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Comparison of diffuse infrared and far-ultraviolet emission in the Large Magellanic Cloud: The data

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ABSTRACT

Dust scattering is the main source of diffuse emission in the far-ultraviolet (FUV). For several locations in the Large Magellanic Cloud (LMC), *Far Ultraviolet Spectroscopic Explorer (FUSE)* satellite has observed diffuse radiation in the FUV with intensities ranging from 1000 to 3×10^5 photon units and diffuse fraction between 5% and 20% at 1100 Å. Here, we compare the FUV diffuse emission with the mid-infrared (MIR) and far-infrared (FIR) diffuse emission observed by the *Spitzer Space Telescope* and the *AKARI* satellite for the same locations. The intensity ratios in the different MIR and FIR bands for each of the locations will enable us to determine the type of dust contributing to the diffuse emission as well as to derive a more accurate 3D distribution of stars and dust in the region, which in turn may be used to model the observed scattering in the FUV. In this work we present the infrared (IR) data for two different regions in LMC, namely N11 and 30 Doradus. We also present the FUV∼IR correlation for different infrared bands.

1. Introduction

Interstellar dust grains scatter and absorb incident radiation. A combination of the two processes is called extinction (Trumpler, 2003). These dust properties are all wavelength dependent as well as dependent on the composition and sizes of the grains. The scattered component is observed as diffuse emission in the optical and ultraviolet (UV). The absorbed fraction is re-emitted as diffuse radiation in the mid-infrared (MIR) or far-infrared (FIR) depending on the dust temperature (Draine, 2003). Dust also is an important agent in the fluid dynamics, chemistry, heating, cooling, and even ionisation balance in some interstellar regions, with a major role in the process of star formation. Despite the importance of dust, determination of the physical properties of interstellar dust grains has been a challenging task. The infrared (IR) emission from dust depends not only on the amount of dust present, but also on the rate at which it is heated by starlight.

The spectral properties of the IR emission from dust allow one to infer the composition of the dust, the size distribution of the dust particles, the intensity of the starlight that is heating the dust, and the total mass of dust. The dust scattered UV radiation has been observed in several regions in the Galaxy and beyond by probes like *GALEX*, *FUSE*, etc. It has been found to be associated with regions of thin sheets of material close to hot UV emitting stars (Sujatha et al., 2005). In the MIR we can observe emission from PAH molecules as well as from tiny solid grains which have sizes starting from a few tens of Angstroms. PAH molecules can be detected in the *Spitzer* 8 μm band. These are associated with colder dust clouds. The small solid grains are known as VSGs (Very Small Grains) and can be excited to very high temperatures, resulting in detectable emission in the *Spitzer* 24 μm band (Wu et al., 2005). This VSG emission is seen to be associated with locations close to hot UV emitting stars like HII regions, just like the dust scattered UV radiation. However, the behaviour of the PAH emission in cluster environments has not yet been studied well (Murata et al., 2015). This is mainly due to sparse filter sampling at 8–24 μm in the *Spitzer Space Telescope* (Werner et al., 2004). In contrast, the Japanese *AKARI* satellite (Murakami et al., 2007) has continuous wavelength coverage at 2–24 μm with nine photometric bands in the *Infrared Camera* (*IRC*; Onaka et al., 2007).

The Magellanic Clouds are the nearest extragalactic systems and therefore offer an opportunity for the study of extragalactic abundances (Pagel et al., 1978). Four types of objects are available for studies of this sort: normal stars, supernova remnants, planetary nebulae and HII regions. The Large Magellanic Cloud (LMC) provides a nearby, ideal laboratory to study the influence of massive stars on dust properties because it has a nearly face-on orientation, mitigating the confusion and extinction along the Galactic plane. It is at a known distance, ∼50 kpc (Feast, 1999), so stars can be resolved and studied in conjunction with the

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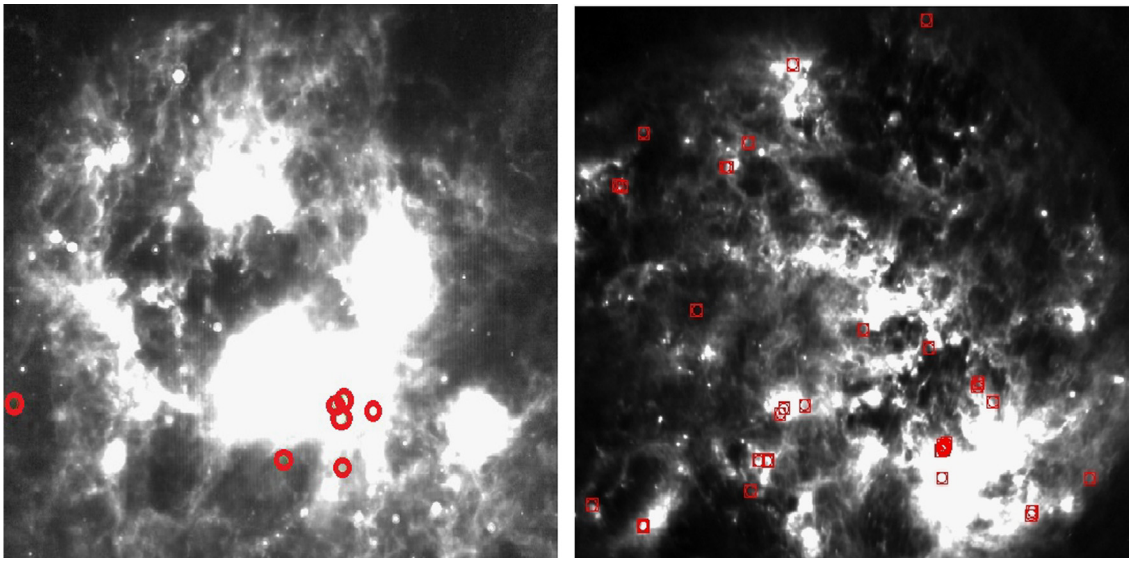

Fig. 1. LMC images taken by the *Spitzer Space Telescope* at 8 μm (left) showing the N11 and the *AKARI* satellite at 24 μm (right) showing the 30 Doradus in the mid-IR with our locations represented in red circles and squares. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

Table 1
Details of *Spitzer* observations.

