Abstract

Dwarf irregular galaxies stand out as the tiniest galaxies identified in the vast cosmos. Their small dimensions result into a low surface brightness, setting them apart from the more structured spiral or elliptical galaxies. Characterized by an absence of well-defined shapes, these galaxies are categorized as ‘irregular.’ They assume a crucial role in the evolutionary processes of galaxies, thought to act as fundamental components for larger galaxies, primarily through merging mechanisms.

The Interstellar Medium (ISM) within dwarf galaxies differs significantly from that observed in other galaxy types, such as spirals. Typically, a galaxy’s ISM contains a substantial amount of material, often reaching several billion solar masses, and is characterized by two primary components: Interstellar Gas and Interstellar Dust. Interstellar gas is predominantly composed of hydrogen and helium, constituting the major portion of the ISM and making up approximately 90% of its total mass. On the other hand, interstellar dust, composed of heavier elements like silicon (Si) and carbon (C), represents a smaller fraction, around 10% of the ISM’s composition. In the case of dwarf irregular galaxies, the ISM is distinguished by a notably high gas content, with neutral hydrogen (HI) being the predominant form, distributed irregularly throughout the galaxy. This substantial presence of gas promotes continuous star formation activities, resulting in the coexistence of young, massive stars alongside older stellar populations. Another defining characteristic of the ISM in these dwarf galaxies is its low metallicity environment, leading to a reduced amount of interstellar dust. In contrast, the ISM within spiral galaxies is more intricate and exhibits higher metallicities. Additionally, unlike the irregular or patchy distribution of ISM in dwarfs, the ISM in spirals tends to display more organized patterns within the spiral arms.

The presence of a metal-poor ISM with a correspondingly low dust content in dwarf galaxies exhibits similarities with features observed in early Universe galaxies. Recent observations of luminous galaxies at redshifts exceeding 10, initially conducted by the *Hubble Space Telescope (HST)* and subsequently by the *James Webb Space Telescope (JWST)*, have brought attention to a scarcity of dust in a subset of these high-redshift galaxies. In this con-

text, dwarf galaxies emerge as crucial analogs that have the potential to replicate conditions prevalent in the early Universe. To gain valuable insights into both distant dwarf galaxies and early galaxies, it becomes imperative to analyze Local Group and nearby group dwarf galaxies on smaller scales. A comparative analysis of the overall emission characteristics and properties of these dwarf galaxies can offer significant understanding into the evolutionary trajectory from early Universe galaxies to their contemporary counterparts.

The main objective of this thesis is to delve into the ISM within dwarf irregular galaxies, with a specific focus on two such galaxies situated in our Local Group and nearby groups: Holmberg II and the Large Magellanic Cloud (LMC). Holmberg II, located in the M81 galaxy group and approximately 3.39 Mpc away, serves as a key sample for our investigation. Its relatively modest inclination angle makes it an exceptionally valuable object for studying the distribution of gas and dust within interstellar discs. Notably, Holmberg II harbors a central star-forming region that emits intensely in ultraviolet (UV) and H. The irregular distribution of HI in Holmberg II gives rise to numerous distinctive shells and cavities, contributing to its unique ISM characteristics. Additionally, Holmberg II is home to one of the brightest ultra-luminous X-ray (ULX) sources in the local Universe, known as Holmberg II X-1. On the other hand, the Large Magellanic Cloud (LMC), another dwarf irregular galaxy in the Local Group, is located approximately 50 kpc away. Its nearly face-on orientation and close proximity provide an advantageous opportunity to resolve individual stars and thoroughly investigate the ISM. These favorable characteristics have made the LMC a prime target for various space-based telescopes. Within the LMC, two significant H II regions, 30 Doradus (also known as the Tarantula Nebula) and N11, stand out as centers of ongoing star formation. Among these, 30 Doradus emerges as the most active star-forming region within the Local Group, exhibiting the highest level of reddening within the LMC.

We initiate the thesis with a thorough exploration of dwarf irregular galaxies, emphasizing their importance in potentially replicating early Universe conditions and their role in unraveling the cosmic chronicles of the Universe's evolution. Our focus extends to describing the distinct characteristics of their ISM, emphasizing the notable differences in ISM compositions when compared to other galaxy types, particularly spirals. Furthermore, we delve into an examination of the distinctive mechanisms propelling star formation within these galaxies, highlighting the variations from the observed star formation processes in other galaxy types.

