THE

ROYAL ASTRONOMICAL SOCIETY OF CANADA

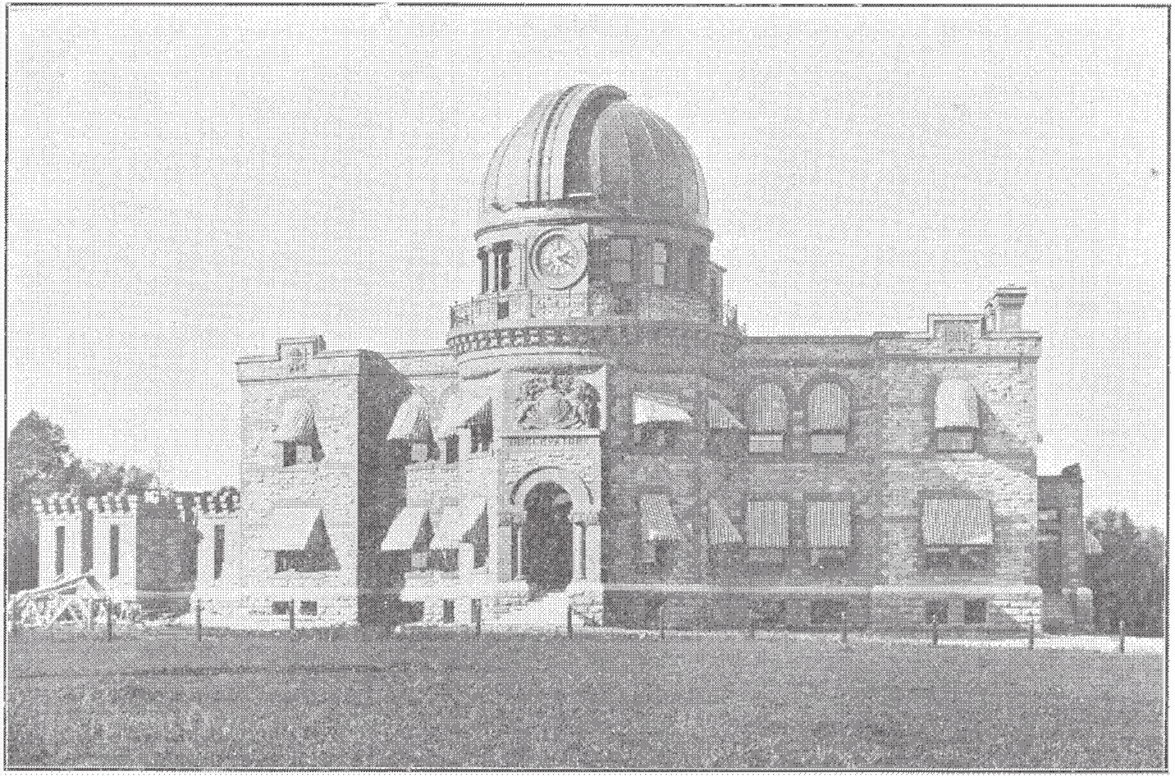
TRANSACTIONS FOR 1905

(INCLUDING SELECTED PAPERS AND PROCEEDINGS)

EDITED BY C. A CHANT.

TORONTO:
ROYAL ASTRONOMICAL PRINT,
1906.

The
Royal Astronomical Society
of Canada.



THE DOMINION OBSERVATORY, OTTAWA.

THE

ROYAL ASTRONOMICAL SOCIETY
OF CANADA

TRANSACTIONS FOR 1905

(INCLUDING SELECTED PAPERS AND PROCEEDINGS)

EDITED BY C. A CHANT.

TORONTO:
ROYAL ASTRONOMICAL PRINT,
1906.

TABLE OF CONTENTS.

The Dominion Observatory, Ottawa (*Frontispiece*)
List of Officers, Fellows and Associates - - - - - - - 3
Treasurer's Report - - - - - - - - - - - - - - - 12
President's Address and Summary of Work - - - - - - 13
List of Papers and Lectures, 1905 - - - - - - - - - 26
The Dominion Observatory at Ottawa - - *W. F. King* 27
Solar Spots and Magnetic Storms for 1904 *Arthur Harvey* 35
Stellar Legends of American Indians - - *J. C. Hamilton* 47
Personal Profit from Astronomical Study - *R. Atkinson* 51
The Eclipse Expedition to Labrador, August, 1905
A. T. De Lury 57
Gravity Determinations in Labrador - - *Louis B. Stewart* 70
Magnetic and Meteorological Observations at
North-West River, Labrador - - - - *R. F. Stupart* 97
Plates and Filters for Monochromatic and
Three-Color Photography of the Corona *J. S. Plaskett* 89
Photographing the Sun and Moon with a 5-inch
Refracting Telescope - - - - - - - *D. B. Marsh* 108
The Astronomy of Tennyson - - - - *John A. Paterson* 112
Achievements of Nineteenth Century Astronomy,
L. H. Graham 125
A Lunar Tide on Lake Huron - - - - *W. J. Loudon* 131
Contributions - - - - - - - - - - *J. Miller Barr*
I. New Variable Stars - - - - - - - - - - - 141
II. The Variable Star ξ Boötis - - - - - - - - 143
III. The Colors of Helium Stars - - - - - - - - 144
IV. A New Problem in Solar Physics - - - - - - 146
Stellar Classification - - - - - - *W. Balfour Musson* 151
On the Possibility of Life in Other Worlds *A. Kirschmann* 159
Transpacific Longitudes - - - - - - - - *Otto Klotz* 175

Obituary Notices

J. J. Wadsworth - - - - - - - - - - - - - - 207
Larratt W. Smith - - - - - - - - - - - - - - 208

ERRATA.

Page	26	line	1	for	1904	read	1905.
“	57	“	22	“	D. Menzies	“	W. Menzies.
“	60	“	36	“	Johnston	“	Johnson.
“	61	“	34	“	assited	“	assisted.
“	71	“	18	“	$\varphi = 4^h$ etc.	“	$\lambda = 4^h$ etc.
“	78	“	last	“	degrees	“	dynes.
“	82	“	23	“	Matashquan	“	Natashquan.
“	101	“	14	“	Eyanin	“	Cyanin.
“	126	“	30	“	Clarke	“	Clark.
“	127	“	29	“	Jansen	“	Janssen.
“	128	“	11	“	Rowlands	“	Rowland.
“	128	“	20, 31	“	Rutherford	“	Rutherfurd.
“	83, 85	The figures are one-half size of original and scale should be altered accordingly.					

Any error in the name or address of any member should be reported at once to the Secretary.

THE

ROYAL ASTRONOMICAL SOCIETY

OF CANADA.

Officers, 1906

Honorary President—WILLIAM F. KING, B.A., C.E., LL.D.,
CHIEF ASTRONOMER, OTTAWA.

President—C. A. Chant, M.A., Ph.D.,
Lecturer in Physics, University of Toronto.

First Vice-President—ALFRED T. DELURY, M.A.,
Associate Professor of Mathematics and Astronomy, University of Toronto.

Second Vice-President—W. BALFOUR MUSSON,
22 Park Road, Toronto.

Treasurer—GEORGE RIDOUT, Nordheimer Building,
77 York St., Toronto.

Secretary—J. R. COLLINS, 23 North St., Toronto.

Recorder—MISS ELSIE A. DENT, 17 St. James Ave.

Librarian—KENNETH M. CLIPSHAM, 15 Spencer Ave.

Curator—ROBERT S. DUNCAN, 516 Ontario St.

Other Members of Council

Honoris Causa:

A. ELVINS, *Past President.*

JOHN A. PATERSON, M.A., *Past President.*

R. F. STUPART, F.R.S.C., Director of the Toronto Observatory and Superintendent of the Dominion Meteorological Service, *Past President.*

Elected:

JOSEPH POPE, C.M.G., F.R.S.C., Ottawa.

Rev. D. B. MARSH, D.Sc., F.R.A.S., Aberdeen Observatory, Hamilton.

A. F. MILLER, Toronto.

Honorary Fellows

Limited to Fifteen.

SIR ROBERT STAWELL BALL, Kt., M.A., LL.D., F.R.A.S., Etc., Etc.,
Fellow of King's College; Lowndean Professor of Astronomy, and Director of the Observatory, University of Cambridge, Cambridge, England.

EDWARD EMERSON BARNARD, M.A., D.Sc., F.R.A.S., Etc., Etc.,
Professor of Astronomy, University of Chicago; Astronomer, Yerkes Observatory, etc., Williams Bay, Wisconsin, U.S.A.

JOHN A. BRASHEAR, D.Sc., F.R.A.S., LL.D.,
Chancellor, and Professor of Astronomy in the Western University of Pennsylvania, Director of the Allegheny Observatory, etc., Allegheny, Pa., U.S.A.

SIR WILLIAM HENRY MAHONEY CHRISTIE, K.C.B., M.A., D.Sc. (Oxon.), F.R.S., F.R.A.S.,
Astronomer Royal, Greenwich, England.

SIR GEORGE HOWARD DARWIN, M.A., LL.D. (Glasgow), D.Sc. (Dublin), Dr. Phil. Nat. (Padua), F.R.S., F.R.A.S., Etc., Etc.,
Plumian Professor of Astronomy and Fellow of Trinity College, Cambridge, England.

ARTHUR MATTHEW WELD DOWNING, M.A., D.Sc., F.R.S., F.R.A.S., F.R.G.S.,
Superintendent of the Nautical Almanac, Verulam Building, London, England.

M. CAMILLE FLAMMARION, Astronome, For. As'e, R.A.S.,
Membre de l'Institut de France; Membre du Bureau des Longitudes; Past President and one of the founders of La Society Astronomique de France, etc., etc., Directeur de l'Observatoire, Juvisy, Seine et Oise, France.

SIR SANDFORD FLEMING, K.C.M.G., C.E., LL.D., M.I.C.E., Etc.,
Chancellor Queen's University, Kingston; Winterholme, Ottawa, Canada.

GEORGE ELLERY HALE, S.B., Sc.D., LL.D., F.R.A.S., Etc.,
Director of the Solar Observatory of the Carnegie Institution, Mount Wilson, Cal., U.S.A.

EDWARD SINGLETON HOLDEN, LL.D., D.Sc., For As'e, R.A.S.,
West Point, N.Y., U.S.A.

SIR WILLIAM HUGGINS, K.C.B., D.C.L. (Oxon.),
LL.D. (Cantab., Edin. et Dubl.), Ph.D. (Lugd. Bat.), F.R.S., F.R.A.S., Hon. F.R.S.E., Cor. l'Institut de France, 90 Upper Tulse Hill, London, S.W., England.

SAMUEL PIERPONT LANGLEY, LL.D.,
D.C.L. (Oxon.), D.Sc. (Cantab.), PH.D., For. As'e, R.A.S.,
Secretary of the Smithsonian Institution, Washington, D.C.

M. MAURICE LOEWY, Membre de l'Institut de France et du Bureau des Longitudes,
Directeur de l'Observatoire de Paris, Membre des Academies de
Berlin, St. Petersbourg, Vienne et Washington, et For. As'e,
R.A.S., etc., etc., l'Observatoire, Paris, France.

SIMON NEWCOMB, LL.D., D.Sc., For. As'e,
R.A.S., Cor. l'Institut de France, President of the Astronomical and
Astrophysical Society of America, etc., etc., Washington, D.C.

EDWARD CHARLES PICKERING, PH.D.
LL.D., D.Sc., For. As'e, R.A.S., Etc., Etc.,
Paine Professor of Practical Astronomy and Director of the Observatory,
Harvard University, Cambridge, Mass., U.S.A.

Corresponding Fellows

Limited to Twenty-five.

SHELBURNE WESLEY BURNHAM, M.A., As'e, R.A.S., Etc.,
Professor of Practical Astronomy, University of Chicago; Astronomer,
Yerkes Observatory, Williams Bay, Wisconsin, U.S.A.

WILLIAM WALLACE CAMPBELL, Sc.D.,
Director of the Lick Observatory.

MISS AGNES M. CLERKE, Hon. Mem., R.A.S.,
68 Redcliffe Square, London, S.W., England.

WILLIAM FREDERICK DENNING, F.R.A.S., Etc., Etc.
Bishopston, Bristol, England.

THE REV. THOMAS HENRY ESPINELL COMPTON ESPIN, M.A., F.R.A.S., Etc.
President of the Newcastle Astronomical Society; Director of the
Wolsingham Observatory, Tow Law, Darlington, England.

EDWIN BRANT FROST, A.M.,
Professor of Astrophysics, and Director of the Yerkes Observatory,
University of Chicago.

JOHN ELLARD GORE, F.R.A.S., M.R.I.A., Etc., Etc.
Ballysodare, Ireland.

WILLIAM FREDERICK KING, B.A., LL.D., C.E., D.L.S., Etc.,
Chief Astronomer, Department of the Interior, Ottawa, Canada,
Director Government Observatory.

EDWARD WALTER MAUNDER, F.R.A.S., Etc., Etc.,
Superintendent of the Solar Department of the Royal Observatory,
Greenwich, London, England.

W. H. S. MONCK, M.A., F.R.A.S.,
16 Earlsfort Terrace, Dublin, Ireland.

CLEMENT H. McLEOD, MA.E., F.R.S.C.,
Member Can. Soc. C.E.,
Superintendent of McGill College Observatory, Montreal P.Q.

THE R'T REVEREND JERVOIS ARTHUR NEWNHAM,
M.A., D.D.; Bishop of Saskatchewan, Prince Albert, Saskatchewan, N.W.T.

WILLIAM H. PICKERING, S.B., Etc., Etc.,
Astronomer, Harvard College Observatory, Cambridge, Mass., U.S.A.

LEWIS SWIFT, PH.D., F.R.A.S., Etc.,
Marathon, N.Y., U.S.A.

PROFESSOR A. WOLFER,
Director of the Observatory, Zurich, Switzerland.

Life Fellows

ALFRED T. DELURY, M.A., University of Toronto,
Associate Professor of Mathematics and Astronomy.

ANDREW ELVINS, ESQ., 217 Huron St., Toronto.

LADY WILSON, 34 Russell St., Toronto.

JOSEPH POPE, C.M.G., Etc., Ottawa.
Under Secretary of State.

Honorary Associates

LEON, PROF. LUIS G., Mexico, Mexico.
LEON, SENORA DOLORES GONZALOS, " "
MAUNDER, MRS. A. S. D., 86 Tyrwhitt Rd.,
St. Johns, S.E., London, England.

Fellows and Associates

Abbott, Dr. A. R., 55 Bathurst St., Toronto.
Atkinson, Rev. Robert, Chesley, Ontario.
Bain, William, Blake, Lash & Cassels, Toronto.
Baldwin, Mrs. M. E., Mashquoteh, Deer Park, "
Balmer, Mrs., 131 Grace St., "
Banks, Mrs. Greenhow, 59 Isabella St., "
Barr, J. Miller, St. Catharines, Ontario.
Bell, Clarence, Osgoode Hall, Toronto.
Biggar, Emerson B., 471 Marion St., "
Blake, F. L., D.L.S., Life Associate,
Astronomer, Magnetic Observatory, Toronto.
Brady, Rev. R. E. M., B.S., Hamilton, Ontario.
Britnell, John, 248 Yonge St., Toronto.
Brooking, Miss L. W., 403 Bloor St., W., "
Brown, Merritt A., 17 Chestnut St., "
Bryce, Peter Henderson, M.A., M.D., Ottawa.
Buckingham, Geo. S., Maxwell, Ontario.
Burke, Rev. J. W., B.A., Rector and Canon,
Carleton Place, Ontario.
Burns, J. W., New Westminster, B.C., Canada.
Burwash, Rev. John, M.A., D.Sc., Victoria College, Toronto.
Carlyle, R. C., 497 Church St., "
Carpmael, Miss Agnes M., Rosedale, "
Chant, Mrs. C. A., 52 Avenue Rd., "
Chant, Clarence A., M.A., Ph.D., " "
Charles, Herbert J., Aurora, Ontario.
Choquette, Rev. Charles P., M.A.,
St. Hyacinthe College, St. Hyacinthe, Quebec.
Clark, John Murray, M.A., K.C., 70 Tranby Ave., Toronto.
Clipsham, Miss Lilian C., 15 Spencer Ave., "
Clipsham, K. M. " "
Collins, John Robinette, 23 North St., "
Collins, Zoro M., " "
Cotter, H. M. S., Hudson's Bay Co. Agent, N.W. River, Labrador.
Dearness, John, M.A., London, Ontario.
DeLury, Alfred T., M.A., Life Fellow, etc.,
110 Bedford Rd., Toronto.

Denison, Mrs. Flora MacD., 22 Carlton St., Toronto.
Dent, Miss Elsie A., 17 St. James Ave., “
Dent, Miss Lilian M., “ “
Dewar, R. St. F., Cor. Follis and Markham Streets, “
Donovan, Miss Carol H., Winnipeg, Manitoba.
Duncan, Robert S., 516 Ontario St., Toronto.
Eddis, Mrs. W. C., 14 Elgin Ave., “
Eddis, Wilton C., “ “
Ellis, John, J.P., Swansea, Ontario.
Elvins, Andrew, Life Fellow, etc., 217 Huron St., Toronto.
Evans, Miss L. Mary, 226 Jarvis St., “
Evel, J. J., Hamilton, Ontario.
Falls, Miss A. Elvira, Brakedene, Simcoe, “
Farquhar, J. D., 185 Seaton St., Toronto.
Forest, Miss Isabella, 31 Harbord St., “
Foster, Harold W. A., 100 Bedford Rd., “
Fraser, Miss Jessie, 58 Palmerston Ave , “
Fraser, Alexander, M.A., Parliament Buildings, “
Gauthier, Louis, C.E., Dominion Observatory, Ottawa.
Gibson, T. W., Bureau of Mines, Parliament Buildings, Toronto.
Graham, L. H., B.A., East Toronto, Ontario.
Grant, Arthur Law, 1081 Queen St. W., Toronto.
Gray, Henry, Principal Fern Ave. School, “
Grenfell, Dr. Wilfred T., Labrador.
Gullen, Dr. Augusta Stowe, 461 Spadina Ave., Toronto.
Gunn, Miss M., 824 College St., “
Hadden, David Edward, F.R.A.S., etc., Alta, Iowa, U.S.A.
Hagarty, Miss Sarah E., 33 Harbord St., Toronto.
Hall, Robert P., Toronto Junction, Ontario.
Hamilton, J. Cleland, M.A., LL.B., 86 Glen Rd., Toronto.
Harrison, Henry, 165 Clinton Ave., Jersey City, N.J., U.S.A.
Henderson, Judson J., 77 St. Patrick St., Toronto.
Howell, David J., 10 Czar St., “
Howitt, Rev. F. E., Hamilton, Ontario.
Hughes, Bernard B., 40 Isabella St., Toronto.
Hughes, James Laughlin, P.S.I., City Hall, “
Hull, Prof. G. Ferrie, Ph.D., Dartmouth College,
Hanover, N.H., U.S.A.
Hunter, Andrew F., M.A., Barrie, Ontario.

Hutty, J. H., 528 Yonge St., Toronto.
Inrig, Alexander, 7 Sussex Ave., "
Inrig, W., " "
Jackson, Walter E., B.A., The Observatory, "
Jaques, W. Charles, B.A., Port Rowan, Ontario.
Jarvis, Mrs. Laila C., 89 Glen Rd., Toronto.
Jarvis, Percival B., " "
Jenkins, Griffith Parry, Hamilton, Ontario.
Jennings, Frank P., Reddeholm, Duffield Rd., Derby, England.
Johnson, Alfred S., B.A., Chicago, Ill., U.S.A.
Kavanagh, Rev. I. J., S.J., M.A., B.Sc.,
Loyola College, Montreal, Quebec.
Kelly, Dr. C. I., King St. W., Hamilton, Ontario.
Kelley, John Douglas, Swansea, "
Keran, Mrs. S. D., 148 Avenue Rd., Toronto.
King, Mrs. W. J., 321 Sumach St., "
Kirschmann, A., Ph.D., University of Toronto, "
Lackie, Miss Sarah, 12 Markham Pl., "
Livingston, Rev. G. H., William St., Hamilton, Ontario.
Loudon, Mrs. James, 83 St. George St., Toronto.
Lyman, Walter E., B.A., Mechanic's Bu'ld', Montreal, Quebec.
Macara, John, Dominion Observatory, Ottawa.
Mackie, Robert, 9 Wright Ave., Toronto.
Macklem, Rev. Dr. T. C. Street-, Prov. Trinity Coll., "
Marr, John, 220 Pacific Ave., Toronto Junction, Ontario.
Marsh, Rev. D. B., D.Sc., F.R.A.S.,
258 Aberdeen Ave., Hamilton, "
Maybee, J. Edward, M.E., 103 Bay St. 'Toronto.
McDiarmid, Fergus A., B.A., Dominion Observatory, Ottawa.
McEachren, Miss, 148 Mutual St., Toronto.
McFarlane, John B., B.A., University of Toronto, "
McKay, Prof. A. C., B.A., LL.D.,
Chancellor of McMaster University, "
McKim, Miss, 25 Grosvenor St., "
McMaster, Miss Minnie H. 132 Bleecker St., "
Meneilley, Miss J., 31 Harbord St., "
Merrishaw, Mrs. F. R., 376 Markham St., "
Miller, Allan Frederick, 280 Carlton St., "
Moss, Mrs. Charles, 547 Jarvis St., "

Musson, W. Balfour, 22 Park Rd., Toronto.
Near, W. Percy, B.A., St. Mary's, Ontario.
O'Neill, Miss Nellie, 49 Robinson St., Toronto.
Panton, Mrs. H. E., "The Manse," Stratford, Ontario.
Parker, Thos., 43 St. James Ave., Toronto.
Paterson, John A., M.A., K.C., 167 Walmer Rd., Toronto.
Peagam, H. E., 254 Yonge St., "
Petry, Charles B., 61 Isabella St., "
Pettit, Douglas, 76 St. Mary St., "
Phillips, John, 125 Victor Ave., "
Plant, William Henry, 278 Borden St., "
Plaskett, John S., B.A., Dominion Observatory, Ottawa.
Pope, Joseph, C.M.G., F.R.S.C., etc.,
Under Secretary of State, "
Ptolemy, R. A., 209 McNab St., Hamilton, Ontario.
Raland, G. A. F., Battleford, N.W.T.
Ridout, George, 86 St. Albans St., Toronto.
Ridout, Capt. John G., 103 Bay St., "
Robinson, T. H., 526 Yonge St., "
Rounthwaite, Rev. J. F., 61 Balfour St., Brantford, Ontario.
Russell, James A., Windsor, N.S., Canada.
Scott, Miss M. T., Branksome Hall, 102 Bloor St., E., Toronto.
Simard, Rev. Henri, Laval University, Quebec, Canada.
Sims, Miss E., 35 Breadalbane St., Toronto.
Sinclair, A., M.A. 125 Cumberland Ave., "
Smith, Miss Florence, 557 Delaware Ave., "
Smith, Goldwin Larratt, B.A., Summerhill Ave., "
Spry, William, The Daly House, Simcoe St., "
Stewart, Louis B., D.L.S., School of Practical Science, "
Stewart, R. Meldrum, M.A., Dominion Observatory, Ottawa.
Stinson, Walter C., Petrolea, Ontario.
Stupart, R. F., F.R.S.C., etc.,
Director Magnetic Observatory, Toronto.
Titus, F. E., Gore Bay, Ontario.
Thomson, Arthur, B.A., Bendale, "
Thompson, J. F., M.A., Bowmanville, "
Todhunter, James, 85 Wellesley St., Toronto.
Tremayne, Rev. H. O., Lambton Mills, Ontario.
Upton, Charles, Tower House, Stroud, Gloucester, England.

Ward, Rev. G. B., M.A.,	Essex, Ontario.
Watson, Albert D., M.D.	10 Euclid Ave., Toronto.
Wells, Eric C.,	210 Smith St., "
Wetherbee, Weston, Fellow,	Albion, N.Y., U.S.A.
Wilson, Lady, Life Fellow,	34 Russell St., Toronto.
Williams, Julius M.,	Hamilton, Ontario,
Woodall G.,	8 Plymouth Ave., Toronto.
Woods, Miss E. B.,	91 Breadalbane St., "
Workman, Miss Florence,	166 Walmer Rd., "
Wright, John J.,	12 Adelaide St. E., "
Yule, Andrew,	Aurora, Ontario.

Carlyle, R. C.,	Kew Beach, Toronto
Cowan, John,	216 Cottingham St., "
Donnelly, Capt. Thomas,	Kingston, Ontario.
Hoyles, G. E.,	Cannington, "
Humberstone, Mrs. C. E.,	Newtonbrook, "
Lowry, G. W.,	139 Dovercourt Rd., Toronto.
Moore, Isaac E., B.A.,	Rothesay, N. B.

TREASURER'S REPORT.

ROYAL ASTRONOMICAL SOCIETY OF CANADA.

CASH STATEMENT FOR 1905.

RECEIPTS.		
Cash in Bank January 1st, 1905		$ 217.72
Sale of Exchanges	$ 5.05	
Bank Interest from July to Nov. 30	6.75	
Members fees	176	
City of Toronto Grant	100	
Ontario Government Grant	600	
Total Receipts for the year		887.80
		$1105.52
EXPENDITURE.		
Bank Interest on over draft	.50	
Lantern Slides	10.80	
Caretaker	11.68	
Fire Insurance premiums	13.95	
Flowers and Engrossing	15	
Society's Seal	20	
Rent	20.80	
Removing Expenses	30.75	
New Books	38.93	
Postage, Stationary, Printing	68.91	
Public Meetings	69.72	
Transactions balance for last year	75	
Transactions this year	216.14	
Total Expenditures		592.18
Cash in Bank, Dec. 31, 1905		513.34
		$1105.52

GEORGE RIDOUT,
TREASURER,

Toronto, Dec. 30th, 1905.

I hereby certify that I have examined the cash-books, vouchers, etc. and find them correct.

WILLIAM BAIN,
AUDITOR.

Ward, Rev. G. B., M.A.,	Essex, Ontario.
Watson, Albert D., M.D.	10 Euclid Ave., Toronto.
Wells, Eric C.,	210 Smith St., “
Wetherbee, Weston, Fellow,	Albion, N.Y., U.S.A.
Wilson, Lady, Life Fellow,	34 Russell St., Toronto.
Williams, Julius M.,	Hamilton, Ontario,
Woodall G.,	8 Plymouth Ave., Toronto.
Woods, Miss E. B.,	91 Breadalbane St., “
Workman, Miss Florence,	166 Walmer Rd., “
Wright, John J.,	12 Adelaide St. E., “
Yule, Andrew,	Aurora, Ontario.

Carlyle, R. C.,	Kew Beach, Toronto
Cowan, John,	216 Cottingham St., “
Donnelly, Capt. Thomas,	Kingston, Ontario.
Hoyles, G. E.,	Cannington, “
Humberstone, Mrs. C. E.,	Newtonbrook, “
Lowry, G. W.,	139 Dovercourt Rd., Toronto.
Moore, Isaac E., B.A.,	Rothesay, N. B.

TREASURER'S REPORT.

ROYAL ASTRONOMICAL SOCIETY OF CANADA.

CASH STATEMENT FOR 1905.

RECEIPTS.		
Cash in Bank January 1st, 1905		$ 217.72
Sale of Exchanges	$ 5.05	
Bank Interest from July to Nov. 30	6.75	
Members fees	176	
City of Toronto Grant	100	
Ontario Government Grant	600	
Total Receipts for the year		887.80
		$1105.52
EXPENDITURE.		
Bank Interest on over draft	.50	
Lantern Slides	10.80	
Caretaker	11.68	
Fire Insurance premiums	13.95	
Flowers and Engrossing	15	
Society's Seal	20	
Rent	20.80	
Removing Expenses	30.75	
New Books	38.93	
Postage, Stationary, Printing	68.91	
Public Meetings	69.72	
Transactions balance for last year	75	
Transactions this year	216.14	
Total Expenditures		592.18
Cash in Bank, Dec. 31, 1905		513.34
		$1105.52

GEORGE RIDOUT,
TREASURER,

Toronto, Dec. 30th, 1905.

I hereby certify that I have examined the cash-books, vouchers, etc. and find them correct.

WILLIAM BAIN,
AUDITOR.

THE

ROYAL ASTRONOMICAL SOCIETY

OF CANADA.

SELECTED PAPERS AND PROCEEDINGS.

PRESIDENT'S ADDRESS AND SUMMARY OF THE SOCIETY'S WORK IN 1905.

(ADDRESS AT ANNUAL "AT HOME," JANUARY 23, 1906.)

ASTRONOMICAL AND ASTROPHYSICAL PROGRESS IN 1905.

AFTER referring to the happy relations existing between the President and Council, to the Society's loss in the death of Larratt W. Smith, J. J. Wadsworth and Arthur Harvey,* and to the loss to the astronomical world abroad by the death of Paul Henry, Pietro Tacchini, Ralph Copeland and Walter F. Wislicenus, the address was as follows :—

THE OTTAWA OBSERVATORY.

The most important event in the history of Canadian Astronomy during 1905 was the completion of the Dominion Observatory, located on the Experimental Farm on the outskirts of Ottawa. The building is a beautiful one, constructed of gray stone with brown stone trimmings, and finished in polished oak. The chief instrument is a 15-inch equatorial refractor by Brashear, with mounting by Warner & Swasey. I am sure we all congratulate the Federal Government on the handsome official home for astronomy, and Dr. King on having such a splendid institution to preside over.

---

* For obituary notices see end of this volume; that of Arthur Harvey was given in last year's Transactions.

THE SUN.

The most interesting solar occurrence during the year was the total eclipse of August 30, and to us in Canada an event second only in importance to the establishment of the Dominion Observatory. In my address a year ago I explained the honorable part the Society had in initiating the expedition. In the name of our Council a memorial was sent to the Premier, calling attention to the approaching phenomenon and urging the despatching of an expedition. As most of you know, the path of the total phase began in Manitoba, crossed James Bay and Labrador, and then, in the Old World, passed over Spain, Algeria, Tunis, Tripoli, Egypt, ending in Arabia. Although the prospects for fair weather were better in Spain or Africa, yet we knew that those portions of the path would be well attended to, and so we urged that our expedition go to Labrador. Our proposal was received and acted upon in a generous spirit. I need not refer at length to what happened. The first portion of the expedition sailed from Quebec on August 4, and the second on August 21, all returning together and reaching Quebec on September 7. The most extensive portion of the equipment was that provided by the Dominion Observatory and under the immediate management of Mr. John S. Plaskett. It consisted of four cameras and three spectrographs. Instead of pointing these at the Sun, they were placed on rigid cement piers, and the rays of light reflected into them by a large cœlostat. Next in importance was the outfit brought from the Royal Observatory at Greenwich by Mr. E. Walter Maunder, who, with his wife, had been invited by Sir Wilfrid Laurier to take part in the expedition. Two members of the British Astronomical Association, Messrs. Upton and Jennings, also accompanied the expedition and assisted Mr. Maunder. In addition there was a complete outfit for determining absolutely and for recording photographically the magnetic elements, and also for obtaining other meteorological data. This was sent out by Director Stupart, and was in charge of Mr. William Menzies. Instruments for finding the latitude and longitude of the station and for measuring the value of gravity, as well as numerous other telescopes, polariscopes, etc., were carried on the expedition. With great labor, but all performed with light hearts, the preparations were pushed forward, no obstacles such as frequent showers or the annoying black flies and mosquitoes being allowed to stop the work, until at last the installation was complete. After this were tedious adjustments and numerous rehearsals, until all was ready for the great event. But it was of no avail! On the morning of August 30 the sky was covered with heavy leaden clouds, and no observations, except of the weird darkness at the time of totality, were made. It is true the determinations of the magnetic elements, of the geographical position of the station and of the force of gravity are of considerable value, but we had hoped to write a bright page in the astronomical annals of Canada and were sorely disappointed. There was only one other station in America, namely, at Sandwich Bay on the Labrador, where the party from the Lick Observatory was located, and here there was no success. In Spain there were many parties. On this portion of the path of totality the time of the total phase was longest, namely $3^m\ 45^s$. A favored location was a plateau in the neighborhood of the ancient city of Burgos, in Castile, on an elevation 2,700 feet above the sea. Here, in the middle of Spain, it was confidently expected that the weather would be favorable. On the day before the eclipse the King of Spain came to inspect the camps representing the various countries. One of the astronomers expressed to him some apprehension lest the weather on the morrow should be unfavorable. "Have confidence in the sun of Castile," His Majesty replied. However, the confidence was not entirely justified. All the morning clouds were floating about, and at the time of the total phase, which took place at 1 o'clock, the sky was clear enough for successful work for but one minute out of the 3¾. At some places the results were rather better, but in others they were worse; indeed, taken together, the observations in Spain were a failure.

At Palma, in the Isle of Majorca, was a large concourse of astronomers, among them Sir Norman Lockyer and his party. Here, also, many clouds rendered the operations only partially successful. Along the remaining portion of the eclipse path, however, the circumstances were favorable. At Tripoli Professor Todd, of Amherst College, with his automatic apparatus obtained 250 photographs. He reports also that the curious phenomena known as the "shadow bands," were seen exceptionally well.

At Assouan, in Egypt, were American and English parties, and many successful photographs were taken.

A proper discussion of the mass of material obtained requires considerable time, and few results have as yet been published. It is confidently expected, however, that great additions will be made to our knowledge of the Sun.

A striking paper appeared in a recent number of the Astrophysical Journal on the "Figure of the Sun." In it the author, Prof. C. L. Poor, of Columbia University, gave strong evidence to show that the Sun is not spherical in shape, but that it oscillates from an oblate spheroid at the time of maximum spot-activity to a prolatespheroidwhen the activity is at a minimum. The variation is, of course, not great, but the result is extraordinary. Another sunspot period of eleven years should fully confirm or disprove the conclusions drawn.

At the Smithsonian Institution the study of the solar radiation and the transparency of the atmosphere has been continued. At various observatories throughout the world, especially the Yerkes, the Meudon, the South Kensington and the Potsdam, the spectroheliograph is used on every clear day to determine the distribution of some metallic vapors in the Sun's atmosphere. Professor Hale reports good progress in the construction of the great solar observatory on Mount Wilson, California. This work is being prosecuted at the expense of the Carnegie Institution, and will undoubtedly prove of extraordinary value in our study of the Sun.

Everyone recognises that the weather is a determining factor in the economic condition of a country. At present we can safely forecast the weather's condition for twenty-four hours in advance, sometimes for a longer period. This is certainly a great achievement, and the amount of property saved by a single prediction of a great storm would pay for the maintenance of the service for a whole year. I believe in no country in the world is a higher percentage of forecasts found to be verified, and I have been pleased with the attention given to some of these matters recently in the press. I hope to see our Society materially assist in securing a proper appreciation of the value and interest of such work as the Meteorological Service unceasingly carries forward.

Now, the Sun is the ruler of our system, and it is universally admitted that if we could find out the secret of the Sun we should have a key to unlock many of the secrets of the Earth. It is confidently hoped that by a study of solar and terrestrial phenomena, we shall ultimately be able to forecast our weather for a much longer time in advance—probably to predict the general character of an entire season.

By a study of the years from 1884 to 1904 W. N. Shaw has shown that the dryness of the autumn is the dominating element in the yield of wheat the next year. In a paper by H. I. Jensen, of the University of Sydney, N.S.W., the conclusion is reached that maximum terrestrial activity as exhibited in volcanic outbursts, earthquakes and climatic variations is coincident with maximum and minimum solar agitation. Sir Norman and Dr. W. J. S. Lockyer have also made similar researches.

It is true that the problem of finding the relation between solar activity and terrestrial phenomena is a very difficult and complicated one, but it is a matter of commanding importance, and should compel the attention of scientific men everywhere.

On September 27–29 there was a meeting at Oxford, England, of the International Union for Coöperation in Solar Research, and a series of resolutions for guidance in coöperation throughout the world were drawn up. It was pointed out that the need was urgent that all should work in harmony to cultivate the ample field.

THE PLANETS.

A year ago Prof. W. H. Pickering was triumphing in the demonstration of the correctness of his announcement, first made in 1898, that he had discovered a ninth satellite to Saturn. There are two remarkable points in the elements of its orbit, one that it is at the great distance of 8,000,000 miles from its primary (and requiring a year and a half to make a revolution), and the other that its motion is retrograde.

On the examination of several photographic plates selected from those used in determining the orbit of this satellite, still another was found. This *tenth* satellite is a very small body, about 38 miles in diameter, much smaller than any other satellite of Saturn. Its orbit is inclined at 39·1° to the ecliptic, and its eccentricity is considerable, being 0·23. Its mean distance from the planet is 906,000 miles. Its magnitude is 17·5, and it is thus much beyond ordinary telescopes. Its period is 20·85 days.

There have also been interesting developments in the family of Jupiter. The first real celestial discovery—namely, the first revelation of Galileo's telescope made on January 7, 1610—was that Jupiter had four satellites. A fifth was seen by Barnard at the Lick Observatory in September, 1892. This one is very small and so near the planet that it is quite beyond the reach of telescopes less than 18 or 20 inches in aperture.

When the 36-inch Crossley reflector at the Lick Observatory was reconstructed, it was proposed that it be used in a search for additional satellites to the outer planets. Photographs taken on December 3, 8, 9, 10 (1904) when compared together showed the planet to be accompanied by a body of the 14th magnitude. Others on January 2, 3, 4 showed the same thing and suggested its dependence on Jupiter. On January 28 the object was easily found in the great 36-inch refractor, in the place predicted from the Crossley photographs, and a few minutes of observation showed that it had a motion of about +20″ in R. A. per hour, and comparison with neighboring stars showed it to be of about the 14th magnitude. The inclination of its orbit is about 30°, and its period of revolution 250 days, or a little less, its distance 7,000,000 miles, and its diameter probably less than 100 miles.

A further examination of some of the Crossley photographs showed a much fainter object present, which on examination turned out to be a *seventh* satellite. Its inclination is about 30°, period 265 days, distance 7,300,000 miles. Its diameter is only about 35 miles, and it appears as a star of the 16th magnitude. Perrine, who was the discoverer of both satellites, suggests that the large inclination of their orbits indicates that probably neither of these bodies was originally a member of Jupiter's family, but that they have been "captured" by the giant planet.

Interesting work has also been done in comparing with each other the apparent magnitudes of the original four moons. Dr. P. Guthnick, by using a Zöllner photometer on an eleven-inch refractor, thought he could detect variations in their brightness, the variations coinciding with the periods of their revolutions about Jupiter; and his conclusion therefore was that the satellites always present the same face to Jupiter just as our Moon does to us.

Wendell, however, of the Harvard College Observatory, obtained no evidence of variability; but it is curious to note that while his visual observations made the order of brightness of the satellites invariably to be iii, i, ii, iv, a study of the plates taken at the Cape of Good Hope Observatory by Prof. W. de Sitter reveals no variations in brightness, but their order is found invariably to be iii, ii, i, iv. Thus there seems a considerable difference in the photographic and visual estimates of the brightness of these objects.

The markings on Mars have long been of great interest to the astronomer, and ever since Schiaparelli in 1877, '79 and '81 announced the discovery of the so-called canals and their gemination, the interest has been greatly intensified. These markings are near the limit of human vision, and it has often been contended that these apparent lines are only a physiological effect. During the past year, however, some striking evidence has been obtained at the Lowell Observatory, in Arizona, at which place Mars has long been one of the chief objects for observation. On May 11 Mr. Lowell drew a sketch of the planet as seen by him. Immediately afterwards Lampland, a very capable assistant, took a series of photographs and obtained indubitable evidence of the reality of the canal-like markings. It now seems probable that Schiaparelli's views will be completely confirmed.

Dr. T. J. J. See, of the U.S. Naval Observatory, Mare Island, Cal., publishes some interesting calculations of the internal densities, pressures and moments of inertia of the principal bodies of the planetary system. From a discussion of all available data he gives for Uranus a rotation period of $10^h\ 6^m\ 40^s{\cdot}32$ and an oblateness of $\frac{1}{25}$; and for Neptune a period of $12^h\ 50^m\ 53^s$, and an oblateness of $\frac{1}{40}$. He calculates that the pressure at the centre of the Earth is equal to that of 2883·152 km. of mercury, or that of a column 7,838 times as high as the Eiffel Tower. For the pressure at the Sun's centre he obtains 212 billion atmospheres. A column of mercury to produce this (if under terrestrial gravitational acceleration) would have to extend a greater distance than from the Earth to the Sun!

THE STARS.

The Harvard College Observatory continues its great task of developing the physical side of astronomy, and none of its work is of more importance than that on the stellar universe. In a fire-proof building, constructed specially for the purpose, are 180,000 photographic plates and the number is continually increasing. These furnish the only existing history of the starry heavens. An examination of these negatives leads to important discoveries every year. The curator of these photographs is Mrs. Fleming, and while examining, on August 31, the Draper Memorial plates, she discovered a new star in the constellation Aquila. In July, 1900, she had discovered a new star in this same constellation, and so the second one was known as Nova Aquilæ No. 2. On tracing its history it was found that while a close examination of plates (taken in South America) which showed all stars down to the 16th magnitude, exhibited no trace of it on August 15, yet three days later, on August 18, its magnitude was 6·5. On August 21 it had fallen to 7·5 and on August 26 it was 10. From this time on the decrease was not so rapid.

Miss Leavitt, of the same Observatory, has made some striking discoveries of variable stars in the Magellanic Cloud. Some years ago she found 57 variable stars there, and in order to study this portion of the heavens more closely, further photographs were taken at the South American station. These were examined at Cambridge, and on them 910 variables were discovered, an average of one to every 308 stars in the Cloud. The examination of 40,000 stars outside of this region gave an average of one variable in 3,300 stars.

An important addition to the data concerning the positions, inter-mutual distances and the movements of the Pleiades stars has been published in the Transactions of the Astronomical Observatory of Yale University. In 1884–6 Director Elkin triangulated these with the heliometer, but on discovering an error a new reduction was made. A comparison of these with the measurements made at Königsberg in 1840 gives evidence of motion of 9 of the 58 stars examined.

A valuable determination of the Constant of Aberration has been just published by Prof. C. L. Doolittle of the Flower

Observatory of the Universitv of Pennsylvania. After a laborious calculation of more than 15,000 observations he reaches as his value of this important constant 20″·54. By using this quantity and the velocity of light it is possible to determine the distance of the Earth from the Sun. The value obtained by Doolittle is about $\frac{1}{300}$ greater than that agreed upon at the Paris Conference of 1896, and if we take the velocity of light as 186,330 (as found by Newcomb and Michelson), the new value of our distance from the Sun comes out to be 93,194,000 miles.

COMETS.

There were five comets discovered in 1905, the first and the third by Giacobini, of Nice, on March 26 and December 6, respectively ; the second by Schaer, of Geneva, on November 17, and the other two by Mr. Lowell and Mr. Slipher when examining photographs made in November.

A METEOR'S PATH.

Some interesting results giving the actual path of a meteor observed by many people in south-west Germany have been published. The length of the path was 241 miles and the duration of its flight 9 sec. The mean velocity relative to the earth was 25·9 miles, and the absolute height above the earth's surface was 19 miles.

THE SOCIETY'S WORK DURING THE YEAR.

THE REGULAR MEETINGS.

During the year there were twenty regular meetings of the Society, and many interesting and valuable papers were read. Early in the year Mr. John A. Paterson presented a paper, admirable both on its scientific and its literary side, on "The Astronomy of Tennyson." The paper on " Personal Profit from Astronomical Studies," by the Rev. Robert Atkinson, of Chesley, whose absence from our meetings is much regretted, showed what pleasures there are for the modest student of astronomy. The subject of "Lunar Photography" was treated in a very interesting manner by Rev. Dr. Marsh, of Hamilton. He described at some length the experiments he had made in photographing the Moon, and exhibited some very successful pictures he had obtained. He is continuing his experiments and we hope to hear from him again. An account of the recent important trans-Pacific longitude determinations by Dr. O. J. Klotz and Mr. F. W. O. Werry was given by the former. In addition to giving a statement of the scientific results, Dr. Klotz took his large audience with him on a visit to the South Sea Islands, the numerous lantern illustrations making the trip a very real one. The paper by Mr. Harvey, on "Solar Spots and Magnetic Storms in 1904," was set down for April 4, but it was not given as the lamented death of our former president occurred three days after that date. The paper, however, was so nearly completed that it can probably be put in suitable form for publication. "Some Achievements of Nineteenth Century Astronomy" were outlined by our active member from East Toronto, Mr. L. H. Graham. Our venerable and beloved friend, Mr. Andrew Elvins, who, though his body feels some of the infirmities of eighty-two years, has still the heart of youth in his love for science, had promised the Society a paper for May last on "The Cause of Weather Changes." But at that time his health was feeble, and his place was ably taken by Director Stupart. It is a great pleasure for us to have Mr. Elvins with us to-night, and to know that he has the strength to undertake the preparation of a paper to be given to the Society in March. Various subjects connected with the stars were treated in a capable manner. Mr. J. Miller Barr, of St. Catharines, gave an account of several variable stars he had discovered, Mr. A. F. Miller gave a most admirable address on Binary Stars, including in it some measurements he had made with his own equatorial, and Mr. W. B. Musson in his paper on "Stellar Classification" gave a comprehensive survey of the efforts which have been made at the Harvard College Observatory to reduce to a systematic whole the multitudinous spectroscopic observations which have been made to determine the constitution of the stellar worlds above us. Mr. J. C. Hamilton's paper on "Stellar Legends of the North American Indians" showed much research and outlined many interesting beliefs of the aborigines. The shape of the Earth and the way in which its mountains are formed were treated by Mr. J. R. Collins and Professor Coleman, respectively, and a simple explanation of the striking phenomenon known as the harvest moon was given by Mr. J. E. Maybee. The conclusions of Alfred Russell Wallace as to "Life in Other

Worlds" were combated in a very able manner in a paper by Professor Kirschmann. The total eclipse of August 30 was the subject for discussion on three evenings. On the first Mr. J. S. Plaskett, of the Dominion Observatory, Ottawa, explained the nature of the preparations being made to observe the eclipse; on the second the present speaker gave an account of our expedition to Labrador; and on the third evening a summary of results obtained all along the eclipse track was given. In addition there were two open-air meetings with the telescopes. One evening was unfavorable, but on the other the sky was clear and the attendance was very large.

