22. COMMISSION DES ÉTOILES FILANTES, DE LA LUMIÈRE ZODIACALE ET DES PROBLÈMES ANALOGUES

PRÉSIDENT: M. FÉLIX DE ROY, *Rue Saint Benoît*, 15, *Mortsel, Anvers, Belgique*.

MEMBRES: MM. Astapovich, Boothroyd, Bosler, Bousfield, Cabannes, Cap, Chant, M. Davidson, Dobson, N. Donitch, Dufay, Elvey, Fedynsky, Mme Flammarion, MM. Gatterer, Grouiller, Guth, Mlle Hoffleit, MM. Hoffmeister, Housman, Leonard, Loreta, McIntosh, Millman, Nielsen, Olivier, Öpik, Prentice, Rudaux, V. M. Slipher, Svoboda, Vandekerkhove, Yamamoto.

The Commission formed a Sub-Commission on Zodiacal Light, presided over by Prof. Issei Yamamoto. The constitution of a sub-commission on the light of the night sky and kindred phenomena was proposed, but left in abeyance, pending the Stockholm Meeting. Dr Jean Dufay kindly consented to write, at the President's request, a paper on the present state of the problem of the light of the night sky, which is printed with this Report.

At its Paris meeting, in 1935, the Commission recommended that a list of the existing organizations or directorships for meteor work should be drawn up, with full addresses, in view, *inter alia*, of a more complete exchange and distribution of reprints. Such a list has been prepared by the President after some consultation and correspondence, and is published as an Appendix to the Report. It is hoped that this list will prove of value in bringing together workers in different countries of the world for investigations requiring international co-operation, and in encouraging meteor studies in the large areas of the southern hemisphere where, with the notable exception of New Zealand, they are still utterly neglected. It cannot be too strongly emphasized that the need for accurate and detailed knowledge of the distribution of meteor radiants well below the celestial equator, and of the varying activity of the sporadic meteors caught up by the southern part of the Earth's atmosphere remains very great, and that profitable results are awaiting intelligent research in this interesting province of astronomy.

The wish was also expressed at Paris that gnomonic maps covering a larger area of the sky than those now in use, and including all stars down to magnitude 6·0, should be made available to observers. Most of the special charts existing each cover only comparatively small sections of the sky, or are on too small a scale. This is true even of the excellent series of twelve maps recently drawn up by Mr Haruhata, of the Tokyo Observatory. The chart published by the *Commission des Étoiles filantes de la Société Astronomique de France* covers the whole of the northern sky, but is on the stereographic projection, and only goes down to Dec. – 10°. It is to be regretted that, despite a diligent search, the copper plates of the large gnomonic maps, to the size of 30 inches square, ruled at intervals of one degree, and described by T. W. Backhouse in his *Star Catalogue* (1911) could not be recovered. It was planned to have prints of the nine plates known to have been engraved reproduced as well as possible, when the welcome news was received that V. Guth has proposed a new form of atlas for meteor work, which has been elaborated by members of the Czech Astronomical Society, and seems to fulfill the chief desiderata of observers. Proofs of this atlas will be presented to the Commission at its forthcoming meeting.

The last three years have witnessed, not only a new impulse to the amount of work done on meteors, but also universal recognition of its importance in several major lines of research. Thanks, chiefly, to the work of Hoffmeister, Olivier and

https://doi.org/10.1017/S0251107X0001806X Published online by Cambridge University Press

Öpik, it is increasingly recognized that these "minor bodies" are playing a significant part in the solar system, and in interstellar space as well, and that they may be directly related to the dark matter of the universe. In addition, their study is more and more intimately related to geophysical and cosmogonical problems, the most important of which are those relating to the conditions of the upper strata of the Earth's atmosphere. It was estimated that the number of papers published in 1935 on meteors and meteoric problems was five times as large as in 1925. This proportion is now exceeded, and the next decennial increase may well be tenfold. It is hardly possible therefore to describe this progress in detail. Attention must be restricted in this Report to a general survey of this large field, to new lines of research, and to some unpublished results, together with suggestions recommended by individual members of the Commission, and presented for discussion at the Stockholm Meeting.

1. *Meteor organizations*. Meteor observation on a large scale, by bodies of observers working under a central direction, is especially active in North America, under the American Meteor Society and the Royal Astronomical Society of Canada, in the Union of Soviet Socialist Republics, under the Section of Comets and Meteors of the Sternberg Institute of Moscow and "Mirovédénié", in the British Isles, under the Meteor Section of the British Astronomical Association, in Czechoslovakia, under the Meteor Section of the Société Astronomique Tchèque, in New Zealand, under the Meteor Section of the New Zealand Astronomical Society, and in Japan and Korea, under the Oriental Astronomical Association, with K. Komaki. Some of the Japanese observers are also located in Brazil. Elsewhere, meteor observation is chiefly the work of individuals. In the U.S.S.R., work on meteoric astronomy is now carried out in 13 observatories or institutes, including Odessa, Omsk, Stalinabad, Tashkent, Tomsk and Vladivostock, so that good use is made of the geographical distribution of these large territories.

2. *Visual observations*. The American Meteor Society reports 60,000 meteors for 1935–37, including counts, the Czech Astronomical Society at Prague, 25,000 meteors by 65 observers in 16 stations, most of which were counts for hourly rates, the Japanese observers, over 23,000 observations, the Canadian observers cooperating with the Dominion Observatory, Ottawa, and the Dunlap Observatory, Richmond Hill, over 8000, the New Zealand observers, 2800 meteors, and several thousands were made in Great Britain and in the U.S.S.R.

With the help of his wife, C. Hoffmeister secured a new important series of observations during a ten-month stay in Windhuk, S.W. Africa ($\phi = -22°{\cdot}6$) in 1937–38. This series will be included in an extensive investigation now in progress at the Sonneberg Observatory, and relating to frequencies, velocities and radiants, from which final results may be expected within one or two years. The material investigated is based, not only on the Sonneberg observations, but also on the American observations (C. P. Olivier and many others), the series of J. D. Williams (Arizona), McIntosh (New Zealand), and P. J. M. Prentice (England).

Most of the periodic showers have been well kept under observation by the various bodies of observers. A new shower (Aurigids) was detected simultaneously on the night of Aug. 31—Sept. 1, 1935 at Sonneberg (Hoffmeister and Teichgräber) and Prague (Guth), some members of which may have been seen as early as Aug. 7–8 by S. Holm at Copenhagen. It has been related to Comet Kiess (1911 II), to which S. Natanson already ascribed a similar shower observed on Aug. 21, 1887.

Mr Thos. C. Poulter, Executive Director of the Research Foundation of the

Armour Institute of Technology, Chicago, has sent an interesting report on the meteor observations, which he made and conducted during, and on the occasion, of the Second Byrd Antarctic Expedition, 1933–35, of which he was the second in command and the senior scientist. The meteor programme consisted of (*a*) observations made on the same 21 dates, April 19—August 13, 1934, in many stations distributed from $-80°$ to $+60°$, in the seven continents and on several islands, for counts, real paths, and co-ordinates through circular reticles covering a solid angle of 50°; this part was primarily designed to investigate the distribution of meteors in latitude over both hemispheres, and yielded 23,000 observations; (*b*) observations in the Antarctic (7000 meteors) made as follows: (1) on a rotating platform by four observers using reticles at 45° elevation, in a few cases during 24 hours (2000 meteors), (2) a single observer watching the zenith through a reticle (1000 meteors), (3) observations with two pairs of 7×50 Zeiss U.S. navy binoculars directed at the zenith and covering a field of about 7° (2800 meteors); from 6 to 35 faint meteors per minute were sometimes seen in this way, (4) simultaneous observations with the Advance Base at a distance of 100 miles, giving a few duplicates only, (5) five trains of long duration yielding velocities W–E of more than 100 miles an hour, (6) fireballs.

Meteor streaks have been intensively observed by Gurjew, Tsesevich and Loreta, the latter recommending the systematic use of binoculars. An extensive study of train phenomena is in progress at the Flower Observatory.

3. *Telescopic meteors*. Faint meteors are systematically observed in Germany (A. Teichgräber) and in the U.S.S.R. (I. S. Astapovich) and, as occasion arises, by an increasing number of variable star observers. The Russian observations of 1930–37 have yielded 40 radiants. An installation is being built in Moscow whereby 17 mirrors will direct into the objective of a large comet finder the reflexion of an equal number of sections of the sky; it is hoped to observe in this way 10 to 12 "telemeteors" per hour, and to time their duration with a chronoscope of high precision. According to V. A. Bronstein, the height of most telescopic meteors would lie between 70 and 90 km., most of them being hyperbolic.

