21. LIGHT OF THE NIGHT-SKY (LUMINESCENCE DU CIEL)

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INTRODUCTION

Studies of airglow, zodiacal light, and galactic light in this triennium were almost as active as in the last. Results of observations obtained during and after the IQSY were the major contributions in this term. Night Airglow studies during the IQSY were widely reviewed in the *Annals of the IQSY*, vol. 4, in which the following articles are included:

"Night Airglow Observations during the IQSY" (F. E. Roach, L. L. Smith and J. R. McKennan);
"Airglow Research during and since the IQSY" (G. Weill);
"Hydrogen and Hydroxyl Emissions in the Nightglow" (N. N. Shefov and Yu. L. Truttse).

Proceedings of the NATO Advanced Study Institute, July 29–August 9, 1968, entitled *Atmospheric Emissions*, contains some ten significant papers on airglow both in observations and interpretations. Many of them are referred to in the following sections.

Many stations have been engaged in airglow observations since the beginning of the IASY in 1969, although the number of stations seems to be a little less than during the IGY. Stations near the equator and in the southern hemisphere, however, are more numerous and active than during the IGY in response to the strong wishes of many airglow researchers. These efforts are being made especially by G. Weill's group of France, V. J. Dachs' and Lange-Hesse's groups of Germany.

It is noteworthy that interferometer measurements have been widely introduced in airglow studies and many valuable works are being performed recently. Airglow measurements from space have been fruitful and appear to be promising in many respects. Spectral domains not observable from the ground have provided valuable information about the very high atmosphere. It is also noteworthy that very faint emissions previously undetectable by filter photometry have come to be regularly observable.

The proceedings of the Symposium on the Zodiacal Light and the Interplanetary Medium was published during this past triennium (NASA SP-150, edited by J. L. Weinberg).

Studies of zodiacal light and the interplanetary medium since the colloquium in Honolulu in 1967 were also very active, including observations from spacecraft. Interesting results about the effects of solar activity on the zodiacal light have been presented. Work on interstellar particles has cast light on the importance of the study of galactic radiation in connection with airglow and zodiacal light studies.

Suggestions for future studies and research items were proposed by some researchers. Among them, the importance of studying the brightness and spectral distribution of the integrated starlight and the method of correcting observations for extinction and scattering are emphasized. Observations of the interplanetary medium and zodiacal light from space probes in the future will be promising directions in this field.

Most of the references to Soviet studies were taken from the report prepared by Dr E. V. Fesenkova, and references to studies on the zodiacal light were mainly contributed by Dr J. L. Weinberg.

I. AIRGLOW, GENERAL

An excellent and extensive atlas of the airglow spectrum was published by A. L. Broadfoot and K. R. Kendall of Kitt Peak National Observatory (*J. geophys. Res.*, 73). The atlas covers the wavelength region 3100–10000 Å and has two major advantages over earlier atlases: (1) the intensity

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scale is strictly linear; and (2) the whole region accessible from the ground by photoelectric techniques is shown to a uniform, absolute scale. This atlas is undoubtedly a great help for airglow researchers, in addition to the photographic atlas by Krassovsky *et al.* published in 1962.

The differential brightness of the airglow spectrum between 1·02–1·13 μ was measured at a spectral resolution of 27 Å by A. W. Harrison (*Planet. Space Sci.*, **17**).

The night airglow data during IQSY were published by World Data Center A (Report UAG-1). This book contains (*a*) hourly zenith intensities of emissions, 5577 Å, Na I, 6300 Å, OH, 3914 Å, and (*b*) hourly values of the ratio of intensity (north/south) near or at zenith distance 75°.

The international calibration of airglow photometers has been an important problem in assessing the general level of maximum reliability of individual airglow measurements and in assessing how far systematic variations from place to place on the globe are significant. In 1968, before the start of the IASY, M. Gadsden proposed a convenient way to circulate a radioactive phosphor source among the main regional stations for the intercalibration of their photometers. The calibrations were carried out in 1969 at several stations in Europe, India, Japan, as well as in U.S.A. The result will be shortly published by Gadsden.

Based on spectral and electrophotometric observations, L. M. Fishkova (*Geomag. Astr.*, vol. 9) showed that the continuous spectrum of the nightglow in 4700–6700 Å corresponds to the spectral type G2, but possesses two broad emission bands near 5950 Å and 6200–6300 Å.

Airglow stations near the equator and in the southern hemisphere are being active, especially in the African zone. The French and German groups are operating a few stations in South West Africa. The station at Tahiti in the South Pacific, operated by the French group, is important as a low latitude station with the station in Hawaii. They are obtaining observations of many airglow emissions using photoelectric photometers.

Another low latitude station at Mt. Abu in India is continuing observations in the visible and near infra-red regions. An Ebert-Fastie type spectrometer is near completion there to be used for near infrared OH studies.

The importance of the study of airglow continuum is emphasized by M. F. Ingham and P. V. Kulkarni. The brightness and spectral distribution of the integrated starlight is still not known with sufficient accuracy and the method of correcting observations of the diffuse light of the night sky for extinction and scattering are very rough. It would be worth paying more attention to these aspects of our work in the future.

II. NIGHTGLOW VARIATIONS

Correlations between the airglow intensity and solar activity were studied by many researchers. N. Rosenberg and S. P. Zimmerman (*Planet. Space Sci.*, **15**) have analysed 5577 Å line intensities observed at Sacramento Peak since 1956, and showed statistically significant positive correlations between the two, being influenced both by solar ultra-violet radiation and solar corpuscular radiation. K. Yano (*Planet. Space Sci.*, **15**) and M. N. Gnevyshev (*Planet. Space Sci.*, **16**) demonstrated a similar tendency in the same period. R. Shapiro (*Planet. Space Sci.*, **17**) considers that there is no significant association between solar corpuscular radiation and the intensity of 5577 Å.

Variations of other airglow emissions with the solar cycle are shown by G. Weill (*Ann. IQSY*, vol. 4). The intensities of OH and Na D seem to have continuously decreased throughout the recent solar cycle.

From the measurements of 6300 Å during the IGY and IQSY, the Soviet researchers have shown that the emission 6300 Å is closely connected with the solar activity, namely the solar activity index $F_{10.7}$. The details will be described in Section III. L. L. Smith and W. R. Steiger (*J. geophys. Res.*, **73**) concluded that the 6300 Å emission has a seasonal variation, but it appears to be a function of the solar cycle.