Target name	gl	gb	I_8 (MJy sr^{-1})	I_{24} (MJy sr^{-1})	Henize no./comments
SNR0449-693	280.9115	−35.8492	0.90 ± 0.18	21.69 ± 0.48	N77A, N77D (HII region)
SNR0450-709	282.6024	−35.2981	0.21 ± 0.12	20.61 ± 0.09	N78 (Emission nebula)
SK-67005	278.8562	−36.3031	1.49 ± 0.11	20.51 ± 0.07	N3 (Exciting star)
SNR0454-672	278.2105	−36.0629	0.98 ± 0.21	21.07 ± 0.18	S3 (C1 object in NGC 1735)
SNR0454-665	277.2729	−36.2522	0.69 ± 0.19	16.89 ± 0.13	S2 (Emission-line star)
SK-67D14-BKGD	278.2475	−36.0221	1.29 ± 1.03	16.36 ± 0.11	S3 (C1 object in NGC 1735)
SNR0455-687	279.8756	−35.5509	2.19 ± 0.16	16.03 ± 0.05	N84 (Emission nebula)
LH103204	277.1267	−36.0851	2.23 ± 0.21	17.76 ± 0.23	N11, N11B (HII region, HD 32256)
PGMW-3223	277.1008	−36.0451	4.38 ± 1.08	19.16 ± 0.36	N11A (HII region, HD 32340)
SK-68D15	279.4643	−35.5125	0.70 ± 0.20	21.04 ± 0.42	N91 (HII region, NGC 1770)
LH103073	277.1354	−36.0335	6.98 ± 2.61	26.97 ± 3.30	N11A (HII region, HD 32340)
PGMW-3053	277.1473	−36.0309	20.78 ± 7.73	60.05 ± 39.05	N11A (HII region, HD 32340)
PGMW-3070	277.1460	−36.0271	30.87 ± 24.11	83.59 ± 52.14	N11A (HII region, HD 32340)
SK-68D16	279.4828	−35.4927	2.32 ± 0.32	20.26 ± 0.39	N91 (HII region, NGC 1770)
PGMW-3168	277.1277	−36.0103	7.14 ± 1.30	23.45 ± 1.63	N11A (HII region, HD 32340)

interstellar gas and dust (Stephens et al., 2014). The LMC is located at a high latitude (~30°; Putman et al., 1998) and hence it is not much affected by extinction from the Milky Way (MW) dust. For these reasons, the LMC has been targeted by every space-based IR observatory to study dust properties and calibrate dust emission as star formation indicators. The first report of *Spitzer Space Telescope* observations of an LMC H II complex was made by Gorjian et al. (2004) for LHA120-N206 (N206 for short; designation from Henize, 1956); its dust emission was qualitatively compared with that of the Orion Nebula. Subsequently, the entire LMC was surveyed by *Spitzer* in the Legacy program Surveying the Agents of a Galaxy's Evolution (SAGE; Meixner et al., 2006). More recently, the *AKARI* space telescope has been instrumental in observing the LMC.

Oestreicher and Schmidt-Kaler (1996) state that not only dust cloud properties, but also the distribution of the dust itself is important for understanding the structure and dynamics of the LMC. The highest reddening occurs in the regions of 30 Doradus and the supershell LMC 2 where color excess E_{B-V} reaches a maximum of 0.29. The lowest reddening is observed in the region of supershell LMC 4 with $E_{B-V}=0.06$. The HII region N11 also shows a high reddening with E_{B-V} up to 0.24.

Therefore by studying locations which have observations in the FUV and the MIR, we can hope to identify the particular grain population responsible for the observed emission. We should expect to find a better correlation between the UV and 24 μm intensities near hot O and B-type stars compared to the UV – 8 μm correlation. Here, we compare the FUV diffuse emission with the MIR diffuse emission observed by the *Spitzer Space Telescope* and the MIR and FIR diffuse emission observed by *AKARI* telescope for the same locations.

2. Observations and data analysis

We have selected a list of 81 LMC locations observed by the *FUSE* UV telescope as published in Pradhan et al. (2010). Among these 81 locations, 43 were available in the *Spitzer* and *AKARI* archives and have been considered for this work. These 43 locations include 15 *Spitzer* observations (8 μm and 24 μm) and 28 *AKARI* observations (15 μm, 24 μm and 90 μm). The 8 μm data have been taken from observations by *Spitzer Infrared Array Camera (IRAC)* which is a four-channel infrared camera that provides simultaneous images at four wavelengths 3.6 μm, 4.5 μm, 5.8 μm and 8 μm. All four detector arrays in the camera are 256 × 256 pixels in size, with a pixel size of

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