SPECIAL LECTURES.

Beside the regular meetings the Society gave a series of eight public lectures in the latter part of the winter. They were held in the Chemical Building of the University, and were by Professor De Lury. I think it safe to say that never before in the history of Toronto was a course of lectures on a scientific subject so well attended. Week after week the large room was filled, the interest being sustained to the end. The average attendance was over 400. This certainly speaks well both for the study of astronomy and for the manner in which it was presented. It is proposed to continue this work, and the course this year will probably begin in February.

THE SOCIETY'S SEAL.

For a number of years the Society had under consideration the selection of a design for an official seal, and I am happy to say that during the past year the work was brought to a completion. The central portion of the design is the figure of Urania, the muse of Astronomy. This sketch is after a sculpture by Flaxman. Above her head, on a starry background, is the motto, "Quo Ducit Urania" (*i.e.*, Where Urania leads, we follow), suggested by Prof. John Fletcher, of University College. Above this again is the royal crown, and surrounding all is the name of our Society. The sketches from which the seal was cut were made by Mr. John Ellis, and I think great praise and our sincere thanks are due him for the infinite pains he took with the work.

THE UNIVERSITY AND THE SOCIETY.

At the close of my address a year ago reference was made to a proposed extension of the study of astronomy in the University and to the relation between the University and the Society. Shortly afterwards a course for graduation in Astronomy and Physics was drawn up, and on interviewing the members of the Faculty directly interested in it I found all cordially in favor of it. I would like to mention, in particular, the hearty support given by Professors Baker and De Lury to the proposed advance. As every one supported it, the Senate speedily instituted the course, and it is in operation this year. It demands considerable work in astronomical measurements and in spectrum analysis, and hearty thanks are due to Director Stupart and Mr. Blake, of the Observatory, who courteously offer all the assistance in their power.

Soon after this a committee from the Council of our Society had an interview with the Board of Trustees of the University. After expressing satisfaction with the recently-established course in Astronomy and Physics, it was suggested that the University and the Society might with advantage unite their forces. The proposition was made that the University supply suitable rooms for the Society's meetings, and also accommodation for its library and instruments, the University to be allowed to use the library and instruments. The proposal was very cordially received, and it is hoped that in the near future it will be carried out.

The University have now before them the problem of supplying proper facilities for teaching Astronomy in a thoroughly practical manner. It was at first suggested that the present main building of the Magnetic Observatory, when the Director has obtained his new quarters, be adapted for astronomical purposes. But its site encroaches too closely on the proposed site of the other buildings; and even if this were not the case it would be so completely surrounded by high walls that the horizon would be too limited for satisfactory work. It will thus be necessary to find some other site, and a good horizon can hardly be secured without going to the elevation to the north of the city.

Whatever observatory is constructed must, of course, first of all supply proper appliances for ordinary instruction. But I hope it will not stop there. I think no department of a great University does its whole duty until it undertakes the work of research, and in Astronomy this is especially desirable. There are many valuable investigations which can be made by the careful and persistent observer. Indeed this year a useful research is being prosecuted with the 6-inch telescope of the Observatory by a graduate of the University (a member of Mr. Stupart's staff). But I have already indicated very important work on the Sun which waits to be done, and I think our University should lend assistance in the solution of some of the great outstanding problems of solar physics. To undertake this we would require a first class telescope of considerable aperture, and I beg you to commend the project to the friends of the University.

To further encourage the study of Astronomy the Society decided to institute a gold medal, and to offer a copy of it each year to the University for competition in the course in Astronomy and Physics. There is on exhibition to-night a wax model of the medal. It is the work of Messrs. P. W. Ellis & Co. of this city. We were very anxious to have the dies executed in the best possible manner, and we were glad to find a Toronto firm able to undertake the work. Messrs. Ellis are using every endeavor to produce a genuine work of art, of which we shall all be proud.

EXTENDING OUR SOCIETY.

Finally, let me refer to a project now before the Society, namely, to multiply its membership in every part of our land and thus to make it truly national in character. Chief Astronomer King, now our Honorary President, and Director Stupart, my predecessor in the presidential chair, are ready to render every possible assistance, and I see no reason why our Society should not unite in a living bond all the Astronomical interests of Canada. Our country is yet young and there is much work to do, but I am convinced that if we are all united in our efforts we shall attain results worthy of the noble subject that we study and of the noble land we live in.

PAPERS AND LECTURES, 1904.

January 10—Society's Annual At-Home.

January 24—"Mountain Building." Prof. A. P. Coleman, Ph.D.

February 7—"The Astronomy of Tennyson." John A. Paterson, K.C., M.A.

February 21—"Personal Profit from Astronomical Studies." Rev. R. Atkinson, Chesley.

March 7—"The Total Solar Eclipse of August 30, 1905." J. S. Plaskett, B. A., Dominion Observatory, Ottawa.

March 21—"Lunar Photography." Rev. D. B. Marsh, D.Sc., F.R.A.S., Hamilton, Ontario.

April 4—"Solar Spots and Magnetic Storms of 1904." Arthur Harvey, F.R.S.C.

April 18—"A Telescope Without a Lens." C. A. Chant.

May 2—"Longitude Determination in the Pacific." O. J. Klotz, LL.D., Ottawa, Ontario.

May 16—"Achievements of Nineteenth Century Astronomy." L. H. Graham, B.A.

May 30—"Causes of Weather Changes." R. F. Stupart, F.R.S.C.

June 13—"The Figure of the Earth." J. R. Collins.

June 27—Open Air Meeting at the Observatory.

October 3—"The Expedition to Labrador to Observe the Total Solar Eclipse of August 30, 1905." C. A. Chant, President.

October 17—"Stellar Legends of the North American Indians." J. C. Hamilton, M.A., LL.B.
"An Explanation of the Harvest Moon." J. Edward Maybee, M.E.

October 31—"Life in Other Worlds." Prof. A. Kirschmann, Ph.D.

November 14—"A New Problem in Astrophysics." J. Miller Barr, St. Catharines.

November 28—"Stellar Motions." A. F. Miller.

December 12—"Stellar Classification. W. Balfour Musson.

December 26—Annual Meeting.
"Results of Expeditions to Observe the Eclipse of August 30, 1905."

FREE PUBLIC LECTURES.

A course of eight Elementary Lectures on Astronomy, were given by Professor DeLury, during February and March.

Through the courtesy of the University Authorities, these lectures were delivered in the Chemical Building of the University, and were uniformly well attended.

THE DOMINION OBSERVATORY AT OTTAWA.

BY

W. F. KING, CHIEF ASTRONOMER.

TO the minds of many, perhaps most, of the Canadian public the word "observatory" conveys the idea of an institution where meteorological observations are taken, and from which are issued weather predictions and storm warnings. They are familiar with the work of the Toronto Observatory, in regard to these predictions especially, and know that there are numerous minor stations equipped for meteorological observation, scattered over the country, and supported or assisted by the Canadian Government through its Marine Department.

Though there are astronomical instruments at many of these stations, astronomy is altogether a secondary matter, appearing doubtless to the outsider a merely ornamental part of the practical science of meteorology.

The Dominion Observatory differs essentially from these institutions in not being a meteorological observatory, but having a purpose purely astronomical. In view of the recent completion and equipment of the new building, it may be of interest to trace the development of practical applications of astronomy under the Department of the Interior, to fill practical needs, and to show how an appreciation of the value thereby rendered has caused the Government and Parliament to make provision for the advancement of astronomical science.

On the admission of Rupert's Land and the North-West Territories into Canada, their public lands became the property of the Dominion, and provision had to be made for their survey and administration. The Dominion Lands Office, which was organized for this duty, afterwards developed into the Department of the Interior, one of the largest departments of the public service of Canada.

It was recognized that, owing to the vast area which was to be laid out into farms, two things were to be looked to: accuracy of survey, sufficient to obviate the possible accumulation of large errors, and such a systematic arrangement of townships and sections as would facilitate record and descriptions for titles.

To secure these ends it was decided that the survey lines should be referred in direction to the true meridian, as determined by astronomical observation. This was already the practice in Ontario and Quebec, magnetic bearings for purposes of description having been done away with many years before, but the further improvement was made that the lines dividing townships and sections should be north and south, or east and west astronomically, within small limits of deviation. With the working out of the survey system, methods of observation for azimuth have been improved and simplified, so that now a very efficient local control is secured over each township surveyed. At the same time simple record and description was ensured by the adoption of the "checker-board" system of rectangular townships and sections of as nearly as possible equal area.

The townships being of equal area and laid off from a "principal meridian," a few years' surveying developed the fact that the "jogs" resulting from convergence of meridians would, when the surveys came to be extended far westward, become so great as to interfere with the usefulness of the system of record in relation to the description of townships by "ranges" west of the principal meridian.

It was therefore decided to establish new principal meridians at convenient intervals, from each of which the regular system might be started again, these meridians to be near enough together to prevent the undue accumulation of the effects of the earth's curvature.

To facilitate prompt survey of lands wherever needed for settlement, without destroying the regularity of the system, it was desirable that these meridians should be in known longitude, and it was accordingly decided to place them four degrees of longitude apart, on the exact degrees 102, 106, etc., west of Greenwich. It is not the purpose here to go into details of these surveys, but to elucidate the above statement as to the utility of these meridians for prompt survey, one instance may be mentioned. The settlement of Prince Albert on the Saskatchewan lay just to the east of the third initial meridian (106°). Its survey was readily made, in conformity with the system as if projected from the second meridian, by survey eastward from third meridian, whereas the projection of the base line system westward from the second meridian would have involved very great expenditure of time and money in surveying over the intervening region, where surveys were not at the time needed.

In 1874 and 1875 the second initial meridian in longitude 102°, was determined by a triangulation from the first by the "special survey." From considerations of cost, however, triangulation was discontinued, and subsequent meridians were established by chain measurements.

As a check upon these measurements, astronomical observation was resorted to. Latitudes were observed to check the north and south measurements, and it was proposed to determine longitudes by means of the telegraph, which in 1876 extended from Winnipeg to Edmonton. After one or two attempts, however, this idea was abandoned, owing to irregularity in the operation of the telegraph line, the efficient maintenance of which over such an extent of uninhabited country was a most difficult matter.

The latitude observations were continued until the whole of the prairie section of the territories had been provided with main governing lines according to the survey system. The accordance of these observed latitudes with the theoretical ones was such as to inspire confidence in the accuracy with which surveys in favorable country could be made with transit and chain, and at the same time to indicate the value of astronomical basal points for surveys in less level regions. Accordingly when in 1885 it became necessary to carry the surveys into the mountainous regions of the British Columbia "Railway Belt," astronomical determinations were again resorted to. By the terms of union, British Columbia was to hand over to the Dominion Government a belt of land twenty miles wide on each side of the Canadian Pacific Railway as constructed. This had to be surveyed by the Department of the Interior and it was decided to extend the rectangular system into the Belt. As the country passed through by the railway for the five hundred miles from the summit of the Rocky Mountains to salt water is nearly all mountainous, the projection of base lines, etc. by the ordinary methods was impossible, and a system of traverse survey with transit and chain along the railway right-of-way was used. Astronomical co-ordinates of certain basal stations from which the survey points could be accurately located in their theoretical positions in the survey framework were determined, latitudes by zenith telescope observation, and longitudes by telegraphic exchange of time. As the telegraph line was not, in the survey season of 1885, completed across the mountains, connection was made with the U. S. Coast Survey longitude chain at Seattle. Several points along the railway were thus determined in 1885 and 1886, and in the latter year the longitude was carried eastward to Winnipeg. In the two years next following, several points were determined in longitude on the prairie section, thus affording the check in longitude which had been aimed at several years before, though unsuccessfully, for the reason stated above.

About this time need began to be felt at the head office at Ottawa for a small observatory in which observations for personal equation, etc., could be made, chronometers rated, and where observers could practice, a most important matter in longitude work where everything depends upon the constancy of the observer's personal equation, a condition only to be secured by constant practice. The rating of chronometers to be used by members of exploring expeditions to the northern regions was also important.

A suggestion was made to erect a small transit house in Ottawa for this purpose, but owing to premature publication in an exaggerated form, wherein the intended building was represented to be an observatory of considerable pretensions, the proposal met with opposition on the ground that the money to be expended could better be applied to the wants of existing observatories. This argument was surely most fallacious, nevertheless it prevailed, and the project was defeated.

For a while the accommodation needed for this public service was supplied by a small building erected on a private lawn, but in 1890 a transit house 18 by 9 feet was built on a lot belonging to the Government. This building contained two piers upon which the transit instruments could be set. Outside at the western end of the building was placed a third pier with a surrounding platform for the reception of a reflecting telescope of 8½ inches aperture, without clockwork or circles. This instrument was protected by a box cover on rollers, so that it could be moved to one side. Owing to limited space no proper provision could be made for the storage of instruments or for a clock room. Resort was had at different times to the use of a chronometer in the building, then to one in the cellar of an adjoining private house, with electric connection to the transit house, then to a clock in an office up town. Finally a suitable place for the clock was found in the basement of one of the Government buildings, where the clock was attached to a solid wall, and in a tolerably uniform temperature. Connection was of course made by wire with the chronograph in the transit house.

Rough as the setting was, the instruments were good, and much interest in astronomical operations was aroused among the frequent visitors to the place—an interest which proved of value later on, when better accommodation was asked for.

While this observatory continued in use for the other purposes mentioned, determinations of longitude, save for one in 1890, were for various reasons discontinued for some years. Even the position in longitude of the Ottawa observatory remained undetermined, until 1896, when connection was made with Montreal and with Winnipeg, thereby completing the chain begun in 1885. The closing error between Seattle and Montreal, the two ends of the chain, where it connected with the telegraphic longitudes of the United States and the trans-Atlantic longitudes, was found to be but a small fraction of a second of time.

In 1900 the longitude of Vancouver was determined from Ottawa, and since then a number of points in Ontario and Quebec mainly have been determined in latitude and longitude. Experience and improved instrumental equipment have simplified matters, so that the number of longitude determinations made under the Astronomical Branch of the Department of the Interior during last summer was seventeen. The purpose for which these observations have in general been made is the fixing of points for the correction of existing maps. Most maps have to be compiled by a process of building up isolated surveys. Errors accumulate to a degree which can hardly be understood by those not familiar with the work. The draughtsman in compiling has often to adjust discrepancies by a species of guesswork, with the frequent result of making things worse, unless he is provided with closing points of well determined position. Closing points are best furnished by a trigonometrical survey, but without that, as has been the case in Canada hitherto, astronomical points, though not in all respects a complete substitute for trigonometrical points, serve that particular purpose.

In 1903 and 1904, the chain of longitude across Canada, terminating at Vancouver as determined in 1900, was carried across the Pacific, following the route of the cable, to a closing on the Australian longitudes, as brought eastward from Greenwich. The closing error in the complete circuit of the globe was one-fifteenth of a second of time. It may be remarked that, although the longitude carried across the Pacific in 1903 by the U. S. Coast and Geodetic Survey has secured prior publication of results, the Canadian circuit of the globe was first in time, so far as regards the actual observations.

To return to the subject of the new observatory, in 1898 the Minister of the Interior, recognizing the need for better accommodation for the astronomical branch of his department, authorized the Chief Astronomer to prepare a statement of the instruments and of the character of the building which would be necessary.

At first it was intended to confine the work to the longitude determinations calling, in the way of instruments, for clock and transit, but adding a moderate-sized equatorial for public exhibition merely. The building was to be of the simplest character, containing, besides the instrument rooms, three or four rooms for office purposes. So the first estimate allowed $6,000.00 for instruments, among which were a 10-inch equatorial, clocks, etc., and $10,000.00 for a building. At its next session Parliament voted the $16,000.00 asked for.

But then the question of site came up. It was desired to have the building near the Government buildings in the centre of the city. This desire had reference to the proposed scope of the institution, as above stated, and also to the requirements in regard to the departmental duties in other matters of the officers concerned.

It was found that the available sites within a reasonable distance of Parliament Hill were such as to call for a more expensive building than originally intended. Then it became evident that a fine building in a prominent place would be looked upon as, in some sort, a national observatory. It would not be fitting that such an institution should have small or inferior instruments. If the instruments were to be large enough for use in original investigation, the centre of the city was not the place for them. On the other hand, a building outside the city would require more office accommodation (looking again to departmental requirements which could not be ignored), as well as some provision for dwelling houses, or transport of officials to and fro. It became apparent that, in these circumstances, the amount voted for building and instruments was not sufficient, and delay ensued.

In 1901 Parliament voted $15,000.00 for a telescope and apparatus and $15,000.00 towards the construction of a building. The Chief Astronomer was thereupon authorized to make a contract (with Messrs. Warner & Swasey, of Cleveland) for the construction of a 15-inch equatorial with spectroscopic and other attachments.

The question of site was again considered, and in order to limit as far as possible the expense and inconvenience which would result if a site difficult of access were chosen, it was endeavoured to find a suitable place within the city, but remote from the business section. From first to last some twenty proposed sites were examined, and it was finally determined to place the building on land belonging to the Government within the boundaries of the Central Experimental Farm.

The contract for the construction of the building was let in 1902, and the foundation was laid in the fall of that year. In October, 1904, the building was sufficiently advanced, with the dome in position, to have the equatorial instrument set up, which was done, and its adjustments were made during the winter. In April, 1905, the building was occupied by the Observatory staff. Since that time good progress has been made with the interior fittings and the installation of instruments. An extension is being built for a transit house, in which provision is made for a meridian circle. Pending completion of this annex temporary sheds are used to shelter the transit instruments.

As will be seen from the foregoing the present situation is a development from the application of astronomy to problems of a geodetic nature, initially in the West in connection with surveys of Dominion Lands, more recently in the eastern provinces. The union of the management of the International Boundary Surveys with that of the astronomical work has also tended to strengthen the position of the Astronomical Branch of the Department of the Interior in this direction. Geodetic applications of astronomy must continue to occupy the attention largely of the Observatory staff, especially now that a general trigonometric survey of Canada has been begun. Gravity, seismographic, and possibly magnetic work, as related to geodesy, will also fall within the scope of operations.

Another practical utility is the determination of time and its distribution by electrically controlled clocks. This system was initiated in 1902 by an experimental system on a small scale, in one of the departmental blocks. This proving successful, an extensive system was carried out after the new observatory had been completed, and now the four principal government buildings are provided with dials operated electrically by master-clocks, of which each building has one. The master-clocks are themselves controlled by a synchronizing current sent from the principal clock at the Observatory.

In the direction of Physical Astronomy, also, provision for research has not been neglected. Besides the star spectroscopic apparatus belonging to the 15-inch equatorial, a mounting for a concave grating for solar work has been placed in one of the rooms, and it is further intended to provide a building for a cœlostat in the rear of the Observatory.

This last summer, also, as it is hardly necessary to recall, the Chief Astronomer organized an expedition to observe the total eclipse of the sun at North-West River, Ungava. While, unfortunately, the weather was such that the scientific results were very meagre, the expedition is memorable as the first one of any consequence undertaken by the Dominion Government for a purely scientific purpose.

SOLAR SPOTS AND MAGNETIC STORMS FOR 1904.

BY

ARTHUR HARVEY.

THE sun-spots and magnetic disturbances of 1904 present interesting examples of periodicity and of being connected through some common cause.

The accompanying diagram shews, firstly, the daily mean readings at Agincourt (Toronto) of the horizontal component of magnetic force. The figures, reduced to C. G. S. units, are given in a table furnished by Director Stupart,* but the graphical representation is better adapted to show at a glance the nature of the phenomena recorded. Such a representation is often called a curve, but it shews nothing so much as angularities. If we smooth them by the standard formula $\frac{a+e+2(b+d)+4c}{10}$, we obtain a curve which somewhat reduces the excessive dislocations, but I admit my preference for the unsmoothed verity. The horizontal straight lines are the monthly means of the same component. The diagram shews, secondly, the sun-spot record. The spots noted in the northern solar hemisphere are above the magnetic curves, those in the southern hemisphere below them. The record relied upon is that published quarterly in the *Comptes Rendus de l'Academie Francaise* by M. J. Guillaume, of the Lyons Observatory. The spots are shewn as at the time when each was on the central solar meridian, the days of the spot-centrality being exactly over those of the magnetic curves. This gives about 27¼ spaces for the semi-circumference of 360°, and if the width of the spot belt were on the same scale it would be some thirteen times narrower than I have represented it. My reason for spacing degrees of solar latitude on the same scale as the days, is, that the differences of spot-latitude would not have been so well shewn if contracted. The relative sizes of the spots are in very fair proportion to the width of the spot-zone. The record gives them in millionths of the semi-surface, foreshortening allowed for. The square root of their areas has been taken for the spot-diameter,

---

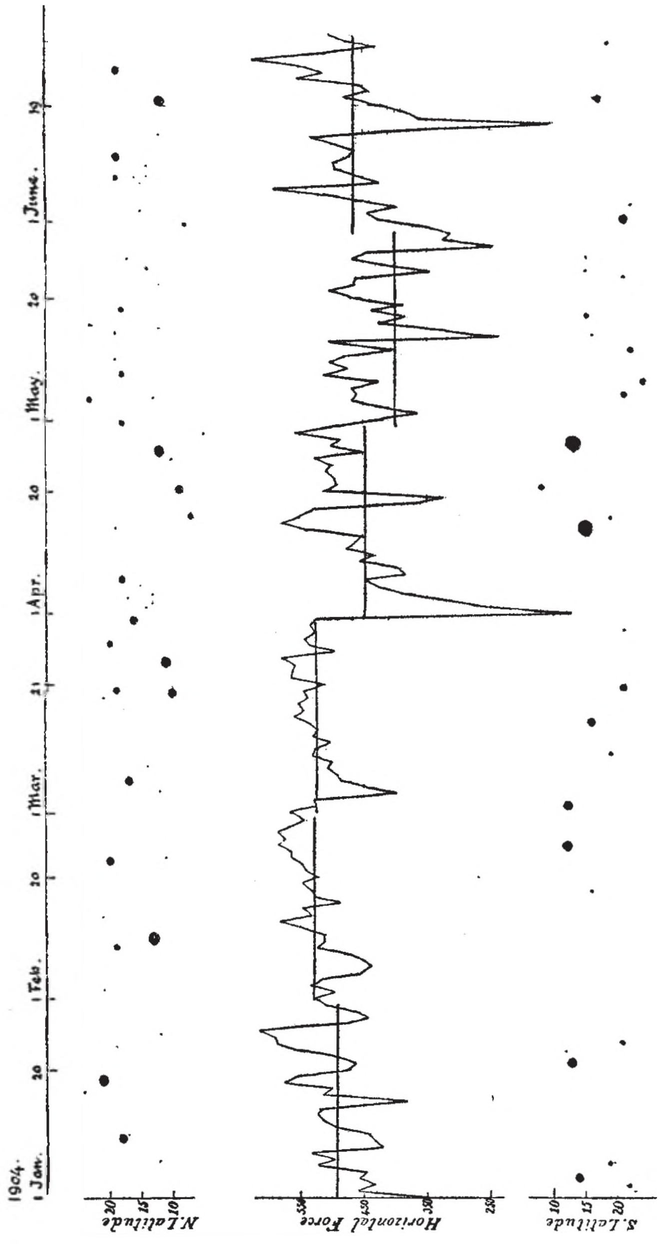
* See Report of Meteorological Service of Canada for 1904, part 6.

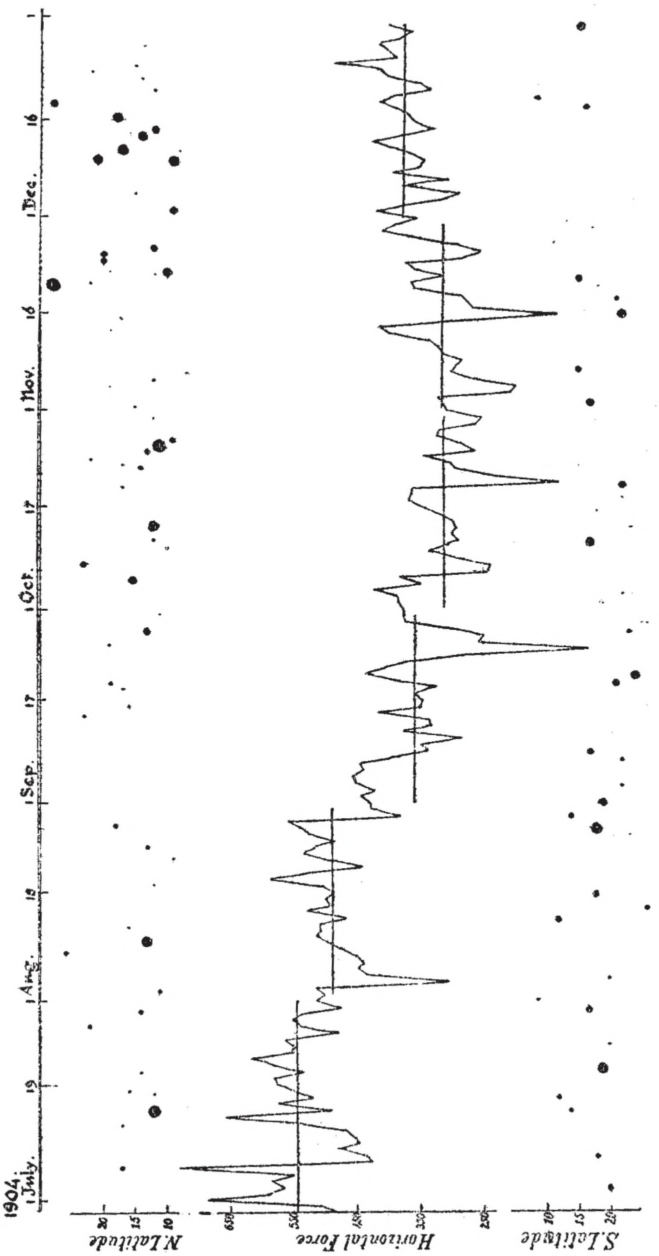
and as groups are thrown together in the record, all spots are here treated as single.

In the northern spot-belt the first fine spot of the year is timed for centrality January 10·6, at latitude 18° and was watched until the 15th, when it was too near the limb to be further visible. As we do not know what transpired on the further side of the sun we cannot tell if the somewhat smaller spot which came into view, February 6th, was the same or another which broke out in the same region. This spot passed the meridian February 9·4 in latitude 19°. The time between the two centralities is 2·55 days longer than the period accepted for solar rotation. If then it was a new spot we have a clue to the extent in longitude of this disturbed solar area; viz. 23½°, which is about the width of the spot-zone. A much larger spot follows, one day later and 6° nearer to the equator, and the two disturbances interact. The first effect is usually repulsion, the end is union or absorption. In the case of our spot it seems to be driven a degree and a half northward by its larger neighbor, but it re-occupies its place in the third rotation period, central, March 6·5 at lat. 17° and in the fourth, central, March 31·0 at lat. 16°. Union with the force evidenced by the large spot alluded to at the second period, now takes place, and a fine spot, central April 26·7 at lat. 12° testifies thereto at the fifth rotation period. Only "pin holes" mark the sixth, but the spot re-appears for the seventh, central June 19·6 at lat. 12°; for the eighth, central July 14·9 lat. 12° and the ninth, central August 10·2 lat. 13°. To make its history more complete we should have account of two appearances in the previous year, and we then have the following table from its birth as a "pin hole" in November 1903.

TIME OF CENTRALITY.

1903.	November	18·5^{d}	lat.	22°			
	December	14·1	"	20	period	25·6	days.
1904.	January	10·6	"	18	"	27·5	"
	February	9·4	"	19	"	29·4	"
	March	6·5	"	17	"	26·1	"
	"	31·0	"	16	"	25·5	"
	April	26·7	"	12	"	27·7	"
	May	....		...		....	


1904.
1 Jan.
20
1 Feb.
20
1 Mar.
21
1 Apr.
20
1 May.
20
1 June.
19
N. Latitude
20
15
10
Horizontal Force
550
450
350
250
S. Latitude
10
15
20


N.Latitude
10
15
20
Horizontal Force
650
550
450
350
250
S.Latitude
10
15
20
1904.
1 July.
19
1 Aug.
18
1 Sep.
17
1 Oct.
17
1 Nov.
16
1 Dec.
16
1

1904.	June	19·6	lat.	12	period	53·9	days.
	July	14·9	"	12	"	25·3	"
	August	10·2	"	13	"	26·3	"
				10 rotations in		265.7	"
				Average period for 1 rotation		26·6	"

Suppressed for two periods it breaks out again :

1904.	October	26·4	lat.	11°	period	77·2	days.
	November	22·5	"	10	"	27·1	"
				4 rotations in		104·3	"
				Shewing for the 14 rotations		370	"
				Average for 1 rotation		26·43	"

Perhaps the theory of coalescence should not be considered in this reckoning. In that case we have for the first six appearances 134·1 days, giving 26·8 days for the average, and for the rest, that is, treating the great spot, central April 26·7, as No. 1, we have 105·5 days or 26·4 days for the average.

Turning now to the southern hemisphere we find a different state of things. The spots average about 3° further from the equator than those of the northern hemisphere and the spot-zone is very much more disturbed, seeming not to have settled down since the outbursts of October, 1903. Between the 4th and 18th October of that year, one of the greatest spots ever seen was traversing the disc ; central October 11th, mean latitude 22°. It was, however, not long lived, for a smaller one forming near it on October 17th, just as it was passing off the limb, seemed to have destroyed its activity while lost to our view, for it rapidly diminished on reappearance and vanished before completing its second passage. This is the more remarkable because, according to M. Guillaume, there had been nothing to compare with it in size since the spot, central September 9th, 1898, at 12° latitude. It covered 19° in longitude and 7° in latitude. Were these two great spots related? It would almost seem so, notwithstanding the 10° greater distance from the Sun's equator of the second. If my period for solar rotation, 27·2456 days, be correct, the 67 rotations between the two appearances call for 1825·45 days, while the actual number between September 9th, 1898, and October 11th, 1903, was 1826. There was another spot, central October 31·9, 1903, with only a fourth of the area of its big companion, which was coincident at its centrality with the greatest magnetic storm of recent years. In this disturbed southern hemisphere, then, the following are the principal "repeaters":

TIME OF CENTRALITY.

1904.	January	3·9	s. lat.	14°			
	March	2·2	"	13	period	58·3	days.
	April	27·2	"	13	"	56·0	"
	July	16·9	"	12	"	80·7	"
	August	13·8	"	12	"	27·9	"
					8 rotations	222·9	"
					Average for 1 rotation	27·8	"

Another series seems to begin with July 21·3, as follows:

1904.	July	21·3	s. lat.	19°			
	August	17·7	"	18	period	27·4	days.
	October	11·6	"	17	"	54·9	"
	November	7·3	"	15	"	26·7	"
	December	30·9	"	13	"	53·6	"
					6 rotations	162·6	"
					Average for 1 rotation	27·1	"

Perhaps also

1904.	September	20·9	s. lat.	24°			
	October	20·5	"	22	period	29·6	days.
1905.	February	4	"	14	"	106·5	"
					5 rotations	136·1	"
					Average for 1 rotation	27·2	"

thus culminating in the largest spot on record.

Here we have at once an excellent example of the apparent irregularities which perplex and confuse solar observers and students. The two sets of spot phenomena, northern and southern, have nothing in common except the steady in-drift towards the equator, but that is much less rapid in the south. The rotation period is 27·8 days in the south as against 26·6 days in the north, far more different than the difference of latitude of the spot-belt ought to show. One cannot escape from the conclusion that the solar surface, on or just below which these manifestations occur, is composed of most tenuous and mobile gases and vapors. It follows that the tremendous explosions and the immense forces we have heard of from our old authorities are not required to account for the changes we see. A rapid current of a few degrees in breadth, on or near the equator, seems to be sweeping round the Sun, thus causing the spot-indraft, the resultant, perhaps, or back-eddy of the solar atmospheric tides, due to planetary influence. We know that on our Earth the mathematical equator is not coincident with the meteorological or the magnetic equators, if the term is permissible, and it would be surprising if we found absolute Aristotelian symmetry on the Sun.

Turning now to the recurrences of magnetic phenomena, we find them equally remarkable for periodicity. Beginning with the disturbance of January 8–12, and taking the lowest reading, on the 9th, as the date of reckoning, we have the following fine series:

MAGNETIC RECURRENCES.

1904.	January	9				
	February	6	interval	28	days.	
	March	4	"	27	"	
	April	1	"	27	"	
	"	26	"	25	"	indistinct.
	May	24	"	29	"	
			5 periods	136	"	
			Average for 1 period	27·2	"	

Here we must break off the series because from this date the northern disturbances affect us more, because the position of the Earth with respect to the Sun changes, and the influence of the southern disturbances appears, as it should, to lessen.

We re-commence, then, with

1904.	July	7			
	August	4	interval	28	days.
	"	30	"	26	"
	September	25	"	26	"
	October	21	"	26	"
	November	16	"	26	"
	December	14	"	28	"
			6 periods	160	"
			Average for 1 period	26·6	"

And now, in lieu of comment of my own I will quote what

M. Ch. Ed. Guillaume said at a meeting of the Astronomical Society of France, December 7, 1904, he being a pupil of the eminent solar astronomer, Rudolf Wolf:

"Physicists deny the possibility of the solar action in the phenomena of terrestrial magnetism. I do not know if such action be *possible*, but I can affirm that it exists."

The successive magnetic periods usually tend to shorten a day or two, as the disturbance fades away, to be replaced by another. But when we take a really great magnetic storm, accompanied by an important sun-spot, this irregularity disappears in great part. Thus in the *Trans. Can. Inst. 1901*, page 110, I show a series of such important storms and spots, and the interval of 27·24575 synodical (or 25·35447 sidereal, as calculated in our Transactions for 1897) seems to crop up with pertinacity.

Now, Jupiter goes round the Sun in 4332·5 days, and 159 times 27·24575 is 4332·07 days. It would seem, then, that this period is connected with Jupiter's motion, and I should affirm it were it not for the one extra rotation due to the synodical rotation of the Sun as seen from Jupiter, which being allowed for gives 27·417 days for the synodical period in question.

Imagine, now, Jupiter and the Sun to be the only bodies of the system. On the Sun, at the place where the *radius vector* connecting their centres cuts the circumference, or, to allow for lag, 15° to 30° from it, of solar longitude, is a small *hill* of solar vapor—probably confined to the slightly denser strata below the photosphere, as on earth the tides affect the denser fluid, water, far more than the lighter one, the air. This *hill* is, of course, duplicated on the opposite side of the Sun, again paralleling terrestrial features. The law is given by Herschel (526): "If any part of any system connected either by material ties or by the mutual attraction of its members be continually maintained by any cause, whether inherent in the constitution of the system or external to it, in a state of regular periodic motion, that motion will be propagated throughout the whole system and will give rise in every member of it, and in every part of each member, to periodic movements executed in equal periods with that to which they owe their origin, though not necessarily synchronous with them in their maxima and minima." Steadily, then, with the deliberation of the great planet it moves around the Sun, causing some mixture of strata and some consequent change of condition at every rotation: period fixed and unchangeable, 25·51 days.

We might in the same way suppose the Sun and the Earth the only two bodies, and we should have an earth-tide on the Sun; period fixed, on the same assumption as to the rate of the Sun's rotation, at 27·246 days, and we should look for disturbances at that interval. The synodical period with respect to Venus is 28·58 days.

Now, if the system finds itself with two planets in exact opposition or in exact conjunction, two tides will be superimposed and a larger disturbance result. Their joint effect will be felt until the *radii vectores* are perhaps at an angle of 45°, and when the vertices of two waves do not coincide, their joint height has its maximum at a point intermediate between them. The joint period, Jupiter-Earth, would be a little longer than the Earth period alone, viz., 398·88 days; the period, Jupiter-Venus, still shorter, 270 days, and the period, Earth-Venus, 583·93 days. The formula is $\frac{Pp}{P-p}$, P and p being the respective periods.

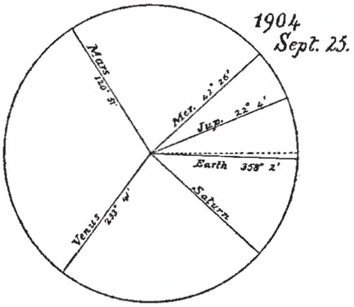
When the International Solar Institute was formed at Montevideo and I was made honorary President, I proposed to it the study of these waves, and the following paragraph, from the Toronto *World* at the end of 1900, shews that the subject is not a new one to me:

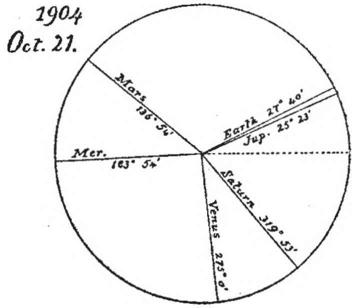
"Mr. Harvey had also proposed to the Institute the study of solar tides. If these be anything like a nucleus to the Sun, there would be certain slight tides in the fluids or even vapor around it, caused by the planets revolving around the Sun. They would be greatest in the case of Jupiter, and it would take a little more than eleven years for that tide to sweep around the Sun. The conjunction of Jupiter with other planets, that is, the combination of their pull when both on the same line with the Sun, would, of course, influence the height of such little tides. Mr. Harvey thinks this Jupiter period may have some connection with the maxima of sun-spots, also repeated, about every eleven and a quarter years. He proposed to work out the tidal disturbances due to all the planets, and to see how far the maximum of tide corresponded with the maximum of spot-disturbance. It is understood that Señor Carrasco has undertaken this work, Mr. Harvey's branch being the correlation of solar phenomena with terrestrial magnetism."

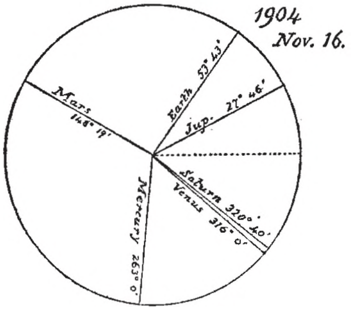
I am sure that Señor Carrasco would have done it more justice than I can, but I will show you diagrammatically how interesting it is.

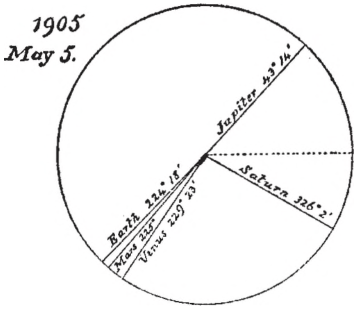
In charting the magnetic curves for 1904 and especially when noticing the three great "fingers" just alluded to, with very regularly spaced disturbances on each side of them, it was evident that the planet Jupiter was controlling the situation. Had it been the tidal wave, due principally to one of the inferior planets, the recurrences could not have been so frequent and regular. The *Nautical Almanac* gives the following positions for the various planets as to their right ascension, or heliocentric longitude, at the dates of these three storms :

	Sept. 25, 1904	Oct. 21, 1904	Nov. 16, 1904
Jupiter	22°·04′	25°·23′	27°·46′
Saturn	318 ·45	319 ·53	320 ·40
Mars	120 ·51	136 ·54	148 ·19
Earth	358 ·02	27 ·40	53 ·43
Venus	233 ·41	275 ·00	316 ·00
Mercury	42 ·26	183 ·54	263 ·00









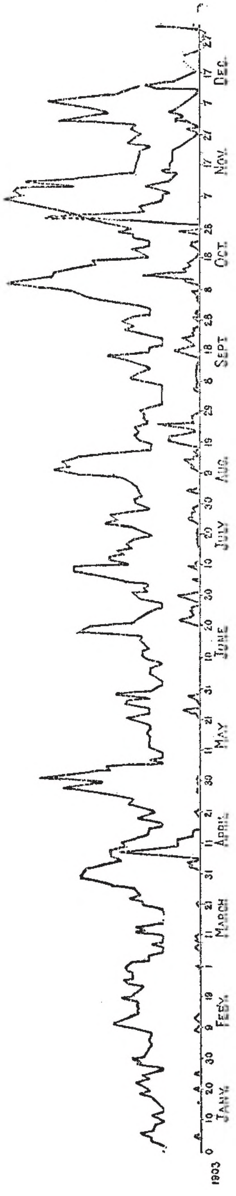
If we draw diagrams from these data, it will be seen that on September 25th, Venus has just passed opposition to Jupiter, Mercury the same, and the Earth is coming to a conjunction. On October 21st the Earth is virtually in conjunction with Jupiter. On November 16th the Earth is still acting with Jupiter, the other planets being in quadrature and having no effect on the Jupiter-Earth tide. On extending the diagrams to include May 5th, 1905, there is to be a remarkable joint pull of Jupiter, the Earth, and Venus, the only planets of real importance in this connection, though the influence of Mercury, which was in direct opposition only a week before, is still positive. Saturn alone is in solitary quadrature. This then should mark the apex of the present solar spot maximum.

To aid in the study of this subject I have made tables of the heliocentric conjunctions of the planets for the last thirty years; reckoning back from the data given in the *Ephemeris* for 1905. They will require correction, because no allowances have been made for eccentricities and perturbations—I not having access to a series of nautical almanacs. The tables shew :—

Jupiter-Earth,	opposition	1903	February	26
" "	conjunction	"	September	18
" "	opposition	1904	March	31
" "	conjunction	"	October	21
Jupiter-Venus,	"	1903	February	11
" "	opposition	"	June	11
" "	conjunction	"	November	8
" "	opposition	1904	March	7
" "	conjunction	"	August	4
" "	opposition	"	December	2
Earth-Venus	conjunction	1903	September	21

Chronologically arranged the dates are :—1903—February 11 : February 26 : June 11 : September 18 : September 21 : November 8. 1904—March 7 : March 31 : August 4 : October 21 : December 2. A magnetic curve for 1903 is shewn herewith.

On February 11th, 1903, Jupiter and Venus, in conjunction, started a solar tide which can be traced by a slight depression in the H. F. magnetic curve from 8th to 13th ; also by a spot which,



SUN-SPOT CURVE, 1903, COMPARED WITH DEPRESSIONS IN THE CURVE OF MAGNETIC HORIZONTAL FORCE.

as Jupiter was in south heliocentric latitude, was south of the equator. On the 26th the Earth wave possibly adds to the volume of that being formed, and on April 6th we have at two periods' distance, 54 days, the most severe magnetic storm of the half year, and a very large spot, central on the 8th.

The opposition Jupiter-Venus of June 11th does not seem to be connected with a disturbance, but the Jupiter-Earth conjunction of September 18th ushers in a considerable disturbance, marked on the 19th. It apparently re-enforces a storm which manifested itself on August 21, and helps to cause a very stormy period which has not ceased yet. It would seem then, from this first examination, that an impulse begins with the conjunction (or opposition) of Venus or the Earth with Jupiter, and that once set in motion, it develops until a large spot and magnetic disturbance result, at the rotation period of the spot zone affected. In 1904, the planetary effects are much more marked. On March 7th we are in a depression of considerable force, which had been violent on the 4th. This is a Jupiter-Venus opposition. The Jupiter-Earth opposition of March 31st brings about a very severe storm the next day, April 1st; the Jupiter-Venus conjunction of August 4th gives another, which goes on careering around the Sun, to this day. The Jupiter-Earth conjunction of October 21st is a noticable dip, and so is the Jupiter-Venus opposition on December 4th, which manifests itself on the 5th.

[Mr. Harvey did not live to fully complete his manuscript. See page 22, *ante*].

STELLAR LEGENDS OF AMERICAN INDIANS.

BY

J. C. HAMILTON.

AMONG the Red Men there is always found "medicine" or mystery. The medicine man is trained in his youth to memorize and fast for days at a time when he has visions and communes with the Great Spirit.

His memory becomes very capacious and retentive, and by these men old legends are carried down through generations. There have been many remarkable relators of old myths. Some of these deal with celestial subjects, especial prominence being given to the seven stars known as the Pleiades. The Aztecs, or ancient Mexicans, in a national festival kindled the sacred fire as the Pleiades approached the zenith. So also did the Tuscayans of the southwestern plains.

The Arapahoes, Peruvians, Kiowas and Yuncas regarded this constellation with reverence. The Adipones of Brazil and some other nations claim that they sprang from the Pleiades. In California it was deemed calamitous to look at them heedlessly.

Many researches have been made into the origin of the North American tribes and their notions of astronomy and religion. The Salishans of British Columbia say that their ancestors came from Asia in the thirteenth century. The Algonquins, including the Blackfoots, Bloods, Ojibways, Crees, Ottawas and other tribes found north of the Great Lakes, preceded them six hundred years in coming to North America. A people known as Mound Builders preceded them, remains of their work being still found by the Saskatchewan River and the Lake of the Woods.

The legends are not easy of classification. The Cherokees of North Carolina have as distinct stellar myths as our natives on the Pacific slope. Towards the Atlantic the long contact with European customs and religion has caused the Micmacs and other tribes there to forget many old myths. The Micmac word for Indian, *Ellenu*, reminds one of the Greek Hellen. Their language is also full of compound words of many syllables, and, as Cotton Mather said, some words looked as if they had been growing since the confusion of Babel. There were doubtless two or more streams of early immigration from North and South, which sometimes met. It was in South America that the cult of the Pleiades was most highly developed. Here this most wonderful group was watched with constant interest and homage. It marked the seasons, the time to sow and reap, and the most important feasts and ceremonies.

The ceaseless twinkling of these stars suggested dancing. They were sometimes called the Singers, just as in classic poetry we read of the "Chorus of the Pleiades." The Canadian Indians have many of these legends. Commencing with the Blackfoot, who called the Pleiades "The Seven Perfect Ones"; Crowfoot, the great Blackfoot chief, claimed that his people came originally from the south. The Hydahs and other far-western tribes, some of whom worship the Sun and the Moon, have many myths, some of which have a similarity to Greek legends, though more simple in thought and construction, as may be expected from such races.

