15. COMMISSION POUR L'ETUDE PHYSIQUE DES COMETES

PRÉSIDENT: Professor Dr K. Wurm, Hamburger Sternwarte, Hamburg-Bergedorf, Germany.

MEMBRES: Baldet, Bertaud, Beyer, Biermann, Bobrovnikoff, Bouska, Dobrovolsky, Douglas, Dufay, Mme Herman, Herzberg, Hunaerts, Levin, Liller, Lyttleton, McKellar†, F. D. Miller, Poloskov, Richter, Rijves, Steavenson, Swings, van Biesbroeck, Vanýsek, Vsekhsvyatsky, Waterfield, Whipple.

INTRODUCTION

The period of the last three years since the Moscow meeting was not distinguished by any bright object comparable with Comet Arend-Roland 1956*h* or Comet Mrkos 1957*d* of the period before. Comet Burnham 1959*k* which seemed at first very promising remained finally more or less disappointing. Profiting still somewhat from the two bright objects just mentioned, during the period of this report the activity in the field of the physical study of comets kept on a high level. Remarkable for the last years is, in particular, the increasing application of modern and refined techniques of observation.

There are signs that in the near future a particular problem, namely 'the formation of the tails' will come again strongly into discussion. It is felt by many to be an extremely unsatisfactory situation that the most spectacular phenomenon of comets is yet so fragmentarily understood. Since this problem is intimately connected with the problem of the physical state of the interplanetary space, the same is evidently also of a high actuality.

The following report cannot claim to be complete about its subject. Intentionally omitted are many published remarks about the general aspect, the dimensions, activity and brightness of comets. In this respect it appears very satisfactory to have the possibility to refer to the very informatory reports which are regularly published by Miss E. Roemer in the *Publications of the Astronomical Society of the Pacific.*

PHOTOMETRY

M. Beyer (Bergedorf) continued his visual observations of the brightness and structure of comets. His new series of observations, which comprises 10 different objects, is at present in preparation for publication. G. van Biesbroeck has continued keeping track of all observable comets paying special attention to their magnitudes and general appearance. He has published his results from time to time in the *Astronomical Journal.* J. Bouska (**1**) published visual and photographic magnitudes of Comet Arend-Roland, 1955*e* Mrkos, 1959*b* and 1959*k*. Secular variations of the absolute brightness of several periodic comets have been studied by Z. Sekanina (**2**). A. M. Bakharev determined visual brightnesses of the comets 1959*b* and 1959*k* (**3**). Isophotic contours of the comets 1959*b* and 1959*k* in blue and in red light have been determined by O. V. Dobrovolsky, R. P. Buschko and P. Jögibeckow (**4**). F. Baldet and Ch. Bertaud measured total photographic magnitudes for a number of comets of the last years, which so far are only partly published (**5**). Z. Ceplecha (**6**) has published isophotes of Comet Arend-Roland from photographs taken in blue and in orange-red light. The mean colour index (blue minus orange-red) is found to have a maximum of +0·9 on April 29 and it decreases to −0·05 by May 2. There appeared variations of colours over the tail as large as 0·45. Isophotes of the same comet (from blue-sensitive and panchromatic plates) have also been published by B. Ruzickova and M. Plavec (**7**) and also by G. A. Manova, O. D. Dokuchayeva and B. A. Vorontsov-Velyaminov (**8**). V. Vanýsek and B. Ruzickova (**9**) and V. Vanýsek and

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J. Tremko (10) made photo-electric determinations of the brightness of Comet Arend-Roland between April 22 and May 6.

W. Liller (11) has carried through and now published photo-electric spectro-photometric observations of the tails of the two comets Arend-Roland 1956*h* and Mrkos 1957*d*. His instrument, which was used at the Newtonian focus of the 24–36 inch Curtis Schmidt telescope (University of Michigan), has been described in detail in (12). At the times of observation (1956*h*: April 26·1 and 30·2; 1957*d*: August 23·2) most of the light between λ 3400 and λ 6400. was found to be of a continuous nature in both objects and of a colour redder than sunlight. According to the author a comparison of the observed energy distribution with theoretical curves of light scattering by small particles strongly suggests that spherules of iron with average diameters of 0·6 microns produced this radiation. The same author obtained upon several nights scans of the spectrum of comet Burnham 1959*k* in the region of the head using his equipment at the focus of the 24-inch Cassegrain reflector at the University of Michigan. He was able to construct truly monochromatic isophotes in the CN- and C_2- bands (not yet published). As expected, the CN bands came from a larger area than those of C_2.

