22. COMMISSION DES METEORES, DE LA LUMIERE ZODIACALE ET DES PROBLEMES ANALOGUES

PRESIDENT: M. F. L. WHIPPLE, *Harvard College Observatory, Cambridge* 38, *Mass., U.S.A.*

MEMBERS: MM. Astapovich, Bečvář, Bosler, Chant, M. Davidson, Dobson, N. Donitch, Dufay, Elvey, J. W. Evans, Fedynsky, Fesenkov, Mme Flammarion, MM. Gatterer, Guth, Harang, Housman, Kaplan, Kopal, LaPaz, Leonard, Link, McIntosh, Millman, Nielsen, Nininger, Olivier, Öpik, Porter, Prentice, V. M. Slipher, Störmer, Vandekerkhove, Watson.

SOUS-COMMISSION DE LA LUMIÈRE ZODIACALE ET DE LA LUMIÈRE DU CIEL NOCTURNE

PRÉSIDENT: M. DUFAY.

MEMBRES: MM. Horace W. Babcock, Bousfield, Cabannes, Cap, S. Chapman, Dauvillier, N. Donitch, Elvey, Fesenkov, Gauzit, Harang, Housman, Link, V. M. Slipher, Störmer, Struve, Swings, Vegard.

The scope of this Report is to cover briefly the progress in the study of meteors and meteorites since the 1938 meeting of Commission 22. The Sub-Commission on the Zodiacal Light has been expanded to include also the Light of the Night Sky and is now presided over by M. Jean Dufay. The ever-increasing scientific interest in the problems of nocturnal radiations and the fascinating difficulties of interpretation promise an exciting future for research in these two observationally related fields. On the other hand, the present intensive interest in the earth's upper atmosphere and in ionospheric research makes interpretation in any one field of research in Commission 22 even more dependent upon knowledge of results in the other fields. Hence it appears essential that Commission 22 and its sub-commission keep in close *rapport* and that a considerable overlapping of membership be maintained.

Progress in the application of radar and other electronic techniques to the observation of meteor ionization trails has recently become of outstanding importance. The contributions of many workers, particularly the British J. S. Hey and G. S. Stewart,* E. Appleton and R. Naismith,† and others are revolutionizing the methods of meteor observation; Hey, Parsons and Stewart‡ and A. C. B. Lovell report the actual measurement of meteor velocities electronically! Intensive work in this field is being conducted in Canada by P. M. Millman and his colleagues, in Russia by B. Levin and his colleagues and by at least four active groups in the United States. It appears that Commission 22 must pay special attention to this new technique of observation.

The extremely active meteor shower from the Giacobini-Zinner comet on the night of October 9, 1946, aroused world-wide interest. Its accurate prediction coupled with extensive observations by all known techniques marks this shower as the most important event in meteor history during at least this century. Any attempt to describe the phenomenon or to list observers and observational results would extend this Report unduly; also the facts are so generally known that recapitulation appears superfluous.

1. *Meteor Organizations.* A certain disruption of activity among some meteor organizations has occurred during recent years. Among these organizations listed in the 1938 volume of the *I.A.U. Transactions*, those from the following countries have become inactive or have failed to reply to correspondence: Belgium, Esthonia, France, Hungary, Italy, Spain and the U.S.S.R. Active groups in these countries and other unlisted active meteor organizations are requested to notify Commission 22 of their address, officers and general scope of activity.

* J. S. Hey and G. S. Stewart. *Proc. Phys. Soc. Lond.* **59**, 858–83, 1947.

† E. Appleton and R. Naismith. *Proc. Phys. Soc. Lond.* **59**, 461–72, 1947.

‡ J. S. Hey, S. J. Parsons and G. S. Stewart, *M.N.R.A.S.* **107**, 176–83, 1947.

The Society for Research on Meteorites has changed its name to The Meteoritical Society. Its president is now A. S. King of Mount Wilson Observatory, Pasadena, California, U.S.A. An Institute of Meteoritics, with L. LaPaz as Director, has been established at the University of New Mexico, Albuquerque, New Mexico, U.S.A.

2. *Visual Observations*. Meteor astronomy lost one of its keenest observers in the death of E. Loreta of Bologna, Italy. Activity in the visual observation of meteors or in the analysis of visual observations has been resumed or maintained in Canada by P. M. Millman, in Czechoslovakia by A. Bečvář and V. Guth, in Denmark by A. V. Nielsen, in Germany by C. Hoffmeister, in Great Britain by J. G. Porter and J. P. M. Prentice, in Japan by the Meteor Section of the Oriental Astronomical Society with K. Komaki, in New Zealand by the Meteor Section of the New Zealand Astronomical Society under the strong impetus of R. A. McIntosh, in the United States by the American Meteor Society and C. P. Olivier and in the U.S.S.R. by I. S. Astapovich, A. Bakharev, B. Levin, S. V. Orlov and K. A. Voroshiloff. Recently a group of observers under S. van den Bergh has commenced meteor observations in the Netherlands.

