Abstract

Infrared has characteristic property of transparency through the dust. It is obvious from the Wien displacement law that cool objects radiate (thermally) maximum in infrared band of electromagnetic radiations. Moreover, from Hubble's observation of expansion of universe, it is known that visible light from distant objects is red-shifted thereby moving the longer wavelengths to the infrared part. Since the infrared radiations penetrate more than the visible and UV light, they can easily reveal the processes at work in star forming regions which are typically enshrouded in clouds of gas and dust. Areas where infrared plays an important role are (Glass, 1999): (i) study of primeval galaxies and high red-shift Quasi-Stellar Objects, (ii) mapping the interstellar dust in the galactic plane, (iii) in the better understanding of stellar distributions and physical processes occurring near the Galactic Center, (iv) discovery of brown dwarfs and planetary candidates.

Most of the atoms and molecules in the universe have their origin in the stars. As stars burn and eventually die out, they produce heavier elements which are then ejected into interstellar space (as a star blows off its outer layers during its final phases). Some of these elements then combine to form molecules. Since every atom and molecule has unique spectral transitions the only way to understand the details of the atoms and molecules is through spectroscopy. Depending on the smallest wavelength interval ($\Delta\lambda$) that can be resolved, we have three categories of spectroscopy. One with the resolution R $\sim$ 100; named as low resolution

spectroscopy. It is useful in measuring metallicity and gravity of a star as these parameters have subtle effects on the shape of the stellar continuum. The other category with R $\sim$ 1000 is named as medium resolution spectroscopy. With the medium resolution atomic features can be resolved in an average manner. With third category having R $>$ 10,000, named as high resolution spectroscopy, individual molecular lines can be resolved (Kitchin, 1995).

Infrared radiation is categorized into three regions: near, mid and far infrared. The boundaries between these regions are not strictly defined. The criterion that determines the wavelength to be included in any of these three regions depends on detector technology used for gathering infrared light. Infrared domain starts from 1 μm and extends towards longer wavelengths. The region from 1 μm to 5 μm is known as Near Infrared (NIR), from 5 to 30 μm is mid infrared and from 30 to 350 μm is far infrared. The wavelength longer than 350 μm is now referred to as sub-millimeter. The NIR is again sub-divided into three regions: J band with 1.25 μm, H band with 1.65 μm, K band with 2.2 μm, L band with 3.5 μm and M band with 4.8 μm as central wavelengths (Glass, 1999).

As a result of the efforts of placing the telescopes at high altitudes, above most of the water content of the atmosphere, near infrared region is getting significant attention next only to the optical region of the overall electromagnetic spectrum. Moreover, the development in size and quantum efficiency of detectors is helping in the rapid growth of NIR technology. The spectroscopic studies and building of spectral libraries in NIR region has special importance in the stellar population synthesis of galaxies, clusters and AGN's. The libraries consisting of different spectro-luminosity classes can help in getting the composite spectra, which could be used to compare the observed integrated light spectrum of the above mentioned objects.

In the present thesis, a spectroscopic database of stars in NIR region has been compiled. This database has a large range in stellar parameters, e.g., temperature, metallicity and gravity. The necessary observations were carried out using the 1.2 meter Gurushikhar Infrared Telescope (GIRT) at Mt. Abu, India. The instrumentation used was the HgCdTe 256 × 256 NIR array (NICMOS3) based spectrometer. The spectra have a moderate resolution of 1000 in J, H and K bands. The present database is available online at http://vo.iucaa.ernet.in/~voi/NIR_Header.html The present thesis has been divided into six chapters as follows:

Chapter 1 starts with a brief introduction of different branches of observational astronomy, e.g., Gamma-ray astronomy, X-ray, UV, Optical, Infrared, Microwave and Radio astronomy. The role of infrared astronomy in understanding different process operating in planetary objects, stars, galaxies and interstellar dust has been reviewed. The importance of infrared and spectroscopy has been emphasized. The challenges of making observations in the infrared are discussed. A detailed survey of available libraries in ultra-violet, optical as well as in near-infrared has been carried out. It has been noticed that there are around 50 libraries in the wavelength range 1-25 μm where substantial number of stars have been observed. Out of these only 21 libraries are available in an electronic form (Sordo & Munari, 2006). The largest and most comprehensive libraries in the NIR have been described in greater detail. A summary of the present Gurushikhar Infrared Telescope (GIRT) library is provided at the end of chapter 1. The significance of the GIRT NIR library has been emphasized.