With the Leiden Observatory equipment, described earlier by M. Schmidt and H. van Woerden (13) the latter author and E. Raimond have made since 1958 photo-electric monochromatic observations of 5 comets (1958*a*, 1959*f*, 1959*e*, 1959*b*, 1959*k*) which are being prepared for publication.

V. Vanýsek (14) determined for several objects photo-electric colour differences between the Sun and comets. He finds that the scattering particles give a positive colour excess which could be explained by the action of dielectric dust particles with diameters 3×10^{-5} cm. M. F. Walker (15) measured photo-electric colours and magnitudes for comet Schwassmann-Wachmann I on 1958 December 4, and also on several nights for Comet Baade 1954 *h* and Comet Macfarlane-Krienke 1955*f* (16).

W. M. Sinton (17) has published a series of photo-electric magnitudes and colours of Comet Burnham 1958*a*. Focal-plane diaphragms with apertures between 23·8 and 350 seconds were employed. The brightness variation within the coma was studied.

NUCLEUS

F. L. Whipple gives a short abstract concerning the results of the research of cometary nuclei (18). According to the author our present knowledge indicates that a comet must have a nucleus with some internal rigidity, provided with a greater source of gaseous material than is possible by absorption or other gaseous attachment processes. The 'sand bank' model is shown to be inadequate and the Lyttleton version of this model quite untenable. The gas-to-dust ratio in comets appears too great for a 'sand-bank' comet. Physical and gravitational processes for Sun-grazing comets will destroy the Lyttleton model in one passage; an 'icy' comet nucleus of reasonable icy strength with a maximum radius of tens of kilometres can withstand solar tidal action. The icy model meets some difficulties when confronted with outbursts like those of Comet Schwassmann-Wachmann I.

Miss E. Roemer estimated magnitudes of the nucleus of Comet Giacobini-Zinner (private communication to P. Swings) which have been used by P. Mianes, S. Grudzinska and A. Stawikowski (19) to determine with certain assumptions the linear diameter of the nucleus which is found to be of the order of 1 km. L. Houziaux (20) derives, using an albedo $A = 0{\cdot}1$, for the nuclei of Comet Bester 1948 I, Bappu 1949IV and Mrkos 1957*d*, from published visual brightness radii of 4·8, 4·2 and 26 km. Rather interesting is a photograph of Comet Baade 1954*h* taken with the Crossley reflector of the Lick Observatory by Miss Roemer and described by M. F. Walker (16). The picture shows a broad conic jet directed against the Sun

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and originating in the nucleus. Spectrograms have shown that the comet had a pure continuous spectrum without a trace of band emission (**16**). The comet stood about 4 A.U. from the Sun on the dates of observation.

SPECTROSCOPY, POLARISATION

J. Hunaerts (**21**) carried through a thorough investigation of the structure of the violet CN band λ 3883 on high resolution plates taken by J. L. Greenstein (**22**) with the Coudé spectrograph of the Palomar 200-inch, which were mentioned already in the report for the Moscow meeting. He finds that the essential features of the rotational structure of the band can be explained by the fluorescence mechanism taking account of the so called Swings effect (influence of the absorption line in the solar continuum on the strength of excitation). There remains but to explain a secondary effect (the so called Greenstein effect) which consists of a change of the relative intensity of some lines when turning from the sunward to the tailward side of the coma. The author deals in another paper with the structure of the same band in a spectrum of Comet Whipple-Fedthke 1943 I (**23**). After the method, which he has outlined in earlier papers (**24**) for the hydrids OH, NH and CH, he proceeds to calculate the life-times of the rotational states in the ground electronic level. In the case of Comet Mrkos 1957*d*, mentioned above, the same procedure was not practicable because the stronger excitation (heliocentric distance $r = 0{\cdot}6$ against $r = 1{\cdot}4$) introduced already extreme difficulties. For the lowest rotational states, $K'' = 1$ and $K'' = 2$, life-times of $10^h\ 22^m$ and $8^h\ 36^m$ are found, which are much larger than for the hydrids (500 to 1300 seconds).