Of great interest are the observations and analysis of meteors observed via the rocking mirror method by E. Öpik,* who concludes that a large percentage of visual meteors possess hyperbolic velocities and occur at lower heights than shower meteors of nearly comparable geocentric velocities. On the other hand, J. G. Porter,† from a lengthy analysis of British meteor observations, concludes that his data do not indicate hyperbolic velocities nor a marked seasonal effect in height. R. A. McIntosh,‡ from all visual trajectories, finds a seasonal effect in height and confirms the relatively greater height for the shower meteors. H. C. Plummer§ finds an increase in meteor height with number. An independent analysis of visual meteor observations has been conducted by B. Levin|| who finds no evidence for hyperbolic velocities. A valuable catalogue of southern meteor radiants has been published by R. A. McIntosh.

3. *Telescopic Meteors*. Observations have been made by J. D. Williams, R. Brandt and others, while analyses of frequencies have been made by F. G. Watson, J. D. Williams¶ and C. Hoffmeister. Through the visual and telescopic ranges the numbers appear to vary inversely as the luminosity or somewhat more slowly.

4. *Photography*. Meteor photography has been conducted largely in Canada by P. M. Millman, in Czechoslovakia under the direction of A. Bečvář, in the U.S.S.R., and at Harvard in the United States. Numerous observers over the world were successful in photographing meteors from comet Giacobini-Zinner.

Analyses of single meteor trails have been made by S. Arend and J. Hunaerts, P. F. Sitnikov, K. P. Stanjukowitsch, N. N. Sytinskaya and F. G. Watson. Trails are great circles within a few minutes of arc.

Harvard results, by F. L. Whipple** and recently Z. Kopal, L. Jacchia, and Miss F. Wright, from two-camera photography with rotating shutters, show that the Taurid stream is associated with Encke's comet, that the Geminid orbit is extremely small, and that few, if any, hyperbolic orbits exist among the bright meteors while 'asteroidal-type' orbits are fairly frequent. Measures of daily motions and cosmic spread of radiants have been made for the Taurid, Geminid and Perseid showers. Small but measurable meteor decelerations make possible the calculation of upper-atmospheric densities which show a marked seasonal effect. A very large photographic programme is being planned, utilizing a 'super-Schmidt' type of camera designed by J. G. Baker and to be made by the Perkin-Elmer Corporation in the U.S.A.

* E. Öpik. *Pub. Tartu Obs.* **30**, No. 5, 1940; ibid. No. 6, 1941.

† J. G. Porter. *M.N.R.A.S.* **103**, 134–53, 1943; ibid. **104**, 257–72, 1944.

‡ R. A. McIntosh. *M.N.R.A.S.* **100**, 510–28, 1940; *Jour. R.A.S. Can.* **37**, 305–15, 1943.

§ H. C. Plummer. *M.N.R.A.S.* **101**, 76–83, 1941.

|| B. Levin. *Ast. Jour. U.S.S.R.* **23**, No. 2, 1946.

¶ J. D. Williams. *Ap. J.* **92**, 424–33, 1940.

** F. L. Whipple. *Proc. Am. Phil. Soc.* **79**, 499–548, 1938; ibid. **83**, 711–45, 1940; ibid. **91**, 189–200, 1947; *Rev. Mod. Phys.* **15**, 246–64, 1943.

A number of meteor spectra have been obtained by P. M. Millman* especially, and by A. Bacharev and by C. O. Lampland. An unusually bright high-dispersion and high-excitation spectrum obtained by A. N. Vyssotsky† deserves special attention. Millman concludes tentatively that the state of ionization and excitation in meteor spectra is closely related to the geocentric velocity and that all meteors in a single shower have similar spectra. Shower meteors appear to arise from stones. Colours have been obtained by Ch. Hetzler and by N. N. Sytinskaya.

It appears that the detailed character of meteorite orbits should be determined with great precision within a few years by photographic and electronic techniques—and to surprisingly faint magnitudes.

5. *Methodology*. Reduction methods for visual and photographic meteors have been investigated by I. S. Astapovich, A. Bečvář, V. Guth, H. Inouze, A. S. Jagolin, V. Maitre, R. A. McIntosh, J. P. M. Prentice, E. F. Reilly, and K. P. Stanjukowitsch, while useful tables have been prepared by V. Guth, A. V. Nielsen‡ and E. Willis. A number of writers have criticized E. Öpik's use of harmonic mean heights. Methods for calculating orbits have been published by B. de Jekhowaky and C. C. Wylie. The methods used at Harvard for photographic-meteor reductions will be published soon.