Under the auspices of the Commission, the Comet and Meteor Section of the Sternberg Astronomical Institute of the Moscow University organized in 1937 an attempt at international observations of telescopic meteors. Twelve observers in Canada, Italy, the U.S.A. and the U.S.S.R. took part in it, with telescopes ranging from 1·2 to 6 inches aperture and fields from 1°·0 to 8°·0. They were asked to watch the zenith between 11^h and 13^h, local astronomical time, on 12 dates, and selected regions centred on bright stars on 12 other nights. Although, generally speaking, the international dates were not favoured by good weather conditions, some interesting results were derived from 102 meteors observed on 45 nights in 13 stations. A preliminary discussion shows that the distribution of these meteors is not accidental, the existence of a definite direction becoming apparent from simultaneous observations at different points of the Earth, and the directions from the northern hemisphere being prevalent. The number of telescopic meteors seems to increase very little after midnight. Ordinary and telescopic meteors form an uninterrupted sequence. At the epoch of the activity of great showers, up to 50 telemeteors near the radiants and even at 40° to 50° from the radiants belong to these showers. However, independent radiants of telescopic meteors appear to exist. There is no sensible latitude effect in the number of telescopic meteors between $\phi = +38°$ and $+60°$. The strongest influence on their numbers is exerted by the transmission coefficient of the atmosphere, then by twilight and white nights, and in a lesser degree by moonlight. During certain nights, the number of these meteors is abnormally great.

4. *Results from visual observations*. The amount of data deduced from systematic observations has been greatly increased. With regard to heights E. Öpik published (*H.A.* **105**, 549, 1937) the important results of over 3500 individual measures from the Arizona Expedition, together with an illuminating analysis, and some preliminary conclusions from a comparison of theory and observation. Other work on true paths was published by C. P. Olivier and J. P. M. Prentice, and similar work is now under way at Prague. Several hundreds of real paths from observations in the U.S.S.R. are being prepared for reduction and publication. The first knowledge of the variation in meteor rates in the southern hemisphere was provided by R. A. McIntosh in a paper read before the 1937 meeting of the Australian and New Zealand Association for the Advancement of Science. It is interesting to note that, excluding the known elliptic streams, the rates confirm the high cosmic velocities first shown by C. Hoffmeister.

E. Öpik has made observations of meteor velocities with the rocking mirror apparatus associated with a reticle of reference, the latter being supposed to reduce systematic errors in the measurement of the length of the trail. The irradiation of meteors has been especially studied in the U.S.S.R. (Petrov, Maltzev, Fedynsky), with promising results. C. C. Wylie's statistical investigations on daily numbers of bright meteors and on the annual deposit of meteoric material are of importance, and are being continued.

Several of the periodic showers have been the subject of further investigation, the Leonids by V. Fedynsky, S. Koslovskaja and A. Losinskaja, the Orionids by J. P. M. Prentice, the Eta Aquarids by R. A. McIntosh. A discussion of all the Russian observations of the Perseids by V. Fedynsky has shown that, besides the central radiant, an eastern, and perhaps a southern branch are active, the former being connected with the comet 1870 I; local condensations were observed in the shower, giving rise to local intensifications of hourly rates and "local" radiants.

The list of group radiants, from British observations in 1929–31, published by J. P. M. Prentice (*Mem. B.A.A.* **32**, 1, 1936) is a model to be imitated, since it gives, not only the number of meteors from which each radiant is deduced, but also the diameter of the radiant area, a weight, and all relevant details. A revised catalogue of 827 meteor radiants and corresponding orbits has been published by N. N. Sytinskaya (Leningrad, 1937). A new list of radiants is also in preparation at the Sternberg Institute, Moscow, including only those believed to be quite reliable, the number of which is estimated at 170. The first systematic knowledge of the distribution of southern radiants, though necessarily still incomplete, was given by R. A. McIntosh (*M.N.* **95**, 709, June 1935). The method developed by the same observer to determine radiants from telescopic observations (*J. B.A.A.* **46**, 73, 1935) may well be followed up.

5. *Photography*. Although decisive progress with photographic observations of meteors seems to depend chiefly on better optical means and plates of higher sensitivity to yellow light, so that, up to now, the ratio of photographed meteors to the duration of exposures remains small, no effort should be spared to increase the observational material, and to publish it in a form suitable for computation of radiants. The application of precise photogrammetric methods to photographs of paths, as developed by S. Arend and E. Vandekerkhove, yields results so vastly superior to the best visual observations, that, even in the case of group radiants, more important results may be expected from photography than anything done so

far. The curvature of two paths recently measured at Uccle has been found slightly hyperbolic by S. Arend, and if this could be confirmed for doubly observed paths it might lead to definite conclusions as to refraction in the upper atmosphere.

P. M. Millman and D. Hoffleit have published (*H.A.* **105**, 601, 1937) a preliminary discussion of 14 meteor photographs obtained with a rotating shutter at the Oak Ridge station of the Harvard College Observatory, showing the great importance of the method, chiefly with respect to the measure of deceleration of meteors in the atmosphere. Since that paper went to press, photographs from two stations (Cambridge and Oak Ridge) have been secured for 18 meteors, and F. L. Whipple has analysed the material for six of them. The velocity measured for a Perseid agrees well with the known velocity of the associated comet, and a Geminid is found to have been moving in an orbit with a period of 1·8 years. Of four sporadic meteors studied, three are found to have been moving in short-period orbits with very small inclinations, very similar to those of asteroids with perihelion distances less than one astronomical unit, and suggesting an "asteroidal" type of meteor. The fourth sporadic meteor was moving with retrograde motion in a nearly parabolic or possibly hyperbolic orbit, of "cometary" type. Important conclusions are drawn from the measures of deceleration coupled with measures of velocity and luminosity.

In the U.S.S.R., 40 cameras are now at work in Moscow, Stalinabad and Tomsk, with focal ratios 3·5 to 4·5, and, in 1937, over 35 trails were obtained. In the two first stations, a single large rotating sector, built on a separate pillar, is serving five to seven cameras at the same time, and its actual speed is measured directly after the appearance of every bright meteor. In 1935–37, the Canadian organization has obtained 38 direct photographs in 261 hours of exposure (8 with rotating shutter) and 3 meteor spectra in 154 hours (2 with shutter). In England, E. H. Collinson has published his work in 1929–34, with 20 meteors and 6 true paths. In Japan, K. Yosii has undertaken systematic observations, and secured 50 trails. Several paths have also been obtained in Czechoslovakia, where the Ondřejov Observatory has tried a rotating sector.

The pioneer work done by Elkin at Yale in 1893–1909, and turned over to C. P. Olivier for completion, has appeared (*A.J.* **46**, 41, No. 1061, 1937). The methods as well as the results are of importance, the latter confirming that the end heights of Leonids are not lower than about 90 km., in accordance with the visual observations made in the United States.

P. M. Millman suggests that, in view of the difficulties experienced in the operation of moving shutters with synchronous motors, especially in cold weather, a rigid series of tests concerning their speed should be made frequently while they are employed in meteor observation. Synchronization of shutters by radio control, as attempted by W. T. Whitney (*Pop.A.* 1937 March), if found effective, may help to overcome this difficulty. N. N. Sytinskaya suggests that the most suitable optics for meteor photography would be an objective of 200 mm., opened at F/2 which, on plates of speed 1000–2000 H.D., would secure meteors down to 2^m–3^m.

6. *Spectra*. Distinct progress has been made during the last three years in the spectrography of meteors. P. M. Millman has studied 15 spectra photographed between 1933 and 1937 (*H.A.* **82**, No. 7, 1935), and hopes to publish soon a third paper on the analysis of such spectra, pending a discussion of all meteor spectra photographed to date. He has also attempted to publish complete annual lists of meteor spectrograms, in view of a catalogue similar to the catalogue of meteor trails kept at Harvard by D. Hoffleit (over 600 trails). Prompt modification of omissions in, and suggestions for improvements to, the already published lists or

catalogues, are requested by both authors. Seven spectrograms were obtained and studied in the U.S.S.R. between 1904 and 1937. A detailed study of a meteor spectrogram has been carried out in Sweden by C. Schalén and G. Wernberg (*Upsala Medd.* No. 68). Attention should be called to the rotating spectrograph devised by John S. Hopkins (*Pop.A.* 1937 March), in order to increase the efficiency of such apparatus. No efforts should be spared to obtain a spectrum of a persistent streak, which, according to the theoretical views of N. Gurjew, should be similar to that of the aurora.

7. *Fireballs.* Though the number of large meteors investigated by computers is steadily increasing, it is felt that many observations of such bodies still remain unused. Some organization may possibly be set up to remedy this deficiency, in connexion with a sequel to the Niessl-Hoffmeister Catalogue. It should be noted in this respect that F. Watson keeps up-to-date a card catalogue of observations of fireballs which was begun at Harvard College Observatory by the late W. J. Fisher.

Many bright meteors are no doubt observed each year at sea by mariners who possess expert knowledge of position, time, and bearings. The example set up by the U.S.A. Hydrographic Office in encouraging such observations, and in collecting and publishing reports on fireballs, should be followed by all the nations which possess a similar organization.

Two of the large meteors recently observed deserve special mention: (1) the meteorite of Prambachkirchen (J. Rosenhagen), owing to the large amount of curvature shown by the path in its lower part; (2) the bright meteor of July 23, 1936, owing to its persistent train, for which an increase of height by several kilometers, due, no doubt, to thermal convection, could be established. In regard to its very small heliocentric velocity, C. Hoffmeister suggests that this meteor, with several others, should be included in a new class of so-called "planetary meteors", whose orbits have aphelia near the Earth's orbit, or slightly outside of it ($a<1$). Attention should be called to the instructions devised by C. C. Wylie for measuring angles of the apparent paths of spectacular meteors.