A study of the rotational structure as achieved for the hydrids and the CN molecule was until recently not possible for the C_2 bands because of an insufficient resolution of the bands. The situation changed with the high resolution spectrograms of Comet Mrkos 1957*d* obtained by J. L. Greenstein. These spectrograms reveal also the essential features of the rotalional lines of the Swan bands. A. Stavikowski and P. Swings (**25**) have used these plates to study this structure under the viewpoint of the fluorescence-excitation. It is found that intensity anomalies within the (1,0) and (2,0) vibrational transitions are due to the presence of absorption lines in the exciting solar continuum. It is thus proved that the C_2 Swan bands like the other investigated band systems (CN, OH, NH, CH) are also excited by fluorescence. The present investigation had gained particular interest since it was recently found by E. N. Ballik and D. A. Ramsay (**60**), that the lower $^3\Pi_u$ electronic state of the Swan bands does not represent the normal ground state of the C_2 molecule, the latter being an $^1\Sigma_g^+$ state about 610 cm^{-1} below the $^3\Pi_u$ state. P. Swings (**26**) gave some predictions and theoretical considerations about the UV spectra of comets.

M. Walker (**16**) publishes a spectrum of the distant Comet Baade 1954*h* which proves to be completely continuous (solar spectrum). The photo-electric determined colour gives that of a main-sequence star between G8 and KO. The same author took also in 1958 December a spectrogram of Comet Schwassmann-Wachmann I. The pure continuous spectrum of solar reflexion type had the colour of a G8V star (**15**).

M. Blaha, A. Hruska, Z. Svestka and V. Vanýsek (**27**) measured the polarisation in photographic light in Comet Arend-Roland and Comet Mrkos 1957*d* at different distances from the nucleus into the tail. For the first object they found an increase in the percentage polarisation with increasing distance from the nucleus reaching 20% to 25% at 8 minutes from the head centre. The observation is explained by a higher gas component within the tail. The phase angles during the times of observation changed only slightly between 93° and 81°. In the case of Comet Mrkos 1957*d* the authors found a lower polarisation of 10% to 15%. The same was nearly independent of the distance from the nucleus. They describe to this comet a smaller dust part which is in agreement with the spectroscopic observations. A. A. Hoag (**28**) publishes a longer series (Aug. 27 to Sept. 17) of photo-electric polarisation measurements in total light for Comet Mrkos 1957*d*. He measured at different places in head and tail. Polarisations between 20% and 7% are found depending on the phase angle which changed from 56·5° to 35·0°. M. K. Vainu Bappu and S. D. Sinvhal (**29**) have also made measurements of polarisation of Comet Mrkos 1957*d*. They used interference filters in order to separate the continuous emission from the bands. The latter authors published also a paper about the polarisation of cometary nuclei (**30**). M. T. Martel (**70**) has published measurements of polarisation for Comet 1957*d* (Mkros) and Comet 1959*b* (Giacobini-Zinner).

L. Houziaux and L. Battiau (**31**) have published values of the mean intensity functions of the Mie scattering theory for three simple size distribution functions and for the following parameters: index of refraction $n = 1{\cdot}33$; $x = \frac{2\pi a}{\lambda} = 0{\cdot}4$ to $5{\cdot}2$; phase angle $\theta = 0°$ to 180°. The degree of polarisation is also reported.