Observations of various nightglow emissions at Tsumeb (South West Africa) were made by J. Dachs (*Phys. Atmos.*, vol. 41), who studied nightly and seasonal variations and their relation with the ionosphere. Airglow inside the southern auroral zone was studied by M. A. Gordon

(*Planet. Space Sci.*, **16**) showing a seasonal decrease and pronounced diurnal maximum of 5577 Å and 6300 Å emissions.

Latitudinal variations of 5577 Å were observed during a shipboard expedition by J. A. Greenspan and J. H. Woodman (*J. atmos. terr. Phys.*, **29**). T. P. Markham and R. E. Anctil (*J. atmos. terr. Phys.*, **29**) measured the 5577 Å and 6300 Å from a jet aircraft.

Spatial movement of nightglow was studied by L. H. Wilkins *et al.* (*J. atmos. terr. Phys.*, **29**) who studied E-W motion of mid-latitude aurora at Moscow, Idaho, by auroral radar.

A chart of isophotes of the 5577 Å line was drawn by M. P. Korobeinikova and G. A. Nacirov in Ashkhabad, and the isophotes are characterized by periodic variations of probability of streamlining of isophote directions with maximum amplitude approximately four days after the beginning of a geomagnetic storm.

At Haute Provence, 6300 [O I] and 5200 [N I] emissions in travelling ionospheric disturbances were observed by G. Weill and J. Christophe-Glaume (*C. r. Acad. Sci.*, **264**). The maximum N I emission is delayed by about 12 minutes with respect to the O I emission.

Variations of hydroxyl airglow during the solar cycle, its seasonal variations, and the latitudinal dependence were extensively studied by N. N. Shefov (*Planet. Space Sci.*, **17**). The work is described in Section VII.

The long discussed problem on the correlation between the 5577 Å line and the green continuum, was treated by F. Shanchez Martinez and R. Dumont (*Semin. Astr. Geodes. Madrid*, No. 60), and very close correlation, even quantitative, was obtained. R. Robley (*C. r.*, **265**) also found a positive correlation.

III. AERONOMY, EXCITATION PROCESSES, AND DOPPLER TEMPERATURE

Many geophysical rather than astronomical studies have been done, especially many important interferometric investigations have been made.

Measurements of the width of the 5577 Å line made with a Fabry-Perot interferometer were reported by E. B. Armstrong (*Planet. Space Sci.*, **16**) who gave many important results: the apparent line width was increased by small magnetic disturbances, and the temperature at an altitude of 90–100 km showed a variation coinciding in phase with the seasonal intensity variation. He also suggested that the wind velocities in the 90–100 km region could be measured by Doppler shifts.

Measurements of the speeds of neutral winds in the thermosphere by Doppler shifts in the 6300 Å line were made also by E. B. Armstrong (*Planet. Space Sci.*, **17**) and they were compared with the neutral wind patterns for altitude 250–300 km shown by theoretical models. A very broad agreement with the models is evident, but the local conditions in the thermosphere may have an influence on winds. The changes in height of the region emitting the 6300 Å line may be responsible for some of the observed effects.

The measurements of atomic oxygen emission at 6300 Å during IGY and IQSY render it possible to make some conclusions about the behaviour of the upper atmosphere higher than 200 km at the time of geomagnetic disturbances (V. I. Krassovsky, N. N. Shefov, Yu. L. Truttse; *Planet. Space Sci.*, **16**). It was shown that the emission 6300 Å is closely connected with solar activity, namely that a close connection exists between this intensity and the solar activity index $F_{10.7}$. For sufficient geomagnetic disturbances ($D_{st} > 100\,\gamma$) the log of emission intensity of the line can be lenearly related with the indices D_{st} and $F_{10.7}$.

Regular observations in Zvenigorod have shown that the increase of this emission is connected with some enlargement of its contour giving evidence of some warming up of the upper atmospheric strata. In the time of reddish polar aurora the emission continuum is increased and this speaks for an augmentation in the atmosphere of molecular NO.

The whole planetary energy released in time of greatest geomagnetic disturbances was determined empirically. It surpasses the energy of the particles in the magnetosphere. Evidently this heating of the upper atmosphere is followed by some variations of its density at different heights.

In Abastumani the emission of O I (6300–6364 Å) was investigated in crepuscular conditions and different regularities of its appearences were established on the basis of observations made in years 1962–68. It turned out to be possible that the maximum of this emission in spring and autumn is connected with low latitude polar aurora.

Twilight and nightglow spectral shapes of both 5577 Å and 6300 Å lines were measured by M. A. Biondi and W. A. Feibelman (*Planet. Space Sci.*, **16**), and they found that no evidence for a dissociative origin of the ^{1}D or ^{1}S oxygen was obtained, and the temperature of O(^{1}D) atoms from the thermal Doppler shape was obtained as a function of time after sunset. The same kind of interferometric measurement of the 5577 Å line in aurora was made by R. V. Karandikar (*Planet. Space Sci.*, **16**), and the Doppler temperatures of various types of aurora were given. A few observations were obtained for the sub-visual aurora, and the Doppler temperature showed the bulk of the values in the range 400–700 K with a pronounced peak around 430 K and also a minor peak in the range 250–300 K obtained for the faint diffuse glows. It was suggested that the sub-visual aurora was a distinct type with temperatures higher than other forms and possibly originating at comparatively higher altitudes.

The effective Doppler temperatures of the 6300 Å line are calculated by R. G. Roble *et al.* (*Planet. Space Sci.*, **16**) using the data of Evans through the night during solar cycle minimum.

Forbidden transitions in the upper atmosphere were widely reviewed by F. E. Roach (*Transitions Interdites Spectres Astres*, Liège, 1968).

A theoretical study of 6300 Å emission in connection with Barbier's formula was made by T. F. Tuan (*Ap. J.*, **157**).

The atmospheric movements of atomic oxygen density with altitude was studied by rocket-borne measurements by M. Gadsden and E. Marovich (*J. atmos. terr. Phys.*, **31**), and showed that the 5577 Å emission depends mainly on the occurrence of pressure waves of vertical wavelength down to several tens of kilometers. M. Gadsden (*J. atmos. terr. Phys.*, **30**) has interpreted the observed distribution of atomic sodium in terms of release from dust particles of meteoric origin in the upper atmosphere.