8. *Meteorites.* The Society for Research on Meteorites (S.R.M.), under the active impulse of F. C. Leonard and H. H. Ninninger, and its various commissions, has performed important work in bringing together the astronomical and astrophysical study of meteors and the mineralogical investigation of meteorites. It has promoted the publication of a valuable series of papers which now form the first volume of its *Contributions* (3 fascicles, 1935–37). A report of its President for the term 1933–37 has been published in *Pop.A.* 1937 Aug.–Sept. Useful lists of meteorites have been compiled by I. S. Astapovich, F. Heide, H. H. Ninninger and I. Yamamoto, and the distribution of 1204 falls and finds studied by P. M. Millman (*Journal R.A.S. Can.* **32**, 4, 201, 1938). It seems that there is a need for a systematic catalogue of meteorites, on international lines, which should include the exact location of all known falls and finds, if possible to 0'·1. During the last three years, Dravert, Krinov and Kulik secured no less than 16 new meteorites in the U.S.S.R. territories, as the result of many painstaking trips.

Little progress has been reported on the investigation of the large known meteoric masses. S. J. Belykh has published the geographical co-ordinates of the place of the great Siberian fall of 1908 June 30, from astronomical observations (*Publ. of the State Trust of the Main Geodetic Works*, No. 4: Astronomical Determinations of 1928–1929, pp. 163–175, 1937). A two-motor hydroplane, with L. A. Kulik, surveyor Abramov and engineer Petrov, was sent in the summer of 1937 to the district of Pudkamennya Tunguska, to effect an aerial survey of the region of the fall, which was partially performed; an additional aerial survey was planned for 1938. In regard to the Arizona Meteor Crater, all work, so far as C. P. Olivier has been informed, has stopped, due to the impossibility, at present, of financing the expensive operations needed, when the chances of recovering an important metallic mass are uncertain. Neither has anything further been heard about the recovery of the Chinguetti (Adrar) meteorite, the existence of which has been recently put in doubt.

According, however, to a letter addressed to Prof. Bosler by Mr G. Ripert, administrateur en chef des Colonies en retraite, who discovered the mass in 1916, and brought back the fragment analysed by Prof. A. Lacroix, "the metallic nature of the rock cannot be doubted". The possibility therefore still exists that it has been covered up with sand from the desert, and a magnetic exploration of the site is more desirable than ever.

W. Tscherkas and P. Tschirwinsky published statistical investigations of falls of meteorites compared with fireballs. I. S. Astapovich completed in 1937 an investigation of 66 orbits and radiants of meteorites, showing that there are several sources of their origin, differing in space and time. Axel Corlin has examined the conditions under which meteorites may be built up from interstellar particles (*Zeitschr. für Astroph.* **15**, 239, 1938).

9. *Meteoric dust.* The problem of the origin of metallic dust deposited from the atmosphere or found in the soil or on the ocean floor has recently attracted renewed attention. L. Rudaux has inferred from ten-day collections of such dust in July-October, made from 1927 to 1936, that magnetic particles were more plentiful at the beginning of August, and finds another maximum at the end of August or in early September. In 1928, and also in 1933, copious deposits also occurred in October (Giacobinids!). Systematic observations on these lines are very desirable.

10. *Methods.* It may perhaps be remarked that there is no general agreement as to the accuracy of meteor work in different countries, and very little information by which this could be judged. There have been frequent discussions in the past in regard to the various types of errors that occur in meteor observations, and on how to evaluate them. Such discussions have become increasingly important with the growing number of amateur observers. Miss D. Hoffleit urges that those who supervise untrained amateurs should devise observational programmes that the untrained can carry out with accuracy sufficient for the needs of the professional. Experiments with artificial meteors in planetaria or otherwise, already suggested by the Commission in 1932 (*Trans. I.A.U.* **4**, 118) and effected on a small scale in Germany and in the U.S.S.R., should be made whenever possible. The accidental errors (quadratic means) of experienced and inexperienced observers, as tabulated by Ermakov, are characteristic in this respect.

I. S. Astapovich, M. Davidson, V. Fedynsky and K. Stanjukowitsch, C. Hoffmeister and B. S. Whitney have developed methods of determining real paths in the absence of observations of characteristic points of the apparent paths, independently of the supposition that different observers recorded the same part of the path. V. Guth has elaborated a simple graphical method, extending G. van Biesbroeck's method, for the computation of real paths. At the Observatory of the Czech Polytechnical School, J. Svoboda has proceeded with his experiments on an artificial meteor, and has prepared a detailed report for the Stockholm Meeting. Indirect methods of determining the velocity of meteors have been indicated by several Russian computers.

11. *Theory.* The physical theory of meteor phenomena has been steadily developed, chiefly by E. Öpik, J. Hoppe, I. S. Astapovich and Fletcher Watson. In addition to his series of important papers in the *Tartu Observatory Publications*,

E. Öpik is preparing a treatise on Meteor Theory, which will be awaited with great interest. Several investigators including E. Esclangon have undertaken a more detailed study of the resistance of the air to meteors. At the Midwest Meteor Association (Iowa), C. C. Wylie has had the resistance function developed and the equations integrated. Computations will be made on several of the most accurately observed meteors as a check on the method.

12. *Meteoric matter in space.* In the hands of C. Hoffmeister, E. Öpik and F. Watson, studies of the distribution of meteoric matter in space have recently led to important results. It is now fairly well ascertained that most of the sporadic meteors are of interstellar origin. In an important memoir (*Sitzungsber. Preuss. Ak. der Wiss. Phys.-Math. Kl.* **18**, 1936) Hoffmeister, with the aid of the results of his second voyage to South America, confirmed the existence of the interstellar meteoric current from Taurus towards Libra-Scorpius, and succeeded in determining a preliminary position of its vertex and antivertex, based upon the annual variation of the normal frequency and the mean apparent heliocentric velocity of meteors. A relation between this system of minor bodies and the dark clouds of the Milky Way is now suspected, though both the work of Schoenberg, Jung and Wilkens at Breslau, and that of F. Watson Jr. at Harvard (*H.A.* **105**, 623, 1937) show that the general absorption of light which they produce is only a small fraction of that found in photometric investigations, or allowed from dynamical considerations by Oort. The analyses made so far strongly emphasize the necessity of further observational material, especially in regard to faint meteors.

13. *Treatises and conferences.* C. Hoffmeister has published a volume *Die Meteore, Ihre kosmischen und irdischen Beziehungen* (Leipzig, 1937) which forms an up-to-date counterpart, in the German language, of C. P. Olivier's *Meteors.* It would be useful if a similar treatise could enrich the French astronomical literature. F. Heide's *Kleine Meteoritenkunde* (Breslau, 1934) also deserves mention. At the suggestion of the Sternberg Institute, two successful conferences on Meteoric and Cometary Astronomy were held in Moscow, on 1935 Dec. 17–18, and 1937 Jan. 29–31, where many reports were presented, and illuminating discussions took place. It is to be hoped that the transactions of both conferences will be published in some of the West-European languages. Since 1937 a course of meteor astronomy is read at the Faculty of Mathematics of the Moscow University; in 1938 the same course is to be read at the Saratov University. Since 1936 a useful ephemeris of the equatorial co-ordinates of the Apex, and of its longitude, has been given for every ten days in the Czech Astronomical Almanac (Hvězdářská ročenka) edited by the National Observatory of Prague. Axel V. Nielsen has computed a "Table for facilitating the determination of the perturbations of meteors by the Earth", which will be printed before long in the publications of the Aarhus Observatory.

SUGGESTIONS

Among the suggestions presented by members of the Commission are the following:

1. That all publications of meteor frequencies should be accompanied by specific statements as to the part of the sky and the size of the field observed, the magnitude of the faintest stars visible in the field, the exact times of beginning and ending of the observations, as well as the number of persons observing (D. Hoffleit).

2. That the various methods for the observation of meteors (drawing of the apparent path, timing of appearance and duration) should be submitted to critical discussion (Svoboda).

3. That the various methods for the determination of group radiants from observed paths should be experimented (Svoboda).

4. That a systematic programme of meteor photography should be instituted at several pairs of co-operating stations, utilizing both spectrographs and direct cameras equipped with rotating shutters (Millman).

5. That the Niessl-Hoffmeister catalogue of great meteors (1925) should be supplemented, possibly in the loose-leaf form, together with a revision of the numerous cases of unused observations (Guth-Nielsen).

6. That, when a great meteor is observed from a large area, the material collected by several organizations should be sent to the central station of the country over which the end point of the path is situated, to be discussed and published there (Hoffmeister).

7. That, for the determination of the true path of a bright meteor from comprehensive observational material, the Galle-Niessl method should be more widely used, since it appears to be superior to other methods (Nielsen).

8. That papers on the determination of true paths of bright meteors should include the observations themselves, in order to allow a judgment on the results (Nielsen).

9. That a uniform method of listing meteorites be formulated, means taken to investigate all reports of meteorite falls and finds for the purpose of ascertaining their authenticity and of compiling an international catalogue of same (Millman-Leonard).

10. That a complete and systematic bibliography of meteorites be resumed and published, preferably at regular intervals (Leonard).

11. That a standard terminology and notation for meteors and meteorites be discussed and adopted (Leonard).

12. That the Commission should discuss and adopt a general programme of simultaneous observations, on a uniform plan, and in widely different regions and altitudes, of the metallic dust which is present in the atmosphere (Rudaux).

