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Studies of diffuse UV radiation

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Abstract. The upcoming TAUVEX mission is expected to provide us with high quality data from observations over large parts of the sky in different wavelength bands. We propose to use this data for the study of diffuse radiation field and its sources in the UV, where much of the energy transfer between the stellar radiation field and the interstellar medium occurs. In this paper we describe, our method for development of tools and techniques to extract the astrophysical diffuse radiation using available GALEX data which will be used to analyse the data from the TAUVEX mission, our future plans and expected science returns.

Keywords : ultraviolet: ISM – ISM: dust: extinction, diffuse radiation

1. Introduction

Astronomy has always been dominated by the study of individual sources, whether stars, galaxies or nebulae. In such an environment, interstellar dust has been considered a hinderance, blocking and altering the light from the more interesting objects and the primary interest was in removing its effects. However, we now understand that interstellar dust (and gas) is interesting in its own right and plays a crucial role in the evolution and dynamics of a galaxy, as well as in star formation.

Observations of the interstellar dust present difficulties because of their diffuse nature and low surface brightness compared to other sources of radiation from instrumental dark count to zodiacal light to unresolved stars. In principle, the ultraviolet (UV) should be one of the best spectral regions to observe this radiation because of the low background,

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as much as 5 magnitudes/square arcsecond less than in the optical (O'Connel 1987). The ultraviolet is also important in that most of the energy of the stellar radiation field is in the UV and absorption of this radiation by the dust grains powers their infrared emission which could in some cases dominate the light from galaxies.

The observed diffuse UV radiation field is almost entirely due to starlight scattered by interstellar dust. Two major UV missions are expected to be launched in the near future: TAUVEX, scheduled for an early 2008 launch into a geostationary orbit and ASTROSAT/UVIT, scheduled for a late 2008 launch. Both of these missions will produce data over large parts of the sky, which can be used to study this dust scattering in our Galaxy.

The UV satellite, GALEX was launched in June 2003 and has already observed many regions over the sky in two wavelength bands - FUV (1528 Å : 1344-1786) and NUV (2271 Å : 1771-2831). These data are available over the web, including some of our own observations, with a total data volume close to 100 GB and provide an unmatched database with which to probe the diffuse UV radiation and hence the dust properties. In this paper, we describe a sample GALEX observation (DIS 8 - SIRTFEL_03), the method adopted to reduce the diffuse part and the expected science returns.

2. Objectives and science returns

Our main objectives are:

(1) Development of automated tools and techniques to reduce the GALEX observations which will be invaluable for TAUVEX and ASTROSAT missions, thus enhancing the scientific returns from such missions.

(2) Development of techniques for analyzing diffuse background images. GALEX data will be used to validate the procedures and to investigate the nature of the diffuse radiation field, its sources, and the properties of the interstellar dust grains as a function of wavelength. In addition we also intend to study the corelation of diffuse UV radiation with hydrogen column density in the ISM using these data.

(3) Implementing the software and techniques already developed, for the analysis of TAUVEX data in collaboration with the TAUVEX science team. TAUVEX data will supplement and extend GALEX data to map the entire sky and is expected to yield crucial new insights into the formation and evolution of the interstellar dust.

3. Observations and data analysis

The Galaxy Evolution Explorer was launched into a low-Earth orbit (690 km) by a Pegasus XL launch vehicle on April 28, 2003. Using a 50 cm telescope and a dichroic

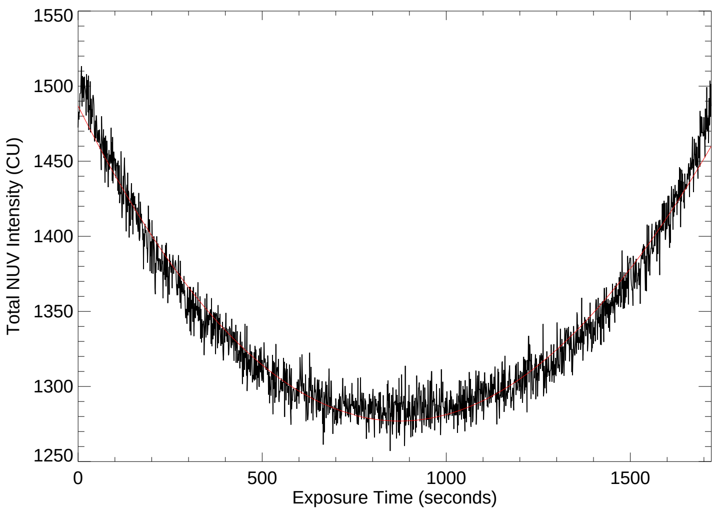

Figure 1. The variation of total signal in the NUV band in CU (photons cm^{-2} s^{-1} sr^{-1} Å^{-1}) during one visit.