A photometer for observing meteor trains has been devised by N. Sytinskaya.

6. *Fireballs and Trains*. Research on the trajectories and velocities of fireballs is very active in Europe, U.S.S.R. and the United States. C. C. Wylie§ has studied additional fireballs with low heliocentric velocities and deduces asteroid-type orbits for these objects. A similar result is reached by N. N. Sytinskaya.|| In this connection, C. Hoffmeister,¶ in a general survey of the orbital data, divides meteor orbits into ecliptical (short-period asteroidal), cometary, and hyperbolic groups. A. V. Nielsen contests a short-period orbit for the Pultusk meteor.

Important studies of meteor trains observed in Tadjikstan have been made by V. V. Fedynsky,** while C. P. Olivier†† has published two analyses involving nearly 1500 long-enduring trains. Olivier finds average velocities of the order of 200 km./hr.

7. *Meteorites*. The work in Meteoritics has become so great and the literature so rich that no short competent survey is possible. Especially noteworthy is the activity incited by The Meteoritical Society. In the U.S.S.R. numerous papers have appeared in *Meteoritics*, the official publication of the Meteorite Committee of the Academy of Sciences of the U.S.S.R. Among the active workers in this field have been H. H. Nininger, L. LaPaz and J. D. Buddhue in the U.S.A. and L. A. Kulik, P. L. Dravert and P. N. Chirvinsky in the U.S.S.R.

It is hoped that V. G. Fesenkov and A. E. Krinov will soon report fully on the crater-forming fall of February 12, 1947, north-east of Vladivostok. Evidence for ancient meteor craters in geological strata has been presented by J. D. Boon and C. C. Albriton and supported by R. A. Daly.‡‡

A geographical system of co-ordinate numbers for Meteorites has been devised by F. C. Leonard and applied by him in a comprehensive catalogue of 1347 meteorite falls of the world, the first publication of the Institute of Meteoritics of the University of New Mexico, U.S.A. Several papers on meteorite statistics have been published by F. C. Leonard§§ and B. Slalin and by L. LaPaz. Valuable catalogues of Meteorites have

* P. M. Millman. *Jour. R.A.S. Can.* **34**, 117–29, 1940; ibid. **34**, 469–79, 1940. *H.A.C.* No. 782, 1946.

† A. N. Vyssotsky. *Ap. J.* **91**, 264–66, 1940.

‡ A. V. Nielsen. *Medd. Ole Rømer Obs.* No. 12, 1938.

§ C. C. Wylie. *Pop. Ast.* **48**, 41–2, 1940; ibid. **48**, 306, 1940.

|| N. N. Sytinskaya. *Meteoritics*, **2**, 103, 1941; ibid. **2**, 110, 1941.

¶ C. Hoffmeister. *Pop. Ast.* **55**, 492–97, 1947.

** V. V. Fedynsky. *Ast. Jour. U.S.S.R.* **21**, 291–305, 1944.

†† C. P. Olivier. *Proc. Am. Phil. Soc.* **85**, 93–135, 1942; ibid. **91**, 315–27, 1947.

‡‡ R. A. Daly. *Jour. Geol.* **55**, 125–45, 1947.

§§ F. C. Leonard. Various papers. *Pop. Ast. and Contr. Soc. Met.* 1941–6.

been published by M. H. Hey,* I. S. Astapovich and especially by A. L. Coulson† of India.

The physical and metallurgical structure of Meteorites has been studied intensively by Lord Rayleigh, J. D. Buddhue, U. Dehlinger, E. A. Owen, S. W. J. Smith and J. Young, R. M. Leard, and by H. Brown and C. Patterson. The volume by S. H. Perry‡ of the U.S. Smithsonian Institute is especially valuable. Harrison Brown (in the Press) has proved that meteorites must have cooled under a pressure of the order of 10^6 atmospheres, hence are fragments of a broken planet comparable to Mars in mass.

Isotopic abundances in meteorites have been studied by R. D. Evans, B. F. Murphy and A. O. Nier, G. E. Valley and H. H. Anderson,§ and by H. Brown and M. G. Inghram. No anomalies with respect to terrestrial substances appear.

F. A. Paneth|| and colleagues have had to increase the estimates of maximum meteorite ages by the helium method to nearly 7×10^9 years after allowing for the effect of thorium. C. Bauer has shown that small helium content is associated with massive meteorite falls and that cosmic rays may play an important role in the production of helium in small meteorites. Hence the helium ages may represent only upper limits.