IV. TROPICAL AIRGLOW

Tropical enhancement of the 6300 Å and the second layer of 5577 Å have been two of the major items of interest in tropical airglow since the IGY. A good number of papers has dealt with this problem during the triennium. Some researchers used observations obtained at Haleakala, Hawaii, which is favorably situated for the study of tropical airglow. W. E. Brown and W. R. Steiger (*Nature*, **216**) compared the brightness of the 6300 Å line with the electron content determined by the HF signals from the synchronous satellite, and found that the large increases in the intensity are preceded by nocturnal increases in electron content. W. E. Brown, W. R. Steiger and F. E. Roach (*Nature*, **220**) have come to the surprising conclusion that a large night-time source of ionization is required in the tropics which can occur at any time between midnight and dawn, but the most likely time is 0150 (L.M.T.).

Using photometric observations of 6300 Å at Mt. Abu and Haleakala, S. R. Pal and P. V. Kulkarni (*Ann. Geophys.*, **24**) showed that the post-midnight enhancement and the superposed 6300 Å hump can be reasonably accounted for by considering the dynamics of the night-time *F*-region including vertical drifts during those hours.

Preliminary results obtained in Debre Zeit (Ethiopia) are presented by G. Weill *et al.* (*Ann. Geophys.*, **24**). The green doublet of N I at 5199 Å was regularly recorded, and it is highly correlated to 6300 Å intensities, being consistent with production of N(^{2}D) by electronic dissociative recombination of NO^+.

V. MID-LATITUDE ARCS

Owing to the unexpected relatively moderate activities in the present solar maximum not many observations have hitherto been obtained, but a few studies on the mid-latitude arcs have been published.

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Based on the measurements from Haute Provence and Tamanrasset, G. Weill and J. Christophe-Glaume (*Ann. Geophys.*, **23**) made an extensive study and tried to detect systematic variation during sudden commencement of geomagnetic storms. Storm effects on night airglow are characterized as follows. The A Group (5577, O_2 bands and continuum) increases by a few percent during the main phase, and the green line shows a positive post-perturbation with a marked intensity increase 35 hours after SSC; and the B Group (OH, Na) decreases by about 10% during the main phase; the red line of 6300 Å behaves differently at the two stations.

Some M-arcs observed in 1967 at Moscow, Idaho, were reported by T. Ichikawa and J. S. Kim (*J. atmos. terr. Phys.*, **31**). They obtained the southward motion of the arc with an average speed of 32 $\mathrm{ms^{-1}}$. The arc was analysed together with the visible aurora (I) by I. Ichikawa *et al.* (*J. geophys. Res.*, **74**) who found that the southern edge of the visible aurora was very close to the northern edge of the M-arc. The characteristic motions of the visible aurora and the M-arc were also studied.

Morphology and dynamics of the M-arcs observed in 1968 and 1969 at Whiteface Mt., N.Y., were studied by T. Old *et al.* who found that the observed arcs differ in many respects from the arcs observed during the IGY.

The detailed results of M-arc aurorac observed around the last solar maximum at Memembetsu, Hokkaido, were published (Reprint from *Rep. geomag. geoelect. Obs.*, 1967, No. 8.)

VI. EXCITATION OF 6300 Å BY PHOTOELECTRONS

Pre-dawn enhancement of the 6300 Å [OI] emission as the result of the travel of photoelectrons from the magnetically conjugate region has received wide interest by airglow as well as geophysical researchers.

M. L. Duboin, G. Lejeune, M. Petit and G. Weill (*J. atmos. terr. Phys.*, **30**), based on optical observations of the ionosphere above St. Santin de Maurs made concurrently with Thomson scattering soundings, confirmed that the pre-dawn enhancement of the oxygen red lines occurs in synchronism with electronic heating in the F-region at times of sunrise in the magnetically conjugate area. A preliminary calculation indicated that photoelectron impact is directly responsible for the excitation of $O(^1D)$.

H. C. Carlson and G. Weill (*Ann. Geophys.*, **23**) found many important features about the solar cycle control on the timing of 6300 Å pre-dawn enhancement. At Haute Provence the onset occurs 70 min earlier at solar maximum than at solar minimum activity. The observations at Arecibo in 1965–67 confirmed the effect, and a preliminary calculation showed that it is quantitatively interpreted by the combined variation of upper atmospheric neutral temperatures and of the solar ionizing flux through the 11-year cycle.

Photometric observations made in 1965–68 by R. W. Smith (*Planet. Space Sci.*, **17**) revealed that the enhancement is a regular occurrence, at least up to geomagnetic latitude 59·5° N in the manner reported from lower latitudes. The onset time shows a solar cycle, seasonal and irregular variation. Long period variations are suggested to be related to thermopause temperature and the solar EUV intensity. Heights of emission are deduced from the azimuthal measurements which are mostly in the region 250–300 km. There is a trend towards increasing height with increasing thermopause temperature.

Some theoretical considerations were made by J. R. Catchpoole (*J. atmos. terr. Phys.*, **29**). The latitude dependence of the enhancement was studied by R. T. Bennett (*J. geophys. Res.*, **74**) who found the upper limit $L \sim 3{\cdot}2$, while M. R. Torr and D. G. Torr (*J. geophys. Res.*, **74**) claimed that it was observable in winter at the antarctic station where $L = 4{\cdot}0$.

Using the observations at Tohkatta, Japan, M. Okuda and K. Misawa (*Rep. Ionos. Space Res. Japan*, **23**) studied the time variation of the effect vs. the changes of the solar zenith angle at the conjugate point, and the daily dependence of the effect on the geomagnetic activity.

Evidence was presented for the existence of a flux of fast photoelectrons arriving from the conjugate ionosphere by J. V. Evans in his study of midlatitude *F*-region densities (*Planet. Space Sci.*, **15**).

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VII. HYDROXYL (OH) NIGHTGLOW

Extensive studies of hydroxyl nightglow have been made by Soviet researchers. The analysis of observations made in the last years in Zvenigorod near Moscow (V. I. Krassovsky, N. N. Shefov, Yu. L. Truttse; *Ann. Geophys.*, **24**, *Planet. Space Sci.*, **17**, *Nature*, **218**) reveal variations of intensity of the OH hydroxyl band with periods of 5·5 years and 26 months during solar cycle activity. Intensity variations of the OH bands from median vibrational level are greater in the winter and summer months and smaller in spring and autumn. The variations of rotation temperature show a marked maximum in winter and minimum in summer and within the limits of errors coincide with variations of atmospheric temperature at a height near 80 km. The vibration temperature corresponding to these observations attains its maximum in winter (nearly 11000 K) and minimum in summer (nearly 5600 K), so that the intensity variations of OH at upper and lower vibration levels are quite different. The total energy of hydroxyl emission attains its maximum in summer.