beam-splitter, light from the sky is focused onto two detectors, one in the far-ultraviolet (FUV) (1350 - 1800) and the other in the near-ultraviolet (NUV) (1800 - 3200). The field of view of the instrument is circular with diameter 1.25 degrees and has a spatial resolution of about 4.5/6.0 (FUV/NUV) arcseconds (FWHM). The primary goal of the mission was to study the evolution of galaxies at low to moderate redshifts but, of course, the instrument has been used for many other purposes (see Martin et al. (2005) for references).

The observed details are provided as FITS files in the Space Telescope MAST system from whence we have downloaded several dozen observations to allow us to develop the procedures to extract the dust scattered component. The diffuse UV radiation field is comprised of several components (Leinert et al. 1998) including the instrument dark count. The dark count has been measured at about an average of 20 (58) counts/s in FUV (NUV) band over the entire detector.

Airglow from the Earth's atmosphere is a strong function of the observation direction and the time of day and as such is expected to vary throughout an observation. We have used the event counter on the instrument, which records the count rate of the detector during each visit, to track the total signal. These curves have the same shape for all observations (Fig. 1) and we have assumed that the minimum in the curve corresponds to zero airglow, expected in the middle of the orbital night. We can then estimate the average contribution of the airglow to the observed signal and find it to be at a level of about 50 photons cm^{-2} s^{-1} sr^{-1} Å^{-1} in the GALEX observations. However in the case

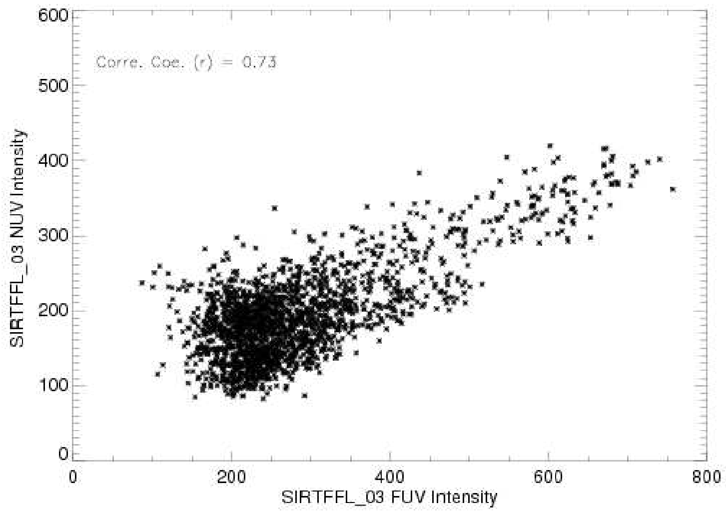

Figure 2. Correlation between FUV & NUV intensities for Dis8.

of TAUVEX, as it is in the geostationary orbit, the terrestrial emission which often affect satellites in lower orbits will not be present (except for the Lyman lines of hydrogen which will be blocked by the filters).

Next to consider is zodiacal light i.e., sunlight scattered from interplanetary dust grains. The spectrum of the zodiacal light is essentially the solar spectrum and, as the Sun is a cool star, there is very little flux below 2000 Å. The level of zodiacal light is dependent on the angle from the Sun and the distance from the ecliptic plane and can vary from 300 to 10,000 photons cm^{-2} s^{-1} sr^{-1} $Å^{-1}$ (photon units) in the NUV (considering the fact that GALEX is constrained to operate at more than 90 degrees from the Sun) but not more than 5 photon units in the FUV detector. Leinert et al. (1998) has tabulated the zodiacal light intensity in photon units as a function of helioecliptic coordinates and we have used these values in our procedure to account for the zodiacal light.

Only after the removal of the contributions due to airglow and zodiacal light can we assess the contribution of the radiation of interest to us: the diffuse Galactic background. This radiation is almost entirely due to dust scattered starlight and the extragalactic light which may be due to a variety of sources (Henry 1991), perhaps the most interesting of which is a recombining intergalactic medium (Henry1999). The Galactic light is a strong function of line of sight and can vary from almost nothing at the Galactic poles to a few lakh photon units near OB associations, such as Orion. On the other hand, the extragalactic background should be constant, except for Galactic extinction, with a value of about 300 photon units.

