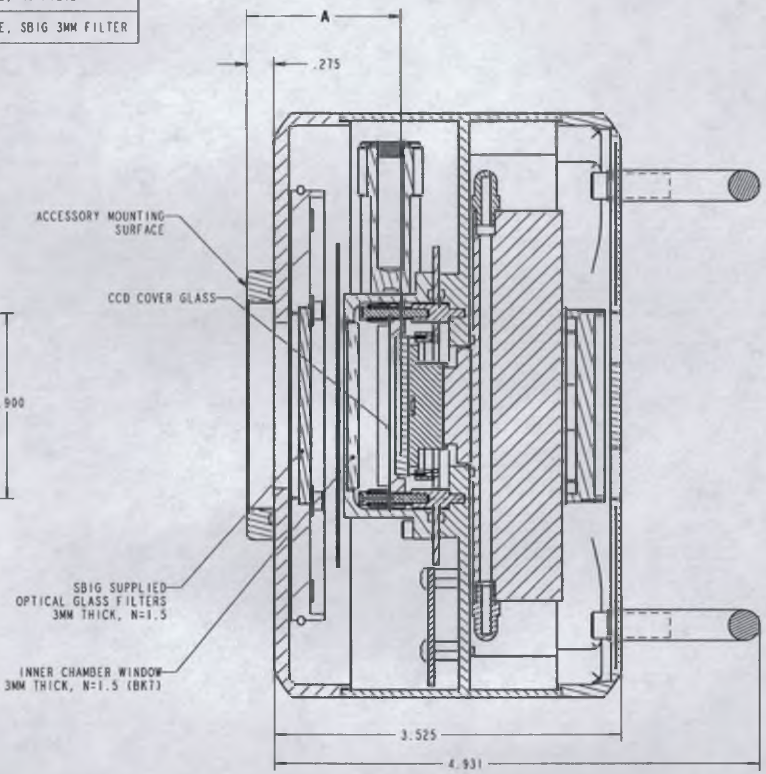
1.559	MECHANICAL FOCAL PLANE
1.509	OPTICAL FOCAL PLANE, NO FILTER
1.470	OPTICAL FOCAL PLANE, SBIG 3MM FILTER





SECTION B-B

MOUNTING INTERFACE DRAWING

NOTE:
DIMENSIONS SHOWN ARE NOMINAL.
ACTUAL DIMENSIONS MAY VARY FROM CAMERA TO CAMERA DUE TO TOLERANCE CONDITIONS.

REVISIONS: ZONE | REV | DESCRIPTION | DATE | APPROVED

PARTS LIST

APPLICATION

APPROVALS | DATE
9/10/02

SBIG ASTRONOMICAL INSTRUMENTS

TITLE: CAMERA, LARGE FORMAT, 1001

SIZE D | CAGE CODE 1BCX9 | DWG NO. 2400

SCALE | SHEET 1 OF 1

Obadiah August 19, 2005.

Cooling.

3 Temp sensors.
One on top of the thermoelectric cooler stack
In new camera there is a two-stage cooler
Selector switch on power supply
Rotary switch.
Another on CCD sensor itself.
Third one labeled hot. tells case temp of
the camera box.
It'll never get so hot to damage anyth

When you turn on ~~sensors~~ cooler
note all 3 sensors - they will read ambie
temp. Voltmeter will read °K.
10 mv / °K.
TEC, CCD + Hot = ambient

Full max (24-26V), less in winter.

Cooling Water.

747 Lost Part of Wing Slat, TWA Says

April 29, 1989 | From Associated Press

LONDON — A TWA Boeing 747 flying from Los Angeles to London with more than 200 people on board lost part of a wing slat as it prepared to land at Heathrow Airport, the airline said Friday.

The Department of Transport said officers from the Air Accident Investigation Bureau have launched an inquiry into the April 20 incident, which a TWA spokesman called a "minor accident."

Aviation experts said the loss of a slat may affect low-speed handling and might force an aircraft to land at a faster speed.

The leading edge slats are 6 feet long and positioned along the front of each wing to increase lift. They are operated hydraulically to change the air flow over the wing and allow the aircraft to land at a slower speed.

A TWA spokesman, who demanded anonymity, said a 2-foot piece of the slat between the fuselage and the No. 3 engine on the right wing fell off after a bolt broke. This forced up the flap, breaking off a section of it, the spokesman said.

However, he said the damage did not cause any problems with the handling of the aircraft and denied there had been any emergency.

The spokesman said the piece that fell off would have weighed about four pounds. He said authorities were notified but the piece has not been found, he said.

ROM THE ARCHIVES

ing car aims to take wing in the commercial
rket
il 19, 2012

ne that crashed in Iran may give away U.S.
rets
ember 6, 2011

rl Icahn Relishes His Raider Role : TWA Is Latest
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CN3fg
Palomar

December 1988
To
June 1996


N3fg
ecember 1988-
ne 1996
Resolution of the City Council
City of San Diego

IAUC 5045: 1990 MB

Circular No. 5045

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MARSDEN or GREEN@CFA.BITNET MARSDEN or GREEN@CFAPS2.SPAN

1990 MB

H. E. Holt reports his discovery of a fast-moving asteroidal object, and the following observations have been reported:

1990 UT	R.A. (1950)	Decl.	Mag.	Observer
June 20.26631	16 51 35.45	- 2 32 05.7	17.0	Holt
20.30486	16 51 32.24	- 2 30 57.1		"
22.22014	16 49 08.53	- 1 35 30.4	17.0	"
22.26163	16 49 05.28	- 1 34 20.1		"
23.21111	16 47 57.07	- 1 07 54.2	17.0	"
23.26631	16 47 52.87	- 1 06 23.6		"
26.26163	16 44 31.75	+ 0 12 07.5	16.2	Helin
26.28819	16 44 29.85	+ 0 12 45.9		"

H. E. Holt and D. Levy (Palomar). 0.46-m Schmidt telescope. Measured by C. M. Olmstead. Communicated by E. Bowell.
E. Helin, B. Roman, and K. Lawrence (Palomar). 0.46-m Schmidt telescope. Measured by Roman.

Preliminary orbital elements from the above observations:

```
T = 1990 Oct. 29.359 ET          Peri. =  97.323
e = 0.07064                      Node  = 244.170    1950.0
q = 1.40345 AU                   Incl. =  19.559
  a =  1.51012 AU      n = 0.531112      P =   1.86 years
```

1990 ET	R.A. (1950)	Decl.	Delta	r	V
June 18	16 54.59	- 3 41.0	0.492	1.482	16.1
23	16 48.20	- 1 13.6			
28	16 42.76	+ 0 54.5	0.518	1.472	16.4
July 3	16 38.48	+ 2 41.9			
8	16 35.45	+ 4 09.2	0.557	1.463	16.7
13	16 33.70	+ 5 17.4			
18	16 33.20	+ 6 08.5	0.606	1.454	17.0
23	16 33.94	+ 6 44.3			
28	16 35.86	+ 7 07.0	0.661	1.446	17.3

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23	16 48.20	- 1 13.6			
28	16 42.76	+ 0 54.5	0.518	1.472	16.4
July 3	16 38.48	+ 2 41.9			
8	16 35.45	+ 4 09.2	0.557	1.463	16.7
13	16 33.70	+ 5 17.4			
18	16 33.20	+ 6 08.5	0.606	1.454	17.0
23	16 33.94	+ 6 44.3			
28	16 35.86	+ 7 07.0	0.661	1.446	17.3
Aug. 2	16 38.88	+ 7 18.8			
7	16 42.91	+ 7 21.4	0.719	1.438	17.5

1990 June 29   (5045)   Daniel W. E. Green

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SUPERNOVA 1990N IN NGC 4639

G. Sonneborn, Goddard Space Flight Center; and R. Kirshner, Center for Astrophysics, report: "Low-dispersion ultraviolet spectra (range 200-335 nm, resolution 0.6 nm) of SN 1990N have been obtained with the IUE satellite on June 26.8, 28.3, 30.6 and July 2.7 UT. SN 1990N was detected longward of 250 nm on each date. The mean flux in the range 300 +/- 15 nm was 1.9**10-14 erg cm-2 s-1 A-1 on July 2. The ultraviolet flux has approximately doubled every two days during this period, while the shape of the spectrum has changed very little. The spectrum resembles IUE spectra of other type Ia supernovae: it has the pronounced flux maximum at 310 nm. However, the secondary maximum usually seen at 290 nm (e.g., in SN 1981B) is not present in SN 1990N. The following visual magnitude estimates were obtained with the IUE Fine Error Sensor (400-700 nm) on the dates given above: 14.4, 14.0, 13.4 and 13.2, indicating that the ultraviolet has been rising at about twice the rate of the optical brightness. Detection of a large ultraviolet flux increase in a type Ia supernova is unprecedented. Photometry and spectroscopy are needed in other wavelength regions, in particular optical coverage extending shortward of 400 nm."

V3890 SAGITTARII

K. Sekiguchi, South African Astronomical Observatory reports: "The spectral evolution of V3890 Sgr has been monitored using the 1.9-m telescope at Sutherland since May 5. The overall development of the spectrum closely resembles that of the 1985 outburst of RS Oph. The red-region spectrum (range 560-760 nm, resolution about 0.35 nm FWHM) taken on June 22 shows the emerging TiO bands of an M4 III star. Strong coronal Fe VII 608.6-nm emission, which was absent on May 14 (IAUC 5015), and the Fe X 637.4-nm line are present. The star at the Duerbeck and Williams positions (6" east and 10" north of V3890 Sgr) was also observed. No detectable emission line was seen in its spectrum. This suggests that the star observed by Williams (1983, Ap.J. Suppl. 53, 523) was in fact V3890 Sgr = N Sgr 1962 in quiescent state and that his finding chart was incorrect."

1990 MB

Corrigendum. E. Bowell informs us that this object (cf. IAUC 5045) was actually discovered by David H. Levy. Both Levy and H. E. Holt were involved with the Palomar observations.

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1990 MB

Several contributors, initially E. Bowell, Lowell Observatory, have remarked on the possibility that this object might be a "Mars Trojan"--the first of its kind. Further astrometric and physical observations of it would therefore be particularly desirable. The orbit below, from MPC 16700, is still based on only a 24-day arc. Numerical integration of this orbit over an interval of 60 000 days shows the distance between 1990 MB and Mars to vary over a range of 0.3 AU during each revolution period P. There is essentially a secular (long period?) trend to the distances, however, diminishing from 1.9-2.2 AU around 1860 to 1.2-1.5 AU around 2020. Minimum distances from the earth, Venus and Jupiter are rather consistently 0.5, 0.8 and 3.5 AU, respectively.

T = 1990 Oct. 29.2403 ET		Peri. = 95.4805	
e = 0.065461		Node = 244.4378	1950.0
q = 1.422997 AU		Incl. = 20.2267	
a = 1.522672 AU	n = 0.5245594	P = 1.879 years	

1990 ET	R.A. (1950)	Decl.	Delta	r	V
July 28	16 35.65	+ 7 08.4	0.681	1.461	17.3
Aug. 7	16 42.55	+ 7 23.9			
17	16 53.14	+ 7 09.2	0.802	1.447	17.8
27	17 06.93	+ 6 34.6			
Sept. 6	17 23.50	+ 5 48.6	0.921	1.436	18.1
16	17 42.43	+ 4 57.5			
26	18 03.50	+ 4 06.0	1.034	1.428	18.4
Oct. 6	18 26.44	+ 3 18.8			
16	18 51.00	+ 2 38.9	1.144	1.424	18.6
26	19 16.99	+ 2 09.5			
Nov. 5	19 44.18	+ 1 52.6	1.253	1.423	18.7
15	20 12.32	+ 1 49.7			
25	20 41.21	+ 2 01.7	1.367	1.426	18.9

COMET LEVY (1990c)

Total visual magnitudes: July 24.90 UT, 6.5 (A. Pearce, Scarborough, Western Australia, 20 x 80 binoculars; 25.30, 6.8 (J. V. Scotti, Tucson, AZ, 10 x 50 binoculars); 26.30, 6.6 (J. E. Bortle, Stormville, NY, 10 x 50 binoculars); 27.31, 6.3 (Scotti); 27.85, 6.3 (Pearce; 0.75-deg tail in p.a. 231 deg).

1990 July 28 **(5067)** **Brian G. Marsden**

1990 MB

With reference to IAUC 5067, H. Kinoshita, National Astronomical Observatory, Tokyo, writes that a 10 000-year integration by M. Yoshikawa using the orbital elements given there "clearly shows this minor planet is a stable Martian Trojan"; and K. A. Innanen, York University, Toronto, notes in the abstract of a very recent paper by S. Mikkola and himself that "contrary to intuition, there is clear empirical evidence for the stability of motion around the L4 and L5 points of all the terrestrial planets over a timeframe of several million years".

E. Bowell, Lowell Observatory, provides the improved orbital elements below from observations that now cover a 40-day arc. These new figures indeed suggest greater stability than do the set on IAUC 5067, and a computation by B. G. Marsden, Center for Astrophysics, shows the object's distance from Mars to change only from 1.5-1.8 AU around 1850 to 1.3-1.6 AU around 2400.

```
                  Epoch = 1990 Nov.  5.0 ET
T = 1990 Oct. 29.1464 ET          Peri. =  95.2727
e = 0.064820                      Node  = 244.4595  1950.0
q = 1.424769 AU                   Incl. =  20.2806
  a =  1.523524 AU    n = 0.5241192    P =   1.881 years
```

COMET LEVY (1990c)

Total visual magnitude estimates (cf. IAUC 5070): Aug. 7.05 UT, 5.4 (B. H. Granslo, Fjellhamar, Norway, 7x35 binoculars); 9.14, 5.5 (A. Pereira, Linda-a-Velha, Portugal, 9x34 binoculars); 11.20, 4.5 (C. S. Morris, Pine Mountain Club, CA, naked eye); 13.71, 4.6 (M. Ohkuma, Tokyo, Japan, 11x80 binoculars); 15.17, 4.3 (G. Kronk, Troy, IL, naked eye).

IAUC 5075: V1521 Cyg; 1990 MB; 1990c

Read *IAUC* 5074 SEARCH Read *IAUC* 5076

Display *IAUC* number Clear

Circular No. 5075

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V1521 CYGNI

E. B. Waltman, R. L. Fiedler, and K. J. Johnston, Naval Research Laboratory; and F. Ghigo, National Radio Astronomy Observatory, report that the source Cygnus X-3 (V1521 Cyg) is flaring at radio frequencies. The NRL-Green Bank Interferometer Monitoring Program observed intensities of 8 Jy at 8.3 GHz and 7 Jy at 2.2 GHz on Aug. 15.0 UT.

1990 MB

With reference to IAUC 5067, H. Kinoshita, National Astronomical Observatory, Tokyo, writes that a 10 000-year integration by M. Yoshikawa using the orbital elements given there "clearly shows this minor planet is a stable Martian Trojan"; and K. A. Innanen, York University, Toronto, notes in the abstract of a very recent paper by S. Mikkola and himself that "contrary to intuition, there is clear empirical evidence for the stability of motion around the L4 and L5 points of all the terrestrial planets over a timeframe of several million years".

E. Bowell, Lowell Observatory, provides the improved orbital elements below from observations that now cover a 40-day arc. These new figures indeed suggest greater stability than do the set on IAUC 5067, and a computation by B. G. Marsden, Center for Astrophysics, shows the object's distance from Mars to change only from 1.5-1.8 AU around 1850 to 1.3-1.6 AU around 2400.

```
                   Epoch = 1990 Nov.  5.0 ET
     T = 1990 Oct. 29.1464 ET         Peri. =  95.2727
     e = 0.064820                     Node  = 244.4595  1950.0
     q = 1.424769 AU                  Incl. =  20.2806
       a =  1.523524 AU    n = 0.5241192    P =   1.881 years
```

COMET LEVY (1990c)

Total visual magnitude estimates (cf. IAUC 5070): Aug. 7.05 UT, 5.4 (B. H. Granslo, Fjellhamar, Norway, 7x35 binoculars); 9.14, 5.5

OBSERVING RUNS WITH DAVID LEVY

1988 Dec 13-14	E.M. & C.S. Shoemaker, D.H. Levy (40 cm Bigelow Schmidt)
1989 Aug 29-30	C.S. Shoemaker, D.H. Levy
1989 Oct 30-Nov 5	E.M. & C.S. Shoemaker, D.H. Levy
1989 Nov 6	D.H. Levy
1989 Nov 22-28	E.M. & C.S. Shoemaker, H.E. Holt, D.H. Levy
1990 Feb 20-24	E.M. & C.S. Shoemaker, D.H. Levy
1990 Mar 26-1 Apr	E.M. & C.S. Shoemaker, D.H. Levy
1990 Apr 20-22	E.M. & C.S. Shoemaker, D.H. Levy
1990 Oct 2-26	E.M. & C.S. Shoemaker, D.H. Levy
1990 Nov 11-17	E.M. & C.S. Shoemaker, D.H. Levy
1991 Jan 16	E.M. & C.S. Shoemaker, D.H. Levy
1991 Jan 17-19	C.S. Shoemaker, D.H. Levy
1991 Jan 20-22	E.M. & C.S. Shoemaker, D.H. Levy
1991 Feb 7-13	E.M. & C.S. Shoemaker, D.H. Levy
1991 Mar 9-13	E.M. & C.S. Shoemaker, D.H. Levy
1991 Apr 14-20	E.M. & C.S. Shoemaker, D.H. Levy
1991 Oct 2-8	E.M. & C.S. Shoemaker, D.H. Levy
1991 Nov 7-13	E.M. & C.S. Shoemaker, D.H. Levy
1991 Nov 30-Dec 6	E.M. & C.S. Shoemaker, D.H. Levy
1991 Dec 31-Jan 4	E.M. & C.S. Shoemaker, D.H. Levy
1992 Feb 4-5	E.M. & C.S. Shoemaker, D. H. Levy
1992 Feb 8-9	C.S. Shoemaker, D.H. Levy
1992 Feb 25-Mar 1	E.M. & C.S. Shoemaker, D.H. Levy
1992 Apr 2-8	E.M. & C.S. Shoemaker, D.H. Levy
1992 Apr 26-30	C.S. Shoemaker, H.E. Holt, D.H. Levy
1992 Jun 3-8	E.M. & C.S. Shoemaker, G.J. Leonard, D.H.Levy
1992 Oct 22-26	E.M. & C.S. Shoemaker, H.E. Holt, D.H. Levy
1992 Nov 25-Dec 1	E.M. & C.S. Shoemaker, D.H. Levy
1993 Jan 23-29	E.M. & C.S. Shoemaker, D.H. Levy
1993 Feb 15-18	E.M. & C.S. Shoemaker, D.H. Levy
1993 Mar 23-29	E.M. & C.S. Shoemaker, P. Benjoya, D.H. Levy
1993 May 21-24	E.M. & C.S. Shoemaker, D.H. Levy
1993 May 25	E.M. & C.S. Shoemaker, D.H. Levy, D.K. Williams
1993 May 26-27	E.M. & C.S. Shoemaker, D.H. Levy
1993 Jul 21-27	E.M. & C.S. Shoemaker, D.H. Levy
1993 Aug 12-19	E.M. & C.S. Shoemaker, D.H. Levy
1993 Nov 15-20	E.M. & C.S. Shoemaker, D.H. Levy, T. Melis
1993 Dec 7-13	E.M. & C.S. Shoemaker, D.H. Levy
1994 Jan 3-9	E.M. & C.S. Shoemaker, D.H. Levy
1994 Mar 12-13	C.S. Shoemaker, P. Jedicke, D.H. Levy
1994 Mar 14	C.S. Shoemaker, D.H. Levy, D.K. Williams
1994 Mar 15	C.S. Shoemaker, T. Dickinson, D.H. Levy, D.K. Williams
1994 Apr 2	C.S. Shoemaker, D.H. Levy

1994 Apr 3-8	C.S. Shoemaker, H.E. Holt, D.H. Levy
1994 May 11-16	E.M. & C.S. Shoemaker, D.H. Levy, T. Spahr
1994 Jun 2-8	E.M. & C.S. Shoemaker, D.H. Levy, T. Spahr
1994 Sep 7-12	C.S. Shoemaker, S.J. Edberg, D.H. Levy
1994 Sep 30-Oct 1	C.S. Shoemaker, D.H. Levy
1994 Oct 2-3	E.M. & C.S. Shoemaker, D.H. Levy
1994 Nov 27-Dec 4	E.M. & C.S. Shoemaker, H.E. Holt, D.H. Levy

~15 asteroids with the Shoemakers
+ ~5 asteroids " Henry Holt.

PACS DISCOVERY LIST 1989

Object	Discovery	Number	Name	Magnitude	Type
89 AZ	890108			19.5	Apollo
89AQ1	890109			9.0	Trojan
89 AR1	890108	4007	Euryalos	10.0	Trojan
89 AU1	890114	5258	Not ours	10.0	Trojan
89 AL2	890108	4833	Meges	9.4	Trojan
89 AM2	890111	4834	Thoas	9.2	Trojan
89 AN2	890109	4902	Thessandrus	9.5	Trojan
89 AO2	890109	5244	(Van Houten's)	9.9	Trojan
89 AV2	890111	7119	Hiera	9.8	Trojan
89 AP9	890114			18.0	
89 AB10	890111			11.5	Trojan
89 BL	890131	5123	(Oshima's)	9.9	Trojan
89 BW	890131	5283	Pyhrrus	9.3	Trojan
89 BX	890131	5025		9.9	Trojan
89 BB1	890130	5259	Epeigeus	10.3	Trojan
89 CK1	890202	4836	Medon	9.5	Trojan
89 CQ1	890202	4543	Phoinix	9.9	Trojan
89 CH2	890201	5126	Achaemenides	10.1	Trojan
89 CJ2	890201	5041		10.5	Trojan
89 CK2	890201	5284	Orsilocus	9.9	Trojan
89 CB9					
89 CC9					
89 CD9					
89 CE9					
89 CF9					
89 CG9					
89 CH9					
89 EV1	890304			16.8	
89 EX4					
89 EY4	890307	6545	(Antal)	10.0	Trojan
89 EE6	890307			18.1	
89 EO11	890309	5285	Krethon	9.9	Trojan
89 NX		5211	Stevenson		Phocaea
89 OB	890729	9172	Abhramu	16.0	Amor
89 OW	890729			16.5	
89 OX	890729			16.8	
89 OK1	890729			17.2	
89 ON1	890309			17.9	
89 PA	890802	6901	Roybishop	14.0	MarsX Hung
89 PU	890802	13937	Roberthargraves	13.5	High i
89 QF	890831	6259	Minos	18.1	Apollo
√89 QH1	890829	5427	(Brorfelde's)	13.2	High i

89 RV1	890901			16.0	
89 RJ2	890902	19140	Jansmit	14.0	MarsX Phoc
89 RO2	890903	8356	Wadhwa	12.5	MarsX Phoc
89 SZ	890927	4867	Polites	9.4	Trojan
89 SA1	890927			18.0	
89 ST5	890930			11.5	Hilda
89 SC7	890801	5130	Ilioneus	9.8	Trojan
89 SO7	890928			17.5	
89 SP7	890928				
89 SQ7	890928				
89 SR7	890928			17.5	
89 SS7	890928			18.0	
89 ST7	890928			17.8	
89 SU7	890928			17.0	
89 SV7	890928			17.5	
89 SW7	890928			17.9	
89 SX7	890928			13.4	
89 SY7	890928			17.3	
89 SZ7	890928			17.7	
89 SA8	890928			17.9	
89 SB8	890928			17.2	
89 SC8	890928	22294	Simmons	14.5	Main belt
89 SD8	890928			17.9	
89 SE8	890928	16452	Goldfinger	17.6	Main belt
89 SF8	890928			17.2	
89 SG8	890928			17.2	
89 SH8	890928				
89 SW13					
89 VA	891102			17.5	Aten
89 VB	891101			20.0	Apollo
89 VN5		8358	Richblakley		
89 WM	891128	4503	Cleobulus	15.5	Amor
89 WN	891122			14.3	Phocaea
89 WF2	891122	19980	Barrysimon	14.5	Phocaea

Q When was the comet or asteroid 192P/Shoemaker-Levy 1 (Shoemaker-Levy) first and last observed?