Besides these regular variations of OH emissions their disturbed variations have also been detected. After the maximum of main meteor-showers the intensity of OH increases over a period of 3–4 days. A similar phenomenon is observed also with the appearence of noctilucent clouds.

Moreover, there exist variations of more than 20 days' duration after geomagnetic disturbances; the intensity of OH bands at first increases (by $+80\%$ at $K_p = 9$), but rotation and vibration temperatures diminish. The maximum amplitude of perturbed intensity variations is attained several days after the corresponding disturbance. The analysis of observations made at different latitudes shows that the perturbance spreads from the zone of polar aurora with a speed of ~ 10 m s^{-1} in meridional direction. The period of intensity and temperature variation after geomagnetic disturbance is equal to 6 days on the average according to the Zvenigorod data and increases with growth of index K_p. These variations are a consequence of molecular dissociations resulting from penetrations of corpuscles in the zone of polar aurora. This gives supplementary energy approaching at maximum to 10^{23} ergs when $K_p = 7$.

The seasonal variations of intensity and rotation temperature of OH bands in visible and infrared spectral regions were studied also in the Astrophysical Institute, Alma Ata (Z. V. Kariaguina, V. E. Mozaeve). It was shown that in summer the temperature value of OH and its variations are smaller. The intensity and temperature of OH bands are not correlated between themselves but, on the contrary, a sufficiently strong correlation exists between intensities of OH and hydrogen line Hα.

From the spectra of several bands of OH nightglow, rotational temperatures have been derived by G. J. Kvifte (*Planet. Space Sci.*, **15**), giving an average of 210 ± 10 K. No seasonal dependence or latitude effect is found. The spectrum between 1·02 and 1·13μ has been measured at a spectral resolution of 27Å by A. W. Harrison (*Planet. Space Sci.*, **17**) and the rotational temperature of 240 ± 20K for (4–1) band and 220 ± 20K for (5–2) band were obtained by comparison with synthetic spectra. Absolute brightnesses of the two bands were also given.

At Abastumani Observatory the bands of hydroxyl OH are investigated in twilight conditions. Two principal types of intensity and temperature variations were established: (1) the increase with brighter twilight, i.e. at lesser solar depressions below the horizon, mainly in the morning and in summer, and (2) relatively small and irregular variations at middle twilight most frequently in winter time and in the evening as much as in the dawn. The first type of variations can be observed most frequently at the fourth day after a geomagnetic disturbance. The second type of variations does not depend on geomagnetic activity. These differences between the morning and evening values for the intensity and temperature of OH emission disappear completely with solar depression greater than 11°.

A seasonal course of OH emission was revealed in winter with a maximum at 18°—12° of solar depressions, and in summer at lesser solar depressions. It is possible that these regularities of the crepuscular OH emission depend on dynamical processes in the mesosphere (T. I. Torochelidse, *Bull. Acad. Sci., Georgian SSR.*, **52**).

VIII. HYDROGEN AIRGLOW

Since the last triennium, the Soviet colleagues have been especially active in these studies.

In the years 1967–69 investigations of the red hydrogen line Hα in the night sky were continued with an interferometric system supplied with a Fabry-Pérot etalon (P. V. Shcheglov). Observations were made at the same time by Z. V. Kariaguina and V. E. Mozaeva at the Astrophysical Institute, Alma Ata, and by L. M. Fishkova in Abastumani. It was discovered that the morning hemisphere of the night sky is more luminous in this line emission in comparison with the evening one, that in the antisolar point there is a deep minimum of Hα emission and that in the northern part of the sky this Hα emission sometimes undergoes changes not related to its twilight course. Calculations from these data of the concentration of neutral hydrogen showed some changes with a period of several tens of minutes. A comparison with similar observations from different places leads to a provisional conclusion that the areas of these disturbances of neutral hydrogen are inhomogeneities of a few hundreds of kilometers in dimension.

It was shown on the basis of spectrographic Hα observations made in Abastumani that the distribution of atomic hydrogen corresponds to the presence of a symmetrical geocorona with some diurnal variation of hydrogen content (at night the amount of hydrogen is 5–6 times greater). Seasonal variations of Hα intensity reduced to a certain Earth's shadow height, namely to 1000 km, are nearly the same during the whole year. Their summer minimum does not exceed 20% of the mean annual value. The observed intensity of Hα also enables the deduction of the vertical distribution of the total quantity N(H) of atomic hydrogen in the column of atmosphere from 250 to 2700 km. In general this quantity increases with a decrease of solar activity. In addition, the observations in Abastumani have shown that the intensity of Hα in the twilight is several times greater than in nocturnal conditions. At the same solar depression some rise in Hα emission in the dawn in comparison with the evening was also observed. From such observations it is possible to obtain the hydrogen concentration at heights up to 200 km.

Continuous observational series during 1962–68 reveal the dependence of Hα emission on solar activity, the phase displacement being 1·5 or 2 years (I. A. Chvostikov, T. C. Megrelichvili).

Very interesting measurements of the emission rate of the Hα line were made with a photoelectric spectrometer at Haute Provence by M. F. Ingham (*M.N.R.A.S.*, **140**). Care was taken to make proper allowance for the integrated star light, the zodiacal light, the airglow continuum, and also for contamination by galactic sources. The results show that there is sufficient neutral hydrogen in the exosphere for multiple scattering of solar $L\beta$ radiation to be important. Ingham believes that measurements of Hα have a certain advantage over $L\alpha$ observations.

Observations of Hα emission were made at Camden, Australia, by E. B. Armstrong (*Planet. Space Sci.*, **15**) and the following results were obtained. There is a definite build-up of the hydrogen content during the night, and the maximum content is attained soon after midnight. The temperature at the exosphere base rises significantly before dawn at that altitude. The concentration of hydrogen towards the plane of the ecliptic is possibly less marked than previously reported. The absolute intensity of the Hα emission is higher than would be expected from reported measurements of the solar $L\beta$ intensity.

Observations of Hβ emission were made with a Fabry-Pérot interferometer at Testa Grigia in the Italian Alps by N. K. Reay and J. Ring (*Planet. Space Sci.*, **17**). They obtained an emission rate of 0·1–0·2 rayleigh, probably representing the addition of two components, galactic and non-galactic. The emission at galactic latitudes greater than $\pm 15°$ is interpreted as being non-galactic in origin and is discussed in terms of both geocoronal and interplanetary emitting regions.