13. That the Government of France should again be most respectfully urged to take steps to explore the site of the great Chinguetti (Adrar) meteoritic mass (Olivier).

14. That all meteor observations and falls of meteorites be timed in some uniform system of notation, either U.T. or G.M.A.T., or, at least, that none of such observations be published without stating the kind of time used (Loreta).

15. That the region at about 55 km. in the Earth's atmosphere, where few meteors disappear, be especially studied (Dobson).

16. That members of the expeditions for observing the total eclipse of the Sun in South Africa, 1940 Oct. 1, be asked to carry out meteor counts on their way, especially in the tropical zone, and in the southern hemisphere (Guth).

17. That the observations made by and under the care of Thos. C. Poulter, during the Second Byrd Antarctic Expedition (1933–35), be discussed and published as soon as possible (de Roy).

18. That some observatory in the southern hemisphere should devote a portion of its activity to the study of meteors, and preferably an observatory in New Zealand, where work of this kind has already been done with marked success for several years (de Roy).

FÉLIX DE ROY
President of the Commission

https://doi.org/10.1017/S0251107X0001806X Published online by Cambridge University Press

APPENDIX I

LIST OF ORGANIZATIONS AND DIRECTORSHIPS FOR METEOR WORK (1938) AND REQUEST FOR THE EXCHANGE OF REPRINTS

BELGIUM. Bureau Central Météorique de la Société d'Astronomie d'Anvers (F. de Roy), 1, Rue du Lion de Flandre, Antwerp.

CANADA. Royal Astronomical Society of Canada (Peter M. Millman), David Dunlap Observatory of the University of Toronto, Richmond Hill, Ont.

CZECHOSLOVAKIA. Meteor Section of the Czech Astronomical Society (V. Guth), Štefánik Observatory, Praha IV, Petřín.

DENMARK. Ole Roemer Observatoriet (A. V. Nielsen), Aarhus.

ESTHONIA. Astronomical Observatory of the University of Tartu (E. Öpik).

FRANCE. Commission des Étoiles filantes de la Société Astronomique de France (Mme G. C. Flammarion), Observatoire de Juvisy, Seine-et-Oise.

GERMANY. Universitäts-Sternwarte Berlin-Babelsberg, Abteilung Sonneberg (C. Hoffmeister), Sonneberg in Thüringen.

Astronomisches Büro (Oswald Thomas), Salesianergasse, 8, Wien III.

GREAT BRITAIN. Meteor Section of the British Astronomical Association (J. P. M. Prentice), Star Ridge, Battisford, Needham Market.

HUNGARY. Reichsanstalt für Meteorologie und Erdmagnetismus (Anton Réthly), Kitaibel Pal-utca, 1, Budapest II.

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JAPAN. Meteor Section of the Oriental Astronomical Society (Issei Yamamoto), Izumidono, 59, Kyoto.

NEW ZEALAND. Meteor Section of the New Zealand Astronomical Society (R. A. McIntosh), 18 Landscape Road East, Mount Eden, Auckland, S. 1.

SPAIN. P. M. Ryves, The Briars, Buxted, Sussex, England.

SWEDEN. Meteor Section of the Astronomical Society "Tycho Brahe" (Axel Corlin), Observatory, Lund.

SWITZERLAND. Astronomisches Institut der Universität (S. Mauderli), Bern.

UNITED STATES OF AMERICA. American Meteor Society (C. P. Olivier), Flower Observatory of the University of Pennsylvania, Upper Darby, Pa.

Midwest Meteor Association (C. C. Wylie), University of Iowa, Iowa City, Iowa.

Society for Research on Meteorites (H. H. Ninninger), 1955, Fairfax Street, Denver, Colorado.

U.S.S.R. Meteor Section of the Sternberg Astronomical Institute of the University of Moscow (I. S. Astapovich), Novo-Vaganskovsky per, 5, Moscow 22 Priesnja.

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The above organizations and astronomers are prepared, subject to limitations resulting from their own programme, to take part in any programme of observations requiring international co-operation. Anyone wishing to have such observations made should circularize a request for co-operation through the Central Station or Director of his own country.

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APPENDIX II

L'ÉTUDE DE LA LUMIÈRE DU CIEL NOCTURNE

1. L'extrême complexité de la lumière du ciel nocturne est aujourd'hui un fait bien établi. Une partie de la lumière, émise dans la haute atmosphère, donne un spectre de bandes et de raies brillantes fort compliqué. Cette luminescence intéresse probablement plusieurs couches d'altitudes différentes; elle s'apparente dans une certaine mesure aux aurores polaires, peut-être en relation avec l'activité solaire, l'ozone atmosphérique et même les diverses couches ionisées que révèle la propagation des ondes radio-électriques.

Au spectre discontinu de la haute atmosphère, se superpose un spectre continu dont l'origine n'est pas simple. Une partie de ce rayonnement provient évidemment des étoiles faibles, une autre doit être rattachée à la lumière zodiacale et ne peut être localisée dans l'espace avec certitude. Enfin la diffusion de la lumière des étoiles, dans la galaxie, intervient pour une part appréciable.

L'étude de la lumière du ciel nocturne est ainsi en rapport avec un grand nombre de questions très diverses: il n'est pas possible de la faire tenir dans un chapître déterminé de la physique du globe ou de l'astrophysique. On doit se féliciter de la voir désormais figurer au programme d'une Commission de l'Union astronomique internationale.

Un exposé d'ensemble a été édité par la *Revue d'Optique* en 1934 (Ch. Fabry, J. Dufay, J. Cojan, *Étude de la lumière du fond du ciel nocturne*). Je signalerai ici quelques travaux plus récents et particulièrement ceux qui ont été publiés depuis 1935.

2. *Brillance du ciel: mesures photométriques et travaux théoriques.* La plupart des auteurs de mesures photométriques cherchent actuellement à séparer les diverses "composantes" de la lumière du ciel. William Brunner a utilisé à cet effet les nombreuses mesures visuelles de la brillance au zénith qu'il a faites en Suisse en 1931–32 (*Publik. Eidg. Sternw. Zürich*, **6**, 1935). L'appareil utilisé est un photomètre à plages analogue à ceux qui m'ont servi autrefois. Le mémoire contient aussi des mesures relatives au crépuscule et à la lumière zodiacale ainsi qu'une discussion des mesures antérieures. La brillance mesurée en 1931–32 surpasse d'au moins ½ magnitude celle que j'avais obtenue de 1923 à 1926. Il n'est pas certain que cette différence provienne exclusivement, comme le pense l'auteur, d'erreurs systématiques dans les mesures antérieures.

Pour isoler la brillance d'origine atmosphérique, Fesenkov propose une méthode basée sur l'observation d'une plage galactique brillante, d'une nébuleuse obscure voisine et du ciel au pôle (*C.R. Acad. Sc. U.R.S.S.* **3** (VIII), 25, 1935). D'après les mesures faites à Kitab (U.R.S.S.), avec un nouveau photomètre binoculaire (*Russian Ap. J.* **12**, 595, 1935), la luminescence atmosphérique interviendrait en moyenne pour ⅘ de la brillance au pôle; le reste proviendrait à peu près également des étoiles faibles et de la lumière zodiacale. On ne tient pas compte ainsi de la diffusion galactique.

Elvey et Roach ont étudié la répartition de la brillance sur la voûte céleste au moyen d'un photomètre enregistreur muni d'une cellule photoélectrique au potassium (*Ap. J.* **85**, 213, 1937), qui permet de faire des observations très rapides. Ils parviennent ainsi à séparer les diverses "composantes" de la lumière du ciel nocturne: luminescence et diffusion atmosphérique, brillance d'origine zodiacale et "composante cosmique", comprenant à la fois la lumière des étoiles faibles et la lumière diffusée dans la Voie Lactée. La lumière des étoiles faibles pouvant être évaluée à partir des dénombrements d'étoiles, on obtient par différence la lumière diffusée. L'existence de celle-ci est mise en évidence pour la première fois d'une manière parfaitement nette.

Il est intéressant de rapprocher des prévisions théoriques les résultats de ce remarquable travail. J'avais montré comment on pouvait en principe évaluer la brillance diffusée, dans un schéma simple de galaxie, sans négliger les diffusions d'ordre supérieur (*C.R.* **201**, 1323, 1935). Les calculs, fort laborieux, ont été développés par Wang Shih-Ky (*C.R.* **201**, 1326, 1935; **202**, 284, 1936; *Publ. Obs. Lyon*, **1**, No. 19, 1936), à partir des données relatives à l'absorption. L'accord entre les valeurs ainsi calculées et celles qui résultent des mesures ultérieures d'Elvey et Roach est réellement surprenant (*C.R.* **205**, 719, 1937).

En reprenant le calcul de la diffusion galactique par une autre méthode, Fesenkov est arrivé à un résultat peu différent (*Russian Ap. J.* **14**, 413, 1937). Il montre, dans le même mémoire, en s'appuyant sur les dénombrements de Hubble, que les nébuleuses extra-galactiques ne doivent contribuer à la luminosité du ciel que pour une part insignifiante.