A The celestial body 192P/Shoemaker-Levy 1 was first observed on October 24, 1990. It has an orbital period of 17.2505 years. The comet 192P/Shoemaker-Levy 1 was last observed on 3/9/08.

Compare All Comets and Asteroids

FAQ'S for 192P/Shoemaker-Levy 1

› Is the comet or asteroid 192P/Shoemaker-Levy 1 potentially hazardous?

Details about 192P/Shoemaker-Levy 1

Find and compare all Comets and Asteroids

192P/Shoemaker-Levy 1

IAU NAME	Shoemaker-Levy
DIAMETER	0 km
EARTH MOID (AU)	0.6239
EARTH MOID (LD)	242.816
DATE OF FIRST OBSERVATION	October 24, 1990
DATE OF LAST OBSERVATION	3/9/08
ORBITAL PERIOD (YEARS)	17.2505

See more details »

Popular Questions

› Which comet or asteroid is the largest?

Other ways users ask this question:

What is 192P/Shoemaker-Levy 1 orbital period?

What is the orbital period of the comet or asteroid Shoemaker-Levy?

How long does it take for Shoemaker-Levy to orbit the earth?

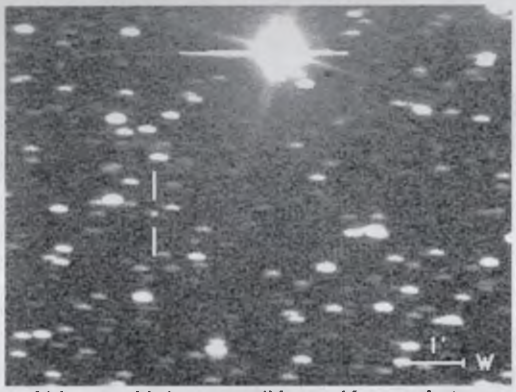
When was Shoemaker-Levy first observed?

Source: NASA

GARY W. KRONK'S COMETOGRAPHY

137P/Shoemaker-Levy 2

Past, Present, and Future Orbits by Kazuo Kinoshita



The CCD image was taken on 1999 July 8.68, using a 0.60-m f/6 Ritchey-Chretien telescope.

Discovery

During the last half of November of 1990 Carolyn S. Shoemaker (Palomar Observatory, California, USA) discovered images of an asteroidal object on plates taken on October 25, November 13, and 15. The magnitude was estimated as 17 on October 25 and 17.7 on November 13. The plates were obtained by Eugene M Shoemaker, David H. Levy, and herself.

Prediscovery images were then located on plates exposed at Palomar Observatory by H. E. Holt, H. R. Holt, C. M. Olmstead, and J. A. Brown on September 17 and 20. The magnitude was determined as 17.6.

Gareth V. Williams took the available positions and computed an elliptical orbit with a perihelion date of 1990 September 25 and an orbital period of 9.27 years. He said the orbit indicated this was a Jupiter-crossing object. The object was given the minor planet designation of 1990 UL3.

Brian Skiff (Lowell Observatory, Arizona, USA) announced that CCD images obtained with a 1.1-m reflector on December 7 revealed a straight tail extending 29 arc seconds toward PA 67°. Before this announcement, S. Larson and Levy (University of Arizona) obtained CCD images of the comet with the Catalina 1.5-telescope on December 19 and detected a tail extending 28 arc seconds toward PA 58°. Thus, the "minor planet" proved to be a comet.

Historical Highlights

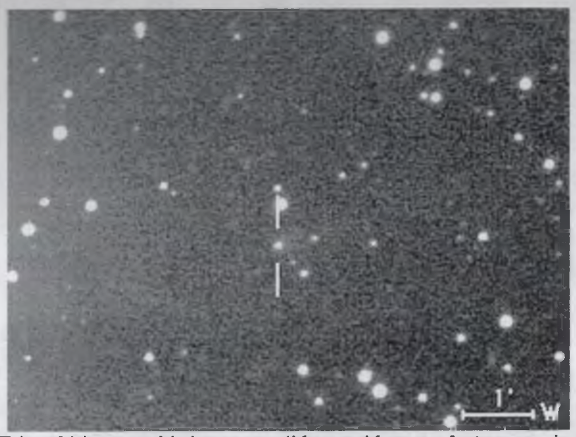
- During the discovery apparition the comet was only followed until 1991 January 15, when astronomers at the Anderson Mesa station of Lowell Observatory detected it. They determined the nuclear magnitude as 18.2.

- After acquiring all available positions, S. Nakano determined a revised orbit which indicated the comet would next reach perihelion in February of 2000. Searches actually began in 1998, and on May 19 and 20 C. W. Hergenrother recovered the comet with the 1.2-m reflector at Mt. Hopkins. His precise positions indicated Nakano's prediction required a correction of only -0.5 day. Hergenrother said the comet appeared stellar in appearance and had a magnitude of 21.0.

GARY W. KRONK'S COMETOGRAPHY

129P/Shoemaker-Levy 3

Past, Present, and Future Orbits by Kazuo Kinoshita



This CCD image was taken on 1997 December 4.74, using a 0.60-m f/6 Ritchey-Chretien telescope.

Discovery

Caroline S. Shoemaker, Eugene M. Shoemaker, and David H. Levy (Palomar Observatory) reported discovering this comet on images obtained with a 0.46-m Schmidt telescope on 1991 February 7.34 and February 8.26. The magnitude was estimated as 16.5 and the comet was described as "moderately diffuse, with hint of a tail to the northwest."

Historical Highlights

• Following the acquisition of images up through 1991 February 11, Brian G. Marsden (Central Bureau for Astronomical Telegrams) computed the first orbit which inicated the comet was moving in a short-period orbit. This preliminary orbit indicated a perihelion date of 1991 February 26 and an orbital period of 7.26 years. The comet was ignored in the weeks that followed, and new observations did not become available until April. At that time Marsden was able to revise the orbit, which indicated a perihelion date of 1990 December 26.8 and a period of 7.25 years. Final orbits following the acquisition of additional observations indicated a perihelion date of December 12.8.

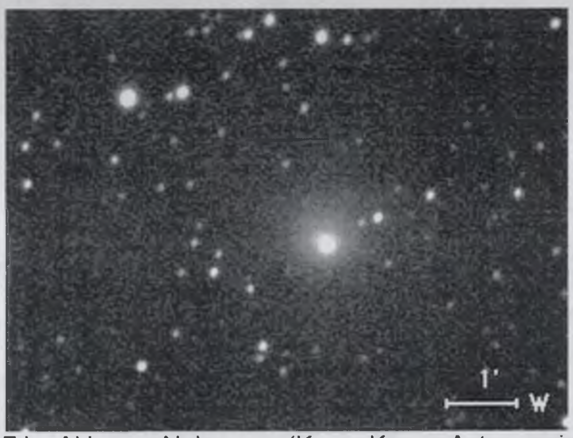
• As noted above, the comet was largely ignored during its discovery apparition. Since it was already passed perihelion, the magnitude faded from 16.5 at discovery to 17.5 in mid-April. The comet was last seen on May 5, when the magnitude had dropped to 19.

• S. Nakano provided a prediction for the 1998 return, but, before searches could be made for a recovery, word came that A. Maury, M. Lundstrom, and G. Hahn had accidentally recovered the comet on minor planet survey plates obtained with the 0.9-m Schmidt telescope at Caussols on 1996 October 17.99. The comet was described as diffuse, with a magnitude of 19.3. The position indicated Nakano's prediction required a correction of -0.1 day. Revised computations indicated the comet would arrive at perihelion on 1998 March 4.9. With a perihelion distance of 2.82 AU, it was not expected to become brighter than magnitude 16, although this was based on the incomplete coverage of the 1991 apparition. During late January of 1998, some observers were estimating a brightness greater than 15.

GARY W. KRONK'S COMETOGRAPHY

118P/Shoemaker-Levy 4

Past, Present, and Future Orbits by Kazuo Kinoshita



Copyright ? 1997 by Akimasa Nakamura (Kuma Kogen Astronomical Observatory, Japan)

The CCD image was taken on 1997 January 11, using a 0.60-m f/6 Ritchey-Chretien telescope.

Discovery

C. S. Shoemaker, E. M. Shoemaker, and D. H. Levy (Palomar Observatory, California, USA) discovered this comet in Virgo on films exposed on February 9.46 with the 0.46-m Schmidt telescope. The comet was described as diffuse and magnitude 17. There was also a short tail extending toward the west.

Historical Highlights

- Daniel W. E. Green published the first parabolic orbit for this comet on February 13, using positions obtained at Palomar and other observatories. It indicated a perihelion date of 1990 October 8. After the arrival of further observations during the next couple of weeks, the comet was officially announced as a short-period comet on February 26, with Brian G. Marsden having computed an elliptical orbit with a perihelion date of 1990 July 19 and an orbital period of 6.82 years.
- With the comet having passed perihelion seven months prior to

discovery, it steadily faded after February. The final observation was obtained on April 19 at Oak Ridge Observatory. Shortly thereafter a revised orbit indicated a period of 6.53 years.

- S. Nakano predicted the comet would next arrive at perihelion on 1997 January 12. The prediction enabled James V. Scotti to recover the comet on 1995 June 22.45. Scotti used the 0.9-m Spacewatch telescope at Kitt Peak. The comet was described as stellar with a magnitude of 21.9. The Scotti's position indicated the predicted perihelion date was only in error by 0.6 day.

- The 1997 apparition was rather favorable as the comet became brighter than magnitude 13 from 1996 November through 1997 March.

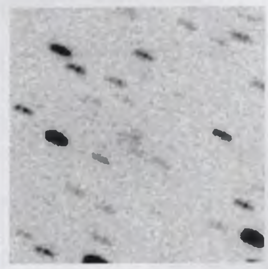
181P/Shoemaker-Levy 6 (2006)

~~Japanese version~~ ~~Home page~~	*Updated on February 12, 2007*

★ ~~Profile~~

Designation	181P/2006 U4
Recovery Date	October 26, 2006
Magnitude	18.2 mag
Recoverer	R. H. McNaught and D. M. Burton (Siding Spring)

★ ~~Pictures~~



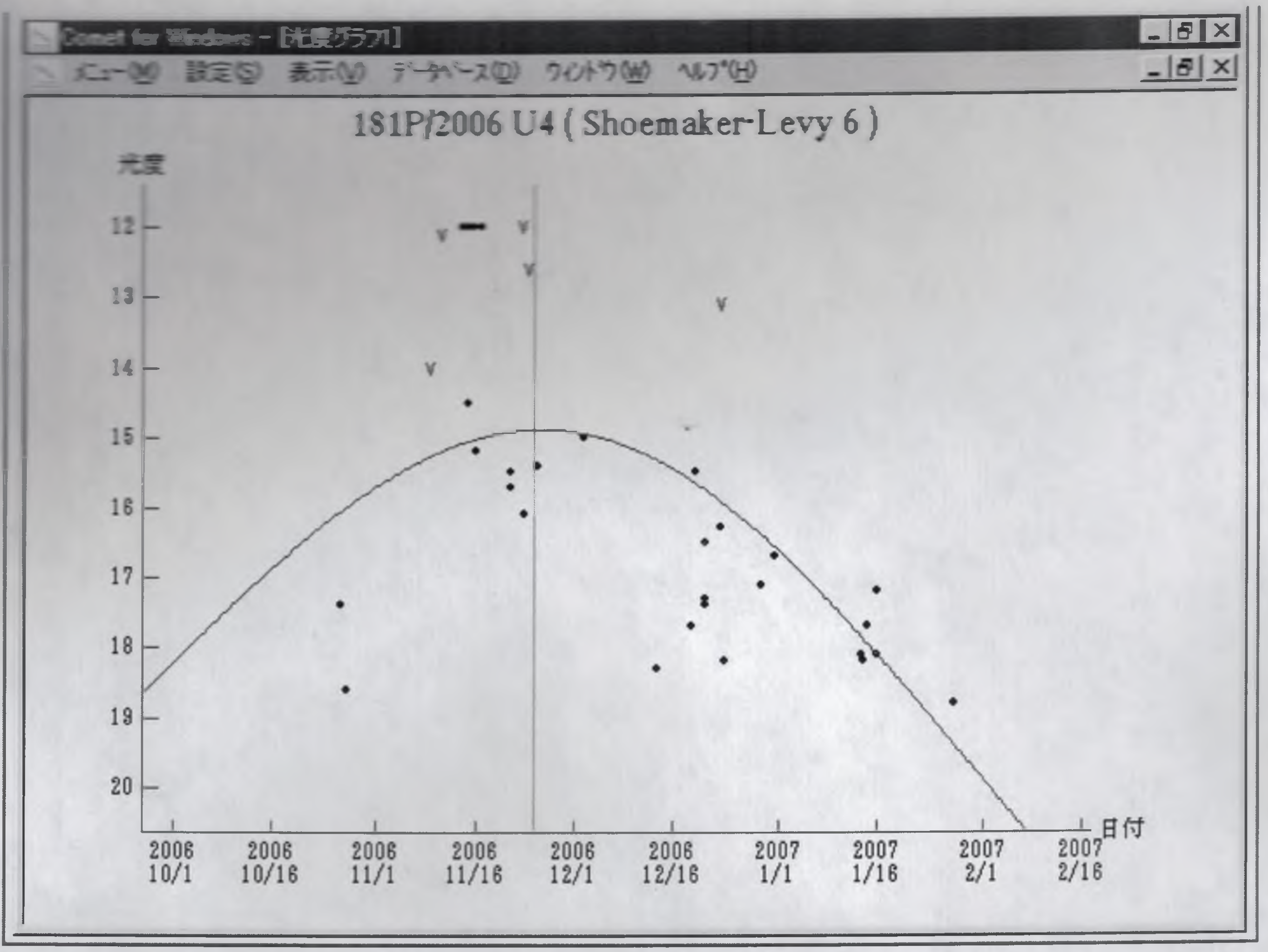
★ Orbital Elements

```
                Epoch = 2006 Dec. 11.0 TT
T = 2006 Nov. 25.0013 TT         Peri. = 333.5580
e = 0.706643                     Node  =  37.8728  2000.0
q = 1.127551 AU                  Incl. =  16.9267
  a =  3.843617 AU    n = 0.1307959    P =   7.535 years
```

★ Finding Charts

Magnitudes Graph

m1 = 13 + 5 log d + 40 log r



The orbital elements are calculated by Dr. Brian G. Marsden and printed on IAUC 8767.
The charts are made with StellaNavigator Ver.2.0 for Windows (AstroArts / ASCII).
The magnitudes graphs are made with Comet for Windows.

145P/Shoemaker-Levy 5 (2000)

~~Japanese version~~ ~~Home page~~	*Updated on November 1, 2009*

★ Profile

Designation 145P/2000 R1
Recovery Date September 6, 2000
Magnitude 18.5 mag
Recoverer Lincoln Laboratory Near-Earth Asteroid Research project

★ Orbital Elements

```
                Epoch = 2000 Aug.  4.0 TT
T = 2000 Aug. 17.0846 TT         Peri. =   6.2331
e = 0.529360                     Node  =  29.6904  2000.0
q = 1.988623 AU                  Incl. =  11.7706
  a =  4.225360 AU    n = 0.1134772    P =   8.686 years
```

★ Finding Charts

GARY W. KRONK'S COMETOGRAPHY

138P/Shoemaker-Levy 7

Past, Present, and Future Orbits by Kazuo Kinoshita

Discovery

This comet was discovered by Carolyn S. and Eugene M. Shoemaker and David H. Levy on photographic plates exposed with the 0.46-m Schmidt telescope at Palomar Observatory (California, USA) on 1991 November 13. It was described as diffuse, with a condensation and was estimated as magnitude 16.5. An image on the 15th acted as an additional confirmation.

Historical Highlights

• Daniel W. E. Green (Central Bureau for Astronomical Telegrams) computed the first orbit which was published on November 25. It was a parabolic orbit with a perihelion date of 1991 September 15, a perihelion distance of 1.23 AU, and an inclination of 10 degrees. He added, "This may be a short-period comet." This suggestion was confirmed by Green's colleague B. G. Marsden, who used additional positions obtained into December and published a short-period orbit on December 5. It indicated the perihelion date was October 27, the perihelion distance was 1.63 AU, and the orbital period was 6.72 years. Eventually the orbital period was refined to 6.73 years.

• J. V. Scotti (Lunar and Planetary Laboratory, Arizona, USA) recovered this comet on CCD images obtained on 1998 July 25.43. The comet was described as magntiude 20.7 with a coma 6 arc seconds across. There was a tail extending 0.5 arc minute in PA 264 degrees. Precise positions indicated the prediction published by Marsden required a correction of -0.7 day.

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Media Inquiries

If you have any questions, please **email me**

GARY W. KRONK'S COMETOGRAPHY

135P/Shoemaker-Levy 8

Past, Present, and Future Orbits by Kazuo Kinoshita

Discovery

This comet was discovered by Carolyn S. and Eugene M. Shoemaker and David H. Levy on photographic plates exposed with the 0.46-m Schmidt telescope at Palomar Observatory on 1992 April 5. The magnitude was determined as 17.0 and there was possibly a very faint tail towards the west. This team obtained confirming images on April 7 and 8.

A few days after the discovery announcement, A. Savage (Siding Spring, Australia) found a prediscovery image obtained on a plate exposed with the 1.2-m U.K. Schmidt on March 30. It revealed a tail extending 30 arc seconds to the northwest.

Historical Highlights

• The comet was officially announced by the Central Bureau for Astronomical Telegrams on April 9. The Palomar group had obtained enough positions to enable B. G. Marsden to compute a parabolic orbit with a perihelion date of 1992 October 28, a perihelion distance of 1.44 AU, and an inclination of 8 degrees. Marsden added, "It is quite likely that the comet is a short-period one." Following the acquisition of additional positions, including the prediscovery one from March 30, S. Nakano confirmed Marsden's suspicion by computing a short-period orbit with a perihelion date of 1992 May 21, a perihelion distance of 2.72 AU, and an orbital period of 7.59 years. Although the orbit was generally correct, the large perihelion distance made these early computations somewhat uncertain. Following the comet's final observations on 1993 September 16 revisions in the orbit revealed a perihelion date of June 13 and an orbital period of 7.47 years.

• This comet was recovered on 1998 January 22 by C. W. Hergenrother. He was using the Smithsonian Astrophysical Observatory's 1.2-m reflector at Mt. Hopkins. The magnitude was given as between 21.7 and 22.0. The precise positions indicated the prediction required a correction of +0.03 day. Hergenrother confirmed the comet with the Lunar and Planetary Laboratory's 1.5-m reflector at the Catalina station on January

28. He said the coma appeared moderately diffuse and 5 arc seconds across.

GARY W. KRONK'S COMETOGRAPHY

D/1993 F2 Shoemaker-Levy 9

A NASA Hubble Space Telescope (HST) image of comet P/Shoemaker-Levy 9, taken on May 17, 1994, with the Wide Field Planetary Camera-2 (WFPC-2) in wide field mode. This required 6 WFPC exposures spaced along the comet train to include all the nuclei. The image was taken in red light.

Discovery

Carolyn S. and Eugene M. Shoemaker and David H. Levy (Palomar Observatory in California) examined a photograph exposed on 1993 March 24.36 as part of a routine asteroid survey. Although the team had already discovered numerous comets during the previous few years, this photograph held a most unusual object. As the plate was slowly scanned a comet was found which resembled a dense linear bar, with a faint, wispy tail. At a later date, they said their initial reaction was that the comet appeared "squashed." The comet was reported to the appropriate authorities, and was named Shoemaker-Levy. A more formal name of periodic comet Shoemaker-Levy 9 was later given to the comet when astronomers realized it completed one orbit around the sun every 17 years and was therefore classed as a short period comet. This was the ninth short-period comet discovered together by the Shoemakers and Levy. While the comet's initial appearance was certainly something new and unusual, the comet's location was also of interest. Brian G. Marsden's announcement of the comet on IAU Circular 5725 included his remark that "The comet is located some 4 degrees from Jupiter, and the motion suggests that it may be near Jupiter's distance." As orbits were computed it was soon realised that the comet was actually in orbit around Jupiter. An independent discovery was reported by O. Naranjo (Merida), who found the comet on a photograph exposed on March 26.2.

In the days following the comet's discovery, additional images of the comet were found on earlier plates taken elsewhere. K. Endate (Kitami) found an image on a photograph exposed on March 15.6. S. Otomo (Otomo Observatory) photographed it on March 17.6. The team of E. Helin, K. Lawrence, and C. Brewer (Palomar Observatory) found images exposed on March 19.4.

Historical Highlights

• **The Orbit:** IAU Circular 5726 (1993 March 27) contained the first orbits determined for this comet. B. G. Marsden used 9 positions obtained on March 24, 26, and 27, and computed a parabolic and an elliptical orbit. Both orbits indicated rather close approaches to Jupiter, with the parabolic indicating a close distance of 0.31 AU on 1993 March 30 and the elliptical indicating a distance of 0.04 AU on 1992 July 28. With the help of the March 15 prediscovery position and further observations up to April 1, Marsden announced on IAUC 5744 (1993 April 3) that the parabolic solution "was no longer viable" and provided a revised elliptical solution indicating a close approach of 0.007 AU from Jupiter on 1992 May 16. He added that a tidal breakup presumably required an approach to 0.001 AU. After another month and a half of positions had been obtained, Marsden provided a greatly improved orbit on IAUC 5800 (1993 May 22). This indicated the comet passed 0.0008 AU from Jupiter on 1992 July 8.8 UT, at which time it was torn to pieces. Even more interesting was that the comet would collide with Jupiter during July of 1994. Later calculations revealed the 21 pieces of this comet would strike Jupiter during the period of 1994 July 16 to 22.