IX. OTHER EMISSIONS IN THE NIGHTGLOW

(N_2^+)

There has been a long-standing argument whether or not the N_2^+ emission is present in the night-glow. A. L. Broadfoot and K. R. Kendall reported in "The Airglow Spectrum" (*J. geophys. Res.*,

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73) that the absence of the emission is obvious in this spectrum but the $1R$ limit cannot be lowered owing to the blending of what appears to be a strong unidentified band at about 3908 Å.

(N I)

Very faint emissions previously undetectable by filter photometry now seem to be regularly observable. Observations of the 5200 Å [N I] line at Haute Provence were reported by G. Weill and J. Christophe-Glaume (*C. r.*, **264**). Close correlation between the 5200 Å [N I] and 6300 Å [O I] emissions were revealed, the ratio of radiation rates being about three percent. Implications for the *F*-region recombination processes have been studied by G. Weill (*C. r.*, **264**) with the following results. The lifetime of the $N(^2D)$ state at 250 km is of the order of 12 min, the ratio of excitation of $N(^2D)/O(^1D)$ is of the order of 4, and the recombination of nitrogen molecules at this altitude predominates over that of the oxygen molecules.

The green doublet 5200–02 Å of N I was studied by B. P. Saxena (*Ann. Geophys.*, **25**) who found the intensity maximum in the *F*-region, in agreement with Weill *et al.*

X. TWILIGHT AIRGLOW

A study was made of the intensity distribution among the Meinel bands and first negative system of N_2^+ due to resonance scattering of sunlight by A. L. Broadfoot (*Planet. Space Sci.*, **15**). Absolute transition probabilities were used to calculate the relative populations among the ion states under resonance scattering conditions. Photon scattering rates were calculated for most of the ion bands and it was suggested that an appropriate value for the 3914 Å band would be 0·05 photons s^{-1} per ion. Sunlit auroral spectra of N_2^+ were also discussed. He made a study of the tropospheric scattering of the emission, constructing a model for the whole twilight atmosphere (*Planet. Space Sci.*, **16**).

In Abastumani the investigation of twilight emission of sodium was performed taking into account the screening influence of the low atmospheric strata. The effective height of the screening for this emission varies 40 and 10 km for solar depressions from 6° to 13°. This permits the derivation of the vertical distribution of the atmospheric sodium and the elucidation of its new properties (T. I. Torochelidse). In particular, it turned out that in winter the height of the maximum content of sodium is 10–15 km lower than in summer. It depends also on the atomic concentration.

In Abastumani observations of the twilight intensity at symmetrical points of the solar vertical were commenced following a method of V. C. Fesenkov. Their purpose is to detect cosmic matter in the Earth's upper atmosphere.

The O_2 band at 1·58 μ was observed with a scanning Fabry-Perot system by R. L. Gattinger (*Can. J. Phys.*, **46**). The brightness at a solar depression angle of 6° was about 25 kR, but the emission could not be detected in the morning twilight. A theoretical discussion indicated that the ozone dissociation mechanism is probably the correct one.

Measurements of twilight helium 10830 Å emission arising from resonant scattering of sunlight in the upper atmosphere were made by B. A. Tinsley (*Planet. Space Sci.*, **16**), and intensities from less than 200 R to greater than 1000 R were found for solar depression angles greater than 10°. A marked maximum in the emission rate was found in the winter of 1966–67. The possible latitude variations in atmospheric constituents and the effects of conjugate point photoelectrons are discussed with regard to the north-south asymmetry and winter maximum. A strong northerly emission accompanying a moderate magnetic storm was observed, and the possibility of considerable solar cycle variations, at least at low latitude, was indicated.

Photometric measurements of the helium line with a Fabry-Pérot instrument were performed by Y. P. Neo and H. N. Rundle (*Planet. Space Sci.*, **17**). They recorded large fluctuating enhancements while visible auroras were present. The intensity decay during twilight is consistent with the excitation of triplet helium atoms by collision of photoelectrons with ground state helium atoms, followed by resonance scattering.

Observations of many twilight emissions are being made at Haute Provence by N. Doan. He pointed out that the Li I and Ca II emissions are connected with meteoric swarms, though they are much affected by atmospheric movements. He also found that the He I line at 3889 Å is fairy strong, being 10–20 rayleighs.

Ca II twilight emissions in the southern hemisphere at Adelie Land, Antarctica, were first observed by G. Weill (*Ann. Geophys.*, **22**). The observations confirmed the seasonal nature of the intensity variations and indicated a large maximum in early June. The Ca I resonance line at 4227 Å did not appear on any spectra. Aircraft observations of the Ca II emission were made by T. P. Markham and R. E. Anctil (*Planet. Space Sci.*, **15**), and they identified the K line with an intensity of 30 rayleighs.

G. I. Kvifte and L. Wallace studied a method of determining the atmospheric sodium concentration from twilight observations (*Planet. Space Sci.*, in press). A. L. Broadfoot is currently making observations of sodium D_2/D_1 emission in twilight at Kitt Peak.

XI. DAY AIRGLOW

The daytime airglow might not belong to the field of our commission, but as it has close connection with the twilight or night airglow, studies of day airglow will be briefly introduced in this section. Some studies by rocket borne instruments are included in this section.

Observations of 5577 Å [O I] emission of the dayglow were obtained with a rocket photometer from the equatorial launch site at Natal, Brazil, by B. S. Dandekar (*Planet. Space Sci.*, **17**). He observed that the emission comes from three different ranges of altitudes: a layer around 96 km which contributes about 40% of the total emission, a second layer 110–150 km, and a third around 150 km of about 30% of the total emission. The probable excitation mechanisms of the layers were given.

The daytime 5577 Å emission was also observed by A. H. Jarret and M. J. Hoey (*Planet. Space Sci.*, **15**), who found the maximum varying from an estimated 50 to 100kR, being possibly auroral emission rather than general O I dayglow.

Observations of O_2 bands in dayglow were made by several researchers. L. Wallace and D. M. Hunten (*J. geophys. Res.*, **73**) made rocket observations of the A band over the range 35–128 km, and (0–1) band 59–95 km. The major production processes have been identified. Calculation of the transmission function for a self-absorbed band and production and transmission of the nightglow emission were also discussed.

The O_2 band at $1{\cdot}58\,\mu$ was observed with a ground-based spectrometer by R. L. Gattinger (*Can. J. Phys.*, **47**), and the brightness was found to be approximately 630 kR.