DENSITIES, MASSES

It has been realized by a number of authors that in regard to the physical theory of cometary atmospheres a better knowledge of the gas densities was urgently needed. B. A. Vorontsov-Veliaminov (**32**) has used objective prism spectrograms of Comet 1943 I (1942*g*) Whipple-Fedtke (obtained by Tevzadse on 11 March 1943) to determine total amounts of the molecules CN, C_2 and C_3 within the head of this comet and their partial densities. The calibration of the emission knots is done by use of stellar spectra on the same plate. Isophotic contours are also constructed for the different emission knots. From the absolute monochromatic emission of the band groups the author finds the following total number n_t of the three compounds: $n_t(CN) = 1{\cdot}3 \times 10^{33}$; $n_t(C_2) = 7{\cdot}1 \times 10^{31}$; $n_t(C_3) = 2{\cdot}7 \times 10^{31}$. From the isophotes follows that the gas densities varied approximately inversely as the square of the distance from the nucleus. Near the nucleus they were of the order of 10^{11} molecules /cm³ and at the measured border of the head ($3{\cdot}7 \times 10^5$ km from the nucleus) of the order of 1 for CN and C_2 and the order 0·05 for C_3. It seems to the present writer that the central densities of 10^{11}/cm³ may more or less be spurious since the density law R^{-2} (R = distance from nucleus) can hardly be used right to the centre. A radius of the coma of $3{\cdot}7 \times 10^5$ km seems also somewhat too large. P. Ahnert (**33**) gives for the same date from direct photographs only about half that value. K. Wurm (**34**) carried through a re-discussion of his earlier estimates (**35**) of the C_2- and CO^+ partial densities in Halley's comet (1910) near perihelion. The earlier procedures of the density determination needed some corrections. The new figures obtained are a density $N(C_2) = 10^{5{\cdot}5}$ molecules/cm³ in the neighbourhood of the nucleus and $N(C_2) = 10^{1{\cdot}5}$ at $R = 10^5$ km. The partial density $N(CO)^+$ derived rests on photometric results of K. Schwarzschild and E. Kron (**36**) and refers to that part of the tail, where it emerges from the head. The earlier value of $N(CO^+) = 1$ has to be raised by more than two orders of magnitude to $N(CO^+) = 3 \times 10^2$. A new attack of the density problem has also been made by several authors at the Institut d'Astrophysique, Université de Liège. Next, P. Mianes, S. Grudzinska and A. Stawikowski (**19**) determined CN and C_2 densities of the periodic comets Encke 1957c and Giacobini-Zinner 1959b. The observational material consisted of photoelectric magnitudes of two limited spectral regions centered on the CN band λ 3883 and the C_2 group λ 5635 and was secured by P. Mianes at the Observatoire de Haute Provence. The magnitudes were measured with five different diaphragms of increasing sizes. Comet Encke shows a pure gas spectrum whereas in Comet Giacobini-Zinner the continuous emission is very strong. The necessary corrections for this continuum, when determining the CN and C_2 magnitudes, remain somewhat questionable. The authors give the following results. Comet Encke has at $R = 4 \times 10^4$ km from the centre of the head a density $N(CN) = 3$

which decreases to $N(CN) = 0{\cdot}5$ at $R = 9 \times 10^4$ km. The values for $N(C_2)$ are approximately the same. In the case of Comet Giacobini-Zinner it is found $N(CN) = 47$ and $N(C_2) = 2{\cdot}5$ for $R = 1 \times 10^4$ and $N(CN) = 1$ and $N(C_2) = 0{\cdot}05$ for $R = 5{\cdot}5 \times 10^4$ km. Since the applied corrections of the measured magnitudes for the strong continuous emission must be regarded as rather uncertain, it remains questionable, whether the large difference between the CN- and C_2- densities has a real meaning. In general it is found, that the abundances of CN and C_2 are of the same order of magnitude.

Spectrograms of Comet Bester 1947*k* made by P. Swings and T. Page at the McDonald Observatory, Texas, show simultaneously the tail bands of CO^+ with the CN bands (**37**). S. Grudzinska (**38**) has used these spectrograms to make a comparison of the abundances of CN and CO^+. On the plates the bands of the two compounds can be followed to a distance of 130 000 km from the nucleus. For a photometric comparison the CN band λ 4216 and the CO^+ band λ 4248/4272 were selected. From the relative intensity of these bands and by taking into account the structures of the two band systems in question it is found that the CO^+ abundance supersedes that of CN by a factor 30 to 40.

M. Schmidt and H. van Woerden (**13**) isolated with an interference filter the (1,0) band of C_2 in Comet Mrkos 1955e and measured photo-electric magnitudes in this band with different diaphragms. L. Houziaux (**39**) has used these measurements to determine the density and density distribution in C_2 within the inner part of the head of this comet. According to the author the density varies from $N(C_2) = 2{\cdot}8 \times 10^3$ to $N(C_2) = 7 \times 10^1$ from regions close to the nucleus to regions located at one minute of angular distance ($5{\cdot}5 \times 10^4$ km) from the nucleus.

