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Interstellar dust studies with TAUVEX

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Abstract. We propose to carry out studies on the properties of interstellar dust using TAUVEX. Through the multi-band TAUVEX observations, particularly with the use of filters optimized for extinction observations of the 2175 Å feature, combined with optical observations and 2MASS archived data, we can derive the extinction curve from UV to near-IR for stars located in different regions and environments. The extinction curve is a sensitive indicator of the properties of the interstellar dust and, as such, will allow us to trace the properties and evolution of the interstellar dust as a function of environment.

Keywords : ISM: dust, extinction – galaxy: general

1. Introduction

The existence of dust in the vast space between stars was known to astronomers for 70 years. The first knowledge on the interstellar dust came from the obscuration of starlight by the micron sized grains in the interstellar medium which is often termed as interstellar extinction (Trumpler 1930). Apart from its role in extinction, interstellar dust plays vital importance in governing several physical, chemical as well as biological processes in our galaxy, though the dust-to-gas mass in the interstellar gas is around 0.6 %. Much of our knowledge on interstellar dust continues to be based on the amount of attenuation of star light, and its dependence on the wavelength and spectral features. The wavelength dependence of interstellar extinction is due to scattering and strongly constrains the grain size distribution, whereas the spectral features of the extincted light reveal the chemical composition of the grains as it is due to resonant absorption. Interstellar extinction

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varies with the direction significantly implying that the properties of interstellar dust is not uniform in the Galaxy.

Interstellar extinction is more reliably determined using pair method by comparing the spectrophotometry of the same spectral type stars; one having negligible dust and the other being heavily reddened. Comparing the two spectra together with the assumption that the dust extinction goes to zero at very large wavelengths, the wavelength dependent extinction can be determined as $A_\lambda = 2.5 \ \log_{10} \ (\frac{F_{\lambda 0}}{F_\lambda})$, where $F_{\lambda 0}$ is the unattenuated star flux and F_λ is the reddened star flux. This method is used to measure extinction curve in many cases over a range of wavelengths extending from near-IR to UV.

2. Optical and UV extinction curves

The dimensionless quantity $R_V = A_V/(A_B - A_V)$ is the common measure of the slope of the extinction curve in the optical region. For very large grains (much larger than a micron) the value of R_V goes to infinity and for grains, which have dimension much less than a micron, Rayleigh scattering causes very steep extinction of $R_V \sim 1.2$ falling in the lower end of the Mie domain for visible dust. As a result of large variations in the grain size distribution in our galaxy, the value of R_V varies from 2.1 towards HD 210121 (Welty & Fowler 1992) to as large as 5.8 towards HD 36982 (Fitzpatrick 1999). The normalized extinction curve A_λ/A_I (A_I is the extinction at I band) can be approximated by a seven parameter function of λ given as $A_\lambda/A_I = f(\lambda; R_V, C_1, C_2, C_3, C_4, \lambda_0, \gamma)$ where, the parameters C_3, λ_0 and γ determine the strength and shape of the UV bump at 2175 Å whereas the coefficients C_1, C_2, C_4 determine the slope and curvature of the continuous extinction at $\lambda < 3030$ Å. For wavelengths larger than 3030 Å, the normalized extinction curve depends only on wavelength and parameter R_V.

The optical and UV extinction can be approximated by a one parameter family of curves, since the values of six parameters $(C_{1-4}, \lambda_0, \gamma)$ can be derived, if R_V is known Cardelli et al. (1989). However, if there are direct measurements of UV extinction, improved fit to the observations can be obtained by fitting $C_{1-4}, \lambda_0, \gamma$ to the measured UV extinction.

3. Dust in our galaxy

As indicated, the value of R_V varies largely with respect to the line of sight implying that the size distribution of the grains varies significantly if we assume that the chemical properties are the same. The larger value for R_V may indicate grain growth by accretion and coagulation. Also the width and the peak of the UV bump at 2175 Å show a large variation with line of sight, however, the peak value always occurs at 2175 Å (some circumstellar/ISM has the peak displaced to red 2400 Å, which would be interesting to study) indicate the dispersion in chemical composition in the Galaxy. Distribution of R_V

at different locations of the Galaxy, taking into account the direction and the depth of the line of sight, (this would be distinctly different from GALEX) was not yet investigated. Such an investigation will help constrain the characteristics of dust and UV emission features at different locations of the Galaxy. This will in turn constrain the physical processes governing the enrichment of dust and its distribution in the Galaxy.