Among the Crees and Ojibways a common name for the group was the Fisher stars, from a fancied resemblance to that animal. Many of their stories have counterparts among the Cherokees of North Carolina and more southern nations. Imagination was affected by the surroundings. The Arabs called the Pleiades a band of riders on camels; the Germans used an ancient term, the "Hen and Chickens"; the Carrier Indians styled them a "Herd of Caribou"; the Eskimo "A number of dogs pursuing a bear," and the finer Greek sense made them the "Garden of the Hesperides," or "Isle of the Blest." Persian imagination made them a cluster of twinkling jewels. Many beautiful illustrations were given, gathered from various parts of North and South America. A Hydah tradition tells us of seven giant brothers, who, while fishing, harpooned a great monster, who dragged their vessel swiftly over the ocean towards a whirlpool, where death awaited them, but as they drew near, the rope broke, the whale sank into the ocean, but the impetus given was such that they sailed over up to the sky, and became the Pleiades. The same story is found in Northern California where the seven adventurers were called the Holgates. We are told of Hiawatha:—"Many things Nokomis taught him, of the stars that shine in Heaven." Longfellow informs us that the stories woven into his Indian Edda were mostly taken from Mr. Schoolcraft's *Algic Researches.* Of the stellar myths, so compiled, "Osseo Son of the Evening Star," is stated by Mr. Schoolcraft to be Algonkian.

Mr. Schoolcraft was the United States Indian Agent at Mackinac, and a noted delineator of Indian life and customs. His talented wife was a granddaughter of Waub-Ogeeg, an Ojibway chief and poet. Longfellow no doubt obtained some legends at first hand from Canadian Red Men themselves in the regions of Algoma and Thunder Bay.

Of these Bukjinené, the Garden River chief, son of Shinwauk, and grandson of Shinguaconse, from whom an Ontario township is named, must not be forgotten. Shinguaconse, or the Little Pine, was the leader of our Indian allies at the taking of the Mackinac stronghold by the British in 1812, and was a noted medicine chief and warrior. Shinwauk was with Brock at Queenston Heights, and on his return never tired telling of the deeds of that day, and composed a song to celebrate the victory, which is still sung by his tribe. The Indian Childrens' Home near Sault Ste. Marie bears his loyal name.

Bukjinené died in February, 1900, in his 86th year. Many of the exploits of Hiawatha were common lore in his mind. He often spoke of Longfellow, with whom he smoked many a pipe as he told his stories "fresh with the odors of the forest." As he grew old and feeble Bukjinené longed again to see or hear from the poet, so he sent two of his sons all the way to Cambridge to greet him, They were astonished to find that Longfellow had been dead since 1882.

Kwasind, the strong man of the Edda, was, it is stated, an actual character of the Indian village near Sault Ste. Marie.

The Wyandot tribe lived 260 years ago where Toronto now is, and gave that name, meaning "Land of Plenty," to this region. They were known in the Jesuit writings as Tionnontates, or the Tobacco Nation. Their neighbors to the north were the Neutrals, and beyond them, south of the Georgian Bay, were the Hurons, all of whom suffered from the Iroquois.

The Wyandots occupied this region only some ten years, then emigrated westerly, and finally settled in Kansas and

Nebraska, where they are now civilized, flourishing and interesting citizens. The first Governor of the State of Kansas was William Walker, a Wyandot. They have mostly lost their custom of story-telling and forgotten their legends, but Mr. W. E. Connelley, author of *Wyandot Folk-Lore,* gathered them from their old men many years ago, and to him we are indebted for some beautiful examples. When they lived here "The Little People," or fairies, played on the meadows on moonlight nights; the woods, the water, and the air had their weird creatures of the Red Man's fancy. Two of these stories, "The Singing Maidens" and "The Sword and Belt of Orion," seem from their allusions to have been composed when the Wyandots dwelt in and about where our fair city of Toronto now stands. "The Singing Maidens" were the Pleiades, daughters of the Sun and Moon, fair, happy, dancing girls, who looked from the sky on the inhabitants of the earth, and in their father's absence dropped down and played awhile with the Indian children.

It is instructive, and even inspiring, to find that most of the imagery of the best known Indian poem was gathered by Schoolcraft and Longfellow from Canadian Indians. Indeed that poet, led by his native sympathies, laid the site of his poem on the South, instead of the North side of the Great Lakes, and made the Iroquois Hiawatha, in preference to the Algic Manabozhu, his hero-god, the representative of native legend and song.

What shall we say too, when we find such an interest taken in celestial phenomena by our aboriginal predecessors on this "Land of Plenty," and remember how few now-a-days, with all the school learning, can distinguish even the chief constellations or call the great stars by their names! And yet the same orbs move and burn above us as shone upon and inspired those Red Men two hundred and sixty years ago, and, as we observe the marvels of our winter sky, we may well say of the celestial Urania, as was said of the renowned Queen of Egypt:—"Age cannot wither her, nor custom stale her infinite variety."

PERSONAL PROFIT FROM ASTRONOMICAL STUDY.

BY

R. ATKINSON.

ONLY as an amateur who has profited by the labors of great men, do I venture to speak to-night. It has been a pleasure to me to read what such men have found out, and to verify, so far as possible with very limited appliances, their discoveries.

Among the ranks of the amateur students of Urania all sorts and conditions and degrees are found, ranging from such master minds as the late Rev. T. Webb, down to the individual who studies the constellation groups with unaided eye, for the simple pleasure of knowing the places and appearances of the stars. It is amongst these last I find myself, yet have I pleasure in the thought that far in advance, yet in the same company, are found these gifted souls.

Those familiar with astronomical research will be quick to recollect that not a few of the ablest investigators have been men who found the time necessary for their studies in the few brief minutes or hours that could be snatched from the engagements of a business career. One thinks of the country physician who first discovered the periodicity of sun-spots, of the busy musician who startled the world with the discovery of a new planet, and of that rural clergyman who found time to compile our *vade mecum*, Webb's *Celestial Objects for Common Telescopes*.

Astronomy, then, may easily be the busy man's science and recreation. One need only look around this Society to find abundant proof of this. From the schoolboy to the man grown grey, each has to work hard and yet devote rare hours of leisure to the pleasures of research. Such a fact is enough to indicate that in such studies there must be found some gain, for, it is hardly to be imagined that people will continue for years to pursue some line of thought or action unless they find in it some permanent advantage.

Now, so far as pecuniary profit is concerned, astronomy is a niggardly mistress. In other sciences research may lead to results that can be turned to advantage in a material sense. Lord Kelvin, Prof. Graham Bell, Edison, Marconi, are all cases in point. But to the astronomer no such lure is held out. It is not for the sake of her donatives we cultivate the acquaintanceship of Urania. She holds no horn of plenty in her hands. It is for her own sake we seek to know her.

Enlargement of one's knowledge is an imperative necessity. The measure and character of this enlargement, of course, varies greatly. What is old and trite to one man can be very new to another. Though we can find out what is already known through reading, every one must in a large degree be a discoverer for himself. In fact, what we read has little value until we verify it. A few degrees higher than this is the finding, to be verified by the experience of others, what already we ourselves have seen. In this we can share the feelings of the original discoverer. The sensations of a Galileo can be shared when for the first time we turn a telescope upon Jupiter or Saturn. The sudden seeing of the wonderful orb itself is something that no amount of description can prepare for. Perhaps we might describe this pleasure of discovery as being one element in the personal profit that accrues to astronomical studies. Not in the fullest degree, yet to some extent, every star-gazer is

> "Like some watcher of the skies
> When a new planet swims into his ken."

The olden time enjoyed many advantages we are robbed of. Sometimes we think men of other days had altogether too large a share of life's pleasures. *Then* the trackless waste came, so to speak, to the very threshold, but now it has been so mapped and laid out that to the outermost limit the adventurer must go to find the utterly new. In spite of this enough remains to tempt the earnest explorer. The prizes are few and, with rare exceptions, for those who are possessed of an excellent equipment. Yet everyone may profit by finding out *for himself* what may be a matter of general knowledge.

I believe that one of the saving influences in life is having a hobby. No matter how entrancing may be our regular toil, its very monotony tends to make it irksome. A sense of constraint creeps in. We are driven by the demands of our position, and labor becomes a worry. Then it is we require a tonic for the mind. Idleness is no cure. Monotony must be altered to variety, the tension be relieved if we are to carry responsibility easily. Some here can bear witness to the value of astronomical study as a *re-creation.* No doubt similar relief can be afforded by other studies. But we know of no more accessible field than the expanse above us, and if we neither have nor wish to have instrumental aid, yet how easy to turn to either sky or book and engross an otherwise tired mind in an exalting theme. "Lift up your eyes on high and behold." And having done so, have we not felt many a time like him about whom Longfellow wrote:

> "NATURE, the old nurse, took
> Her child upon her knee,
> Saying, 'Here is a story book
> Thy Father has written for thee.
> Come wander with me,' she said,
> 'Into regions yet untrod,
> And read what is still unread
> In the manuscripts of God':
>
> And he wandered away and away
> With Nature, the dear old nurse,
> Who sang to him day and night
> The rhymes of the Universe.
> And whenever the way seemed long
> Or his heart began to fail,
> She would sing a more wonderful song
> Or tell a more marvellous tale."

In this rambling essay we may now turn from the thought of recreation to the profit we have in these studies as an *education.* We would like to take that word very widely. One can never forget the striking saying of Kepler when unraveling the laws of planetary motion. As he perceived the three great principles he exclaimed, "I am thinking the thoughts of God." It was a fine and memorable utterance. Our idea is that there is great advantage in having the mind *withdrawn*, drawn out to the consideration of grand phenomena, of deep problems. I have heard it suggested that astronomy as a study cannot benefit because it must depress a man with a sense of insignificance. It may be a time-worn reply but one cannot forbear using it, that the comparison should not be between the physical and the physical, wherein man must appear as an atom, but between the intellectual and the physical.

"The mind is the measure of the man," and instead of depression there might well be exultation at the ability "to range afar from star to star."

Can we conceive of a more sublime study than astronomy? Though it be only the mere outskirts of it that we have visited, to return to ordinary interests seems to be a descent.

From the contemplation of such objects one returns to the more urgent tasks of the day with a renewal of mental vigor. To occupy the thoughts with these great ideas provides a change complete and delightful. And enhancing this are the accessibility and variety characteristic of astronomy. Even if our work be on the humblest level, that of simple observation, it affords a variety of interest that custom cannot stale. Thus easily is a pleasure of the highest kind obtained, and it is a pleasure that endures.

In addition to all this there comes the profit of the enriching of one's mind. A man who, if he was an apostle, was also a citizen of the world, gave us a very useful rule of life when he said, "Whatsoever things are pure, honest, lovely, and of good report; think on these things." And what lovelier things can we think about than the stars and planets?

From the little the writer has studied about them he has certainly added some riches to his mind. No one, and least of all, no member of this Society will count it an impropriety if here he says he has been impressed with the Divine Magnanimity when he looked at the heavens. "When I consider *Thy* heavens, the work of Thy fingers, the moon and the stars, which Thou hast ordained"; then, say I, "What is man, that Thou art mindful of him, and the son of man, that Thou visitest him?"

After a few years' reading and star-gazing certain ideas seem to become of outstanding interest and importance.

First among these should be named *Unity*. My impressions may be without foundation, but, mistakenly or otherwise, the idea (mainly through what I have read of the researches of such men as Sir Wm. Huggins, and the work of those inquiring into the structure of binary or trinary systems) has become firmly rooted in my mind that this great Universe is a real Unity. In conversation with others, I find the same thought in their minds. It is, of course, no new idea, but I can truly say that to me it has been a great gain. And a gain, too, in this way, that what in the regions of philosophy and theology is, we might say, assumed, is in this science established by patient, difficult investigation. From a vast array of facts this principle is gradually coming to light, that we are in and are part of, not a chaos but a cosmos, and an indissoluble bond, whatever it be, binds the stellar hosts into one great harmony.

Along with this has come the certainty of *Progress*, or if we might so put it, of a Life History. There is a growth from nebula to *dark* star. I need not say that it is my desultory reading in the literature of astrophysics that has taught me this. I presume it is an article in all our creeds to-day. It is a commonplace. But to me it has been a great thought. The way that, to my fancy, it reaches out and touches many things that seem far enough removed from the purely astronomical region, is surprising. To realize that order and plan underlie the mighty mechanism of the heavens is something that links this tiny world and one's tiny self to the vast processes and forces working in the Universe. The sweep of these embraces star and star-gazer. I may have misunderstood or misinterpreted the writings of great authorities in astronomy, and particularly in the region of astrophysics, but the more strongly every day I continue to be interested in these subjects, is this assurance of a life history—a birth, a growth, a decay—for every star for and the whole Galaxy, impressed upon me. The striking facts about the origin and career of *Nova Persii* have added another link to the chain of knowledge in this respect. I believe it has been a great gain to our age to have with us men who, with a soaring ambition to find out the workings of creative energy at first hand, have "hitched their waggon to a star." Were it not that we are now so used to it, it would seem incredible that men, so utterly insignificant when compared with the objects they study, should not only be able to describe the life history of a star, but actually to illustrate each step in the process by a case in point. How enormously should this fact enhance our regard for the Queen of Sciences!

Last of all, the thought of *Destiny* has become very vivid in connection with my astronomical reading. By this I mean the now commonly accepted maxim that the worlds had a beginning and they will have an end. Somehow one used to think of the stars as unchangeable and eternal; nowadays nothing is surer than that they are neither fixed, changeless, nor everlasting. To recapitulate the facts that bear this out would be to insult the intelligence of this society. Addison's imagination was not overheated when he wrote:

> "The stars shall fade away, the sun himself
> Grow dim with age, and nature sink in years."

"Finality" is written across this *apparently* enduring universe, an "end of all things."

These great generalizations, no doubt, are familiar enough to every one who has read a little in astronomical lore. To me, personally, it has been a great advantage to become seized of them, to realize how well established they are.

But I must close lest I add prolixity to my other sins. I have only spoken of that wherein there has been personal advantage to myself in astronomical study. Others with a far fuller experience can speak of greater gain in a sense quite different from mine. Permit me to say that one great boon to me has been the association with such men as astronomy has brought me to. I will always cherish the recollection of the gatherings of this Society, and the associations I thereby formed as being amongst the happiest and most profitable of my life.

CHESLEY, ONTARIO.

THE ECLIPSE EXPEDITION TO LABRADOR, AUGUST, 1905.

BY

A. T. DELURY.

EARLY in the year 1905, the Canadian Government, having at its service the staff and equipment of the recently established Dominion Observatory, decided to send an expedition to Labrador to observe and report on the total solar eclipse of August 30. Dr. King, Chief Astronomer, was charged with the organization and direction of the expedition, and through him the Royal Astronomical Society of Canada was invited to co-operate, and to name six of its members to be of the observing party. The Society readily complied, and the share in the undertaking assumed by it would seem to call for some account of the expedition in the Transactions. This the kind permission of Dr. King makes possible.

The observing party was made up as follows:

Dr. King, in charge, and Messrs. Plaskett, Macara, Gauthier, Near, of the Dominion Observatory;

Mr. L. B. Stewart, Professor of Surveying in the Faculty of Applied Science, University of Toronto;

Mr. D. Menzies of the Toronto Magnetic Observatory;

Mr. and Mrs. Maunder of the Greenwich Observatory;

Messrs. Jennings and Upton of the British Astronomical Association;

Messrs. Chant, Collins, De Lury, Howell, Marsh, Maybee, of the Royal Astronomical Society of Canada;

Mr. Jenkins of the Hamilton Scientific Association;

Father Kavanagh of Loyola College;

Mr. Joseph Pope, Under-Secretary of State;

Fathers Lajeunesse, Simard and Choquette of Ottawa University, Laval University, and St. Hyacinthe College.

The *personnel* of the party having been determined, conferences were held in order to come to an understanding as to the work to be undertaken by each, and then some months were given to special preparation of plans and apparatus. It was arranged that Mr. Stewart should proceed in advance of the main body of the expedition—by way of Newfoundland, sailing by one of the boats that make Labrador ports from St. John's—in order to select a place at the same time suitably situated for observing the eclipse and possible from the point of view of a camping ground. The party was to consist of two contingents, the first and more numerous made up of those free to start at an early date and having extensive preparations to make on the ground; the second to leave in time for the observations.

The first contingent sailed from Quebec August 4th, by the SS. *King Edward*, Captain Belanger, chartered to continue her regular North Shore trip into the less familiar waters of the Labrador. On August 11th the steamer cast anchor at the mouth of the North West River, and Mr. Stewart was able to announce that the clearing on the north bank of the river, just to the east of the Hudson's Bay Post, afforded a good camping ground, not far from the central line of totality, and with a clear eastern horizon. The initial difficulties were thus not so great as there had been every reason to expect.

Through the kind co-operation of Mr. Cotter, the Hudson's Bay Company's factor, at the post, and M. Michel Duclos of the post of the Revillon Fréres, it was a comparatively easy matter to remove supplies and instruments from the vessel and transport them to the spot selected for the camp. In a short time all the preparations for a stay of three weeks in camp were completed, and the work of building piers for, and mounting and adjusting the instruments was begun. This work in its turn was completed in good time, and a full week remained for testing and making further adjustments. For several days preceding August 30th, frequent drill practices were held at dusk and in the early evening, so that at the critical time there might be no hitch or confusion.

It may now be in place to give an outline of what was to be done by each section of the party.

The director, employing a four-inch telescope, was to observe and record the times of contact, and to make visual observations of the corona.

Mr. Plaskett was in charge of the cœlostat, which consists essentially of a large plane mirror, mounted so as to rotate about an axis in its plane parallel to the axis of the earth and driven by clock-work at such a rate as to reflect by a stationary beam into receiving cameras and spectroscopes the light of the Sun. The mirror of the cœlostat was 20 inches in diameter and the receiving cameras and spectroscopes were grouped together and firmly fastened in a horizontal position to a heavy plank, 10 feet 6 inches long, 2 feet wide and 3 inches thick, resting on and bolted to cement piers. The attached cameras and spectroscopes were the following:

(1) A camera with objective of 5 inches aperture and 45 feet focal length, giving an image of the Sun 5 inches in diameter on a plate 14 by 17 inches. This was to be used for photographing the corona, with special attention to detail in the inner corona.

(2) and (3) Two twin cameras with objectives of 4 inches aperture and 10 feet focal length, giving images of the Sun 1⅛ inches in diameter on plates 6½ by 8½ inches. One of these objectives was corrected for the photographic blue and violet light and was to be used on ordinary plates, while the other was corrected for the visual yellow and yellow-green rays, and was to be used with a yellow screen on orthochromatic or yellow sensitive plates to yield photographs of the corona—the inner corona and the extensions—in blue and yellow light.

(4) A camera with a Cooke photo-visual objective, of 4½ inches aperture and 81·8 inches focal length, giving an image of the Sun about ¾ of an inch in diameter on a plate 4¾ by 6½ inches, specially sensitized for green and red light. Color screens were to be used to obtain negatives suitable for making a photograph, in three colors, of the corona, as well as a photograph of the inner corona in light of the wave-length of that yielded by coronium, the object being to determine the distribution of coronium in the corona.

(5) An objective grating camera, consisting of a concave grating of 4 inches aperture and 10 feet radius, ruled 15000 lines to the inch. At the remote end of the box was a sliding plate-holder, moved by rack and pinion, containing a curved film 9 by 9 inches. On this film there could be made, side by side, nine exposures of the spectrum of the "flash" and the corona, and the exposures could be made to follow one another rapidly by simply moving the plate holder a short distance by the rack and pinion. On the film there could thus be obtained nine spectra,

9 inches long and about ⅝ of an inch wide, the range being from λ 6000 to λ 3500, that is to say, from the red to the ultra violet, the film being specially sensitized to all the spectrum colors.

(6) A prismatic camera, consisting of two flint prisms of about two inches aperture, placed in face of an objective of 2½ inches aperture and 30 inches focal length. At the end of the camera box was placed a sliding plate-holder, similar to that in (5), carrying a film 5 by 6 inches to obtain nine photographs, 5 inches long and ⅜ of an inch wide, of the "flash" and the corona, the range being from λ 6000 to λ 3900.

(7) A spectroscope, receiving the light from a concave mirror of 8½ inches aperture and 6 feet focal length, which was to give photographs of the spectra of the light of the "flash" and the corona. The wave-lengths of the coronal lines were thus to be accurately determined.

The different cameras and spectroscopes were to be operated by Messrs. Macara, Near, Howell, Maybee, Stewart and Plaskett.

Mr. and Mrs. Maunder brought with them the large photographic camera employed by them at Mauritius in observing the eclipse of 1901, the small photographic camera with which Mrs. Maunder in 1898 obtained the first photographs of the outer coronal streamers, and a third camera equatorially mounted and fitted with a four-inch Dallmeyer lens, similar to the one to be employed by Turner in Egypt. The photographs obtained by the companion instruments at the stations in Labrador and Egypt, the one set therefore being taken about two hours later than the other, were to be brought together and the changes in form and appearance of the corona in that time were to be studied.

Mr. and Mrs. Maunder were to be assisted by Messrs. Jennings and Upton.

Dr. Marsh and Mr. Jenkins, of Hamilton, came equipped with three photographic cameras. These were mounted equatorially and were to be employed for photographing the corona and the coronal streamers. The large telescope of 5 inches aperture and 75 inches focal length, was to be operated by Dr. Marsh, and the other two by Mr. Jenkins and Mr. Johnston, Editor of *The Technical World* and the *Business Man's Magazine*, who accompanied the expedition as the representative of several American magazines and newspapers.

Dr. Chant proposed to determine the nature and the intensity of the polarized light emitted by the corona at different distances from the Sun's limb. Eye-observations were to be made with a polarimeter, in which a coarse grating, a double-image prism and a Nicol's prism were the essential parts. Photographs were to be taken with a camera attached to Dr. Marsh's equatorial. In it a double-image prism was placed in front of an achromatic lens of aperture 1 inch and focal length 36 inches. By comparing the images produced the nature of the light was to be inferred. This camera was in charge of Father Lajeunesse.

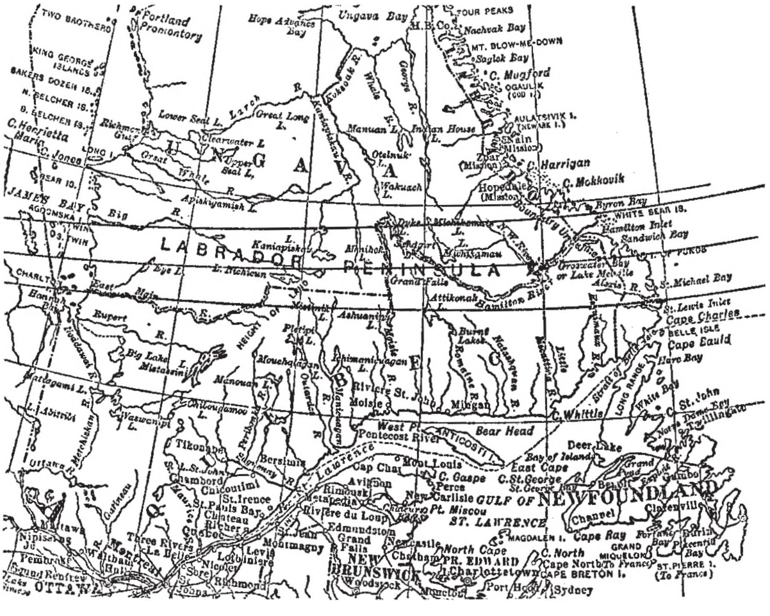
Mr. Collins, with apparatus in the main designed by himself and his brother Mr. Z. M. Collins, was to obtain a series of photographs showing the eclipse in its successive stages. In this way a sort of kinetescopic representation of the eclipse could be obtained. Changes in the form or position of the coronal streamers would give certain indications as to the nature and condition of the coronal extensions, for manifestly such change could not be due to the motion of appreciable masses with ordinary velocities.

Father Kavanagh had devised an apparatus, mounted like a telescope, and provided with a screen to cut out everything but the outer coronal streamers and with a reticulation which would allow him by direct vision to record accurately the place and extent of noticeable changes.

Mr. De Lury was to make a series of records, at short intervals, by direct vision, of the changing phenomena of the eclipse. Further, for some days previous to the eclipse, certain observations were to be made in connection with atmospheric electricity by means of specially devised electroscopes. Any abrupt effects at the time of the eclipse were to be noted, The marked humidity of the atmosphere, during the days just before the eclipse, materially interfered with the observations.

In addition to the undertakings directly associated with the eclipse, Mr. Menzies, assited by M. Gauthier and Mr. De Lury, made determinations of the horizontal magnetic force, and of the declination and dip of the needle, and Mr. Stewart determined the latitude and the longitude of the station, as well as the force of gravitation. Accounts of these observations and determinations will be found in later papers of this volume.

As every one, interested in the eclipse, knows, the Fates were in the end unpropitious, and the morning so anxiously awaited brought only disappointment. In the early days of the preparations it became evident that, while the proportion of good weather was quite high, the proportion of sunshine was rather low, and as chances were estimated forebodings arose. The Monday immediately preceding the Wednesday of the eclipse was exceedingly bright and fine, and optimism was at a premium ; but Tuesday brought heavy clouds and rain. Tuesday evening, dark and drear, witnessed the most exacting of the drill-practices, and all retired hoping against hope. On Wednesday morning every one was up and about quite early, but it was felt that the chances were hopelessly adverse. The sky was overclouded, and with those deep closely-woven clouds that suggest almost infinite depth. A ray of hope came a half hour or so before the important moment, as the wind began to disturb the clouds to the northeast.



MAP SHOWING PATH OF TOTALITY ACROSS LABRADOR AND THE LOCATION OF THE ECLIPSE CAMP AT N. W. RIVER.

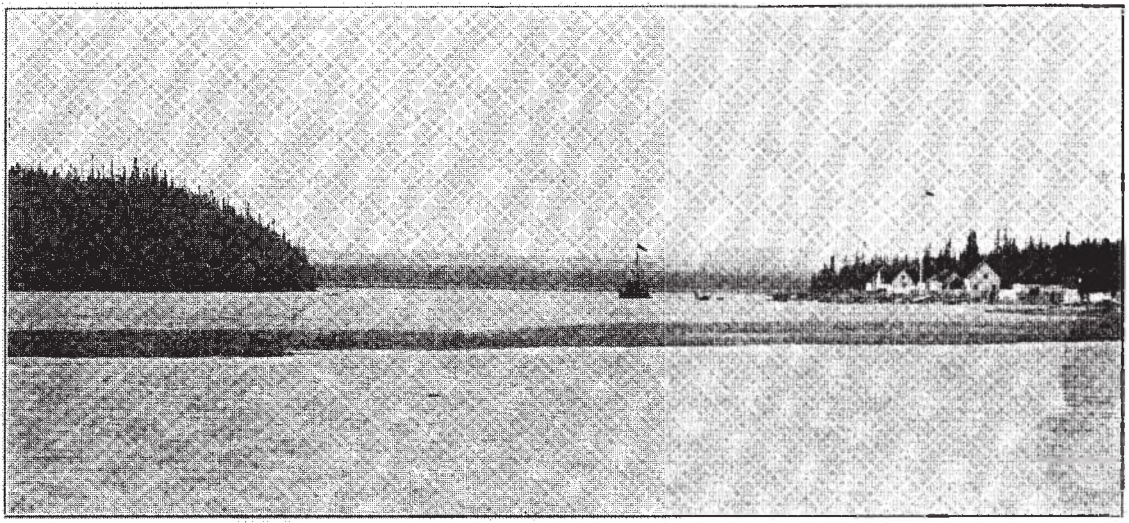
DR. W. F. KING,
CHIEF ASTRONOMER, COMMANDING THE EXPEDITION.

MEMBERS OF CANADIAN ECLIPSE EXPEDITION.

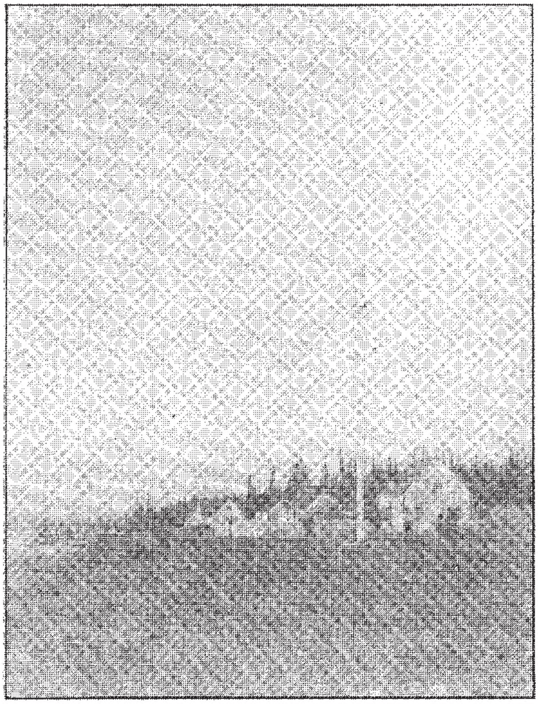
First Row (Standing), Reading from Left to Right; J. E. Maybee, D. B. Marsh, W. E. Lyman, Fr. Lajeunesse, W. Menzies, F. P. Jennings, M. Aldous, C. Upton, J. R. Collins, Fr. Simard, Fr. Choquette, J. A. Russell, W. George.

Second Row: L. B. Stewart, Fr. Kavanagh, W. F. King, Miss King, Mrs. Codd, Mrs. Maunder, E. W. Maunder, D. J. Howell, A. T. DeLury.

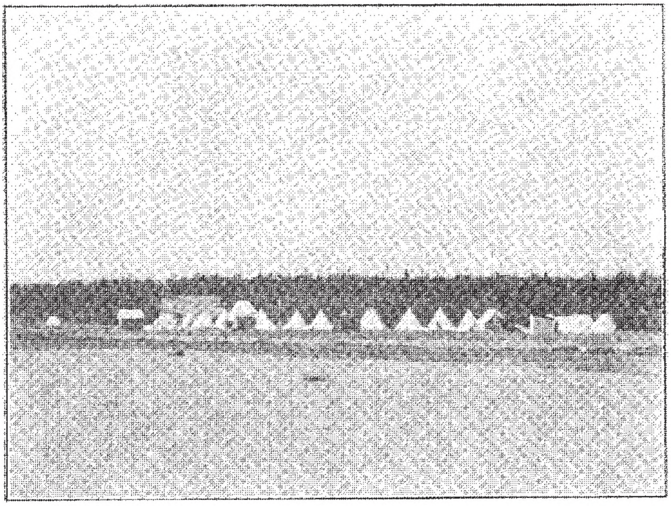
Front Row: G. P. Jenkins, H. H. Lyman, C. A. Chant, J. S. Plaskett, Jos. Pope, J. Macara, L. Gauthier, A. S. Johnson, W. P. Near.



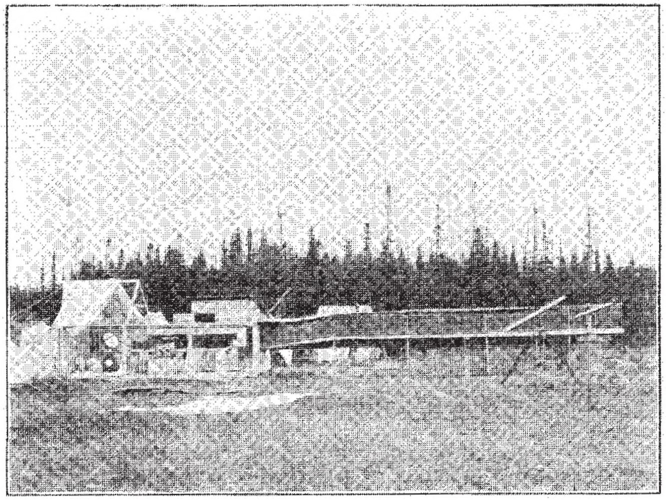
NORTH-WEST RIVER, LABRADOR—LOOKING WEST.



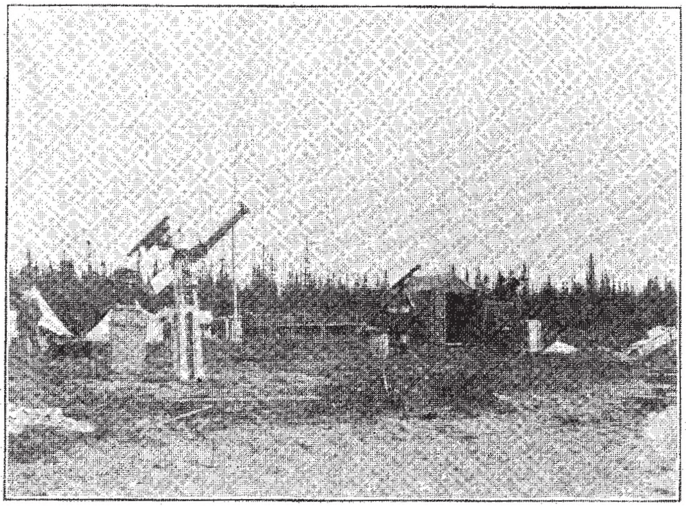
HUDSON'S BAY POST, NORTH-WEST RIVER.



VIEW OF THE ECLIPSE CAMP.



DOMINION OBSERVATORY OUTFIT.



GREENWICH OBSERVATORY OUTFIT.

The impression did not last, and, while every one marched to his place at the instruments, it was with the air of complying with a formality. Soon darkness came down from the west, not gradually, but rather by abrupt small changes, and what "we went out for to see" was taking place behind the veil. A solitary bird in the adjoining forest uttered a plaintive cry as if night were returning too soon. But the darkness—not intense but sufficiently pronounced to call for artificial light to make readings—was short lived. The sky began to brighten in the west and the second dawn came creeping over those hills, which swathed in soft purple had been, for so many evenings, a foreground for such sunsets as one may not hope again to see.

It was now over. Disappointment claimed every one, and none more than the director who, foreseeing and resolute, had hoped to the last.

When, on the return voyage, Rigolet was reached, news came of the like ill fortune that had awaited the Lick observing party at Cartwright, though there was a story of a fisherman who, situated in the mean, some miles down the inlet, had seen the eclipse in all its glory. All along the north shore of the Gulf, where the eclipse was seen as partial, the weather was very favorable. When the party reached Quebec the first inquiry was as to the success of the parties sent to Spain and North Africa from many of which reports of success had come.

It is to be regretted that the first undertaking of the kind by the Canadian Government should have been without success in its first objects, but it is the fortune of war, and the hope is that, next time, a similar attempt may find a kindlier sky.

GRAVITY DETERMINATIONS IN LABRADOR.

BY

LOUIS B. STEWART.

AMONG the duties assigned to the writer in connection with the Canadian eclipse expedition of August 1905, was that of determining the force of gravity at the point chosen for the observing station ; and it is here proposed to give a brief account of the pendulum apparatus used, and an abstract of the observations and results.

In order that the gravity determinations might be of practical use, it is necessary that the geographical position of the station be known, and therefore to the writer was also allotted the task of finding the latitude and longitude of the place. A small observing shed, 8 ft. × 10 ft. was constructed, having a transit slit in the roof closed by a trap-door, and in it two concrete piers were built, one in the centre to serve as a support for the theodolite used in the astronomical work, and the other in the north-east corner on which the pendulum apparatus was installed. The theodolite pier was in the form of a truncated square pyramid about three feet in height, and having a base two and a half feet square bedded a foot and a half in the ground. The other pier was lower, rising to about a foot above the floor of the observatory and having a base of the same dimensions as that of the theodolite pier.

The theodolite was by Troughton & Simms, and had a horizontal and a vertical circle, each ten inches in diameter, and divided to 5′ spaces, which were further subdivided by reading microscopes to single seconds.

The instrument having been adjusted in the meridian, latitude was determined by observing the meridian zenith distances of stars ; the program for a night's work including, if possible, an equal number of north and south stars ; and all north stars were sighted with circle west, and south stars with circle east. Observations were taken on two nights, observing nine and twelve stars respectively on the two occasions. The reduction of a night's work was made by Least Squares, each star observed furnishing an equation in which the unknowns were corrections to assumed approximate values of the latitude and the zenith point of the circle.

The telescope of the instrument was provided with five transit threads, and time was determined in the usual way by transits of stars. Two transits of the Moon were observed for longitude, but the value of the results was lessened by the fact that the observations had to be taken during strong daylight so that it was impossible to observe the companion stars, thus making it necessary to depend upon the uniformity of the chronometer rate and the stability of the instrument for a greater length of time than was desirable. Consequently, although the two values of the longitude are very accordant, it is quite possible that they are affected by considerable constant errors.

The geographical position of the station was found to be as follows :

$$\varphi = 53^\circ\ 31'\ 31{\cdot}45'' \pm 0{\cdot}05''$$
$$\varphi = 4^h\ 00{\cdot}^m\ 41{\cdot}19^s.$$

In addition to the general scientific interest attached to the investigation of any of the constants of nature, gravity determinations have a further importance to the geodesist from the fact that they add to the accumulation of data by which the compression of the earth, regarded as an ellipsoid of revolution, may be found by the aid of Clairaut's well-known theorem ; and to the geologist in his study of the variations of density of the earth's crust. Arc measurements are necessary in order to find the scale upon which our terrestrial spheroid is constructed, but pendulum experiments furnish the readiest and possibly the best means by which its figure may be determined.

The problem of finding the absolute value of g is a difficult and lengthy one. The instrument employed in its solution is the reversible pendulum which is constructed on the principle of the mutual convertibility of the centres of suspension and oscillation of a body vibrating under gravity, so that when the pendulum has been adjusted so that its periods are the same, or very nearly so, whether it is suspended from one point of support or the other, the length to be measured is the distance between those points, thus obviating the difficulty experienced in determining the length of a pendulum whose form approximates to that of the simple pendulum. The time of vibration must also be observed with extreme precision.

The problem of determining *g* absolutely thus resolves itself into the accurate measurement of a length and a period of time. Moreover several corrections must be applied to the observed quantities. On the other hand, relative determinations of gravity, which are made with the invariable pendulum—one whose parts are rigidly connected and permit of no adjustment—involve only the measurement of a period of time, and its necessary corrections, and are therefore made with comparative ease. The pendulum having been swung at a station where *g* had been previously determined, and its observed period reduced to some assumed standard conditions of temperature, pressure, etc., it has then merely to be swung at a place where *g* is required and its period reduced to the same standard conditions, when the value of *g* at the latter place is found on the principle that the force of gravity is inversely as the square of the time of vibration. The invariable pendulum thus affords the readiest means of finding *g* at a number of stations, and this was the type of instrument used in the Labrador work.

The apparatus there used was similar in every respect to that of the U. S. Coast and Geodetic Survey and described in detail in the report for 1891. The essential parts are the half-second pendulums, three in number; the receiver in which they are swung, and in which the air pressure may be reduced to any desired amount; and the flash apparatus by which the time of vibration of a pendulum is compared with the half-second intervals of a chronometer. A more detailed description of these parts is now given.

The pendulums are made of an alloy of 10 per cent. aluminum and 90 per cent. of copper, a composition that has been found to resist corrosion well. The rods are rectangular in cross-section, with rounded edges, and the bobs are in the form of a bi-convex lens, so that the pendulums offer as little resistance as possible to the air when in motion. The knife edges are continuous pieces of agate passing completely through the heads of the pendulums and firmly secured to them.

The receiver (fig. 2) is a brass casting 38 centimeters high, having a rectangular base 21 by 28 centimeters and tapering to 17 centimeters square at the top, where it is closed by an air-tight fitting cap. It is supported on three foot screws, which also serve for levelling. It has two openings closed by plate glass, through one of which (fig. 2*j*) the flash of light from the flash apparatus may pass to the mirror attached to the pendulum ; and through the other the observer may read the arc of vibration of the pendulum. A starting lever *r*, by which the pendulum is set in motion, is attached to the receiver, to be operated from the outside. A projecting shelf on the inside carries the agate planes on which the knife edges of the pendulum rest during a swing, and a special levelling device is provided for bringing the planes to the level position. An air-pump and a manometer are also provided for exhausting the receiver and registering the pressure.

The flash apparatus (fig. 1) consists of a small metal box mounted upon a tripod stand and surmounted by an observing telescope. The box contains an electro-magnet the coils of which are connected with the chronometer circuit, which during an experiment is interrupted automatically by the chronometer every alternate second. To the armature of the magnet is attached a long arm *d*, which is drawn upwards by a spring when the circuit is broken, and thus opens momentarily a shutter in the end of the box, allowing a flash of light from a small lantern, attached to the apparatus, to pass through. The apparatus must have been previously so adjusted in position that the flash of light falls upon a small mirror fastened to the swinging pendulum near its point of support, and the reflected ray is received in the observing telescope. As the time of swing of the pendulum is not precisely half a second the apparent directions of the successive flashes reflected from the mirror will vary, and when the flash from the moving mirror appears to coincide with that from a fixed mirror attached to the pendulum support and as near the other as possible, the time shown by the chronometer is noted. The flashes then continue across and disappear from the field of view, but after the lapse of a few minutes they reappear crossing the field in the opposite direction ; and when the moving flash again coincides with that from the fixed mirror the time is again

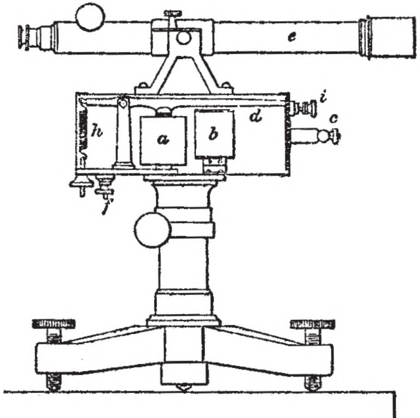


Fig. 1.

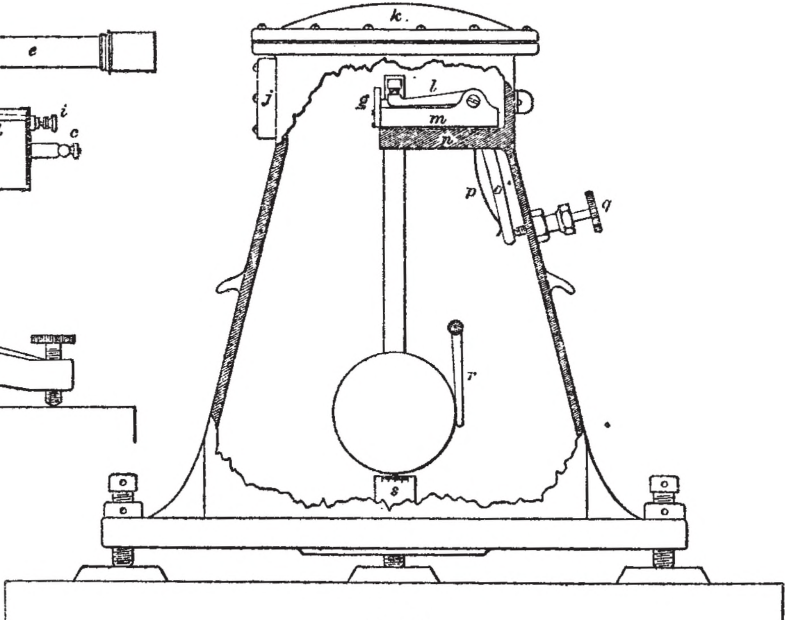


Fig. 2.

SIDE ELEVATION OF RECEIVER AND FLASH APPARATUS AND SECTION THROUGH SHUTTERS.

noted. In the interval of time between two coincidences observed in this way the pendulum gains or loses one vibration on the chronometer, whence the period of vibration of the pendulum follows. In making an experiment twelve such coincidences are observed, then on subtracting the time of the first from that of the eleventh, and the time of the second from that of the twelfth, two values of the ten-coincidence interval of the pendulum are found; and if the first and eleventh are up-coincidences—*i.e.*, observed during an upward progress of the moving flash across the field of view of the telescope—then the second and twelfth are down-coincidences. The mean of the two periods is, of course, taken.

The temperature of the pendulum during an experiment is given by a thermometer attached to a dummy pendulum suspended at rest inside the receiver; the bulb of the thermometer dipping into a small recess in the pendulum rod, with the space about it filled with metal filings of the same composition as that of the pendulum. The thermometer thus placed is assumed to indicate correctly the temperature of the experimental pendulum.

The amplitude of the arc of vibration is read from a small millimeter scale *s* attached to the floor of the receiver and immediately behind a projecting tongue on the lower side of the pendulum bob, on which a vertical white line is drawn. A small observing telescope provided with a vertical thread and movable by a quick-motion screw in a direction parallel to the plane of vibration of the pendulum is attached to the receiver in front of the small window mentioned above, and by bringing its thread to coincide with the line on the pendulum in its two extreme positions right and left, readings on the scale may be taken, which are afterwards reduced to arc, the distance of the scale from the agate planes of the pendulum support being known.

In taking an observation then the various steps are as follows: The flash apparatus having been adjusted in position about two yards from the receiver and the dummy pendulum with its thermometer having been put in its place in the receiver, the pendulum to be swung is placed on the lifting lever *l*, by which it is lowered so as to rest on the agate planes, which have been carefully levelled. The cap is then placed on the receiver and the air pressure within it reduced to as near the standard pressure as possible. The pendulum is then set in motion and the observer stations himself at the observing telescope of the flash apparatus and notes the time of the first coincidence. The arc of vibration is then read, and also the temperature and pressure. He then notes the times of the second, third, and fourth, and finally those of the tenth, eleventh, and twelfth coincidences, and then again notes the arc, temperature, and pressure. The pendulum is then reversed and the observations repeated as above described. The two remaining pendulums having each been swung in its two positions in a similar manner completes the series of observations for the determination of gravity at the station.

The observations taken with pendulum No. 1 at the Labrador station, with their reduction, are now given, and also the results obtained with the other pendulums.

The observations were as follows:

Date, August 29th, 1905.
Pendulum No. 1,
Chronometer, Dent 49950 (sid.)
– adopted rate + 3·003^s

SWING NO.	COINCIDENCES			SEMI-ARC		THERM'R ON DUMMY	MANO-METER
	NO.	DOWN OR UP	TIME	L	R		
			H M S				CM.
1	1	U	13 34 18	4·3	3·8	9·3° *C.*	9·25
	2	D	38 08				
	3	U	42 02				
	4	D	45 52				
	11	U	14 12 48				
	12	D	16 38	3·6	3·1	9·3°	9·25
		PENDULUM REVERSED.					
2	1	U	15 18 14	3·6	3·4	9·4	9·85
	2	D	22 02				
	3	U	25 58				
	9	U	49 12				
	10	D	52 56				
	11	U	56 52				
	12	D	16 00 40	3·2	2·9	9·6	9·95

The reduction is then made according to the following form:

TABLE SHOWING THE REDUCTION OF THE PENDULUM OBSERVATIONS.

