21. LIGHT OF THE NIGHT SKY (LUMIERE DU CIEL NOCTURNE)

PRESIDENT: R.H. Giese
VICE PRESIDENT: K. Mattila
ORGANIZING COMMITTEE: *R. Dumont, Yu.I. Galperin, M.S. Hanner, A.C. Levasseur-Regourd, F. Sanchez-Martinez, H. Tanabe, J.L. Weinberg*

I. INTRODUCTION

The light of the night sky consists of atmospheric components (airglow, light scattered in the atmosphere) and - even in the case of spaceborne observations - of zodiacal, galactic and extragalactic light. Although all components are of similar importance, investigations on zodiacal light have profitted most by the space age since their object of research, the interplanetary dust cloud, became accessible to direct in-situ measurements. Lunar samples and measurements by micrometeoroid detectors provide individual and eventually detailed information on impact events, which however are limited in number and therefore restricted in statistical significance. Zodiacal light investigations involve scattered light of many particles in large volume elements and therefore provide global information about physical properties and spatial distribution of interplanetary dust grains, however just in terms of average values. Therefore both sources of information are complementary and a synthesis can only be achieved by synoptic interpretation of zodiacal light, micrometeoroid, and meteoroid investigations also including dynamical aspects. Measurements of zodiacal light (and emission) from rockets, manned or non manned spacecraft, and deep space probes gained drastically in importance compared to ground based observations. On the other hand investigations on airglow have become more and more a topic of geophysics (aeronomy). They remain relevant however to astronomy as far as photometric features are concerned. These general trends continued in the last triennium and have influenced the activities of our commission.

Although the light of the night sky involves three rather different fields of interest (aeronomy, physics of the planetary system, galactic and extragalactic astronomy) the observational methods and problems are closely related and the results (surface brightness and separation of components) are of equal importance for all investigators, independently of their preferred field of interest. Therefore the commission provided an excellent platform for exchange of results and experience on common problems concerning the light of the night sky which is understood not exclusively in terms of visible light but involving more and more the domain of ultraviolet (UV) and infrared (IR) radiation.

Activities in the field of the commission were concentrated during the past triennium mainly in rocket and satellite experiments and in thorough interpretations of the results obtained by earthbound spacecraft (e.g. D2B, Salyut) and especially by the great deep space probe missions Helios and Pioneer. A highlight was the latest results of the IRAS team contributing much to our field. On the other hand cancellation of the US-Spacecraft for the Out-of-Ecliptic Solar Polar Mission (ISPM) caused considerable damage, since with the Zodiacal Light - Background Starlight Instrument (ZLE) scheduled for ISPM NASA spacecraft we lost the unique opportunity to obtain photopolarimetric measurements from a position out of the ecliptic plane.

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At the end of the triennium preparations were completed for a meeting summarizing the present state of the art concerning the zodiacal dust cloud in a synoptic way: the IAU Colloquium No 85 at Marseille (July 9 to 12, 1984). The proceedings of this meeting ("Physical Properties and Interactions of Interplanetary Dust", Giese and Lamy eds., to be published 1985 by Reidel, Dordrecht) will include about 70 reviews and contributed papers. Books covering topics relevant to our commission were published by Hodge (1981: Interplanetary Dust), by Fishkova (1983: The Night Airglow of the Earth Midlatitude Upper Atmosphere, in Russian), and by Megrelishvili (1981: Regularities of the Variations of Scattered Light and Emission of the Earth Twighlight Atmosphere, in Russian). A review article on "Origin and Evolution of Interplanetary Dust Grains" (33.106.029) was presented by Lamy (1983).

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II. AIRGLOW AND ATMOSPHERE

Numerous papers on the airglow have been published in this triennium. However, since most of them are included in the category of geophysics, we report here only papers on photometric features of astronomical interest.