Spectrographic measures of meteorites in the laboratory have been made by W. W. A. Johnson and D. P. Norman,¶ and laboratory spectrophotometric measures by E. L. Krinow.

Meteoritic dust has been collected by H. H. Nininger and H. E. Landsberg and its consequences considered theoretically by J. Kaplan and A. R. Khan.

The origin of tektites has been discussed by H. O. Beyer, K. Himpel, J. Kaspar, L. LaPaz and W. C. Rufus.

8. *Theory*. The physical theory of the meteoric process has been further investigated by E. Öpik, J. Hoppe and B. Levin. Certain aspects of the problem have been studied by M. Khan, C. Hoffmeister, C. C. Wylie, T. Gustafson, A. Hadding and F. Link**. It is apparent that many experimental data essential to an exact solution of this problem are still lacking. In addition, certain meteoritic data for visual and photographic meteors are highly uncertain. Nevertheless, the general confirmation by V-2 rocket firings of the atmospheric densities, determined from photographic meteors at Harvard, shows that the present theory is qualitatively correct.

A general theory of Jupiter perturbations on orbits with aphelia within Jupiter's orbit has been developed by D. Brouwer. This method generalizes the special case of the Taurid meteors and Encke's comet studied by F. L. Whipple.

9. *Treatises*. I. S. Astapovich and V. V. Fedynsky have published a book in the Russian language entitled *Meteors* (126 pp., 73 illus., Academy of Science of the Soviet-Union, Moscow, 1941) and F. G. Watson a book in English, *Between the Planets* (214 pp., 106 illus., Blakiston Co., Philadelphia, Pa., U.S.A., 1941). Both books are written for the highly intelligent layman. Watson's book also considers comets and asteroids.

The following suggestions have been presented for consideration by the Commission:

(1) That more simultaneous electronic and visual or photographic observations are needed. Detailed interpretation of the electronic observations is still handicapped by this lack. (E. Öpik and others.)

(2) That emphasis in visual observing programmes be directed toward the determination of meteoric magnitudes, frequencies and radiants rather than the determination of heights and velocities. Comprehensive statistical correlations of visual with photographic or electronic observations are now of the greatest importance. (F. L. Whipple.)

* M. H. Hey. *Pub. British Museum*, 1940 (136 pp.).

† A. L. Coulson. *Mem. Geol. Survey India*, Vol. **75**, 1947.

‡ S. H. Perry. *U.S. Nat. Mus. Smithsonian Institution, Bull.* No. 184, 1944 (206 pp.).

§ G. E. Valley and H. H. Anderson. *Phys. Rev.* **59**, 113–14, 1941.

|| W. J. Arrol, R. B. Jacobi and F. A. Paneth. *Nature, Lond.*, **149**, 235–8, 1942.

¶ W. W. A. Johnson and D. P. Norman. *Ap. J.* **97**, 46–50, 1943.

** F. Link, *Pub. Obs. Nat. Prague*, No. 18, 1947 (25 pp.).

(3) That suitable star-charts for visual observations be made more available. (P. M. Millman and others.)

(4) That new efforts be made to induce governmental agencies such as Naval or Weather organizations to gather and publish data on fireballs and meteor trains. (C. P. Olivier.)

(5) That the preparation of an appendix to the v. Niessl-Hoffmeister catalogue be considered. (A. V. Nielsen.)

(6) That astronomers make special effort to encourage specialists in physical research to apply new research methods in laboratory studies of meteorites; and that such studies should cover systematically all representative classes of meteorites. (F. L. Whipple.)

(7) It is recommended that simultaneous observation of meteors by electronic (radar) and visual or photographic means be extended because this Commission is convinced that the continuation and extension of such research is now essential to the proper advance of meteoric astronomy and of researches related to it.

F. L. WHIPPLE
President of the Commission

Report of meetings

PRESIDENT: M. F. L. WHIPPLE.

SECRETARY: M. J. KAPLAN.

The report of the Commission, prepared by the President and printed in the Draft Reports, was unanimously accepted by the members of the Commission.

A special session of the Commission, to discuss reorganization of the Commission to include research on fundamental problems of the Earth's upper atmosphere, was called by the President at a time later in the programme.

The six recommendations of the Commission, published in the Draft Reports, were passed, with minor modifications, by the Commission. The resolutions as approved by the Commission are as follows:

(1) It is recommended that simultaneous observations of meteors by electronic (radar) and visual or photographic means be extended, because this Commission is convinced that the continuation and extension of electronic (radar) observations is now essential to the proper advance of meteoric astronomy and of researches related to it. (Proposed by E. Öpik and others.)