• Perhaps the best set of observations obtained during this comet's apparition was that provided by Akimasa Nakamura (Kuma Kogen Astronomical Observatory, Japan). Using a 0.60-m telescope he determined the total magnitude, measured the length of the comet, and provided magnitude estimates of several of the nuclei. A small sample includes the following observations obtained during the first six months of 1994.

> **January 8.85:** The total magnitude was estimated as 15.1 and the coma length was 2.8 arc minutes. He said the fragments were oriented on a line extending from PA 64° to PA 244°. Nuclear magnitude estimates: G=18.8, H=19.1, K=18.8, L=19.0, Q=18.7, R=19.3, S=19.6.
>
> **April 13.73:** The total magnitude was estimated as 15.2 and the coma length was 5.2 arc minutes. He said the fragments were oriented on a line extending from PA 63° to PA 243°. Nuclear magnitude

estimates: G=18.7, H=19.0, K=18.8, L=19.1, Q=18.4, R=19.6, S=19.5.

June 1.55: The total magnitude was estimated as 15.0 and the coma length was 6.8 arc minutes. He said the fragments were oriented on a line extending from PA 64° to PA 244°. Nuclear magnitude estimates: F=19.6, G=18.7, H=19.0, K=18.9, Q=18.3, R=19.1, S=18.7, W=19.7.

- **Some Interesting Impact Results:** Here are a few of the most interesting announcements.

--The Kuiper Airborne Observatory detected water within the "splash phase" of Fragments G and K.

--Near-infrared Spectroscopy was obtained at the United Kingdom Infrared Telescope at Mauna Kea, Hawaii. In a paper by T. Y. Brooke, G. S. Orton, D. Crisp, A. J. Friedson, and G. Bjoraker it was revealed that carbon monoxide was detected at the site of the L event about four hours after impact.

--Detection of sodium, iron, magnesium, calcium, and manganese was made during the impact of fragment L, while sodium D was found during the impact of Q1.

--Observations of the impacts of A, H, and Q were made at the Serra La Nave Station of the Catalina Astrophysical Observatory by C. Blanco, G. Leto, and D. Riccioli. Photometric monitoring of Europa and Io revealed slight brightenings at the time of the A and Q events.

Remnants of 1994 Comet Impact Leave Puzzle at Jupiter

by Robert Roy Britt, Senior Science Writer
Date: 23 August 2004 Time: 06:06 AM ET

Jupiter's atmosphere still contains remnants of a comet impact from a decade ago, but scientists said last week they are puzzled by how two substances have spread into different locations.

The new study also discovered two previously undetected chemicals in Jupiter's air.

Grasping what chemical compounds are in and above the Jovian clouds and how they move about could help scientists understand planets outside our solar system, too, said the researchers who produced the work.

From July 16 through July 22, 1994, more than 20 fragments of Comet P/Shoemaker-Levy 9 collided with the gaseous planet, all coming in at about the same latitude, 45 degrees south. Fragments up to 1.2 miles (2 kilometers) sent plumes hot gas into the Jovian atmosphere. Dark scars lasted for weeks.

Shocks created by the impacts led to high-temperature chemical reactions that produced hydrogen cyanide, which rem in the air but has been spread around a bit in the years since. The comet also delivered carbon monoxide and water, wl through an interaction with sunlight, scientists suspect, was converted to carbon dioxide.

The Cassini spacecraft, now at Saturn, examined Jupiter as it swung by. The new study draws on infrared data from Cassini collected in 2000 and 2001.

The hydrogen cyanide has diffused some both north and south, mixed by wave activity, explained Michael Flasar of NASA's Goddard Space Flight Center. Jupiter's cloud bands carry material around the planet swiftly, but the bands do not mix easily. Not surprisingly, hydrogen cyanide is most abundant in a belt at the latitude where the comet was absorb At five degrees of latitude change in both directions, its presence drops off sharply.

The highest concentration of carbon dioxide, however, has shifted away from the latitude of the impact. It is most preva poleward of 60 degrees south and decreases abruptly, toward the equator, north of 50 degrees south. Another smaller spike in its presence occurs at high northern latitudes, around 70 to 90 degrees north.

Perhaps the two chemicals got distributed at different altitudes, and are being moved around by different currents, Flasa told *SPACE.com*. Or maybe the formation of the carbon dioxide was more complex than thought. He said it might hav involved carbon monoxide first moving away from the impact area and then interacting with other substances at higher latitudes before being converted to carbon dioxide.

"At high latitudes, precipitation of energetic oxygen ions probably occurs, associated with Jupiter's magnetically induced lights, known as aurora," Flasar explained. "These energetic ions could react with Jupiter's atmosphere to produce hydroxyl, which can oxidize carbon monoxide to produce carbon dioxide."

If all that sounds complicated, you're not alone in wondering what's going on.

"We're scratching our heads, and we need to work through these, and perhaps other, scenarios," said Flasar, who is principal investigator for Cassini's Composite Infrared Spectrometer.

The study, led by Virgil G. Kunde of the University of Maryland, was published Thursday in the online version of the journal *Science*.

The work also uncovered two new compounds, diacetylene and a so-called methyl radical, which are products of the breakup of methane by ultraviolet radiation from the Sun. These were expected but had not been observed at Jupiter before.

So far as astronomers know, the more than 100 giant planets found outside our solar system might be something like Jupiter. Only one has had its atmosphere probed. Better knowledge of the substances in Jupiter, and how things move around, should help set the stage for grasping the formation and evolution of gaseous extrasolar planets, the researchers say.

"An understanding of the processes governing the composition and distribution of chemical species in Jupiter's atmosph is required to successfully understand the chemical composition of extrasolar planets," they write in the journal.

- Comet's Scars on Jupiter

This article is part of SPACE.com's weekly Mystery Monday series.

Shoemaker-Levy 9 and Jupiter - Meudon, France

3 July 1996.

Catherine and Thérèse

Kevin Zahnle.

Started with the discovery picture - Probably a 1.5 km diameter comet, 0.5 g/cc.

or 1.0 km prograde rotator, but 1.0 g/cc ~~com~~ - denser comet

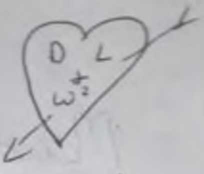
In old days, we knew that explosions had to occur atop water layer.
David C. will argue that larger impacts went below NH_3 clouds.

1st prec. was meteor trail -
2nd fireball pops into view
~~Main event~~
3rd prec. (G & K only) - ? dust & stuff related to "cylinder of explosi

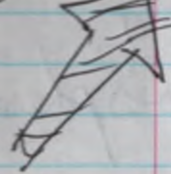
"Main Event": 10-12 min. after impac
Bounces.

↓ Mt was predominat
Jupiter Mass. NOT comet mas

Dec 29, | Dec 1 | Jan | Feb | mid March | April | May 22 May



FIRST ANNOUNCEMENT OF CHANGED JUPITER



7.-Meudon - 4 July 199

Long Term Response of Jovian Atmosphere
Evolution of new atmospheric ~~sptos~~ species
A. Marten

New Name -- Wendee Wallach-Levy
W^2L.

Sites still very apparent in IR after two months. 18, 30μm.

H_2O detection but no further monitoring.
All observed chemical products are unseen(?) in Jupiter's atmosphere
Detected CO, CS, HCN

more monitoring CO, CS HCN needed

JUPITER STILL SHOWING EFFECTS HCN CS

Long Term Response of the Jovian Atmosphere
evolution of Thermal Structure
Bruno Bézard.

~~Bright~~ Brightness enhancement over impact site might not necessarily mean physical enhancement. (?)

I love (my) David!!!

Increase in ammonia + water vapor has negligible effect of radiative cooling of perturbed atm.

Dynamic effects be be significant on (~~i.e~~ e/g. horizontal mixing with surrounding environment).

Meudon – 14. 5 July 1996.

Magnetospheric effects: interpretation of radio data : S J Bolton

Jupiter's synchrotron radiation was observed by telescopes from around the world and ALL observers saw drastic changes in the emission

- increase in intensity
- irregular evolution of the beaming curve during the

Beautiful image of magnetosphere : VLA Map.

S. Rad. emitted by relativistic electrons trapped in J's "Van Allen Radiation Belts."
It is narrowly beamed.

Emitted from principally 2 regions near the equator at 1.5 R_J and from pockets at high latitudes connected to field lines reaching out to over 2 R_J.

As J rotates the emission intensity varies!

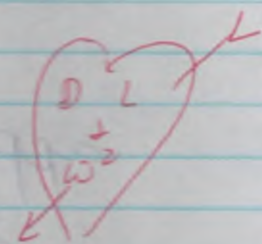
~~We connected~~ so
We made the connection; you do the dissection - S-L9 discover team motto, W. Ut

Meudon - 15.

27's s. read. 3 potential mechanism

- Radial diffusion enhancement.
- MHD shock acceleration.
  Shock forms at

Yes! I'll marry <u>you</u>!



impact side, scatters electrons?

How are impact sites and intensity increase correlated.? Future Work

We know the impacts had an effect, just what is the question.

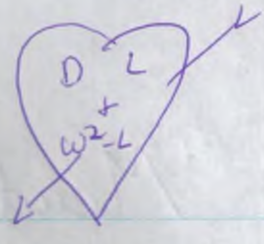
Beautiful video!

FROM MODIN TO MEUDON

by Wendee Ph brewer

Questions are relating mag sync. behavior to aurora ~~and tat~~ to dust

2.S. Dust was very complicated



Meudon - 22.

Jaques Crovisier from UV + visible
Emission

The paradox of the quest for the
composition of S-L9.

"Comet people want comp.
from impact
characterist.

Jupiter peoples want to
? { know imp condition
from comet compo-
sition. (?)

All sp. obs. prior to impact were
negative!

Comparing composition of
S-L9 with Hale-Bopp.

If size compared, then
production rates would be very
small.

MAGNESIUM FLASH
just before impact of G.
lasted a few minutes,

learn about comp. from
atomic observations

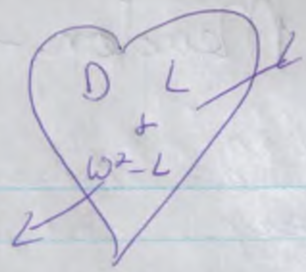
Meudon - 23. 23

Paul Weissman + Terry Rettig were saying very nice things abt. you this noon. Paul in so many words, said you express so well the poetic or romantic side of astronomy, that many of us feel but "serious" scientists are reluctant to express.
Well, You do!
I said, "What! That practical joker!!"

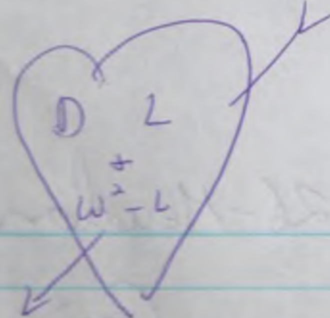
Strong emissions occurred during the Splashback phase. eg CA, Fe
No definite conclusions about S-L 9 composition.
further modelling is still needed.
AND, when is next S-L 9 meeting.

Richard West.
Synthesis of the Conference.
General Remarks
SL9 was a long process, very complex. Started no more than 3 years ago.
Discovery 1993
Impact 1994
Meetings - This is #5 or #6
79 papers
131 participants

24 - Meudon
45 USA
25 France
11 UK
10 Germany, Japan
Books - several published.



- The Comet
  Born outside Neptune in Kuiper Belt moved inside several thousand? yrs away.
  Captured 1929 ~
  Astrometric fit incredible
  Event of breakup + impact "extremely rare"
  Evolution
  low internal strength object.
  some dust production but not much.
  - Nucleus - unresolved as to composition
  of 2ndary splitting what keep it together. Some strength must be there.
  Rubble pile or discrete body
  Truth somewhere in between
  Fragmentation may be helped by outgassing



25 - Meudon

- The Impacts
  - Meteor Phase (Bolide) — We have spectra meteor
    - ablation fragmentation
    - Energy deposition
    - Sizes of fragments
  - Fireball Phase:
    - Dynamics, Cooling, chemistry
  - Splashback.

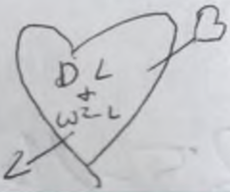
Echoes on satellites from D and E events.
Looks convincing but something seems not to fit

It seems that most agree: Galileo went down in an atypical region of Jupiter + can't readily compare with S-L9.

Probably no fragments beyond 1 km in size, say most.

Fireball really went up through the funnel. Cooling happened very quickly - we know this from Galileo measurements.

Formation of Grains plays an important role - silicates
6×10^{14} grams

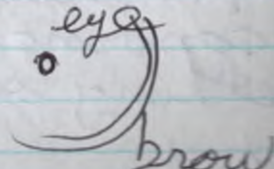


26-Meudon

Grains will be subject for long time.

Chemistry - Na, Mg, Cr, Fe.

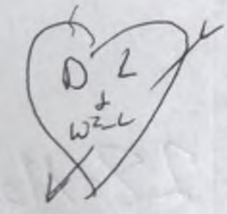
Plumes not homogeneous.
2 different developments.
~~Mod~~
Water.
How high



brow higher than the eye.

Long-Term Response.
Temperature Curves.
New Species of HCN, CO and SS persisted, for about 2 years - till now!
NH_3 was still visible 8 months after.

Dust might contain ~~the~~ some secrets!
Haze still visible. Lat?? spreading
June 1995.
-70 to -20. Not N. of -20
because of a barrier there.



27-Meudon.

Morphology.

Rings – show the way science evolves.

We don't know what causes the rings. Water is not 10x solar.

Magnetosphere

Radio Emission

Very complex lots of strange emissions + obvious that all observed changes were coming from ♃'s rad. belts.

– Auroral Effects.

various stages, about 5 stages beginning with the blinking spot.

Xrays from K impact, also other comets (Levy 1990c).

— What's next.

We agree:

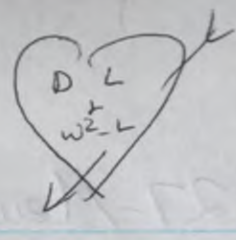
An object hit Jupiter.

=

≡.

Major questions

– Internal construction favors comet – not rubble pile



28-Meudon

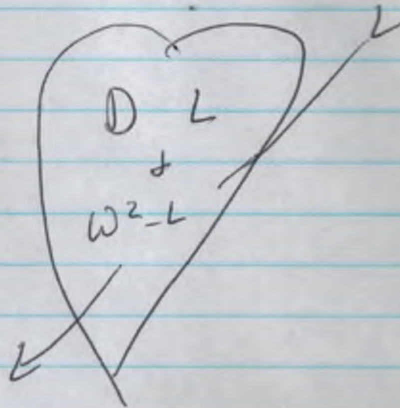
- Fireball models
- Seismic Waves? Maybe we'll see something.
- Sizes
- Chemistry in fireball/splash
- dust grains
- How long will new specie[s] last?
- Ring phenomena - what are they?

Best Quotes

No name yet for the stuff
Andy: ~~Gunk~~. Volatile Brown Gu[n]
Crawford: Pancake Theory
First 3 mins
Jupiter Big Bang.
Kracke: We need some more observations
Julia: One point didn't fit curv[e]
Andy: Meteorology does not transfe[r] from one planet to another
Paul: Don't expect to use impact times for any other comet

29-Meudon

Maybe another meeting?



THE END!

That's all Folks!

CN3h

December 17, 2001

January 19, 2006.

September 2004.

We will get a D-K from Celestron NOT.
Instead we will get a 24" RC. low alt.
+ a 20" RC. higher.
? 16" RC or 14 Celestron

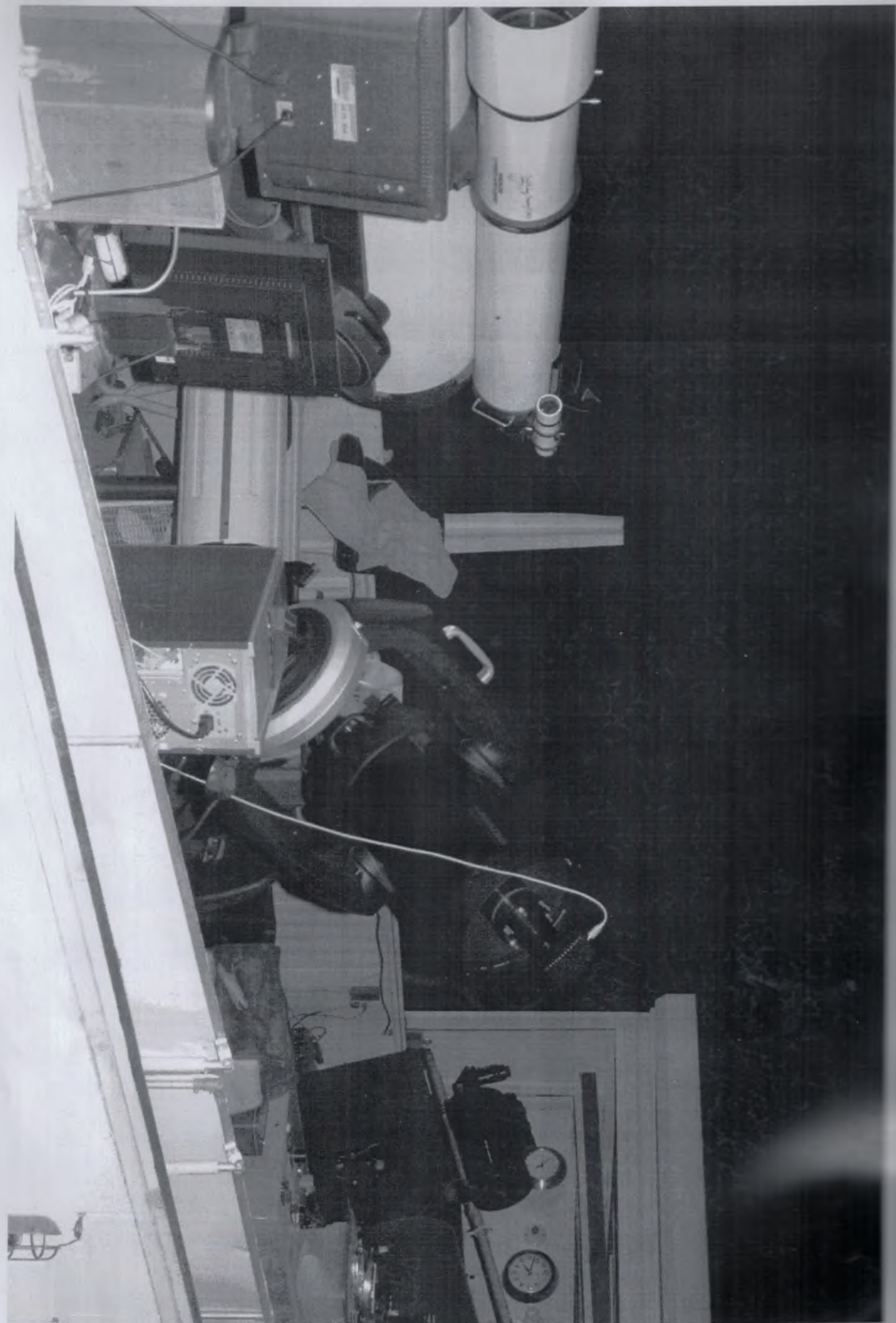
Wind at night, steady trade wind 10mph range
from E.
clamshell will block some of it.

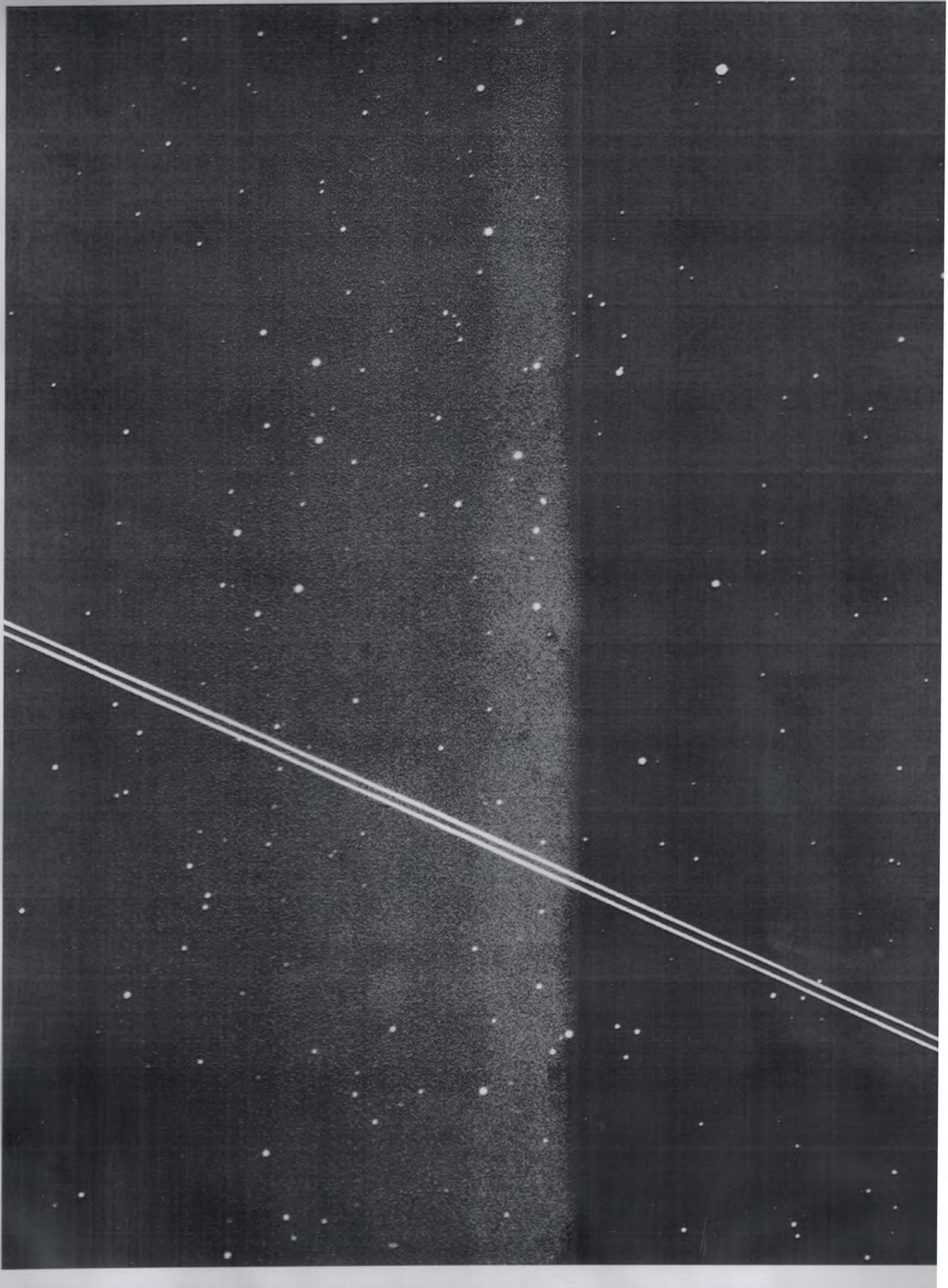
Brad's Mount is $140K

Software:
CCD soft to operate mt & camera.
Maxim DL: Image Processing.
integrating into ACP had lots
of kinky problems.
To optimize scope performance,
ACP wasn't best way to go.
Only files that have detections will have
to be moved to Odie.
with large interactive scripts, ACP is limite

CN3h-11
Digital Comet Hunting with POTUS.