557.7 nm [OI], NaD, and OH A faint pattern visible to the naked eye was observed by Armstrong 1982 (31.082.037) in the northern region of the night sky at the CSIRO Solar Observatory (30°3S, 149°6E), similar to the phenomenon previously observed by Peterson (26.082.143) in Hawaii. From his photographic and photometric observations, Armstrong concluded that the emission responsible for the visible pattern is 558 nm airglow enhanced by the effect of a gravity wave passing through the emitting layer.

Analysing airglow data obtained at Cachoeira Paulista (22.7°S, 45.0°W) in 1977-82, Takahashi et al. 1984 (   ) concluded that (1) monthly averaged variation of 558 nm emission has revealed a significant semidiurnal oscillation with a seasonal change of the phase of maximum, (2) the 558 nm and NaD emissions show a predominant semiannual variation, but no significant seasonal variation was found for the OH(8,3) emission, (3) a possible correlation was observed in long term variation between the 558 nm emission and the solar activity.

Gegawale and Tillu 1983 (33.082.011) found that the intensity ratios of OH(9,4)/OH(7,3) are systematically different between two types of the nocturnal intensity variations; "continuous decrease" type (observed on 70% of nights) and "increase followed by decrease" type (30% of nights) , observed at Poona, India.

The first photographs of the OH airglow taken by Peterson and Adams 1982 (34.082.072) at Albuquerque during the 5-6 July 1982 total lunar eclipse revealed large (20-30km) east-west waves from horizon to horizon which drifted north-ward at 10-15 m/sec. These waves were not typical of the ripples they have found to be well-correlated with lower lunar transit.

Observations of the nocturnal 558 nm glow in Ashkhabad were used for the study of internal gravity waves by Gavrilov and Sved 1982. Height measurements of the E layer were related to the intensity of the 558 nm glow by Gorbunova et al. 1982 (31.083.029). Several papers on the height of the 558 nm emission layer, characteristics of atmospheric waves according to OH observations, and aeronomical processes were published by Megrelishvili 1982 (31.003.090), 1983

(37.082.088) and Megrelishvili and Fishkova 1983 (37.082.087), 1984 (37.082.032) and Toroshelidze 1983 (37.082.089).

630 nm[OI] Orographic sources were related to emisions (Shefov et al. 1983 (34.002.085) such as to hydroxyl emission temperatures and 630 nm intensity.

The north-south aligned equatorial 630 nm depletions were observed by Mendillo and Baumgardner 1982 (32.082.093) with a new all-sky imaging system on Ascension Island (8.0°S,14°W), and by Carman 1983 (33.082.010) with photometers at Vanimo (2.7°S, 141.3°E). Mendillo and Baumgardner reported that the airglow depletions occur most often before midnight, often cover one-fourth of the sky and are usually not aligned with magnetic meridians. Instrumentation and results of the tropical airglow works during the last few years were reviewed by Kulkarni 1983 (37.082.023)

Space borne Observations From the airglow data measured by the AE-E satellite, Abreu et al. 1982 (32.082.051) developed global pictures of the 630 nm emissions at low latitudes between 1800 and 0400 LT for solstice and equinox conditions. The latter map is more symmetric than the one for solstice condition, in which the winter hemisphere is brighter than the summer hemisphere.

Torr 1984 (preprint) reported first results of atmospheric spectral imaging from Spacelab 1 covering the atmospheric emissions between 30 nm and 1270 nm.

Photographic pictures of Sodium D and airglow emissions (80-100 km) were obtained from space during the Salyut 6 and 7 mission (cf. Koutchmy and Nikolski 1983 (33.106.012). Furthermore noctilucent clouds were observed by Salyut 7.

Atmosphere Color and brightness of the night sky in the crimea derived from observations between 1973-79 were presented and compared to other observation sites by Lyutyi and Sharov (1982).

Gadsden 1982(32.082.085) reviewed the observational facts about the noctilucent clouds, which appear during the summertime at high latitudes near the top of the mesosphere and seem to be ice particles nucleated by either meteoric smoke or by atmospheric ions.