(2) It is recommended that suitable star-charts for visual observations be made more available, and that a committee consisting of Millman (chairman), Bečvář, Olivier and Prentice be named to study the form and publication of these star-charts. (Proposed by P. M. Millman and others.)

(3) That astronomers make special effort to encourage specialists in physical research to apply new research methods in laboratory studies of meteorites; and that such studies should cover systematically all representative classes of meteorites. (Proposed by the President.)

(4) That emphasis in visual observing programmes be directed towards the determination of meteoric magnitudes, frequencies and radiants, rather than the determination of heights and velocities. Comprehensive statistical correlations of visual with photographic or electronic observations are now of the greatest importance. (Proposed by the President.)

(5) That new effort be made to induce government agencies such as Naval and Weather organizations, and Variable Star Associations, to gather and publish data on fireballs and meteor trains. (Proposed by C. P. Olivier.)

(6) That the preparation of an appendix to the von Niessl-Hoffmeister Catalogue be considered. (Proposed by A. V. Nielsen.)

Resolutions 1, 2 and 3 were presented to the General Assembly and were later approved by that body.

Notes on the resolutions:

(3) Mr Federer offered to print and distribute star-charts for meteor observers. The Gnomic Star Chart Atlas by M. Guth at Prague has been completed and a copy was shown to the Commission.

(4) M. Dufay pointed out that in France meteorological observers now carry out the recommendation. He suggested that variable star associations be included. He also offered to write out instructions to observers and to send them to Mr Olivier. M. Naef pointed out that Mr Thomas in Vienna issues instructions for meteor observations and M. Baldet stated that there are detailed observations of meteors and fireballs in North Africa and the Sahara.

The chairman presented a recommendation from Mr LaPaz, that a thorough investigation be made of all phases of the recent meteorite fall near Vladivostok. The Commission voted to table this resolution until the astronomers of the U.S.S.R. could be consulted.

Report on the meeting of the Sub-commission on Zodiacal Light and Light of the Night Sky

PRESIDENT: M. J. DUFAY.

SECRETARY: M. J. KAPLAN.

The chairman called first on Dr Whipple, who presented a proposed outline of the work of Commission 22 in order to take into account the great advances and increased interest in these problems. Dr Whipple's outline follows (attached to the minutes by vote of the Commission):

Observations (related results in parentheses and detailed below):

A. Meteors (and meteor trains):
  1. Visual (*a*, *d*, *f*).
  2. Photographic (*a*, *d*, *e*?, *f*) (spectra included).
  3. Radar (*a*, *b*?, *d*, *e*, *f*, *g*?).
  4. Meteorites (*a*, *c*).

B. Night Sky Light:
  1. Night sky (*b*, *d*, *e*, *f*, *g*).
  2. Twilight sky (*b*, *d*, *e*, *f*, *g*).
  3. Aurorae (*b*, *d*, *e*, *f*, *g*).
  4. Zodiacal (*a*, +?).
  5. Gegenschein (*a*, +?).

C. Other Methods:
  1. Fraunhofer Corona (*a*, +?).
  2. Ozone measures (*d*, *e*, *f*, *g*).
  3. Searchlight work (*d*, *f*).
  4. Rocket research (*c*, *d*, *e*, *f*, + + ...).
  5. Other geophysical methods, such as propagation of sound, noctilucent clouds, etc.

Results concerning

(*a*) Nature and origin of small bodies in the solar system (bearing on comets, asteroids and interstellar dust).
(*b*) Nature of interplanetary (and interstellar) gas.
(*c*) Cosmic rays.
(*d*) Atmosphere of the Earth (density, temperature, pressure).
(*e*) Atmospheric composition (including dissociation, ionization, etc.).
(*f*) Atmospheric variations with day, season, latitude (also with solar variations).
(*g*) Ultra-violet solar radiation.

Following the discussion Dr Swings presented a paper on suggestions for spectroscopic investigation of the night sky, twilight and aurorae. This paper is attached to the Minutes, by vote of the Commission.

A scientific session was held on August 16, at 20.15. The following papers were presented:

J. Kaplan: 'Production of Night-Sky Radiation in the Laboratory.'

A. Colacevich: 'A New and Extremely Rapid Camera Optical System.'

J. Dufay: 'Spectres crépusculaires.'

M. Nicolet: 'Structure de la Haute Atmosphère déduite de l'Etude des Mécanismes de Dissociation et d'Ionisation.'

Tcheng Mao Lin: 'Polarisation de la Lumière zodiacale.'