All density determinations mentioned involve the f-values of the band systems as the most important physical constant. By all authors the following numerical values have approximmately been used: $f(CN) = 0{\cdot}02$; $f(C_2) = 0{\cdot}02$, $f(CO^+) = 0{\cdot}002$ (references concerning the derivation of these values are to be found for instance in (**19**)). Since there exists some uncertainty with regard to the accuracy of these data, it may not be without interest to note that certain observations concerning the heads of comets allow the conclusion that the real f-values for CN and C_2 are certainly *not larger* than given above (**34**). This conclusion can be drawn from the fact, that expanding CN, C_2- haloes as those as described by N. T. Bobrovnikoff for Halley's Comet (**40**) remain essentially circular-symmetrical with respect to the nucleus. The latter is a consequence of the very low repulsive force exerted by light pressure. In this respect it is of interest to repeat here an observation of J. L. Greenstein (**22**) concerning the symmetries and asymmetries in his Palomar spectra of Comet Mrkos 1957*d*. He remarks that the C_2- and NH_2- lines are symmetric in extension and intensity (in respect to the nucleus) in the direction to the Sun and the direction to the tail, whereas the *D*-lines of sodium are asymmetric in the sènse of a higher intensity on the tailward side. Since the f-value of the sodium resonance lines is nearly 100 times larger than that of the carbon bands, the sodium atoms suffer a high repulsive force by light pressure ($1 - \mu \approx 50$).

Summarising, it can be said that we have now—as far as the orders of magnitudes are concerned—a fairly reliable knowledge of the partial densities of the gases (CN, C_2, CO^+) within cometary atmospheres. For comets which reach with heliocentric distances between $r = 0{\cdot}5$ and $r = 1{\cdot}0$ a reduced visual magnitude H around 4 (as for instance Halley's Comet 1910 and Comet Brooks 1911*V*) and in which the gas component prevails, we may assume CN- and C_2-densities close to the nucleus of the orders 10^4 to 10^6 and near the borders of the head ($R = 10^5$ km) of the orders 10^0 to 10^1.

When the tail activity is high, in the densest parts of the tail along the axis and near the head we encounter certainly CO^+ densities as high as 10^3 to 10^4. As can be shown (**34**), within the long and sharp tail rays, the same orders of magnitudes must be reached, otherwise with lower densities the same would hardly be detectable.

V. Vanýsek (**41**) has tried to determine the dust content of comet heads with a predominantly continuous emission. He describes to all particles the same effective albedo 0·1, assumes a certain size distribution and derives the total number of particles from the absolute brightnesses. Assuming further a material density equal to 1, he arrives at a dust mass of 10^{11} to 10^{12} g for *the brighter objects like Comet Arend-Roland. For the average mass density within the heads* he finds $\rho = 10^{-18}$ g/cm^3.

W. Liller (**11**) deals with the same problem for the tails of the two comets Arend-Roland and Mrkos 1957d. He starts with his photo-electric spectrophotometric observations within the tails of these comets which have shown, that at the time of observation most of the light was continuous and redder than sunlight. He compares the observed energy distribution with theoretical curves of light scattering by small particles, and finds indications, that spherules of iron with average diameters of 0·6 microns and masses of 8×10^{-13} g produced this radiation.

For the mass density at the places of observation in the tails there is found 1×10^{-20} g/cm^3 for Comet Arend-Roland and $2{\cdot}5 \times 10^{-20}$ for Comet Mrkos 1957*d*. An estimate of the total masses within the visible tails gives 9×10^{13} g and 2×10^{14} g respectively. The rate of mass loss by the comets is estimated by taking the acceleration of the particles by light pressure equal to 1 cm/sec^2. The same amounts then to 8×10^7 g/sec and 1×10^9 g/sec respectively.