III. ZODIACAL LIGHT

Measurements

General Observations of the Zodiacal Light Most observations have been space observations, especially with the two Helios probes. The general picture of the zodiacal cloud arising from 4 papers (Leinert and Planck 1982, 30.106.026, 31.106.005, Leinert et al. 1982, 30.106.031 and 30.106.032), and summarized in a very useful table (Leinert et al. 1982, 31.106.039) by the Heidelberg group, is that of a very regular, smooth and constant distribution of the dust. No dissymmetry in the polarization state with respect to the antisolar direction has been found, and the only changes (both with short time scale and over the solar cycle) deal with interplanetary plasma, not with the dust. The negative polarization on the borderline of the gegenschein is confirmed. The invariance of the brightness and degree of polarization over 6.5 years including a minimum and a maximum of the solar cycle is remarkable (less than 2% and 0.01, respectively).

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Observations, from the atmospheric Explorer C, D, and E, yielded some galactic and zodiacal light surface maps between 732 and 429 nm (Abreu et al. 1982, 31.106.028).

Verlhac (1983) gave preliminary results of a polarimetric study of the zodiacal light far from the sun, as observed photographically in the blue (460 nm) and in the near IR (800 nm) from Salyut 7. The polarization degree seems to be somewhat higher in the near IR.

Preliminary results of a Doppler-Fizeau spectrometry at high ecliptic latitudes by Robley et al. 1982 (31.106.034) are in favour of high radial velocities.

Ground-based observations are reported by Asaad 1982 (31.106.040 and 31.106.37) from Abu-Simbel, Egypt, with special attention to possible intrinsinc variations. Pfleiderer and Leuprecht 1983 (34.155.099) reported about results of the analysis of Pfleiderers surface photometry which is meanwhile completed (isophote maps in V: zodiacal light and Milky Way).

A contribution to the problem of separating the zodiacal light from other components of the night skylight from ground has been given in his thesis by Alvarez Martin (1981).

Inner Zodiacal Light Photographic observations at rather low elongations have been made from the Salyut manned spacecraft. From Salyut 6 (Grechko et al., 1982 31.106.003) have been reported a strong N-S dissymmetry of the cone and an elongation gradient from 25 to 40° steeper than previously found. However, a telluric interpretation, due to the upper airglow emissions, is suggested by the authors for both effects. Pictures have also been taken from Salyut 7 by Russian and French cosmonauts, down to 22.5° elongation (Koutchmy and Nikolski, 1982 32.106.043), adding their contribution to knowledge of the inner zodiacal cloud. During the solar eclipse July 31, 1981 Shestakova and Shcheglov 1983 obtained velocity distributions of the inner F-corona grains at 3-7 solar radii by Fabry-Perot interferometry, which were the basis of a model (Shestakova 1983). A balloon observation of the total solar eclipse June 11, 1983 was carried out by a Japanese-Indonesian team involving photopolarimetry of the F-corona in the visual and near infrared wavelength region.

Ultraviolet Observations An important study of the zodiacal light in the UV domain has been made by Cebula and Feldman 1982 (32.106.045) in two directions at small elongations (21 and 30°), near the ecliptic. Down to 210 nm the colour was found slightly redder than the sun. The upper limit found for the zodiacal brightness at 180 nm, although being 4 times higher than expected from the solar flux, is lower than previous determinations and cannot be considered a true indication of any brightening of the zodiacal light in the UV. The elongation gradient is only slightly steeper than usually obtained in the visible domain. Fahr, Ripken and Lay 1981 (30.106.20) investigated plasma-dust interactions in the solar vicinity which lead to observational consequences in UV. Their corresponding sounding rocket experiment scheduled for 1985 is described by Neumann et al., 1983 (34.035.010).

Infrared Observations Hauser et al. 1984 reported first results of the IRAS satellite. They reveal bright emission from interplanetary dust which dominates the celestial background at 12, 25, and 60 μm except near the galactic plane. At 100μm zodiacal dust emission is dominant only near the ecliptic plane.