4. Our programme with TAUVEX

We propose to make the following investigations:

1. The interstellar extinction map (from UV to near IR) using TAUVEX, new optical observations (photometry & spectroscopy) and optical and 2MASS archived data. The interstellar extinction curve constructed by combining UV to near-IR data will help to constrain most characteristics of interstellar dust.
2. Variation of 2175 Å feature at different lines of sight using TAUVEX.
3. Study of interstellar extinction and 2175 Å feature along different depths of lines of sight. This in turn will help us to investigate the characteristics of dust and emission features at different locations of the Galaxy.

TAUVEX, consisting of three equivalent 20 cm UV imaging telescopes with a choice of filters for each telescope, will image large parts of the sky in the wavelength region between 1400 and 3200 Å with a spatial resolution of about 6″ to 10″, depending on the wavelength. TAUVEX will be used to measure the fluxes at 1770 Å, 2180 Å, 2680 Å and 2220 Å using narrow-band filters SF1, SF2, SF3 and NBF1, respectively. These observations will provide us with three points for the interstellar extinction in the UV domain, including at 2175 Å bump. The previous all sky survey in UV was performed by the Belgian/UK Ultraviolet Sky Survey Telescope (S2/68) in the ESRO TD1 satellite (Thor-Delta rocket system which became known as the TD satellite) which carried out a controlled scan of the whole sky. It measured the absolute ultraviolet flux distribution between 2740 Å and 1350 Å of point sources down to tenth visual magnitude for unreddened early B stars. The catalogue of TD1 mission "Catalogue of stellar UV fluxes" (Thompson et al. 1978) can be used to obtain four more values for interstellar extinction at wavelengths 2740, 2365, 1965, & 1965 Å for stars brighter than $m_v = 10$. From these points the ultraviolet region of the extinction curve can be better fitted than earlier with the seven-parameter relation of Cardelli et al. (1989), as well as the variation of 2175 Å bump can be obtained at different lines of sight.

In Fig. 1 we present the distribution of B0-5 III-V stars obtained from the "All-Sky Compiled Catalogue of 2.5 Million Stars" (ASC catalogue, Kharchenko 2001). This catalogue has a compilation of 2501304 stars with the limiting magnitude V=12–14. The B type stars, selected from the ASC, has been compared with those observed by TD 1

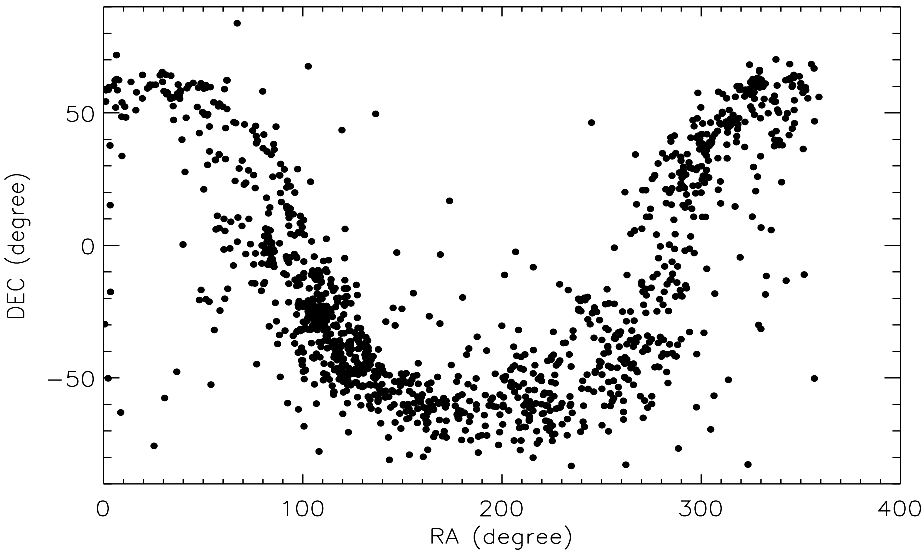

Figure 1. The distribution of B0-B5 III-V stars obtained from the "All-Sky Compiled Catalogue of 2.5 Million Stars".

in the histogram presented in Fig. 2. Because TAUVEX can detect unreddened early B stars down to at least six magnitudes (S/N $\sim$ 10) in one scan when compared to TD 1, even at the declination of 0° where the available time per scan is shortest, we plan to observe a large number of stars in different regions of the Galaxy. For stars, which will be common to both TD 1 and TAUVEX, we will have six data points in UV range covered by TAUVEX which will provide a better fit than earlier. But for fainter sources ($m_V >$ 10), even though we will have only three data points, they will be new.