PEND.	POSITION	SWING NO.	DATE	10-COINCIDENCE INTERVAL	SEMI-ARC		TEMPERATURE	MANOMETER
					INITIAL	FINAL		
1	D	1	Aug. 29	2310^{s}	46′ 53″	38′ 47″	9·3° *C.*	$9{\cdot}25^{cm}$.
	R	2	" "	2318	40 31	35 18	9·6	9·90

PEND.	SWING NO.	PERIOD (UNCORRECTED)	CORRECTIONS (IN 7th DEC. PL.)				PERIOD (CORRECTED)	*g*
			ARC	TEMP.	PRES.	RATE		
1	1	$0{\cdot}5010846^{s}$	−48	+238	−30	+174	$0{\cdot}5011180^{s}$	981·333
	2	·5010808	−38	+226	−36	+174	·5011134	·351

By applying the above corrections the observed period was reduced to an indefinitely small arc, temperature 15° *C.*, pressure 60 mm., and the sidereal second. The corrections were computed by the following formulæ :

$$\text{Arc correction} = -\frac{PM}{32} \cdot \frac{\sin(\varphi+\varphi')\sin(\varphi-\varphi')}{\log\sin\varphi - \log\sin\varphi'},$$

in which

P = the period of the pendulum in seconds
M = the modulus of the common logarithmic system,
φ and φ' = the initial and final semi-arcs of vibration.

$$\text{Temperature correction} = +\ 0{\cdot}00000418\ (15^\circ - T)$$

in which

T = the observed temperature Centigrade.

$$\text{Pressure correction} = +\,0{\cdot}000000101\left\{60 - \frac{Pr}{1+0{\cdot}00367\,T^\circ}\right\}$$

in which

Pr = the mean of the observed pressures in millimeters at beginning and end of swing
T° = the mean temperature of pendulum during the swing

$$\text{Correction for rate} = 0{\cdot}00001157\ RP$$

in which

R = rate of chronometer in seconds per sidereal day
P = period of the pendulum.

This correction is additive if the chronometer is losing.

The results from the three pendulums then are :

Pendulum No. 1, g	= 981·342	dynes.
" " 2, "	= ·329	"
" " 3, "	= ·352	"
Mean	= 981.341	"

The pendulums had been previously swung in Washington by Dr. Klotz, and their periods reduced to the same standard conditions as above.

For comparison, the value of g computed by Helmert's formula—

$$g = 980{\cdot}632\ (1 - 0{\cdot}002644 \cos 2\varphi + 0{\cdot}000007 \cos^2 2\varphi)$$

is

980·393 degrees.

MAGNETIC AND METEOROLOGICAL OBSERVATIONS AT NORTH-WEST RIVER, LABRADOR.

BY

R. F. STUPART.

IT having been deemed advisable that magnetic and meteorological records should be obtained at the eclipse station at North-West River, both during and prior to the time of totality, application was made to the Dominion Government for permission that an observer with the necessary instruments should accompany the expedition which was to be fitted out under the direction of Dr. W. F. King, the Chief Dominion Astronomer. The Honorable the Minister of Marine and Fisheries having granted the necessary authority and Dr. King having accepted the assistance offered, I deputed Mr. William Menzies, the officer under whose immediate supervision the Magnetic Observatory at Agincourt has been placed, to prepare the necessary instruments and subsequently accompany the expedition. It was deemed altogether expedient that the various instruments used should be self-recording and should be as follows: A declinometer to show the variations in the declination of the magnetic needle; a bifilar magnetometer to register the changes in the horizontal component of the earth's magnetism; also a barograph and a thermograph.

In order that the magnetic instruments should record photographically, it was necessary to provide a dark shelter for them, and Mr. Menzies undertook the construction of a suitable shelter and the various mechanical contrivances necessary for adapting our instruments to the peculiar circumstances. Scale values and details of instrumental adjustment were determined by the writer.

Mr. Menzies gives the following description of the shelter and instruments: "The shelter was a shed roof erection eighteen feet long and nine feet wide, the side walls of seven and nine feet, leaving a pitch of two feet for roof, inclined to approximate magnetic south. The mode of construction was as follows: The boards forming the sides were nailed longitudinally to four 2 × 4″ scantling cut to lengths selected for height of side walls, this being done flat on ground. They were then raised, simply resting on edge, in shallow trenches made to level ground, temporarily stayed and the end boards secured longitudinally making allowance for door to the east (this being the most convenient). These end boards were then nailed to upright scantling in middle of same. Four 2 × 4″ rafters were secured between the north and south walls and eighteen foot boards nailed to them to form roof, kept flush with walls. All lumber was dressed for convenience in handling. Light tarred paper was placed perpendicularly from roof to ground and secured in place by ordinary plasterer's lath, nailed upright over each lapping joint, the ends of each piece of paper being folded back on roof and temporarily secured with copper clouts. Single laths were placed obliquely between upright ones to prevent possible bagging of paper and liability of its being torn by wind. Heavier roofing felt was placed longitudinally on roof, with lap of about 8 inches and secured at intervals of three feet with rows of lath running with pitch of roof. Non-actinic light was admitted by cutting an opening in the middle of north side of building and inserting ruby glass of suitable dimensions. Ventilation and means of carrying off heat of lamps was provided for by suitable openings. A shallow trench was dug around building and the excavated earth heaped against building. These various operations secured a perfectly light-proof and weatherproof structure which was subjected to some severe tests of wind and rain without impairment. The nails used in construction were of hard copper wire, 2½ inch.

DESCRIPTION OF PHOTOGRAPHIC RECORDING MAGNETOMETER AND MODE OF MOUNTING.

"The base plate was of selected, well-seasoned whitewood, carefully oiled and varnished on all surfaces after having been prepared to dimensions selected, viz., 10 ft. 6 in. long, 20 in. wide and 1¾ inches in thickness. The brass magnetometer boxes were mounted in suitable positions at each end of this plate and the recording cylinder immediately between each instrument. The centre line of cylinder, photographic lenses and tops of base mirrors were the same height from surface of base plate. Provision was made for cutting off traces at beginning of each hour, for an interval of two minutes, by means of an electrically actuated balance carrying shields and regulated by auxiliary clock, in same manner as Agincourt instrument. Scales with reading telescopes were placed in angles between incident and reflected photographic ray at radial distances which made each scale division equal to one millimeter measured on cylinder, and the height of scales from base was so arranged that a slight inclination in perpendicular between fixed and movable mirrors superimposed reflections of scales, and by means of paper shields sliding on scales and cutting off any selected portion thereof, the values of fixed or movable scales could be read in telescopes, thus assuring identity of scales and photographic ordinates. All mountings were secured to the bed plate with suitable bolts passing through same to countersunk nuts, so that there were no projections at the bottom of plate. All adjustments, measurements and determinations of arc value were made in Toronto, so that in final mounting all that was necessary was to observe, that when magnets were adjusted their mirrors were in the same plane as the fixed ones which remained in position on the bed plate. The recording cylinder and the magnetometer boxes were enclosed with the usual light-excluding boxes and tubes. The brass suspension tubes were unscrewed from magnetometer boxes and during transportation were secured inside light-excluding tubes. In transportation all parts not remaining fixed to bed plate were individually secured, no packing medium being used and no casualties occurred in transportation.

"In anticipation of local difficulties in securing stable mounting for bed plate, the packing box containing instrument was constructed with copper nails and brass screws, movable legs being fitted to it so that it might be used as a table on which to place bed plate.

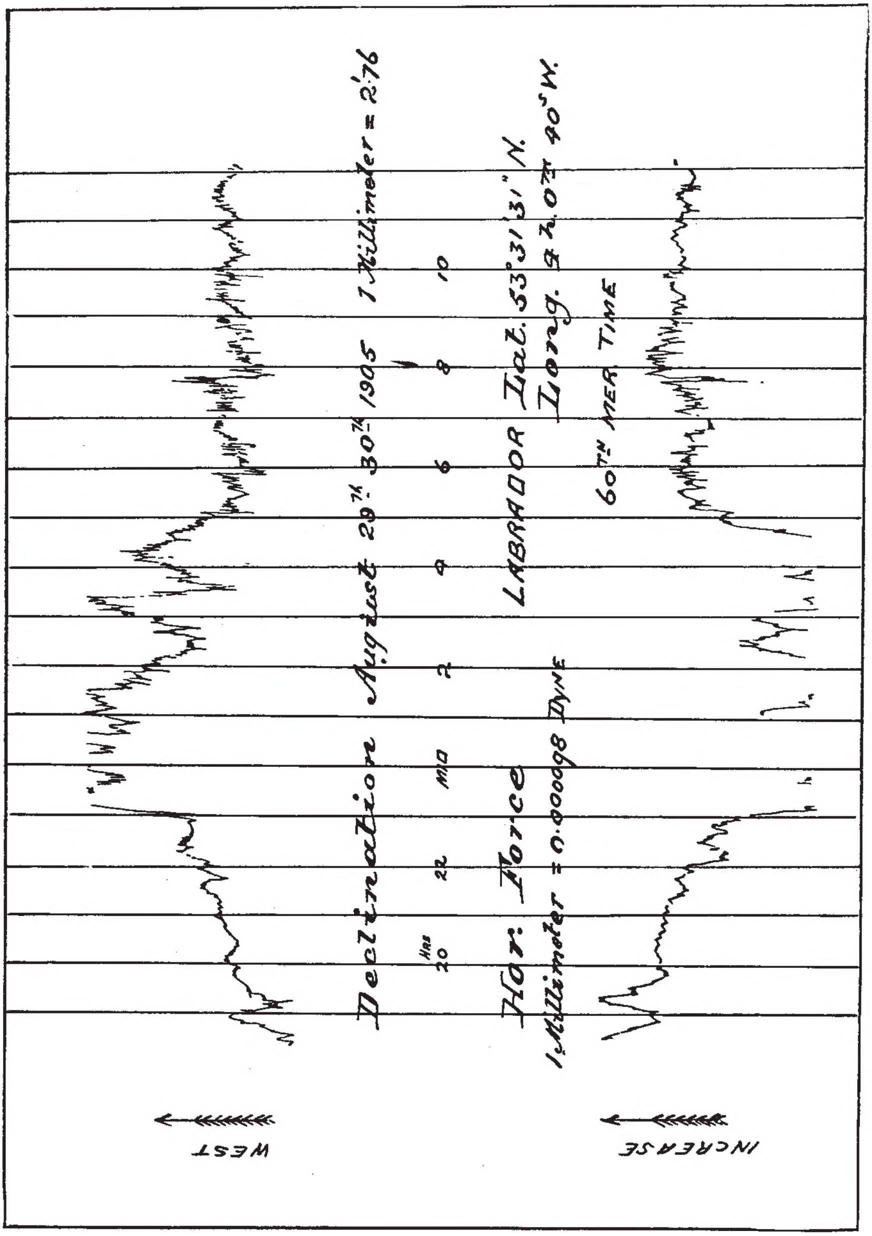
"Owing to the limited time at command, this plan was followed and the following is a brief description of precautions taken to secure necessary stability. The four-inch square legs, five feet long, were secured in their positions to the sides of box so that the bottom of the same was uppermost, the top being removed. The bottoms of legs (which were splayed to about double the width of the box) were securely nailed to bed piece of 2 in. plank, about five feet in length, and suitably braced. Trenches were dug in soil (coarse sand) about 18 inches wide and 5 ft. 6 inches long. In these the legs were firmly bedded so that the box was in Magnetic E. and W. line; its top level, about twenty-nine inches above the ground line. The trenches were filled up with concrete and sand. Braces were then screwed from sides of box to legs at ground line. On test, this proved to be a rigid support. The plate was bolted to this table by brass bolts provided for the purpose; a batten through which the bolts passed was inserted between plate and table to facilitate final levelling and to prevent any tendency to warping. When dismounting instrument, the box was freed from ends of longitudinal braces and unscrewed from legs, allowing same to remain imbedded in the ground.

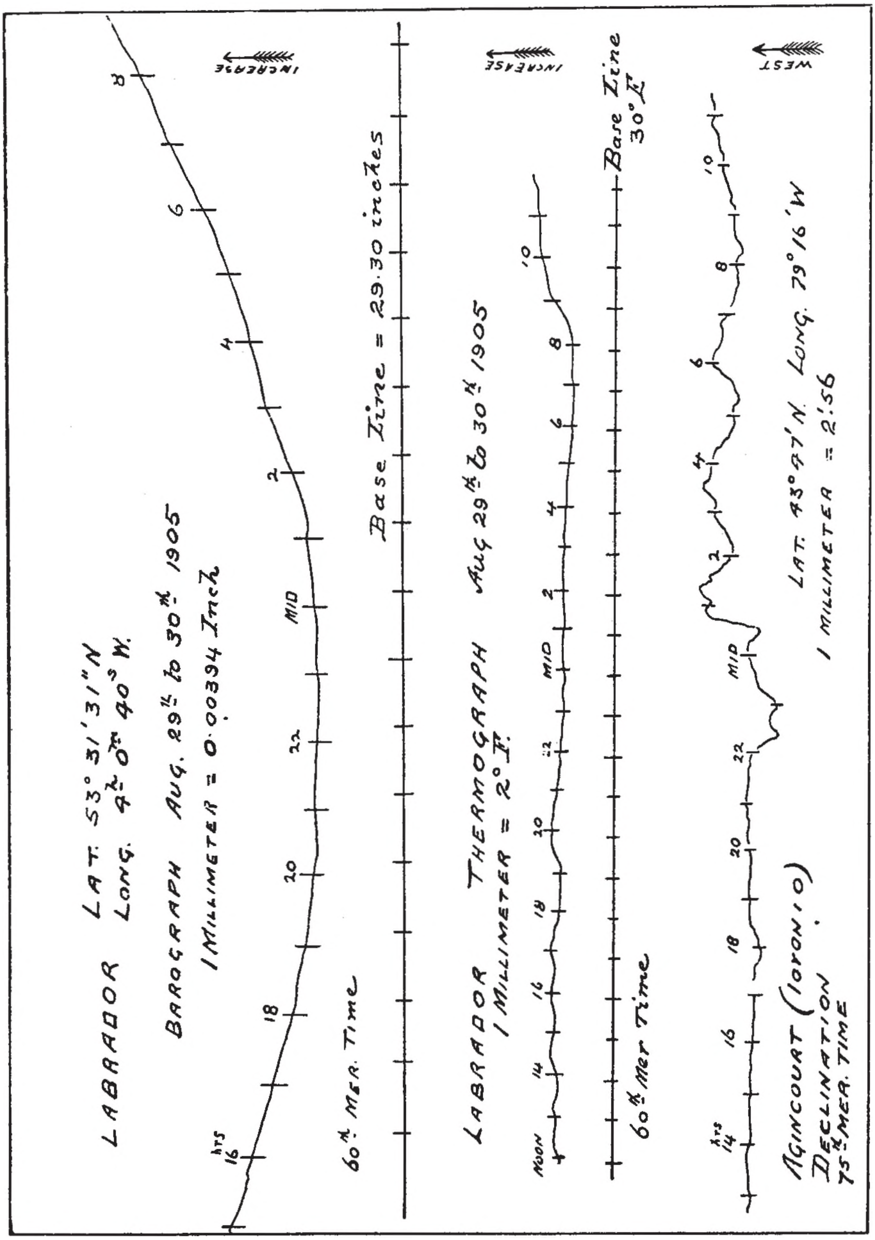
"The bolts securing plate to box were in line with the legs which were about fourteen inches from the ends of the box. Altogether I think this was an expeditiously constructed and satisfactory mounting. The adjustment of the slab perpendicular to magnetic meridian was for convenient use of arms carrying a deflecting magnet for the determination of bifilar scale coefficient."

Mr. Menzies reports: "The ship left Quebec on Friday 4th, about 7 p.m. and after a prolonged but interesting voyage reached Matasquan on August 8th, and then with only members of expedition aboard started for destination; reached Rigolette at 2.40 p.m. on Thursday, August 10th, and anchored there until early Friday morning when we took final departure for North-West River and arrived at 10 a.m. when we immediately began landing cargo. With the assistance of all on board this was quickly accomplished. All passengers disembarked early Saturday morning and the vessel returned to Quebec.

"Saturday was laboriously spent in pitching tents, transporting stores, etc. Sunday was necessarily taken up with arrangement of details about camp. We started at 3 a.m. Monday morning to convey lumber, etc. from the landing place to point selected for instrument shelter, this being some distance to west of western limit of camp to assure being free from local disturbance, and most of the material was on the ground before breakfast.

"Dr. King then kindly assigned Mr. L. Gauthier to assist in the construction of the shelter, mounting of instruments, etc.


Declination August 29th 30th 1905 1 Millimeter = 2'.76
Hrs 20 22 MID 2 4 6 8 10
LABRADOR Lat. 53°31'31" N.
Long. 4h 07m 40s W.
60th MER. TIME
Hor. Force
1 Millimeter = 0.00098 Dyne
WEST
INCREASE


LABRADOR LAT. 53° 31' 31" N
LONG. 4h 0m 40s W.
BAROGRAPH AUG. 29th to 30th 1905
1 MILLIMETER = 0·00394 Inch
60th MER. Time
Base Line = 29.30 inches
INCREASE
hrs 16
18
20
22
MID
2
4
6
8
LABRADOR THERMOGRAPH Aug 29th to 30th 1905
1 MILLIMETER = 2° F.
60th Mer Time
Base Line 30° F
INCREASE
NOON
14
16
18
20
22
MID
2
4
6
8
10
AGINCOURT (TORONTO)
DECLINATION
75th MER. TIME
LAT. 43° 47' N. LONG. 79° 16' W
1 MILLIMETER = 2'.56
WEST
hrs 14
16
18
20
22
MID
2
4
6
8
10

By ignoring the ten-hour system and disregarding weather conditions we, with the kind assistance of Prof. A. T. De Lury, had shelter erected ; differential recording instruments mounted ; cement pier and shelter tent erected for determination of absolute values, all being completed and ready for final adjustment on Friday 17th. In addition, the meteorological instruments were put in position. These consisted of sensitive air barograph with chamber sunk six feet in ground to assure constancy of temperature, Richard thermograph, standard barometer and thermometers for comparison.

"All this was accomplished by unremitting labor, and I gladly take the opportunity of testifying to the valuable assistance rendered by these gentlemen during these operations and subsequently, Professor De Lury in entering and reducing observations, and Mr. Gauthier in taking simultaneous readings of the differential instruments during absolute determinations. All instruments were finally adjusted and recording from 18th to day of breaking camp. Prof. L. B. Stewart, who preceded the expedition, had established the meridian from which he laid down bearing of a well-defined mark, selected by me, its azimuth being determined S. 18° 04′, 10′ E. It was read direct during absolute declination determinations without any change either in altitude or focus of the reading telescope.

"As soon as the magnetic instruments had been installed at the observing station, determinations of absolute magnetic values were made with a portable magnetometer, Elliott No. 48, and thus the true value of the scale readings of the differential magnetometers became known and the variations indicated by the photographic traces can be measured off for any hour and minute during which the instruments were in adjustment between August 17th and August 30th. The instruments were put in operation during the evening of the 17th, and there were no important magnetic changes during the following 24 hours. A remarkable feature of the curves during the night of the 18th–19th and three following nights were large westerly excursions of the declination needle, generally beginning before midnight and continuing for some hours, while the horizontal force curve showed large decreasing movements corresponding in time. Other hours of these days were not much disturbed. The night of the

22nd-23rd was undisturbed, and unfortunately the curve for the following night was lost owing to the clock having stopped. Just prior to 10 p.m. on the 24th the declination magnetic moved abruptly eastward while there was a small but sharp increase of force, and then until after 5 a.m. there was continued disturbance. Pronounced disturbance again began at 9 p.m. 25th, and continued until about 1.30 a.m. 26th, after which there was little movement until about 10.50 p.m. 26th, when the declination began a remarkable movement westward, in the following hour changing through an arc of over 1° 26′ while H. diminished over 0·0035 C.G.S., exact amounts being undeterminable as in both instruments the record passed off the paper: by 1 a.m. the readings were again normal and quiet, and continued so until the following night. At about 10 p.m. 27th, disturbance began and continued to a moderate extent up to 1 p.m. of the following day, when it increased greatly and many large changes, both of declination and force, were registered up to 5 a.m. of the 29th. Some hours of a more quiet magnet then followed, but a disturbance began before noon and continued. Just before 11 p.m. the declination magnet swung abruptly to the westward and the force diminished, both records passing off the paper, and until 5 a.m. the declination magnet was generally much to the westward of the normal reading and there were some very pronounced changes, while the force magnet also showed large and abrupt changes and much of the record was lost by the light passing beyond the limits of the paper.

"During the forenoon of the 30th, including the time of the eclipse, the magnets were so disturbed that it is probable that any eclipse effect will have been completely masked.

"The barograph showed a steady increasing pressure during the forenoon of the 30th with no noticeable irregularities.

"The thermograph curve clearly shows a slight fall in temperature during the time of totality followed by a rather abrupt rise.

"The barograph was an air barometer with a scale value such that one-hundredth of an inch change in the mercurial barometer was represented by a change of two-tenths of an inch in the ordinate of the air barometer trace. The thermograph was a large-sized instrument by M. Jules Richard, of Paris."

PLATES AND FILTERS FOR MONOCHROMATIC AND THREE-COLOR PHOTOGRAPHY OF THE CORONA.

BY

J. S. PLASKETT.

THE programme of observations planned for the party sent out by the Canadian Government, which, under the direction of Dr. W. F. King, Chief Astronomer for the Dominion, proceeded to North West River at the head of Lake Melville, to observe the total eclipse of the Sun of August 29–30, 1905, included monochromatic photographs of the corona by red, yellow, and green light, as well as photographs taken on ordinary plates or by blue and violet light. In order to insure the best possible results it was necessary to choose the plates most suitable for their respective purposes and to adjust the required screens or filters to transmit, with as little diminution as possible, the proposed wave-lengths and, at the same time, to completely absorb the remainder.

Although there have been many investigations on the sensitiveness of photographic plates to light of different wave-lengths, and on the absorption of various coloring matters used as screens or filters for such plates, none, so far as I could discover, gave exactly the required information. The principal difficulty was to discover a plate sufficiently sensitive and a screen sufficiently pure to obtain a photograph of the corona by the light of the brightest line, that at λ 5303, in the emission spectrum of the luminous gas, called, for want of a better name, coronium, of which no terrestrial or other celestial analogue has yet been discovered, and which is one of the main constituents of the inner corona. Shackleton proposed photographing the corona by light of this wave-length, and gives directions in *Monthly Notices*, LX., p. 433, for preparing filters for this purpose; but, as we shall presently see, the plates proposed to be used, Cadett Spectrum, were insufficiently sensitive in the required spectral region to show much effect through a monochromatic screen. Other investigations on plates and screens are not, as a rule, specific enough or do not deal with the regions under consideration, and besides contradictory results have sometimes been obtained by different observers. Apparently the only satisfactory course was to make a series of experiments on the color sensitiveness of plates and the absorption of dye-stuffs for use as screens, with special regard to the desired qualities, taking care to test them under as nearly as possible the conditions of use.

Let me state at the outset what it was proposed to do in photography of the corona by monochromatic light at the eclipse, and then we shall be in a position to attack the problem of choosing the most suitable plates and filters:

(*a*) Photographs of the corona by light of wave-length λ 5303, to determine the distribution of coronium gas around the Sun.

(*b*) Photography of the corona by red light of wave-lengths between about λ 6000 and λ 6700 to determine the distribution of red light in the corona and prominences, and to form a three-color, red-record negative.

(*c*) Photographs of the corona by yellow and yellow-green light between wave-lengths λ 5500 and λ 5800 for the distribution of yellow light in the corona.

(*d*) Photographs of the corona by green light, outside limits of wave-lengths λ 4900 and λ 6000, to form a three-color, green-record negative.

(*e*) Photographs of the corona on ordinary plates, and hence by blue and violet light, wave-lengths λ 3800–λ 5000 say, a suitably exposed negative of this series may be used to form the three-color, blue-record negative.

It was hoped that such a series of photographs would enable us to separate the radiations due to the luminous gas from those due to incandescent particles and to reflected sunlight, and to form some idea of the distribution of color in the corona. Moreover, by a proper choice of plates and adjustment of filters, the negatives made under *b*, *d* and *e* could be combined to form a three-color photograph of the corona, giving a reproduction in its natural colors.

Each of the above propositions requires plates of a different range of sensitiveness. If plates could be obtained sensitive to any desired range of wave-lengths, and to such only, the problem would be a very simple one, as then no filters or color screens would be required. This, however, is not yet possible, for, although plates can be produced sensitive to all visible light as well as to the infra-red and ultra-violet, such sensitiveness usually extends outside the desired range, and the radiations not required have to be absorbed by a suitable filter. As is well known, such plates can be produced in two ways, either by incorporating the sensitizing material, usually some aniline dye-stuff, with the emulsion before coating the plate, or by bathing ordinary plates in a weak solution of the dye. It was desired to use commercial orthochromatic plates, which are prepared by the former method, if the correct color sensitiveness combined with rapidity could be obtained. Such plates are much easier and surer to handle than bathed plates, and entail considerably less trouble, especially in the field.

Every orthochromatic plate has two or more regions or bands of sensitiveness, one due to the silver bromide and hence present in every plate, ordinary and orthochromatic, ranging from about λ 5000 to the ultra-violet; and the other or others due to the special sensitizer or sensitizers employed. More than half the orthochromatic plates manufactured belong to the class of yellow or yellow-green sensitive plates, having, in addition to the silver bromide band, a region in the yellow-green with a maximum about λ 5650, and extending about 200 tenth metres on either side, to which they are very sensitive. They are only very slightly sensitive between λ 5000 and λ 5400 or λ 5500 and scarcely sensitive at all to waves longer than λ 5800. Such plates will answer admirably for *c* in the above list, it only being necessary to determine the most sensitive and the correct intensity of filters; but they will be entirely useless for the other purposes owing to their insensitiveness in the required regions. Whether any brand of commercial orthochromatic plate will serve for *a*, *b*, or *d* can only be determined by a spectroscopic test, as I was unable to find records of the performance of more than half a dozen plates.

Samples of every rapid orthochromatic plate manufactured in England and the United States with some of French and German manufacture were obtained, and also a small quantity of each of the dyes specially claimed by reliable authorities to sensitize strongly in the required regions. These plates, and ordinary plates bathed in solutions of the dyes, were tested for color sensitiveness by photographing the spectrum. The solar spectrum was chosen as the most suitable, not only on account of the absorption lines serving for identification of wave-lengths, but also because of its greater resemblance to the spectrum of the corona than that of any artificial source.

The Brashear Universal Spectroscope belonging to the equatorial telescope at the Observatory is especially adapted for this and similar purposes. It has a collimator of 1¼-inch aperture and 15-inch focus, and a camera of the same dimensions giving spectra 2¼ inches long and up to ½ inch wide on plates 2 inches by 3 inches in size. It can be used with dispersing media of (1) a single light flint prism, (2) a single dense flint prism, (3) a 2½-inch plane grating, 15000 lines to the inch, (4) a train of three moderately dense flint prisms. The light flint gives too small, and the train of three prisms too great dispersion for the purpose, and the choice therefore lay between the dense flint prism and the grating. The prism was chosen to avoid trouble and possible error with diffuse light and overlapping spectra. A prism, as is well known, gives a spectrum which is unduly crowded together at the red end and extended in the violet, while gratings give a normal spectrum. Although this property of the prismatic spectrum would, unless carefully guarded against, introduce errors in the determination of absolute color sensitiveness, it cannot possibly have any effect on the relative values sought in the present investigation. The prism, when set at minimum deviation for $H\beta$, about the centre of the required range λ 3900 to λ 7000, gave a spectrum about 1¾ inches long between the above limits, and it was consequently moved slightly out of the position of minimum deviation in order to include only the above range in the opening, 2¼ inches long, in the camera back. A diaphragm with four rectangular openings, each $\frac{1}{10}$ inch wide, and so spaced as to enable one after the other to be moved into position, was mounted in front of the slit and enabled four spectra, each $\frac{1}{10}$ inch wide, to be made side by side on the same plate. Exposures were given by means of a Thornton-Pickard roller-blind shutter supplied with a time exposure valve, mounted a short distance in front of the slit, which enabled accurately timed exposures of any desired length, between $\frac{1}{90}$ second and 3 seconds, to be made automatically, while longer exposures could be readily timed by a watch. A piece of ground glass attached to the back of the shutter reduced the intensity of the light and diffused it so as to uniformly illuminate the collimator lens. Sunlight was focussed on the slit by attaching the spectroscope to the telescope and pointing to the Sun. It was found necessary to diaphragm the aperture of the objective to 3 inches to reduce the quantity of light and heat to a reasonable amount.

In order to render the resulting negatives truly comparable with each other, the exposures on the plates were always made with the Sun near the meridian in a cloudless sky to avoid changes, due to varying atmospheric absorption or other reasons, in the intensity of the light incident on the shutter, while the quantity reaching the plate was regulated by the length of the exposure. As an exact knowledge of the sensitiveness of some of the plates tested could not be obtained by two or three exposures, eight spectra were made on each variety of plate tested, with exposures of $\frac{1}{25}$, 1/8, 3/8, 3/4, 2, 4, 8 and 20 seconds respectively, and as four spectra could be made on one plate 2 in. × 3 in., this required two plates. To insure uniformity of results, as far as possible, all the plates were developed in the same kind of developer and for equal times, so that a very accurate comparison of the relative values of the plates could easily be made. Not only could the relative sensitiveness of each plate to the different colors, but also the relative sensitiveness of different plates to each color, be readily estimated.

Reproductions of photographs of the solar spectrum, made in the manner just described on some typical commercial plates, are given in Fig. 1. Each plate is represented by three spectra of short, medium, and long exposure, and the general character of the spectrum enables one to form a good idea of the range of sensitiveness of the various plates. But it must be remembered that the spectra reproduced here are not necessarily of the same relative exposures for the different plates, but rather those three out of the eight taken on each plate, which would make the best reproduction and give the best general idea of the color sensitiveness of the plates. Accurate knowledge of the relative values of the plates for the required purposes can only be obtained by comparing the original negatives. However, by comparing in the figure the intensity of the band due to the special sensitizer employed with that due to the silver bromide, one can get a very good idea of the orthochromatic properties of the plate examined.

The range of wave-lengths which affect the silver bromide in the plates is represented by the first two spectra shown, on the Seed "R" and the Ilford Monarch plates, two ordinary plates of first quality. The maximum of sensitiveness, at any rate for the prismatic spectrum, is at about wave-length λ 4600, and the deposit on the negative extends into the green to about λ 5000 with ordinary exposures. This region of sensitiveness is, of course, present in every plate, and the only effect of the color sensitizers is to add an additional region or regions of sensitiveness in the light of longer wave-length, if we leave out of account a slight decrease of sensitiveness of the silver bromide, when a special sensitizer is employed, due probably to the absorption exercised by the coloring material in the film.

The greater number of commercial orthochromatic plates tested belonged to the type previously described, having, in addition to the silver bromide band, a region of sensitiveness in the yellow-green, with a maximum at about λ 5650, due to the special sensitizer employed. But the extent and intensity of this band varied, as is shown in the next six spectra, from a faint and short band in the A. G. F.A. Isolar Ortho. and Mawson Ortho. A, to a band extending about 200 tenth-metres on each side of the maximum, or from about λ 5450 to λ 5800 or λ 5850, and, for some exposures, more intense than that in the silver bromide, in the Cramer Instantaneous Isochromatic. Of the twenty-odd plates of this nature tested, the six shown are fairly representative, the others being intermediate in character. These plates are admirably suited for the purpose outlined in *c* above, not only on account of their relatively high sensitiveness in the required region, but also by reason of their comparative insensitiveness to the colors or, rather, light waves on either side. This considerably simplifies the adjustment of the necessary filter or color screen, but this and the choice of the most suitable plate of this type will be referred to later. Although the relative sensitiveness in the region λ 5450–λ 5000 varies in different plates, being generally

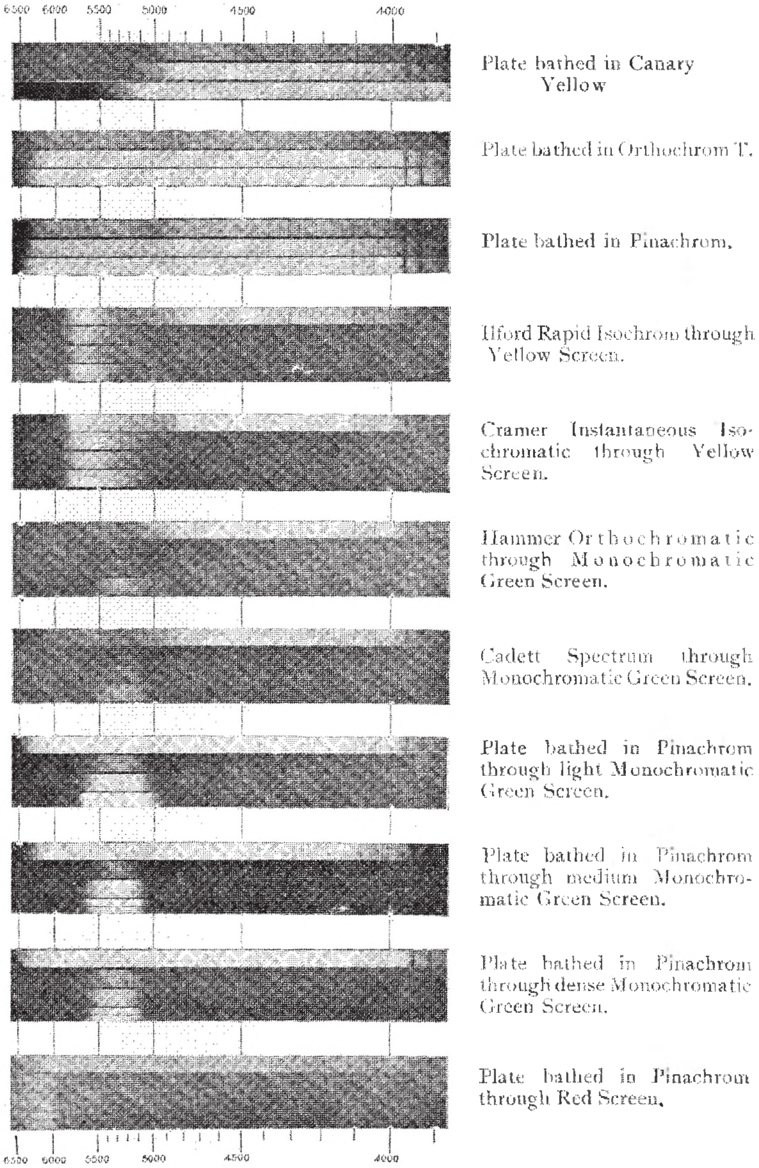

6500
6000
5500
5000
4500
4000
Plate bathed in Canary Yellow
Plate bathed in Orthochrom T.
Plate bathed in Pinachrom.
Ilford Rapid Isochrom through Yellow Screen.
Cramer Instantaneous Isochromatic through Yellow Screen.
Hammer Orthochromatic through Monochromatic Green Screen.
Cadett Spectrum through Monochromatic Green Screen.
Plate bathed in Pinachrom through light Monochromatic Green Screen.
Plate bathed in Pinachrom through medium Monochromatic Green Screen.
Plate bathed in Pinachrom through dense Monochromatic Green Screen.
Plate bathed in Pinachrom through Red Screen.
6500
6000
5500
5000
4500
4000

Fig. 2.

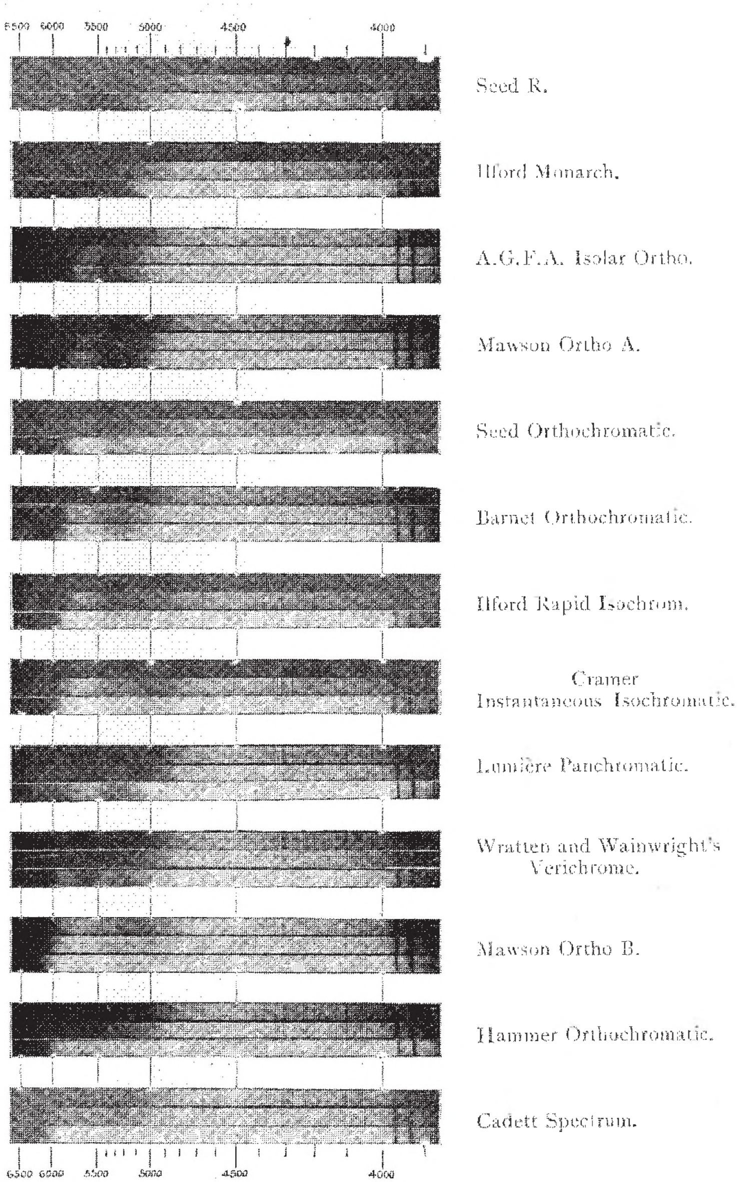

6500 6000 5500 5000 4500 4000
Seed R.
Ilford Monarch.
A.G.F.A. Isolar Ortho.
Mawson Ortho A.
Seed Orthochromatic.
Barnet Orthochromatic.
Ilford Rapid Isochrom.
Cramer Instantaneous Isochromatic.
Lumière Panchromatic.
Wratten and Wainwright's Verichrome.
Mawson Ortho B.
Hammer Orthochromatic.
Cadett Spectrum.
6500 6000 5500 5000 4500 4000

FIG. 1.

higher in those of moderate sensitiveness to the yellow-green, it is in no case sufficiently high to permit reasonable hope of successful results for purpose *a*, photography by monochromatic (λ 5303) coronium light. For photographs by red light, *b* above, they are even less suited, as they require considerable exposure to show the *D* lines.

The remaining commercial orthochromatic plates tested, nine in number, gave spectra well represented by the last five photographs in Fig. 1. As will be seen, they differ from the preceding class in being sensitive to the orange and orange-red. No two plates give exactly similar spectra, the red sensitiveness in some appearing to proceed from a distinct band in addition to the blue and yellow-green, and in others to be due to an extension of the yellow-green band. Some, such as the Lumière Panchromatic and the Wratten & Wainwright Verichrome, are only very weakly sensitive to red, and in none of them does the red-sensitiveness nearly approach the yellow-green-sensitiveness of the plates described above ; the Mawson Ortho. B, and the Cadett Spectrum being decidedly the most sensitive to orange and red. For the purpose in *b*, above, the sensitiveness even of the two plates last mentioned is so weak as to require almost a prohibitively long exposure in coronal photography, probably upwards of a hundred times that given to an ordinary plate. The same is true for the three-color green-record of *d*, though not to so great an extent. In the region λ 5303 for photographs by coronium light, although two or three of them are more sensitive than the previous type, they are, as will be seen when I come to speak of filter tests, still insufficiently sensitive to give much prospect of useful results.

For photographs of the corona by blue and violet light and for the three-color blue-record negative, section *e*, ordinary plates are more suitable than orthochromatic, as they require no filter and there is no lowering of the blue-sensitiveness by the use of a dye, which occurs with orthochromatic plates. The chief essentials in a plate for this purpose are rapidity, freedom from fog, fineness of grain, and non-halation properties. The Seed Non-Halation plate fulfilled these requisites better than any other, and was accordingly chosen for the regular photographic work.

The spectroscopic tests of commercial orthochromatic plates having shown that none of them were suitable for the photographic work, outlined under *a*, *b*, and *d*, it was necessary to test plates bathed in solutions of certain dye-stuffs. As previously stated, the choice of sensitizing dyes for trial was governed by the experience of others, as it was hopeless, in the available time, to attempt to test one-tenth of the dyes that have been experimented with ; and, as practically every dye made has been tested in this way, it was still more hopeless to attempt to discover a new sensitizer. My own previous experience in sensitizing plates, and a reference to the literature on the subject, convinced me that very different and even contradictory results can be obtained by different experiments with what is supposed to be the same dye. Whether these varying results are due to differences in the samples of dye used, or to differences in sensitizing, treating, or testing the plates, the only safe course seemed to be to test each dye with the plates it was proposed to bathe with it, under conditions as nearly as possible like those obtaining at the eclipse. Dyes specifically claimed to sensitize in the required regions, and hence giving promise of useful results, may be divided into three classes:

1. Dyes claimed to sensitize in the green.
2. Dyes sensitizing to all colors, or making plates panchromatic.
3. Dyes sensitizing in the red.

The first class includes certain yellow dyes as Titan, Canary, and Cotton Yellow from Holliday, Nitrophenine from Clayton, and Thiazol Yellow from Bayer, which are stated by Eder and Valenta to sensitize strongly in the green with a maximum about E or nearly λ 5300. But the tests here proved very disappointing, the only effect of the yellow dye, as shown in the spectra on a plate bathed in Canary Yellow, reproduced in Fig. 2, seems to be to slightly diminish the blue and violet sensitiveness, to extend it slightly into the green, and, with very prolonged exposure, to show a trace of sensitiveness in the yellow. The difference in the results obtained may be due to two causes: either the dyes may not be the same, though having the same name, or else the experiments have not been properly conducted in one of the cases. The published spectra by Eder and Valenta appear over-exposed, and sufficient over-exposure might produce the effect there shown. The lower spectrum in the reproduction, which was given about twenty times the exposure of the middle, shows a marked displacement of the maximum towards the red and, although perhaps not visible in the reproduction, there is the beginning of a band of sensitiveness near the *D* lines; a still longer exposure would doubtless show a further displacement, which would make a spectrum approximating those given by Eder and Valenta. However that may be, it is very apparent that such plates will not answer any of the required purposes, and the dyes claimed to render plates panchromatic were next tested.

Three dyes for the above purpose have been recently introduced, Ethyl Red, Orthochrom T and Pinachrom. These are all derivatives of Eyanin, itself a well-known and probably the earliest sensitizer for red. The technical German name for Orthochrom T is *p – Toluchinaldin – p – Bromchinolincyaninaethyljodid*, and all three are German products specially made for sensitizing photographic plates. Tests of these dyes fully bore out the results claimed for them. The sensitiveness of plates bathed in Orthochrom T or Pinachrom in the green and red, the required regions, is nearly as great as in the blue, as shown in the second and third spectra in Fig. 2. It will be noticed that the photographed spectrum given on plates bathed in these dyes is nearly uniform in intensity all along its range, but that, with short exposures, there are traces of three maxima, at λ 6000 or λ 6100, at λ 5300 and at λ 4600. As the exposure is increased these maxima become imperceptible, and the band becomes practically uniform between λ 4000 and λ 6400, which, when compared with the performance of all other plates tested, is a remarkable result. The dyes of the third class, those sensitizing for the red, were not tested when the panchromatic sensitizers gave such good results in both the required regions. They certainly would, as the experiments of others show, give only slight sensitiveness in the green, and though sensitizing further into the red, they do not give nearly so strong a band as Pinachrom in the required range λ 6000 - λ 6700. The three sensitizers above mentioned gave quite similar results, but Pinachrom not only sensitizes further into the red, but also gives a higher general sensitiveness than Ethyl Red and Orthochrom T. It was accordingly chosen for photographs in monochromatic green λ 5303 and for the three-color red- and green-records.

The plates tested for bathing with Pinachrom were the Lumière Special Rapid, the Seed "R" and the Ilford Monarch. The Seed and the Monarch are more rapid than the Lumière, and the Monarch seems to have a slight advantage over the Seed in freedom from fog and rapidity. Plates sensitized with Pinachrom seem to have a wide field of usefulness before them, especially in spectroscopic and three-color photography. Their extreme and uniform sensitiveness to almost the whole range of visible spectra led me to choose them for photographing the "flash" and corona spectra in the prismatic and objective grating cameras that were part of our equipment. In the test for focus of these two cameras spectra of the carbon arc were made on films sensitized with Pinachrom, and the resulting negatives showed remarkably uniform intensity from λ 3800 – λ 6200, the limits given by the cameras. A test of Pinachrom-sensitized plates later, in the star spectroscope, showed that the green, orange, and red parts of the spectra of 2nd and 3rd type stars, as Capella, Aldebaran, Betelgeuse, could be photographed in considerably less time than the blue part of the same stars on ordinary plates.

With the selection of the plates only half the work was accomplished. There still remained the selection and adjustment of the necessary filters to transmit as fully as possible the light whose action was desired, and to completely absorb the rest. The ideal filter or color screen, for this or any other purpose, would be a piece of thin stained glass of the correct absorption with optically worked surfaces. Unfortunately, however, stained glass cannot be obtained of any desired absorption, and one is necessarily confined to liquid filters or stained gelatine or collodion films. Owing to loss through leakage or evaporation, and to the difficulty in keeping the intensity constant in a liquid filter, it was decided to use gelatine films stained with dye solutions. The Cramer Dry Plate Co. coated some thin plate glass with clear gelatine for me in a very satisfactory manner, and these films, when stained in the proper dyes, give beautifully uniform tints, while the intensity can be easily changed. After the filters had been correctly adjusted, those composed of two colors were sealed face to face, while that of a single color had a piece of clear plate glass sealed to its face by Canada Balsam. A narrow piece of lantern-slide binding-strip around the edge completed the filters, which were placed in the cameras close in front of the plates, so that any distortion which might occur through the surfaces only being plate surfaces and not optically worked, would not affect the definition.