The plane of symmetry The IRAS infrared data of Hauser et al. 1984 show that the angular variation in the plane (ε =68.6 to 103.3°) and at a plane ε =90°

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including annual variation at the pole are generally consistent with previously determined dust distributions and with the previously determined symmetry plane (i=3°, Ω=87° from visual observations (Misconi and Weinberg (22.093.001), Leinert et al. (27.106.003).

From numerical integrations of pertubation equations considering the gravitational forces of the planets, radiation pressure, ion drag, and the Poynting-Robertson effect, Gustafson and Misconi (1983) showed that the long-term dynamical evolution of interplanetary dust is strongly affected by the inner planets, and the perturbations may explain the observed inclination of the symmetry plane.

On the other hand, Winkler et al. 1982 (31.106.010) showed from their photographic observation in $140° \leq \varepsilon \leq 180°$ that the brightness profile of the Gegenschein perpendicular to the ecliptic can be represented by a superposition of three components of Gaussian form. The symmetry plane they determined from the centroids (not the peak brightness) of the brightness profiles has Ω =14°±10°, ℧ =206°±6° and i=1.0°±0.4°.

Burkhardt 1982 (31.091.006) revised the position of the invariable plane of the solar system using new sets of masses and orbital elements of the planets yielded by recent spaceflights. Inclination and ascending node of the calculated invariable plane at the new standard epoch J2000.0 are 1°35'13".86 and 107°36'30".8, respectively.

Interpretation of Measurements

Scattering properties of dust grains from laboratory work and theory. Interpretation of optical or infrared measurements of the zodiacal cloud needs information about the differential scattering cross sections and absorption efficiency of typical dust grains including a possible wavelength dependence. Using laser (663 nm) light scattered on single particles in the size range 10 to 200 μm Weiss-Wrana 1983 (33.022.050) obtained scattering functions for terrestrial and meteoritic materials. These investigations are being extended to different wavelengths. Microwave analog measurements were continued at Bochum (8.6 mm) and at Gainesville (3.18 cm) for linear configurations of two (30.063.062) and multiple spheres and in a systematic study for dielectric ellipsoids (Schuerman et al. 1981, 30.063.061). Theoretical studies of rough grains using geometrical optics approaches were continued by Perrin and Lamy(1983),Mukai et al. (1982), Schiffer and Thielheim (1982, 32.106.040). They were in agreement with laboratory results. Colour effects of microroughness were taken into account by Schiffer and Thielheim (1983, 34.106.033). Generally angular dependence of scattered intensity and linear polarization of absorbing irregular grains resemble the volume scattering functions derived from zodiacal light observations. The problem of the exact definition of albedo and its application to irregular particles was treated by Hanner et al. (30.106.034) on the basis of microwave results obtained at Bochum. A workshop on Small Particles and Light Scattering took place at Kiel (Proceedings Thielheim ed., 1984).

Dust Properties from Zodiacal Light Observations To achieve information on scattering properties of interplanetary grains and on the spatial distribution two types of work were published during the triennium:

1. Modelling of the optical properties and of the sizes of interplanetary dust grains mainly from the empirical scattering function and polarization curve, with reference to laboratory experiments (microwaves, laser: Greenberg and Gustafson 29.106.001, Weiss-Wrana 33.022.050 or to theoretical work (Schiffer and Thielheim 32.106.040). There are still disagreements on the nature (dielectric vs. absorbing) and on the shape (irregular, fluffy particles, bird's nests) of the

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scatterers. An unsolved question seems to be the degree of confidence in the empirical volume scattering functions and polarization curves due to the unavoidable increase of their error bars when the scattering angle decreases.

In a paper devoted to the F-corona, Beard (35.160.) showed that infrared coronal polarization measurements could bring rather accurate determinations of the size and albedo of the interplanetary dust, and reveal the heliocentric distance at which the dust vaporizes.