The altitude profile of the infrared oxygen airglow at $1{\cdot}27\,\mu$ was measured with a rocket-borne photometer by W. F. Evans *et al.* (*J. geophys. Res.*, **73**). They found the emission to peak at 49·5 km and the maximum volume emission rate to be 1030 kR km^{-1}. The emission layer agrees with that predicted from an excitation mechanism of the photolysis of ozone in the Hartley continuum. There was some excess emission above 80 km, and possible explanations were considered. Based mainly on this observation, it was pointed out by D. H. Hunten and M. B. McElroy (*J. geophys. Res.*, **73**) that O_2 can be ionized by the 1027–1118 Å band. This source appears to be able to explain the presence of O_2^+ ions in the *D*-region, and quantitative estimates of the production rate were made.

Surface albedo and the filling-in of the Fraunhofer lines in the day sky was studied by D. M. Hunten (*Kitt Peak nat. Obs. Contr.*) who concluded that the principal effect responsible for smearing of the spectrum is probably the so-called Rayleigh wings.

Rocket-borne spectrometers have been used to examine the spectrum of the daytime airglow in the near infrared from 6000 to 11 500 Å, and a number of fainter emissions, N_2^+ emissions at 7875 and 9212 Å, atomic oxygen emissions at 7774 and 8446 Å, and N_2 emission at about 8850 Å, were observed and studied by L. Wallace and A. L. Broadfoot (*Planet. Space Sci.*, **17**). Rocket observations of visible and ultraviolet dayglow were made by T. Nagata *et al.* (*J. Geomag. Geoelect.*, **20**). The emissions observed were O I 6300 Å, N_2 3914 Å, and ultraviolet between 2000 and 3000 Å. Some theoretical interpretations were given on the basis of calculations made for emission rates for various excitation mechanisms. The ultraviolet dayglow in 2400–3200 Å was measured from aircraft and a total emission rate of approximately 300 kR was obtained by L. R. Doherty (*J. geophys. Res.*, **73**).

XII. ROCKET AND SATELLITE OBSERVATIONS OF AIRGLOW

A good many observations of airglow from rockets and satellites were made in this triennium as in the last.

Observations of 5577 Å, 6300 Å, Na D, and the continuum at 5300 Å in the nightglow were made in Woomera by R. G. H. Greer and G. T. Best (*Planet. Space Sci.*, **15**), and emission profiles were obtained. They consider that up to 80% of the 5300 Å emission observed from the earth may be extra-atmospheric in origin.

The profiles of 6300 Å emission were observed by M. Huruhata and T. Nakamura (*Space Res.*, **8**) with two rockets at Kagoshima, and the heights of maximum emission were found at 260 km and 290 km. The height profiles were found to be fairly different for different geographic positions and different solar altitudes. M. Huruhata *et al.* (*Rep. Ionosph. Space Res.*, **21**), made a rocket measurement of 5577 Å emission and the continuum at 5300 Å with both upward and downward directed photometers. A slightly lower height of the maximum 5577 Å emission was obtained than reported in previous studies.

Observations of the OH band, 5577 Å line and the continuum at 5577 Å were made and their altitude profiles were given by D. J. Baker and R. O. Waddoups (*J. geophys. Res.*, **72**).

Two satellite observations of airglow were reported in this triennium, and very interesting results were given. J. G. Sparrow *et al.* (*J. geophys. Res.*, **73**) employed photometers sensitive to three wide spectral bands, carried on the OSO-B2 which was launched in 1965 into a near-circular orbit at an altitude of 600 km, with an inclination of 33° to the equator. The intensity of the continuum was found to vary between wide limits, ranging from 0·1 to 0·9 R $Å^{-1}$ in the visual spectral region and from 0·06 to 0·5 R $Å^{-1}$ in the blue region. Intensity changes of a factor of 2 were often found between observations one orbit or 24° of longitude apart. Features in the longitudinal airglow profile had typical sizes of 1500–2000 km and life times in excess of several days. No latitudinal variation of continuum intensity was observed although a marked variation in intensity occurred during the ten months.

D. D. Elliott and S. R. LaValle (*Space Res.*, **8**) surveyed the equatorial region repeatedly from a polar-orbiting satellite launched in 1966. The measurements were made at 5577 Å and 6300 Å during four months at a local time near midnight. There were red (6300 Å) arcs every night, and green (5577 Å) 9 times out of 13. The red arcs of median brightness of about 150 rayleighs occurred in pairs spaced symmetrically around the magnetic equator. The green arcs frequently occurred in coincidence with a red arc. The red and green arcs typically occurred at ±15° magnetic latitude and were about 10° wide, and the arcs were not dependent on K_p.

Rocket photometry of the far UV twilight airglow was made by H. W. Moos and W. G. Fastie (*J. geophys. Res.*, **72**). $L\alpha$ showed a height profile similar to that of the dayglow with a peak value of 3·6 kR at a height of 152 km. The O I 1304 Å had a maximum value of 110 R toward the horizon, and low intensity emission in 1360–1600 Å was observed.

XIII. PHOTOMETRIC STUDIES OF ZODIACAL LIGHT

Photometric and polarimetric observations of the zodiacal light were reported by many researchers. Observations from space vehicles were performed and many valuable results were reported.

A comprehensive review of the zodiacal light has been given by D. E. Blackwell *et al.* (*Adv. Astr. Astrophys.*, **5**).

Assuming that if the zodiacal light is due to a heliocentric dust cloud, photometric localization of the Sun's equatorial plane is much easier when the Earth is close to that plane, R. Dumont *et al.* (*Ann. Astrophys.*, **31**) made photometric scans in June and December, 1966, and they got an estimate of the inclination to the ecliptic of the heliocentric dust cloud: 1°.9 northward in Leo and 1°.3 southward in Aqr. They found the shifts to be in very good agreement with the hypothesis of a heliocentric dust cloud flattened along the invariable plane and in poor agreement with a cloud flattened along the solar equator. They concluded that the best interpretation is a photometric mixture of the two clouds, unequally flattened on their symmetric planes, perhaps indicating a geocentric dust component in the zodiacal brightness. R. Robley (*C. r.*, **265**) found a positive correlation between the brightness of zodiacal light and the intensity of the 5577 Å airglow line and suggested the existence of a second zodiacal light component. He is continuing the observations at the Pic-du-Midi Observatory in efforts to confirm the existence of this second component.