3. *Mesures colorimétriques*. Lord Rayleigh et Spencer Jones ont discuté l'ensemble des observations faites pendant une dizaine d'années à Terling (Angleterre), à Canberra (Australie) et au Cap (Afrique du Sud) (*Proc. Roy. Soc.* A, **151**, 22, 1935). La brillance du ciel était comparée visuellement à celle d'un étalon radioactif luminescent à travers trois filtres: bleu, rouge et vert, ce dernier isolant approximativement la raie 5577 A. de OI. Des variations régulières de périodes 12 et 6 mois ont été mises en évidence. La variation annuelle est plus importante à Terling qu'au Cap; son amplitude est partout plus grande en vert et en rouge qu'en bleu. La variation semi-annuelle a sensiblement la même amplitude aux trois stations; elle est maximum pour la raie verte, minimum pour le bleu.

A ces variations périodiques se superpose une variation lente, bien définie surtout pour la raie verte. Les moyennes annuelles sont nettement en relation avec la surface des taches solaires. On observe enfin des fluctuations irrégulières, plus marquées à Terling, atténuées au Cap, qui affectent généralement les trois couleurs simultanément, mais sont indépendantes d'une station à l'autre.* Il n'y a pas de relation nette entre ces fluctuations et l'agitation magnétique, bien qu'en moyenne la raie verte soit plus intense pendant les jours perturbés. La brillance moyenne, pour chaque couleur, est comparable dans les trois stations, mais tend à être plus grande à Terling, plus petite au Cap.

Grandmontagne, qui avait décrit précédemment un photomètre enregistreur comprenant une cellule photoélectrique au caesium sur argent oxydé, une grande résistance et un électromètre et avait fait avec cet instrument des mesures en lumière totale (*C.R.* **68**, *Congrès Soc. Sav.* 113, 1935; *Bull. Soc. franç. Phys.* No. 381, 10 S, 1936), s'est attaché depuis plus particulièrement à faire, avec le même in-

* Ces fluctuations ont été aussi observées en lumière totale. Elvey et Rudnick ont étudié leur influence sur l'observation des nébuleuses faibles (*Ap. J.* **86**, 562, 1937).

strument, des mesures colorimétriques, qui mettent en évidence des variations périodiques. Les énergies reçues en moyenne à travers trois filtres, bleu, vert et rouge, sont:

bleu 3500–5000 A.	I
vert 5300–5600 A	I, 74
rouge 5650–9000 A.	83

La température de couleur correspondante serait environ 2280° (*Bull. Soc. franç. Phys.* No. 396, 174 S, 1936; *C.R.* **204**, 337, 1937).

Pourtant, l'indice de couleur de la lumière du ciel nocturne, mesuré par Rudnick (*Ap. J.* **86**, 212, 1937), est en moyenne voisin de celui du Soleil. Ce résultat, conforme à celui des anciennes observations photographiques, tient probablement à l'emploi de plaques dont la sensibilité ne s'étend guère au delà de 6500 A. Les mesures de Grandmontagne montrent donc que la lumière du ciel nocturne est extrêmement riche en radiations rouges de très grandes longueurs d'onde (7000 A. $< \lambda <$ 9000 A.).

4. *Polarisation.* L'étude de la polarisation a été reprise visuellement par Kvostikov et Panschin (*Journ. Phys.* 7^e^ série, **7**, 187, 1936) qui retrouvent à peu près les résultats de mes mesures photographiques de 1925. Le fait que le plan de polarisation semble s'écarter du Soleil au milieu de la nuit, dans le cas des mesures visuelles, résulte probablement, d'après les auteurs, de l'influence de la raie verte, dont l'intensité passe alors par un maximum.

5. *Recherches spectrales.* (*a*) *Instruments.* L'étude de la composition spectrale de la lumière du ciel nocturne a bénéficié des progrès réalisés dans la fabrication des plaques photographiques et dans la construction des spectrographes très lumineux. Parmi les instruments nouveaux, il faut citer:

le spectrographe à un prisme de flint de Cabannes, construit par Cojan (*Helv. Phys. Acta*, **8**, 405, 1935); muni d'un objectif ouvert à F/0·7 de 75 mm. de focale bien corrigé, il permet d'obtenir notamment des clichés normalement posés, de 3800 à 5000 A., en moins d'une nuit;

le spectrographe monté par Garrigue au Pic du Midi (*C.R.* **202**, 1, 1936), comprenant un prisme de flint et un objectif de Cojan ouvert à F/0·55 de 35 mm. de focale; il permet de faire automatiquement une série de poses courtes dans la région du spectre visible;

le spectrographe de quartz imaginé par Arnulf et Lyot (*C.R.* **201**, 1480, 1935); l'objectif est un miroir sphérique aluminisé ouvert à F/1, de 5 cm. de foyer, dont l'aberration sphérique est corrigée par un système de deux lentilles de quartz, jouant également le rôle de collimateur; possédant des qualités analogues à celles du télescope Schmidt, cet instrument donne des spectres remarquablement fins;*

enfin le spectrographe de quartz monté par Otto Struve sur le tube du grand réfracteur de l'Observatoire Yerkes pour l'étude des spectres des nébuleuses (une fente éloignée, sans collimateur, deux prismes de quartz de 60°, un télescope Schmidt ouvert à F/1) et qui donne, en même temps, de bons spectres du ciel nocturne (*Ap. J.* **86**, 612, 620 et 622, 1937).

(*b*) *Identification des radiations émises.* L'identification des radiations émises dans la haute atmosphère est rendue difficile par la petitesse de la dispersion des spectrographes très lumineux.

* Un instrument du même type, de 10 cm. de focale, muni d'un prisme d'uviol, a servi récemment à Bernard à étudier le spectre des aurores polaires et du crépuscule à Tromsø.

Dans la région *ultraviolette*, précédemment étudiée par Dufay (*C.R.* **198**, 107, 1934; *Journ. Phys.* 7ᵉ série, **5**, 523, 1934; *Public. Obs. Lyon*, **1**, No. 9, 1934) et par Gauzit (*C.R.* **199**, 29, 1934; *Journ. Phys.* 7ᵉ série, **5**, 527, 1934), Arnulf a obtenu, avec son nouveau spectrographe de quartz, d'excellents spectrogrammes et publié une liste de longueurs d'ondes (*C.R.* **202**, 1412, 1936). La plupart des radiations, dont la plus intense à 5556 A., ne sont pas identifiées. S'appuyant sur les mesures de Gauzit, Kaplan a proposé récemment d'assimiler quelques-unes d'entre elles aux "tail-bands" de CN (*Phys. Rev.* **52**, 1252, 1937). Gauzit a obtenu de nouveaux clichés avec le spectrographe d'Arnulf; les résultats de ses mesures seront publiés prochainement.

La présence certaine de radiations de longueurs d'onde peu supérieures à 3000 A., la présence possible de radiations de longueurs d'onde un peu inférieures à 3000 A., les unes et les autres très fortement absorbées par l'ozone, suggère inévitablement l'existence d'une couche luminescente à une altitude relativement basse (Cabannes, Dufay et Gauzit, *C.R.* **202**, 612, 1936).

La région 3800–5000 A. a été étudiée par Cabannes et Dufay avec le spectrographe à F/0·7 (*Helv. Phys. Acta*, *loc. cit.*; *C.R.* **198**, 306, 1934; **200**, 1504, 1935; **201**, 696, 1935; **202**, 365, 1936; *C.R.* **68ᵉ** *Congrès Soc. Sav.* 66, 1935). Une liste de plus de 200 radiations, la plupart nouvelles, a été dressée. Kaplan avait suggéré que quelques-unes des radiations du ciel nocturne pouvaient appartenir au système $A \rightarrow X$ des bandes de l'azote (dites bandes de Vegard-Kaplan) (*Nature*, **135**, 229, 1935), auquel Vegard attribuait déjà quelques faibles radiations des aurores polaires. Cabannes et Dufay ont montré qu'effectivement les radiations les plus intenses du ciel, dans la région 3800–5000, appartenaient au système $A \rightarrow X$. D'autres radiations plus faibles pourraient être identifiées avec les bandes de Schumann-Runge de la molécule O_2; enfin un assez grand nombre d'entre elles paraissent identiques aux radiations non identifiées des noyaux cométaires, étudiées par Baldet.

Cabannes a étudié avec le même instrument la région 5000–8000 A. (*Journ. Phys.* 7ᵉ série, **5**, 601, 1934). Il y reconnaît la présence des bandes du Ier système positif de la molécule N_2; celle des bandes telluriques de la molécule O_2 et des bandes de vibration de la molécule H_2O, déjà annoncée par Sommer, paraît aussi très probable.

Les raies 6300 et 6364 A. de l'atome OI sont généralement très intenses. Enfin l'étude de la forte radiation 5894 ± 1 A., découverte par Slipher dès 1929, et que j'avais déjà rapprochée des raies D (*C.R.* **194**, 1897, 1932; *Journ. Phys.* 7ᵉ série, **4**, 221, 1933), a conduit Cabannes et Dufay à imaginer la présence d'atomes de sodium dans la haute atmosphère (*C.R.* **206**, 221, 1938). Les mesures interférentielles dont il sera question plus loin viennent de prouver l'exactitude de cette hypothèse. Déjardin (*C.R.* **206**, 930, 1938) a aussitôt signalé d'autres rapprochements possibles entre certaines radiations plus faibles observées par Cabannes, Dufay et Gauzit et des raies de l'atome neutre de sodium. Le plus significatif (déjà signalé par Bernard) concerne la radiation 3303 A., observée par Dufay et Gauzit, qui coïncide avec le doublet 3302–3303 de NaI. On sait que ce dernier peut se comporter dans une certaine mesure comme une raie de résonance. Parmi les autres radiations rapprochées des raies du sodium, les unes ont certainement une autre origine (bandes du 1er système positif de N_2 par exemple), les autres sont douteuses ou s'éloignent déjà notablement des raies de NaI. Il faut remarquer du reste que la radiation 3303 n'a pas été retrouvée par Arnulf (*loc. cit.*).