For choosing the correct colors, Mr. W. P. Near made for me, in a very satisfactory manner, small test plates of some 50 aniline dyes of which I had samples. These test plates were made from unexposed gelatine dry plates, fixed out in soda hyposulphite, washed and dried. They were cut into pieces two inches square and stained in solutions of the dyes. Three test plates were made from each dye, of light, medium, and strong depths of color, the object of the varying intensities being to thoroughly test the absorptions of the dyes, as some dyes show quite different properties in different concentrations. All these samples were examined spectroscopically for their absorptions, at first visually, while those showing promise of giving the desired absorption were tested photographically by placing them in front of the slit of the spectroscope and making exposures on the corresponding plates. As when testing the plates, exposures of known length were given so that estimates of the relative transmitting power of the various dyes could readily be made.

The screen for the yellow-green record of the corona promised to be the simplest to adjust and it was first tried. Some eight or ten yellow and orange dyes were tested both for transparency to the yellow-green and opacity to the blue and violet. As will be remembered, the plate to be used for this purpose was one of the class first tested, having a strong band of sensitiveness in the yellow-green, λ 5450 to λ 5850, a region of insensitiveness, λ 5400 – λ 5000, and then the silver bromide region from λ 5000 down. A screen absorbing the blue and violet would answer for this purpose, as the plate is insensitive to the other regions except in the yellow-green where it is required to photograph. Tartrazine, by Bayer of Elberfeld, was found to be the most suitable dye, giving complete absorption of the shorter, with practically complete transmission of the longer, waves. Of the plates, whose choice was left until the screens were being adjusted, the Barnet Orthochromatic, the Seed Ortho., the Ilford Rapid

Isochrom, the Edwards Snap-Shot Isochromatic, and the Cramer Instantaneous Isochromatic were the most sensitive in the required region, and a final test through Tartrazine screens showed that the Cramer gave the strongest band in the required region. The fourth and fifth spectra in Fig. 2 illustrate the manner of testing. A spectrum is taken first on the plate direct, and then through three Tartrazine screens of different intensities. It will be noticed that, although the Ilford plate gives a narrower band than the Cramer, the latter is considerably the stronger, and will hence not require so long an exposure as the former. The photographic tests showed further that a Tartrazine screen, which absorbed visually as far as λ 4900, was sufficiently intense to absorb photographically all the blue and violet light.

Although the filter for the yellow-green region is comparatively simple to adjust owing to the strong maximum of sensitiveness in the plate at that point, the same does not hold in regard to the filter for the λ 5303 monochromatic coronium light. A Pinachrom-sensitized plate gives practically uniform sensitiveness all along its range and no maximum at λ 5303 occurs. The filter, therefore, must transmit as fully as possible at λ 5303, and at the same time absorb as abruptly as possible on either side of this wave-length. The problem was quite a difficult one as no dyes in my possession gave abrupt absorptions at the required point. It was not expected that any single dye would give the required absorption, but it was hoped that by combining two dyes, a green to cut off light to the red side, and a yellow or orange to cut off light to the blue side of 5303, to obtain a suitable filter. By far the larger number of the twenty green dyes tested gave so gradual an absorption as to be entirely useless for the purpose. Three or four gave promise of serving the purpose and photographic tests limited this number to two, Brilliant Acid Green 6 B and Alkali Fast Green G, both made by Bayer of Elberfeld. The absorption of these dyes was, however, still too gradual, as complete absorption to λ 5350 or λ 5400 entailed partial absorption of λ 5303, but not to a sufficient extent to prohibit their use. For the dye absorbing at the blue side, Tartrazine was by far the most suitable, absorbing in strongly stained films to λ 5200 or λ 5250 without undue dimming of λ 5303. The final choice of the green dye and adjustment of the required intensities was effected photographically; in fact, two complete filters were made, one with one film of Alkali Fast Green G and one of Tartrazine, and the other with one of Brilliant Acid Green 6 B and two of Tartrazine. Fig. 2 shows tests of three filters, three different exposures on each, one stained to a lighter intensity, and the two above called medium and dense respectively. The medium filter was chosen for use, as, though not quite so pure as the dense, the exposure required to produce the same intensity was considerably less. It was, of course, merely a question of the best compromise between the conflicting interests, shortness of exposure and purity of transmitted light. By making the filter more intense in color, the transmitted band would become narrower but the exposure required would become prohibitive. When it is considered, however, that the intensity and quantity of continuous corona spectrum, that will be transmitted through the medium filter, is relatively small compared to that contained in the emission line at λ 5303, it is evident that the character of the result will not be appreciably affected by the use of a filter passing a band of the width shown in the figure. A test of the medium filter on Hammer Orthochromatic and Cadett Spectrum plates, illustrated in the sixth and seventh spectra in Fig. 2, shows how much more sensitive a plate stained with Pinachrom is than the best of the commercial plates. A careful comparison of negatives showed that at least ten times the exposure was required for the commercial as for the bathed plates. Hence a monochromatic photograph of the corona in this region on commercial plates would be badly under-exposed.

The filter for *b* was to serve two purposes, one to give the distribution of red light in the corona and the other to form the red-record negative for a three-color photograph. For the former purpose a filter absorbing abruptly all light of shorter wave-length than about λ 6000 and transmitting all the red to which the plate is sensitive, to about λ 6700, would be desirable. For the latter purpose, a three-color red filter, both abrupt and gradual absorptions have been used with practically identical results, and so it was considered that the use of a red filter absorbing abruptly between λ 5900 and λ 6000 would not affect the value of the resulting negative for use as a three-color red-record, while it would give a purer monochromatic rendering than a filter in which the absorption ended gradually, starting in the red and shading down into the green from λ 6000 to about λ 5500. Erythrosine was found to be a very suitable dye for the purpose, as it absorbed very abruptly at from λ 5800 to λ 6000, depending on the depth of stain. However, as it transmitted violet light as well as red, it was necessary to use a second absorbing film of Tartrazine. When the two had been properly adjusted by photographic tests and sealed together they formed a filter which worked admirably, as the reproduction, the last spectrum in Fig. 2, shows. In this case also no commercial plates would have served, as the exposure required would be upwards of thirty times that required on the Pinachrom-bathed plates.

For the three-color green-record negative a filter which would transmit light between the wave-lengths λ 4900 and λ 6000, shading off gradually on each side, was required. This filter also contained two films, one of Acid Green 2 G Extra by Bayer, which absorbed the red, part of the orange and the violet, and one of Tartrazine, which absorbed the violet, the blue, and blue-green, as far as required. Both of these dyes were in comparatively light intensity, giving a very transparent filter, and one which is well suited for three-color work with plates sensitized with Pinachrom.

After the filters had been adjusted and sealed they were finally tested, with the plates with which they were to be used, to determine the increase of exposure required over that on an unscreened plate. This is necessary not only to form a guide to the exposure required to get the necessary detail, but also to determine the proper ratio of exposure for the three-color negatives without which untrue colors would result. This ratio is determined by so regulating the exposures that the density given to any white or grey object, in each of the three negatives, is equal. A very suitable test object is a piece of white blotting paper so crumpled up and lighted as to form both lights and shadows. If this is pinned to a piece of black velvet, a number of exposures of varying lengths may be made on the same plate, thus facilitating comparison. For determining the increase of exposure required through the screens, all that is necessary is to make a number of exposures of suitable length, with and without filters, develop the negatives in one tray for the same length of time, and compare the resulting densities. In this way it was found that with the Cramer Instantaneous Isochromatic from 3½ to 4 times the exposure was required, when the screen was used, to get equal density of the resulting negatives. For plates sensitized with Pinachrom it was found that there was required for

The λ 5303 Green Screen 20 to 25 times exposure without screen.
" Three-Color Green Screen 10 " " " "
" Three-Color Red " 12 " " " "

The objectives proposed to be used for this monochromatic and color photography were a Cooke Photo-Visual, 4½-inch aperture and 81·8-inch focus, and a Grubb Visual, 4-inch aperture and 10-foot focus. An exposure of 60 seconds, which was proposed for the λ 5303 green, would be equivalent to 2½ to 3 seconds without a screen on the Cooke lens aperture ratio *f* 18, which is quite sufficient to get full detail in the corona. Hence there were good prospects of successful results in this hitherto untried field, but, unfortunately, clouds at North-West River prevented the final test. I have since learned that photographs through monochromatic screens were made by M. Blum at Burgos, but no information is yet to hand in regard to details or to the success of the photographs.

PHOTOGRAPHING THE SUN AND MOON WITH A 5-INCH REFRACTING TELESCOPE.

BY

D. B. MARSH.

TO give a full account of my experiments on photographing the Sun and Moon with a telescope of small aperture would take up too much space, and I shall simply describe, and that very briefly, the method by which success was attained.

The instrument used to make the accompanying photographs has a "visual" objective of 5 inches clear aperture, made by the John A. Brashear Co., equatorially mounted and clock driven.

To photograph the Sun I proceed as follows: Removing the eye-piece I insert into the adapter a negative lens of focal length 2 inches and diameter 1¼ inches. During the earlier part of my experiments I used a simple lens like Fig. 1, and with it did some fairly good work; but not being able with this to obtain a flat field and thus secure a good focus over the entire image, I went with my difficulty to Dr. Brashear and told him that I desired a lens, or combination of lenses, the same in form as above, but giving a flat field. He said, "You ask for something difficult, and I fear . . . but I will do my best for you." After some weeks I received by mail a lens which looked the same as the simple lens, but on examination it was found to be a combination of three. (Fig. 2). I place this negative lens in the adapter as if it were an eye-piece, and turn the focusing thumb-wheel till the lens is about 1¼ inches inside the prime focus of the telescope objective. I then slip the front board of the camera (with lenses out) over the outside of the adapter, having the

Fig. 1

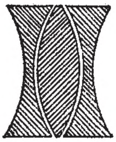
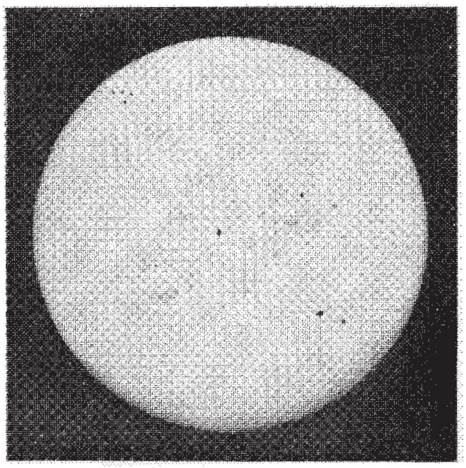


Fig. 2

THE MOON, MARCH 3, 1906.



THE SUN, JUNE 27, 1906.

ground glass about 3¼ inches from the enlarging lens. The Sun's image is then about 2½ inches in diameter, giving a negative of convenient size for contact printing for lantern slides.

By drawing out the camera so that the ground glass is about 8 inches from the enlarging lens, and slightly adjusting the focusing thumb-wheel till the image is sharp on the ground glass, a photograph of the Sun 4 inches in diameter can be obtained. Owing to the excessive light of the Sun I find it necessary to diaphragm the 5-inch objective down to 2 inches.

To expose the plate I use an aluminum drop shutter with a slit $\frac{1}{16}$ in. in width. This is driven with great rapidity directly behind the enlarging lens, making an exposure of about $\frac{1}{1000}$ of a second. I am aware that it is preferable to allow the shutter to pass very close to the plate, but this increases the danger of lines on the negative, caused by particles of dust on the slit.

To photograph the Moon the procedure is exactly the same as with the Sun, making an image of the Moon not more than 4 inches in diameter. Now, however, the full aperture of the objective is used, and the plate is exposed by hand with a cap over the objective. About half-way between the enlarging lens and the plate I insert a heavy yellow screen. This is not yellow glass, but a piece of good plate glass coated with a transparent film stained a deep yellow, which nicely serves the purpose.

The length of exposure depends on conditions. The larger the image the longer the exposure required. With a full Moon and a good sky I expose from 5 to 10 seconds, with a half Moon 15 to 20 seconds, with a crescent Moon 25 to 35 seconds.

As to plates. For the Sun, any good plate of very slow speed and fine grain will give good results. Imperial and Ilford Ordinary are satisfactory, my best results having been obtained with plates coated with lantern plate emulsion. For the Moon the most rapid chromatic plate is preferable. I have used Ilford Chromatic, also Seed's Orthochromatic with good results.

THE ASTRONOMY OF TENNYSON.

BY

JOHN A. PATERSON.

WE may read Tennyson from many points of view. He is a son of the Muses, with many poetic sides—he is polyhedral—all of them polished and lustrous. The description he himself applied to Shakespeare's *Hamlet*, "a many-faceted gem," may well be applied to him. He has an ethical side, an emotional side, a religious side, and he has over and upon these poetic sides countless gleams, streaming out, as it were, from countless facets, sparkling with not only allusions and illustrations, but with propositions of Astronomical and Physical Science. He was pre-eminently a Nature Poet, a Poet of Evolution. He was of the greatest intellectual era the world has yet seen—the Victorian era. He met and talked and thought with the great astronomers and philosophers of his day, and, like Ulysses, "he became a part of all that he had met." He spiritualized astronomy and brought it into poetry. He wove the rough strands of evolution into the golden braid of poetry, and those who refused to listen to Darwin or Huxley, listened to the sweet singer—

"Who sang to us, night and day,
The rhymes of the Universe."

Poetry has been defined, or rather described, as "beautiful thoughts wedded to beautiful words." Before the world had received the priceless gift of Tennyson's poetry, Tennyson's words and Tennyson's thoughts stood before the Altar, and the High Priest there touched life and thought on many sides. At that wedding the Music of the Spheres inspired the choristers, the rhymes of the Universe floated through the service, and the fair Muses of Astronomy and Physical Science were bridesmaids there, and cast over the nuptials the tènder grace and bright beauty of that knowledge where wisdom does not linger, but where she sits enthroned and crowned.

We all like to know great men. We all like to touch great men physically, and still more so, intellectually. Do you recall to mind how Browning looked upon a man who had spoken to Shelley?

"Oh! did you once see Shelley plain,
And did he stop and speak to you,
And did you speak to him again?
How strange it seems, and new!"

Such a touching of Tennyson is, of course, to us impossible, but we will try and touch him as a nature poet, and draw from the well of his life-work the lessons he teaches to us of that science whose potent hand binds us together in the holy bonds of Brotherhood and Sisterhood. For indeed, drawing an illustration from his *Morte d' Arthur*, we here are Knights and Ladies of a Round Table, which is immortal; the devotees of scientific pursuit belong to an eternal guild; this goodly fellowship can never be unsoldered, and never, never can be pronounced that requiem that the Laureate put into the mouth of King Arthur when his valiant knights had fallen in Lyonnesse, "man by man, about their lord." On the contrary, the Knights and Ladies of our "Round Table" stretch the world round, and when one falls out in the ceaseless struggle for truth, another takes his place, and so our "Round Table" is self-preserved, while—

"The months will add themselves and make the years,
And years will roll into the centuries."

Tennyson saw with extraordinary distinctness all that was about him, and interpreted most truly what his eye fed on. He could not take unto himself the vestment of Darwin to whom the proper study of mankind was Nature. The writer of *In Memoriam* could never fall into that limitation; he studied man, but to Nature he was open-eyed and prophet-visioned. And not only did he see definitely, but he could also construct with poetic instinct an imaginary landscape from some traveller's description. To illustrate, let me quote that great passage in *Enoch Arden*, where the poet places him alone in the boundless ocean, upon a coral island. (See the passage beginning "The mountain wooded to the peak" down to "the scarlet shafts of sunrise, but no sail.") Do you not see the shipwrecked sailor gazing wistfully seaward, and yet—no sail? The red sunrise, then the hot, white mid-day, then the crimson sunset, after that the star-spangled bosom of Heaven, and do you not hear the loud surges lash the sounding shore the live-long night? And then do you not see the next monotonous sunrise, and the long, long day, and the next, and still the next, and yet—no sail? Is it not all very plain? And thus the true observer and interpreter of Nature is revealed; the Poet of Nature is touching us, and we touch him. If thou dost not, then blame him not, thou sodden soul, but get thee hence away and read the *Dolly Dialogues*, or go and revel in that scuffle of kites and crows for carrion called "politics."

Milton was the poet of the Puritan theology. His cosmogony was unscientific. It suited the structure and plan of his immortal poem, and it reflected the ordinary teachings of his day. No doubt he was philosopher enough to understand and believe in the Copernican heliocentric theory, yet in *Paradise Lost*, he presented the ancient Ptolemaic theory, with its ponderous *impedimenta* of spheres and cycles and epicycles. A completely created man and an instantaneously and completely created Earth were the working materials, so to speak, and the installation plant of his epic. Newton then lived, but his teachings were not known, except to a few, and not clearly understood, even by them, and the popular science of England was not far in advance of the Hindoo fable of the Earth poised on the back of a turtle, and the turtle upon what the most learned Pundit could not explain. The philosophers of those days had no conception of what eras of wonder were yet to come—they had neither dreamed dreams nor seen visions. The conditions existing then were not "fifty years of Europe," with their bounding enthusiasm, but were rather "a cycle of Cathay," with its droning and drowsy and dismal conservatism. In those days, although indeed it was the far-famed Elizabethan age, poets had not touched the skirts of Science, and although poets then and for years after loved Nature, their eyes were holden and dim to the visions around them, and their ears were dull to the voices calling unto them from the great deep of Nature. It was Tennyson's privilege to see the time which Wordsworth, with prophetic vision, pictured but never saw—the greatest time the world has yet known, when Science, with a power far excelling that of the fabled magician of old, has struck the scales from men's eyes. Wordsworth, in the preface to the second edition of his poems, says: "The remotest discoveries of the chemist, botanist or mineralogist (and let me add to that the astronomer) will be as proper objects of the poet's art as any upon which it can be employed, if the time shall ever come when these things shall be familiar to us, and the relations under which they are contemplated by the followers of the respective sciences shall be manifestly and palpably material to us as enjoying and suffering beings. If the time shall ever come when what is now called "Science," thus familiarized to men, shall be ready to put on, as it were, a form of flesh and blood, the poet will then lend his divine spirit to aid the transfiguration and will welcome the being thus produced as a dear and genuine inmate of the household of men."

He who wrote those golden words never saw the time that he thus so eloquently prophesied, and thus a double loss, one to him and another to the human family.

The Chinese have a proverb—"A man is more like the time in which he lives than he is like his father or his mother." Tennyson met the great scientists of his day, and he took from them both color and contour. His day was a very treasure-house of scientific accomplishment, and from this vast thesaurus, many a golden nugget of scientific truth rolled to his feet, which he took, and with the magic touch of his poetic fancy he stamped as if in a mint and it became coin current, not only for the lady in her boudoir and the man at home, but also for the *litterateur* and the scientist.

We learn from his niece, Miss Agnes Grace Weld, that her uncle was very intimate with the Rev. Charles Pritchard, Professor of Astronomy at Oxford, and we read of Professor Pritchard bringing his microscope to Farringford and showing some recent deep-sea dredgings by polarized light. Tennyson and he worked together at astronomy and geology, and so from Nature up to Nature's God. Professor Pritchard has recorded how struck he was with Tennyson's manner one day, when a scientific man was arguing against religion. Said the Laureate to him, bringing down his fist with tremendous force on the table at which they were sitting and addressing him by name, "There is a God." Pointing, one evening, to the myriads of stars shining above, he said to a friend, "Can some of these other sheep of whom Christ speaks be the dwellers in those distant worlds we are now gazing upon?"

His son also records that, on the evening of that July day of 1855, when Oxford University gave him his Doctor's degree with great *éclat* in the Sheldonian Theatre, Professor Johnson and Professor Adams (he of Neptunian fame), with the poet looked at the nebula in Cassiopeia through the big telescope and also at the ring nebula in Lyra, and some double stars. Not only from the science of astronomy did he draw that wisdom with which he decked his verses, but also from books of travels and Lyell's *Geology*. From an incident recorded in Thomas Pringle's *Travels in Africa*, came the lines in *Locksley Hall:*

> "Slowly comes a hungry people, as a lion creeping nigher,
> Glares at one that nods and winks behind a slowly dying fire."

We also read that scientific leaders like Herschel, Owen, Sedgwick and Tyndall, regarded him as a champion of science, and cheered him with words of genuine admiration for his love of Nature and for the eagerness with which he welcomed all the latest scientific discoveries, and for his trust in Truth.

Many angry things have been said about Carlyle, and not unjustly, on account of these words of his upon Darwin's *Origin of Species:* "Wonderful to me, as indicating the capricious stupidity of mankind,—never could I read a page of it or waste the least thought upon it." Tennyson had the portals of his mind wider open to Truth, and they closed only when she entered. I speak here of the views of Tennyson on evolution generally, although our subject is "Tennyson's Astronomy," but the one includes the other, for the domain of evolution is universe-wide.

Tennyson, when a very young man, in *Locksley Hall* thus interpreted the calm method of Nature and Time in emancipating man:

> "I, that rather held it better, Man should perish one by one,
> Than that Earth should stand at gaze, like Joshua's moon in Ajalon,
> Not in vain the distance beacons. Forward, forward, let us range,
> Let the great World spin forever down the ringing grooves of change,
> Through the shadow of the globe, we sweep into the younger day,
> Better fifty years of Europe than a cycle of Cathay."

Let us hear what he says upon the doctrine of evolution, not only as to our little Earth—a mere speck of dust, as it is, in the

Almighty's balances, which might be blown away with His breathing, and the balances not quiver then by the infinitesimal part of a hair's breadth—not only as to our little Earth, but as to the whole sweep of the Universe, from zenith to nadir, and to the utmost confines of the great concave, if confines there be. (See *The Two Voices* from "I said when first the World began," and the six following stanzas.)

Truly it is a wondrous conception that "in yonder hundred million spheres" there may be intellects enshrined in material coverings of some kind or other who look up to the same firmament as we do. And to those who neighbor us, the Pleiades, "like a swarm of fire-flies tangled in a silver braid," sparkle in the dark; to them, too, Orion blazes with his gorgeous belt; to them also, the pale daughter of Andromeda displays her trembling jewels. The sciences of geology, mineralogy, botany, entomology, chemistry, zoology are earth-centred; we here have our own objects of research, our own elements, our own flora and fauna, our own laboratories; and our brethren throughout the great concave have their own chemical elements too, all of them perhaps, and some of them, no doubt, identical with ours, for so the spectroscope and the language of Fraunhofer's lines teach us. But yet even these cannot be tangibly and actually the same. But with the science of astronomy it is different, for the book and volume of the sky is ours, and also theirs. The scroll of the firmament unrolled before us in all its glory, is also unrolled before them in all its panoply of wonder. In a word, the whole of our Universe reads and learns from the same text-book, and yet there may be other Universes which have different firmaments, and therefore read and learn from different text-books, unfolded and illustrated as ours is by the luminous fingers of Father God. And thus throughout creation there may be whole libraries of Text-Book Firmaments, manuscripts of God revealed and slowly spelled out by created intelligences.

But to follow once again the path of our author's teaching, let me quote in further illustration of the same principle, from the "Ode on the death of the Duke of Wellington." See division lx. from the lines "For though the Giant ages heave the hill," down to "What know we greater than the soul?" and again from *The Ring*, the lines:

"Æonian Evolution, swift or slow,
Through all the spheres—an ever-opening height,
An ever-lessening Earth,"

meaning that ages have passed and generations have occupied the stage of life and the great law of progress is very slow.

See also in *Maud* (part 1, iv, 6):

"So many a million of ages have gone to the making of man.
He now is first, but is he the last? Is he not too base?"

Tennyson, in his poem entitled *Parnassus*, exalts the twin sister-sciences, astronomy and geology, as Muses whom the innumerable succession of years and the flight of seasons cannot destroy.

As illustrative of his doctrine of evolution of man himself, the goal to which Nature aims, he writes in *By an Evolutionist;*

The Lord let the house of a brute to the soul of a man," etc.

And in that same connection occurs that stanza in *In Memoriam :*

"Arise and fly,
The reeling Faun, the sensual feast,
Move upward, working out the beast,
And let the ape and tiger die."

The most popular illustration we have of evolution in astronomical science, is the nebular theory in one or other of its many different forms. Since Laplace's time a great interest had been shown in it and libraries had been written approving, modifying or condemning it. But it was not until 1833 that any English poet, or, indeed, any worker in pure literature, saw its importance as indicating a new standpoint for human thought, or, indeed, gave it any consideration at all. In a foot-note to the *Palace of Art*, published in that year, appeared some stanzas which afterwards disappeared from Tennyson's poems ;

"Hither when all the deep unsounded skies
Shudder with silent stars, she clomb,
And as with optic glasses her keen eyes
Pierced through the mystic dome,
Regions of lucid matter taking form,
Brushes of fire, hazy gleams,
Clusters and beds of worlds and bee-like swarms

Of suns and starry streams;
She saw the snowy poles of moonless Mars,
That marvellous round of milky light
Below Orion and those double stars
Whereof the one more bright is circled by the other."

No poet having literary knowledge, and no more than that, could have written these lines. Here we have the nebular theory —star clusters, Mars' snow-capped pole, the nebula of Orion and the double stars. But though Mars was moonless then, the great telescope at Washington, forty-four years after, discovered two moons, although small and insignificant, and therefore to give the offending line scientific accuracy and to save it from the astronomer's criticism, it has been altered so as to read: "She saw the snowy poles and *moons* of Mars." But we have more of the nebular hypothesis. We find in *In Memoriam*, section lxxxix:

"And last, returning from afar,
Before the crimson circled star,
Had fallen into her father's grave."

Here we have Venus surrounded by the red sunset, setting after the Sun, the Sun being her father, as being the remainder of the original nebula.

And still more and more fully in the address of Lady Psyche to the freshettes of her day in their academic silks in *The Princess* (that herald melody of the higher education of women):

"This world was once a fluid haze of light,
Till towards the centre set the starry tides
And eddied into suns that wheeling
Cast the planets."

And in another wonderful passage he says:

"There sinks the nebulous star we call the Sun,
If that hypothesis of theirs be sound."

And yet again from that perennial fountain, *In Memoriam* (section cxviii), comes this—

"They say
The solid Earth whereon we tread
In tracts of fluid heat began,
And grew to seeming random forms
The seeming prey of cycle storms,
Till at the last arose the man."

Furthermore, our poet must have known something of the theory of the impact of stellar masses, developed since then by Dr. Croll and others. According to this doctrine systems of worlds grow old, and after æons of planetary and stellar decrepitude grow cold, and wander darkling through space, and then under the force of gravity, with fierce velocity collide, and again a growing nebula is re-formed, to pass again through all the gradations of its life, till other planetary systems are again formed, and thus even, although "the Heavens shall pass away with a great noise and the elements shall melt with fervent heat, and the Earth also and the works that are thereon shall be burnt up," yet that is but a process of Nature, and Nature shall again and yet again be re-created in virgin purity and brightness. Hear, too, this poet-philosopher in *Lucretius:*

"For so it seemed
A void was made in Nature. All her bonds
Cracked, and I saw the flaring atom streams
And torrents of her myriad Universe,
Ruining along the illimitable inane,
Fly on to clash together again, and make
Another and another frame of things forever."

And yet again in the same poem, touching the same thought of a continuous re-creation:

"And therefore now
Let her that is the womb and tomb of all
Great Nature, take, and forcing far apart
Those blind beginnings that have made me man,
Dash them anew together at her will
Thro' all her cycles—into man once more," etc.

Mingled with the truths of astronomy, Tennyson had a clear conception of man's spiritual significance, on the one hand, and of man's physical insignificance on the other, and thus we have in the poem, *Vastness:*

"Many a hearth upon our dark Globe sighs after many a vanished face,
Many a planet by many a sun may roll with the dust of a vanished race.
Raving politics, never at rest,—as this poor Earth's pale history runs.
What is it all but a trouble of ants in the gleam of a million million of Suns,"

Tennyson, moreover, knew of the phenomenon of Saturn and his ring, as all ordinary scholars know, but he knew more than most. Doubtless with his astronomer friends, as we have seen, he had been to some extent an amateur observer. No man could write as he wrote if he had only read and heard but had not also seen. He had observed the shadow of the planet upon the ring, and so he writes in the *Palace of Art*;

"And while the world runs round and round, I said,
Reign thou apart, a quiet king,
Still as, while Saturn whirls, his steadfast shade
Sleeps on his luminous ring."

In the lines in memory of Prince Albert appears a fine idea, which at first looks commonplace, but when studied speaks beautifully:

"Her, over all whose realms to their last isle
Commingled with the gloom of imminent war,
The shadow of his loss draws like eclipse,
Darkening the world."

What a noble picture of the Earth and our neighbor Venus is presented in a short fragment, "Move eastward, happy Earth, and leave," etc.

We have a beautiful illustration of the nuptials of poetry and astronomy in *In Memoriam* (section lxxvi).

"Consider," the poet says, "the utter insignificance of the Earth and man's life in the Universe of Worlds. Consider the immeasurable ages of the future, and then reflect that their noblest songs shall be forgotten in much less than the lifetime of a tree on the Earth." "Sharpened to a needle's end" surely means—look away into the depths of space, so far, far away that it shrinks to nothing and dwindles to a needle's point. The same thought is as beautifully expressed, and with a great opulence of astronomical illustration, in the epilogue to *The Charge of the Heavy Brigade*, near the end, in the lines:

"The fires that arch this dusky dot,—
Yon myriad-worlded way,—
The vast sun clusters' gathered blaze
World-isles in lonely skies,
Whole heavens within themselves amaze
Our brief humanities."

In *Locksley Hall*, "Sixty years after," we see again his constant refrain of man's insignificance in the Universe and the evolution of the Earth and man :

"'What are men, that He should heed us?' cried the King of Sacred Song;
'Insects of an hour, that hourly work their brother insects wrong,'"

That is an entrancingly beautiful description of the Earth and Venus neighboring each other and regarding each the other as dwelling places of sentient beings, in the same poem, commencing with the line, "Venus near her! smiling down at this earthlier earth of ours," etc., etc.

In *Lucretius* we find a wonderful description of inter-stellar space in the lines commencing :

"The gods who haunt
The lucid interspace of world and world,"

etc., and we immediately think of the coal sack regions in space, and the great empty ring of vast emptiness and blackness that surrounds our solar system and gives it a splendid isolation, so vast, indeed, that even the onward sweep of the apex of the Sun's way towards Hercules or Vega touches it with little or no calculable effect.

Our poet, too, like Milton, had some knowledge of the technical terms of the science. In *The Princess*, he puts into the speech of Gama :

"You talked whole nights-long up in the Tower
Of sine and arc, spheroid and azimuth,
And right ascension, and Heaven knows what."

It is a saying often quoted, "The undevout astronomer is mad," and the correlate is also true that every devout man, though he may not be skilled in astronomy or know little of its principles, should know something of its scope and of its wonders, and his devoutness will thus be lifted higher and become ennobled.

Tennyson was, I think, the first poet who has woven into the magic of his verses the wonders of the spectroscope. Remember, he lived near London for a long period and he doubtless had been often at Greenwich and had heard the great scientific leaders of the day discuss their great discoveries. In one of his Memoirs he is described as saying "that the spectroscope was destined to make much greater revelations even than it had already made.'' In that masterpiece, *In Memoriam*, he has this stanza :

> "A time to sicken and to swoon,
> When Science reaches forth her arms
> To feel from world to world, and charms
> Her secret from the latest Moon?"

This is a triumphant optimism. It is no time to sicken and to swoon when Science has made such wonderful progress and achieved such magnificent triumphs. And again in the same poem :

> "He thrids the labyrinth of the mind,
> He reads the secret of the star,"

These references to spectrum-analysis do not seem so very remarkable now, but remember that *In Memoriam* was written between 1840 and 1850, and at that time the discoveries of Fraunhofer and Brewster, and Wheatstone and Foucault had not awakened much popular attention, and, indeed, many books on astronomy contained little reference to the subject of spectrum-analysis.

As another illustration of how Tennyson applied Science to illustrate his poetic thought, take the last stanza of section xcii of *In Memoriam :*

> "They might not seem thy prophecies,
> But spiritual presentiments,
> And such refraction of events
> As often rises ere they rise."

Here we have the phenomenon of ''refraction''—presentiments of things yet to come are visible before their realities, as the Sun appears to rise before he actually rises, by the refractive effect of the atmosphere. And this is what he means by the ''refraction of events.'' It is a beautiful figure taken from the field of optical science, as beautiful and suggestive as that other figure of Tennyson's taken from the field of economic science :

> "But who shall so forecast the years
> And find in loss a gain to match,
> Or reach a hand through time to catch
> The far-off interest of tears."

That is, that deep grief may, after all, be an advantage to the properly constituted mind ; that sorrow may, after all, though forced upon us, be a good investment which will bring some rich reward in the future days of these our lives, "the far-off interest of tears." His imagination was so truly poetic, so opulent in beautiful figures, that arts, science and even cold every-day commerce were all tributary to this Master of Song.

I find in some personal recollections by Jowett, the late Master of Balliol College, Oxford, that the poet's great-grandfather had taught him some of the wonders of the starry heavens in a manner which remained with him through life. He was also greatly pleased when informed that Proctor, the astronomer, had said of him that he had made no mistake about the stars in his poems, and a similar compliment was paid to him by an eminent botanist about flowers.

Professor John Tyndall records that he visited the Laureate at Farringford and was admitted to the little room at the top of the house, and there he saw the Atlas of Keith Johnston lying upon the table and also charts of isothermals and isobars, intended to insure the exactitude of some allusions of his to physical science. To secure accuracy in these, he spared no pains. He wanted to be sure of the truth of his metaphors. Lord Houghton states that Tennyson, after composing an exquisite poem upon a flower, discarded it because of some botanical flaw. Mr. T. Watts Dunton speaks also with authority on Tennyson's knowledge of Nature. "Since Dante," he says, "no poet so loved the stars. He had a passion for star-gazing and loved to be bathed in the moonlight." And it is specially pathetic that in a fatal syncope on the 6th of October, 1892, while the light of the full moon, and no other light, streamed through an oriel window over his princely form, this great poet passed as Arthur passed :

"To the Island Valley of Avilion,
Where falls not hail, nor rain, nor any snow,
Nor ever wind blows loudly : but it lies
Deep meadow'd, happy, fair with orchard lawns
And bowery hollows crowned with summer sea."

ACHIEVEMENTS OF NINETEENTH CENTURY ASTRONOMY

BY

L. H. GRAHAM.

WE of the nineteenth and twentieth centuries are prone to forget the achievements of other ages. We have only to recall the names of Ptolemy of the first century, whose earth-centred speculations dominated for 1200 years; of Copernicus whose sun-centred theory wrenched from the universe a great and fundamental truth; of Tycho Brahé of the sixteenth century, who, while repudiating the sun-centre conception, catalogued 777 fixed stars; of Kepler, immortal because of his famous laws, which were foundation stones in the architecture of the universe. We must mention Galileo of the sixteenth, the honored inventor of the telescope, and Newton of the seventeenth, whose law of gravitation is obeyed throughout an infinite range. We pass Huygens and his acquaintance with Saturn, Bradley and his discovery of the aberration of light, and his 60,000 observations. The eighteenth century yielded Sir William Herschel, one of the greatest observational astronomers, who, in 1789, completed his monster forty-foot reflector, and instituted methods of star-gauging which gave a conception of the depths of space. Herschel's work continued for twenty-two years of the new century, during which time he was associated with almost every advance in astronomy. As though by an expiring effort the eighteenth century gave forth from the intellect of Laplace the "Nebular Hypothesis," published in 1796, and which still remains the most probable solution of the genesis and evolution of the material universe.

Thus are we landed on the threshold of the nineteenth century, which certainly fell heir to a gigantic legacy. To carry on the work more highly skilled labor was required, to improve, to refine, to invent. How well this was accomplished remains to be noted.

To comprehend in the compass of an hour the achievements of the Victorian age would be an impossibility. Every nation from America to Japan boasts its honored astronomers and so many workers must be passed over.

To give the great mass of material an organized form, we shall examine it under the following sub-divisions: (1) Instrumental, (2) Spectroscopic, (3) Photographic, (4) Electrical, and (5) Oservational and Inferential.

(1) Astronomical telescopes are (*a*) reflectors, (*b*) refractors. The types of the reflectors are the Newtonian, Gregorian and the Herschelian, differing in details only. The problem of the perfect form of mirrors was solved by substituting the curve of a rotating parabola for that of a partial sphere, thus eliminating the bugbear of spherical aberration. Speculum-metal, an alloy of 126 parts of copper to 58·9 of tin, was cast in the form of mirrors, hence called specula. This takes a fine polish, is hard yet brittle, hence difficult to handle, as almost infinite exactitude is imperative. In 1839 two fine specula, three feet in diameter were polished by steam power. This art of polishing reached such perfection that, in 1842, a six-foot mirror with focal length of 54 feet was completed by Lord Rosse, and set up eighty-nine miles west of Dublin. This remains the largest telescope in the world, with a normal power of six thousand and showing the Moon at 40 miles. But this apparent advantage is nullified by its low position and the troubled state of the air. In 1856 and '57 silvered glass was substituted for speculum-metal, thus increasing the reflecting power $1\frac{1}{7}$ times, besides involving less risk and labor.

During the first half of the century the refractor was superseded by its formidable rival. But the difficulty of chromatic aberration was gradually overcome by combination of flint and crown glass. Then followed, about the middle of the century, by Alvan Clarke and others, a large number of magnificent refractors such as are found at the Lick of California or the Yerkes of Chicago. This latter has a 40-inch aperture, and a 63-foot tube. The cell containing the lenses weighs 1000 ℔s, and the whole is exquisitely balanced on roller bearings and is operated by electrical and hydraulic power.

A climax of mechanical perfection has been reached. The next advance was to get rid of the atmospheric troubles by selecting an elevated aerial calm. The Lick Observatory is 4200 feet above sea-level, and Arequipa, where W. H. Pickering and others have done such excellent work, is 8000 feet high.

The refractor and the reflector are still formidable rivals and it is difficult to forecast the trend of future improvements.

(2) We now proceed to spectroscopic astronomy. Little did astronomers of one hundred and fifty years ago dream, that in the colors that destroyed their labors, lay the means of interpreting the most subtle cosmic phenomena, unreachable, unfathomable by any other means.

The elementary facts of the spectrum were known, and although investigated by Melville, in 1753, with regard to flumes, little of value was accomplished until 1802 when a narrow slit was first used, and in 1814–15 Fraunhofer discovered the transverse lines of the solar spectrum. He counted about 600, mapped 324, and lettered the most prominent. Thus matters stood for nearly fifty years, when, in 1859, Kirchhoff formulated the general principle that vapors and gases of every kind are opaque to the precise rays which they emit, thus providing a key to mysterious lines and bands, and at the same time founding the science of spectroscopy. Kirchhoff's eight-foot map, published in 1862, was accepted as an accurate record of facts, retaining the lettering of Fraunhofer. As a reversing gaseous layer was necessary, such was postulated and afterwards proven to exist in the Sun. He proved the presence of many of the common metals in the solar furnace.

An exhaustive study of terrestrial spectrum analysis followed, forming an idea for further solar and stellar investigation by Sir Norman Lockyer and Professor Young on the Sun's surface as to the character of the spots and its atmosphere. Jansen, in 1868, instituted daylight observances of the prominences, while, in 1869, Professor Harkness discovered that the green ray of coronium in the Sun's corona extended at least 300,000 miles above the Sun's surface. Professor Young discovered the hypothetical "reversing layer" during an eclipse, which he showed to be a tranquil area of from 500 to 600 miles in depth.

The spectroscope also solved the problem of radial motion by minute displacements of the Fraunhofer lines. This was first enunciated in 1842 by Doppler, but the first measurements were by Sir Wm. Huggins in 1868. The reversion spectrum of

Zöllner doubled the line displacements, and Vogel showed that the eastern edge of the Sun approaches at a velocity of 1¼ miles per second, thus proving its rotation. The nature of the sun-spots was studied as were also the up-rushes and counter-gales at 250 to 500 miles per second and to a height of 54,000 miles. Lockyer studied "celestial dissociation" and conceived that elements as oxygen and nitrogen are broken up into simpler molecular constituents. The same investigator labored from 1875 to 1878 on the violet end of the spectrum on a grand scale, which if completed for the whole spectrum would extend 300 feet. He also studied periodicity of sun-spots. Professor Rowlands studied the terrestrial spectra, photographing all those of procurable elements, and later, with assistance from Johns Hopkins University, determined the length of 16,000 solar lines. This placed solar spectrum analysis on a firm basis.

The spectrum of stars and nebulæ was studied by Huggins, who discovered a nebula of glowing vapor in Draco. This and other researches led to the classification of stellar bodies. Almost simultaneously Huggins in England, Secchi at Rome, and Rutherford of New York entered this promising field. Secchi's four types of stars formed a basis for future research, with more refined methods. His four orders are all suns. Other investigators, as Vogel, Lockyer, and Miss Maury, have modified his classification. The whole work has shown a stellar evolution from primitive nebulæ, leading on to robust young suns, of the Sirian type and more mature bodies like our Sun, on to those hoary with age, giving up the sidereal battle to fall into the tomb of darkness.

(3) Photography has been an ally to the telescope by giving permanent records often far beyond the ken of the eye. Draper was an early worker (1840). In 1875 Rutherford produced photographs of the Moon unrivalled for twenty years. In 1878 the camera was applied to eclipse work. In 1886, at Gill's proposal, with Paris as a centre, a photographic chart of the whole heavens was initiated. To complete the work 22,000 plates, each covering four square degrees, and made with uniform telescopes, will give a chart of stars up to the eleventh magnitude. The surmised number is 20,000,000 stars, and twenty-five years was allotted for the enterprise. The work is now satisfactorily

strated, also that the whole spectrum occupied a range three or four times the extent of the visible area. By this wonderful instrument it was demonstrated that three-fourths of the solar energy lies in the infra-red, and scarcely one-hundredth in the ultra-violet. In 1901 Langley embodied his researches in a splendid chart, exhibited before the British Association. He demonstrated that atmospheric absorption was greater in the violet than in the red, and that it varies inversely as the wave-length, and concludes that, if the atmosphere were removed, the Sun would be three or four times more brilliant and of a distinctly greenish-blue color. Many other valuable facts were established, giving the bolometer the very front rank as an instrument in research.

(5) To even enumerate the achievements, observational, mathematical and speculative, of the past century would surpass the limits of a review. Every region of the universe, whence an appreciable quantity of light penetrates our telescopes, has received careful scrutiny. Comets have received extended study by Bredikhine, of Moscow, and others. The Moon, hoary with age, has been exploited by every astronomer, at some period of his work. The valuable work of W. H. Pickering deserves special notice. Each planet has received profound attention. Mars with its snow-caps, "canals" and satellite problems; Jupiter, with its bands and red spots; Saturn, with its varying ring velocities, —all presented fields for speculation and investigation.

A sustained interest has been taken in eclipses, and in the relation of magnetic disturbances to sun-spot phenomena. The surface of the Sun and its gigantic spasms of energy have been studied. Its diameter, period of rotation, the inclination of its axis, have been solved. The nature of its atmosphere, its "reversing" layer, its forms of corona, its unfamiliar elements are problems, together with others without number, that have accumulated on the outer rim of nineteenth century investigation, and are carried over into the twentieth and other centuries for solution.

progressing. Prof. E. C. Pickering, from 1886 to 1889, was instrumental in storing 56,000 plates of the heavens and the number is now over 180,000.

The photographing of the solar spectrum was accomplished by Professor Rowland in 1886, the map having a total length of forty feet, showing thousands of dark lines. Spectrum photographs also were obtained about this time showing line displacements due to radial motion. The spectroheliograph, a combination of the spectroscope and the camera, was practically utilized by Hale and Deslandres about 1889. By this instrument a picture is built up by successive sectional impressions. This remarkable instrument can be used to give photographs at different levels in the Sun's atmosphere, dependent on the fact that vapors of different densities yield different widths of bands. The photographic plate has done good work in revealing lines such as those of Victorium, Helium, and Coronium, as well as hosts of lines in the ultra-violet, beyond the visible vibrations. Thus the astronomical applications of the camera have given permanent records, and fields have been investigated unreachable without its aid.

(4) In astronomical research electricity and its applications have but a limited range. The intense heat of the arc has been used to volatilize metals for spectrum analysis, thus supplying a key to the meaning of the celestial spectra. Rowland, in 1889, obtained arc-spectra to complete his solar chart. One of the most noted inventions was the remarkable bolometer by Professor Langley,* of Washington, which gave heat measurements of a delicacy hitherto undreamt of. It consists of a combination of the spectroscope, the camera and the electric current. The varying flow, due to heat, in a delicate platinum or iron wire, when it is passed through the spectrum, yields differences as small as or less than the ten-millionth of a degree. This variance is indicated by a galvanometer and automatically photographed. Thus it was shown that the hottest part of a spectrum coincides with its point of highest luminosity, in the range close to the *D*-line, destroying the hitherto supposed, three-fold nature of the spectrum. In elevated regions the bolometer became surer and stronger, and an enormous expansion of the spectrum below the red was demon-

---

* Died February 27, 1906.

A LUNAR TIDE ON LAKE HURON.*

BY

W. J. LOUDON.

INTRODUCTORY.

SEICHES are periodic oscillations of any large body of water, caused by the action of wind. The movement which produces them may be compared to that which takes place when, for example, a basin of water is tilted, and then restored to rest. The water in the basin oscillates *bodily* to and fro, this motion being quite distinct from that which arises when a small object is dropped into water and generates *waves*.

The period of oscillation of a *seiche* is found from a theoretical formula, $t = \frac{l}{\sqrt{gh}}$, where l is the length of the body of water and h is its mean depth, g the acceleration of gravity.