Polarimetric observations in narrow bands at 5080 Å and at 5577 Å were made at Haleakala by J. L. Weinberg *et al.* (*Planet. Space Sci.*, **16**), and they found that the polarization of the continuum at 5080 Å is caused both by the polarization of zodiacal light and by atmospheric polarization, and that the polarized component of the 5577 Å line emission is, for large areas of the sky, brighter than that of the continuum at 5080 Å. An important suggestion was made that broad-band measurements can lead to overestimates of the polarization of the zodiacal light, especially for regions near the ecliptic poles. J. L. Weinberg and H. M. Mann (*Ap. J.*, **152**) made observations near 4300 Å, a wavelength region which Powell *et al.* had suggested may contain negative polarization in the region of small elongations ($\varepsilon < 90°$). No negative polarization was detected at these elongations at 4300 Å or at other wavelengths in the visible.

In the interest of studying the particles causing the zodiacal light, M. Daehler *et al.* (*Planet. Space Sci.*, **16**) have observed the profile of the Hβ absorption line in the zodiacal light spectrum at Chacaltaya with a Fabry-Pérot spectrometer. The absorption feature was obscured by Hβ emission of uncertain origin, preventing precise Doppler-shift measurements and no wavelength shift could be shown. Observations of the Hβ line profile in the zodiacal light were repeated in order to decide on the origin of the previously observed emission features with a higher resolving power by P. H. Hindle *et al.* (*Planet. Space Sci.*, **16**). All the scans showed a small emission component which had a concentration toward the ecliptic and showed a shift to the blue side. From this observation, N. K. Reay and J. Ring showed separately (*Nature*, **219**) that the observed radial velocity variation for elongations up to 60° agrees well with that expected of dust particles in circular orbits about the Sun. For this result, L. W. Bandermann and R. D. Wolstencroft (*Nature*, **221**) reached the conclusion that the dust orbits are nearly all direct and of low inclination and low eccentricity. Additional studies have been carried out by D. Clarke *et al.* (*J. Phys.*, **28** and *Modern Astrophys.*, Paris, 1967), J. F. James (*M.N.R.A.S.*, **142**), and N. K. Reay (*Nature*, **224**).

M. F. Ingham and R. F. Jameson (*M.N.R.A.S.*, **140**) have obtained polarization observations of the nightglow and have derived a model for zodiacal dust in a direction normal to the ecliptic.

R. D. Wolstencroft and F. E. Roach (*Ap. J.*, **158**) critically discussed the conflicting values of the brightness of the zodiacal light at the north ecliptic pole reported by various authors during the past four years.

Infrared observations of the outer corona at $2{\cdot}2\,\mu$ by R. M. MacQueen (*Ap. J.*, **154**) showed that the isophotes of the infrared corona have an interpolated peak coinciding closely with the invariable plane, and this apparent concentration of particles in the invariable plane would rule out a major geocentric contribution to the zodiacal light. Infrared observations of the corona at $2{\cdot}23\,\mu$ by A. W. Peterson (*Ap. J.*, **155**) confirm his earlier predictions of thermal emission by zodiacal dust and indicate the existence of a vaporization zone at $3{\cdot}9\,R_{\odot}$.

F. Sanchez Martinez (*Semin. Astr. Geodes. Madrid*, Publ. No. 60) noticed that residual fluctuations of zodiacal light brightness would be governed by solar chromospheric eruptions.

Some very interesting papers about the effect of the solar activity on the brightness and polarization of the zodiacal light were presented by A. S. Asaad (*Nature*, **214**, and *Observatory*, **87**), G. Weill (*C. r.*, **263**) and J. Dufay (*C. r.*, **263**). Asaad plotted the brightnesses of zodiacal light observed since 1950 and found that the brightness increased with decreasing solar activity by a factor of 2, and he concluded that errors of observations and uncertainties in the method of reduction would not explain this relation. As possible explanations of this phenomenon, he pointed out that during the maximum solar activity the solar wind is rather strong and might destroy, evaporate or push away some of the interplanetary material. Another possibility is that when the corpuscular radiation is strong it may cause the very fine particles to spiral away from the sun, whereas during minimum solar activity the spiralling would be toward the Sun.

An analysis of 13 years of nightglow observations towards the zenith and pole from Haute Provence was made by G. Weill and J. Dufay. They found a solar cycle variation of the brightness of the zodiacal light, of total amplitude 25%, almost in opposite phase with solar activity. The maximum zodiacal light precedes the minimum solar activity by two years.

In the Dudley Observatory, J. L. Weinberg is analyzing nightglow data obtained at Haleakala between 1961 and 1969. R. D. Wolstencroft is continuing observations at the Haleakala Observatory on the anticipated annual variation of the relative brightness of zodiacal light at mirror points of high ecliptic latitude in the two ecliptic hemispheres; the position of the axis of zodiacal light; and the brightness and polarization of the integrated galactic light at 5080Å.

Observations of Zodiacal Light from Space Vehicles

The first report of observations of zodiacal light from a satellite was given by J. G. Sparrow and E. P. Ney (*Ap. J.*, **154**). The satellite OSO-B2 had a 9-month operative lifetime from its launch in February, 1965. The photometers were aligned along the spin axis of the satellite, and the nature of the satellite restricted the observations to a constant elongation of 90°. The brightness and polarization of the zodiacal light were measured in visual and blue wavelength regions. The brightness at the ecliptic pole obtained by these observations was 50 S_{10} (vis), being far smaller than that obtained by previous ground-based and rocket observations. The observed degree of polarization was also smaller than the previous results, and for none of the strongest magnetic events was an increase in the polarized component greater than 10% observed. The upper limits of the interplanetary electron density during a number of solar events was 17 electrons cm^{-3} in a cloud of thickness 1 a.u. Additional measurements are being made from OSO-F (E. P. Ney; Univ. of Minnesota) and from OSO-G (Ruoy, Carroll and Aller; Rutgers).

The importance of future studies of the zodiacal light and interplanetary medium from artificial vehicles has been emphasized by many researchers. H. Elsässer (*Nuovo Cim.*, **5**; *Naturwissenschaften*, **56**) pointed out some interesting problems to be solved by observations from space vehicles and described some measurements to be performed in the near future. C. Leinert (*Ster. Weltraum*, 1969). D. Lemke and W. Gabsdil (*Mitt. astr. Ges.*, Nr. 25) described a project for zodiacal light observations with balloons.