2. Remote sensing of the zodiacal cloud in or near the ecliptic. A valuable survey of the in-situ inversion concept, mainly applied to space probes and especially to Pioneers 10-11 has been given by Schuerman and Weinberg 1983 (33.106.028). As shown by Dumont and Pelletanne (30.106.029), local information at given points on the line of sight can be retrieved from the brightnesses and the polarization degrees at the two intersections of that line with the terrestrial orbit. Two "nodes of lesser uncertainty" exist, one inside and one outside the orbit, the locations of which are favourable for disentangling the heliocentric from the angular variations of the scattering coefficient and polarization (Pelletanne 1982, Dumont 1983 34.106.018). The work has meanwhile been extended to locations far from the Earth's orbit and to topics like Doppler and infrared measurements. The method avoids the increasingly doubtful assumption of a homogeneous cloud which in fact is invalidated by its results (significant radial gradient of polarization). This corroborates the conclusions resulting from earlier works of Leinert et al. (30.106.026) and Schuerman et al. (28.106.029).

Spatial Distribution of Dust Attempts have been made by Buitrago et al. 1983 (33.106.011), Buitrago et al. (31.106.038), Mujica et al.(34.106.005) to derive the off-ecliptic distribution of the dust, either by a new inversion process based on integral equations of Volterra types, or by an extension of previous works valid in the ecliptic (28.106.002). The isodensity surfaces are found to be fan-like with a possible, theoretically complete, depletion of the dust near 45° heliographic latitude. Unfortunately, due to the difficulty of the problem, the model-dependence is heavy. Both the ecliptic and the off-ecliptic cases, with less model-dependence in the former case, have been developed in a thesis by Mujica (1981). More conventional models (fan, ellipsoid) were discussed by Kinateder (1983) with respect to diagnostic signatures observable by an Out-Of-Ecliptic Mission. Since there is no such opportunity in the space program this investigation is now being applied at Bochum to all sky observations from the ecliptic plane, including low elongations. Preliminary results seem to provide signatures which allow one to exclude multiple fan models as proposed by Buitrago et al.

IV. GALACTIC COMPONENTS

A review article and summary of the workshop on the ultraviolet background radiation including all different components from airglow to extragalactic has been presented by Henry, 1981 (32.142.082). A computer program for estimating the different components of light of the night sky as observed from a space platform has been presented by Barbieri and Nota (1983).

Optical An extensive photographic UBVR surface photometry of the whole Milky Way has been carried out by Schmidt-Kaler et al. 1983 (33.155.005) using a superwide angle camera with a spherical mirror. Detailed analysis of the data have already been published of the Coalsack region by Seidensticker et al. 1982 (32.155.026), the central area of the Galaxy by Pröll et al. 1983 (33.155.006) and the Northern Milky Way in U colour by Winkler et al. 1982 (31.106.010). Using the Helios 1 and 2 space probes Leinert and Richter 1981 (33.155.033) have measured the UBV intensities and colours along eight strips across the Milky Way. The calibration appears to be very reliable and the results have been used to test previous all sky photometric maps of the Milky Way. Leinert and Richter 1983 (33.167.067) have further used the Helios data in search for polarization of the Milky Way light at l=150° and l=223° and obtain some marginal indication for a polarized component perpendicular to the galactic plane. Toller 1981 (32.155.018), 1982 (33.131.184), 1983 (34.155.096)) has used the Pioneer 10 measurements for a background starlight study in B and R colours with the intention to derive information on large scale galactic structure and the scattering properties of the dust. For the albedo and asymmetry parameter at 440 nm Toller gives values of 0.61 ± 0.07 and 0.6 ± 0.2, respectively, which are in agreement with the previous results. Reynolds 1983 (33.155.109) has analyzed the diffuse Hα emission along galactic equator from l=0° to 240°, also with respect to Hα being scattered by dust.