Begun early in 2010
Using POTUS, the telescope that Dean Koenig set up at the White House, as a part of what might have been the first star party held with the President of the United States.

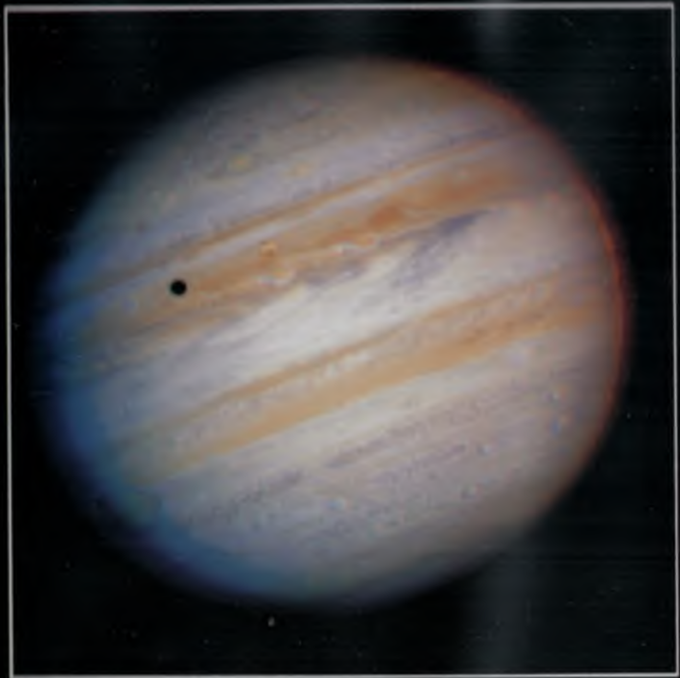




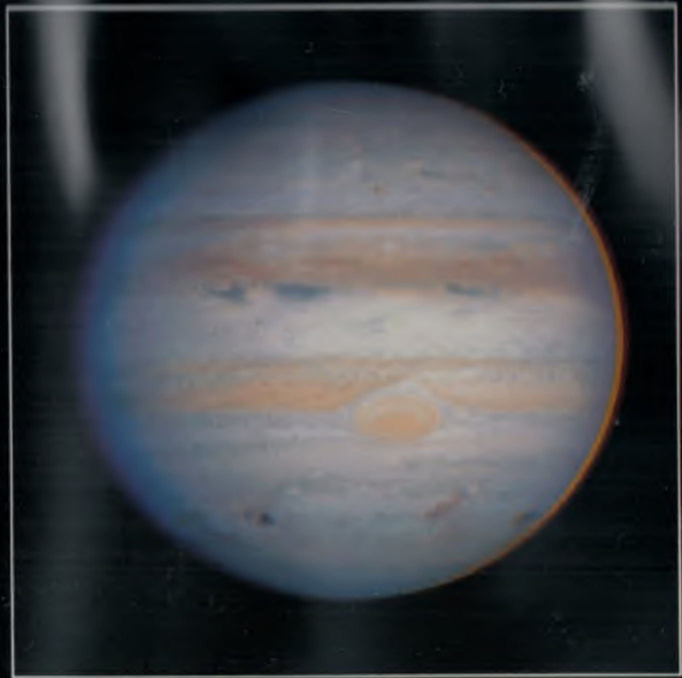
CN3c Potus-CN3h11 Valentine's Day meteoric meteor.

CN3611 June 1/2, 2014
meteoric meteor + satellite in same pic

CN3fg December 1988- June 1996



Jupiter, May 18, 1994



Jupiter, July 22, 1994

Comet P/Shoemaker-Levy 9

University of Hawaii at Manoa

Institute for Astronomy
2680 Woodlawn Drive • Honolulu, Hawaii 96822
Telex: 723-8459 • UHAST HR

Carolyn & Gene Shoemaker
US Geological Survey
2255 N. Gemini Dr
Flagstaff AZ 86001

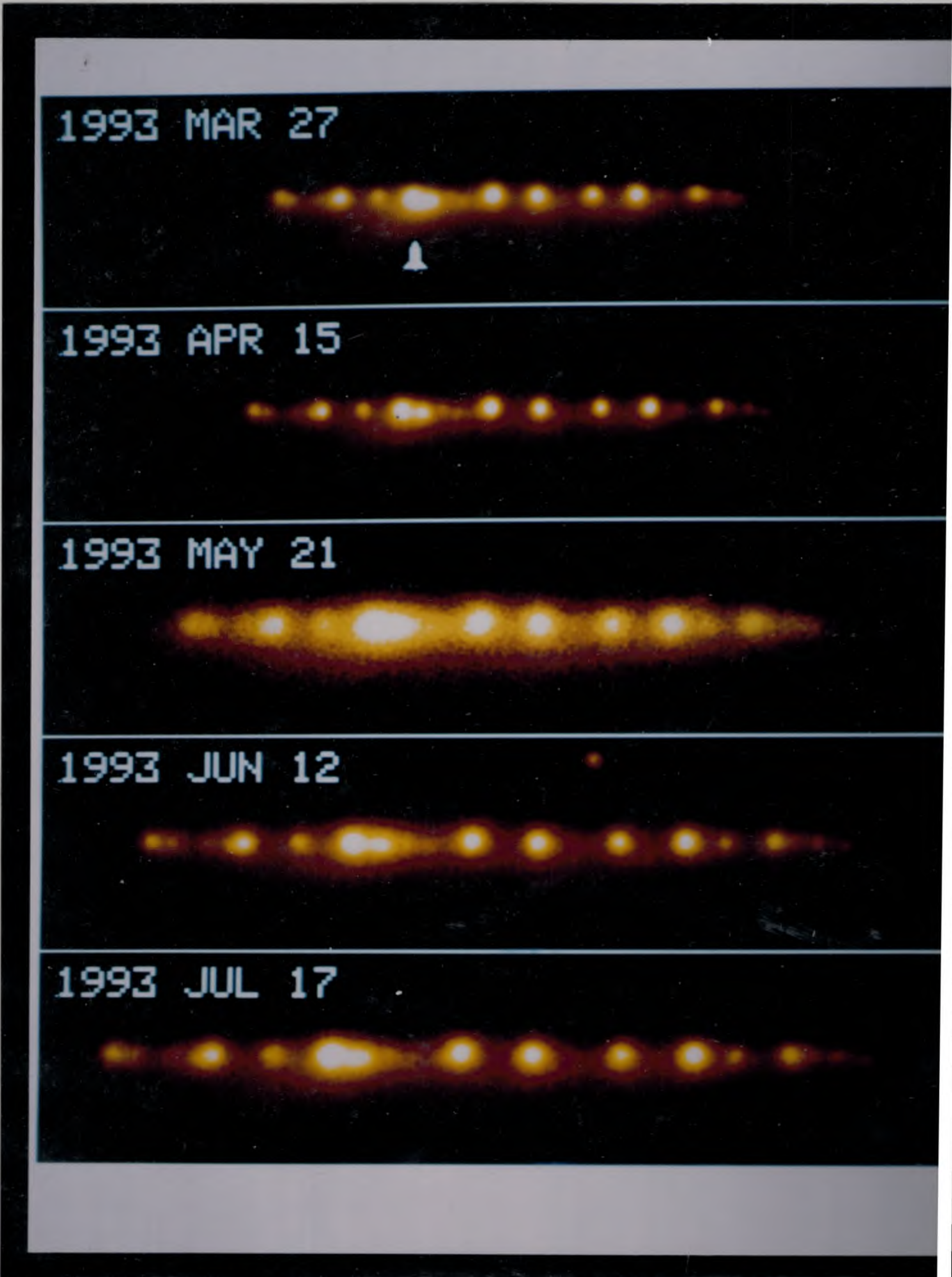
Dear Carolyn & Gene,

Jane Luu & I thought you might enjoy the enclosed CCD image of your newest comet. Some of the 17 countable sub-nuclei are clearly seen, as is the dust 'tail'. It's a real beauty. Can you find another one just like it?

Regards & congratulations,

David Jewitt

PS: Please show Gene Levy - I don't have his address.


1993 MAR 27
1993 APR 15
1993 MAY 21
1993 JUN 12
1993 JUL 17

SPACE TELESCOPE SCIENCE INSTITUTE
Operated for NASA by AURA

NASA esa

NEWS

PHOTO RELEASE NO.: STScI-PR94-21 **FOR RELEASE: Wednesday, May 18, 1994**

COMET P/SHOEMAKER-LEVY 9 "GANG OF FOUR" HST IMAGE

This is a composite HST image taken in visible light showing the temporal evolution of the brightest region of comet P/Shoemaker-Levy 9. In this false-color representation, different shades of red color are used to display different intensities of light.

[top panel] - This shows data taken on 1 July 1993, prior to the HST servicing mission. The separation of the two brightest fragments is only 0.3", so ground-based telescopes could not resolve this pair. The other two fragments just to the right of the closely-spaced pair are only barely detectable due to HST's spherical aberration.

[middle panel] - This shows the first HST observation after the successful servicing mission and was taken on 24 January 1994. The two brightest fragments are now about 1" apart, and the two fainter fragments are much more clearly seen. The light near the faintest fragment is not as concentrated as the light from the others and is elongated in the direction of the comet's tail.

[bottom panel] - The latest HST observation, taken on 30 March 1994, shows that the faintest fragment has become a barely discernible "puff." Also, the second faintest fragment has clearly split into two distinct fragments by March. Continued splitting events, such as those depicted here, will decrease the explosive power of any single impact into Jupiter's atmosphere as the comet makes its fiery plunge into this giant planet during the period 16-22 July 1994. Fortunately, most of the fragments of P/S-L 9 have apparently been stable for at least a year and have NOT shown any evidence for further break-up.

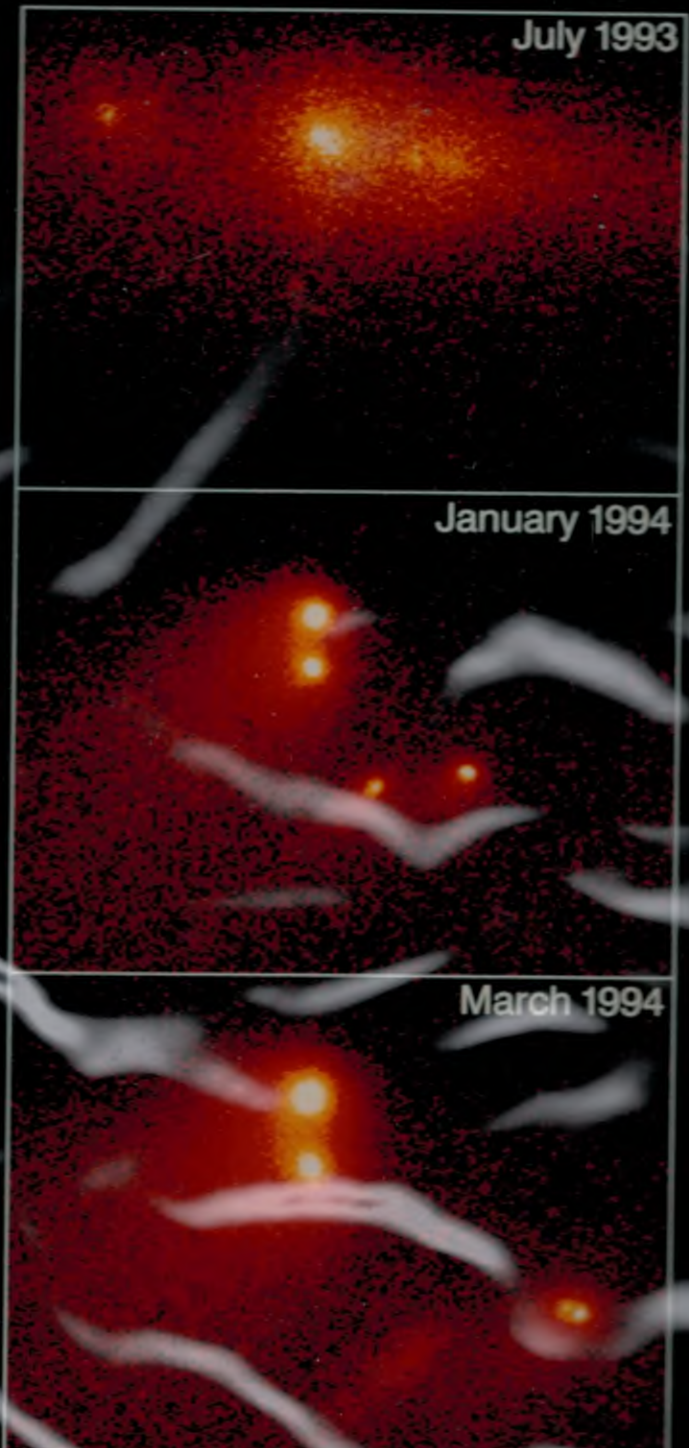
Credit: Dr. Hal Weaver and T. Ed Smith (STScI), and NASA

Photo Release

3700 San Martin Drive
Baltimore, MD 21218 USA
(410) 338-4707

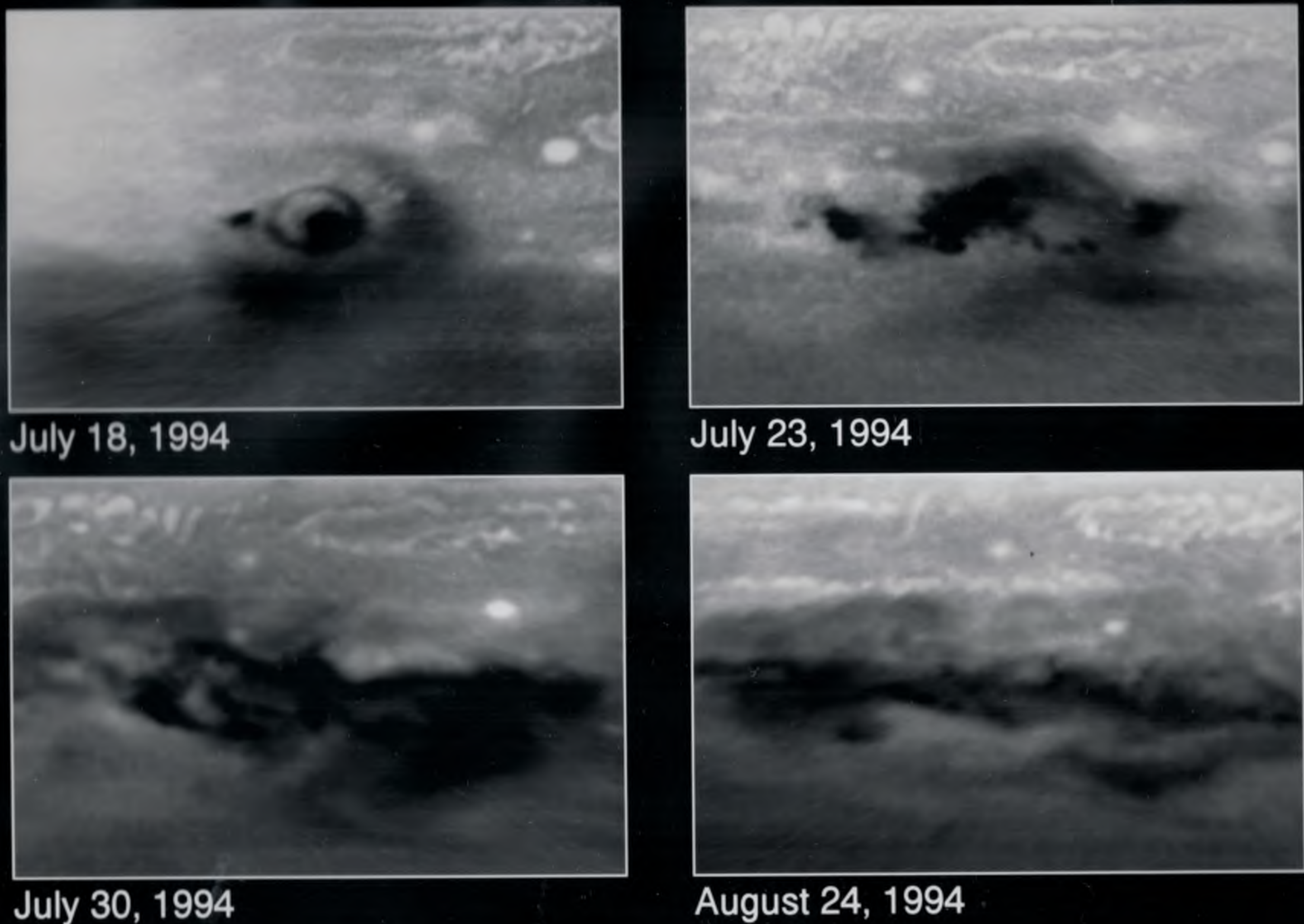
Comet P/Shoemaker-Levy 9 (1993e)