The apparatus used for determining the time of the *seiche* and also for the tracing of the curves representing the lunar tides was constructed as follows:

A hollow cylinder, of galvanized iron, about three feet in length, was placed with its axis horizontal, and was rotated by means of clock-work about this axis once in twenty-four hours. Around the cylinder was wrapped a sheet of paper against which rested a pen filled with ink, and attached by means of a system of pulleys to a float resting on the surface of the water, and protected from local action by a wooden pipe fixed vertically in the water. In order to allow free action of the water on the float, the pipe was open at the bottom and contained a number of inch holes underneath the surface of the water. As the float, which was quite free, rose and fell under the influence of the wave motion, the pen traced on the cylinder the corresponding curves, and, by marking on the paper the time of setting the pen at any point, and subdividing the circle into twenty-four equal parts, the time of any particular wave form could be subsequently calculated.

---

* This investigation was made with assistance from the Canadian Meteorological Service and is published by courtesy of its Director.

The cylinder was of the convenient circumference of twenty-four inches, so that an inch in length on the curve corresponded to an hour of time.

THE LUNAR TIDE.

In examining the curves of *seiches* during the latter part of August, 1905, I was struck several times with the regularity of their general outline, which seemed to be more marked in the absence of wind; and, during the very calm weather of September 6 – 10, I was almost convinced of the action of a lunar tide on the water of Lake Huron and Georgian Bay. The curves for this period showed a well-marked and regular rise and fall twice a day: and although at first I attributed this to a "seiches" movement (because of the previous rough weather), yet a few calculations proved that no oscillation of the lake could give a period of twelve hours.

The average depth of the Georgian Bay is probably two hundred feet, and, as its greatest length is about one hundred and twenty-five miles, its greatest oscillation from end to end could not be more than $\frac{l}{\sqrt{gh}}$ seconds, the time of a single oscillation.

This gives for a complete period of oscillation the value $2 \times \frac{125 \times 5280}{\sqrt{32 \times 200}}$, which reduces to 16,500 seconds or four hours and thirty-five minutes.

Lake Huron itself is deeper than Georgian Bay, having an average depth of probably five hundred feet, and the greatest distance across it, from Mackinac to Moose Deer Point, is about two hundred miles. The time of an oscillation of the lake for this extreme distance could not be much greater therefore than

$$\frac{200 \times 5280}{\sqrt{32 \times 500}}.$$

Twice this number would represent the time of a complete oscillation and would be $\frac{2 \times 200 \times 5280}{\sqrt{32 \times 500}}$, which reduces to

$5280 \sqrt{10}$ seconds, or $88 \sqrt{10}$ minutes, or four hours and forty minutes.

By making calculations similar to the foregoing, I satisfied myself that no oscillation of the lake could possibly produce a period of time extending much beyond four hours, and I was thus led to infer from the oscillation exhibiting a period of twelve hours, the presence of a true lunar tide.

As the pulleys of the tide apparatus were adjusted so as to increase the amplitude of the wave-motions in the ratio of five to three, I proceeded to re-arrange them according to a simpler scheme, so that the tracing of the pen should give the true rise or fall of level, and I should thus be able to obtain the exact value of the tidal change.

I then waited patiently for another calm spell of weather, in order to get, from the records, additional testimony to add to that of the period September 6–10, and to determine, if possible, the maximum and minimum tides.

It was not, however, until September 26 that the weather began to show signs of becoming settled. Fortunately the following day, September 27, was still more settled with all the appearances of prolonged calmness, the barometer being almost stationary. And then, for a period of three whole days, from the evening of September 28 to the evening of October 1, the weather was so calm and the water apparently so quiet as to insure perfect records.

With the exception of a very faint breeze which blew now and then for a few hours during the daytime and was always local, the surface of the lake, as far as could be seen, was like a sheet of glass, which reflected back the rays of the Sun so as to form a perfect image, without a trace of diffusion at the surface of the water.

And it may be added here that during both periods in which I observed the tidal action the weather was not local, but, as the following report shows, prevailed over the whole of Lake Huron and Georgian Bay and probably extended to Lake Superior.

WEATHER ON LAKE HURON,
SEPTEMBER 6-10 AND SEPTEMBER 28–OCTOBER 1, 1905.

HEIGHT OF BAROMETER AND DIRECTION AND VELOCITY OF WIND.

	ALPENA.				PORT HURON.		
SEPT.	A.M.		P.M.		A.M.		P.M.
6	30.12	N.W. 8	30.14	N. 4	30.10	N.W. 10	No reports.
7	30.20	N.W. 6	30.14	W. 6	30.18	S.W. 4	"
8	30.26	N.W. 6	30.24	S.E. 4	30.20	N. 4	"
9	30.26	W. 4	30.18	S. 10	30.28	S.E. 4	"
10	30.16	S.W. 4	30.02	S. 6	30.16	E. 4	"
28	30.10	W. 4	30.04	S.W. 4	30.08	S. 8	"
29	30.12	W. 4	30.06	S. 4	30.10	S.W. 4	"
30	30.14	W. 4	30.04	S.E. 4	30.12	S.E. 6	"
OCT.							
1	30.00	S. 8	29.96	S. 6	30.04	S. 8	"

	SOUTHAMPTON.				PARRY SOUND.			
SEPT.								
6	30.04	N 10	30.10	N. 4	30.02	N.W. 4	30.08	W. 8
7	30.14	N.W. 6	30.12	C. 0	30.12	C. 0	30.10	W. 4
8	30.20	N. 4	30.22	N. 4	30.18	C. 0	30.20	W. 4
9	30.28	S. 4	30.18	S. 4	30.30	W. 4	30.18	S.W. 4
10	30.16	S. 6	30.00	E. 4	30.16	S.W. 4	30.04	N.W. 4
28	30.14	S.W. 6	30.04	N. 4	30.08	W. 4	30.02	N.W. 4
29	30.12	S.W. 4	30.06	S.E. 4	30.10	N. 4	30.06	C. 0
30	30.16	S. 4	30.04	E. 4	30.12	N.E. 4	30.04	N. 6
OCT.								
1	30.02	S. 8	29.98	W. 8	30.04	N.E. 6	29.96	N. 4

It will be seen from this statement that during the period extending from September 6 to September 10 the average velocity of the wind was about four miles an hour and was very variable in direction, so that one can infer that in most places it was entirely local, and due to changes of temperature.

Also, from September 28 to October 1, the average velocity of the wind was about five miles an hour, and more variable in direction during the day than in the former period. I am, I think, safe in saying, from an inspection of this weather record for the two calm periods, that the oscillation of the lake was caused only by the combined action of the Sun and Moon on the water of Lake Huron and Georgian Bay, and that the corresponding curves represent true lunar tides, similar to those which occur in the ocean, but very much smaller in extent.

The following records are given in the order in which they were registered, and show at a glance the sinuous curve indicating a rise and fall of the water level twice a day :

Fig. 1 represents a lunar tide, disturbed by the presence of a movement due to a west wind, which gives the curve a very complicated appearance, but shows at the same time a distinct rise and fall every twelve hours.

This record of September 7 was the first which gave me any positive evidence of the existence of a tide, for it seemed improbable from calculations made that the rise and fall could proceed from a "seiches" movement caused by wind. The interval is from September 7, 9:10 p.m. to September 8, 9:10 p.m.

Fig. 2 is the record for the interval of twenty-four hours, extending from September 8, 9:27 p.m. to September 9, 9:17 p.m. This is complicated by a wind, but as it was very light, the rise and fall are more regular than in the previous record.

Fig. 3 represents the tide of the interval, September 9, 9:23 p.m. to September 10, 9:23 p.m., twenty-four hours. The effect of the wind of the previous days is still in evidence.

In the original records, the paper was twenty-four inches in length, corresponding to the circumference of the cylindrical section, and the time of revolution of the cylinder was twenty-four hours; so that the above figures, as well as those which follow, are true to a horizontal scale of one inch to one hour of time.

Fig. 4 is a record of September 25, 5:30 p.m. to September 26, 5:30 p.m., and was taken because I was uncertain about being able to obtain more records, and the time was drawing near for my departure from the Station. It is interesting, because, in spite of a strong north wind, it shows evidence of a tide, and also because of the regular "seiches" movements which appear in combination with the tidal curve.

Fig. 5 shows the tide of September 28, 6:05 p.m. to September 29, 6:05 p.m., an interval of twenty-four hours. During this time there was no wind, except an occasional puff arising from inequality of temperature in the neighborhood of rocky points projecting into the lake. It is slightly complicated by oscillations of the lake due to previous rough weather.

Fig. 6 shows the tide of the following twenty-four hours, from September 29, 6:05 p.m. to September 30, 6:05 p.m.; and although this record was disturbed by a south-east wind for two hours, yet the only effect this had was to displace the curve

Tide disturbed by west wind

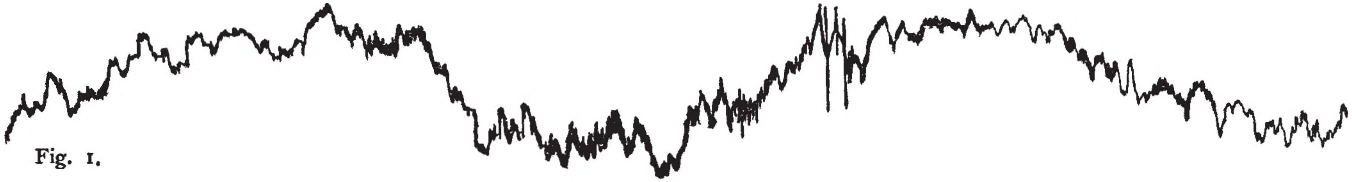


Fig. 1.

Sept. 7,'05, 8:10 p.m.
to Sept. 8,'05, 8:10 p.m.

Tide with light south-west wind

Fig. 2.

Sept. 8,'05, 8:27 p.m.
to Sept. 9,'05, 8:27 p.m.

Tide with faint breeze from south

Fig. 3.

Sept. 9,'05, 8:23 p.m.
to Sept. 10,'05, 8:23 p.m.

TIDE DISTURBED BY NORTH WIND

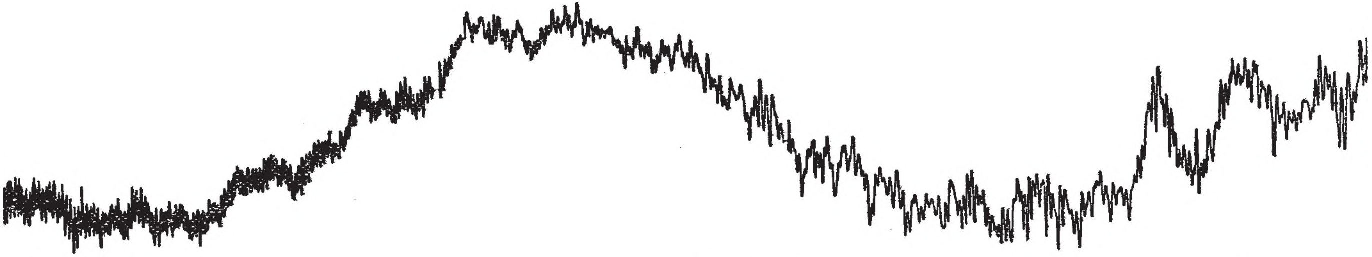


Fig. 4.

Tide slightly disturbed for two hours by south-east wind.

Sept. 25,'05 5:30 p.m.
to Sept 26,'05, 5:30 p.m.

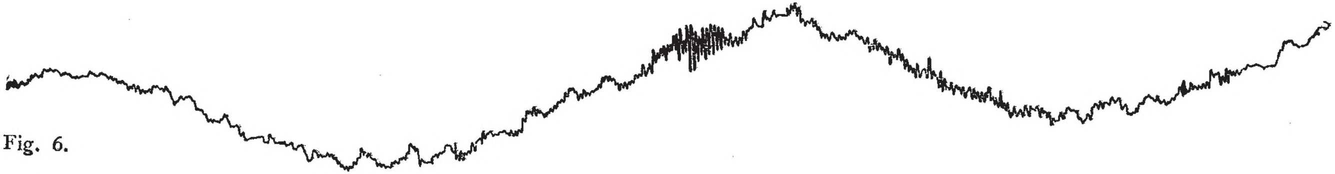


Fig. 6.

Sept. 29,'05, 6:05 p.m.
to Sept. 30,'05, 6.05 p.m.

Tide in calm water.

Fig. 5.

Sept. 28,'05 6.05 p.m. to
Sept 29,'05 6.05 p.m.

Fig. 7.

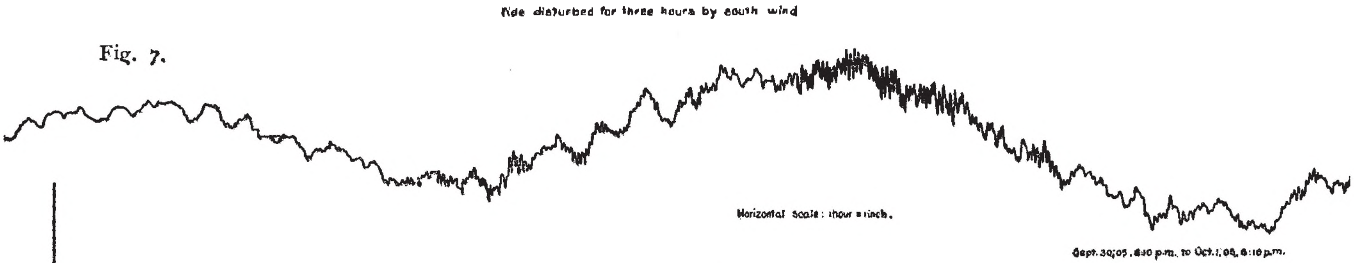
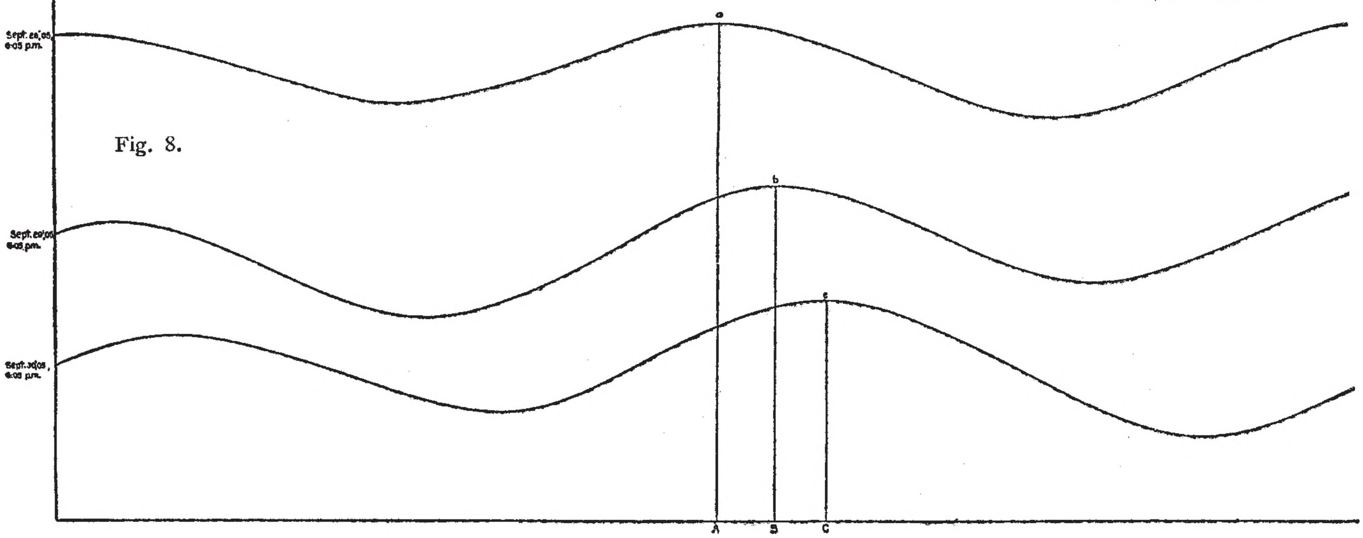

Tide disturbed for three hours by south wind
Horizontal scale: 1 hour = 1 inch.
Sept. 30/05, 6:10 p.m. to Oct. 1/05, 6:10 p.m.

Fig. 8.


Sept. 28/05, 6·05 p.m.
Sept. 29/05, 6·05 p.m.
Sept. 30/05, 6·05 p.m.
a
b
c
A
B
C

slightly in a vertical direction. The wind began to blow about 5:45 a.m., September 30, and died away about 8 a.m. A series of local oscillations was thus formed, as shown in the figure, about half-way from either end.

Fig. 7 shows the tide of the twenty-four hours extending from September 30, 6:10 p.m. to October 1, 6:10 p.m. Five minutes was lost in changing the paper on the cylinder. In this record, also, a slight disturbance was caused by the action of a south wind, which blew faintly for about three hours in the morning (8 a.m. to 11 a.m.), but which did not affect the general outline of the tidal curve.

In order to satisfy myself that the curves represented true lunar tides, I plotted the mean or average curves for the three periods, September 28–29, September 29–30, September 30–October 1, and placed them one above the other, filling in the small interval of five minutes lost on September 30 (6:05 p.m. to 6:10 p.m.) according to the general outline. I then took three points, *a*, *b*, *c*, on the curves, respectively, corresponding to a maximum tide; and, on drawing the ordinates aA, bB, cC I found that the points *A*, *B*, *C* differed in position by about one hour.

The actual distance between *A* and *B* was one inch and one-sixteenth, that between *B* and *C* was fifteen-sixteenths: so that the distance AB corresponded to one hour and nearly four minutes of time, and BC represented an interval of fifty-six minutes nearly.

Thus it will be seen that the maximum tide represented by the point *a* on the upper curve occurs one hour and four minutes earlier than the maximum tide represented by the point *b*. Similarly, the tide represented by *b* occurs fifty-six minutes earlier than the tide represented by *c*.

In other words, the maximum tides lag behind each day by about an hour, as they do in the case of the ocean tides. And what is true of the points *a*, *b*, *c*, is true, of course, also, of any other points on the three curves which are similarly situated, and represent the same rise or fall: so that the tide represented by any given point of the curve lags behind each day about one hour (corresponding to the lagging of the Moon in its orbit about the Earth), and thus proves clearly the existence of a true lunar tide in Lake Huron.

Having settled the question of the nature of the tidal record, the next step was to ascertain if there was any variation of height for the tides corresponding to the times of the new and full Moon. This I was unable to determine, on account of not obtaining records for the time of full Moon, owing to very rough weather.

There was a new Moon on August 30, so that the records of September 6–10 were taken in the first quarter of the new Moon.

The records of September 28–October 1 correspond to the time of a new Moon (there being a new Moon on September 28), and therefore represent a maximum tide.

It appears from these records that the maximum tide, as calculated directly from the three records and measured above the mean level of the water, is about one inch. The minimum tides would, of course, be less.

In order to verify this figure I attempted to calculate the mass of the water of Lake Huron and Georgian Bay, and to determine the attraction of the Sun and Moon on this; but the difficulty of obtaining even a rough approximation to the mass of water in the lake was so great, that my work, even if carried to a final result, would have had no value. As regards the possibility of making further determinations with greater accuracy and at the periods of new and full Moon, the chance of having continuous calm weather for two or three days immediately preceding any given time and also at the particular time in question, is exceedingly small. Such a prolonged spell of calm weather, as was recorded all over Lake Huron during the latter part of September, is a very exceptional phenomenon, which might not occur again for years.

CONTRIBUTIONS

BY

J. MILLER BARR.

I. NEW VARIABLE STARS.*

THE three variables which have been selected for special description in the present paper are comparatively bright stars. Hence their radial movements (which are probably also variable) may be well determined with modern spectrographic apparatus. One of these stars, viz., *h* Leonis, is remarkable for the shortness of its period. Another case of great interest is that of the binary-variable ξ Boötis—of which further details will be found elsewhere in the present volume.

h (6) LEONIS. $\alpha = 9^h\,26{\cdot}5^m$, $\delta = +\,10°\,9'$ (1900).

This star presents a notable exception to the general rule that deeply colored variables have long periods. Its color is deep or orange-yellow; Webb has described it as "deep orange." The period—or at least the interval between successive maxima—is only about *three hours*; so that the case is of exceptional interest. The range is about 0·35 mag. The comparison-stars are ξ, ω and 10 Leonis. On May 7, 1905, *h* Leonis was near *maximum* at $20^h\,45^m$, and near *minimum* at $22^h\,30^m$, Eastern Standard time. At *maximum* the variable is about two grades brighter, and at *minimum* about 3½ grades fainter than ξ Leonis. I give below the magnitudes of these stars according to Argelander, Gould, and Pickering:

	B.D.	U.A.	H. P. REV. (1899).	D.C.	SPECTR.
h Leonis	6·0	5·6	5·30	6·41	*H?*
ξ "	5·3	5·4	5·05	6·00	*H*

The magnitudes of the *Draper Catalogue* (D. C.) are *photographic.*

The observations of the present season confirm those of 1905 (as summarized above), though no attempt has yet been made to re-determine the star's period. *h* Leonis was near its maximum

---

* A revised and amended copy of a paper read before the Royal Astronomical Society of Canada, June 13, 1905. (March 28, 1906.)

brightness on March 24, 1906, at $21^h\,44^m$, E. S. T. It should be added that the *maxima* of this variable are more sharply defined than the *minima* ; the star being near minimum brightness during the greater part of its period.

From an historical point of view, it is interesting to note that some observations on the relative brightness of ξ and h Leonis were recorded by Pigott in the 18th century. Concerning ξ Leonis he wrote as follows (*Phil. Trans.*, 1786): "Montanari says this star was hardly visible in 1693. I found it constantly in 1783, 1784, and 1785 of the same brightness, being of the 5th magnitude ; less than A, π and if any difference rather brighter than h and ω Leonis. Tycho Brahé, Flamsteed, Mayer, Bradley, etc., make it of the 4th magnitude." Mr. Gore, from one of whose valuable papers* I quote the above passage, points out that Ptolemy and Al-Sufi rated ξ Leonis as of the 6th magnitude only. My own observations, like those of Pigott, afford no distinct evidence of change in the light of ξ Leonis, though it was at first supposed that this star, rather than h Leonis, might be the short-period variable.

ξ BOÖTIS. $\alpha = 14^h\,46{\cdot}8^m$, $\delta = +\,19°\,31'$.

This is the binary-star Σ 1888, one of the best known objects in the heavens. The components—magnitudes 5 and 7—are now about $2{\cdot}5''$ apart. The period of revolution of the system is about 128 years.† My observations indicate that the brighter component is variable in a period of about 5·2 days ; the approximate range being 0·3 magnitude. The *decrease* in light is distinctly more rapid than the *increase*. The star was near *minimum* on the evening of May 19, and near *maximum* on the morning of May 23, 1905.

ξ Boötis is rated as 4·64 magnitude in the *Revised Harvard Photometry*. In the *Draper Catalogue* its photographic magnitude is given as 5·49 ; spectrum *G*.

b (1) SCORPII. $\alpha = 15^h\,45{\cdot}0^m$, $\delta = -\,25°\,27'$.

The chief comparison-star is A (2) Scorpii, about 43′ distant from the variable. The catalogues of Gould and Pickering supply the following data :

---

* "Changes in the Stellar Heavens," OBSERVATORY, Nov., 1900, p. 398.

† OBSERVATORY, Jan., 1900, p. 59.

	U. A.	REV. H. P.	D. C.	SPECTR.
b Scorpii	5·3	4·77	4·91	*B* 3 *A*
A "	5·5	4.66	4·90	*B* 3 *A*

My first observation of these stars was made on June 9, 1904, and the variation in relative brightness was detected on the following night. The range is about one-third of a magnitude. The variable is bluish-white, in distinct contrast with *A* Scorpii, which is of a pale yellow tint.

It was evident, almost from the outset, that the period was quite short. A careful discussion of the observations made in 1904 led me to infer that it was *probably* about 7¼ hours. Some of the observations, however—made under good conditions—did not conform with this period; and more recent comparisons have shown that the variation is more or less irregular. For the present, therefore, the period of *b* Scorpii must be considered as undetermined. The *mean* interval between successive *maxima* will probably not exceed ten hours. The uncertainty in this case arises in part from manifest irregularities in the light-curve, but is chiefly due to the star's southerly position, which makes it impracticable in these latitudes to watch it through a whole period on a single night.

II. THE VARIABLE STAR ξ BOÖTIS = Σ 1888.

THIS well-known binary star has now been observed by Argelander's method on 103 nights, the first observation having been recorded on April 13, 1905. The comparison-stars are *o*, *ψ* and *ω* Boötis.

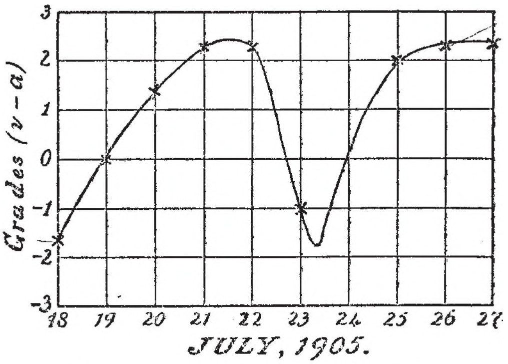
In a previous paper,* the period of ξ Boötis was given as about 5·2 days. A recent calculation, founded on observations extending over five months, gives a period of 5·03 days. This result, though merely provisional, is not likely to be in error by more than 0·02 day.

The characteristic form of the star's light-curve is shown in the accompanying diagram, based on observations made near the end of July, under first-class conditions.†

---

* Read before the Royal Astronomical Society of Canada on June 13, 1905.

† In the diagram, v = ξ Boötis, a = o Boötis. The abscissæ correspond to 22^h Eastern Standard Time on the respective dates.



LIGHT-CURVE OF ξ BOÖTES.

Setting aside the improbable view that the components of ξ Boötis vary synchronously, it is clear that either star *may* be the variable. Taking the observed range for the pair as 0·3 magnitude, and regarding one of the components as constant, I obtain the following results :

(1) If the brighter component is the variable, its range is about 0·35 magnitude. The difference in magnitude of the components is taken as 2·0 when the variable is at its mean brightness.

(2) If the fainter component be the variable, its range must equal or exceed 1·3 magnitude. This minimum range corresponds to an assumed difference of 2·0 magnitude between the components when the variable is at *minimum*.

Now a variation of 1·3 magnitude in the relative brightness of the components of ξ Boötis could hardly have escaped the notice of double-star observers. It is, therefore, highly probable that the brighter component is the variable.

This star is the brightest known example of a comparatively rare type, viz., that in which the *decrease* of light is more rapid than the *increase*. Should it prove to be a spectroscopic binary—which is highly probable—we shall then have to regard ξ Boötis as one of the most interesting triple systems in the heavens.

III. THE COLORS OF HELIUM STARS.

IT is commonly supposed that stars of the Orion or helium type are always more or less bluish in tint. Thus Professor Newcomb, in his work on the stellar universe, speaks of "the blue stars in the constellation Orion"*; and other well-known writers have used similar terms in referring to this important division of the stars comprised in Secchi's first type.

The object of this note is to point out that many of the helium stars—apparently a considerable proportion of the total number—exhibit yellowish rather than bluish tints.

The following lists include all the helium stars whose colors have thus far been carefully noted by the writer:

YELLOWISH
HELIUM STARS.

2 Hev. Camelopardi
Maia.
Merope.
θ^1, κ, π^4, σ, ψ Orionis.
σ, ω^1 Scorpii.

BLUISH OR
WHITE HELIUM STARS.

ξ Cassiopeiæ
Algol.
3 Hev. Camelopardi.
Alcyone.
Electra.
Atlas.
Taygeta.
τ Tauri.
Rigel.
γ, ζ, η, π^5, 25 Orionis.
β Canis Majoris.
η Hydræ.
δ, π Scorpii.

The terms "cream-white" or "cream tint" may perhaps be applied, with general accuracy, to the stars in the first column, while those in the second are comparable, as regards color, to the ordinary electric arc-light. Several stars included in these lists are visually double or multiple; and several are spectroscopic binaries. The brighter components of ψ Orionis and 2 Hev. Camelopardi = Σ 385 are described as "yellow" in Webb's *Celestial Objects*.

In seeking for an explanation of this difference in tint among the Orion stars, we are restricted to two general hypotheses, viz.:

(1) The yellowish tint is due to the selective absorption or

---

* "The Stars: A Study of the Universe," p. 317.

reflection* of the star's light in its passage through the stellar atmosphere.

(2) The difference in color represents an actual difference in constitution or physical state (especially as regards *temperature*) of the light-emitting bodies.

In their application to the stars generally, these rival theories have, of course, been fully discussed by astro-physicists. As applied to the helium stars, it would seem that the first-mentioned hypothesis is distinctly the more probable. On the other hand, the second theory may be at least partially true, and the delicately-contrasted tints here referred to may correspond to different stages in the process of stellar evolution. In this connection it should be noted that the helium group has already been subdivided by spectroscopists. A comparative study of the colors and spectra of many helium stars would probably afford much light on this attractive subject. And such a study might with advantage be extended to the hydrogen stars of the first type, of which Sirius and Vega are familiar examples.

IV. A NEW PROBLEM IN SOLAR PHYSICS.

THE September (1905) number of the *Astrophysical Journal* contains a very interesting and important paper on "The Figure of the Sun", by Dr. Charles Lane Poor of Columbia University.

Dr. Poor's investigation is based partly on accurate measurements of solar photographs (chiefly Rutherfurd's plates), and partly on numerous heliometer measures of the Sun's disc, made by German astronomers in connection with the transits of Venus in 1874 and 1882. The heliometer measures were long since reduced and discussed by Dr. Auwers, who "reached the conclusion that the diameter of the Sun at distance unity is 1919·26″ and that the polar diameter exceeds the equatorial diameter by the amount $P.-E. = +0{\cdot}038'' \pm 0{\cdot}023''$." †

Auwers inferred that the slight excess in apparent length of the polar diameter was "due to the tendency on the part of an

---

* The so-called absorption of light by the Earth's atmosphere seems to be due chiefly to the selective "scattering" of the blue and violet rays by finely-divided matter within this atmosphere. We have reason to believe that a like explanation will hold good for the solar atmosphere—as regards its general absorption of the light-rays.

† This and the following quotation are taken from Dr. Poor's paper.

observer to measure vertical diameters greater than horizontal diameters." It should be added that the German astronomer "grouped together" the observations made in different years, and thus failed to detect the important changes which have been brought to light by Poor's re-discussion of the same data.

Dr. Poor exhibits his results in an effective and convincing diagram, wherein the curve of sun-spot frequency is shown side by side with curves representing the Sun's shape, as derived from the photographic and heliometric data. There seems to be no room for doubt as to the soundness of his main conclusions, which may be thus summarized:

(1) The figure of the Sun (*i.e.*, the photosphere) is changeable, the period of variation coinciding with the eleven-year cycle of spot-frequency.

(2) The equatorial diameter is relatively greatest at the epochs of sun-spot maximum and least at the minimum.

The precise extent of this oscillation in the Sun's shape is as yet uncertain. The photographic measurements—which are probably entitled to greatest weight—point to a variation of at least 1″ in the quantity *P.–E.* This corresponds to a linear range of not less than 450 miles. The fact—apparently demonstrated by the photographic measures—that the polar frequently exceeds the equatorial diameter, is equally curious and suggestive.*

We are here confronted with a new problem in solar physics—a problem whose interest and importance must be recognized by all students of the subject. Its most obvious solution rests on a plausible assumption, viz., that the equatorial region† of the Sun is hottest at the epochs of greatest activity. Thus the equatorial zone would alternately expand and contract in accordance with the observed facts. But this change of shape may be otherwise explained, as I now proceed to show.

In accordance with received views, we may regard the solar photosphere as a stratum of incandescent clouds, formed by the condensation of highly heated vapors rising from the Sun's

---

* The theories considered in the present paper are not inconsistent with this fact, though they afford no explanation thereof.

† This term (or its equivalent, "equatorial zone") is here used in a very extended sense. It must be regarded as including the zones of greatest spot- and prominence-frequency.

interior. At an epoch of minimum solar activity this stratum is in a relatively quiescent state. As time progresses, the equatorial belt becomes more and more disturbed: considerable outbursts occur here and there, resulting in the formation of prominences, faculæ, flocculi, and (ultimately) dark spots. Minor disturbances—such as are associated with the circulatory process whereby the Sun's light and heat is maintained—must also be intensified in the same region; and such disturbances may, collectively, produce a greater effect than those which give rise to the more impressive features of solar scenery.

Consider, now, the effect of this increased activity upon the shape of the photosphere. At the outset, it may appear that the expansion due to up-rushes of heated gas would be compensated by the contraction due to down-rushes of relatively cool matter—such as those which are believed to account for the dark spots. My main contention is, however, that, under the conditions described, *the pressure within the photosphere will exceed the pressure from without*, owing to the causes specified below:

(1) An appreciable part of the up-rushing matter will become condensed into minute particles, and ultimately be driven into space by the pressure of light.

(2) The up-rushing gases must expand horizontally as well as vertically, and hence a portion of this matter will pass into higher latitudes, in which case the contraction (of the equatorial region) due to its downfall on the photosphere would be diminished. This gaseous expansion must give rise to a more or less general circulation of the solar atmosphere, the ascending gases being systematically carried towards the poles.

Thus, the most disturbed and broken region of the photosphere will be subject to the *dominating influence of ascending currents*. The photospheric clouds will be carried upwards, and the radiating shell will slowly expand in the equatorial zone. This expansion is probably accompanied by some contraction in the polar regions of the Sun.

The progressive change of shape will continue until the upward pressure due to ascending currents in the equatorial zone is counteracted by the expansion of the photosphere and the loss of matter by repulsion. At this time the conditions approximate to those of a sun-spot maximum. The solar activity will then begin to decline, and the equatorial zone will contract until the minimum conditions are again reached.

We have here the germ of a possible *explanation* of the sun-spot cycle ; but this aspect of the subject demands careful study, and must be reserved for future discussion. For the present, we may regard the periodical change in the Sun's figure as a *consequence* of the synchronous change in solar activity. The theory is offered with some hesitancy, as a partial and tentative solution of the difficult problem involved.

I shall not venture here to touch upon other related problems of great interest, such as those involved (1) in the existence of definite spot-zones, (2) in the unequal rotation-periods of spots in various latitudes, (3) in the relation between the spot-activity and the form of the corona, or the distribution and frequency of faculæ, flocculi, and prominences. A fairly complete solution of these complex problems is likely to be reached only through the medium of prolonged and careful research.

Brief reference may here be made to the important researches of Arrhenius and other investigators on the pressure due to light, with special reference to solar problems.* According to the well-known theory of Arrhenius, "the solar activity produces numberless negative electrons which serve as condensation-points for the vapors surrounding them in the solar atmosphere, and thus form small, negatively-charged nuclei, which are driven from the Sun by radiation-pressure."† This repulsion of matter occurs chiefly in and about the spot-zones, especially near the epochs of maximum activity. The pressure due to radiation is probably increased by gas-action, as illustrated in the Crookes radiometer.‡ Relatively coarse particles subject to such repulsive forces must ultimately reach the photosphere. In all cases, however, the diminution of gravitative energy must tend in the

---

*Arrhenius, LICK OBSERVATORY BULLETIN, No. 58 ; ASTROPHYSICAL JOURNAL, Oct., 1904, p. 224. Nichols and Hull, ibid,, June, 1903, p. 315. The last-mentioned paper, on "The Pressure Due to Radiation," contains an admirable summary of previous researches on the subject, with copious references to its literature.

†I quote here from a paper by Messrs. Nichols and Hull, ASTROPH. JOUR., June, 1903, p. 352.

‡Cf. Nichols and Hull, ASTROPH. JOUR., June, 1903, p. 356.

same direction—the result being a slow vibration in the Sun's shape, as already explained.

The repulsion-theory receives a certain measure of support from recorded observations on the position of the coronal streamers. I may refer, in particular, to some interesting results secured during the late solar eclipse. As observed at Assouan, Egypt, the corona "had prominent streamers in the sun-spot zones, those on the eastern side being the longer and less divergent, the longest, opposite the large sun-spot, being about two million miles."* These facts accord well with the theory outlined above, in which the chief factor is the action of repulsive forces on matter expelled from the Sun.

Another possible source of variation in the Sun's shape must be taken into account, viz., a cyclical change in the mean rotation-period. It is evident that an *increase* in this period would correspond to a *decrease* in the equatorial diameter and *vice versa.* Now, Wilczynski has shown that the Sun's rotation-velocity may thus vary—possibly, as he suggests, in a period of about 11 years.† His analysis shows, further, that this change would be accompanied by a synchronous change in the Sun's mean temperature—a slower rotation corresponding to a higher temperature. If these deductions are sound, the change of shape due to varying temperature is opposed in direction to that resulting from the Sun's varying rotation. It should be added that the Sun may be hottest at the epochs of *minimum* activity. This view has been advocated, in recent years, by well-known students of the subject.

We may conclude that the observed variation in the Sun's shape is the resultant of several causes or factors, as cited in this paper. At the present time we have no means of estimating, with any certainty, the relative importance of these factors. But further research may supply the desired information, and our problem—despite its obvious difficulties—may ultimately be placed on a definite mathematical basis.

---

* OBSERVATORY, Sept., 1905, p. 355. Cf. Professor Moye's interesting account of the eclipse in the October number of the OBSERVATORY,

† "On the Causes of the Sun-spot Period," ASTROPHYSICAL JOURNAL, Feb., 1898, p. 124.

ST. CATHARINES, ONT.

NOVEMBER, 1905,

STELLAR CLASSIFICATION.

BY

W. BALFOUR MUSSON.

THE foundation for a classification of the stars may be said to have been laid when, in 1814, Fraunhofer directed his attention to an examination of their light, by means of the spectroscope, and made the discovery that not only did their spectra differ from the spectra yielded by the planets, but that they also differed one from another.

A fact of so great significance at once riveted the attention of pioneers in this new field of research, but it was not until a half century later (1863) that Rutherfurd suggested a systematic classification of stellar spectra based upon their inherent peculiarities. Such a classification was made two years afterwards by Secchi, who arranged the well-known grouping which bears his name, and still remains in its main features the standard reference.

Secchi's four types are so well known that it would be superfluous to describe them. The differences upon which they are based, however, represent only their more prominent characteristics, stellar spectra revealing a host of minor variations requiring a far more accurate distinction.

The probable causes of such variations and the conclusions to be drawn therefrom have formed the subject of previous discussions in this society, and it is here proposed merely to examine somewhat more in detail the bases of some of the more elaborate systems of classification which have been advanced—such, for example, as the monumental work of the Harvard College Observatory.

In consequence of the discovery of a new type of star exhibiting a spectrum with bright lines and bands, Secchi's table was extended, at the suggestion of Prof. E. C. Pickering, by the addition of a fifth group. The first three stars belonging to this group were discovered in 1867 by MM. Wolf and Rayet, and the class is now a numerous and distinctive one known as the Wolf-Rayet, or fifth, type.

In 1880-1882 visual observations were made at Potsdam by Vogel and Müller, and a classification formed by Vogel which introduced various subdivisions into Secchi's grouping.

Type I, for example, was subdivided into *a*, *b*, and *c*, according to the appearance of the hydrogen lines.

Type II into *a* and *b*, based upon differences in the hydrogen and metallic lines and, in the case of division *b*, by the appearance of bright lines.

Type III was divided into *a* and *b*, according to the nature of the absorption bands.

Sir Norman Lockyer also proposed a classification consisting of seven groups arranged upon a temperature curve, and intended to form the basis for a development theory. His system will be more fully discussed below.

Photography was now to lend its aid to astrophysical research. In 1872 Dr. Henry Draper obtained a photograph of the spectrum of Vega, this being the first time the characteristic lines of the spectrum of a star had been secured by means of the camera. Huggins had attempted the feat in 1863 but without success. In 1882 stellar photography was again taken up by the Pickerings and lines obtained in the spectra of 45 of the brighter stars of the Pleiades. An 8-inch doublet having been obtained by means of a grant from the Bache fund of the American Academy of Sciences, the work was systematically begun which resulted in the now famous *Draper Catalogue*, the first large research consisting of over 28,000 spectrographs representing some 10,000 stars Each spectrum was described according to an empirical system (later to be developed into a natural order of classification), its intensity being measured at a common point, thus making possible a comparison of stars of different colors and obviating various sources of error.* Upon the removal of the Bache telescope to Peru a second instrument with focal distance 5 inches greater was installed, which rendered possible a considerable advance.

A number of typical stars being selected the lines of their spectra were measured by moving the photographs through the field of a microscope, in some instances over 500 lines being examined in a single spectrum.

---

* ANNALS of Harvard College Observatory, vols. 27, 28.

Perhaps the most important classifications of stellar spectra yet attempted are those of Miss Maury and Miss Cannon of the Harvard College Observatory. Miss Maury's catalogue is based upon the careful examination of 4800 plates of between 600 and 700 stars, and comprises 22 groups.

The comparisons were made by placing the photo-films in contact with the spectra to be compared, similarity in intensity as well as in the position of the lines being considered a means of identification.

It was found that in a general grouping, such as Secchi's, the various types could be arranged in a progressive series, large numbers of identical spectra being discovered even when several hundred lines appeared in each.

The transition from one type to another is in general very gradual, although exceptions of a more abrupt nature are not entirely unknown.

In addition to the 22 main groups of Miss Maury's catalogue a collateral series, designated divisions and lettered *a* to *c*, was introduced to provide for spectral differences of a particular nature, a consideration of composite spectra and bright line stars, however, being excluded.

Division *a* is characterized by the narrowness and sharpness of the single lines, those included in division *b* being wide and hazy. In division *c* the lines of hydrogen are narrow and well defined but their maximum intensity less than in *a* and *b*. The Orion lines are also narrow and of good definition, and those of calcium more intense than in the preceding subdivisions. Spectra allotted to division *c* also contain some metallic lines as yet not found in the solar spectrum.

Space will not permit of anything like an exhaustive review of the many spectral variations noted by Miss Maury, and an attempt will be made to draw attention only to some of the more important. These include the behavior of the Orion lines (most of which have since been identified with helium), and those due to hydrogen and calcium together with the metallic lines commonly described as solar. The magnesium line at λ 4481·4 is also included since its behavior has been considered of importance as an evidence of temperature.

The most striking fact as we advance from the early to the later groups is the concurrent strengthening of the calcium and solar lines with the weakening of those due to helium and hydrogen.

Helium and hydrogen absorption increases side by side from groups I to III after which helium begins to decline, while the calcium and solar lines are either absent or very faint.

From IV to VII helium is decreasing while hydrogen continues its increase. Calcium is also beginning to increase but the solar lines remain faint.

From VIII to XIV hydrogen is decreasing, calcium is very strong and the solar lines are becoming prominent.

From XV to XIX hydrogen is steadily declining and calcium and the solar lines are also on the decrease. After group XVI the transition into Secchi's third and fourth types has begun.

The magnesium line at λ 4481·4 is faint in group III, increases in V and VI, and becomes distinct in VII.

Particular attention is directed to the behavior of calcium, the *K* line of which first appears, though faintly, in group I, remaining faint through II and III, gaining in IV and V and becoming prominent in VI, where the *H* line makes its appearance.

In group VII *K* has increased and *H* become prominent. In the following group the intensity of *K* has doubled and again doubled in IX, while in X it has ten times the intensity of group VII. In XI it has again doubled in strength and is equalled by *H*.

In groups XII and XIII calcium has almost reached its maximum, which is attained in XV and held through XVI and XVII, when it begins to decline.

After a careful examination of the Harvard catalogues we cannot but feel the weight of the evidence in favor of a gradual and orderly sequence of change. The conclusion becomes irresistible that we see before us the record of a long period of development rather than of many original differences in stellar constitution.

Such a view, however, need not necessarily mean that *all* stars have begun their life-history with an identical constitution —the many peculiar spectra observed leave large room for speculation in this respect—but it does involve the acceptance of an evolutional progress once that life-history has begun.

"Relative density, as representing relative richness in potential energy, should be taken as the guiding principle of a natural system of stellar classification."

Such is the opinion of Sir Wm. Huggins,* who considered the behavior of the lines of hydrogen and calcium, in the photographic region of the spectrum, to fairly represent the sequence of increasing condensation. He was not in favor of the multiplication of divisions in the earlier stages of investigation as minor differences might depend upon the original chemical constitution of the star, and instances *α* Cygni as an example of a star which refuses to fall into line. Sir Wm. points out that if the width of the *K* line, together with the general narrowness of the others, be alone considered, this spectrum would be classified as well as on towards the solar type, while the extent of the hydrogen series in the ultra-violet would indicate a much earlier stage, placing it in the category of Rigel and Bellatrix.

Nevertheless, when great numbers of stars are found to exhibit almost identical characteristics throughout an extended range of the spectrum, as was found to be the case when compiling the *Draper Catalogue*, the introduction of new groups would appear to be not only warrantable but necessary.

In thier arrangement of the various types of spectra Sir Wm. and Lady Huggins were guided by the character of the hydrogen spectrum, taken together with that of the *K* line of calcium,† and point out three distinct conditions of the hydrogen lines, viz.:

(1) All lines thin and distinct.

(2) The lines winged and strong, but less distinct, and incomplete in number.

(3) In the photographic region the first three lines only thin and defined. *Hε* diffuse and the lines beyond indistinguishable.‡

Between the years 1878 and 1883, Ritter communicated to *Wiedemann's Annalen* a series of papers, including one on stellar classification, in which the problem was approached from the standpoint of theoretical physics. He arrived at the conclusion that the life of a star might be divided into three periods, marked by the culmination of heat radiation and surface temperature,

---

* ATLAS of Representative Stellar Spectra, page 76.

† Ibid., p, 154.

‡ Ibid. p, 154.

and he regarded the character of the spectrum as depending simultaneously upon the mass and relative age of the star. In some of its features this classification was in harmony with that of Vogel.*

In 1873 Lockyer drew attention to the fact that the evidence accumulated up to that time pointed to the conclusion that in the reversing layers of the stars dissociation was at work, and that one result of dissociation temperatures might be to prevent the coming together of atoms which at lower temperatures compose the metals and compounds. In 1902 he contributed to the Royal Society a paper on the *Temperature Classification of the Stars*, based upon the fact that an extension of the spectrum into the ultra-violet region is produced by increased temperature. The general conclusion was that a classification might be based upon a scale of ascending and descending temperature.

In 1899 laboratory work on the spectra of various substances, under varying conditions, led him to consider justifiable an arrangement according to the chemical sequence revealed by the presence of gaseous and metallic lines, in particular those of helium and hydrogen, and the enhanced and arc lines of the metals.