From the values of R_V for stars which are nearby in the sky but have different distances, the variation of R_V along the line of sight can be determined. Similarly, the variation in the 2175 Å feature along the line of sight can be obtained. Such a measurement for all chosen lines of sight will yield the variation of R_V and 2175 Å feature with respect to the Galactic location. This in turn can be used to study the characteristics of dust and emission feature at different galactic location. To demonstrate, we have chosen a region between $l = 90°$ & $l = 100°$ and $b = -20°$ & $b = -10°$. We found seven B0-5 III-V stars from ASC catalogue located in this region as shown in Fig. 3. We estimated their distances using parallax values given in the ASC catalogue. As shown in the right panel of Fig. 3, their distances range from $\sim$ 100 to $\sim$ 500 pc with an interval of $\sim$ 100 pc. Because TAUVEX can go deeper in magnitudes, we can sample more stars which are located further away in distance with larger $E(B-V)$ (or distance $\sim$ 1 kpc) values.

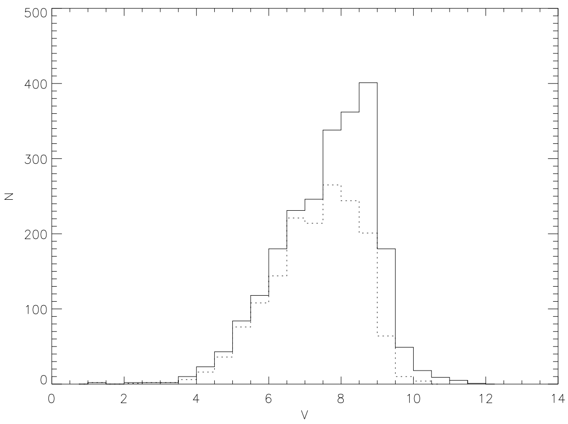

Figure 2. We show a histogram of B type stars selected from the ASC catalogue (solid line) and those observed by TD 1 satellite (dotted line).

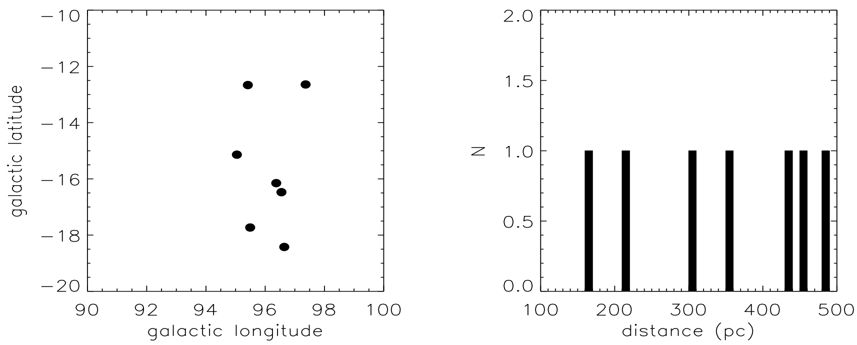

Figure 3. Left: Distribution of stars chosen from ASC catalogue towards the Galactic location $l = 90°$ & $l = 100°$ and $b = -20°$ & $b = -10°$. **Right:** Their distances estimated from the parallax values.

5. Summary

In order to study the properties of interstellar dust we propose to carry out multi-band observations of stars in different regions of the Galaxy using TAUVEX. Using filters optimized for extinction observations of the 2175 Å feature, combined with optical observations and 2MASS archived data, we can derive the extinction curve from the UV to the near-IR for stars in different regions and environments. Such a study will allow us to understand the properties and evolution of interstellar dust as a function of environment.

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