Chapter 1

Introduction

Recent years, some understanding about galaxy formation and its evolution have been formed from studies using different sets of satellite data in multiwavelength bands that establish a standard technique for the measurement of extragalactic radiation.

1.1 Ultraviolet Astronomy

Observations in Ultraviolet band (UV range: 3 nm - 0.4 µm), is highly used in many astronomical problems including planetary science, interstellar and intergalactic media, physical and chemical processes involved in the formation of stellar objects, evolution of galaxies and cosmological studies. Detailed study of interstellar and intergalactic phenomena can be accomplished through UV observations. Since electronic transitions of abundant molecules belonged to this range, such studies enable the understanding of physical properties and chemical reactions taking place in the stars and galaxies. Furthermore UV observations are particularly interesting because the Lyman break is redshifted into the far and near ultraviolet (hereafter, NUV & FUV) for distant objects. The instantaneous rate of star formation in these galaxies are particularly difficult to
discern otherwise. Hence UV observations enable to expand the frontiers of our envelope of knowledge about distant galaxies including active galactic nuclei (AGNs) associated with black holes.

Most of the UV radiation is from hot, massive, O and B stars, that have peak spectral energy distributions in the UV band. Hence, the study of number counts of resolved UV galaxies provides information regarding the history of extragalactic star-formation.

The UV is also important physically in that most of the energy of the stellar radiation is in the UV range and absorption of this radiation by the dust grains powers the infrared emission. Hence, the observations of diffuse ultraviolet radiation, track the transfer of radiation from the stars to the Interstellar Medium. The studies of diffuse UV sky have been an important part of interstellar dust studies over the last four decades though the difficulty of observing faint diffuse sources near the limit of the instrumental sensitivity has been a limitation. Earlier observations in UV have been patchy in both distribution and quality and it is only recently that large scale observations of the diffuse UV sky are emerging.

### 1.2 Extragalactic Radiation

Extragalactic radiation is the total emission from resolved/ unresolved galaxies of our universe. It is subdivided into Near-Extragalactic: Local group of 56 galaxies near to Milky way and Far extragalactic: beyond those. The current astronomical missions conduct 80% of sky survey in UV bands. UV band is very sensitive to detect young
stellar populations in distant galaxies. Young galaxies light up in ultraviolet because they are filled with hot, newborn stars - objects that pack most of their light into ultraviolet wavelengths. It also facilitates the detection of young galaxies formed after Big Bang at distant parts of the universe [17].

1.2.1 Measurement of Number Counts of Galaxies

Extragalactic radiation/light (EGL) in UV can be computed using the number counts of detected/resolved galaxies which provide greater understanding about galaxy evolution. There has been significant work on number counts carried out in two UV bands (NUV: 300-400 nm, FUV: 122-300 nm) over the past few decades. Previous results of the studies of number counts of galaxies in UV are tabulated (Table 1.1). Computation of the number counts of UV galaxies as a function of AB magnitudes is used in the study of UV extragalactic light. Starting from Millard et al. (1992) [47] to Voyer et al. (2011) [74], several people have contributed to the studies of number counts and total Extragalactic Light that vary over mid-high galactic region, spectral bands and instruments (Table 1.1). Xu et al. (2005) [78] had yielded the number count of bright UV galaxies using UV mission of Galaxy Evolution Explorer (GALEX). But, as expected, this results are inexact towards the fainter end. The results from Teplitz et al. (2006) [72] & Gardner et al. (2000) [24] provide better values at the fainter ends. More recent results show that extragalactic light due to resolved UV galaxies computed from GALEX observations is less than 100 photons cm$^{-2}$sr$^{-1}$s$^{-1}$Å$^{-1}$ and limited to diffuse UV radiation [74].
Table 1.1: Previous Studies of Galaxy Number Counts