Evolution of the Brightest Region

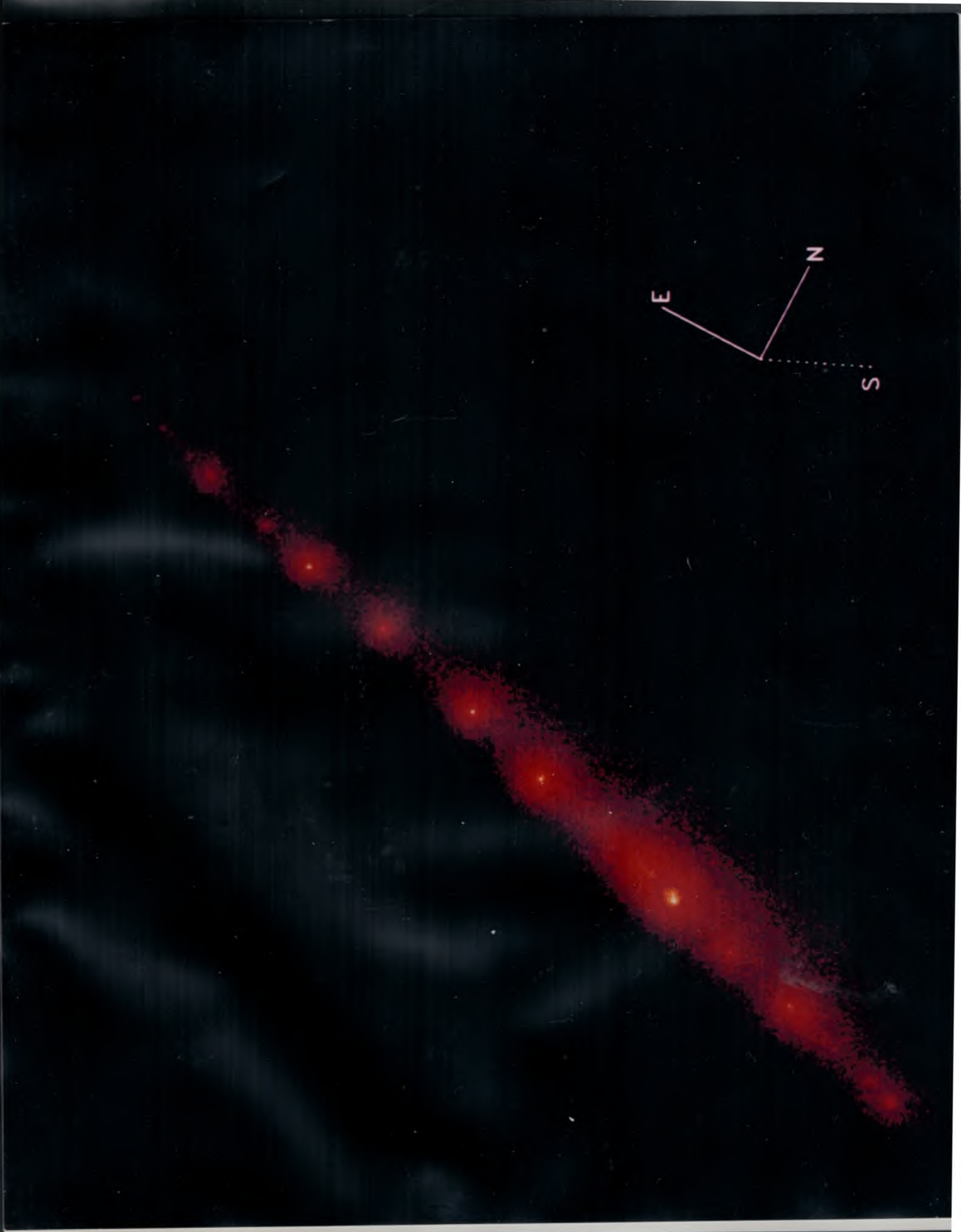


Hubble Space Telescope
Wide Field Planetary Camera

Evolution of D/G Comet Impact Sites on Jupiter



Hubble Space Telescope • Wide Field Planetary Camera 2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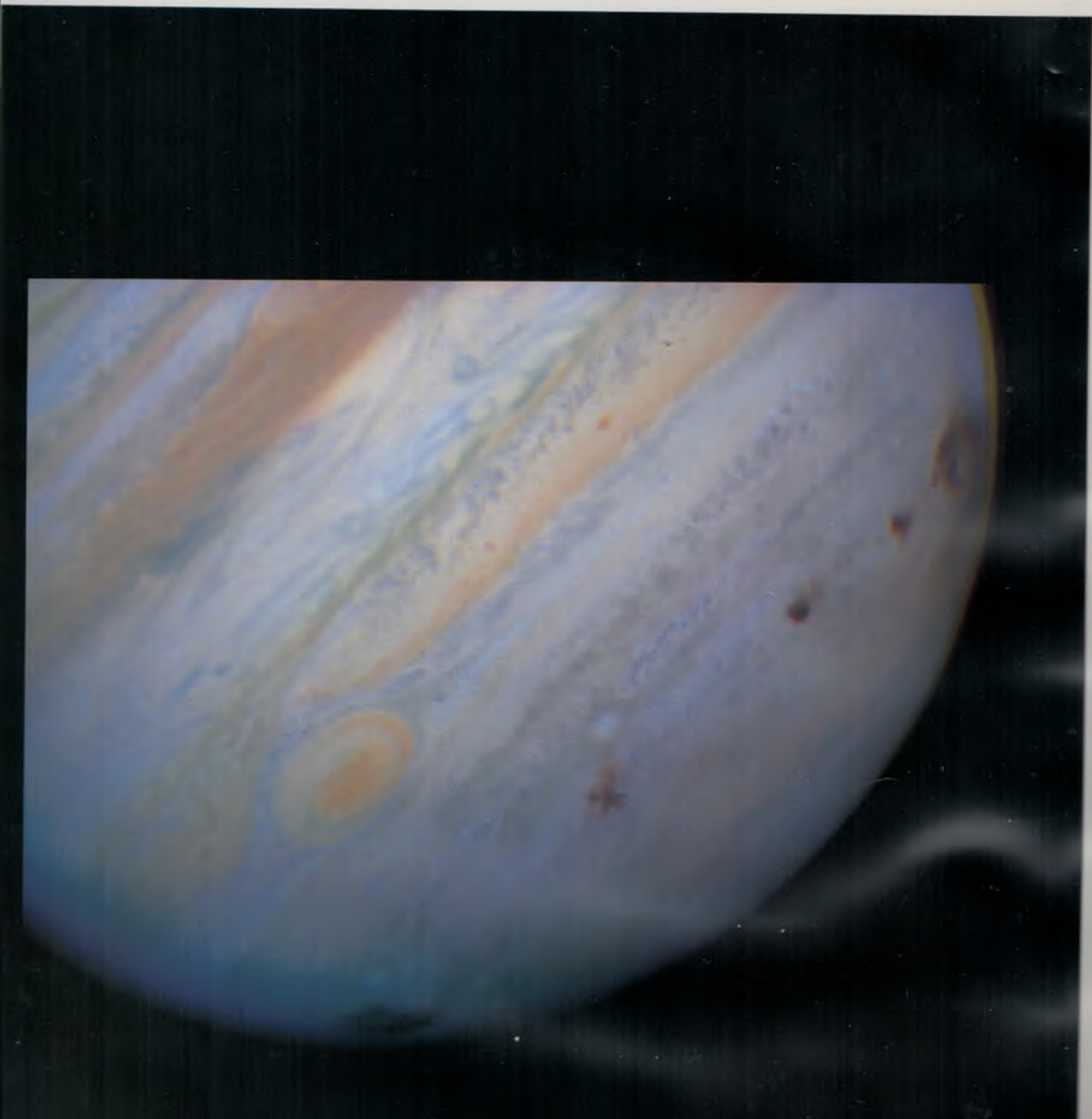
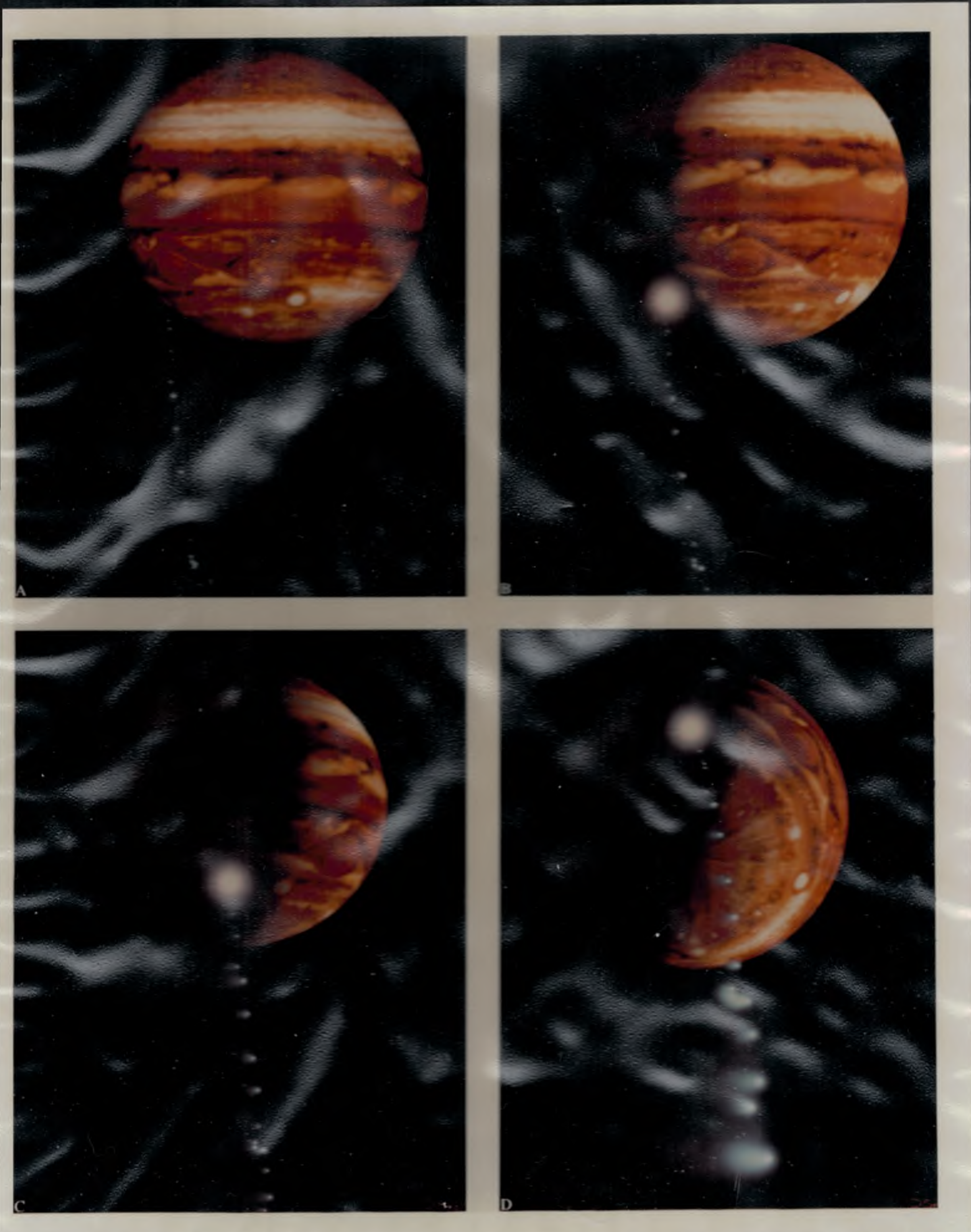
S




A
B
C
D

COMET SHOEMAKER-LEVY 9 COLLISION WITH JUPITER IN 1994

Comet Shoemaker-Levy 9, torn into pieces as a result of a close approach to Jupiter in July 1992, will collide with Jupiter during the third week of July 1994. Of tremendous scientific importance, the impacts of the cometary fragments will release more energy into Jupiter's atmosphere than that of the world's combined nuclear arsenals. Because the impact will occur on the night side of Jupiter, the explosions will not be directly observable from Earth. However, professional and amateur astronomers may observe the impact light flashes reflected off the inner satellites of Jupiter. Any lasting effects on Jupiter, such as atmospheric clouds, ejecta plumes, or seismic thermal disturbances, may be observable an hour or so later when the rotation of Jupiter brings the impact sites into the Earth's view.

Analysis of high resolution images of the comet taken by the Hubble Space Telescope in July 1993 suggests that the major cometary fragments range in size from one to a few kilometers. The large fragments are embedded in a cloud of debris with material ranging in size from boulder-sized to microscopic particles. Although comet-like outgassing of the fragments has not been observed, the fragile nature of the object suggests that it is indeed a comet rather than a more compact asteroid.

Comet Shoemaker-Levy 9 was the ninth short-periodic comet discovered by Eugene and Carolyn Shoemaker and David Levy. It was first detected on a photograph taken on the night of March 24, 1993 with the 0.4 meter Schmidt telescope located on Palomar mountain in California. Subsequent observations were forthcoming from observers at the University of Hawaii, the Spacewatch telescope on Kitt Peak in Arizona, and McDonald Observatory in Texas. These observations were used to demonstrate that the comet was in orbit about Jupiter, and has made a very close approach (within 1.4 Jupiter radii from Jupiter's center) on July 7, 1992. During this close approach, the unequal Jupiter gravitational attractions on the comet's near and far side broke apart the fragile object. The disruption of a comet into multiple fragments is an unusual event, the capture of a comet into an orbit about Jupiter is even more unusual, and the collision of a large comet with a plant is an extraordinary, millennial event.

This color depiction of comet Shoemaker-Levy 9 impacting Jupiter is shown from several perspectives. **Image A** is shown from the perspective of Earth-based observers. **Image B** shows the perspective from the Galileo spacecraft which can observe the impact point directly. **Image C** is shown from the Voyager 2 spacecraft, which may observe the event from its unique position at the outer reaches of the solar system. **Image D** depicts a generic view from Jupiter's south pole. For visual appeal, most of the large cometary fragments are shown close to one another in this image. At the time of Jupiter impact, the fragments will be separated from one another by several times the distances shown. This image was created by D.A. Seal of JPL's Mission Design Section using orbital computations provided by P.W. Chodas and D.K. Yeomans of JPL's Navigation Section.

JPL

NASA

Spectacular first view of Fragment Q impacts on Jupiter
Infrared image in the 2.3 micron methane band taken using MAGIC
on the 3.5-m telescope. Calar Alto Observatory, Spain, 20/07/94

MPIA

R
McDonald
21 July

We show a mosaic of four images of the impact of Comet Shoemaker-Levy 9 fragment R into Jupiter. The upper images were taken with the ROKCAM infrared camera on the McDonald Observatory 2.7m telescope in a filter which isolates absorption by molecular hydrogen at 2.12 microns. The lower images were taken at the same times as the upper images, but are CCD frames taken with the 0.8m telescope in a filter which isolates absorption by methane gas at 0.893 microns. The left two images were taken on 1994 July 21 05:41 UT, and the two right images were taken at 05:43UT. The upper right infrared image shows the brightening due to the impact of fragment R. This flash saturated the detector, and the actual increase in brightness is more than can be shown in this image. Our data show that the flash increased by a factor of 2 in consecutive images taken 18 seconds apart. This brightening is NOT seen in the CCD image in the lower right. This is because the fireball was not hot enough to produce significant flux at the shorter wavelength of the CCD image. ROKCAM images were taken by Dr. Yongha Kim (Univ. Maryland), Dr Beth Clark and Dr. William Cochran (Univ. Texas). CCD images were taken by Dr. Wayne Pryor (Univ. [illegible] Na (Southwest Research Institute) and Dr. Anita Cochran (Univ.

D/G and L

HST 20 Jul 1994

National Aeronautics and Space Administration
Photo Release

Hubble Space Telescope Views Comet Fragment Impacts

This color image shows the impact sites of fragments D/G and L, with a smudge along the planet's left edge where the impact site from fragment Q is just rotating into view. The image was taken with the Hubble Space Telescope's Wide Field Planetary Camera 2, in its high resolution mode (planetary camera mode). Data were obtained shortly after the Q fragment hit the planet at about 4:00 pm EDT on July 20, 1994.

Comet Shoemaker-Levy 9 broke up into 21 fragments during a close passage by Jupiter in July of 1992. As of early morning, July 22, 1994, all comet fragments have impacted the planet. Pre-encounter estimates of the energy of the combined impacts are highly uncertain, and range up to that of a million hydrogen bombs (a million megatons of TNT).

Jupiter was approximately 477 million miles (767 million kilometers) from Earth when the image was taken.

Credit: Dr. Heidi Hammel, Massachusetts Institute of Technology, Dr. Reta Beebe, New Mexico State University, NASA HST.

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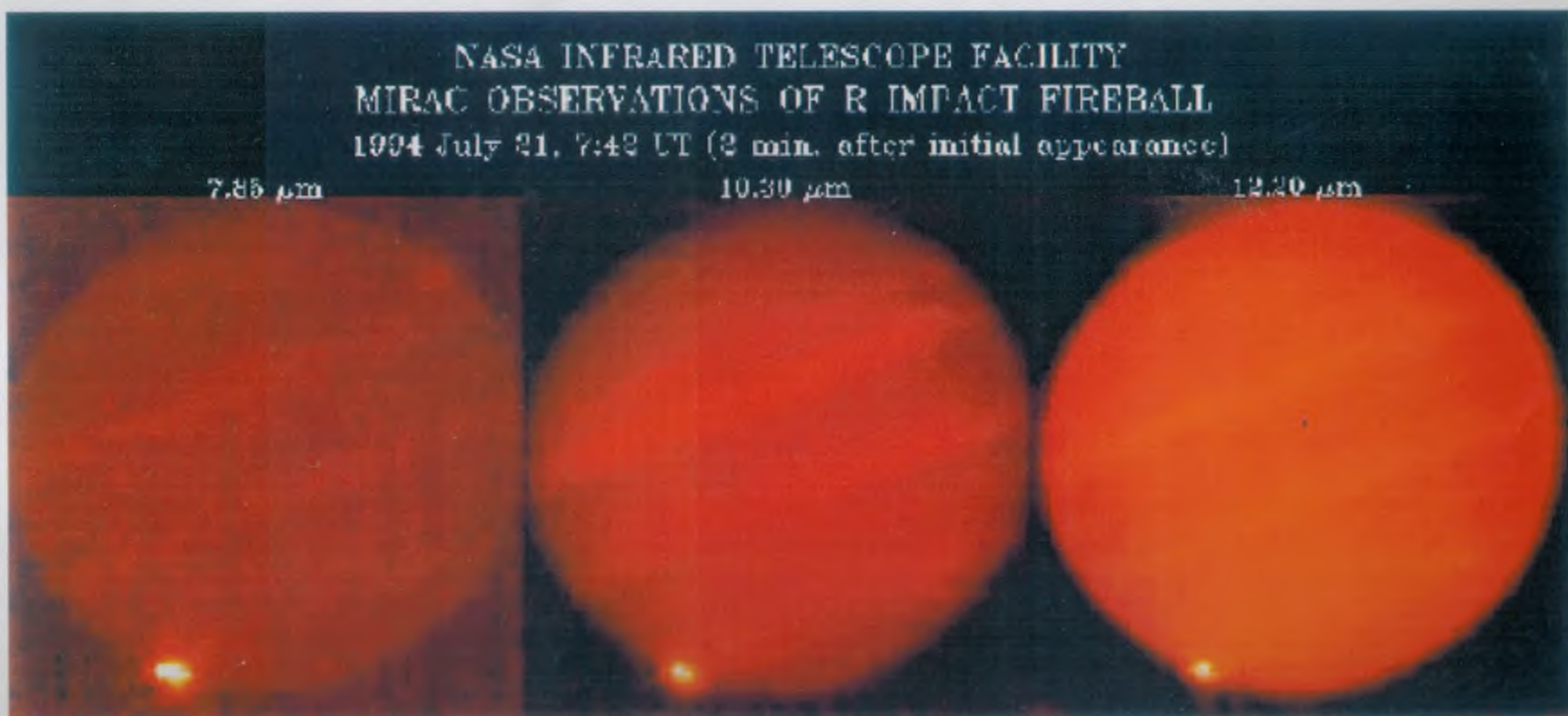
NASA INFRARED TELESCOPE FACILITY
MIRAC OBSERVATIONS OF R IMPACT FIREBALL
1994 July 21, 7:42 UT (2 min. after initial appearance)
7.85 μm
10.30 μm
12.20 μm

HST 21J


Jupiter in Ultraviolet
H
N
Q_2
D/G
B
Q_1
R
L
Hubble Space Telescope
Wide Field Planetary Camera 2

PHOTO RELEASE NO STScI-PRC94-35 **FOR RELEASE: July 22, 1994**

HUBBLE ULTRAVIOLET IMAGE OF MULTIPLE COMET IMPACTS ON JUPITER

Ultraviolet image of Jupiter taken by the Wide Field Camera of NASA's Hubble Space Telescope. The image shows Jupiter's atmosphere at a wavelength of 2550 Angstroms after many impacts by fragments of comet Shoemaker-Levy 9. The most recent impactor is fragment R which is below the center of Jupiter (third dark spot from the right). This photo was taken 3:55 EDT on July 21, about 2.5 hours after R's impact. A large, dark patch from the impact of fragment H is visible rising on the morning (left) side. Proceeding to the right, other dark spots were caused by impacts of fragments Q1, R, D and G (now one large spot), and L, with L covering the largest area of any seen thus far. Small dark spots from B, N, and Q2 are visible with careful inspection of the image. The spots are very dark in the ultraviolet because a large quantity of dust is being deposited high in Jupiter's stratosphere, and the dust absorbs sunlight. Scientists will be able to track winds in the stratosphere by watching the evolution of these features. Jupiter's moon, Io, is the dark spot just above the center of the planet.

We show a mosaic of four images of the impact of Comet Shoemaker-Levy 9 fragment R into Jupiter. The upper images were taken with the ROKCAM infrared camera on the McDonald Observatory 2.7m telescope in a filter which isolates absorption by molecular hydrogen at 2.12 microns. The lower images were taken at the same times as the upper images, but are CCD frames taken with the 0.8m telescope in a filter which isolates absorption by methane gas at 0.893 microns. The left two images were taken on 1994 July 21 05:41 UT, and the two right images were taken at 05:43UT. The upper right infrared image shows the brightening due to the impact of fragment R. This flash saturated the detector, and the actual increase in brightness is more than can be shown in this image. Our data show that the flash increased by a factor of 2 in consecutive images taken 18 seconds apart. This brightening is NOT seen in the CCD image in the lower right. This is because the fireball was not hot enough to produce significant flux at the shorter wavelength of the CCD image. ROKCAM images were taken by Dr. Yongha Kim (Univ. Maryland), Dr Beth Clark and Dr. William Cochran (Univ. Texas). CCD images were taken by Dr. Wayne Pryor (Univ. Colorado), Dr. Chan Na (Southwest Research Institute) and Dr. Anita Cochran (Univ. Texas).

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Hubble Space Telescope NEWS

PHOTO RELEASE NO STScI-PRC94-34 **FOR RELEASE: July 22, 1994**

COLOR HUBBLE IMAGE OF MULTIPLE COMET IMPACTS ON JUPITER

Image of Jupiter with NASA's Hubble Space Telescope's Planetary Camera. Eight impact sites are visible. From left to right are the E/F complex (barely visible on the edge of the planet), the star-shaped H site, the impact sites for tiny N, Q1, small Q2, and R, and on the far right limb the D/G complex. The D/G complex also shows extended haze at the edge of the planet. The features are rapidly evolving on timescales of days. The smallest features in this image are less than 200 kilometers across. This image is a color composite from three filters at 9530, 5550, and 4100 Angstroms.

Credit: Hubble Space Telescope Comet Team and NASA

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Hubble Space Telescope NEWS

Photo Release
STScI-PR94-26a

FOR RELEASE:
July 7, 1994

PHOTO ILLUSTRATION OF COMET P/SHOEMAKER-LEVY 9 & PLANET JUPITER

This is a composite photo, assembled from separate images of Jupiter and Comet P/Shoemaker-Levy 9, as imaged by the Wide Field & Planetary Camera-2 (WFPC-2), aboard NASA's Hubble Space Telescope (HST).

Jupiter was imaged on May 18, 1994, when the giant planet was at a distance of 420 million miles (670 million km) from Earth. This "true-color" picture was assembled from separate HST exposures in red, blue, and green light. Jupiter's rotation between exposures creates the blue and red fringe on either side of the disk. HST can resolve details in Jupiter's magnificent cloud belts and zones as small as 200 miles (320 km) across (wide field mode). This detailed view is only surpassed by images from spacecraft that have traveled to Jupiter.

The dark spot on the disk of Jupiter is the shadow of the inner moon Io. This volcanic moon appears as an orange and yellow disk just to the upper right of the shadow. Though Io is approximately the size of Earth's Moon (but 2,000 times farther away), HST can resolve surface details.

When the comet was observed on May 17, its train of 21 icy fragments stretched across 710 thousand miles (1.1 million km) of space, or 3 times the distance between Earth and the Moon. This required six WFPC exposures along the comet train to include all the nuclei. The image was taken in red light.

The apparent angular size of Jupiter relative to the comet, and its angular separation from the comet when the images were taken, have been modified for illustration purposes.

Credit: H.A. Weaver, T.E. Smith (Space Telescope Science Institute) and J.T. Trauger, R.W. Evans (Jet Propulsion Laboratory), and NASA.