F. L. Whipple: 'Seasonal Variations in the Density of the Upper Atmosphere as Determined from Observations of Meteors.'

SUGGESTIONS FOR SPECTROSCOPIC INVESTIGATIONS OF THE NIGHT SKY, TWILIGHT AND AURORAE

By P. Swings

The present memorandum contains suggestions for investigations which would provide important information to upper atmosphere physicists. The main emphasis is placed on the desirable observations, although laboratory and theoretical investigations will also be suggested.

General Principles

(1) The simultaneous investigation and discussion of the spectra of the night sky, twilight and aurorae are extremely fruitful. The aurorae present over the night sky the advantage of a higher brightness and of an easier determination of the height of emission (by triangulation or possibly by radar). They also offer a wide range of conditions of height (hence of atmospheric temperature and density) and of density or energy of exciting particles. Moreover, the excitation mechanisms of the night sky, twilight and aurorae are different, although the ultimate source of excitation is, in all cases, the Sun. On account of the differences in excitation mechanisms, the spectra of the three sources reveal different atoms or molecules, or different transitions of the same atom or molecule, or different relative intensities, hence rendering comparisons fruitful. There are phenomena which are essentially common to two or three sources, such as the intensity variations of the red [O I] line (twilight and various types of (and heights in) aurorae), the behaviour of the N_2^+ bands (twilight and sunlit aurorae), the selective emission of $\lambda 6560$ (night sky and twilight).

(2) In all three sources an increase in spectral resolution will provide interesting new results. Better wave-lengths and profiles will thus be obtained, facilitating the discussion of the identifications and excitation mechanisms. Additional emission features will also be found.

(3) There is a great need for extending the observed spectral ranges of the three sources. In the case of the night sky, only the region $\lambda < 5000$ may be considered as satisfactorily covered, although an increase in resolution in this region would still be fruitful. The observational night sky data for $\lambda > 5000$ are rather poor, although their need is quite apparent (as will be shown later). Little or nothing is known of the twilight spectrum in the ultra-violet and infra-red regions (especially the latter). The spectroscopic information on aurorae is not sufficient in the ultra-violet, poor in the visual region and entirely absent in the infra-red.

As a first step an extension of the observations toward the red and infra-red would be most profitable. The corresponding spectrographs should of course be as fast as possible, and each emission should be studied with the highest possible resolution. In the case of the aurorae (and possibly also of other sources), the spectrograph should be equipped to render a quick change of dispersion possible, in order to take advantage of occasional higher intensities of certain emissions. For this purpose it seems that a spectrograph equipped with a plane grating (or a mosaic of gratings) and a set of cameras would be the most advantageous.

(4) There is a lack of accurate spectrophotometric data in all three sources. This will be illustrated later on.

(5) The close co-operation of observers, theoreticians and laboratory physicists is required. Obviously the investigation of the night sky, twilight and aurorae must proceed in the light of the information provided by the optical study of the lower layers of the atmosphere (sp. of setting sun, of the ozone layer, of the eclipsed disk of the moon), or by any other physical method (ionospheric observations, meteors, observations from 'V 2's', noctilucent clouds, etc.).

(6) For the identifications, synthetic spectra of low temperature rotational distribution should be prepared for all molecules. In all cases where a fluorescence excitation by solar radiation is envisaged, the synthetic spectra should take into account the presence of absorption lines in the solar spectrum. Such synthetic spectra may differ considerably from the spectra of ordinary laboratory discharges.

Desirable Observational Data on the Night-sky Spectrum

(*a*) Obtain additional data on the bands of the first positive system of N_2 present in the night sky:

- (i) Investigate the infra-red region for structure of the intense $\lambda 10440$ emission of N_2, and for check on absence of the [N I] doublet near $\lambda 10400$.
- (ii) Determine the relative intensities of the (0, 0) and (1, 0) bands. (Check that (1, 0) at $\lambda 8910$ is absent or very weak relative to (0, 0) at $\lambda 10440$.) This is essential for the discussion of the main excitation mechanism.
- (iii) Study the structure of $\lambda 6560$ with higher resolution; this is essential for the identification of the emission which shows a conspicuous twilight effect, and would reveal the distribution of the N_2 molecules as a function of height, if the identification is ascertained and if the fluorescence mechanism of the twilight emission is proved. See next section on twilight.

(*b*) Obtain additional quantitative data on relative intensities of the Vegard-Kaplan bands and, especially, on the distribution of the N_2 molecules on the vibrational levels of the excited electronic state $A^3\Sigma$. This was partly done by Cabannes and Dufay, and should be repeated with more refined photometry and theory. The vibrational distribution on $A^3\Sigma$ would reveal whether the Vegard-Kaplan system is emitted solely as a result of the first positive system (in which case the $v=0$ level should have the highest population), or mainly through another mechanism, such as direct conversion of D (N_2) into excitation energy on the $A^3\Sigma$, v level; or through a combination of various mechanisms.