The group of H. Elsässer is now preparing zodiacal light observations by a balloon-borne telescope and by the German-American space probe HELIOS which will approach the Sun to a distance of 0·3 a.u. Rocket and balloon observations are also being carried out by French and Japanese groups. R. H. Giese and C. Dziembowski (*Planet. Space Sci.*, **17**), derived two types of models of interplanetary dust and suggested measurements that should be made from space probes.

Two zodiacal light experiments are being developed at the Dudley Observatory by J. L. Weinberg and his group: (1) Photoelectric measurements from an Earth-orbiting satellite to be launched in spring 1972. Observations of brightness and polarization will be obtained at ten wavelengths between 4000 and 8200Å. (2) Photoelectric measurements from the Pioneer F/G Asteroid-Jupiter probes: F to be launched in 1972, G to be launched in 1973. Observations of brightness and polarization will be obtained in two broad spectral regions.

XIV. DUST PARTICLES IN INTERPLANETARY SPACE

The basic problems of the distribution and density of dust particles in interplanetary space and the scattering of light by the particles have been studied from many angles both observational and theoretical. Substantial studies were made especially by Soviet researchers in this triennium.

The essential features of the optical method for surveying material from space that has penetrated into the upper layers of the Earth's atmosphere through analysis of twilight phenomena was described by V. G. Fesenkov (*Sov. Astr.–AJ*, **12**). It was readily possible to identify individual irre-

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gularities that develop mainly at a height of about 80 km, and to follow their time variation. Numerical results obtained by reducing the observations were reported.

D. E. Blackwell *et al.* (*M.N.R.A.S.*, **136**) presented a model of the distribution of the interplanetary dust based upon photometric measurements of zodiacal light and *F*-corona and on the distribution function of particle radius obtained from space vehicles. They proposed a model where the dust density decreases and the albedo of the particles increases with distance from the Sun. This model could lead to improved agreement between calculation and observation.

The suggestion of Peale that the earth is surrounded by geocentric dust whose particles are diffusely concentrated toward the ecliptic plane was examined by R. D. Wolstencroft (*Planet. Space Sci.*, **15**), who showed that the contribution of such a cloud to the zodiacal light would be less than 20%.

Purely gravitational capture of cosmic dust by the Sun with the assistance of the planets, and by planets with the assistance of their satellites was proposed by V. V. Radzievskiï (*Sov. Astr.–AJ*, **11**) and approximate quantitative computation of the captured mass was made. The earth captures three orders of magnitude more zodiacal matter than is necessary for sustaining the circumterrestrial cloud with the experimentally observed density. The evolution of the circumterrestrial cloud was also discussed.

The influence of solar radiation pressure on the motion of dust particles in a circumterrestrial orbit was studied by N. B. Divari and Yu. A. Klikh (*Sov. Astr.–AJ*, **11**). They showed that the perigee distance for the orbits of micron-size particles experiences oscillations of substantial amplitude, and consequently these dust particles will sink rapidly into the Earth's atmosphere. Another study of the effects of solar radiation pressure on the particles of interplanetary dust as a function of their radius and density was made by L. M. Gindilis *et al.* (*Sov. Astr.–AJ*, **13**). It was concluded that the micron and submicron components of the dust must primarily consist of comparatively dense particles of an asteroidal origin. For particles of the order of several microns or larger, as well as for very small dimensions, interplanetary space must contain less dense particles of cometary origin in addition to the asteroidal particles. Absorbing particles with radii less than $0{\cdot}1$–$0{\cdot}5\,\mu$ cannot be present in the interplanetary dust.

A meteor model for the zodiacal cloud was presented by N. B. Divari (*Sov. Astr.–AJ*, **11**), who made calculations of the concentration of dust material as a function of the distance from the Sun and the heliocentric latitude on the basis of meteor orbits, and these results were used to compute the brightness and polarization of the zodiacal light. The results were compared with observed values, showing that the meteor model provided a relatively good representation.

Reference should be made to an important paper on the optical scattering from non-spherical randomly aligned, polydisperse particles by R. S. Powell *et al.* (*Planet. Space Sci.*, **15**).

XV. RELATED STUDIES

A very significant study, which has important relationships with airglow and zodiacal light studies, was reported by A. N. Witt (*Ap. J.*, **152**). He carried out new photoelectric measurements of the intensity and distribution of the diffuse radiation in the Galaxy. Contaminations originating in other sources of the night sky light were investigated and taken into account. The residual intensity was interpreted as general galactic starlight scattered by interstellar dust particles, and many properties of the scattering were presented.

C. F. Lillie and A. N. Witt (*Astrophys. Letters*, **3**) detected no diffuse galactic light in the UV (see, also, C. F. Lillie, Dissertation, Univ. Wisconsin, 1968). J. L. Weinberg *et al.* (*Bull. AAS*, in press) have separately observed the diffuse galactic light, and they find a brightness in polarized light of 1 to 2 S_{10} (vis) units at 5300 Å.

Observations and interpretation have also been carried out by F. E. Roach (*Modern Astrophys.*, Paris, 1967), C. J. van Houten (*BAN*, **19**), N. C. Wickramasinghe (*Nature*, **218**), and H. C. van de Hulst and T. de Jong (*Physica*, **41**).

F. E. Roach and L. L. Smith (*Geophys. J.R.A.S.*, **15**) have examined nightglow observations in a search for cosmic light, and they have established an upper limit of 5 S_{10}(vis) units at 5300Å.

The determination of the brightness of any light source outside the atmosphere from ground-based observations was studied by R. D. Wolstencroft and I. G. van Breda (*Ap. J.*, **147**). The results of calculations of the brightness and the degree of polarization of the light scattered in the Earth's atmosphere were presented in the cases of zodiacal light, the integrated starlight, and an isotropic source.

The scattering of light in the troposphere and the polarization of certain components of night-sky radiation were studied by N. B. Divari (*Sov. Astr.–AJ*, **12**) who showed that a quite high degree of polarization must be taken into account when analyzing polarization measurements of the zodiacal light. It was argued that revisions should be made in data on the zodiacal light intensity at the ecliptic pole obtained without allowance for the light from all sources of night-sky emission scattered by the troposphere.

Rocket observations of galactic light outside the airglow layer are being carried out by the group of Tokyo Observatory. H. Tanabe is measuring star fields on the Palomar Sky Atlas in connection with these observations.

The most recent searches for lunar libration clouds have produced negative results and have established upper limits to the brightness that could be associated with such clouds (R. G. Roosen and C. L. Wolff, *Nature*, **224**; J. L. Weinberg *et al.*, *Bull. AAS*, in press).

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