(*c*) *Variations d'intensité des bandes et des raies brillantes*. Les variations d'intensité des bandes 4424 et 4171 A. de Vegard-Kaplan ont été étudiées par Cabannes et Dufay (*C.R.* **200**, 878, 1935). Leur évolution annuelle rappelle celle de la raie verte ainsi que la fréquence des aurores de basse latitude.

Garrigue étudie au Pic du Midi les variations des raies 5577, 5894 et 6300 A. (*C.R.* **202**, 807, 1936; **205**, 491, 1937). Toutes les trois manifestent des fluctuations rapides au cours de la nuit, mais leurs intensités changent peu d'une nuit à l'autre. L'existence d'un maximum pour la raie verte vers le milieu de la nuit n'est pas toujours vérifiée: l'heure du maximum dépend de la région visée. 5577 et 5894 subissent une variation saisonnière, plus marquée pour 5894, avec maximum en hiver, à laquelle paraît échapper la raie 6300. Le rapport des intensités à l'horizon et au zénith est compris entre 1·5 et 7 pour 5577 (valeur la plus fréquente: 2), 2 et 3 pour 5894, 1·8 et 2·5 pour 6300.

Le phénomène le plus remarquable est la diminution d'intensité de la raie 6300 à la fin du crépuscule, pendant lequel elle est excitée par la lumière solaire (probablement par résonance). D'après leurs mesures photométriques, Cabannes et Garrigue (*C.R.* **203**, 484, 1936) trouvent que l'émission serait maxima entre 115 et 120 km. d'altitude, mais qu'elle se manifesterait jusqu'à 800 à 1000 km. Cependant, l'excitation par résonance optique n'agit pas seule, car la raie 6300 est aussi très intense dans l'ombre de la Terre, après le coucher du Soleil. On sait que Vegard avait déjà observé une exaltation de la raie 6300 dans les aurores éclairées par le Soleil. La raie 6300 a aussi été observée par Guth et Link dans le spectre du ciel pendant l'éclipse totale du Soleil du 19 juin 1936 (*Memoirs Czech Astron. Ass.* No. 5, 17, 1937).

Au cours de l'année polaire internationale (1932–33) Currie et Edwards avaient déjà observé au Canada la grande intensité de la raie 6300 au crépuscule, mais leur mémoire n'a été publié que tardivement (*Terr. Magn.* **41**, 265, 1936). Ils signalaient que la raie 5894 se comportait de même. Toutes deux seraient aussi très intenses pendant la pleine lune. L'exaltation de la raie 5894 a été retrouvée et étudiée récemment par Bernard à Tromsø (*C.R.* **206**, 448, 1938). De ses mesures il résulte que l'excitation cesse brusquement quand les rayons solaires dépassent l'altitude de 60 km. Il s'agirait d'une couche relativement mince d'atomes de sodium, localisée vers cette altitude.

Ce phénomène crépusculaire a facilité l'identification de la raie 5894. Des mesures interférentielles faites simultanément au crépuscule par Cabannes, Dufay et Gauzit (*C.R.* **206**, 870, 1938) et par Bernard (*C.R.* **206**, 928, 1938), avec des étalons interférentiels de Fabry et Perot, ont permis de caractériser nettement les raies D_1 et D_2 et de mettre ainsi hors de doute la présence d'atomes de sodium dans l'atmosphère. Comme Bernard l'a montré le premier et comme nous l'avons reconnu également, l'intensité relative des deux raies est la même dans le ciel crépusculaire et au laboratoire. Des poses beaucoup plus longues sont nécessaires pour caractériser les deux raies pendant la nuit. Déjà Cabannes, Dufay et Gauzit ont montré qu'il s'agissait alors aussi de deux raies distantes d'environ 6 A.; leurs observations continuent.

(*d*) *Mécanisme de l'émission.* L'émission des raies verte et rouge de OI, celle des bandes de N_2 (bandes de Vegard-Kaplan et du 1er groupe positif) montrent l'existence dans l'atmosphère d'atomes d'oxygène dans les états métastables ^1S et ^1D, ainsi que de molécules d'azote à l'état métastable A et dans le niveau B.

D'après Cabannes (*C.R.* **200**, 1905, 1935), une pluie d'électrons dont l'énergie ne dépasserait pas 7·1 volts (électrons secondaires de la théorie de Dauvillier) portent les molécules N_2 à l'état A et dissocie les molécules O_2. Elle est aussi capable d'élever au niveau ^1S les atomes O provenant de cette dissociation; des électrons de plus faible énergie les porteraient seulement à l'état ${}^1D$. Le retour à l'état normal des atomes O et des molécules N_2 rend compte de l'émission des raies de OI et des bandes $A \rightarrow X$ de N_2.

Un second mode de luminescence peut résulter des chocs des particules excitées; ainsi s'expliquerait l'élévation des molécules N_2 de l'état métastable A au niveau B, suivi de l'émission des bandes du premier système positif ($B \rightarrow A$). Enfin, la décomposition des molécules O_3 pourrait intervenir dans une couche plus basse en produisant des molécules O_2 (${}^1\Sigma$), capables d'émettre les bandes telluriques ${}^1\Sigma \rightarrow {}^3\Sigma$ et encore des atomes O (${}^1S$). Dans tous les cas, ces derniers, en cédant leur énergie à une molécule H_2O, sont capables de lui faire émettre toutes ses bandes de rotation.

La période semi-annuelle observée par Lord Rayleigh et Spencer Jones correspondrait aux variations de brillance de la couche élevée, liée au rayonnement électronique du Soleil. De même, l'évolution lente qui suit la surface des taches. La période annuelle, dont le sens s'inverse d'un hémisphère à l'autre, correspondrait à la variation de la couche basse, provoquée par la destruction de l'ozone.

Chapman (*Phil. Mag.* **23**, 657, 1937) admet que les molécules O_2 sont dissociées pendant la journée par la lumière solaire (énergie de dissociation 5·1 volts). On a donc, pendant la nuit, un grand nombre d'atomes O (${}^3P$). Une collision triple entre trois de ces atomes peut amener l'un d'eux au niveau ${}^1S$ (4·2 volts) et former une molécule O_2; l'excès d'énergie peut exciter les vibrations ou la rotation de cette molécule. En retombant à l'état ${}^1D$, les atomes ${}^1S$ émettent la raie verte. A leur tour, les atomes ${}^1D$ émettent les raies rouges en retombant à l'état normal ${}^3P$. Mais quelques-uns d'entre eux peuvent se rencontrer avec un atome ${}^3P$, en présence d'une molécule N_2 (X). L'énergie libérée: $5{\cdot}1 + 1{\cdot}96 = 7{\cdot}1$ volts est maintenant suffisante pour porter la molécule N_2 au niveau A, d'où elle retombera à l'état normal en émettant les bandes $A \rightarrow X$. Si l'énergie cinétique du choc triple peut contribuer à l'excitation, on pourra obtenir des molécules N_2 (B) et expliquer l'émission du 1er système positif.

Cette ingénieuse théorie présente l'avantage de rendre compte des faits essentiels sans faire intervenir de particules hypothétiques *d'énergie appropriée*. Elle n'explique pas toutefois les variations périodiques.

6. *Conclusions et suggestions diverses.* L'étude de la lumière du ciel nocturne a fait depuis quelques années d'importants progrès. Elle a permis d'obtenir des renseignements intéressants, parfois inattendus, sur la composition et l'état physique de la haute atmosphère. Déjà elle commence à donner des indications sur les phénomènes qui se produisent dans des régions beaucoup plus éloignées de l'espace.

Bien des questions restent à résoudre. L'origine de beaucoup de radiations émises dans l'atmosphère est encore inconnue. La construction de spectrographes aussi lumineux que ceux dont on dispose aujourd'hui, mais plus dispersifs, facilitera certainement leur identification. Elle exigera des prismes et des objectifs de dimensions de plus en plus grandes. Cojan construit actuellement, pour l'Observatoire de Haute-Provence, un spectrographe analogue à l'appareil actuel de Cabannes, mais de dimensions doubles (150 mm. de distance focale). L'emploi d'étalons interférentiels à faibles différences de marche pourra encore rendre des services, comme pour l'identification des raies du sodium.

Des travaux de laboratoire seront nécessaires pour tenter de reconstituer au moins partiellement le spectre de luminescence atmosphérique et pour préciser le mécanisme—ou les mécanismes—de l'émission. On doit déjà beaucoup aux recherches que Kaplan poursuit depuis plusieurs années sur l'azote actif et qu'il n'a pas été possible d'analyser ici.