The Vegard-Kaplan bands constitute the main emission in the blue-violet region, and their interpretation is essential for the understanding of the night sky phenomena.

(*c*) Examine the ultra-violet region with higher resolution, in order to decide definitely whether or not the Lyman system of N_2 and the Schumann-Runge system of O_2 are present. This is important for ascertaining the excitation mechanism, since the Lyman system of N_2 requires an appreciably higher energy than the well-identified features. However, it should be noted that the desired increase in resolution will not be an easy matter and will require powerful instruments; at the present time the ultra-violet spectrograms obtained in France by D. Barbier may be considered as the best. On their basis, one would rather consider that the Lyman and Schumann-Runge systems are absent, but this should be confirmed once and for all.

(*d*) Emission of H_2O in the red and infra-red, and other molecular or atomic emissions to the red of $\lambda 5000$. Nothing definite may be said at present (except for the [O I] and Na-lines); new observations are needed; see paragraph (*a*) above.

(*e*) Investigation of the real physical nature of the apparently continuous emission. The question of this continuum is still far from settled. Is it a real continuum, or the superposition of weak bands and extensions of bands? The latter view is advocated by Barbier. It could be settled by increasing the resolution in the blue-violet region and by improving the accuracy of the photometry.

(*f*) The most important problem is that of the determination of the heights of emission of the different radiations. In such work great care should be taken to apply properly all necessary corrections, especially those due to scattering and absorption. The discrete emission patches should be studied in detail. Interesting information could perhaps be obtained by photoelectric observations from a night-fired 'V 2'.

(*g*) The study of the variations with magnetic latitude, magnetic activity, season, course of the night, solar phenomena, ionospheric activity should be continued.

(*h*) The night-sky spectrum should be examined after auroral displays or after any other manifestation of solar activity, for two essential reasons:

(i) excited metastable states of long life (such as ^2D of N I) may persist for quite some time at great heights (as appears in an observation by Götz);

(ii) the upper layers may have been perturbed (in temperature or distribution) and remain perturbed for some time.

Desirable Observational Data on the Twilight Spectrum

(*a*) Profile and photometry of the N_2^+ emission at twilight. A rotational intensity distribution obtained with sufficient resolution (about 1 A.) would enable one to decide as to the excitation mechanism of the N_2^+ flash. By precise photometry of the intensity of the N_2^+ flash at twilight and dawn, as a function of the solar depression (similar to the intensity measurements of the red [O I] line and of the yellow Na-line by Elvey and others) the distribution of N_2^+ with height may be obtained, if the fluorescence hypothesis is found to be valid.

(*b*) The twilight effect of Na should be re-examined with refined photometric techniques in order to discuss an hypothesis recently advanced by Vegard according to which the Na-emission results from absorption of ultra-violet radiation. The resonance hypothesis is instead accepted generally. An investigation of the ultra-violet spectrum of the twilight would reveal how the second principal line of Na, at λ3303, behaves; this information would be valuable for a discussion of the Na-problem.

(*c*) The structure of the λ6560 band at twilight should be examined, and compared with that of the emission around this wave-length in the night sky. If the λ6560 emission is a band of the first positive system of N_2, excited by fluorescence, the effect of the solar absorption lines (e.g. of the strong absorption at Hα) should be revealed, while the night-sky emission should not be affected by solar absorption lines. This is important as already stated above.

(*d*) Nothing is known of the twilight spectrum in the infra-red or the extreme red. Yet important data may be expected from such a study. Here are three examples. Are N_2 bands other than λ6560 (especially the 0, 0 transition) enhanced at twilight? Is there any emission of potassium lines (λ7699–λ7664) similar to sodium? Is there any O I-emission near λ8440 or λ7990 excited by ultra-violet radiation (Spitzer's suggestion)?

If photographic methods are found to be impractical, photoelectric measurements with fairly narrow filters or in connection with a dispersing system would be satisfactory.

(*e*) The investigation of the ultra-violet spectrum should be further pursued, in order to check definitely on the possible presence of λ3303 Na, λ3064 OH and λ3565 OH^+.

(*f*) Interferometric determinations of the width of the red [O I] line for different solar depressions would provide important data on the kinetic temperature at various heights.

