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Commission 21: Light of the Night Sky

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1. Introduction

Commission 21, one of IAU's smallest commissions, consists of some hundred members and consultants working to understand and describe the light of the night sky with emphasis on the diffuse components. Many more work on these topics without being members of the commission. Light is here defined in its broader sense of electromagnetic radiation of any frequency. The diffuse components of the light of the night sky encompass a variety of physical phenomena over the full range of cosmic distance scales and include scattered light, thermal emission, line emission, and any other emission phenomena producing a diffuse light source. These attract interest not only as scientific topics of study in their own right but also as an unwanted foreground or background against which all other sky phenomena are observed. Commission 21 has for mandate to promote research and availability of results on issues related to the diffuse light of the night sky. This document is a report on activities in this field and is not confined to the activities of its members, no distinction is made between work carried out by commission members and non commission members. The report is organized starting with a summary of the state of broad surveys that provide most of the observations. The report on developments in the various disciplines start with the sources closest to the observer known as airglow and progresses by way of the interplanetary and interstellar mediums to the increasingly distant integrated starlight, diffuse galactic light and diffuse emission in other galaxies ending with the extragalactic background radiation.

2. Sky surveys

Despite its age, the all-sky infrared survey conducted by IRAS continues to yield improved all-sky IR emission maps, which will be of particular use by providing information about the galactic foreground emissions for the Planck mission. Using COBE DIRBE data for improved reduction, Miville-Deschenes and Lagache (2005) produced the latest generation of IRAS maps, called IRIS, which have benefited from better zodiacal light subtraction, improved calibration and zero-point adjustment and better destriping at scales larger than 0.7 degrees. The Odin satellite continued its successful observations of airglow and of the diffuse interstellar medium (Frisk *et al.*, 2004). The triennium has also seen the launch of the Spitzer in August 2003 capable of performing imaging and spectroscopy in the 3.6 to 160 micron range. It has provided a quantum jump in sensitivity and spatial resolution in our ability to observe emission from dust in our Galaxy and in extragalactic systems. Mid-IR dust emissions are being observed with the InfraRed Spectrograph (IRS) and the InfraRed Array Camera (IRAC), while the far-IR thermal radiation is being probed with the Multiband Imaging Photometer for Spitzer (MIPS). STSAT-1, also known as KAISTSAT-4 followed in September 2003. The primary objective of the mission is to provide spectral information on diffuse hot Galactic plasmas and supernova remnants with the Far Ultra-violet Imaging Spectrograph (FIMS, also known as SPEAR). The same instrument also looks back at Earth to make observations of auroras and airglow with high spatial resolution and detailed spectral information for a space physics mission. Diffuse radiation is also covered from the ground. Although the diffuse radiation is not its primary objective, the Sloan Digital Sky Survey will when complete cover approximately a quarter of the sky in a broad spectral range visible from the ground. In the next triennium coverage particularly to longer wavelengths infrared/submm/mm is also anticipated from the L2 orbiting observatories of Herschel and Planck. Surveys that are specific to diffuse light include the WIZARD (Wide field CCD camera) ground-based campaign aimed at zodiacal light studies (Yoshishita *et al.*, 2002). Observations made to date (Ueno *et al.*, 2005) include calibration using resolved stars to yield reliable colors. Polarization observations are also expected in the coming triennium. Kwon *et al.* (2004) report the development of a wide-field imaging camera system with similar capabilities called WICZO. An all-sky cloud-monitoring system that generates relative opacity maps over many of the world's premier astronomical observatories is described by (Shamir and Nemiroff, 2005) while Otsuka *et al.* (2002) used all-sky imagers to monitor the airglow.

3. Light pollution

A large contingency of professional astronomers, amateur astronomers, and members of the general public voice their concern that light pollution of the skies from artificial lightning significantly degrade their ability to observe the natural night sky. Organizations such as the International Dark Sky Association (www.darksky.org) continue their efforts to help prevent adverse environmental impact on dark skies. They build awareness of the problem of light pollution and of the solutions and educate about the value and effectiveness of quality nighttime lighting. The regional branches of the International Dark-Sky Association organize symposia approximately annually. Early in the triennium, Smith (2003) described the IAU's effort to control light pollution.

4. Airglow

Slanger and Wolven (2002) summarized the beginning of the triennium state of understanding of Airglow Processes in Planetary Atmospheres. New results since then include the observation of magnetic field induced large-scale depletions in 630.0 nanometer airglow intensity at mid-latitude geomagnetic conjugate points (Otsuka *et al.*, 2002). Gravity wave dynamics work based on airglow has to this point used empirical models for the amplitude of airglow brightness fluctuation dependence on the amplitude of major gas density fluctuations. A step forward may be taken by Hickey and Yu (2005) who derived theoretical correlations through modeling of gravity wave dynamics with the chemistry relevant to the observed airglow emission.

In addition to airglow in the terrestrial atmosphere, airglow phenomena in the atmospheres of Venus, Mars, Jupiter and Titan were also studied but are not considered to be part of the diffuse light of the night sky as seen from the Earth. These works are therefore not discussed here.