<table>
<thead>
<tr>
<th>Author</th>
<th>Instrument</th>
<th>Wavelength(˚A)</th>
<th>Area covered</th>
<th>Magnitude limits</th>
</tr>
</thead>
<tbody>
<tr>
<td>Millard et al. (1992)</td>
<td>Balloon borne Telescope</td>
<td>2000</td>
<td>6 degree$^2$</td>
<td>15.0 – 18.5</td>
</tr>
<tr>
<td>Xu et al. (2005)</td>
<td>Galaxy Evolution Explorer</td>
<td>NUV-2310, FUV-1530</td>
<td>$\sim$20 degree$^2$</td>
<td>14.0 – 23.8</td>
</tr>
<tr>
<td>Hammer et al. (2010)</td>
<td>Galaxy Evolution Explorer</td>
<td>NUV-2310, FUV-1530</td>
<td>$\sim$1 degree$^2$</td>
<td>22.0 – 23.5</td>
</tr>
<tr>
<td>Voyer et al. (2011)</td>
<td>Hubble Space Telescope</td>
<td>1614</td>
<td>3.77 arcmin$^2$</td>
<td>21.0 – 29.0</td>
</tr>
</tbody>
</table>
1.3 Extragalactic Background Light (EBL)

The extragalactic background light (EBL) is the integrated intensity of all of the light emitted throughout the history of the universe. It is also defined as extragalactic intensity spectrum from UV to IR (Dwek Krennrich 2013) [19]. The EBL spectrum in UV to IR region captures the redshifted energy released from all galaxies and stars throughout cosmic history. The cosmological principle states that the universe is homogeneous and isotropic at large physical scales (>100 Mpc). Hence EBL is expected to have uniform distribution. They also cause the individual detection of faint galaxies and intergalactic stars extremely tedious. The EBL provides a complete energy distribution in the universe, providing a very powerful constraint on the models of densities of stars and galaxies and the baryonic content of the universe. Measurements of the surface brightness of the EBL from the UV to the IR is given by Dwek et al. (1998) [20] derived from integrated flux of resolved extragalactic sources (Figure 1.1). Recently, the summary of existing EBL measurements is given by Asantha Cooray (2016), shown in figure 1.2 [5]. But there exists some spectroscopic limitations to extragalactic studies (Martin et al. 1991) [44]. Martin et al.(1991) pointed out the problems to extract extragalactic component due to the incorrect measurement of foreground emissions. It make certain constrains on distant galaxy formation scenarios and their existing models till now.

There are several studies on diffuse background radiation conducted in the past at different wavelength. In 1991, Bowyer explained that dust scattered starlight from interstellar dust is a major contributor to diffuse UV background. But Henry (1991)
Figure 1.1: Measurements of the EBL from UV to IR (for details, Dwek et al. (1998))

Figure 1.2: Measurements of the EBL as a function of wavelength (for details, Asantha Cooray (2016))
suggested that the background observed at high galactic latitude is due to exotic origin.\[11, 32\] Here, we shall identify the components and its contribution to diffuse UV to support the Bowyers results. The importance of the study of the UV background is brought out by Murthy (2009) \[49\].

Rapid progress in UV detectors with higher resolution and greater sensitivity have enabled to produce results which show that the most of the UV background near galactic poles might be extragalactic in origin. Due to the high Galactic background, the diffuse UV background remains largely unexplored and will remain a great challenge to estimate. We summarize the foreground and background emissions of satellite images of UV.

### 1.3.1 Foreground Emission

1. **Zodiacal Light** - results from solar radiation scattered by interplanetary dust - one of the significant contributors to diffuse NUV and it depends upon the Sun angle & the distance from the ecliptic plane. The contribution of Zodiacal light using the distribution in the visible with grey scattering is provided by Leinert et al. (1998) \[20\]. He assumed that the ratio between the zodiacal light and the solar spectrum is same at all wavelengths. It should be emphasized that there is essentially no zodiacal light contribution in the FUV band.

2. **Airglow** - line emission originating in the geocorona, is one of the major sources of radiation in the UV. Many of the airglow emissions arise in the ionospheric E layer at \(\sim 90\) km, some in the F region above \(150\) km like Ly and H in the Geocorona. The
main emission lines having the order of magnitudes is about 4-6. At mid latitudes, the airglow is less intense by about one order of magnitude. Airglow is highly time dependent, both on short and long timescales, mainly due to changes in the atmosphere and solar activity. About a factor of 2 variation occurs with the solar cycle, with airglow faintest at sunspot minimum. It has been difficult to derive the airglow because there is no consistency between observations. Thus it is not possible to say definitively what the airglow is in any given observation as of now.