Desirable Observational Data on the Spectra of Aurorae

(*a*) An increase in resolution all over the spectrum would provide important data: on O_2^+ and on additional bands of N_2 (first positive) in the red region; on the system of NO *in the violet region; on additional* N_2^+ *transitions and* Vegard-Kaplan bands all over the spectrum. New molecular systems will most likely also be discovered. The hypothetical atomic identifications will be more easily and thoroughly discussed.

(*b*) Practically nothing is known of the infra-red region. The intensity distribution among the infra-red N_2-bands would be of great interest for comparison with night sky and twilight.

(*c*) An accurate profile should be obtained for the (0, 0) band of N_2^+ in sunlit aurorae. Such a profile—which should be compared with that of N_2^+ at twilight and in ordinary low-altitude aurorae—would reveal the relative importances of collisional and resonance excitation in sunlit aurorae.

(*d*) Additional data should be gathered on the H^-, He I and He II emissions in aurorae, including photometric determinations of the Balmer decrement at different heights.

(*e*) It is essential to have interferometric determinations of width made for the [O I] lines at different heights, with a resolving power higher than was used by Vegard. Such determinations would provide badly needed data on the kinetic temperatures of the atoms at different heights.

(*f*) New measurements of rotational temperatures, based on different molecules (N_2^+ and N_2 at least), in different transitions (especially first and second positive systems of N_2) should be made at various well-determined heights. These determinations could then be compared with the 'atomic' temperatures derived interferometrically, with the theoretical temperatures estimated by various methods, and with the 'ionospheric' temperatures.

(*g*) Further spectroscopic comparisons (especially quantitative intensity ratios of the different bands) should be made for the different types of aurorae at different heights.

(*h*) The intensity ratio $\frac{\text{2nd positive of } N_2}{\text{1st positive of } N_2}$ should be determined at various heights in different types of aurorae. The behaviour of this ratio with height should provide unequivocal information on the energy variation of the exciting particles with height and with type of aurorae.

(*i*) The intensity decrements in the N_2^+ sequences should be better measured, so that comparisons between various types and heights of aurora (including the sunlit aurorae) and also comparisons with twilight may be made. Barbier's suggestion of reabsorption effects in high-altitude aurorae should be scrutinized. As suggested by Barbier, it may be useful to take absorption spectra of bright stars through an auroral display.

Distribution of the Elements in the Upper Atmosphere

(*a*) The de-excitation phenomena should be investigated by measurement of the speeds of the intensity changes of specific forbidden emissions (red [O I]; green [O I]; ultra-violet [N I]; green [N I]; Vegard-Kaplan bands) at well-determined heights, in aurorae of various brightnesses and types. A careful discussion of such measurements would give valuable data on de-excitation processes at different heights.

(*b*) The data obtained in (*a*), combined with quantitative twilight observations and new theoretical data, would provide the distribution in height of:

N_2 (from twilight effect on $\lambda 6560$);
O (from twilight effect on the red line of [O I]);
N_2^+ (from twilight effect on N_2^+).

Photometric measurements in aurorae of well-defined geometry would provide other similar information of value.

(*c*) An accurate determination of the relative populations on the excited levels at different heights in aurorae of various types would provide a sound basis for the determination of the excitation processes in aurorae.

Desirable Laboratory Investigations

Any laboratory investigation on the spectra of N_2, N_2^+, O_2, O_2^+, NO, NO^+, and other atmospheric constituents is useful, especially typical being the valuable work by J. Kaplan on the afterglow. Among other things the Herzberg system of O_2 (vibrational classification

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still in doubt), and Barbier's hypothetical system (carrier unknown) should be the object of laboratory work. Renewed effort should be devoted to the discovery of the forbidden intercombination system of NO. Various energies of dissociation and ionization remain hypothetical, the most important case being the heat of dissociation of N_2. Predissociation effects in N_2 should be further studied.

For the interpretation of aurorae, new experiments should be performed on the excitation of N_2, O_2, ... by hydrogen atoms, in conditions simulating the upper atmosphere as closely as possible.

Desirable Theoretical Investigations

There is a wide variety of pending theoretical problems which are important for upper-atmosphere physics. Outstanding are the following:

(*a*) Since the variations of atmospheric temperature and density are well known, up to about 120 km., the general problem of the dissociation of O_2 should be re-examined in detail.

(*b*) The distribution of N_2 and N should be investigated, as soon as certain laboratory data which are still lacking become available.

(*c*) Our knowledge of the temperature distribution is very unsatisfactory above 100 km. New observations suggested earlier in this memorandum should help considerably.

(*d*) Work on the de-excitation phenomena is desirable.

Once the observational data indicated in this memorandum are available it is likely that the compositions, densities and temperatures will be known at all heights, as well as the mechanisms responsible for the excitation of the night sky, twilight and aurorae.