TAILS, REPULSIVE FORCES, MONOCHROMATIC SHAPES

In his article on comets in Hynek's *Astrophysics* (**42**), which is often quoted, N. T. Bobrovnikoff distinguishes (in line with a classification suggested by S. V. Orlov) two kinds of type I tails. The sub-type I_0 is described as 'rays symmetrical with comet axis; angular distance of rays from axis decreases rapidly with time; new rays develop close to nucleus.' Concerning this type it is further noted that the characteristic repulsive forces $(1 - \mu)$, acting on the material in the rays (CO^+ ions), amount to several thousand. The second kind of the first type—simply designated with type I—is represented by 'straight tails slightly deviated from the radius vector in direction opposite to the motion of the nucleus. Often full of condensation and streams.' The repulsive forces described to this type are said to fall in the range from 20 to several hundred. It needs not to be emphasized that there does not exist in nature a sharp separation of the two sub-types. If there is a strong supply of tail ions from the head, we observe generally a mixture of I_0 and I as with Comet Morehouse 1908. A nearly pure I_0 type is for instance found on some well known photographs of Comet Daniel 1907 taken by Max Wolf, Heidelberg. Concerning the magnitude of the repulsive forces, it must be regarded an open question whether there exists really a difference between the two sub-types. In literature there are reported extreme high values of $(1 - \mu)$ also for individual clouds and condensations and not only for rays and streamers. Furthermore it is necessary to raise again and again the question whether the repulsive forces $(1 - \mu)$ of the order of 10^3 to 10^4 do really exist. Regarding publications of recent origin, there have been reported very high accelerations of tail formations by G. K. Narzarchuk (**43**) for Comet Arend-Roland 1958*h*. This author has derived $(1 - \mu)$ values all between 800 and 2500 for eight isolated clouds. It seems to the present writer, that we have here some reason to be sceptical about the results. As is well known during the time of best visibility of the comet (end of April—first days of May 1957), when the above mentioned material was taken, the Earth stood very close to the orbit plane and the tail axis was also seen from the Earth with a strong foreshortening. A much more favourable situation concerning the relative position of the Earth and the comet, we met with Comet Mrkos 1957*d*. From excellent photographs of this object, obtained with the 48-inch Mt. Palomar Schmidt, Rhea Lüst of the Max Planck Institut, München (**44**) has derived from clear cut formations in the tail $(1-\mu)$ values of the order 50. W. Liller (**11**) mentions for the same comet a determination $(1-\mu) \approx 33$ for a sharp discontinuity within the tail.

Regarding the conception, that tail rays are generally connected with high repulsive forces of the order 10^3 to 10^4 the present writer has shown that the same is certainly not tenable (**45**). The argument is simply that such values contradict the sharp definition of the rays which should become diffused in consequence of the high particle velocities. The existence of well defined structures and formations within long tails speaks generally against extreme high repulsive forces. If they should occasionally appear statistically they can not be of importance.

As indicated already above, it is well known that tail rays are always turning rather quickly (time scale about 10 to 20 hours) to the tail axis. P. Stumpff (**46**) has tried to explain this phenomenon by postulating a regular increase of the acting repulsive forces with increasing distance from the tail axis. Along the tail axis they are assumed to be of the order of 10^1 to 10^2 and to increase sidewards finally up to 10^4. K. Wurm (**45**) has criticized this conception, once with the argument just mentioned, that sharply defined rays are at variance with very high repulsive forces. Secondly, the kind of development of all rays leads unavoidably to the conclusion that, in regard to the process in question a continuous decrease of the velocity component of the CO^+ ions *normal to the tail* axis must play a decisive role. Within each single ray the velocity component of the molecules normal to the axis is the lower the later they left the region of the head. When first publishing this idea (**35**), the velocity normal to the axis was identified with the ejection velocity in that direction. It may but be that this conception means a not well founded restriction. One should perhaps consider the possibility of a slight but steady acceleration of the CO^+ ions in the direction to the axis acting over the whole tail.

It need not be particularly mentioned that we do not yet possess a physical theory of the tail rays nor yet the principles of it. Concerning solely the repulsive forces in the direction of the prolonged radius vector, there has been a general inclination to accept the high-density corpuscle theory as advocated by L. Biermann (**47**). It seems to the present writer (**45**), that some reservation is here not out of place. According to this theory we need, at heliocentric distances $r = 1$A.U. to explain repulsive forces $(1 - \mu)$ of the order 10^2, a corpuscle density as high as 10^3 protons /cm^3, but possibly even much higher ones, since the densities of the tail ions have to be raised by more than two powers of ten above the value originally assumed in the theory. High-density solar streams of this extreme kind are on the other hand difficult to bring in agreement with the relatively long life-times of the CN and C_2 molecules in the head of comets (see (**45**)). Furthermore, streams with such extreme densities would be expected to make their appearance only more or less sporadically which is in contradiction with the steady character of the basic phenomena in comets.

In order to be able to set limits to the really existing corpuscle stream densities, it will be very important to find the real extensions of the monochromatic CN and C_2 heads. Some work in this direction has been done for some time at the Observatory of the University of Michigan (**48**), but it seems not yet possible to draw a definite conclusion from them concerning the real life times of the molecules before dissociation or ionization. B. A. Vorontsov-Velyaminov mentions (**32**) a diameter of the CN^- head of Comet Whipple—Fedtke 1942*g* of $3{\cdot}7 \times 10^5$ km. If such dimensions are substantiated the life times of the CN molecules must be larger than assumed until now.