Near Infrared Near Infrared surveys of surface brightness near the galactic plane were performed by Hayakawa et al. 1981 (30.156.001), at 2.4 and 3.4 μm. The interpretation of near IR surface brightness is similar to the optical wavelength region, including the model for the distribution of volume emissivity (i.e. stars) and for the extinction. Galactic mid- and far IR emissions are dominated by a different source (thermal emission by dust) and are not covered by this review.

Ultraviolet Zvereva et al. 1982 (32.157.012) and Severny and Zvereva 1983 (34.142.043) have presented 110-185 nm surface brightness measurements carried out on board of the satellite Prognoz-6. At low latitudes $|b| \leq 30°$, DGL is observed and interpreted in terms of dust scattering models. At high galactic latitudes a good correlation has been found with soft X-ray background brightness and neutral hydrogen column density. The authors suggest that hot (10^5 - 10^6K) interstellar gas is responsible for the observed emission in some high galactic regions. A line emission component of the hot coronal gas is suggested by the observations of Feldman et al. 1981 (30.158.161). Deharveng et al. 1982 (31.131.162) have investigated the contribution of the warm ($\sim 10^4$K) intercloud gas to the UV background and conclude that it is in general unimportant. Joubert et al. 1983 (34.142.044) in a continued analysis of the D2B-Aura satellite data at 169 and 220 nm confirm the existence of a correlation of the UV sky brightness with the HI column density and the interstellar extinction. The asymmetry factor of the scattering phase function is determined to 0.6-0.7. Further small scale I(UV) vs. N(HI) correlation studies have been made by Jakobsen et al. 1982 (33.142.090). Andersson et al. 1982 (32.157.001) and Henry 1981b (29.157.005), 1982 (32.162.188), 1982 (32.142.082) using Apollo 17 data, have found no DGL from dusty moderate galactic latitude fields at λ =118-168 nm and conclude that either the grains are extremely strongly forward scattering (asymmetry factor g = 0.9) or their albedo is low ($\leq$ 0.2). Jakobsen 1982 (31.131.067) suggests that the UV background intensity vs. HI column density correlation may be partly due to rapid H_2 photodissociation in addition to the scattering.

V. EXTRAGALACTIC COMPONENT

Using the Pioneer 10 photopolarimeter data Toller 1983 (33.161.030) has derived an upper limit of 3.9 $S_{10}(V)_{G2V}$ at the 2σ level for the brightness of the extragalactic background at 440 nm. This measurement was free of airglow and zodiacal light contamination but a large correction was needed to account for the galactic foreground starlight. The UV background level, after substraction of the galactic components, has been found to be in the range 160-360 units at 220 nm and 150-700 units at 160 nm (Feldman et al. 1981, 30.158.161, Joubert et al. 1983, 34.142.044, Tennyson et al. 1982, 32.142.064) (unit= photons $cm^{-2}s^{-1}Å^{-1}sterad^{-1}$). Weller 1983 (33.142.103) using 122-150 nm measurements from the Solrad 11 satellite gives the upper limits of 180 and 280 units near the north and south galactic poles, respectively. Wulf-Mathies et al. 1983 (33.0335.056) have presented observations of the extreme UV background and give as upper limit to the extragalactic contributions the value 3.90×10^4 units in the wavelength regime 75-94 nm, and 9.7×10^3 units in the band 104-100 nm. In addition, EUV measurements have been reported by Kimble and Bowyer 1982 (33.142.089). Paresce 1983 (34.161.294) has presented a review on the attempts to measure the UV background radiation of cosmological origin.

Theoretical calculations on the contribution of galaxies to the ultraviolet and optical background radiation have been presented by Code and Welch 1982 (31.158.094) for nonevolving and evolving galaxies. They used the UV energy distribution curves as obtained from OAO 2 measurements. They conclude that normal galaxies can account for anything from a few percent to all of the measured background radiation. Bruzual 1981 (32.066.034) has carried out similar calculations. Ceccarelli et al. 1983 (34.161.148) have proposed for the measurement of the far IR extragalactic background a new method, which utilizes the dipole anisotropy due to the observer's motion.

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