### 1.3.2 Background Emission

The background emission consists of the following components 1) Diffuse Galactic light - galactic light scattered by intergalactic dust 2) Fluorescence of molecular hydrogen 3) Various line emissions 4) Diffuse Extragalactic sources

Polarization of starlight, IRAS detection of cirrus etc. have made evidence to support dust scattering starlight at low to high galactic latitudes. The modelling of dust scattered light using bright star catalog is done by Murthy and Henry (1995) [51].

Duley and Williams (1980) [18] suggested that diffuse UV background includes fluorescence of molecular hydrogen as one of the major components of interstellar medium. The distribution of H$_2$ fluorescence over entire sky is highly significant in the ISM studies and has been detected using IUE observations (Witt et al. 1989) [77]. The statistical evidence of detection of H$_2$ fluorescence emission from UVX space shuttle data is given by Martin, Hurwitz & Bowyer (1990) [45]. But these detection could not be confirmed from Voyager observations (Murthy et al. 1991) [50].
Different line emissions were observed from the spectra of hot stars of highly ionised species in ISM as mentioned by York (1982), Jenkins (1984), Cowie and Songaila (1986) [79, 83, 15]. This work extended by Spitzer (1992) to show that galaxy may have a hot halo [67]. It will help in the discovery of other constituent of diffuse sky.

The current observational outcome regarding diffuse extragalactic sources arouse great curiosity. But the measurement of extragalactic cosmic ultraviolet background is difficult by direct methods. Murthy 2014 [52] has created maps of the diffuse UV radiation, in both FUV and NUV bands, using the latest GALEX all-sky data release (GR6+GR7)\(^1\) and is shown in Figures 1.3 & 1.4.

In 2009, N.V Sujatha et al. [70] analysed GALEX observations of high Galactic cloud Sandage (38\(^0\)) for the study of diffuse UV radiation. Their paper discussed about the following (1) the instrumental effects in FUV and NUV band, (2) significant contribution of airglow using Telemetered Event Counter (TEC) of the spacecraft in NUV and FUV, (3) Next major contributor to diffuse radiation field - zodiacal light in NUV

\(^1\)https://archive.stsci.edu/prepds/uv-bkgd/
band. After the subtraction of above three, the remaining signal contained H$_2$ fluorescent emission, starlight scattered by interstellar dust and extragalactic component. This method adopted and applied to the region of Draco and found that dominant contributor to diffuse UV background is entirely by dust scattered starlight [71].

From the previous studies of diffuse UV, we have concluded that for deep GALEX image at high galactic latitude region, as it is almost totally free of dust, the diffuse UV cannot due to dust scattered light. Figures of Sandage cloud 1.5 & 1.6 indicate that a bright extragalactic UV background radiation field exists (See Henry 2008 results).

1.4 Statement of the Problem

The extragalactic background places strong limits on the evolution of galaxies in the early universe and thus provides insight into the nature of the current universe. The UV radiation at high galactic latitudes is dominated by extragalactic radiation largely from distant galaxies. There is little interstellar dust at high latitudes and so the major part of the emission is due to extragalactic radiation.
Figure 1.5: Lack of correlation of FUV and GALEX brightness (for details, Henry 2008)

Figure 1.6: GALEX field of view of Sandage cloud (for details, Henry 2008)
1.4.1 Objectives

The main objectives are:

1. Find the number counts of galaxies using GALEX observations and study contribution of the same at various galactic latitudes.

2. Study of deep GALEX observations near the Galactic poles and use Spitzer-IRAS data in the infrared in constraining the extragalactic ultraviolet radiation.

3. Investigate whether the sample of Spitzer galaxies at fainter magnitudes are also detected by GALEX.

4. Map the diffuse UV radiation which is anticipated to be anti-correlated with the dust.

5. Estimate the contribution of Extragalactic Light in total UV radiation at different galactic latitudes and compare those with the existing results.

6. Study of diffuse UV radiations and the contribution of background from extragalactic origin.