V. I. Tcherednitchenko (**49**) continued his study of dissociation—and ionization—processes in cometary atmospheres. D. O. Mochnatsh (**50**) has derived formulae for calculating the

F*

surface brightness in the heads of comets at different times after the beginning of an isotropic emission from the nucleus. L. S. Marochnik has tried to estimate an upper limit of the magnetic field strength within the rays of Comet Brooks 1911 (**51**). L. Biermann and E. Trefftz (**52**) investigated theoretically the transfer of momentum in charge exchange collisions of the kind $H^+ + CO \rightarrow H + CO^+$. It is found that by this process only little momentum is transferred from the proton to the CO^+ ion.

G. Larsson-Leander (**53**) published his observations of Comet Arend-Roland and discussed in particular the properties of the anomalous tail. Concerning this anomalous tail or 'spike', a paper of E. J. Öpik (**54**) deserves particular attention. The author shows convincingly that the freedom of geometrical interpretation of the spike is very limited and the absolute dimensions of the same can be given rather exactly. The author points out that the small thickness of the spike normal to the orbit plane demands, beside a very small outburst velocity, also a pure radial action of the radiation pressure, which is very remarkable.

Well marked rectilinear streaks appeared, as is well known, in the tail of type II of Comet Mrkos 1957*d* around 12 August 1957. A. McClure and W. Liller (**55**) have made a preliminary analysis of this appearance in considering these streaks as 'terminal synchrones' in the sense of Bredikhin. S. K. Vsekhsvyatsky (**56**) has but put forward arguments that the formations in question cannot be considered as synchrones chiefly because of their short life times and of their rapid variability.

D. E. Osterbrock (**57**) has studied the positions of the tails of two comets at large heliocentric distances (4 to 5 A.U.). As was found already earlier by M. Beyer with comets between 2 and 4 A.U. the position angles of the tails indicate a real position in space midway between the radius vector and the orbit behind the comet. The author is inclined to consider these tails as made up of neutral gases like H_2, CN, C_2 or poly-atomic compounds. But this conception is hardly tenable since it can be said that neutral particles are not able to form tails, the life times until ionization or dissociation being much to small.

B. L. Meek (**58**) has published an investigation of the form of cometary tails in relation to the magnitude of the repulsive forces.

COMETARY AND SOLAR ACTIVITY

It would of course be most interesting if a cometary brightness could be an indicator of solar activity. O. V. Dobrovolsky has written a monograph 'Solar activity and unsteady processes in comets' in which the present status of the problem is reviewed. The article is not yet available, and at present is being printed. Despite many earlier papers in which a proof of a positive correlation between solar activity (spot numbers, flares) and brightness fluctuations has been claimed, the subject has remained controversial. This follows also from a recent paper published from the Institut d'Astrophysique de l'Université de Liège (**59**) in which three comets (Arend-Roland 1956*h*, Mrkos 1957*d*, Encke 1957*c*) are analysed in regard to brightness fluctuations. It is stated, that much more accurate photometric data than generally now achieved are necessary in order to bring the question to a decision.

SUGGESTIONS FOR CONSIDERATIONS

The suggestions and recommendations received from the members of Commission 15 by letter or verbally, reveal themselves mostly identical with those already reported by P. Swings at the last meetings of the IAU. They are expressed in short under the following items (numbering is different from the earlier ones).

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1. Monochromatic photometry (photographic or photo-electric) in the emission bands, the D-lines of Na and the continuous emission.

2. Spectra with higher resolution; tail spectra with slit in all regions.

3. Spectrograms of far distant comets.

4. Magnitudes of nuclei, colours of nuclei, dimensions.

5. Monochromatic photographs; real extension of mono-chromatic CO^+ emission in tail and head; series of such photographs in one night to study the formation and development of tail rays. Monochromatic isophotes of head and tail.

6. Continuation of existing series of visual and photographic observations (M. Beyer, G. van Biesbroeck, Miss E. Roemer).