Pour séparer le mieux possible les diverses "composantes" de la lumière du ciel nocturne, la méthode d'Elvey et Roach, qui a déjà fait ses preuves, reste pleine de promesses. Mais le problème est difficile à résoudre par la seule étude de la répartition de la brillance sur la voûte céleste en lumière totale. Il sera sans doute avantageux d'associer aux mesures photométriques des observations spectrales et, au besoin, des mesures de la proportion de lumière polarisée. La luminescence atmosphérique donne un spectre essentiellement discontinu (nous n'avons aucune raison de supposer qu'il s'y ajoute une luminescence à spectre continu); il faut en profiter pour tenter de l'isoler.

Parmi les recherches qu'il semble particulièrement urgent d'entreprendre, je signalerai:

1° L'étude du spectre dans le rouge extrême et l'infra-rouge. Cette région est encore la plus mal connue. Slipher a indiqué qu'il avait observé des radiations jusqu'à 1μ (*M.N.* **93**, 666, 1933) et les mesures photoélectriques de Grandmontagne montrent qu'il se produit une émission intense entre 7000 et 9000 A. au moins.

2° L'étude de la répartition de l'énergie dans le spectre continu, sur laquelle on n'a actuellement que peu de renseignements purement qualitatifs et qu'il importerait de connaître pour déterminer quelles espèces de particules interviennent dans la diffusion (zodiacale et galactique). Elle est rendue difficile par le grand nombre de raies et de bandes d'émission.*

3° La mesure de la brillance du ciel sur de petites aires de quelques minutes de diamètre, dépourvues d'étoiles jusqu'à la 16^e^ ou la 18^e^ magnitude par exemple, qui permettrait d'éliminer pratiquement la brillance d'origine stellaire. Elle pourrait être effectuée aisément par la méthode photographique de Ch. Fabry, appliquée à un réfracteur de long foyer.

4° Enfin il serait bon de considérer à nouveau, avec des données récentes, le rôle possible de la diffusion de la lumière par les météorites, sur lequel insistait autrefois Pierre Salet et qui a été un peu perdu de vue.

Ces recherches relèvent plus de l'initiative individuelle que de la coopération. Mais il est extrêmement désirable que les chercheurs puissent échanger leurs vues, élaborer en commun un programme de travail et se partager la besogne. Toute idée de coopération proprement dite n'est d'ailleurs pas exclue. Il serait notamment intéressant d'effectuer, à diverses latitudes, des mesures de l'intensité des principales bandes et raies brillantes, suivant une même méthode. De même, il conviendrait que plusieurs observatoires, éloignés les uns des autres, se chargent d'effectuer périodiquement des mesures de brillance sur des régions bien définies du ciel, suivant une même méthode, avec des appareils standard, afin de surveiller l'évolution de la brillance et d'étudier ses variations d'un point à l'autre de la terre. La méthode photographique de Ch. Fabry, appliquée cette fois à de très petits instruments, serait encore à recommander.

* D'après les mesures de spectrophotométrie visuelle de Cerniajev, Kvostikov et Panschin (*Journ. Phys.* 7^e^ série, **7**, 149, 1936), dans lesquelles interviennent, il est vrai, les raies et les bandes d'émission, la répartition de l'énergie pourrait varier au cours de la nuit. Les auteurs observent au milieu de celle-ci un maximum dans le vert et un minimum dans le bleu. Ils pensent que la lumière bleue est diffusée dans des couches très élevées de l'atmosphère.

Mesures colorimétriques

En associant de nouveaux filtres colorés à son photomètre à cellule photoélectrique, Grandmontagne a constaté l'existence d'un premier maximum de la brillance spectrale dans la région 5800–6500 A. (qui contient les 2 raies rouges de l'atome d'oxygène) et d'un second maximum plus important dans l'intervalle 6900–9000 A.

La variation annuelle observée en utilisant toutes les radiations de longueurs d'onde supérieures à 5800 A. rappelle beaucoup celle que Lord Rayleigh a observée à Terling.

Les mesures faites au crépuscule montrent que la brillance du ciel au zénith se stabilise plus vite en lumière rouge qu'en lumière bleue lorsque le soleil descend sous l'horizon.

Recherches spectrales

L'étude des clichés obtenus par Gauzit confirme l'existence de radiations dans la région correspondant à la grande bande d'absorption de l'ozone, jusque vers 2900 A. Ces radiations doivent être émises dans l'épaisseur même de l'ozone ou à très basse altitude.

Les bandes les plus intenses du spectre ultra-violet n'ont pas été rattachées à un système connu. Suivant une suggestion de Cabannes, elles formeraient un nouveau système qui pourrait correspondre à une transition entre deux états faiblement excités de la molécule d'azote.

La radiation intense 3471 A.—que Kaplan identifie à la raie interdite $^2P \rightarrow {}^4S$ de l'atome NI et qu'il est parvenu à exciter dans la phosphorescence de l'azote, en même temps que les bandes de Vegard-Kaplan, à pression relative élevée—montre qu'il existe probablement des *atomes* d'azote dans la haute atmosphère. Des mesures récentes ont d'ailleurs ramené à 7·34 électron-volts l'énergie de dissociation de la molécule N_2.

Dans les régions bleue et violette, Cabannes, Dufay et Gauzit proposent d'attribuer un grand nombre de radiations du ciel aux bandes des molécules CH et CN. On observe en effet de bonnes coïncidences avec les premières raies de rotation des bandes de CH vers 4300 (système $A^2\Delta \rightarrow X^2\Pi$) et vers 3900 A. (système $B^2\Sigma \rightarrow X^2\Pi$). De même pour les bandes violettes de CN appartenant aux séquences $\Delta v = +1$ et $+2$ (4216 et 4606 A.). La structure de ces bandes dans le ciel nocturne serait à peu près la même que dans les comètes: on trouve un maximum de la branche P et un maximum de la branche R correspondant à la 9e ou 10e raie de rotation—et, de plus, dans chaque branche, un maximum voisin de l'origine de la bande. On explique notamment ainsi *toutes* les radiations du ciel comprises entre 4606 et 4476 A., en faisant intervenir les bandes de vibration depuis $0 \rightarrow 2$ jusqu'à $5 \rightarrow 7$.

En vue de confirmer cette attribution, il serait intéressant de reprendre l'étude de la région 3800–3900 A., encore très mal connue, où se trouve la forte séquence $\Delta v = 0$ de CN.

Variations d'intensité des bandes et des raies brillantes

De nouvelles observations confirment l'existence de la variation saisonnière annoncée par Garrigue pour les raies 5890–5896 A.

Le doublet du sodium s'affaiblit énormément en été au point de disparaître à peu près entièrement. Il est également beaucoup plus faible qu'en hiver pendant le crépuscule. Toute hypothèse destinée à rendre compte de la présence et de l'excitation des atomes de sodium dans l'atmosphère doit avant tout expliquer cette très importante variation. Il serait désirable d'effectuer des mesures dans l'hémisphère austral en même temps que dans l'hémisphère boréal.

JEAN DUFAY.

APPENDIX III

REPORT OF THE SUB-COMMISSION ON ZODIACAL LIGHT

1. ORGANIZATION. During the Fifth General Assembly of the International Astronomical Union held at Paris in July 1935, it was resolved to organize a Sub-commission of Commission 22 for handling the problems of zodiacal light and related phenomena, and some time later I was invited to preside over this Sub-commission. My first duty was to get into personal touch with every astronomer, professional as well as amateur, in any part of the world, who was interested in this branch of science. Up to this time my list includes about 100 names, of which England has 10, France 4, Germany 7, Italy 1, Switzerland 3, Rumania 4, Russia 3, India 2, U.S.A. 8, South Africa 6, Brazil 4, Australia 7, New Zealand 1, China 1, and Japan about 40. Some groups are fairly well organized, for instance in England, South Africa, Japan and Brazil, while other observers are quite independent or isolated.

In December 1937, a circular was distributed to most of these persons by the President of the Sub-commission, in which circular attention was called to the coming meeting at Stockholm; astronomers concerned were invited to communicate their opinion about a score of points of importance concerning the progress of researches and observations during recent years. Within a few weeks I received answers and communications from Mr Kenzi Araki, Rev. R. B. Bousfield, Dr C. T. Elvey, Mr A. F. I. Forbes, Mr Minoru Honda, Mr W. B. Housman, Mr E. Loreta, Mr T. Oisi and Mr J. F. Paterson, some with important notes and valuable suggestions for our future programmes.

In March 1937, a special observatory for zodiacal light was built at Seto, Hirosima-ken, Japan, and three observers are since exclusively carrying out observations and related researches at this observatory, under my supervision. This station is managed by the Oriental Astronomical Association, and naturally this is the actual centre of activity of the Zodiacal Light Section of the Association, which previously had its seat at Kwasan Observatory or Krasiki Observatory for more than ten years in the past. The international central bureau of our Zodiacal Light Sub-commission is also established temporarily at this Seto Observatory, where Mr K. Araki is acting as its secretary.