In this system the stars were arranged in 16 groups along a temperature curve, on the assumption that the chemical changes were due to temperature, the groups containing the hottest stars, on the dissociation hypothesis, being placed at the top of the curve. He believed the result to justify the sequence of 1892 which depended on the extent of the ultra-violet spectrum.†

The experimental investigations of Sir George Stokes, Langley, and others tend to show that the maximum radiation moves towards the more refrangible end of the spectrum as the temperature increases, *i. e.*, the *relative* proportion of the violet region is increased.

Sir Norman Lockyer presents a number of photographs ‡ in which are contrasted the spectra of white stars with those of a solar type, and which he claims, in accordance with the above-

---

* A fairly full statement of Ritter's theory may be found in the ASTROPHYSICAL JOURNAL, Vol. VIII.

† PROC. R.S. Vol. 73.

‡ Ibid.

named law, clearly demonstrate the higher temperature of the former. To quote his own words: "Taking the stars assumed to be the hottest in the chemical classification we find that in all cases the relative length of the spectrum is reduced and the relative intensity is increased as a lower temperature is reached. That is to say, where two spectra having their intensities about the region of $H\beta$ to $H\gamma$ equal, are compared, we find that in the cooler stars, according to the chemical classification, the emissions in the red preponderate, whilst in the hotter star the ultra-violet is more extended and intense." A reduction of intensity in the continuous spectrum beyond the hydrogen series he does not consider as affecting the results.

This conclusion is, of course, diametrically opposed to that of Sir Wm. Huggins who places the solar stars on a higher temperature level than helium and hydrogen stars.

Huggins accepts the shifting of the maximum radiation towards the ultra-violet as an evidence of increasing temperature, but appears to rest chiefly upon the intensity and extension of the continuous spectrum beyond the hydrogen series, and regards the maximum temperature to be attained in stars of the solar type, after which a decline begins.* To the writer the photographs submitted both by Sir Norman Lockyer and by Sir Wm. Huggins appear to be far from conclusive, but it should be borne in mind that many details may be indistinct or lost in reproduction which are well marked in the original negatives.

The question of the relative temperatures of hydrogen and solar stars would therefore appear to be one still pressing for solution. Professor Frost holds that "in the light of our present knowledge, or better, in the darkness of our present ignorance, temperature is a somewhat unsafe basis for classification."

In the Proceedings of the Royal Society for August, 1905, Vol. 76, Dr. W. E. Wilson contributes a highly interesting paper on *The Evolution of the Spectrum of a Star during its Growth from a Nebula*, in which he concludes that after a certain point increase of temperature would have little effect upon the spectrum, but that the effect of differences of pressure in stars of equal temperatures might be very marked. He also believes that when

---

† ATLAS of Representative Stellar Spectra, p. 85.

the temperature is slightly above or below the critical point at which photospheric clouds are formed, a striking change in the spectrum would result, and therefore considers it impossible to classify stars solely on a temperature scale.

After a review of the subject the thought which naturally suggests itself is that some uniform system for the classification of stellar spectra is much to be desired, and indeed such is coming to be the opinion of astro-physicists.

Under the title, "A Desideratum in Spectrology," Prof. Edwin B. Frost in the *Astrophysical Journal* for December, 1905, presents a plea for an international congress to deal with the question. Early tables were, of course, based upon the results of visual observations, but with the introduction of photography it was inevitable that these should become inadequate. As an instance of the confusion at present existing, Professor Frost points out that the star Procyon is classified under no less than 8 different symbols. He considers a theoretical basis of classification such as that of Lockyer or Vogel undesirable, since theories of development are subject to modification, or rejection, as fresh data accumulate.

Observed facts, apart from their interpretation, seem to offer the only safe foundation upon which to build, and probably no better system could be chosen than that of Secchi or the Harvard Catalogues which are founded upon the actual appearance of the spectrum irrespective of the causes of its origin. A universal terminology would, of course, be necessary. Professor Frost also maintains that the whole extent of the ultra-violet, as well as the visual spectrum, and the entire range of the distribution of energy should be taken into consideration.

Appended is a comparison of some of the various tables of classification now in use :

DRAPER CATALOGUE	MISS MAURY (ORION.)	SECCHI	VOGEL	LOCKYER
	I to V			
	VI			
A to D	VII to XI	I	I a	IV
	XII			
E to L	XIII to XVI	II	II a	III and V
M	XVII to XX	III	III a	II
N	XXI	IV	III b	VI
O and P	XXII	(V)	I c and II b	I

ON THE POSSIBILITY OF LIFE IN OTHER WORLDS.

BY

A. KIRSCHMANN.

THOUGH the fixing of the date of my paper * for Hallowe'en night is purely accidental it must appear quite appropriate to the subject, for this night, even in the time of our heathen Celtic and Germanic ancestors, was devoted to thoughts and customs referring to the hereafter. And the early Christian Church, which so cleverly fought the heathen customs by adopting them and adapting itself to them, fixed the festival in honor of All Saints and All Souls on this date, which, as Flammarion points out, has been used by many ancient peoples for a certain religious festival which had to do with the culmination of the Pleiades, the precession of the equinoxes, and the souls of the dead now living in other worlds. Our heathen ancestors were neither the savages nor the representatives of rude paganism that the Mediæval Church, which has carefully destroyed all vestiges of their culture, would have us believe. The mythology of the Teutonic nations was almost absolutely free of idolatry, and the gods like Woden, Thor, Balder, Freia, etc., which the Church transformed, some into devils, some into saints, were, before contact with Christianity, only a kind of demi-gods, ancestral heroes, and as such only tools in the hands of the All-Father, who at the end of this world will destroy gods and men alike and create a new world with new gods and new men. Ethically and metaphysically the Teutonic mythology is immeasurably superior to the worship of personified natural forces of the Greeks and Romans, no matter how high the perfection with which their plastic art represented their gods. The belief of Teutonic nations in an existence after death was especially strong. And the same can be said of the Celts who believed in the inhabitation of the Moon and the planets (the inhabitants of the Moon lived according to them in deep crevices. Did they thus show their knowledge that the Moon had no atmosphere?) and who would go even so far as to lend money to be repaid in another world.

---

* Read Oct. 31, 1905.

It is not the purpose of this paper to *depict* life in other worlds. If I would attempt it my picture would be a miserable chromo, a wretched bungling compared with those of abler authors such as Swedenborg, or Athanasius Kircher, in bygone times, or Flammarion* and Kurt Lasswitz† in our times ; for their pictures are real works of art (though less of science). What we wish to discuss is simply the question of the possibility of life in *worlds other than our own*, a question which has been so admirably answered in the affirmative by many scientific men (I may mention here only one, Mr. Richard A. Proctor, whose book *Other Worlds Than Ours* is so generally known), and a question which has been so vigorously answered in the negative by no less a man of science than the great evolutionist Alfred Russell Wallace, in his celebrated book, *Man's Place in the Universe.* It is chiefly the disproving of the contentions maintained in Mr. Wallace's book that is the task of this paper.

But if this question, the possibility of life in other worlds, be the kernel of the nut which I shall try to make at least somewhat palatable to your scientific taste, then the nut must also have its shell which ought to be cracked first. One part of the shell is the question, What is life? Thus I propose to look first into that problem, and after we have swallowed the kernel we may cast a glance at the other half of the shell, viz., the question, What can legitimately be meant by "other worlds?"

The question, "What constitutes life?" has in this form only lately become of general interest, whilst hitherto even scientific people were satisfied with the ordinary conventional distinction of the organic and inorganic, and the question which troubled them most was not the *nature* of life, but the *origin* of it on this earth. Everybody is acquainted with the many forms of life around us, but nobody has ever witnessed the process of the transformation of lifeless matter into living matter. Therefore whenever we see life arise we say there must have been some kind of germinal cell for a start, or, as expressed in the old dictum, which appears in such a new light since the discoveries of Prof. Jacques Loeb of the University of California—the dictum, *Omne vivum ex ovo.*

---

* "Mondes habités et Mondes imaginaires."

† "Auf zwei Planeten."

There are three theories about the origin of life. First, a purely materialistic and mechanical one which has in its extreme version only a few adherents, among them Professor Haeckel. This theory of "Abiogenesis" or "spontaneous generation" says that life is only the result of a more complicated play of the ordinary forces, that the machinery of living organisms is only different in degree from other machinery.

Second, the theory which was held by Helmholtz and others, that the germs of life have come to the Earth with fragments of exploded worlds. The chemist Arrhenius has lately developed this theory somewhat further, claiming that a hypothetical living matter must be supposed to be conveyed through space in particles so small that they cannot be detected by means of the strongest microscopes, and that these minute living germs obviously do not lose their vitality in the low temperature of inter-stellar space. I think the revolutionising experiments of Mr. J. B. Burke, of the Cavendish Laboratory, Cambridge, who, in his "radiobes," produced what appeared to be life in an apparently sterilized medium by the rays of radium, should be considered from the standpoint of this theory. If the cosmical life-dust is so fine as Arrhenius claims, it will penetrate like ether all ponderable matter, and cannot be excluded by any kind of sterilization.*

Third, there is a theory once held by Fechner, and by many since, which claims that all matter is alive or was alive, leaving open the question whether in matter of great condensation and stability it is extinct or latent.

I do not believe in the existence of matter, if matter be defined as anything else than a certain combination or complication of states of consciousness. Wherever we try to be consistent with regard to the ultimate properties attributed to matter we fall into insolvable contradictions. I have shown that the "indispensable" conservation of the quantity of matter is hopelessly irreconcilable with the fact of the relativity of magnitudes.† The untenableness of any theory of matter is now no longer a philosophical fad. It is beginning to be realized by physicists and chemists, *e.g.*, Professor Ostwald, of Leipzig, in his book, *Lectures on Natural Philosophy*.

---

* See also an article of Dr. McKenzie on "Ultramicroscopic Organisms."

† "Die Dimensionen des Raumes," in PHILOSOPHISCHE STUDIEN, Festschrift, Vol. I., p. 409. Also published separately (Leipzig, 1902).

If I could believe in the existence of matter at all, the last of the above-mentioned theories would seem to me the most consistent from a philosophical point of view, since we have, in the last instance, no other criterion for the existence of life than a certain kind of movement, viz., movement with a will or purpose. All definitions of life which have hitherto been given either beg the question as, *e.g.*, that of Aristotle, that it is the combination of the operations of nutrition, growth, and decomposition (where nutrition and growth certainly presuppose life), or are applicable to non-living organizations. Thus, *e.g.*, Spencer's definition of life as "the continuous adjustment of internal to external relations," would be just as well applicable to a steam engine, a modern printing machine, or a self-feeding arc lamp.

In the last analysis, as we have said, the criterion for the existence of life is *movement with will or purpose*; but as we have no right to declare will and purpose absent where we do not see it, we have no right to declare any matter to be dead. We can distinguish between voluntary and involuntary action with certainty only when it is our own, for we *know* no other life or will than our own, and infer that of others by analogy. But the analogy that is so evident for animal organisms cannot be declared totally absent in any movement, whether it be organic or inorganic. Where, then, should we draw the line between the organic and the inorganic? Crystallization certainly plays a rôle in the life of the cell, and in the very heart of it. Should we not regard the formation of crystals as the lowest kind of voluntary movement or the simplest kind of life known to us? Consequently, perhaps the molecule, the atom, the ion or the electron has a will. Do they not choose between different chemical combinations? Are not the different stages of chemical affinity something akin to love and hatred? Is not the *status nascendi*, in which they react differently and more vigorously than under ordinary circumstances, somewhat similar to a display of affection? And, after all, are the movements of the celestial bodies so essentially different from those of the molecules of the living cell? Think of the planets whirling around the nucleus of their central body. Think of the inrush of comets and meteoric swarms into the solar system, or even into its central body—a process very similar to the entrance of the spermatozoon into the ovum. Perhaps the whole galactic system is nothing but one huge cell of an immense organism. It has a belt of clusters and resolvable nebulæ, and poles where the irresolvable nebulæ prevail. The Magellanic clouds in the southern sky, which have both kinds of nebulæ, would represent the nuclei. We must not forget that the greatness of the universe known to us is only relative. The Law of Relativity of all magnitudes is not a speculation but a fact which is given with every experience, and which can be verified at any moment. But we have become accustomed to close our eyes to it. There is nothing absolutely great or small in the world; and the mathematical conception, so much indulged in, of the approximation to zero is one of the worst fictions which human intelligence ever invented. There can be no part of substance or of empty space though ever so small, which, regarded from another standpoint, is not a large part of matter or of space. Consequently, a single molecule of chalk with its atoms of calcium and oxygen and carbon—these again consisting of millions of ions, and those again of sub-ions, and so on *ad infinitum*—may be a whole solar system again with central body, and planets and satellites, containing life in many forms, but for our measure too small to be ever perceived. And, on the other hand, the whole universe as far as we can fathom it may be only a small aggregation of particles or cells of a greater and higher organism absolutely unfathomable by us.

Of the three aforementioned theories the two last are incompatible with Mr. Wallace's idea. He contends that life does not come to us from other parts of the cosmos, that it has arisen on the Earth, and that it could rise here only—and nowhere else. Let us now turn to some of his arguments. Wallace makes the three following propositions: *

(1) Since the chemical elements are the same on all the stars, and the laws which act upon the elements combining and modifying them are the same, organized living beings wherever they exist in nature must in their essential nature be the same also.

(2) On our Earth the biologist recognizes a fundamental unity of substance and structure dependent on the requirements of the living organisms built of the same elements, in the same

---

* Vide, p. 188

proportions, and subject to the same laws. From these two premises he concludes :

(3) That within the universe we know there is not the slightest reason to suppose organic life to be possible except under the same general conditions and laws which prevail here (on the Earth).

Now I claim that neither are the premises correct, nor is the conclusion logically legitimate. The first premise is obviously incorrect, for :

First, there are not throughout the whole universe the same elements. There are lines in the star spectra which are not yet identified by the chemist, nor found in the solar spectrum. No oxygen has hitherto been found in the Sun, and no coronium on the Earth. And have the infra-red and ultra-violet spectra of the stars been sufficiently investigated? May there not be elements which give no light? And, after all, are the seventy-nine or eighty chemical elements of the present day final? or are they elements only because we have not hitherto succeeded in further separating them ? If we consider their grouping in series, with regard to their atomic weight, their chemical affinity and electrolytic properties, and the similar behavior of certain composite radicals, we may soon come to the conclusion that they are only modifications of one or several elements. Moreover, the spectroscopic evidence establishes only the existence of oscillations of certain frequencies, and since the lines of the gases broaden, and their spectra thus approach the continuous spectrum when the gas is under high pressure, and since at very high temperatures all chemical compounds dissociate, a continuous spectrum may just as well be regarded as the manifestation of an infinite series of elements, of which only those are known to us which show their characteristic chemical qualities at temperatures within the limits of our investigation.

Second, it may be quite true that the laws of nature are the same throughout the universe, but in order to state that their interaction is the same throughout the universe and under so varied conditions, we should first know them all, but we know only a few of these "laws," and even thes every incompletely. What, after all, is a "law of nature"? I claim that at best it can be defined as a proposition of geometry plus some hypothetical assumption or belief. Thus the law of gravity consists of the geometrical proposition that surfaces of spheres are to each other as the squares of their radii, and the additional assumption that there are distant acting forces which lose nothing of their energy on the way. In no case can we without knowing all the conditions and all the laws foretell the events under conditions different from those within the realm of our knowledge. Gravity and atmospheric pressure are so different on other celestial bodies that we cannot even imagine the state of affairs on their surface. Consider, *e.g.*, the curious formations of the mountains of the Moon, or the condition of matter in the Sun's photosphere and reversing layer, for which we have no equivalent in earthly experience.

Third, what an enormous change, *e.g.*, will the difference in the obliquity of the axis of a planet produce—conditions the consequences of which it will be impossible without experience to foretell. Our Earth, Mars, Saturn and probably Neptune have a moderate inclination toward the ecliptic. Jupiter has almost none, while that of Uranus is enormous. I shall not here enter into a discussion of the differences in the change of the seasons, but with regard to the position of the arctic and tropic circles I may point out some characteristic features of planets whose inclination is between 0 and 90 degrees. If the inclination is less than 45 degrees, the arctics are nearer to the poles and the tropics are nearer to the equator, leaving a temperate zone between them. But if the inclination is greater than 45 degrees the arctics are nearer the equator and the tropics nearer the poles, leaving between them a zone where conditions prevail which we could scarcely imagine. Mr. Wallace's argument that exactly an inclination of 23 degrees is necessary to make life possible can never hold, for we have no certainty that the inclination of the Earth's axis has been really the same during the Paleozoic and Mesozoic age as it is now.

Fourth, gravity plays an enormous part in the making up of size and shape of the animal bodies. Even if we would assume that muscular energy were the same all over the universe, we could not say anything of the size and shape of the inhabitants of other worlds without taking into consideration gravity. For muscular energy grows with the square section, *i.e.*, with the second power of the linear magnitude, but weight with the third power. This circumstance sets limits to the sizes of the different animals on this earth. Giants fifty feet high, as in fairy tales, are absolutely impossible, for such a giant could not stand on his own feet. A man ten times the size of us would be indeed a hundred times as strong, but nevertheless he would collapse into a heap, for he would be a thousand times as heavy. That is the reason why elephants are differently constructed from deer, and why there is a limit to the size of flying creatures on this earth. With regard to the size of birds Nature had to give up that branch of development because the bodies and especially the brains would become too heavy for the wings. So it continued the course of development by starting from a lower branch again, in wingless animals with heavy brains, leaving it to them to find the way to fly when once they have brains enough. In an atmosphere of different constitution, and on a planet with different gravity the conditions for winged creatures must be completely changed. Consequently we could not even guess anything about the size or shape of flying creatures on other planets.

Wallace and many others seem to think that only an atmosphere exactly like our own would give breath to living creatures. He holds that unless it have the very same composition and density—even the same amount of dust in it—no life will be possible. But have we any guarantee that our atmosphere has always been the same? Is it not as good as proven that in the earlier geological periods it was different from what it is now? (Note, *e.g.*, the vegetation in the Paleozoic periods.) And have we not ourselves experienced an enormous change in the atmosphere since the reign of steam and coal began?—such an essential change that even the lightning is affected, and the danger of being struck is now about ten times greater than it was fifty years ago. Even in the form of the lightning-flashes there is a considerable change. A third of a century ago the zig-zag lightning prevailed, whilst at present temporarily and spatially split-up serpent-lightning is predominant. We can form no idea of the changes in the forms of life as brought about by totally different atmospheres as those of the outer planets certainly are. It is indeed an unwarranted assumption to say there is no life possible under conditions other than those on this earth. It has always been held that there could be no life on the Moon because it has no perceptible atmosphere. I am not perfectly convinced of that. Do not miners live half their lives in subterranean cavities? Do not the people in New York whose working time is only half spent in their office and the other half in "getting there," spend a great part of their time in tunnels and subways? Have we not learned to chemically produce oxygen and nitrogen in large quantities? Do we not hear of submarine boats and of divers? Now the Moon, though she is the daughter of the Earth, is in a certain way older than the Earth, *i. e.*, more advanced in age. (development). The same might be true of her inhabitants. The Moon has certainly lost her atmosperic halo, and it may be no longer possible for the Selenites to remain on the surface But they may have withdrawn to the interior, together with the remnants of the atmosphere and perhaps provide themselves now with condensed air and condensed food and spend their time in scientific research, *e.g.*, the investigation of the heavens. The Earth especially would form a most interesting subject, appearing to them four times as large in diameter as the Moon looks to us, and remaining stationary at its position in the sky. Their telescopes for observing the Earth could therefore be hewn into the rock for hundreds or even thousands of feet, and be provided with enormous refractors (perhaps of liquid or solid air), thus furnishing a great magnifying power which, since their observations cannot be frustrated by atmospheric vibrations, would allow them to see much more of the Earth and of us than we see of the Moon and of them.

Fifth, Wallace claims that only under certain conditions of heat is life possible. He forgets that heat, gravity and atmospheric pressure *co-operate* to bring about the conditions which he has in view. When he holds that the inner planets are too hot and the outer ones too cold, he forgets that a dense atmosphere such as certainly exists on Venus and Jupiter must have a mitigating influence in both directions. And he also forgets that physically there is no such thing as cold. The transformation of the uniform series of possible physical temperatures from zero to infinite, different only in intensity, into a manifoldness of two antagonistic qualities, heat and cold, with even a changeable zero-point between, is purely *psychical.* If this zero-point can vary for us in the different seasons—or on account of after-effects and contrast—we should assume that it can vary considerably more under other conditions of gravity and pressure. It is said that life could not exist on Jupiter because its surface is still red-hot. But if the zero-point of the sense of temperature of the Jovians is shifted for a few hundred degrees they will have as pleasant a walk on that red surface as we do on the green grass. After all, the ordinary notions of physical temperature as used in cosmology are rather vague and misleading. It is said that the loss of temperature produces contraction, and, on the other hand, contraction is made responsible for the increase of temperature. This is tantamount to saying that a loss of temperature is the cause of a gain of temperature in the same body, which is absurd. The fallacy consists in taking temperature sometimes as the effect and sometimes as the cause of the molecular movement, *whereas we have no right to take temperature as anything else than the molecular movement itself.* If temperature consists in time and space relations of the kinetic or dynamic elements of matter, or in changes of those relations, then it is clear that *the elements themselves*, no matter whether they are atoms, centres of force, ions or electrons, *cannot have any temperature* at all. Therewith vanishes also the difficulty which the nebular as well as the planetesimal hypotheses encounter at their very start. The Kant-Laplace theory assumes a high temperature for its original gaseous nebula, whilst the planetesimal theory, on the contrary, must start with an extremely low temperature. But the physical states, *gaseous*, *liquid* and *solid*, are not simply explicit functions of temperature. They are functions of the *co-operation of temperature*, *pressure* (gravity), and *original velocity*. It is not true that the gaseous form of a substance is conditioned by a certain heat. It is bound to a certain heat only at a certain pressure. If a gas is under extremely low pressure it needs very little heat to retain its gaseous form, and finally, if the particles are at a certain great distance from one another it ceases to be a gas, and does not become either liquid or solid, though it cannot be said to have any temperature at all. Here is where the nebular and the planetesimal hypotheses come together. If matter be dissolved not only into its molecules or atoms but into its last ions or electrons, and if these are far enough apart to no longer yield to repelling forces, then we have a matter which is neither gaseous nor liquid nor solid, and which has no temperature. Such matter cannot be said to be cold, for cold means of low temperature.

When Mr. Wallace declares that a certain quantity of water and a certain proportion of water and land and even a fixed arrangement of their surface distribution are necessary to make organic life possible at all, he will certainly not meet with much approval, but if he even goes so far as to say that these relations, especially the configuration of the continents, have not materially changed since life appeared on our planet, he will find his theory in almost fatal contradiction to the generally acknowledged results of modern geological science.

But the worst feature of Mr. Wallace's theory is that he claims that life is only possible on a planet under the specifically adjusted co-operation of the following conditions:

(*a*) A certain distance from the Sun.

(*b*) A certain mass of the planet. (If the mass be too small the planet cannot retain its hydrogen, and consequently its sufficient supply of water; if too large it has too much water.)

(*c*) A certain ratio between water and land.

(*d*) A certain surface distribution of the water.

(*e*) An atmosphere of a certain density and a certain chemical composition.

(*f*) A certain amount of dust and atmospheric electricity.

Not only must all these conditions be fulfilled but their quantitative relations must be adjusted to the nicest point. Only where this wonderful adjustment is accomplished is life possible, and this adjustment exists and can exist only on this earth.

It seems that the cosmologist Wallace completely abandons the ideas of the evolutionist Wallace, whom we should reasonably expect to hold fast to the variation of species and to the adaptability of the organism to its environment and to changed conditions. We should further expect him to confine this adaptability not only to the limits of terrestrial changes. There is no logical ground for such a limitation and we see no reason why the celebrated author should not assume that even in a change of conditions beyond the range of experience on this planet "the fittest might survive." The wonders of the heavens in double and multiple stars, in changeable stars of regular and irregular periods, allow us just a glimpse, a bare hint of the vast possibilities of different complications of conditions, so different indeed that all our imagination of the effects must fail. If we then dogmatically declare that among these hundreds and thousands of possible adjustments of heat, pressure, light, electricity, etc., there could be none capable of giving rise to some kind of organic life, no matter how unknown to us, we follow the uncertain principle of induction and analogy too slavishly and fall into the error of materialistic pantheism. There is a legitimate form of pantheism, as that of St. Paul who speaks of God as the one " in whom we live and move and have our being." Whether I say I am a part of God or a creature of God amounts to the same thing. The difference is only a matter of words. The great error of the materialistic pantheist is not that he makes the world a part of God (St. Paul did the same), but that he makes it the *only* part, *i. e.*, the whole of God.

In regard to the second premise of Mr. Wallace it is absolutely incorrect to say that living organisms are made up of the same substance, in the same proportions. The bulk of the animal body may consist chiefly of water and carbon and nitrogen in similar proportions, but the more essential differences are certainly made up by other substances, as phosphorus, calcium, iron, etc., and perhaps the quintessence consists in some ultra-microscopic germ, or in that infinitesimal, cosmical life-dust mentioned above.

To say that life is dependent on the prevalence of the four organogens on the surface of a planet is again incorrect. They are only the organogens under the conditions of heat, gravity, and pressure as they prevail on our earth. Under other conditions of heat and pressure, other substances, iron, gold, silicon, may play the rôle of organogens and form compounds with similar characteristics as those very complex and changeable chemical (organic) combinations which respond with partial or complete decomposition to slight stimulation. The neglect of this circumstance is the greatest mistake all those have made who have hitherto written on the subject.

If on a smaller planet where gravity is not sufficient to retain the hydrogen in the atmosphere no water exists, another material may take its place. Thus, *e.g.*, it is by no means certain that the white polar caps so well observed on Mars, and so clearly indicating a change of seasons analogous to our own, consist of snow or ice, for it is very questionable whether the atmosphere of Mars contains any water at all, but they might just as well be precipitations of carbonic acid.

Thus we must come to the conclusion that within the universe known to us there is not the slightest reason to doubt that life is possible under conditions other than those prevailing on our earth, and other than those prevailing in our solar system.

Wallace not only proclaims that the earth is the only bearer of life on account of its unique position in the solar system, but he tries to give the solar system a quite unique position with regard to space as well as to time, viz., an almost central position, and this a permanent one, in the universe. It lies, according to him, near the centre of an enormous, spheroidal, stellar system of which the galaxy, with its myriads of clusters and resolvable nebulæ, forms the equatorial belt, whilst the regions remote from the galaxy and characterized by the preponderance of irresolvable nebulæ mark the poles. The greater stars seen by us form a central cluster at the outskirts of which the solar system is situated. This position of the Sun enables it to get enough fuel for its heat supply in form of meteoric showers to keep its temperature constant for millions and millions of years, for only under that condition could life arise. The weakest point in the whole argument is, that Wallace does not show why other suns similarly situated have not the same advantage. Another weak point is this, that he always speaks of a *central* position, though according to his statements the solar system must be many light-years away from the centre. At the centre he supposes there are many dark suns but we do not see them. (His reasons for the absence of any obscurations through these dark suns are very vague.)

I shall not here discuss the merits of such a theory and the obvious inconsistencies of it. But I shall point out one striking fault. Wallace claims that this galactic spheroid to which all visible stars belong *is the whole universe*—there is nothing beyond it.

Herschel and with him many other astronomers have regarded the Milky Way and all its belongings as a ring-formed or spiral system, outside of which there were many others of similar nature, but at enormous distance. Wallace regards all the other ring and spiral nebulæ as parts of the galactic system. Now this question must be open to dispute as long as our knowledge of the third dimension in stellar affairs is in its present stage, where only the parallax of a comparatively small number of the nearer stars (not even including some of the very brightest ones, *e.g.*, Canopus) is ascertained, whilst the distance of the Milky Way and the different clusters and nebulæ can only be the subject of widely diverging guess-work. There is one theory which, though old, plays a conspicuous part in Wallace's argument—and the falsity of which nobody hitherto seems to have realized. It is said that if infinite space were throughout populated with stars, no matter at what distances from one another, we should see the whole firmament ablaze, illuminated with a brightness equal to that of the Sun. For if the whole infinite space were spangled with stars we would necessarily meet at some distance a star in any direction in which we might look. Even Mr. Proctor,* who held to Herschel's theory, and who so vigorously advocated a view diametrically opposed to that of Mr. Wallace, saw no other escape from this difficulty than to assume that light might yet lose some energy on the way, if enormous distances have to be considered (it is generally accepted that the intensity of light is inversely proportional to the square of the distance, which implies that it loses nothing in traversing space).

But the whole argument quite unjustly leaves out of consideration the factor of time. Light needs time to traverse space, and though it needs only eight minutes to travel from the Sun to us, it requires years to come even from the nearest fixed stars to us, and certainly thousands of years from the outskirts of that galactic system to which we belong. The limitation of the stellar universe perceptible to us is consequently not only a question of distance and intensity, but also one of time. A star may not be seen, because its light is not old enough. Its messages in the form of rays of light have not yet reached us. A star at a distance of ten thousand light-years from the Earth must have been shining for ten thousand years before its first message arrives at our planet. If the whole infinite space is strewn with suns of different age, and if they are not just distributed in such a manner that the oldest ones are at the greatest distance from us, then the

---

* R. A. Proctor, "Other Worlds Than Ours," p. 261 ff.

number of stars we can see must decrease with the distance. The further we go from the Earth the less will be the number of stars whose light messages have reached us. And if the light of the stars is not eternal (according to Wallace it is of comparatively short duration, our Sun alone being an exception with regard to the length of its light and heat-giving period), then there must be a distance in which we can see no stars at all, no matter how many there may be. Thus we have no right to declare the limits of the stellar world visible to us to be the limits of the existing universe. All who have discussed this matter seem to have forgotten this circumstance.

But are there only the stars which we can see? And here we arrive at our last question—the other shell of the nut, with which I wish to close the discussion.

It is not the dark stars, in Mr. Wallace's sense, to which I want to refer here, nor to the planets and satellites revolving around their suns; but I wish to refer to the fact that what *we* perceive is by no means *all.* We have only states of consciousness corresponding to *certain* limited selections of oscillations. Some oscillations appeal to the sense of hearing (16,000 to 50,000, a second); some are interpreted as heat, others as light. Some, as the X-Rays and the ultra-violet rays of the spectrum, we do not perceive at all. We have to play tricks on nature in order to make these agencies write their signature in characters decipherable by us. There are vast regions within the territory of possible vibrations (from zero to infinity) *which we do not perceive at all,* not even indirectly by using tricks. There may be worlds absolutely different from ours, and which, though intermingling with ours, we can never perceive, because we have no organs for the periodicities of their characteristic vibrations. For a being endowed with senses susceptible to these vibrations the universe would have a totally different aspect. As a poor example, think of beings who would not be sensitive to the ordinary rays of light but to the X-Rays instead. What would they see of all the striving and thriving humanity on this Earth? Not much more than bones, yea, *shadows of bones and money.*

There is one more point which should make us modest with regard to our statements about what is possible in other worlds. We are accustomed to think that we are a part of this world—an item in space and time. But this is a matter of belief, not of knowledge or science. On closer examination we find that what we can say *with certainty* is that the whole world as we *know* it is *a part of us*—of our consciousness. Not that we are in space and time—but space and time are in us. They are the glasses through which alone we can see. We can look *through* them but not *at* them. If we attempt to take them off to look at them, we are totally blind. What they are objectively we do not know. They are the tools with which consciousness works. And this consciousness cannot cease, for ceasing is a relation in time, and time is only the tool of consciousness. Nevertheless, consciousness may get rid of space and time when once we give up—not the ghost but—the body.

We may express it metaphorically—though all metaphors always limp behind the truth. Time and space are for us the instruments with which we grasp the world. We have a lease of these instruments, and usually a lease for less than ninety-nine years. Whether with different mental instruments other worlds may be opened to us, whether the evil in this world is real or is only a distortion produced by the inadequacy of the tools or the imperfection of us who handle them, we cannot know in this life. We may discover when the lease runs out.

TRANSPACIFIC LONGITUDES.

BY

OTTO KLOTZ.

I. METHODS OF WORKING AND RESULTS OBTAINED.

ON December 31, 1900, articles of contract were made by Her Majesty's Government, Canada, New South Wales, Victoria, New Zealand and Queensland on the one part, and the Telegraph Construction and Maintenance Company on the other, for the construction and laying of the Pacific cable.

The contract called for the completion of the whole cable on or before December 31, 1902. It was finished two months earlier, and after undergoing the required test of a month, entered upon its commercial career on December 8, 1902.

Thus was the project, that had been advocated with persistence from some quarters for a quarter of a century, and by none more than by our own Sir Sandford Fleming, made an accomplished fact; the missing link, of about 8000 miles across the Pacific between Canada and Australia, in the world's metallic girdle was now supplied.

Before laying a cable a survey is always made along the proposed route in order to select the most favorable ground, just as the railway engineer runs lines of levels before the final location of the railway. The cable engineer determines his levels by means of the sounding line (piano wire) and at the same time obtains samples of the ocean bed. It may be stated here that the direct route of the Pacific cable between the stations was departed from, in order to avoid hills, craters and hard or undesirable ground for the cable to rest upon.

From the survey the number of miles (nautical) required for the different stations was as follows :

From Vancouver Island to Fanning Island. . .	3,654
‘‘ Fanning to Suva, Fiji	2,181
‘‘ Suva to Norfolk Island.	1,019
‘‘ Norfolk to Southport, Queensland	906
‘‘ Norfolk to Doubtless Bay, New Zealand .	513

The first section of the cable is about a thousand miles longer than any that had been laid before. This necessitated a considerable increase in copper for the conductor and in gutta percha for the dielectric. The working speed of a submarine telegraph cable depends on, and is inversely proportional to the product of the total resistance of the conductor multiplied by the total electro-static capacity of the core, so that, other things being equal, the speed varies inversely as the square of the length of the cable. In the long section there were used 600 pounds of copper and 340 pounds of gutta percha per nautical mile. On the Suva-Fanning section 220 pounds of copper and 180 pounds of gutta percha, and on the remaining three sections the copper and dielectric were in equal proportions of 130 pounds each.

In the neighborhood of Fiji, at a depth of 2,500 fathoms, a temperature of 34·1° F. was noted, being the lowest temperature taken during the survey. There is very little difference in the temperature of the ocean at great depths, say below 3,000 fathoms, over a great extent of the Earth's surface, the temperature being only a few degrees above the freezing point, or 32° F.

The greatest depth, 3,070 fathoms, about three and a half miles, was found on the Fanning-Fiji section, where the bottom specimens consisted principally of radiolarian ooze. This ooze is found at the greatest depths, and was obtained by the *Challenger's* deepest sounding in 4,475 fathoms. The United States steamer *Nero* sounded in 5,269 fathoms, 6 miles (this last being the deepest sounding recorded in the ocean), and the material brought from the bottom was radiolarian ooze.

Of the 597 samples of sea bottom obtained on the Pacific cable survey, 497 were such that they could be divided into distinct types of deposits. It was found that

294 samples referred to globigerina ooze,
65 " " " red clay,
43 " " " radiolarian ooze,
45 " " " coral mud or sand,
27 " " " pteropod ooze,
12 " " " blue or green muds,
11 " " " organic mud or clay.*

---

* Report of Sir John Murray.

The pressure at a depth of 3,000 fathoms, in which a considerable portion of the Pacific cable is laid, is about four tons to the square inch. When the cable is being laid at such depths, it will be approximately twenty miles astern of the ship before it touches bottom.

Deep sea cables last longer in the tropics than in the northern oceans. The reason is to be found in the fact that in the tropics marine life, from which globigerina ooze is derived, is more abundant than in the more northerly or southerly waters. It is the Sun and the warmed surface water that call into life these countless globigerina, which live for a short space, then die and fall to the bottom like dust, making such a good bed for the cable to rest in. In the arctic currents, where the surface is cold, the water does not teem with life in the same way as it does in the tropics, and consequently there is less deposit on the bottom of the ocean.

A submarine cable consists, first, of a core, which comprises the conductor, made of a strand of copper wires, or of a central heavy wire surrounded by copper strips as in the Pacific cable, and the insulating covering, generally made of gutta percha, occasionally of India rubber, to prevent the escape of electricity. As far as cabling is concerned, this is really all that is necessary, an insulated conductor. This, however, would not, in the first place, be sufficiently heavy to lay in the ocean, and secondly, would be too easily injured and destroyed by the many vicissitudes to which it would be subjected. For this reason a protection in the form of a sheathing of iron or steel wires surrounds the core; the nature, size and weight of the sheathing being dependent upon the depth of the water and kind of ground over which it has to be laid. The deep sea section, being the best protected from all disturbing influences outside of displacement of the Earth's crust by earthquakes or volcanic action, is naturally the one of the smallest dimensions; and for the shore end, which is exposed to the action of the waves, to driftwood, to the grinding of ice in the more northerly latitudes, and to the danger of anchorage, especially of fishing boats, the sheathing must be very heavy. So that while the deep sea cable is somewhat less than an inch in diameter, that for the shore ends is nearly 2½ inches in diameter. The action of the waves is limited to a depth of only about 13 fathoms, so that their influence on the cable, manifested by wear and chafing, is confined to the shore end.

The Pacific cable is equipped with the most modern apparatus at the various stations, and the cable is worked duplex, that is, messages are sent and received on the same cable at the same time.

Canada had carried longitude work from Greenwich across the Atlantic and thence to Vancouver. The completion of the British Pacific cable offered an opportunity for continuing the work across the Pacific in the interests of navigation and geography, besides tying for the first time longitudes brought eastward from Greenwich with those brought westward, making the first longitude girdle round the world.

In October, 1902, the Hon. Clifford Sifton, then Minister of the Interior, authorized the carrying out of the trans-Pacific longitudes, and the Governors of the South Sea, Australia and New Zealand were officially notified thereof.

In preparing the programme for carrying out the work, the climatic conditions of the various stations to be occupied were studied, so that the most favorable times and seasons might be chosen. It was found that Suva, Fiji, was the governing factor, as it was by far the rainiest place of the series.

The work was placed in my charge, and Mr. F. W. O. Werry, B.A., was associated with me as the other observer.

The instrumental outfits of the two observers were practically the same. Each observer was provided with a Cooke & Son astronomical portable transit of three inches clear aperture, one of 34 inches, the other of 36 inches focal length. Each transit was provided with reversing apparatus. The transits of stars were observed over eleven threads in groups of three, five and three respectively. The eye-piece attachment carried a micrometer—one revolution about a minute of arc with thread parallel to the transit threads—for latitude work, and the whole attachment was necessarily movable through 90 degrees, so that the movable or micrometer thread becomes horizontal. The recording of transits was made by means of a key on a Fauth barrel chronograph. Each observer was provided with two sidereal box chronometers, one being a spare in case of accident. There were besides dry cells, switchboards, and minor accessories to complete the outfit. I carried, too, a half-seconds pendulum apparatus and a Tesdorpf magnetic instrument, the latter similar to the ones furnished Drygalski of the "Gauss" on his Antarctic expedition.

At each station, that is, at Fanning, Suva, Norfolk, Southport and Doubtless Bay, a brick or cement pier was built and an observing hut to cover the same. At Vancouver, which is used as a longitude reference point for the whole of British Columbia, we have a permanent transit house.

Bamfield, on the west shore of Vancouver Island, is the eastern end of the Pacific cable, and was not occupied as an astronomical station, but simply as an exchange station, that is, for the comparison of the Fanning and Vancouver chronometers, to be described more fully later.

Longitude work consists in simply determining the accurate sidereal time for each of two places, the longitude of one of them being known at an absolute instant, and then comparing such times. The difference between them will be the difference in longitude. The operation may be briefly stated. Each observer determines the error of his sidereal chronometer at a particular instant, then by means of the telegraph line or cable the two chronometers are compared, to be explained later; this comparison may be likened to an instantaneous photograph of both chronometers. Applying the respective chronometer corrections for the instant of comparison to the times thus shown by the two chronometers, we obtain the absolute local sidereal time for each place for the same instant, and, as before, the difference between these times is the difference of longitude.

Now suppose we have a transit instrument with a single vertical thread and that thread situate in the axis of collimation; furthermore, the axis of the telescope horizontal, no inequality nor ellipticity of pivots, and the pointing of the telescope truly in the meridian; then if we record the transit of a star across the thread, and the time noted is free from personal equations, we obtain immediately the clock corrections by comparing the observed time with the right ascension of the star for that time and day. The many conditions imposed in the last sentence show the many sources of error, the effect of which must be evaluated ere we obtain the desired quantity—the clock correction; in other words, the true local sidereal time at a given instant.

We must therefore devise means for determining the instrumental errors, some of which are practically constant—inequality and ellipticity of pivots; while the others—level, azimuth and collimation—are more or less variable from day to day. Careful readings at the beginning and end of a season of the former will evaluate them. For the latter, we will speak of the level corrections first. This quantity is determined directly by means of the striding level placed upon the axis of the instrument. Readings should be taken as frequently as the intervals between stars admit. With sensitive levels, reading about a second of arc for each division, great care must be exercised in allowing the level to come to rest. My own practice is not to take a reading until fully a minute has elapsed after placing the level, and as a light is necessary for reading at night, the reading should be taken quickly, for even a short exposure of the level to light will cause a change in the reading. I consider the six-minute interval between stars the minimum during which a deliberate reading (including reversal of level) for inclinations of the axis can be made. How to treat the various level readings for one position of the instrument will depend upon circumstances. The readings may show a decided and unquestionably gradual change of level; in such a case the readings may be plotted and the level reading for each star interpolated therefrom. If, on the other hand, the level readings are confined within the errors of reading and small fluctuations, we may then take the mean of the various readings as the reading for that position of the instrument. The angular value of the level reading expresses the angle between the vertical plane (in the case under consideration, the meridian) reading and that described by the transit; the two great circles intersecting each other in the horizon, where the level correction is nil. The level factor, usually designated by B, is expressed by $\cos(\varphi - \delta) \sec \delta$. This factor, computed for each star, multiplied by the inclinations of the axis, expressed in time, gives then the level correction to be applied to the respective transits. Errors of level are measured directly, while those of azimuth and collimation with portable astronomical instruments are not directly measured, as is the case with the large transits in observatories. This leaves then the determination of three unknowns—the azimuth, collimation and clock corrections—the minimum number of stars to determine which is three. With only three stars, however, there would be no measure of the accuracy of the observations, for one, and only one, value for each of the unknowns would satisfy the three observation equations; there would be no probable error. If the instrument is not in the meridian it is evident that the times of transit of stars north of the zenith will suffer a correction of opposite sign from those to the south. If the telescope is pointing west of north, north stars transit too late, and south stars too soon, and *vice versa* if pointing east of north. As north or polar stars move slowly, they are well adapted for obtaining the azimuth correction, and hence one polar star is included in each time set for each position of the instrument and the general azimuth factor, designated by A, is $\sin(\varphi - \delta) \sec \delta$. With the collimation error, however, the correction for north and south stars is of the same sign for one position of the instrument, for the sight line describes a small circle parallel to the great circle described by the axis of collimation. But when the instrument is reversed, then the error is of opposite sign, and the transits of stars are similarly affected. The effect of the collimation error becomes therefore more apparent, and is more accurately deduced when some stars are observed in one position of the transit, and others with the telescope or axis reversed.

The effect of the collimation error on the times of transit varies directly as the secant of the declination of the star; hence the collimation factor, usually designated by C, is $\sec \delta$.

In order, therefore, to obtain a satisfactory time determination which is really the quantity sought, we observe more than the absolutely necessary three stars, and find the most probable value by the method of least squares.

In the programme of the trans-Pacific longitudes it was arranged that (barring cloudy nights) on each night there should be two independent time determinations, each determination to be derived from 14 stars, divided into two groups of 7 each, of which one was a polar. Furthermore, one group was observed clamp east, and the other clamp west. The six other stars of each group were "time" stars, and selected near the zenith and south (in the northern hemisphere) thereof. Instead of three, we now have 14 observation equations from which to deduce the three unknowns, already mentioned—by the usual method of forming the three normal equations. It is desirable to reduce the effect of azimuth and collimation on the derived clock correction; we attain this by making the algebraic sum of the azimuth factor as small as possible, and similarly with the algebraic sum of the collimation factors.

In deducing the time correction, it evidently must signify the correction at some particular epoch, for every clock and chronometer has a rate. The epoch chosen is generally the mean of the various transits constituting a set, and the transit of each star is corrected for rate, as if all stars had been observed at that mean time. If, after having obtained the azimuth and collimation errors, we apply them with their respective factors to each transit and compare this corrected transit with the apparent right ascension corrected for aberration, we obtain the clock correction of that transit or star, and the difference between this and the clock correction of the normal equation gives us a "residual." Each star thus furnished a residual, and from them is found the probable error of a single observation as well as of the deduced clock correction from all the stars. The average probable error of the latter is about $0{\cdot}01^s$, for good work.

A word about rate. Rate is one of the most difficult problems with which we have to deal in field longitude work. It is not the magnitude of the rate, although a small rate is very desirable, but the constancy. This is the crux. A chronometer may have an apparently constant daily rate, yet the hourly rate for the 24 hours may and does vary. Again, the rate is not the same when the current is on as when it is off; the former obtaining when observing, and the latter the rest of the day. The rate deduced from two independent time determinations of the same night, when the temperature is practically constant during the time of observation, and the clock is in circuit with the battery (one cell) only during that time, is seldom, if ever, the same as that obtained from day to day observations.

In our programme we have two independent time determinations for each night. Each set of transits is reduced to the epoch of the mean of the times of transit of the stars comprising that set. The rate which is applied for each transit to the mean epoch, and for which some magnitude must be assumed, is practically a vanishing quantity in the resulting clock correction. The ideal time of exchange would be at that epoch, when the effect of rate is eliminated. But, for various reasons, this is found to be impracticable. In the programme, then, of two independent time determinations, for obvious reasons the exchange was arranged to take place about midway between the two epochs.

An interpolation between the two epochs gives the clock correction at the instant required, that of the signals. This assumes that the rate is constant during the interval, and is represented by a straight line. If extrapolation is necessary, as sometimes occurs, the rate value has less weight. It is highly desirable that the temperature of the chronometer be kept as uniform as possible, and if necessary, special provision made to attain this end.