7. Additional laboratory investigations of observed and expected molecules in cometary atmospheres.

8. Polarisation measurements (monochromatic).

It has been suggested (P. Swings, M. Beyer) to discuss at the Berkeley meeting the status of these pending problems and to ask for new specifications (as far as necessary and appropriate). Several other authors have made the proposition (M. G. J. Minnaert, V. Vanýsek, P. Stumpff) to discuss at the meeting in particular and extensively the theme: the formation of comet tails. The present writer is rather inclined to prepare such a discussion. He intends to ask several colleagues to prepare short papers for this purpose. The following separate themes are provisionally considered:

1. Introductory report (short survey of the problem).

2. Types of cometary tails.

3. Observed repulsive forces.

4. Extensions (diameters) of the CN and C_2 heads in comets.

5. Formation and development of tail rays.

6. Ionization and dissociation of molecules by atom and ion impact.

7. The corpuscle-stream theory of cometary tails.

GENERAL DISCUSSION

S. K. Vsekhsvyatsky emphasizes in a letter the importance of the observation of less bright comets which may reveal properties different from those of the bright ones. He recommends to make efforts to use also the largest telescopes for comet observations.

As a good subject for further discussion W. Liller mentions in connection with his paper on the dust content of Comet Arend-Roland and Comet Mrkos 1957*d* the problem of the masses of these bright objects.

It will be necessary to discuss again at the Berkeley meeting the introduction of an 'International Bulletin', for the rapid publication for physical observations of comets as proposed by R. L. Waterfield and S. K. Vsekhsvyatsky. Nothing has happened so far in this respect. There has also been made several times the suggestion (V. Rijves) to make good photographs of comets of the past more generally available by a distribution of paper copies. Also this point has to be considered anew at the meeting. In this connexion it may be mentioned that a comparative study of photographs of a comet taken on the same night in Europe and America will probably prove very fruitful and enrich our knowledge about the development of tails.

LABORATORY WORK

Laboratory work of interest for cometary physics remained essentially confined to the work done at the National Research Council of Canada. G. Herzberg writes as follows:

Extensive laboratory work has been carried out at the National Research Council of Canada in the field of spectra of diatomic and polyatomic molecules during the last three years. Of this work, the following items may be of interest in connection with the spectra of comets.

(*a*) It has been established that the ground state of the C_2 molecule is not the lower $^3\Pi_u$ state of the Swan bands but is the lower $^1\Sigma_g^+$ state of the Mulliken and Phillips systems. (**60**). The $^3\Pi_u$ state is only 600 /cm above the $^1\Sigma_g^+$ state. The prominence of the Swan bands in cometary spectra indicates that there must be a considerable concentration of metastable C_2 molecules.

(*b*) The resonance transition of the NH molecule which occurs strongly at 3340 Å in cometary spectra has been investigated in the laboratory (**61**), under very high resolution in absorption and the rotational analysis of this spectrum has been somewhat revised, particularly for low rotation which is important for the cometary emissions.

(*c*) The A–X and C–X bands of N_2^+ have been re-investigated. In the case of the former (**62**) the vibrational numbering has been confirmed by isotope investigations. In the case of the latter (**63**) accurate rotational data have been derived and evidence for pre-dissociation has been obtained.

(*d*) The spectrum of CH^+ has been re-investigated and extended up to the fourth vibrational level of the upper state (**64**). Unfortunately the improved knowledge of the vibrational levels of the upper state makes the previously accepted value for the dissociation energy of CH^+ (and therefore for the ionization potential of CH) less certain.

(*e*) Extensive wave-length data on the spectrum of NH_2 in the red part of the spectrum have been published (**65**) together with a detailed analysis of this spectrum. It is now possible to say which lines would be expected under low-temperature conditions and a detailed comparison with high-resolution cometary spectra could now be carried out.

(*f*) A spectrum of CH_2 has been found in the vacuum ultra-violet at 1400 Å, which corresponds to a transition of the linear form of this molecule (**66**). In addition, more recently, a complicated many-line spectrum has been found in the red region of the spectrum which has been shown to be due to a non-linear form of CH_2 whose lowest state is a single state lying slightly above the lowest state of linear CH_2. It seems probable that, just as in the case of C_2, emission bands with the slightly excited meta-stable state as lower state will occur in the spectra of comets. However, up till now, a search that has been carried out together with Professor Swings has been unsuccessful.

(*g*) Detailed investigations on the spectra of the free radicals HNO (**67**) and NCO (**68**) have been completed. Although these spectra are in the easily accessible region, no identifications with cometary features have as yet been made.

In connection with the discussions of the corpuscle theory of cometary tails a summary report of N. V. Federenko (**69**) with the title 'Ionization in collision between ions and atoms' is of particular interest.

K. WURM
President of the Commission

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