2. RECENT TREND OF RESEARCHES. Regular observations, mostly visual, of the zodiacal light have been actively carried out by amateurs as well as professional astronomers in many parts of the world in recent years. We can see their reports very often in the current numbers of the *Journal of the British Astronomical Association*, *Popular Astronomy*, *Bulletins of Kwasan Observatory* or *of the Oriental Astronomical Association*, the *Journal of the Astronomical Society of South Africa*, *Die Sterne*, *Gazette Astronomique*, *Hemel en Dampkring*, *Die Himmelswelt*, *Beiträge zur Geophysik*, *Bulletins de la Société Astronomique de France*, *La Nature*, *Das Weltall*, *Gli Astri*, *Memorie della Società Astronomica Italiana*, etc. Well compiled and systematized reports of results of observations by organized groups of observers

have been published in the *Memoirs of the British Astronomical Association*, XXIX, 4, and XXXII, 3, the *Journal of the Astronomical Society of South Africa*, IV, 2, *Kwasan Observatory Bulletins*, Nos. 142, 164, 166, 168, 179, 190, 208, 212, 252, 255, 273, 275, 299 and 325. These Japanese series are fairly uniform in form and material, so that Dr C. T. Elvey utilized them to detect annual variations of the zodiacal light (*Astroph. Journ.* **86**, p. 84).

For the purpose of getting more objective data of the phenomena, very fast photographic equipments have been tried on the zodiacal light and Gegenschein. Mr T. Sakamoto was successful, since 1932, in getting reliable images of these faint objects by utilizing a 30 mm. rock-crystal sphere as objective, while Mr M. Honda is now obtaining hundreds of good photographs of zodiacal light at Seto by means of an Ernostar F/2 camera. (Both of these series are as yet unpublished.)

The photo-electric method was applied by Dr F. Schembor to the photometric study of twilight in 1929 (*Gerland's Beiträge zur Geophysik*, XXVIII), and in the same year Lord Rayleigh made similarly a photometric study of the light of the night-sky with a calcium cell photometer (*Proc. Roy. Soc.* A, **124**). More recently, Dr C. T. Elvey used extensively the photo-electric photometer in studying the light distributions of the Gegenschein, zodiacal light and the general night-sky (*Astroph. Journ.* **77**, 56; **85**, 213; **86**, 342 and 562).

The very extensive studies by Drs J. Cabannes, J. Dufay and others on the spectrum of the night-sky and the zodiacal light are extremely suggestive for the elucidation of various phenomena of the light of the sky in day and night. (These are mostly published in the *Comptes Rendus* of the Paris Academy, the *Publications de l'Observatoire de Lyon* and the *Helv. Phys. Act.*) Dr V. M. Slipher made observations of the spectra of auroral and nitrogen lines of emission in the zodiacal light (*Pop. Astr.* **38**). On the other hand, Drs D. J. Eropkin and N. A. Kosirev made an analytical colorimetric and spectrophotometric study of zodiacal light and found that the colour index of the zodiacal light was $+0^{m}{\cdot}75$, resembling closely the Sun's light, while the auroral emission line $\lambda 5577$ underwent undeniable variations during the night. It is apparent from these and other investigations that photometric and spectroscopic problems of the zodiacal light are very intimately connected with those of twilight, aurora, and general night-sky background.

Dr J. Dufay made a photographic determination of the polarization of the zodiacal light in 1924–5 and Dr Tokio Take-uchi very recently carried out similar observations with a quartz-sphere camera. They both agree that the degree of polarization at solar elongation 60° is 0·15 (see *C.R.* **181**, and *Publ. Tokyo Kogyo-Daigaku*, XXII).

Visual observers of the zodiacal light usually see quite a variety of forms and orientations of the pyramid, even during the same night. The axis and the outlines apparently undergo changes, as also the distribution of brightness within the whole area of illumination. Some observers doubt the reality of these changes and light fluctuations, but most of the keen observers, since the time of George Jones, agree in recognizing such phenomena.

With regard to the so-called "zodiacal band" and the Gegenschein, observers differ among each other concerning the question whether these phenomena are directly connected or arise from different causes (as suggested, for instance, by Dr Hoffmeister; see below).

Some observers, following George Jones and Friedrich Schmid, report observations of the *lunar* zodiacal light. K. Araki, T. Kamei and several others have found it quite independently.

Mr Mihoru Honda reported that he saw the zodiacal light at Esasi during the 2-minute totality of the solar eclipse on June 19, 1936 (*Nature*, No. 3546). Later Dr C. H. Smiley reported a similar experience made on June 8, 1937, in Peru (*Nature*, No. 3559). Dr N. Donitch (*Transactions*, I.A.U. **5**, p. 277) has suggested that the zodiacal light is the extension of the solar corona, so that this kind of observation will, if repeated in future, be very valuable.

As to the nature of the zodiacal light it is not yet clear in how far the phenomenon is influenced by light of atmospheric origin; the importance of the latter was especially stressed by Dr Fr. Schmid (*Das Zodiakallicht*, Hamburg, 1928). Dr Hoffmeister's theory, according to his recent publication (*Veröffentlichungen der Univ.-Sternw. zu Berlin-Babelsberg*, X, 1), does not assume a single swarm of cosmical dust around the Sun, but two bodies instead: a swarm strongly concentrated toward the Sun and extending scarcely up to the Earth, and a ring-shaped swarm suspended near the mean position of the asteroids. W. Brunner (*Publ. Eidgen. Sternw. zu Zürich*, VI) takes an intermediate point of view, and while he recognizes the peculiar and important roles of both the heliocentric swarms of dust and the terrestrial atmosphere in forming the apparent zodiacal light, he emphasizes the role played by the very high ionosphere of the Earth in forming the zodiacal "band". Following the example of Newcomb (1905) and E. A. Fath (1908), Dr G. Zacharov observed the northern extent of the zodiacal light as far as 45° from the Sun's centre (*Russ. Astron. Journ.* 1927, p. 203).

Recently, Sir Joseph Larmor made an interesting suggestion about the probable origin of the matter causing the zodiacal light, applying Poynting's principle of radiation pressure (*Nature*, No. 3561). He thinks of a nebula-like disk of particles around the Sun as the remains of the original whirling solar nebula, still existing even beyond the Earth, and very loosely packed.

3. PRESENT AND FUTURE PROGRAMMES. In order to clear up the problems of apparent variations of form and brightness, a special programme of simultaneous observations of zodiacal light has been carried out since 1934 by the observers of Japan and Australia. In the beginning there were some difficulties in agreeing about the exact times of field observations, because of local conditions of twilight and civil times. Finally, however, the following schedule was set up:

March 1	to April 1	at $11^h\ 00^m$ U.T.	
June 7	,, July 4	,, $17^h\ 50^m$,,	and $12^h\ 00^m$ U.T.
September 15	,, October 15	,, $18^h\ 00^m$,,	
November 15	,, December 25	,, $11^h\ 00^m$,,	and $17^h\ 40^m$ U.T.

All results are being assembled at the Seto Observatory, where they are systematically studied and compared.

Co-operation for this kind of simultaneous observations is very much to be desired for other parts of the world.

The most important things to be considered in connection with these schemes of co-operation between visual observers are uniformity of the methods of observation and their standardization, which were practically lacking in the past. The star charts used, for instance, have been chosen quite arbitrarily, which makes it frequently almost impossible to try comparisons of observations sent from the fields. At present six kinds of zodiacal star charts are being used, prepared respectively by R. B. Bousfield, A. F. I. Forbes, W. B. Housman, F. W. Smith, G. F. Zacharov and the Kwasan Observatory, each having peculiar merits. Quite recently, the Seto Observatory published a new set of such charts. I think it will be necessary, in future, to adopt the best of these charts for universal use.

Local organizations of observers of the zodiacal light are necessary in furthering field work. At present there are about 100 observers (which is quite insufficient) in the world, who are mostly disconnected. Only England, South Africa, Australia and Japan have more or less organized bodies. But in view of the necessity of more co-operation among observers and also of coaching amateurs by fully experienced workers, the number of organizations should be increased, especially in Europe, Northern Africa, India, Siberia, North and South America. In this connection some means of international correspondence and communication of news and ideas among observers, as well as organizations, are necessary.

Photometers of suitable types are highly recommended to be used by professional and experienced observers of zodiacal light and light of the night-sky. Dufay's type would be most efficient and convenient in the field. Professional physicists, however, might use photoelectric and other types of photometers according to their ideas and opinions. These photometric observations would not only furnish reliable measures of brightness, but also standards and good references to the results of visual observations of amateurs.

Full treatment of the zodiacal light and the related phenomena must include observations of meteorology, solar activity, aurora, terrestrial magnetism, atmospheric electricity, and wireless disturbances. Close connection with special institutions engaged in these kinds of observations would therefore be desirable.

Inclusion of zodiacal light observation in the programme of solar eclipse expeditions is recommended. On the other hand, determinations of the northern and southern limits of the zodiacal light should be repeated by observers living at high latitudes in both hemispheres during the season of summer or winter solstice. At low latitudes, however, regular and possibly continuous observations are urged, in which the greatest possible uniformity in methods and equipments should be aimed at.

To avoid the probable subjective influences of the visual observer the introduction of the photographic method is very welcome. In these days it is fairly easy to get a fast lens of moderate size and to build a simple camera to be used together with plates or films of the highest sensitiveness. Past experiments of some of our colleagues justify these programmes.

Spectroscopic observations require special experience and training, so that these kinds of researches will have to be repeated by professional astronomers. Past results have, however, disagreed in some points, which ought to be cleared up in future through continuous and co-operating programmes of observers. Work on polarization of sky illuminations will be and should be extended, possibly also to the zodiacal "band" and the Gegenschein, whereby the nature of these phenomena might be elucidated.

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