5. Scattering and thermal emission from the interplanetary dust cloud (Zodiacal Light)

Photo-polarimetric nightsky observations at Mt. Haleakala, Hawaii from 1968 obtained by J. L. Weinberg still yield new Zodiacal Light brightness maps. Kwon *et al.* (2004) derived maps with spatial resolution of 2 degrees square at 10 percent relative brightness uncertainty level. They show asymmetries in the ZL brightness distribution over the morning and evening sides and also over the northern and southern ecliptic hemispheres that are in broad scale agreement with thermal emission data. Leinert *et al.* (2002) reported 29 featureless ISOPHOT spectra of the Zodiacal light that they interpret as evidence for a well-mixed zodiacal cloud. Fixsen and Dwek (2002) combined observations in the 10–1000 micron wavelength interval from the DIRBE and FIRAS instruments on the COBE satellite to derive a sharp break in the dust size distribution at a radius of about 30 micron. Hahn *et al.* (2002) described Clementine observations of the inner Zodiacal light brightness. Reynolds *et al.* (2004) used improved Fraunhofer line Doppler shift observations and reductions to limit the fraction of retrograde orbits to less than 10 percent and they report no observable net dust outflow from the solar system. The reduction of the spectra included the discovery and removal of extremely faint, unidentified terrestrial emission lines that contaminate and distort the underlying Mg I profile and may have affected earlier measurements. Reach (2005) used the infrared spectral and imaging capabilities of the Spitzer space telescope to find new structures in the Zodiacal light including dust trails from short-period comets. He also found weak 9-11 micron silicate spectral features from some comets and the zodiacal light and the color temperature of cometary dust trails.

While dust instruments on the Ulysses, Galileo and Cassini missions have monitored dust impacts, most particles are smaller than the dust particles giving rise to the Zodiacal light therefore and since these are impact rather than light data they are not covered in this report. The emergence of new space- and ground-based instruments promises an exciting next triennium.

6. Radiation from Interstellar Dust

Interstellar dust contributes to the diffuse sky background by scattering stellar radiation and by emitting radiation through a number of processes. Dust scattering properties are essential input parameters for models of radiative transfer in galaxies and as a constraint for dust models. Gordon (2004) provided the most recent review of dust scattering properties as derived from observations at UV, visible, and near-IR wavelengths. Observations by orbiting X-ray observatories Chandra and XMM/Newton also permit the study of X-ray scattering as a further constraint for interstellar dust models (Dwek *et al.*, 2004). Dust emission occurs through photoluminescence via electronic transitions in very small particles at optical wavelengths, through vibrational and bending modes at mid-infrared wavelengths, through non-equilibrium and equilibrium thermal emission in the near-infrared to sub-mm spectral range, and through microwave emission in the 10–100 GHz regime due to electric dipole radiation from rapidly spinning charged nanoparticles. Optical photoluminescence is being observed in two broad bands, the extended red emission (ERE) and the recently discovered blue luminescence (BL). The ERE has been reviewed recently by Witt and Vijh (2004). The carrier of this emission process remains unidentified, although recent work on the excitation requirements for the ERE (Witt *et al.*, 2006) has provided new constraints which point to macro-molecular ions as a possible source. BL has been discovered recently (Vijh *et al.*, 2004, 2005a,b) in the Red

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Rectangle nebula and other ordinary reflection nebulae. The spectral characteristics and spatial morphology of this emission suggest fluorescence by small, neutral PAH molecules as a likely source. Given that small PAH molecules are not expected to survive long in the diffuse interstellar medium, it seems likely that the BL carriers are produced by phot-fragmentation of larger PAHs or of PAH clusters. PAH molecules and ions are also implicated as the probable source of the mid-IR aromatic emission features. The status of this field has been advanced significantly by ISO results, as reviewed by Peeters *et al.* (2004). Information about the galaxy-wide distribution of the aromatic emission features has been enhanced substantially by sensitive observations with IRTS/MIRS (Onaka 2004; Sakon *et al.*, 2004).

Efforts to separate the cosmic background radiation (CBR) from various galactic foreground emissions (Jaffe *et al.*, 2004) have revealed the presence of a dust related component which displays all the characteristics expected from electric dipole radiation produced by rapidly rotating nanoparticles (Finkbeiner *et al.*, 2004), as originally predicted by Draine and Lazarian (1998).

7. Diffuse Light in Galactic Clusters

The long-elusive diffuse light in galactic clusters, presumably due to light from stars stripped off their galaxies as a result of tidal interactions during close passages, is finally being detected (Zibetti *et al.*, 2005; Adami *et al.*, 2005, Aguerri *et al.*, 2005; Mihos *et al.*, 2005). Typical surface brightness values are in the range from 27.5 mag arcsec^{-}2 to 32 mag arcsec^{-}2, with the intra-cluster diffuse light showing a stronger central concentration toward the cluster centers than is exhibited by the cluster galaxies.

8. Cosmic Background Radiation

Claims that the extragalactic background radiation at optical wavelengths has now been detected (Bernstein *et al.*, 2002a,b) remain contested (Mattila 2003; Bernstein *et al.*, 2005). The uncertainties about the intensity and spectrum of the optical extragalactic background radiation also affect the interpretation of the interpretation of the near-infrared extragalactic background light, for which measurements were reported recently by Matsumoto *et al.* (2005). If both the optical and near-IR measurements are correct as published, the combined spectrum can be interpreted successfully as resulting from the red-shifted emission spectrum of massive Population III stars at redshifts of z 7–10. However, concerns focus on the fact that the derived spectrum of the near-IR background light is almost identical to the spectrum of the zodiacal light (ZDL), raising the possibility that uncertainties in the current Zodiacal Light models used in correcting the observations may have been underestimated. Fortunately, very high energy gamma-ray spectra from blazars are attenuated by photons from the extragalactic background light (Dwek and Krennrich 2005), and future gamma ray observations may in time provide an independent method for the determination of the density of background photons.

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Bo Å. S. Gustafson President of the Commission

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