We investigate gas and dust physical properties and chemistry of diffuse interstellar medium in the Large Magellanic Cloud (LMC). Photometric and spectroscopic data of total twelve diffuse regions were obtained as part of the LMC legacy programs, Surveying the agents of Galaxy Evolution and Herschel Inventory of The Agents of Galaxy Evolution. The Spitzer infrared spectra of these regions reveal low J rotational transition lines of H$_2$ and aromatic band emissions due to PAHs. By fitting the rotational diagram of H$_2$ we determine temperature and column density of warm molecular gas. Dust temperature and mass are measured by fitting the far-infrared spectral energy distributions obtained with the Herschel photometric images. In addition to Spitzer and Herschel data, we use HI map for atomic gas mass, and CO map to trace cold molecular hydrogen. Our goal is to constrain the state of ISM by determining mass, temperature and gas-to-dust ratio. From preliminary analyses, we present gas and dust physical properties and gas-to-dust ratios of two diffuse regions. We derive gas-to-dust ratios of 240 in these regions assuming a CO-to-H$_2$ conversion factor $2 \times 10^{20}$ cm$^{-2}$ K$^{-1}$ km$^{-1}$ s.
1. Introduction

The nearby Large Magellanic Cloud (LMC) galaxy is an excellent site for the studies of chemical and physical properties of Interstellar medium (ISM) due to its proximity, (∼49.97 kpc; [8]), low metallicity (0.5 Z⊙; [9]), and favorable viewing angle (∼24°; [7]). At a distance of ∼50 kpc, the LMC permits us to resolve ISM small scale structures in sub-parsec scales. We investigate the gas and dust physical properties and thereby gas-to-dust ratio of some selected extended regions in the LMC. The diffuse ISM regions of the LMC have been observed as part of the Spitzer legacy program, Surveying the agents of Galaxy Evolution (SAGE-LMC) [5]. As part of SAGE spectroscopic program (SAGE-Spec), spectral maps of 12 diffuse regions were obtained using Infrared Spectrograph (IRS) on the Spitzer Space Telescope. Spectra were integrated over an area of 1′×1′ from each region in a wavelength range 5−38 μm. The details of observation and coordinates of observed diffuse regions can be found in Kemper et al. [3]. The integrated IRS spectra of these regions show strong H2 low J rotational lines, S(0) (v = 0−0, J = 2−0, 28.2 μm) and S(1) (v = 0−0, J = 3−1, 17.0 μm). At shorter wavelengths (5−12 μm) the most intense transitions S(2) through S(7) are highly contaminated by strong aromatic bands of Polycyclic Aromatic hydrocarbons (PAHs). In addition to the Spitzer data, we use Herschel Inventory of The Agents of Galaxy Evolution (HERITAGE) photometric images for dust measurements [6]; HI map [4] to trace the atomic gas; and CO maps to trace the cold molecular hydrogen. In this proceeding, we present measurements of gas and dust physical properties in two diffuse regions.

2. Dust mass and temperature

To determine dust temperature and mass, we use the Far Infrared (FIR) Spectral Energy Distributions (SEDs) constructed with PACS1 (100 and 160 μm) and SPIRE2 (250 and 350 μm) fluxes, which were integrated over 30′′ aperture radius for each sample region. The SEDs were fitted with single-temperature modified blackbodies [2]. In our fitting method, the emissivity β is allowed to vary between 1 < β < 2. Dust masses were obtained for 160 μm fluxes, assuming that dust is mostly spherical silicate grains with mass density ρ=3 g cm−3, radius a = 0.1 μm and absorption efficiency Qem(160) = 5.5 × 10−4 following the method reported in Gordon et al [2]. The two observed regions show dust temperature in the range 18 − 22 K with dust masses 69 ± 20 M⊙ and 35 ± 8 M⊙ respectively (see, Table 1).

3. H2 column density and excitation temperature

Using the IDL package PAHfit [10], we measured the spectral line intensities [10]. PAHfit can simultaneously fit every dust feature, starlight, atomic and molecular lines, and returns the best fitted parameters (Figure 1). Using the measured line intensities, the level populations were calculated by assuming that lines are optically thin and the level populations are thermalized in the Local Thermodynamic Equilibrium (LTE). Consequently, we determined the excitation temperature Text and H2 column densities NH2(extern) by fitting the rotational diagrams. In our analyses,

1Photodetector Array Camera and Spectrometer
2Spectral and Photometric Imaging Receiver
two-temperature model was used to fit the rotational diagrams: a cold component with temperature in the range 70 – 130 K and a warm component with an upper limit < 1200 K. Rotational diagram of H$_2$ along with two-temperature model fits for two diffuse regions are shown in Figure 2.

The cold molecular gas is traced by CO ($J=1-0$) observations obtained with the MAGellanic Mopra Assessment (MAGMA; resolution 1') and the NANTEN (resolution 2.6') surveys [11]. The CO integrated intensities were extracted over a 30'' radius aperture size for every diffuse region. These intensities (K km/s) were then converted to H$_2$ (cold) column densities NH$_2$(c) and masses assuming the Galactic CO-to-H$_2$ conversion factor of 2.0×10$^{20}$ cm$^{-2}$ K$^{-1}$ km$^{-1}$ s [1]. The atomic gas is traced by 21 cm line emission observations by the Australia Telescope Compact Array (ATCA) and Perkes single dish telescope spanning 11.1°×12.4° on the sky at a spatial resolution 1' [4]. The HI intensities were integrated within the aperture radii 30'' from HI map and converted to column densities. The gas-to-dust ratio was determined by dividing total gas mass which was derived by the sum of atomic gas, cold molecular gas and warm molecular gas, to total dust mass.

### 4. Results

The gas-to-dust ratios along with atomic, cold molecular, warm molecular gas masses and dust masses are given in Table 1. We derive a gas-to-dust ratio 240 in both regions. The cold H$_2$ mass fraction is negligibly small in region 2, while warm H$_2$ is approximately 40% of gas mass. In region 1, the cold H$_2$ is > 50% of total gas mass and the warm H$_2$ mass is very small fraction compared to cold molecular and atomic components. Atomic gas is nearly 40% of total gas in region 1 and more than 50% in region 2.

### References


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Figure 1: Segments of H$_2$ S(0) and S(1) line fits using PAHfit. The black squares indicate the observed spectra, superimposed are: the best fit model (green), PAH features (blue) and spectral line features (violet).

Figure 2: Rotational diagrams of H$_2$ for two observed regions along with the best fit two-temperature models.