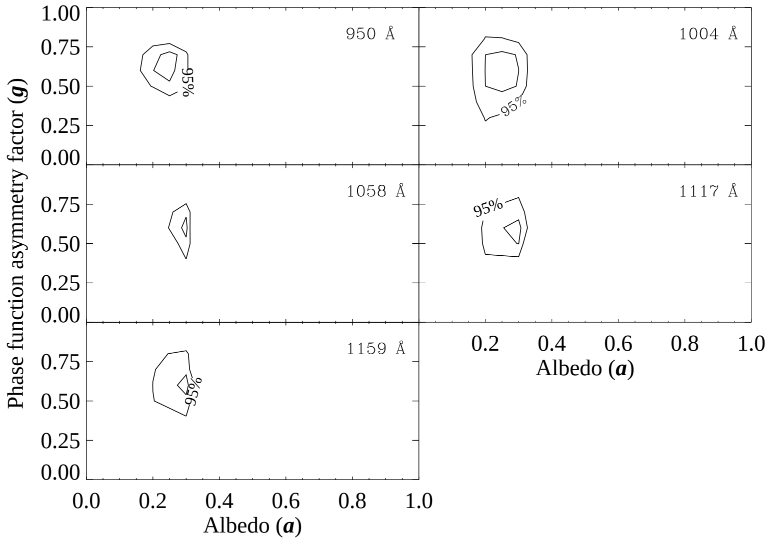

Figure 3. 67% & 95% confidence contours (g versus a) for the Coalsack region at different wavelengths.

The procedure adopted earlier is illustrated in Fig. 2, for one of the GALEX data sets (e.g. Dis 8 - SIRTFEL_03). After the removal of stars present in the field, we have subtracted all of the foreground emission such as airglow and zodiacal light and plotted the dust scattered component of NUV against the FUV for the center 1.0 degree field after increasing the pixel size to 1 arcminute squared to increase the signal to noise. Because the spectral shape of the diffuse radiation field is flat (Murthy & Henry 1995), the NUV should be correlated with the FUV and, indeed, in this observation it is. As mentioned above, GALEX has observed fields over the entire sky, albeit limited to high Galactic latitudes. We plan to examine all these fields, as they become available, to probe the dependence of the diffuse Galactic light (and hence the dust) on environment.

4. Modeling

While the first step in our proposal is to extract the diffuse background from the GALEX data, our goal is to understand the properties of the dust grains which are the major contributors to the background. We have earlier modeled the dust scattered light using the observations obtained with the FUSE (Far Ultraviolet Spectrographic Explorer) at wavelengths below 1200 Å (Sujatha et al. 2005; Shalima et al. 2006) and derived the properties of dust grains in different regions, and the same methodology will be used here.

The diffuse UV light is due to light from O and B stars scattered by interstellar dust.

As such, we have to know the distribution of the sources (stars) and the scatterers (dust). Fortunately, there are only about 10^5 stars that are bright enough (within a few hundred parsecs of the Sun) to contribute to the UV scattering (Sujatha et al. 2004) and their spectral types and locations are tabulated in the Hipparcos catalog. Sujatha et al. (2004) have used these data to calculate the stellar radiation at any point in space. The dust distribution is more difficult to trace but can be estimated from the infrared 100 μm emission (Schlegel et al. 1998) and the column density of neutral hydrogen from 21 cm survey (Dickey & Lockmann 1990).

We have developed a Monte Carlo model to use these inputs along with the scattering function of the dust grains to predict the scattered radiation in any direction as a function of the optical properties (albedo and phase function) of the dust grains. We have applied this model to FUSE observations in Ophiuchus (Sujatha et al. 2005) and the Coalsack (Sujatha et al. 2007) finding that the albedo of the dust grains could have a value 0.3 ± 0.1 and the phase function asymmetry factor may be 0.62 ± 0.14 (Fig. 3).

5. Conclusion

We plan to use data from the available GALEX mission and the forthcoming TAUVEX and ASTROSAT missions to study the diffuse UV radiation field and, by extension, the optical properties of interstellar dust grains in the UV, where much of the energy transfer between the stellar radiation field and the interstellar medium occurs. We are now developing techniques to extract the astrophysical diffuse radiation from the large set of GALEX data already available.

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