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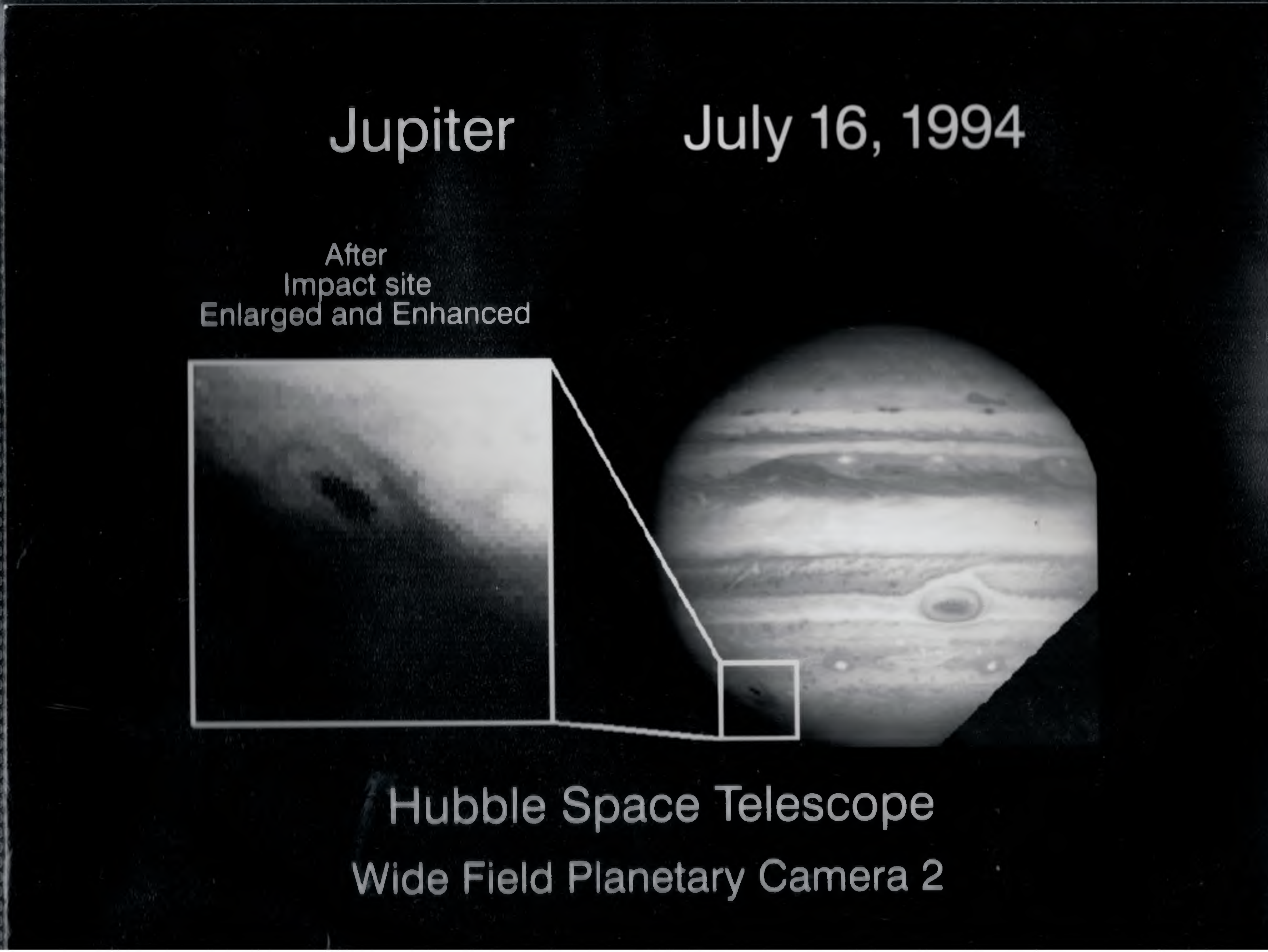
Jupiter
July 16, 1994
After
Impact site
Enlarged and Enhanced
Hubble Space Telescope
Wide Field Planetary Camera 2

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Hubble Space Telescope NEWS

NASA esa

PHOTO RELEASE NO.: STScI-PR94-28 **FOR RELEASE: July 17, 1994**

HUBBLE IMAGE OF COMET SHOEMAKER-LEVY FIRST FRAGMENT IMPACT WITH JUPITER

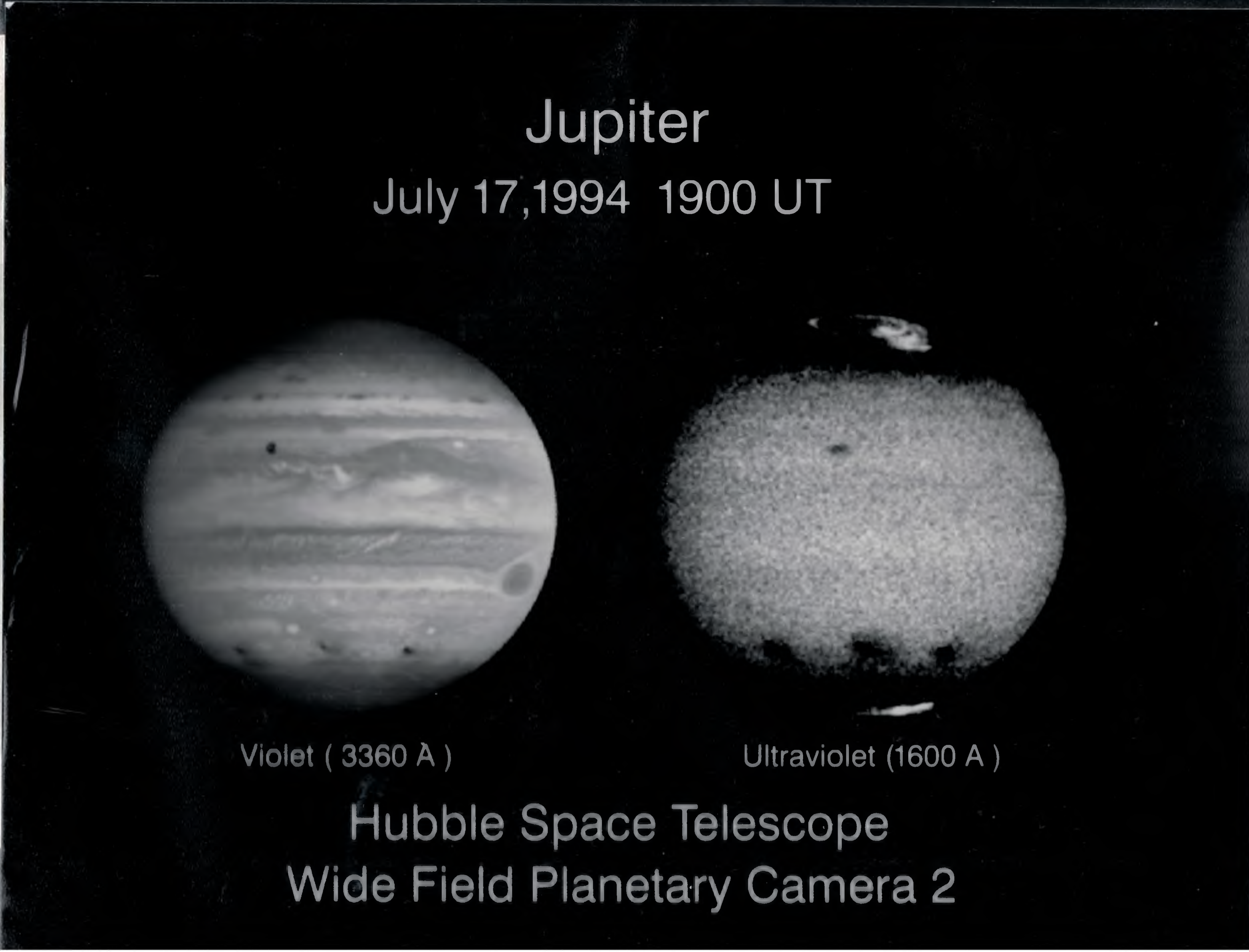
This NASA Hubble Space Telescope image of Jupiter's cloudtops was taken at 5:32 EDT on July 16, 1994, shortly after the impact of the first fragment (A) of Comet Shoemaker-Levy 9. A violet (410 nanometer) filter of the Wide Field Planetary Camera 2 was used to make the image 1.5 hours after the impact.

The impact site is visible as a dark streak and crescent-shaped feature in the lower left of the image, and is several thousand kilometers across. The comet entered the atmosphere from the south in the direction of the streak at an angle of about 45 degrees from the vertical. The crescent-shaped feature may be the remains of the plume that was ejected back along the entry path of the projectile. The features are probably dark particles from the comet, or possibly condensates dredged up from Jupiter's deep atmosphere.

Comet Shoemaker-Levy 9 broke up during a close passage by Jupiter in July of 1992. The fragments will continue to impact the planet through 22 July 1994. Pre-encounter estimates of the energy of the combined impacts are highly uncertain, and range up to that of a million hydrogen bombs (a million megatons of TNT).

Jupiter was approximately 477 million miles (767 million kilometers) from Earth when the image was taken.

Credit: H. Hammel, MIT
and NASA


Jupiter
July 17,1994 1900 UT
Violet (3360 A)
Ultraviolet (1600 A)
Hubble Space Telescope
Wide Field Planetary Camera 2

Operated for NASA by AURA

NASA esa PHOTO RELEASE No. STScI-PRC94-31 FOR RELEASE: July 18, 1994

JUPITER'S COMET COLLISION SITES AS SEEN IN VISIBLE AND ULTRAVIOLET LIGHT

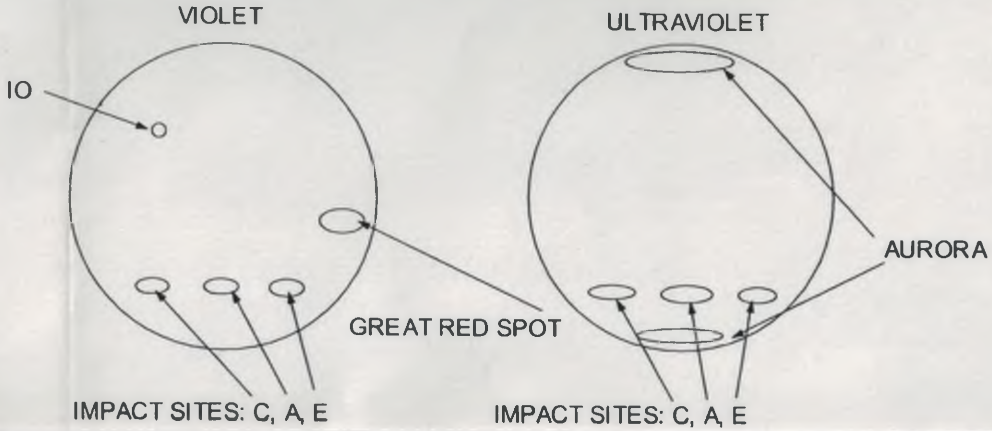
This comparison of visible light (blue) and far-ultraviolet (FUV) images of Jupiter taken with the Wide Field Planetary Camera-2 (WFPC-2) on NASA's Hubble Space Telescope show how the appearance of the planet and of comet Shoemaker-Levy-9 impact sites differ at these two wavelengths (1400-2100 and 3100-3600 Angstroms). The images, taken 20 minutes apart on July 17, 1994 (around 19:00 UT), show the impact sites on the south hemisphere, from left to right, of comet fragments C, A and E, about 12, 23, and 4 hours after each collision. Jupiter's satellite Io is seen crossing above the center of the disk, and the famous Great Red Spot is near the eastern limb.

While visible light reflects off top of Jupiter's cloud decks, ultraviolet light doesn't penetrate any deeper than Jupiter's stratosphere and higher altitude levels (100's of kilometers above the cloud tops). (The grainy appearance of Jupiter in the FUV is due to the darkness of the planet at this wavelength.) Jupiter's aurora can be seen around the north and south poles where the atmosphere appears dark due the presence of hazes These emissions are produced when energetic charged particles from Jupiter's magnetic field collide with molecular hydrogen in the upper atmosphere.

In the visible image, the impact sites appear as localized dark spots with diffuse halos. In the ultraviolet image the impact regions appear darker and more extended, because the FUV is more sensitive to smaller amounts of particles, and/or that the horizontal winds in the upper atmospheric levels may be faster. The dark appearance is due to presence of enhanced amounts UV absorbing molecules, scattering hazes and dust. This material should be a combination of gases from Jupiter's lower atmosphere as well as comet volatiles and impact by-products that were carried up from deeper in Jupiter's atmosphere and deposited into the stratosphere and thermosphere. Material should also have been deposited from ablation of the fragments and dust during entry.

Tracking the motions with WFPC-2 FUV images of the dark comet fragment "clouds" throughout the impact period should reveal for the first time the magnitude and direction of the high altitude winds on Jupiter. The Jovian auroral emissions will also be monitored with both WFPC-2 and the Faint Object Camera (FOC) to determine if the associated processes are affected by the comet's passage through the magnetosphere or changes in the upper atmosphere.

Credit: John Clarke, University of Michigan
and NASA



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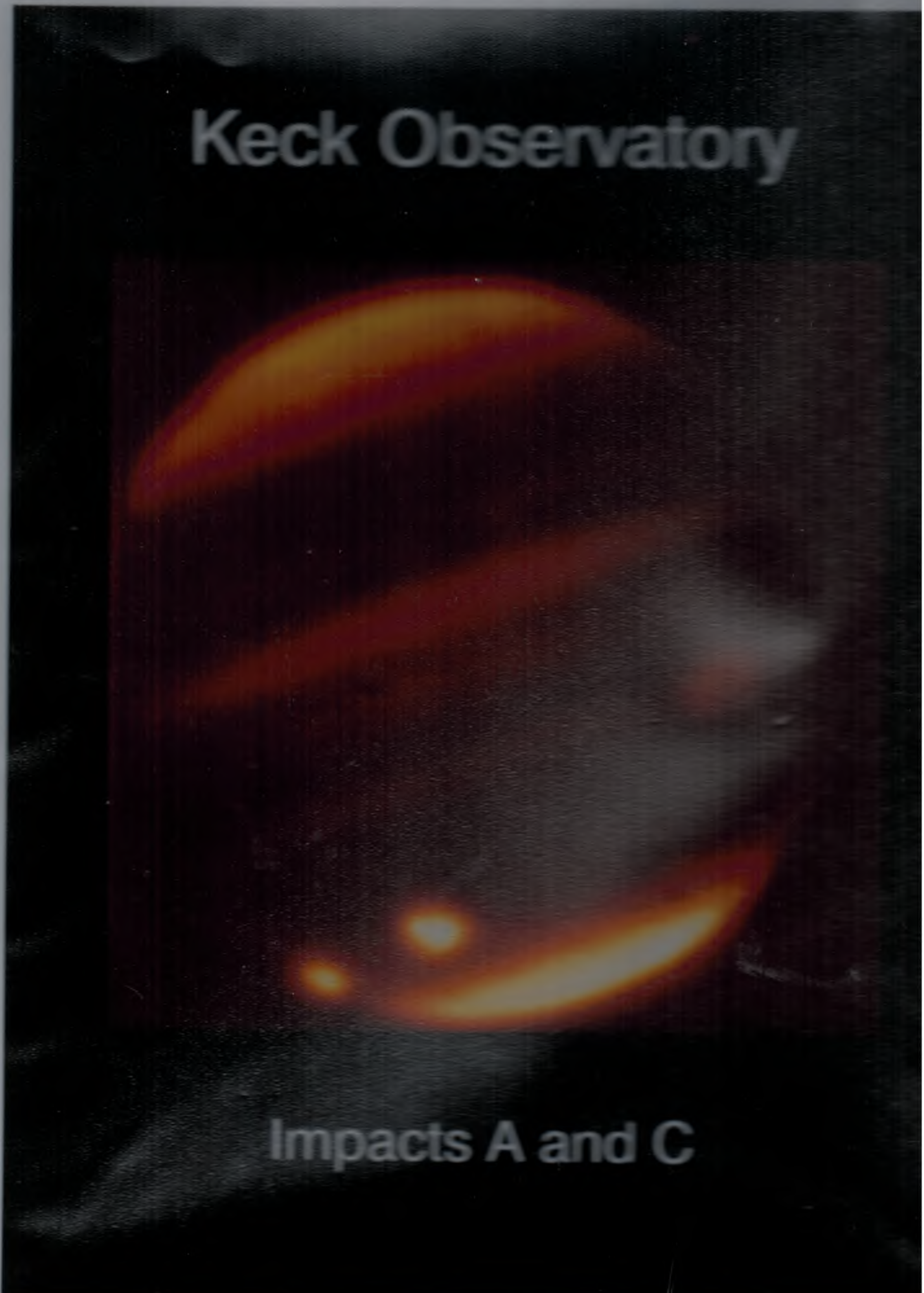
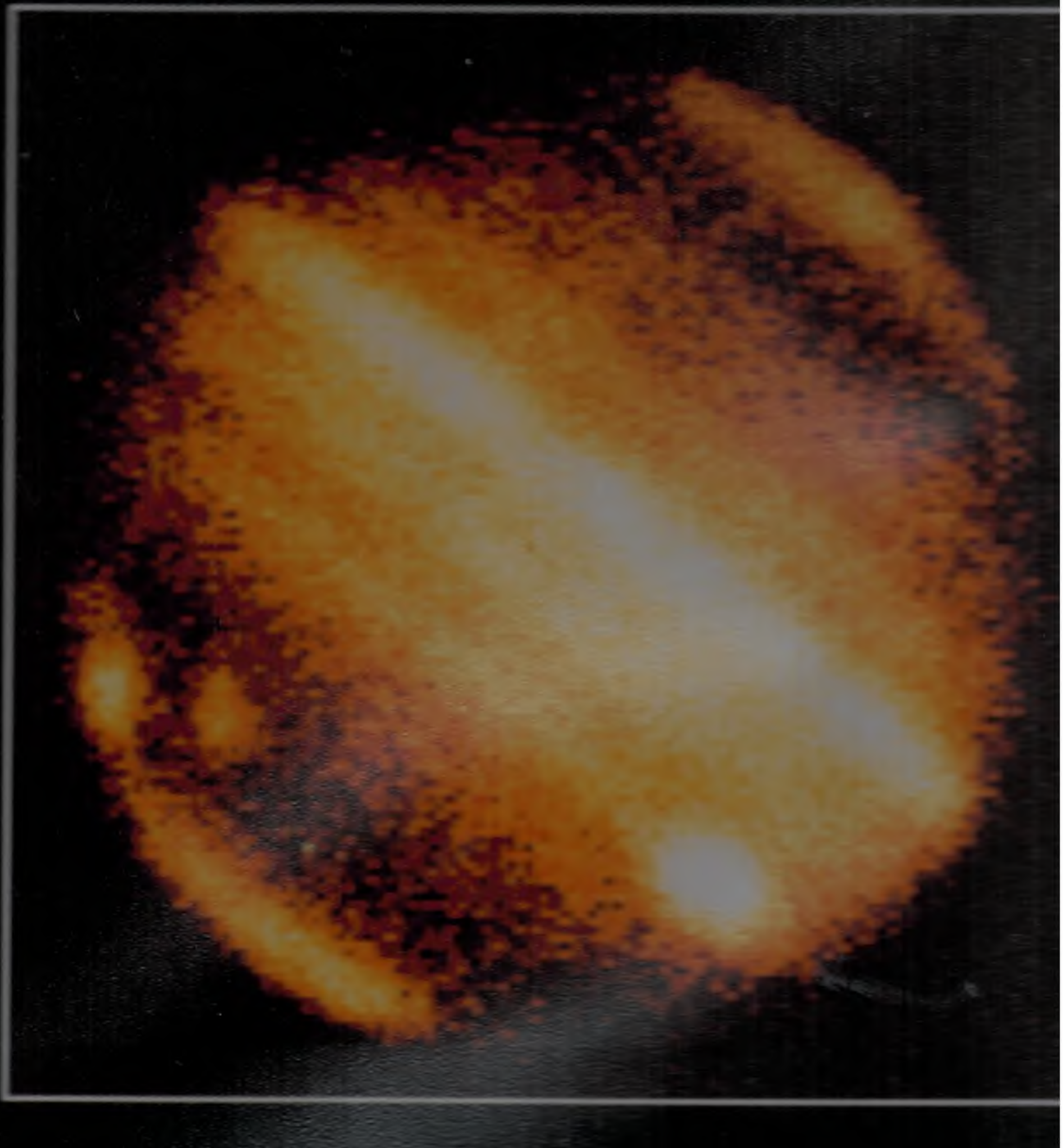


InfaRed Telescope Facility

Jupiter



July 17 1994

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Credit: HST Comet Team and NASA

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Hubble Space Telescope NEWS

PHOTO RELEASE NO STScI-PRC94-36 **FOR RELEASE: July 23, 1994**

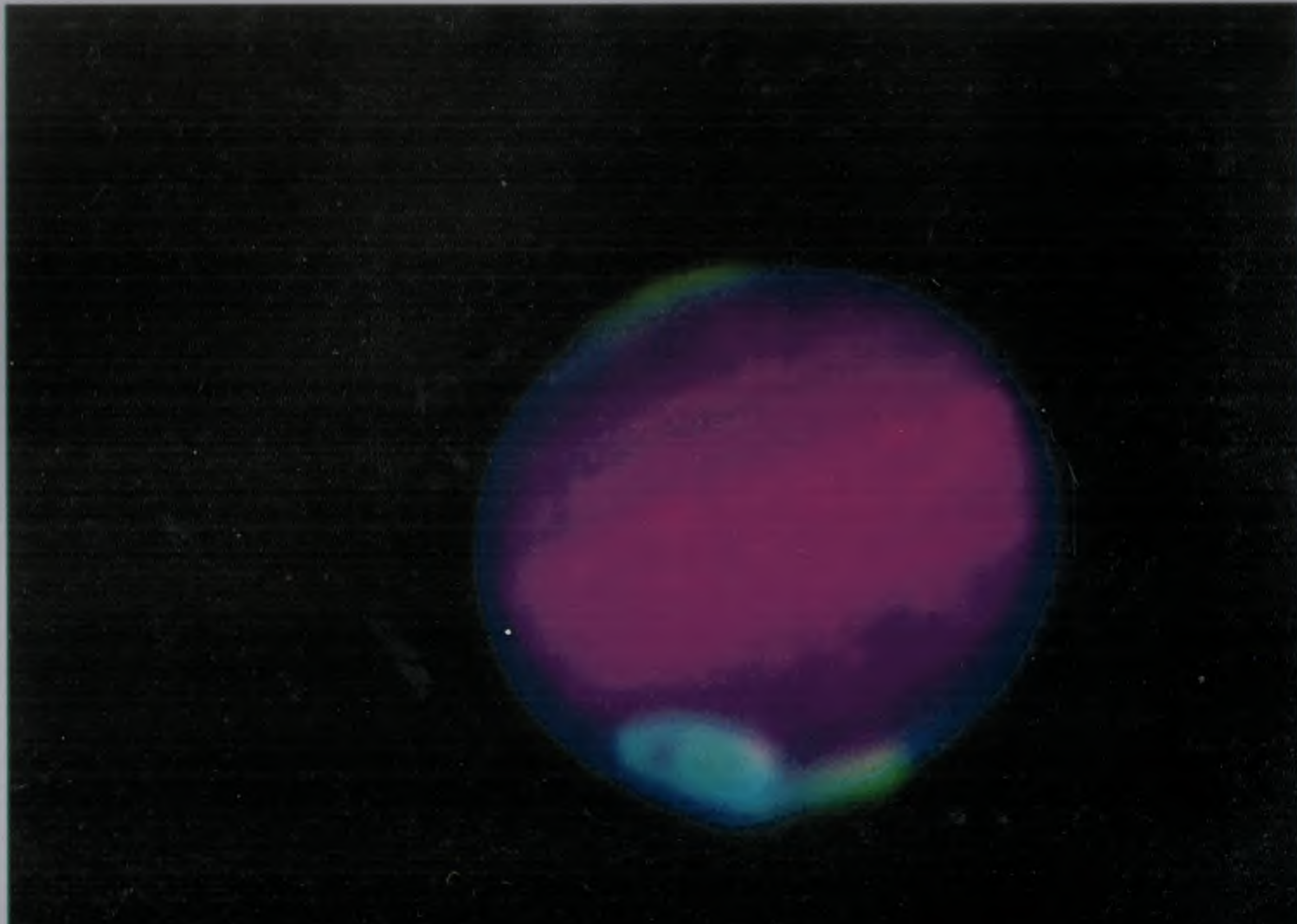
FLAT PROJECTION OF LARGE COMET IMPACT ON JUPITER

This is a NASA's Hubble Space Telescope image of the impact sites of fragments "D" and "G" from Comet Shoemaker-Levy 9 which collided with the giant planet Jupiter. The picture has been image processed to correct for the curvature of the disk of Jupiter, so that the spot appears flat, as if the viewer were hovering directly overhead.

The large feature was created by the impact of comet fragment "G" which impacted Jupiter on July 18, 1994. The smaller feature to the left was created on July 17, by the impact of comet fragment "D".