We are supposed now to have made a complete time determination and are ready for exchange of signals, that is, of a comparison between the two clocks of the two stations.

As some of the exchanges were overland lines, I shall explain this method of exchange first, taking the case of Vancouver and Bamfield. Each of these stations was supplied with a "switchboard." The portable switchboard has been in use many years and has given every satisfaction. On it are mounted a talking relay, a signal relay, and a pony or clock relay ; the last is never on any circuit but that of the chronometer with one dry cell. Besides, there are an ordinary talking-key and a signal-key, the latter breaking circuit when depressed while the ordinary telegraph makes circuit. Along one edge of the board there is a row of binding posts for connecting with the clock, chronograph, main line, and batteries, of which there are three dry cells for the chronograph, and, as stated, one for the chronometer. And lastly, there is a three-point switch, by means of which the main-line can be thrown on or off the points of the clock relay, and plugs to cut in or off any relay. While observing, the chronograph circuit passes over the points of the clock relay, and as the clock or chronometer breaks circuit every two seconds (omitting the fifty-eighth second so as to identify the minute), the points of the clock relay separate every two seconds, and hence record the clock beats on the chronograph. In the chronograph circuit is the break-circuit observing key, too, by means of which the transit of each star over the eleven threads is recorded.

It is customary when beginning the exchange to put the telegraph line for a minute at each station over the points of the clock relay, whereby the circuit of the main line is broken by each chronometer every two seconds, that is, we let the clocks (chronometers) record simultaneously over the line, each chronograph thus obtaining the record of both clocks. From this record we immediately see the relative position of the respective minutes, in fact, of the seconds too, enabling one readily to identify corresponding arbitrary signals, by means of which the more accurate chronometer comparison is made. Theoretically the comparison by the chronometers recording directly over the line, as above, is as good as by arbitrary signals. The trouble lies in scaling or measuring the former. As, for an interval of a minute, the relative position of the two-second breaks of the two chronometers is the same, after having measured one such interval on the chronograph sheet, the mind is involuntarily biased, we know that all the others should be the same, and consequently we cannot measure, say 30, our minimum number, with that freedom of mind, as would be the case if we did not know what measure to expect. Hence the device of the arbitrary signals. In this case each chronometer records only on its own chronograph. One observer now sends by means of the signal (break circuit) key 20 arbitrary signals; the chronograph circuit which always passes over the points of the clock relay is now made to pass, too, over the points of the signal relay, which is on the main-line circuit. Hence a signal sent will be recorded on each chronograph, and each chronograph has its own chronometer record for interpreting any signal, just as it interprets the transits while observing.

As the word implies, these arbitrary signals are intentionally made irregular and will average about two seconds apart. The other observer now sends similarly 40 signals, and again the former 20 more, so that the mean of the times of sending of the two observers about coincides, thereby eliminating differential rate of the two chronometers. It is customary when sending signals to give a "rattle" with the key at the beginning and end of each set. If there is no trouble on the line the whole exchange is over in five minutes. A few minutes are required for conversation about the condition of the sky. If the prospects are hopeless for the night for one, the other desists from further observations.

The accuracy with which these comparisons are made is far beyond the accuracy that is possible in a time determination; while the probable error of the latter is, say $\pm 0{\cdot}01^s$, that of the former is generally less than $\pm 0{\cdot}002^s$.

The exchange on the cable is similar to that just described of arbitrary signals. The chronograph here is replaced by the paper fillet of the cable service. It is scarcely necessary to observe that nowadays signals (messages) on the cable are not read by means of deflections of a small mirror, interpreted on an opal glass scale by means of a reflected beam of light, but are read from the fillet of paper on which a siphon records in ink the deflections. As the current is very weak, the siphon is not in direct contact with the paper but by an ingenious vibrating device it deposits a tiny drop of ink at very brief intervals. A cable message looks like a profile of the Rocky Mountains, the ups and downs having an interpretation like the dots and dashes in the Morse system of telegraphy. From experience it is found impracticable to have the clock recording directly on the cable for interpreting signals sent or received. However, it is necessary to have a time-measuring scale on the fillet. We accomplish this by attaching another siphon to the frame of the cable instrument; this one is quite independent of the cable. It is actuated by a long vertical rod attached to the horizontal arm of an ordinary sounder and connected to the siphon by a silk fibre. This latter siphon drags an ink line on the fillet. The sounder is put in circuit with the clock, and hence every time the clock or chronometer breaks circuit the sounder makes a sharp break in the line on the fillet and a time scale is obtained close to and parallel with the zero line of the cable siphon. By projecting vertically these recorded clock breaks upon the cable siphon record, we can interpret in time the arrival or departure of a signal sent by the cable key. We must know, however, the relative position of the two siphons. The signals are sent with one of the two cable keys. On cables there are always two keys, one for sending positive and the other for sending negative currents. To the lever of the cable is adjusted for our purpose another lever which is in the clock circuit. It is so adjusted that the moment the cable key makes contact, that is, sends a current into the cable, at the same moment the clock circuit is broken; thereby both siphons record the event simultaneously, and the parallax between the two siphons is obtained. As a check on the value thus obtained for the parallax, a slight tap is given to the frame carrying both siphons, thereby disturbing both and the parallax obtained. By the above arrangement when sending signals we have two records on the fillet, one by the clock siphon, the other by the cable siphon. In receiving signals there is, of course, only the record of the cable siphon, the other siphon recording only the chronometer beats, which on the fillet measure about one inch for the two seconds. The speed of the fillet may be varied to any degree. It will be seen that a comparison of clocks by this means is simply a matter of careful linear measurement. Were the records for a given signal at the two stations instantaneous, then the two records would be identical, but such is not the case. Each signal arrives late at the distant station, and therefore the two records, from each observer sending, will differ by twice the time of transmission, assuming that the time of transmission is the same in each direction, an assumption which we cannot avoid. On the long section of the cable between Bamfield and Fanning, about 4,200 statute miles, the time of transmission was a third of a second, equivalent to about 12,000 statute miles per second.

In the first longitude work by cable, before the introduction of the recording siphons, instead of arbitrary signals, the clock beats were sent by hand at intervals generally of 10 seconds, and the time of arrival of the signal, as indicated by the reflecting galvanometer, was noted by the "eye and ear" method. The uncertainties and "personal equation" in this method of exchange and comparison of clocks are apparent.

We have now explained briefly how the clock correction is obtained for a given instant, and how the comparison of the two clocks is made. The application of the clock corrections respectively to the times of exchange gives apparently the local sidereal time for each place at the same instant. Each value is, however, affected by a small correction, the personal equation of each observer. As the quantity sought is the difference between the local sidereal times, the absolute personal equation of each observer is unimportant; it is the difference between the two personal equations that affects the difference of longitude. On land lines where the ready means of transportation is good, it has been customary (up to the present, when by the introduction of the registering micrometer the personal equation is eliminated) for the observers to exchange stations, the mean result of the two differences of longitude being free from personal equation; this is on the assumption that the personal equation of the observers remains constant during the longitude campaign. On this assumption, if there is a series of stations, odd in number, and the observers occupy alternate stations, it will be seen that the odd-numbered stations will be free from personal equation, and the even-numbered ones affected by it. Now, between British Columbia and Australia, and also between British Columbia and New Zealand, the number of stations is odd, *i.e.*, there are three intermediate stations, Fanning, Suva, and Norfolk; hence Southport (Queensland), Doubtless Bay (New Zealand) and (Fiji) are free from personal equation.

Personal equation observations were, however, made at Ottawa by the two observers using the same clock and determining its clock correction at the same time on the same stars with the two transit instruments, and the resulting difference of personal equation, $0{\cdot}124^s$, applied to Fanning and Norfolk.

Southport was connected with the observatories at Sydney and at Brisbane, and similarly Doubtless Bay with the observatory at Wellington. Personal equation observations were made between the respective observers.

It was on September 29, 1903, that the first satisfactory clock exchange was had with Sydney, and so this night may be considered as the time when longitude from the west first clasped hands with longitude from the east, and the first astronomical girdle of the world was completed. The immediate reasons for the first telegraphic connection in longitude between Australia and the prime meridian, Greenwich, were: (1) With a view to confirming the position of the eastern boundary of the colony, now State, of South Australia, 141° E.; (2) for obtaining the longitude of stations to be occupied for observing the transit of Venus in 1882. To attain this end connection was made astronomically between Sydney, Melbourne, Adelaide, Port Darwin and Singapore. A connection was made, too, between Sydney and Wellington. All Australian and New Zealand longitudes at present rest on the position of Singapore as accepted in 1883, which then, quoting from the Government report of South Australia, for 1886 "had twice been telegraphically determined—first in 1871 by Dr. Oudeman, of Batavia, and Mr. Pogson, of Madras; and more recently by Commander Green, United States Hydrographic Department." The determinations of the latter were accepted. It may be remarked that at this time the Thomson (Lord Kelvin) recording siphon had not yet been introduced, and that the clock exchanges between Port Darwin and Singapore over the cable were made by use of the deflecting mirror or reflecting galvanometer, already spoken of, a method involving more or less uncertainty in noting by "eye and ear" the movement of the mirror and the instant of time of its occurrence.

Singapore was dependent in position upon Madras, the initial meridian for the Great Trigonometrical Survey of India.

For over a century observations have been taken, from time to time, to determine the longitude of Madras. The early ones, before the advent of cables and telegraphs, were dependent mostly on lunar observations, some on Jupiter's satellites. In 1891 the Survey of India had not adopted the then best value, so that at the International Geographical Congress, held at Berne in that year, the question arose, why the known error in longitude of 2′ 30″ was not corrected on the Indian maps and charts. This gave rise to a discussion in India, and the whole longitude work was reviewed, with the result that a determination *de novo* was decided upon, carrying the work directly from Greenwich *via* Potsdam, Teheran, Bushire and Karachi, where connection was made with the three arcs of the Great Trigonometrical Survey between Karachi and Madras. This work was carried out by Captain (now Major) S. C. Burrard, R.E., and Lieutenant Lenox Conyngham, R.E., in 1894-96.

The resulting longitude of Madras was $5^h\,20^m\,59{\cdot}137^s \pm {\cdot}022^s$. In 1903 a re-determination of Greenwich–Potsdam was carried out by Professor Dr. Albrecht and Mr. Wanach. Stations were exchanged and observations made with a Repsold registering micrometer. The exchange of stations was made to test the elimination of personal equation by means of the registering micrometer, and the result was highly satisfactory, the weighted mean of the one result agreeing with the weighted mean of the other to the third place of decimal of a second of time. It may be stated here that the introduction of the registering micrometer in longitude work marks a distinct epoch in that class of work, not only in assuring greater accuracy in the results, but also in very materially reducing the cost of longitude work of the first order by the saving of time and money in doing away with the necessity of exchange of stations. Since the completion of the trans-Pacific longitude work, the two Cooke transits used in that campaign have been provided with registering micrometers, made by Saegmüller, of Washington, and the longitude work of 1905 was carried out with that attachment.

From the 1903 determination by Albrecht we have for the longitude of Potsdam $0^h\,52^m\,16{\cdot}051 \pm {\cdot}003^s$. This value is ${\cdot}098^s$ greater than that of Burrard, obtained in the series of 1894–96, referred to above.

In the reduction (1885) of the Australian longitudes, the longitude of Madras was accepted as $5^h\,20^m\,59{\cdot}42^s$, and the derived value of Sydney was $10^h\,04^m\,49{\cdot}54^s$. In making the comparison between the longitude of Sydney as brought from Greenwich eastward with that brought westward (by Canada) the best and most recent available data are utilized for the longitude of Madras.

Taking then Albrecht's value for the arc Greenwich-Potsdam, and the values of Burrard for the arcs Potsdam-Madras we obtain for the longitude of Madras $5^h\,20^m\,59{\cdot}235 \pm {\cdot}021^s$. As there have been no new determinations of the various arcs from Madras to Sydney, the values given in the report of May, 1885, by Ellery, Todd and Russell on Australian longitude are used. Adding the value to the above accepted value, we obtain for Sydney $10^h\,04^m\,49{\cdot}355^s \pm {\cdot}088$. The Canadian value is $10^h\,04^m\,49{\cdot}287^s \pm {\cdot}058$. Difference $0{\cdot}068^s = 1{\cdot}02'' = 84$ feet for the latitude of Sydney. That is, the first girdle of the world closed within 84 feet.

Final Longitude Values.

STATION	LONGITUDE							
	TIME			PROB. ERROR	ARC			PROB. ERROR
	H	M	S	S	°	′	″	″
Vancouver	8	12	28.368 W	±.050	123	07	05.520	± .75
Fanning	10	37	33.774 W.	±.054	159	23	26.610	± .81
Suva	11	53	42.389 E.	±.055	178	25	35.835	± .82
Norfolk	11	11	41.146 E.	±.056	167	55	17.190	± .84
Southport	10	13	39.782 E.	±.056	153	24	56.730	± .84
Sydney	10	04	49.287 E.	±.058	151	12	19.305	± .87
Brisbane	10	12	06.044 E.	±.073	153	01	30.660	±1.09
Doubtless Bay	11	33	56.146 E.	±.060	173	29	02.190	± .90
Wellington	11	39	05.087 E.	±.075	174	46	16.305	±1.12

II. OBSERVATIONS AND NOTES OF TRAVEL.

To be accustomed to observing in the northern part of the northern hemisphere and thus suddenly transported to the southern hemisphere for the sphere of action, plays havoc with one's mental picture of the sky on a clear night.

Polaris, that has done such good service these many years, is far below the horizon. Vega, that bright orb, has left its accustomed place in Canada south of the zenith, and now describes a small arc across the northern horizon. The Great Bear has retired to his den to await our return from the southern trek. Even Orion and Sirius and Procyon have crossed our zenith and joined the hosts to the north. However, for our loss of Polaris, Cassiopeia, Ursa Major, Draco and other northern friends we have been presented with effulgent and dazzling Canopus, only rivalled by Sirius, with bright Achernar and the pretty Southern Cross with its conspicuous pointers, Alpha and Beta Centauri. Alpha Centauri is the nearest star to the Earth, being distant only four-light years; that is, light with a velocity of 186,000 miles a second would not quite get here in four years. The constellation of the Southern Cross is really not a conspicuous object in the sky, and many people living in the southern hemisphere cannot point it out, which can scarcely be said of the Great Bear in the northern hemisphere. The ancients did not recognize it as a separate constellation, but included it in the constellation of the Centaur. There is no bright star near the south pole to guide the surveyor or sailor or wanderer as our pole star does. Even the astronomer longs for polars to keep check on his azimuth. The "coal sacks" or partly starless spots are conspicuous in the southern sky, appearing like small black clouds, in contradistinction to the fleecy Magellanic clouds hovering about Hydra.

Summer weather prevailed throughout the campaign, although Fiji was occupied in the dead of winter, which term or designation seems to a Canadian absurd when he is at the time melting in the tropical hothouse. Christmas was, for my first time, spent working under a summer sky. It is undoubtedly plesant for people to picnic, have regattas and similar outdoor amusements on that day, but it is contrary to all traditions of Yuletide, and it is devoid of that sacredness of the hearth and family ties that our more severe northern clime calls forth, when the earth is bound fast in snow and ice only the more to quicken the warmth of hearts.

In one of Elia's delightful essays he tells us: "I have no astronomy. I do not know where to look for the Bear, or Charles's Wain; the place of any star; or the name of any of them at sight. I guess at Venus only by her brightness; and if the sun on some portentous morn were to make his first appearance in the west, I verily believe that, while all the world were gaping in apprehension about me, I alone should stand unterrified, from sheer incuriosity and want of observation." There is no doubt that the lack of observing or noting things in nature is very general. People see things a hundred, a thousand times, yet it leaves no mental impression, and if a change takes place it passes without notice.

One would imagine that the fact that the path of the Sun and the Moon in the northern hemisphere (outside of the tropics) is always to the south of the zenith is so impressed upon every adult, that if either should pass to the north it would seem strange and, therefore, would be noticed. But such is not or very rarely the case. The hyperborean goes to the antipodes and is oblivious of the relative changed position of our two luminaries, and worse, is indifferent and doesn't care. However, when passing from one hemisphere to another on shipboard, some will be persuaded to look through a smoked glass or telescope to see "the crossing of the line"! Poets have been great sinners in astronomical lore. Without the slightest qualms they let the crescent moon, or Venus, or Sirius, or Vega, or Orion shine, rise and set in any part of the heavens to suit their fancy. Even artists have shown impossible positions for the Moon. Perhaps in the future the function of the eye will be to see.

Contrary to expectation, there was less annoyance from beetles and other insects while observing than is found in Canada. A light in the open at night with us attracts multitudes of moths and beetles, and one's patience is sometimes sorely tried to have an unexpected visitor stake out a homestead on the nose just at the critical moment of the transit of a star, or have a select party of moths take a free ride on the chronograph and interfere with the recording pen. From such tribulations the tropics spared us, although the music of the mosquito is not unknown. The observatories were too new to offer special inducements for a visit from centipedes or tarantulas. In Australia, especially, the white ant is very destructive, and as most of the dwelling houses are built on posts and have no cellar, the posts are capped for protection with projecting sheet-iron, best compared to a large inverted pie-plate. This precaution was taken, too, with the observatories at Fiji, Queensland and New Zealand. When the ant gains access, it attacks the under side of the floor boards, and completely riddles and honeycombs the wood, without, however, wholly piercing the board, so that some fine day one is measuring the distance from the floor to the ground, using the leg as measuring rod.

During the winter months at Fiji there is less rain than during the other seasons, yet it is decidedly wet, although the winter of 1903 was considered remarkably dry for Suva. Due to the mountainous character and the prevailing south-east trade winds, the southerly side of the island (Viti Levu) is far wetter than the opposite or northerly one. The former is clothed in dense vegetation and woods, while the latter is more open and covered with grass. The exasperating thing about the precipitation is that it is so fitful. Instead of pouring buckets for a given number of hours per day, it divides it (that is, in the dry season, for in the wet season "the Arab folds his tent and quietly steals away,") into very many and unequal divisions. Time and again at night the kaleidoscope would have a programme something like this: Cloudy,—clear,—the astronomer at his instrument—hello,—telescope wet,—it rains,—close shutters—ten minutes later, sky smiles as if to disavow it ever rained,—shutters open—get three threads—clouds—a prayer—try another star—is landed—rain again, and so on through the night. Vigilance and patience, however, eventually secure their reward, and a sufficient number of stars and satisfactory nights are secured to move on to pastures new.

Atmospheric electricity was found most vividly displayed at Southport, Queensland. The flashes and crashes were sufficient to disturb people not possessed of hyper-sensitive nerves. However, having been fully informed before the arrival of the pyrotechnics peculiar to the place, when they did come they were looked upon as quite natural.

It may be noted here that on Monday, November 2, the daily papers of Australia brought news of Saturday, October 31, from France, that heavy magnetic disturbances had taken place, causing an interruption or partial interruption of telegraphic and telephone communication with the rest of Europe and with America. Communication was suddenly restored at sunset. Atmospheric phenomena accompanied the disturbance, including an aurora borealis. Being interested in the disturbances caused by earth currents, personal inquiries were made at the Government telegraph office, Sydney, and through the kindness of the Superintendent, Mr. Young, the following was furnished me:

"Particulars of interruptions to telegraph lines in the State of New South Wales, as observed from the chief office (Sydney) on October 31, 1903:

"At 4 p.m. (Greenwich 6 a.m.) the current in the Melbourne quadruplex circuit fluctuated considerably, and at 5 p.m. southern quadruplex circuits suddenly disclosed a foreign element. Two copper wires were the first affected, the galvanometer indicating a varying current from 10 to 25 degrees, which was located between Mittagong and Goulburn. Other southern circuits were unworkable. The disturbance appeared much stronger further south than Goulburn. At 6.50 p.m. it was necessary to close the No. 2 side of the Bathurst (western) quadruplex.

"The northern quadruplex circuits, though not so seriously affected, worked indifferently after 6 p.m. These conditions continued in a more or less aggravated form up to 8.15 p.m., when most of the offices were closed for business. The telegraph lines running in a southerly direction were the most violently affected.''

In the *Monthly Notices* of November, 1903, the Astronomer Royal gives the beginning of the magnetic storm observed at Greenwich, as October 31, 6 a.m., agreeing with the time given for the beginning of the disturbances noted on the telegraph lines in Australia.

These disturbances were simultaneous with the appearance of a great group of spots near the Sun's limb. At Greenwich the movements of all the magnets were extremely violent. The extent of change of the declination magnet was over two degrees in about three hours. Elsewhere, too, over the whole circuits of the Earth, where observations were taken, this great magnetic storm of October 31-November 1 manifested itself on the magnetic instruments.

While engaged at trans-Atlantic longitude work at Canso, Nova Scotia, in 1892, some severe earth currents (magnetic storms) were experienced, notably the one of July 16, which was also recorded at Brest, Malta, Cairo, Madras and east to Singapore; and the one of August 24. The deflections of the siphon on the fillet of paper were far in excess of that caused by the cable current or difference of potential. When the earth currents set in on the evening of the latter date the aurora borealis was quite marked, and appeared swaying in broad faint waves southward from the north. From records of the cable office there, it appears that there are more earth currents at night than during the day time. The most extraordinary feature of the earth currents is that, from the siphon record, one is led to believe that they alternate from one polarity to the other. Professor Preece, however, maintains that, although they are variable they are continuous, and give no indication of alternations. From the direction of the cables it is noticed that the cables running east and west are far more troubled with these currents than cables running north and south. There is, however, a wide difference on east and west lines, and they are felt more on the American than on the European side of the Atlantic. The year 1892 was remarkable in the number and severity of electric storms and earth currents. From the supposed periodicity in the earth currents, corresponding to the eleven-year solar cycle, it was anticipated that 1903 would show abnormal disturbances by earth currents. By the insertion of a condenser at each end, between the cables and the receiving and sending instruments, earth currents through the cable are thereby obviated.

In my journey around the world I visited a number of observatories. At Melbourne the transit is of 8-inch aperture, and is provided with two 4-foot circles, reading with 6 microscopes. There are two large collimating telescopes mounted on stone pillars, and the inclination of the transit axis is obtained by means of a mercury trough in which the threads are reflected and the deviation read with the micrometer. There is no adjustment for azimuth or level. The former keeps within a range (periodic in the year) of 3·6″, being 1·8″ each way. The level varies also periodically, from summer to winter, and from winter to summer, the range being three seconds of time, due to moisture of ground and unequal heating of the building or room, one side being exposed to the rays of the Sun and the other not.

Probably the principal work done here is with the photographic telescope, 13-inch lens, by Grubb. It is mounted like an equatorial, *i.e.*, eccentrically, and not like the companion one at Red Hill, near Sydney, which is of the same size, but is suspended between two steel girders, revolving in right ascension on two pins parallel to the polar axis, the telescope moving in declination. The latter mounting appears the steadier. The clock-work of the Melbourne instrument seems almost perfect. The sidereal clock controls it; if it moves too fast, electric contact is made by a spring to retard it; if it goes too slow, another spring makes contact and accelerates it. The observer can, by means of a key with two contacts, immediately correct the clock-work. The automatic control takes about three seconds before the correction is made. To test the quality of the sky three exposures are made, one of 5 minutes, one of 2½ minutes and one of 20 seconds. If the sky is good the last exposure should show stars of the 9th magnitude. The work assigned to Melbourne in the photographic survey of the heavens extends from −65° to the South Pole. For catalogue work three exposures, forming the apices of an equilateral triangle of sides of 8″ (of arc), are taken to eliminate false images made by dust specks in the development of the plates. The measuring machines for the photographs are made by Repsold, of

Hamburg, and the micrometer reads to tenths and by estimation to a hundredth of a second of arc. For development hydroquinone is used and the water is filtered. The drying is done in a box to exclude dust, and plates of chloride of sodium are placed in a box for drying. A Zeiss comparator had recently been added to the equipment for examining the plates. Melbourne has long been famed for its 4-foot reflector by Grubb, used formerly for the survey of Herschel's nebulæ in the southern hemisphere, but now resting in "innocuous desuetude"; the focal length of the speculum is 32 feet, but with the small mirror (Cassegrainian) for throwing the rays into the eye-piece, it is 120 feet. The highest power used is 1000, giving, then, a field of about 8 minutes of arc. I saw the spare speculum; it weighs about 500 ℔s., is 3½ inches thick at the centre, and the ordinate of curvature at the centre is less than an inch. The gable roof over the telescope can be completely rolled away and the telescope pointed to any part of the heavens, differing thereby from the Rosse telescope. The atmosphere of Melbourne is not good for observing, being full of dust and ammonia, the director, Mr. P. Baracchi, said.

Unfortunately for astronomical work the observatories and their directors in Australia are burdened with meteorological service of the respective states, making the daily forecasts, etc.

In Adelaide there is an observatory equipped with an 8-inch Cooke transit and a 6-inch equatorial, the latter being mostly used for the "Friday public night." Time work is the principal service of the astronomical observatory. Here the veteran Sir Charles Todd is (1904) astronomer, weather officer and Deputy Postmaster-General, including superintendence of the telegraph and telephone systems,—verily, calling forth a strenuous life.

At Cairo (Heliopolis) I found that the invasion of the electric tram in the land of the Pharaohs had necessitated the removal of the observatory, as it included magnetic work, from Heliopolis to Helwan, some 16 miles up the Nile, and which, too, offers a better sky, being situate on the edge of the desert. My visit was on the closing day of the one and the opening of the other. An efficient time service is maintained by the observatory, which is under the able direction of Capt. Lyons, who also has charge of the surveys.

At Heidelberg the Mecca is the Königsstuhl where Prof. Dr. Max Wolf labors, and extends a hearty welcome. The first instrument examined was the Zeiss stereo-comparator, by means of which two similar star plates 12 × 16 inches are compared, utilizing two oculars, one for each plate. Each plate is adjustable in the frame in the two rectangular co-ordinates. The two plates are brought into coincidence by ocular superposition of two stars of each plate. If now we look with one eye we see one plate, then with the other the other plate, so that if a star has changed its light, *i.e.*, is variable, it will at once be seen, or if a new star has appeared it will similarly become apparent. The pin holes or dust specks are readily recognized, too. The celestial area covered by the plates is about 6 by 8 degrees. The exposures are generally of 3 hours. For stars up to the 17th magnitude three nights are necessary, together, say, 17 hours. Dr. Wolf showed me two plates with Saturn and two of his moons; although the difference of the time of exposure was only 15 minutes yet the Earth in that time had laid down by its orbital motion a sufficient base line to give a stereoscopic effect to Saturn; it seemed suspended in the sky far in front of the stars. The perspective of the Moon was pretty, too, being from photographs of the same phase, but at a nine months' interval with different libration. Many beautiful star slides were shown and my attention was especially directed to the nebulæ and the dark space, with but few stars surrounding one side of each, showing the drift of the nebulæ, a fact first discovered by Wolf. The Bruce photo-telescopes are of 16-inch aperture and two metres focal length, the pointing telescope mounted between the two photographic ones of the same diameter has twice the focal length. The whole is moved by clock-work which has a further fine electric control by the observer. His practice in exposing is to pull the one shutter, note the time by chronometer, and twelve seconds later to open the other shutter. This interval is arbitrary and simply allows time to note the time. Plates are dried in 10 to 15 minutes over a radiator. Formerly he used Cramer and Seed plates but now gets them in Germany. Dr. Wolf is of the opinion that no maker's plates are or remain the same; they vary in quality.

A brief visit was paid to the observatory at Munich, which is under the directorship of von Seeliger. Dr. Oertel showed me the various instruments. The 6-inch transit by Merz has been supplied for some years with the Repsold registering micrometer and has given satisfaction. This is the micrometer that is now being adopted generally for portable transits for longitude work, as by it the personal equation is eliminated. The temperature in the transit room, when observing, varies between summer and winter, 50° R. or 112° F. There are about one hundred nights in the year on which observations can be made, but far from being all clear nights. In the room adjoining the transit is the first meridian circle of Fraunhofer, used as a transit instrument now. The photographic telescopes (two) are similar to Wolf's but are only 6-inch aperture. The equatorial is a 10-inch refractor. Electric trains and electric lights are interfering with the observatory work and it is proposed to move the observatory. My guide spoke of the necessity of considering the comfort, especially the social amenities, in the selection of a site for an observatory, saying "an astronomer cannot live on stars alone."

At Leipzig Dr. Peters kindly conducted me through the Observatory. His work is and has been with the heliometer for stellar parallax. The heliometer has a 6-inch divided lens of 2 metres focal length. Dr. Peters said, that the more refined the observations and the closer the attention to all the corrections, the smaller the supposed parallaxes become. The instrument was built by Repsold, "der gute Arbeit liefert, aber sich nichts sagen lässt," as my guide said. The lens is by Ertel. The illumination for the various micrometers, etc., is electric. In another room, on a pier, is a Pistor & Martin's horizontal telescope, about 20 inches long, which revolves transverse to its length, and, in consequence, the observer occupies the same position for various declinations.

The clock room is kept at a fairly constant temperature by means of a thermostat. When the difference of temperature between the outside and room becomes too great, then a change is made in the thermostat setting, so that there are temperatures at 10°, 15°, 20°, and 25° C., at which the room is kept during the year. When the summer temperature exceeds for a time 25°, the artificial heating of the room is abandoned altogether. There is a Tiede, a Riefler and several other clocks. Examination has been made of the amplitude of the arc of the standard clock by means of a micrometer and illumined scale at the foot of the pendulum. By means of this $\frac{1}{100}$ of a millimeter, equivalent to 2 seconds of arc, is read, and the irregularity of the teeth of the escapement wheel determined. The refractor is a 10-inch instrument. Leipzig has about one hundred nights a year available to a greater or less extent for observing. There is a complement of meteorological instruments, but now the "probs" are issued from Chemnitz, to the relief of the astronomer.

At Kiel Director Harzer received me most cordially. The most interesting instrument at the observatory is the new meridian circle, then recently mounted and whose constants and idiosyncrasies had not yet all been determined. It is the most perfect meridian circle I have seen. Provision for everything seems to have been made. Lens 8-inch, by Steinheil; graduation and mechanism by Repsold; weight on axis only 4 lbs; shutter 3 metres open; cloth screen worked electrically for wind or protection in general; electric illumination from city and use of transformers; electric lamps for reading microscopes on circle were on brass mountings, but transmission of heat affected readings, so the mounting was changed to wood; readings by micrometer to 0·4″, by estimation to 0·04″; collimating telescope gives distance of 66 metres, and in addition there is a mire at 7 kilometres; besides a mercury nadir there is, too, a mercury zenith; there is a special provision for determining the flexure of the two tubes of the telescope, set in a cube; a registering micrometer as at Munich; then there is provision for the thorough mixing of the air within and without, for steadiness of image, by means of large galvanised suction pipes; the current was turned on in my presence and a piece of chronograph paper was rapidly drawn into the pipe. The building (meridian) is of iron with hollow walls. The foundation-basement (brick) is double-walled also. In it is the sidereal clock, by Knoblich, of Altona. It is in a glass case, exhausted to 16 mm. and the weight is only 250 grammes (?) A complete study has not yet been made of the clock. A peculiarity has been noticed, and that is, when the weight in its descent approaches the cylindrical bob the rate of the clock changes, and when it has passed the bob, the rate changes to the opposite side of that when approaching. The amplitude is read by two fixed microscopes opposite the arc. The annual range of temperature in the basement (for the clock) is about 5° C. No provision is made for uniform temperature for the year, as the Director does not consider it necessary. The clock face can be seen by means of a tube, reflectors, etc., in the meridian circle room, also heard by means of a telephone. Of the equatorial and minor instruments there is nothing special to record. In a separate room are quite a number of geodetic instruments formerly (before 1864) of the Danish Geodetic Survey, and appropriated by Prussia when Schleswig-Holstein was taken from Denmark. As in Munich and Leipzig, there are at Kiel about one hundred observing nights in the year.

At Hamburg a visit was paid to the Seewarte, under the impression that there was an astronomical observatory in connection therewith. In this I was mistaken. The Seewarte is a marine museum, formerly also a magnetic observatory, and primarily the chief meteorological station for Germany. Nautical instruments are tested and chronometers rated.

The rating of chronometers is done at temperatures varying by 5° C., from 5° to 25° C. There are four boxes artificially heated by gas flames, in which the chronometers are placed; there is accommodation for from 150 to 200 chronometers. The control of the heat is not automatic but is looked after by an attendant. Here were tested Drygalski's chronometers for the South Polar expedition, and they were subjected to a temperature of −5° C. by means of ice and salt. Time observations are made with a small portable transit by observing a time star in the vertical of Polaris (Döllen's method), instead of the more refined method used in the longitude work described. Preference for the former is due to the unfavorable sky in Hamburg, where it is difficult to get a set of time stars.

Here is Alex. von Humboldt's magnetic instrument and Neumayr's portable instruments which he had in the southern hemisphere. The daily weather maps are issued from the Seewarte. In the basement, heavily vaulted, is the old magnetic room, which is circular. From the central pillar (declination) sights could be had through four underground tubes extending to the edge of the hill, on which the building stands, to four distant church steeples, including over 180° of the horizon.

These were for declination determinations. Now, the magnetic observations are made at Borstel.

I met Dr. Heitke, who was busy at the time drawing isobars. The areas of low barometers come mostly from the west across the North Sea and then generally trend northeasterly across the Baltic, seldom crossing Europe. Some lows come from the south, too, these giving rise to the Mistral, Bora, and in Switzerland the Föhn (our Chinook of the Rocky Mountains). Germany, and Europe in general, can never have such a good weather service (prognostication) as we have, especially in eastern North America, for they cannot get telegraphic reports far from the west and learn of the advancing storms as we can.

In the rotunda is a red glycerine barometer (a very long glass tube) on which the atmospheric pressures are seen very much exaggerated compared with the mercurial barometer. In the rotunda there is a machine, too, with a long arm, capable of horizontal rotation for rating and testing anemometers. The results are not wholly satisfactory. I was shown some air pressure instruments that had entered for the competition (first prize 5000 marks), which was decided the day of my visit. The apparatus that got the first prize was a very complicated affair with many copper tubes. There were over a hundred competitors. It seemed questionable if any were adapted for practical work, being much too complicated.

On the following day I visited the astronomical observatory. The Director, Dr. Schorr, being absent, Astronomer Dr. Arnold Schwassmann showed me about. We went to the meridian circle room, where Rümker did his notable astronomical work over half a century ago. He showed me one of Rümker's original note books of observations, foolscap blank books with coarse plain paper for leaves. To the uninitiated the entries made, apparently with a carpenter's lead pencil, are Chinese. Thirteen threads were observed, and the four microscopes read for declination. The instrument is now almost exclusively used for time determinations, about the most important service, apparently, of the observatory at the present time. Measures are under way for the removal of the observatory some 10 kilometres, in order to be rid of the glare of the city electric lights, and hence make more work (photographic) possible.

The principal mean time clock is by Strasser and Rhode, of Glasshütte, Saxony. The most interesting thing about it is the adjustment to absolute (Greenwich standard) time. This is ingeniously and very satisfactorily accomplished by having two small pendulums, one on each side, one direct and one inverted, of the pendulum. Each can in turn be attached to the main pendulum while in motion by a hook dropped by hand into a slot in a small plate in the pendulum rod. In the one case the connection retards the clock one second in one minute ; in the other, accelerates the same amount.

I expressed my doubts of the practical value for the time-ball service of refinements of tenths of a second or less. As there is an interval, through the mechanical and electrical devices for dropping the ball, which has been found here to be seven-tenths of a second between the electric signal of the clock and the actual dropping of the ball, it has been so arranged by suitable mechanism that opens (closes) the circuit at $59\frac{3}{10}$ seconds, and drops the ball exactly at Greenwich noon. Time is furnished automatically to the Stock Exchange and to the city watchmakers and jewellers. The 10-inch equatorial sees little service. It is only after 1 a.m., when some of the city lights are turned off, that any photographic work is done.

A visit was paid, too, to the Royal Observatory of Scotland, on the commanding hill at Blackford Hill station, near Edinburgh, and finally, to the Royal Observatory, Greenwich, through which passes the prime meridian of the world. Both are so well known that any brief description would be superfluous.

It is perhaps a unique experience to have had at the latter, one foot in longitude east and the other in longitude west, and again in Fiji, the preceding year, at the anti-prime meridian, the same phenomenon, with the additional experience that one could walk in a step from one day to another, say from Wednesday to Thursday, or, stepping eastward, from Thursday to Wednesday ; for at the anti-prime the change of day takes place ; the hour of the day or night is, of course, the same, only the day is different, depending upon which side of the 180° meridian one is. It was a great achievement that the nations accepted one prime meridian for the world ; that Greenwich was chosen was but natural, for, through

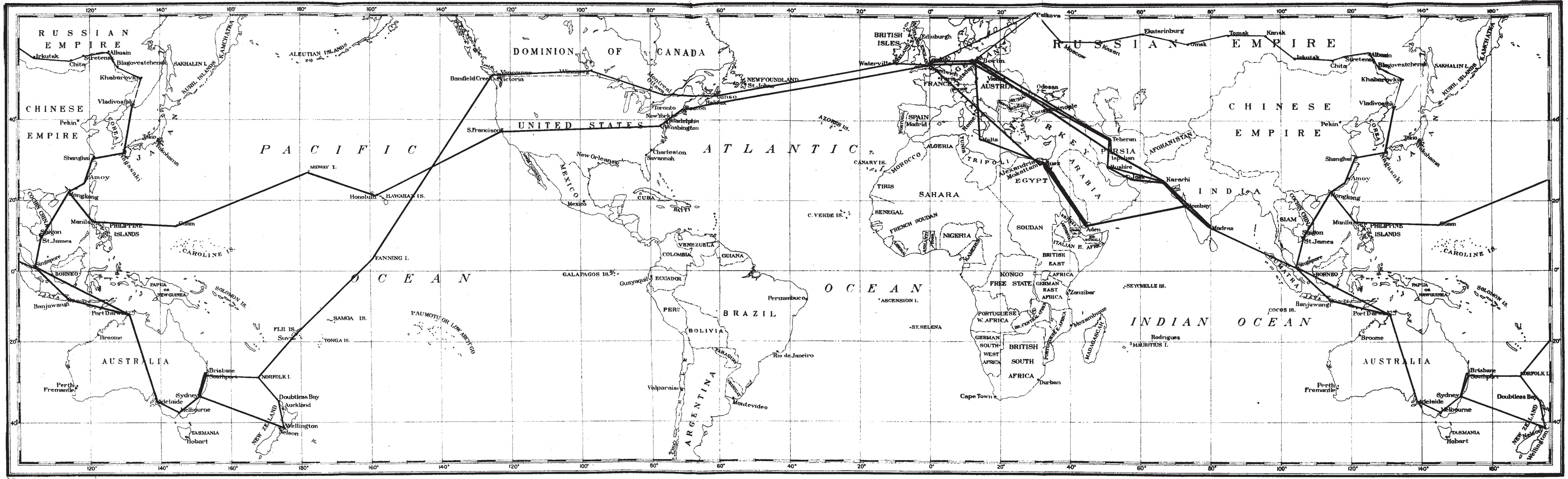
England's pre-eminence as a sea-power, she had charted almost every nook and corner of the world, and her charts, used by other nations, were, of course, referred to the meridian of Greenwich.

Allied to the former is the adoption of standard time in practically all civilized countries, to the great benefit of man. May I be permitted to add that it is to be hoped that before long the English-speaking nations will fall in line with the rest of the world and adopt the national metric system of weights and measures, not for any sentimental reasons, but for those of business and common-sense.

A word before closing about the speed of messages on cables. Let it be remarked at once that the actual time occupied on the cable itself for the transmission of the signal is a negligible quantity, for, if we imagine a single cable of sufficient capacity to compass the earth, a signal would make the circuit in about two seconds. As it is not practicable to have a single cable very many thousands of miles in length, the communication is made by numerous sections, part of which are cable and part land lines. This necessitates repetition by manual transmission, and here is where the unavoidable delay occurs, to say nothing of stress of business causing further delay. As an example of speed under the most favorable conditions may be cited the despatch per British Pacific Cable—the All-Red Line—and Canada, from Melbourne to London, giving the result of the cricket match played with the all-England team. Fourteen minutes in absolute time after the despatch left Melbourne the result of the match was sold in bulletins on the streets of London.

Poor Puck is left far behind, when Shakespeare lets him say: "I'll put a girdle round about the earth in forty minutes."

TRANS PACIFIC LONGITUDE CONNECTIONS



Legend

CANADIAN ARCS	———	UNITED STATES ARCS	———
ENGLISH ,,	———	RUSSIAN ,,	———
INDIAN ,,	———	GERMAN ,,	———
AUSTRALASIAN ,,	———		

DR. OTTO KLOTZ,
TRANSACTIONS, THE ROYAL ASTRONOMICAL SOCIETY OF CANADA FOR 1905.

JAMES JOSEPH WADSWORTH, M.A., M.B.,
SIMCOE, ONT.
BORN 1842, DIED 1905.

OBITUARY NOTICES.

JAMES JOSEPH WADSWORTH.

JAMES JOSEPH WADSWORTH died at Simcoe, Ont., on March 11, 1905, in his 64th year. His birth place was Toronto. From the University of Toronto he obtained the degree of B.A. in 1860, M.A. in 1863, and M.B. in 1869. He was a gold medallist in Arts and a silver medallist in medicine.

For over thirty-three years he was school inspector for the county of Norfolk, and though his duties were arduous, he yet found time for special research in fields unknown to the ordinary busy man. From early life he was deeply interested in astronomy, and while at the University, by contact with other kindred minds and by using the means at his disposal, he developed his taste for science.

When engaged in his lifework he was never without a telescope, large or small, and he finally constructed one for himself. It is a reflecting telescope with a mirror 12½ inches in diameter, and at the time it was made it was the largest reflector in Canada. Its definition is admirable, and when we learn that Dr. Wadsworth not only ground and polished the mirror, but also constructed the machine necessary to accomplish the delicate work, we must conclude that his gifts were many.

Dr. Wadsworth was for many years a member of the British Astronomical Association and of the Royal Astronomical Society of Canada, and to the latter he communicated many interesting observations and notes. He also had a personal correspondence with many prominent astronomers in Great Britain. But perhaps his greatest service to astronomy consisted in the seeds of interest in the subject which he planted as he went about his daily work,—seeds which, warmed by his kindly nature and jovial disposition, will assuredly in the future bear valuable fruit.

LARRATT WILLIAM SMITH.

LARRATT WILLIAM SMITH was born at Stonehouse, Devon, England, on November 20, 1820, and died in Toronto on September 18, 1905. He was educated at Upper Canada College and King's College. The latter institution was formally opened on June 8, 1843, and Larratt W. Smith was one of the class of twenty-six students who then signed the roll. He received the degree of B.C.L. in 1848 and that of D.C.L. ten years later. In 1843 he was called to the bar and later he was made a Q.C. by the Ontario Government. He was elected a senator and twice was vice-chancellor of the University of Toronto. He was president, in 1895, of what is now the Royal Astronomical Society of Canada, and his portrait is the frontispiece for the Transactions for ~~that~~ the year. 1901.

Dr. Smith had also many other interests. In 1837 he served as a lieutenant in the North York militia and he retained an interest in military affairs. His business connections were many and important, and he was also president of the Imperial Federation League.

Dr. Smith's interest in astronomy was much quickened by his association with the late J. G. Howard, who presented High Park to the city of Toronto, and who gave Dr. Smith an excellent three-inch refracting telescope, which the latter, in turn, presented to the Royal Astronomical Society of Canada.

INDEX.

Aberration, constant of, 20
Achievements of Nineteenth Century Astronomy, 125
Astronomy of Tennyson, 112
ATKINSON, R., Profit from Astronomical Study, 51
BARR, J. Miller, Contributions, 141
Colors of Helium Stars, Barr, 144
Comets of 1905, 21
DE LURY, A. T., Eclipse Expedition, 57
Eclipse Expedition to Labrador, 14, 57, 70, 79, 89.
Figure of the Sun, 16, 146
GRAHAM, L. H., Nineteenth Century Astronomy, 125
Gravity Determinations in Labrador, 70
HAMILTON, J. C., Stellar Legends, 47
HARVEY, Arthur, death of, 13
" Solar Spots and Magnetic Storms, 35
KING, W. F., Dominion Observatory, Ottawa, 27
KIRSCHMANN, A., Life in Other Worlds, 151
KLOTZ, Otto, Transpacific Longitudes, 175
LAMPLAND, Photographs of Mars, 19
Lectures, Special Course, 23, 26
Life in Other Worlds, Kirschmann, 151
LOUDON, W. J., Lunar Tide on Lake Huron, 131
LOWELL, Work on Mars, 19
Mars, Canals on, 19
MARSH, D. B., Photographing Sun and Moon, 108
Magnetic and Meteorological Observations at North-West River, Labrador, 79
Medal, the Society's, 25
MENZIES, W., Observations in Labrador, 79
Meteor's Path, 21
MUSSON, W. B., Stellar Classification, 151
New Problem in Astrophysics, Barr, 146
New Variable Stars, Barr, 141
Nova Aquilæ, 20
Obituary Notices, 207
Ottawa Observatory, 13, 27
Papers and Lectures for 1905, 26
PATERSON, John A., Astronomy of Tennyson, 112
Personal Profit from Astronomical Study, 51
Photographing the Sun and Moon, 108
PICKERING, W. H., Saturn's Satellite, 17
Planets, Researches on, 17
PLASKETT, J. S., Photography of Corona, 89
Plates and Filters for Photography of Corona, 89
President's Annual Address, 13
Satellite, tenth to Saturn, 17
" sixth and seventh to Jupiter, 18
" variation in intensity, 18
Seal for the Society, 23
SEE, T. J. J., Elements of the Planets, 19
SMITH, Larratt W., death of, 13, 208
Solar Spots and Magnetic Storms, 35
Stars, researches on, 20
Stellar Classification, Musson, 151
Stellar Legends of American Indians, 47
STEWART, Louis B., Gravity Determinations, 70
STUPART, R. F., Observations at North-West River, 79
Sun, researches on, 14
Tide on Lake Huron, 131
Transpacific Longitudes, Klotz, 175
Treasurer's Report, 12
University and the Society, 24
Variable Stars, 20, 141, 143
WADSWORTH, J. J., death of, 13, 207