In **Chapter 2**, we present the UV observation of the Holmberg II galaxy using the Ultra Violet Imaging Telescope (UVIT) instrument aboard India's pioneering space mission, *AstroSat*, spanning 8 epochs from 2016 to early 2020. Previous observations of this galaxy utilized UV telescopes such as *GALEX*. However, the considerable enhancement in angular resolution achieved by UVIT ($1.2''$ - $1.6''$), representing a nearly threefold improvement compared to *GALEX*, has significantly enhanced our capability to detect and study point sources within the galaxy, including the previously mentioned ULX source. This improved resolution also allows for the effective isolation and study of emissions originating from the ISM, particularly those that are 'really diffuse,' by excluding these point sources from our analysis.

In **Chapter 3**, we present the X-ray observations of the ULX source Holmberg II X-1, conducted simultaneously with the UV observations mentioned in Chapter 2. These ULX sources are known for their high variability in X-ray emissions and prominent emission in the UV spectrum, with the UV emissions resulting from the reprocessing of X-ray photons. Consequently, an expected UV/X-ray correlation is anticipated. Our observations revealed variability in X-ray fluxes by a factor of approximately $\sim$1.5, along with around 25% variability in UV emissions originating from the ULX during the observation period. Our analytical focus was on identifying correlations between these flux variations. Throughout our observation period, we observed the ULX in a state of relatively low variability. We further characterized these observed correlations through three models: the heated donor star, heated disk, and heated wind models, but could not reject any of them. Additionally, we estimated the lower limit of variability needed to dismiss at least a portion of these models, aiming to refine our understanding of the ULX's emission characteristics. The determined lower limit of variability stands at about 2.5 or higher in X-rays and correspondingly at least 60% in UV emissions.

In **Chapter 4**, our focus shifts towards the investigation of the ISM within Holmberg II, using high-resolution UV observations from the *AstroSat*/UVIT instrument, complemented by infrared (IR) data from the *Spitzer* and *Herschel* space telescopes. This chapter is specifically dedicated to examining the interstellar dust component within the galaxy. Interstellar dust plays a crucial role by scattering shorter wavelength radiations, leading to diffuse emissions primarily in the far-ultraviolet (FUV) range. Additionally, these dust grains absorb the remaining portion of shorter wavelengths (mainly UV and optical) and re-emit in longer wavelengths, predominantly in the mid-IR (MIR) and far-IR (FIR) ranges. Our investigation unfolds in three main parts: the initial part focuses on analyzing the correlation between UV and IR emissions within Holmberg II, aiming to determine the nature of dust grains contributing to the diffuse emissions. Our findings indicate that the IR emission primarily originates from warm dust grains, aligning with outcomes from prior spectral studies. The subsequent part delves into studying the diffuse FUV emission attributed to dust scattering in the galaxy. This involves modeling using an established single scattering model, allowing us to derive crucial dust optical properties — specifically, the albedo (α) and asymmetry factor (g). Our results, $\alpha = 0.2$ and $g = 0.5$, show reasonable consistency with theoretically predicted values, supporting the inference that dust scattering significantly contributes to the UV diffuse emission. Our analysis identifies an optically thin medium responsible for this scattering phenomenon in Holmberg II. Lastly, we probe the diffuse IR emission attributed to thermal re-emission by dust grains heated through UV/optical photons. This aims to uncover distinct dust populations characterized by varying temperatures within Holmberg II. Our analysis reveals a complex scenario where the IR spectral energy distribution (SED) cannot be attributed to isothermal dust, requiring the presence of multiple dust populations, up to five, each characterized by different temperatures within the galaxy.

In **Chapter 5**, we turn our attention to the second sample of our study — the LMC — with a specific emphasis on examining the interstellar dust component within it. Within the LMC, our study is directed towards one of its prominent H II regions: 30 Doradus, also known as the Tarantula Nebula. Previous observations encompassed FUV diffuse emissions across various LMC regions using the *Far Ultraviolet Spectroscopic Explorer* (*FUSE*) telescope, in seven distinct wavelength bands ranging from 1004 Å to 1159 Å. Additionally, a UV-IR correlation study for 30 Doradus was also conducted. Building upon these foundations, our approach involves modeling the diffuse FUV emission within 30 Doradus, utilizing the same scattering model employed in Chapter 4. Our analysis uncovers that a thick optical medium plays a key role in dust scattering within this region. Furthermore, our observations reveal variations in scattering optical depths across the region, indicating a heterogeneous and complex dust geometry. This variability suggests a complex interplay of dust distributions and properties within 30 Doradus, presenting a diverse dust environment within this H II region of the LMC.

In **Chapter 6**, we bring the thesis to a conclusion by discussing its implications and looking towards the future, particularly in the context of alternative sources of diffuse UV emission apart from dust scattering.