The dark crescent, nearly 7,460 miles (12,000 km) across, was produced by material thrown high into Jupiter's stratosphere by the explosion created by the "G" impact. The material might be fine sulfur particles produced as a result of the heat of the explosion. The inner ring might be a sound wave expanding from the site of the explosion. This thin dark ring had a radius of 2,330 miles (3,750 km) across when this image was taken 90 minutes after the explosion.

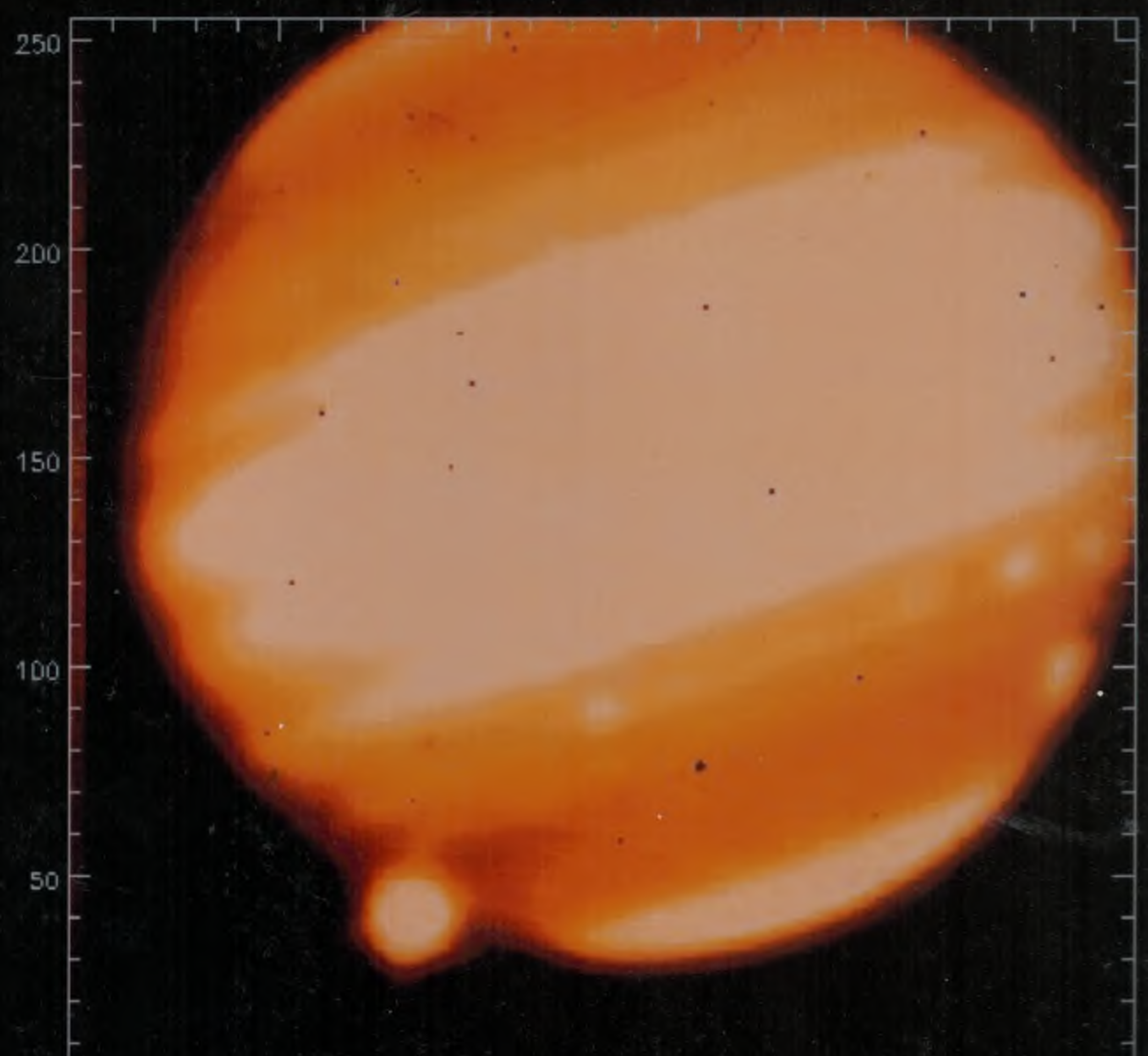
The smallest features in the image are less than 200 kilometers across. This image is a color composite from three separate exposures taken with the Wide Field and Planetary Camera

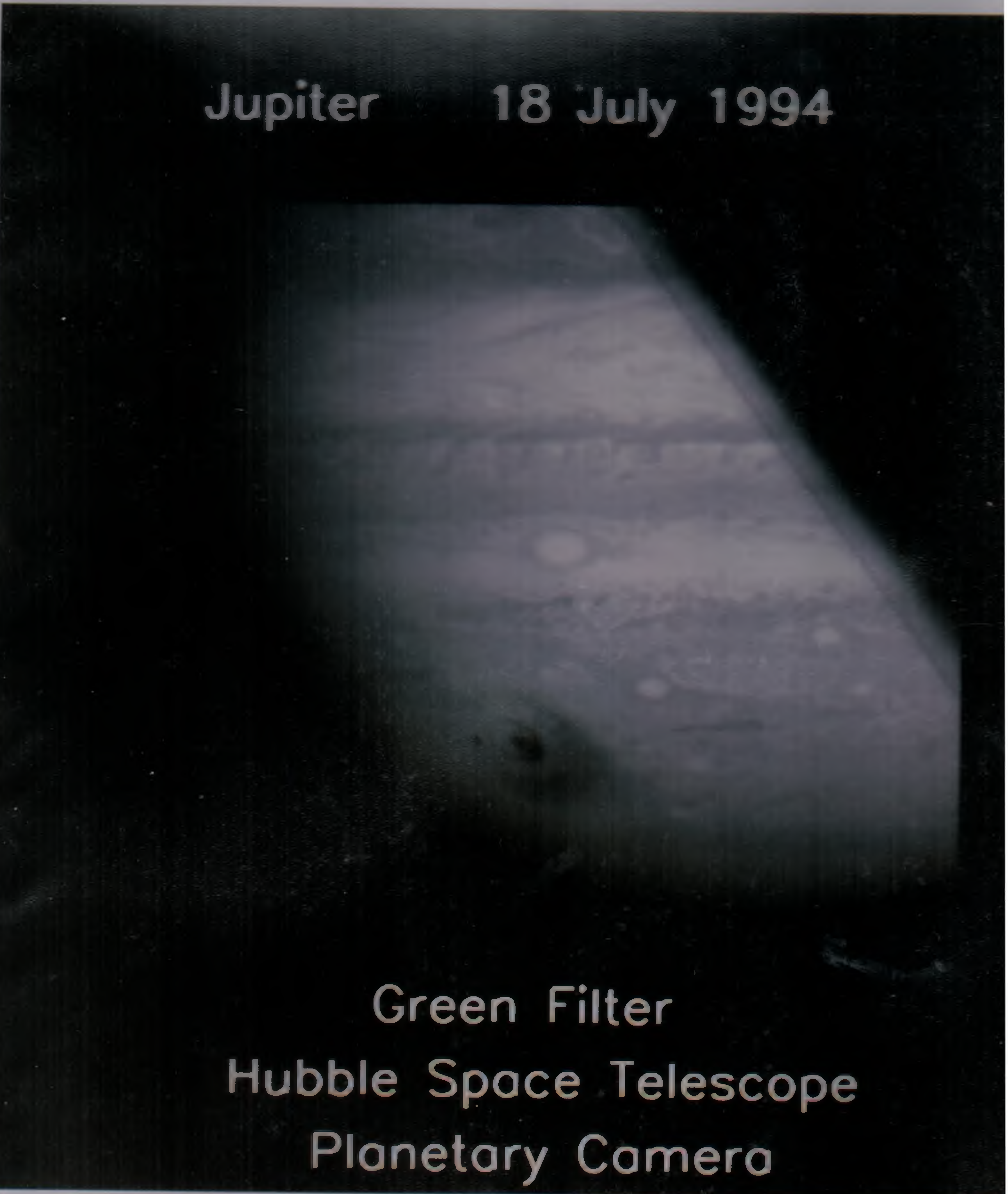


The splash of the impact of Fragment G of Comet Shoemaker-Levy 9 on Jupite
The ring of hot gas is 33000 km wide, and it was expanding at 4 km/s.

The colour coding is 3.09 μm (B), 3.42 μm (G) and 3.99 μm (R)
(Images from Peter McGregor and Mark Allen, ANU 2.3m telescope at Siding Spring)

KECK Impact G 2.2 Microns




Jupiter 18 July 1994
Green Filter
Hubble Space Telescope
Planetary Camera

National Aeronautics and Space Administration
Photo Release

Hubble Space Telescope View of Comet Fragment G Impact Zone

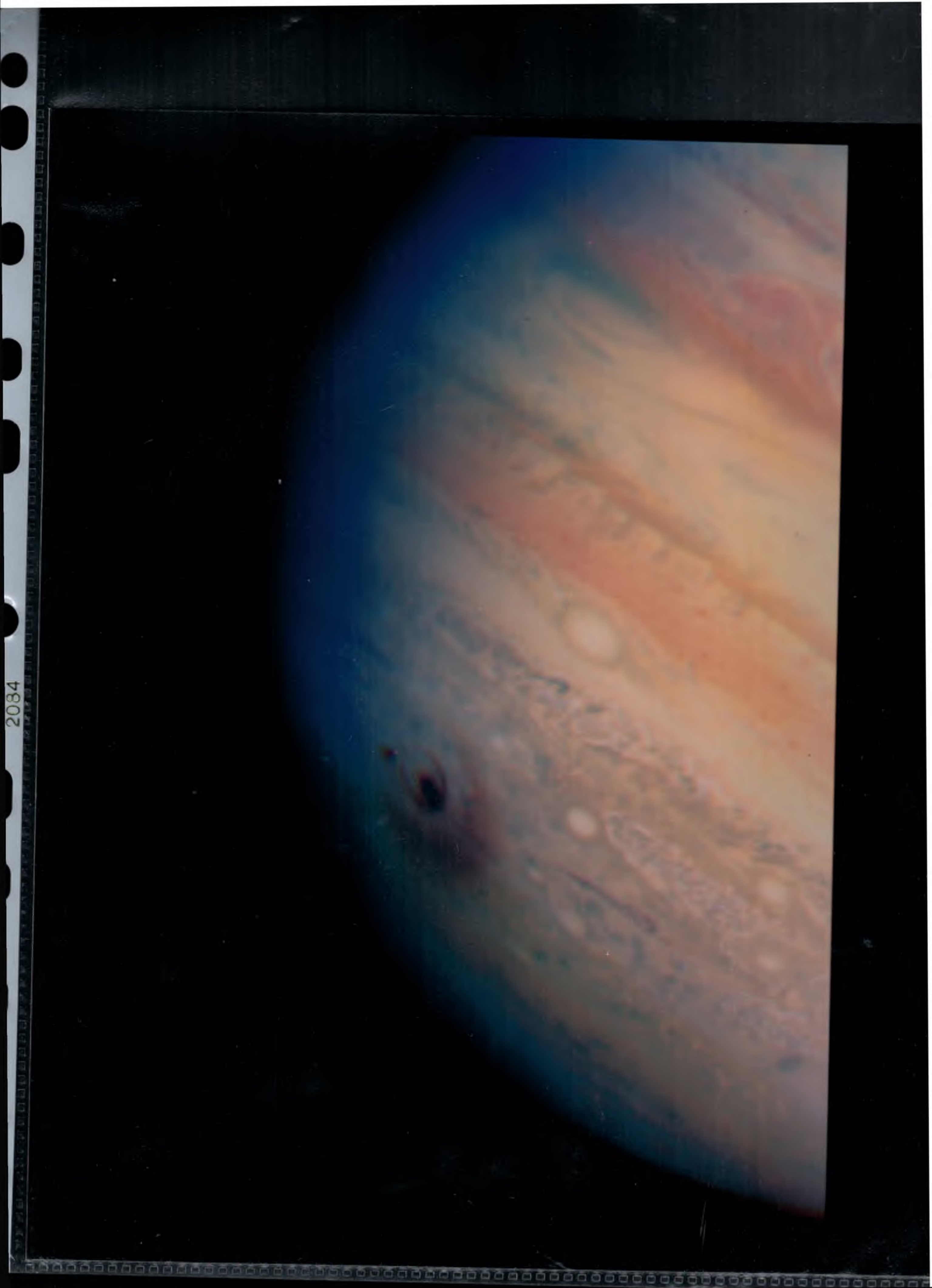
This image shows the impact zone on Jupiter of fragment G of Comet Shoemaker-Levy 9. The image was made in green light with the Planetary Camera channel of the Wide Field Planetary Camera 2 (WFPC2). Data for the image were obtained in the early morning hours of July 18, 1994.

The impact site is visible as a complex pattern of circles seen in the lower left of the partial planet image.

Comet Shoemaker-Levy 9 broke up into 21 fragments during a close passage by Jupiter in July of 1992. Fragment G was one of the brightest and likely the largest of the 21 fragments. Fragments A-H have impacted the planet. Remaining fragments will continue to impact Jupiter through July 22, 1994. Pre-encounter estimates of the energy of the combined impacts are highly uncertain, and range up to that of a million hydrogen bombs (a million megatons of TNT).

Jupiter was approximately 477 million miles (767 million kilometers) from Earth when the image was taken.

Credit: Dr. Heidi Hammel, Massachusetts Institute of Technology, NASA HST.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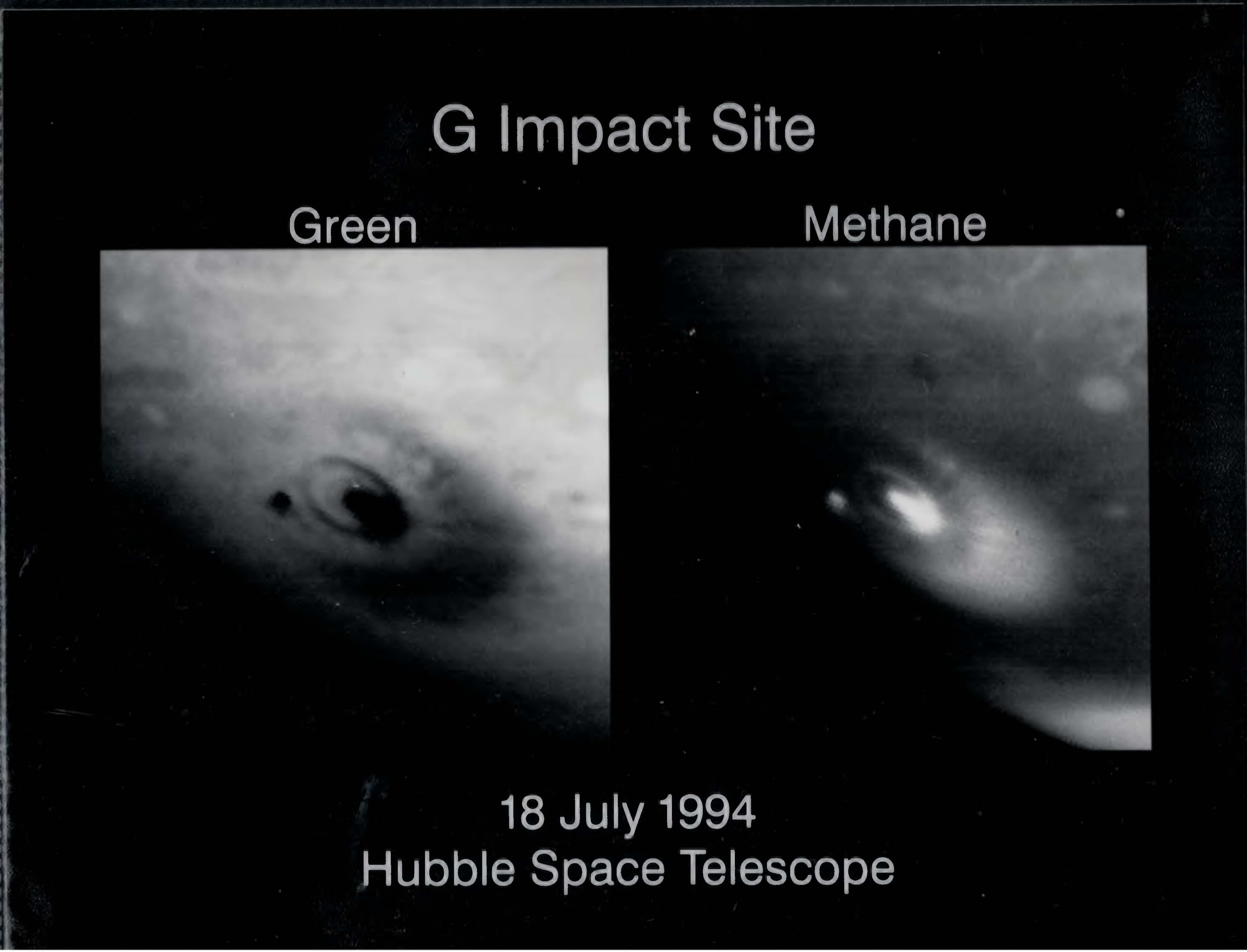
G Impact Site
Green
Methane
18 July 1994
Hubble Space Telescope

National Aeronautics and Space Administration
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Hubble Space Telescope Views of Comet Fragment G Impact Zone

This image shows two views of the impact zone on Jupiter of fragment G of Comet Shoemaker-Levy 9. The image on the left was made in green light with the Planetary Camera channel of the Wide Field Planetary Camera 2 (WFPC2). The image on the right is the same field taken through the WFPC2 methane filter. Data for the images were obtained in the early morning hours of July 18, 1994.

The impact site is visible as a complex pattern of circles seen in the lower left of the partial planet image. The small dark feature to the left of the pattern of circles is the impact site of fragment D. The dark, sharp ring at the site of the fragment G impact is 80% of the size of the Earth.

Comet Shoemaker-Levy 9 broke up into 21 fragments during a close passage by Jupiter in July of 1992. Fragment G was one of the brightest and likely the largest of the 21 fragments. The remaining fragments will continue to impact Jupiter through July 22, 1994. Scientists estimate that the combined energy from all of the impacts will approach the equivalent of 40 million megatons of TNT.

Jupiter was approximately 477 million miles (767 million kilometers) from Earth when the image was taken.

National Aeronautics and Space Administration
Photo Release

Hubble Space Telescope Views of Comet Fragment G Impact Zone

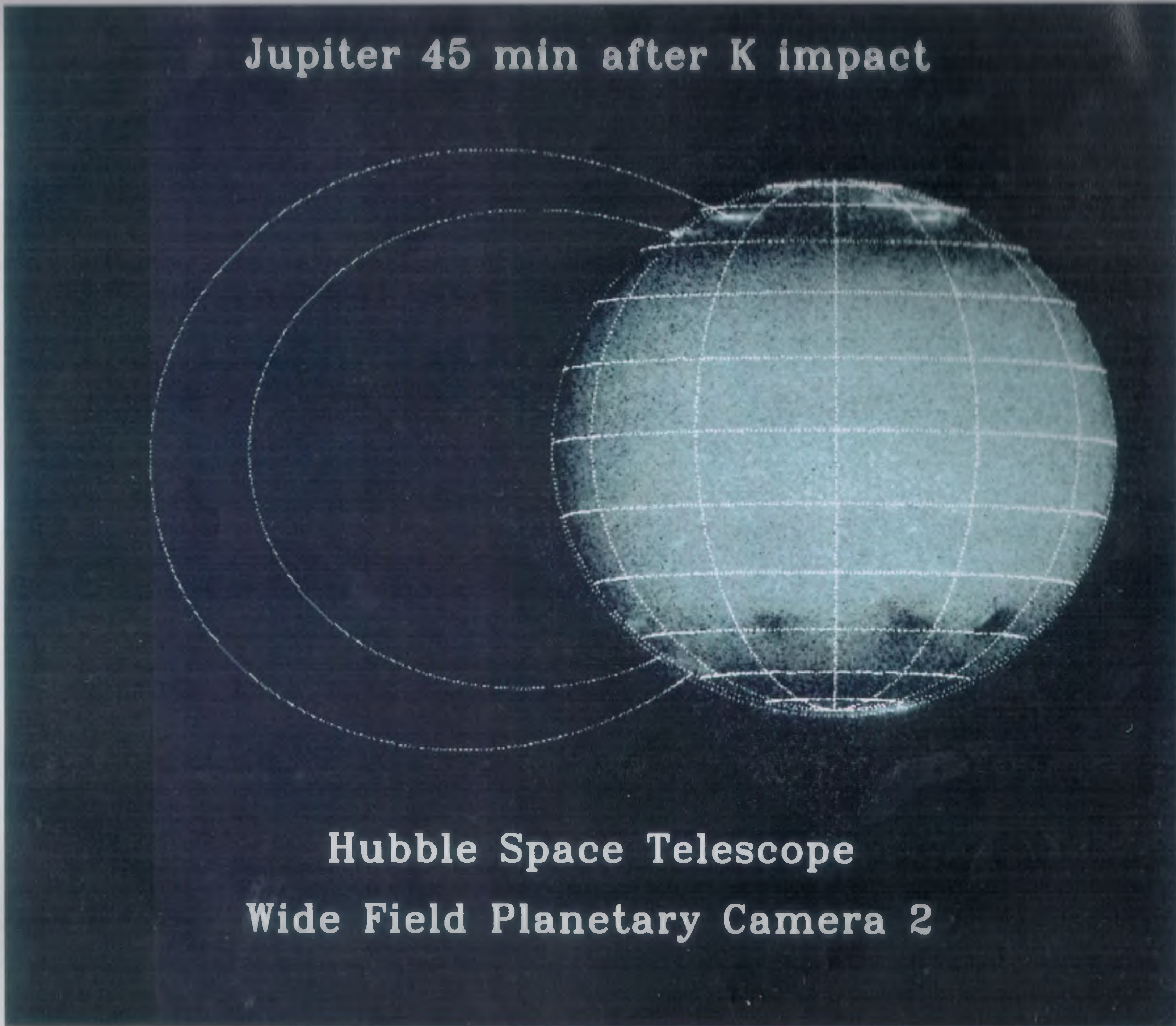
This image shows two views of the impact zone on Jupiter of fragment G of Comet Shoemaker-Levy 9. The image on the left was made in green light with the Planetary Camera channel of the Wide Field Planetary Camera 2 (WFPC2). The image on the right is the same field taken through the WFPC2 methane filter. Data for the images were obtained in the early morning hours of July 18, 1994.

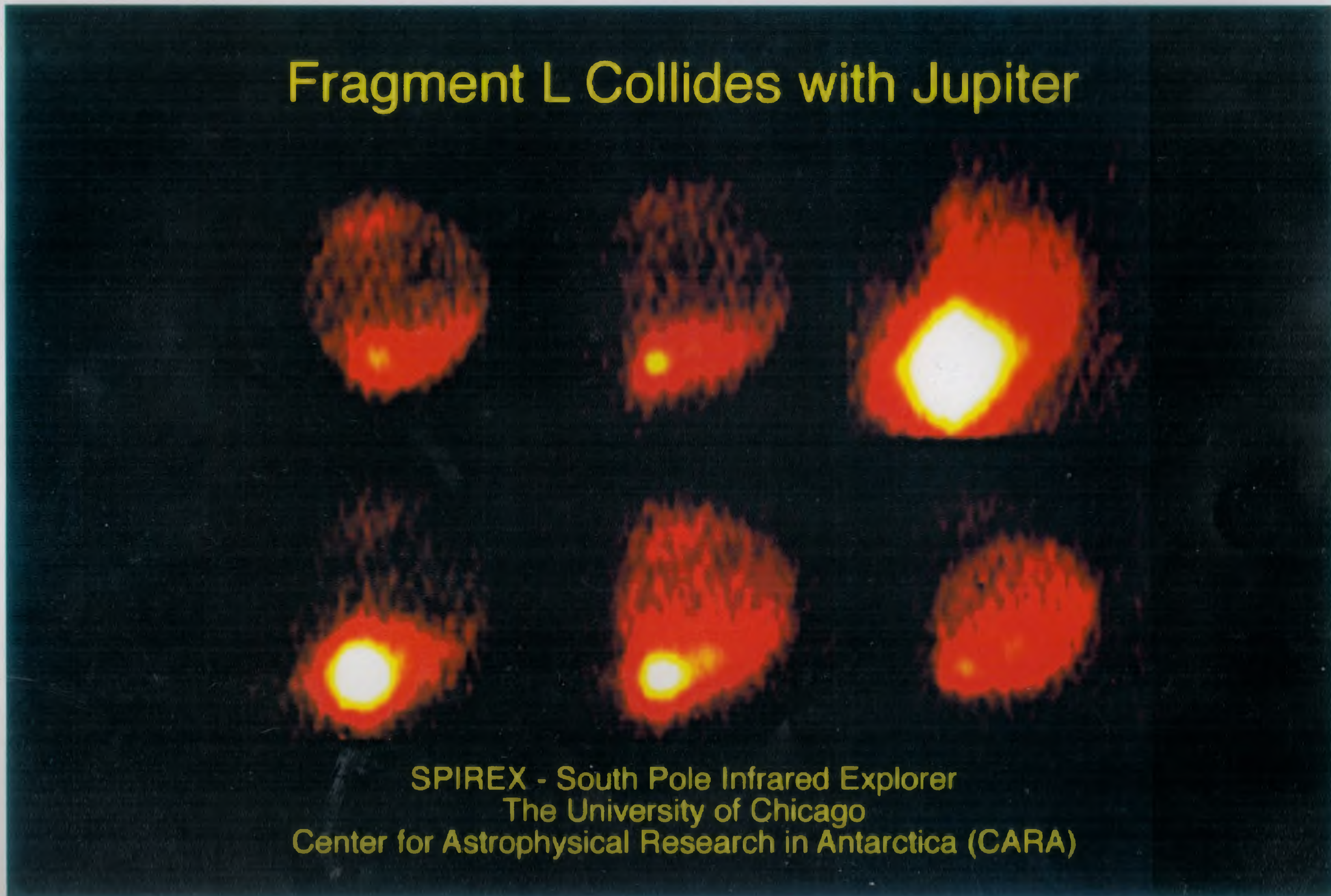
The impact site is visible as a complex pattern of circles seen in the lower left of the partial planet image. The small dark feature to the left of the pattern of circles is the impact site of fragment D. The dark, sharp ring at the site of the fragment G impact is 80% of the size of the Earth.

Comet Shoemaker-Levy 9 broke up into 21 fragments during a close passage by Jupiter in July of 1992. Fragment G was one of the brightest and likely the largest of the 21 fragments. The remaining fragments will continue to impact Jupiter through July 22, 1994. Scientists estimate that the combined energy from all of the impacts will approach the equivalent of 40 million megatons of TNT.

Jupiter was approximately 477 million miles (767 million kilometers) from Earth when the image was taken.

Credit: Dr. Heidi Hammel, Massachusetts Institute of Technology, NASA HST.


Jupiter 45 min after K impact
Hubble Space Telescope
Wide Field Planetary Camera 2


Fragment L Collides with Jupiter
SPIREX - South Pole Infrared Explorer
The University of Chicago
Center for Astrophysical Research in Antarctica (CARA)

South Pole Infrared Explorer--SPIREX
South Pole

Photo Release
July 21, 1994

Infrared Telescope at South Pole Captures Fragment L Impact

This time sequence (upper left to lower right) reveals the impact of fragment L of Comet Shoemaker-Levy 9 with the planet Jupiter. The images were made in infrared light, which is sensitive to the heat produced by the release of energy during the comet's plunge through the atmosphere.

Observers at the South Pole have the unique advantage of being able to image the comet and Jupiter constantly due to fact that Jupiter does not set but remains in view 24 hours a day.

The South Pole Infrared Explorer telescope is operated by the University of Chicago's Center for Astrophysical Research in Antarctica (CARA) and is funded by the National Science Foundation.

Credit: Dr. Hien Nguyen, University of Chicago, South Pole Explorer.

University of Chicago
Chicago, Illinois 60637
312-702-8203

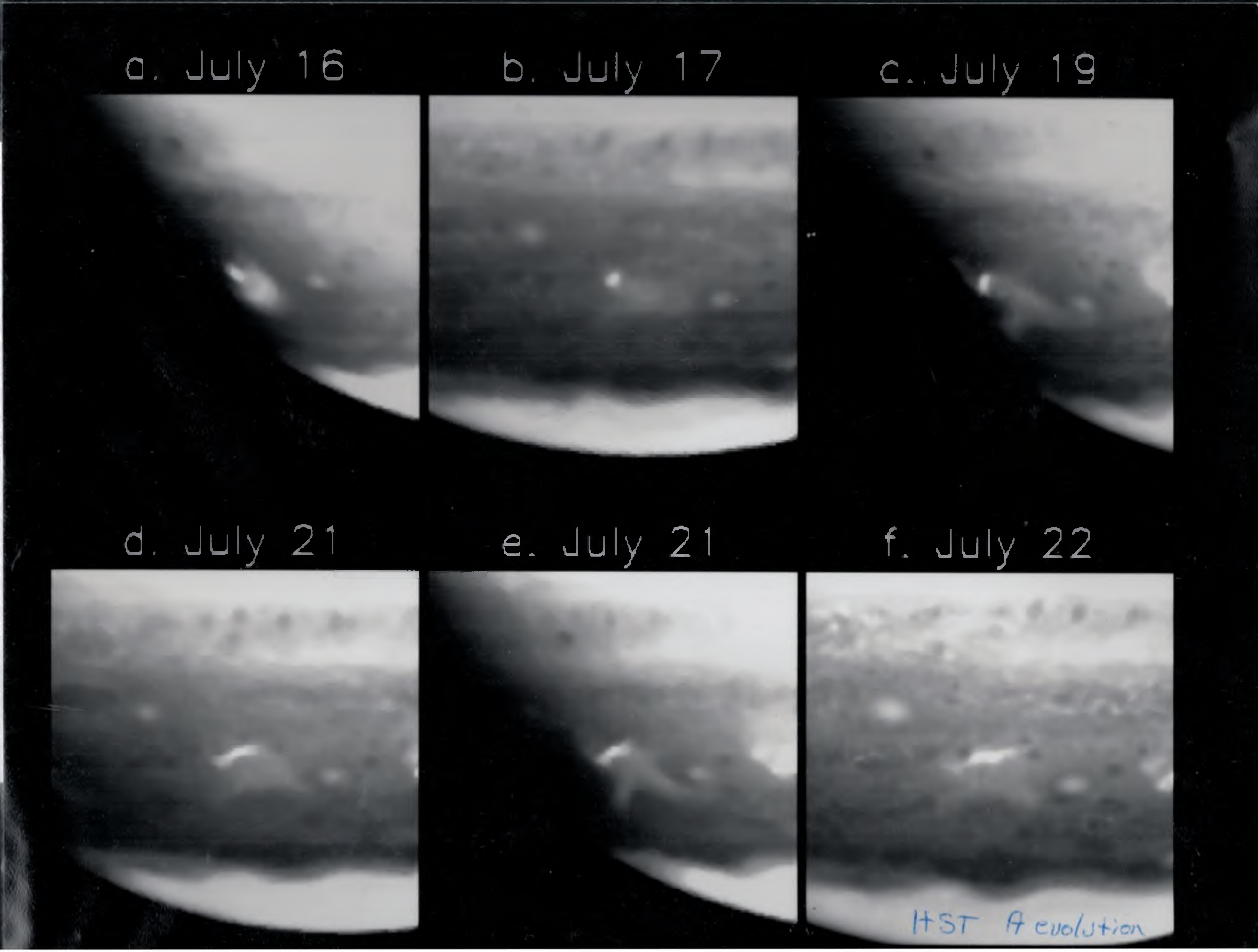

a. July 16
b. July 17
c. July 19
d. July 21
e. July 21
f. July 22
HST A evolution

PHOTO CAPTION

STSCI-PRC94-39

HUBBLE SHOWS EVOLUTION OF EJECTA FROM THE "A" COMET IMPACT SITE

This series of images, which spans more than five days beginning at 5:33 p.m. EDT on July 16, 1994, was obtained with Hubble Space Telescope's Wide Field Planetary Camera-2 using the methane filter that reveals details in Jupiter's higher atmosphere. These images show the development of the ejecta from site A, formed by the impact of the first fragment of comet Shoemaker-Levy 9. Frames b-f were obtained 19.5, 59.6, 90.4, 109.5, and 129.5 hours later than frame a respectively. Frames a, c, and e are seen near the edge of the planet where the viewing angle enhances bright cloud structure, while frames b, d, and f are viewed more face on.

Credit: Hubble Space Telescope Comet Team, and NASA

Jupiter 22 July 1994

"A" impact site
after 5.5 days

Hubble Space Telescope

Wide Field Planetary Camera 2

STSCI-PRC94-38

"BRUISED" JUPITER AS SEEN ON LAST DAY OF COMET IMPACTS

[right]

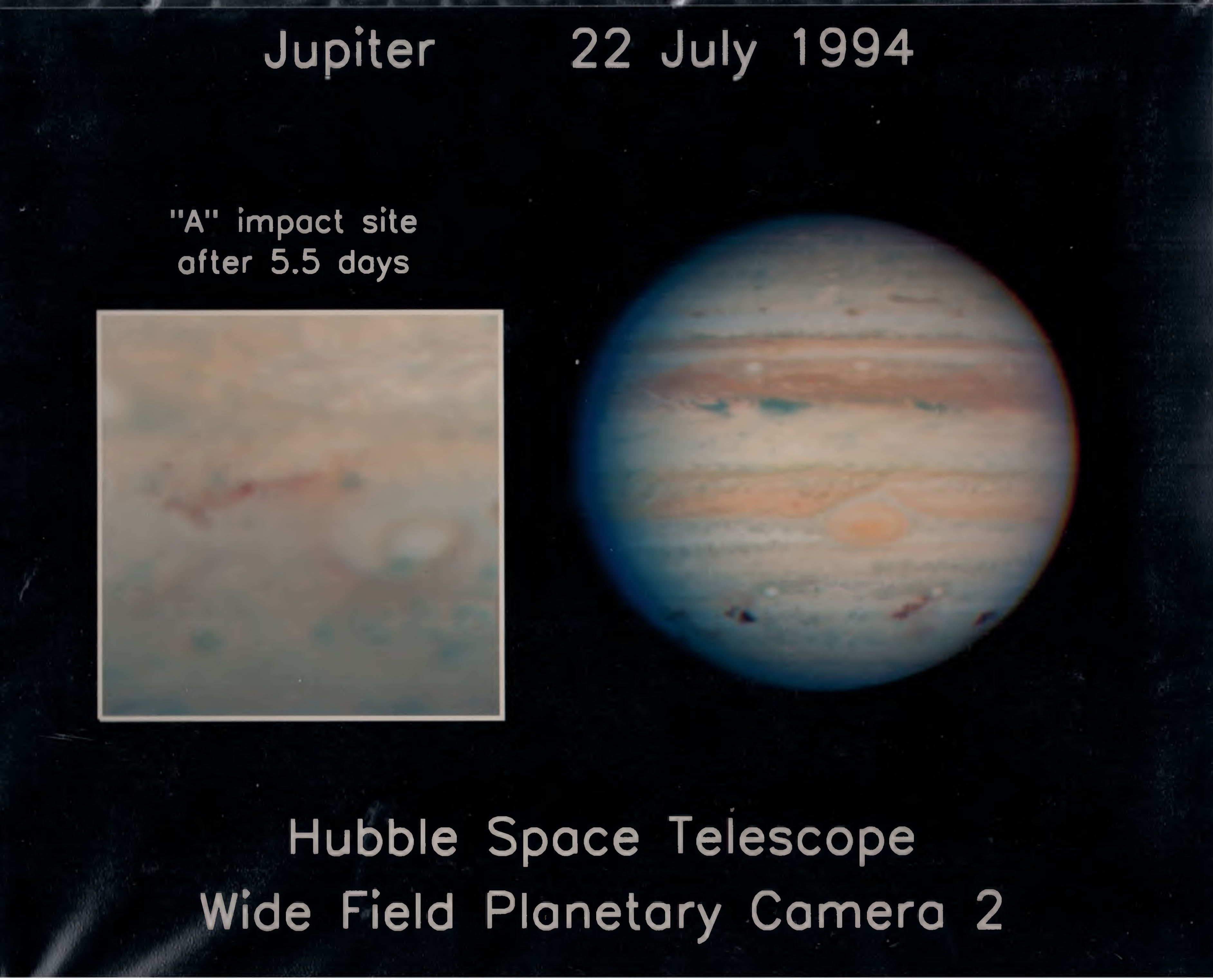
A natural color NASA Hubble Space Telescope view of the full disk of the giant planet Jupiter shows numerous comet Shoemaker-Levy impact sites as seen on July 22, 1994. The A impact site on the lower left limb. From left to right the features are: the A site; the E-F complex near the white oval southwest of the Red Spot; the dispersing H site to the southeast of the Red Spot; and the site of Q, near the eastern edge. Comet fragment A impacted on July 16, E and F on July 17, H on July 18 and Q on July 20. the image was taken with the Wide Field & Planetary Camera-2 (WFPC2) in wide-field mode.

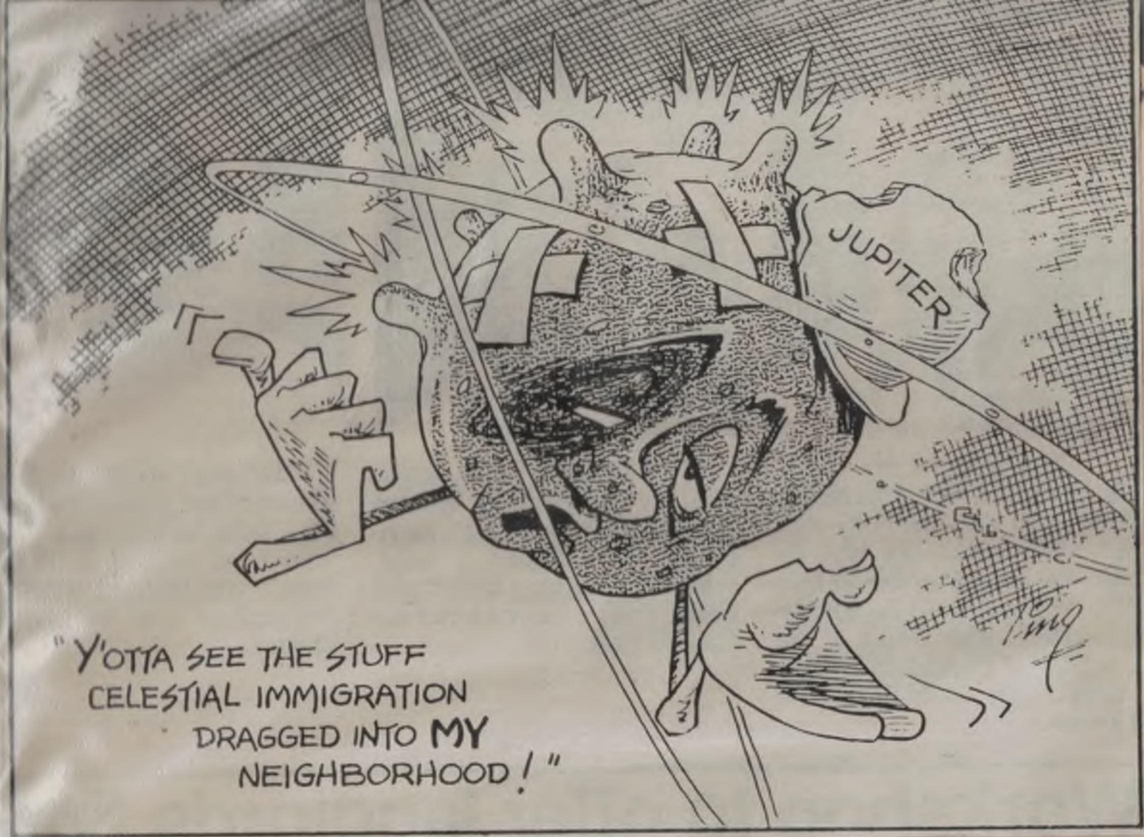
[left]

A close-up view of the dissipating A site taken in the higher resolution planetary camera mode of the WFPC2. This image was obtained one orbit later (about 47 minutes), when the planet had rotated about 50 degrees.

The Hubble detail in both images shows how the impact sites are evolving with time.

Credit: Hubble Space Telescope Comet Team, and NASA


Jupiter 22 July 1994
"A" impact site
after 5.5 days
Hubble Space Telescope
Wide Field Planetary Camera 2



"Y'OTTA SEE THE STUFF CELESTIAL IMMIGRATION DRAGGED INTO **MY** NEIGHBORHOOD!"

Subject: CICLOPS/JPL: Forensic Sleuthing Ties Ring Ripples to Impacts
From: "AAS Press Officer Dr. Rick Fienberg" <rick.fienberg@aas.org>
To: Rick Fienberg <Rick.Fienberg@aas.org>

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Fienberg, AAS Press Officer: rick.fienberg@aas.org,

March 31, 2011

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** Additional contacts appear below. **

Text & Images:
http://www.jpl.nasa.gov/news/news.cfm?release=2011-102

FORENSIC SLEUTHING TIES RING RIPPLES TO IMPACTS

Like forensic scientists examining fingerprints at a cosmic crime scene, scientists working with data from NASAâ€™s Cassini, Galileo, and New Horizons missions have traced telltale ripples in the rings of Saturn and Jupiter back to collisions with cometary fragments dating back more than 10 years ago.

The ripple-producing culprit, in the case of Jupiter, was comet Shoemaker-Levy 9, whose debris cloud hurtled through the thin Jupiter ring system during a kamikaze course into the planet in July 1994. Scientists attribute Saturnâ€™s ripples to a similar object -- likely another cloud of comet debris -- plunging through the inner rings in the second half of 1983. The findings are detailed in a pair of papers published online today in the journal Science.

â€œWhatâ€™s cool is weâ€™re finding evidence that a planetâ€™s rings can be affected by specific, traceable events that happened in the last 30 years, rather than a hundred million years ago,â€ said Matthew Hedman, a Cassini imaging team associate, lead author of one of the papers, and a research associate at Cornell University, Ithaca, N.Y. â€œThe solar system is a much more dynamic place than we gave it credit for.â€

From Galileoâ€™s visit to Jupiter, scientists have known since the late 1990s about patchy patterns in the Jovian ring. But the Galileo images were a little fuzzy, and scientists didnâ€™t understand why such patterns would occur. The trail was cold until Cassini entered orbit around Saturn in 2004 and started sending back thousands of images. A 2007 paper by Hedman and colleagues first noted corrugations in Saturnâ€™s innermost ring, dubbed the D ring.

A group including Hedman and Mark Showalter, a Cassini co-investigator based at the SETI Institute in Mountain View, Calif., then realized that the grooves in the D ring appeared to wind together more tightly over time. Playing the process backward, Hedman then demonstrated the pattern originated when something tilted the D ring off its axis by about 100 meters (300 feet) in late 1983. The scientists found the influence of Saturnâ€™s gravity on the tilted area warped the ring into a tightening spiral.

Cassini imaging scientists got another clue when the Sun shone directly along Saturnâ€™s equator and lit the rings edge-on in August 2009. The unique lighting conditions highlighted ripples not previously seen in another part of the ring system. Whatever happened in 1983 was not a small, localized event; it was big. The collision had tilted a region more than 19,000 kilometers (12,000 miles) wide, covering part of the D ring and the next outermost ring, called the C ring. Unfortunately spacecraft were not visiting Saturn at that time, and the planet was on the far side of the Sun, hidden from telescopes on or orbiting Earth, so whatever happened in 1983 passed unnoticed by astronomers.

Hedman and Showalter, the lead author on the second paper, began to wonder whether the long-forgotten pattern in Jupiterâ€™s ring system might illuminate the mystery. Using Galileo images from 1996 and 2000, Showalter confirmed a similar winding spiral pattern. They applied the same math they had applied to Saturn -- but now with Jupiterâ€™s gravitational influence factored in. Unwinding the spiral pinpointed the date when Jupiterâ€™s ring was tilted off its axis: between June and September 1994. Shoemaker-Levy plunged into the Jovian atmosphere during late July 1994. The estimated size of the nucleus was also consistent with the amount of material needed to disturb Jupiterâ€™s ring.

The Galileo images also revealed a second spiral, which was calculated to have originated in 1990. Images taken by New Horizons in 2007, when the spacecraft flew by Jupiter on its way to Pluto, showed two newer ripple patterns, in addition to the fading echo of the Shoemaker-Levy impact.

â€œWe now know that collisions into the rings are very common -- a few times per decade for Jupiter and a few times per century for Saturn,â€ Showalter said. â€œNow scientists know that the rings record these impacts like grooves in a vinyl record, and we can play back their history later.â€

The ripples also give scientists clues to the size of the clouds of cometary debris that hit the rings. In each of these cases, the nuclei of the comets -- before they likely broke apart -- were a few kilometers wide.

â€œFinding these fingerprints still in the rings is amazing and helps us better understand impact processes in our solar system,â€ said Linda Spilker, Cassini project scientist, based at NASAâ€™s Jet Propulsion Laboratory, Pasadena, Calif. â€œCassiniâ€™s long sojourn around Saturn has helped us tease out subtle clues that tell us about the history of our origins.â€

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Images and an animation:
* http://ciclops.org
* http://saturn.jpl.nasa.gov
* http://www.nasa.gov/cassini

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