Chapter 2 deals with the observations and basic data reduction steps involved in the development of GIRT database. The details about GIRT in regard to its location, aperture, focus, focal ratio etc. have been given. The specifications of NICMOS3 HgCdTe 256 × 256 near-infrared (NIR) array based spectrometer have been provided. The observational log for the date and time of observations, number of standard and program stars observed in each observational run are cata-

loged. Since the selection of stars in the library is an important factor, special care was taken in selecting the stars. Different criteria as well as references used for the same are listed. Set-up of the instrumentation and procedure for the data acquisition are listed here. Steps involved in basic data reduction procedure like cosmic ray removal, 2D to 1D frame conversion, aperture extraction etc. have been explained at the end of this Chapter.

As compared to H and K bands, J band is the least explored near infrared region (Wallace et al. 1997, 2000). The survey carried out on the presently available J band libraries in the literature is discussed in the beginning of **Chapter 3**. This chapter presents the spectroscopic data in J band (11300Å to 13100Å). This database developed is one of the few libraries available for work on stellar population synthesis. The J band database contains 126 spectra, covering a large range of spectro-luminosity classes (Ranade et. al 2007b). The distribution of stars with respect to spectral type and luminosity class are shown graphically. The distribution plots of stars as function of different combinations of parameters such as temperature, gravity and metallicity are also shown. The Image Reduction and Analysis Facility (IRAF) software developed by National Optical Astronomy Observatories (NOAO) was used for the spectral reduction. The steps involved in wavelength and flux calibration of J band spectra are highlighted. The wavelength calibration was done through the telluric absorption lines available in the spectra. The lines used for the spectral reduction are shown. Relative flux calibration was done using the standard method of calibrating the ratio of flux of standard star with the programme star. The detailed steps involved in flux calibration are explained. Each spectrum is continuum shape corrected to its respective effective temperature. To check the accuracy of GIRT spectra, a library of Wallace et al. (2000) was used. Since the resolutions of GIRT and Wallace et al. (2000) were different, efforts were made to bring them on a single platform. The procedure

adapted to do so is explained through a block diagram. The sample spectra for a few supergiants, giants and dwarf stars from GIRT are also shown at the end of chapter 3.

Chapter 4 presents the spectroscopic data in H band. From a survey of the existing literature, it has been noticed that the H band is the most explored near infrared region as compared to J and K bands. This chapter starts with the survey of available H band libraries. Our GIRT H band database contains spectra of 135 stars. It has large range in spectro-luminosity classes similar to J band (Ranade et. al 2004, Gupta et. al 2005). The HR diagram depicting the parameter range covered for these 135 stars is shown. The wavelength calibration was done through the atmospheric OH emission lines printed on sky frames. The sample spectra indicating wavelength lines used is shown. The procedures for relative flux calibration and continuum shape correction were similar to those involved in J band except the change in wavelength region. Except for the sixteen stars observed in one particular observational run, rest of the stars have the coverage from 15200Å to 17800Å . Sixteen stars have the coverage from 15500Å to 17300Å . Validity checks have been performed on the GIRT spectra by comparing with the library of Meyer et al. (1998). The comparison between the two libraries has been graphically shown for several common stars.

On the pattern of J and H band database discussed in chapter 3 and 4, the K band database is presented in **Chapter 5**. K band is well known for the domination of H_2O and CO absorption in the earth atmosphere. Therefore, K band is crucial in near infrared spectroscopy. Chapter 5 starts with the review of K band libraries available in the literature. Our GIRT K band database has 114 spectra (Ranade et. al 2007a). Similar to J and H band, a histogram, and distribution plots for combination of parameter spaces are shown. The steps involved in wavelength and flux calibration of K band are highlighted. The wavelength cal-

ibration was again done through the atmospheric OH emission lines printed on sky frames. The sample spectra indicating wavelength lines used are highlighted. Relative flux calibration and continuum shape correction was similar to J and H band spectra except a different wavelength range in the K band. It has been observed that OH lines were not registered at longer wavelengths and hence most of the K band database is restricted to 20300Å to 22600Å . Depending on the rotation of grating during the observation run, each star has different wavelength coverage in K band. To check the consistency and accuracy of the spectra in GIRT K band, a library of Wallace et al. (1997) was used. Once again, GIRT and Wallace et al.(1997) were different in their resolutions and hence a procedure similar to J and H band GIRT spectra was adapted. The comparison between GIRT and Wallace et. al. (1997) spectra is shown graphically.

Chapter 6 deals with the absolute flux calibration and data validation checks on J, H and K band GIRT spectra before it is made available in the public domain. J, H and K band libraries were normalized at their respective central wavelength value of 12500Å , 16500Å and 22000Å . The procedure for the absolute flux calibration is explained. Each spectrum is binned to 5Å steps and made available as an ASCII file. The data validation of GIRT spectra is demonstrated through (i) comparison between GIRT and published synthetic spectra, and (ii) classification of stars through Artificial Neural Network (ANN) trained on empirical spectra from Meyer et al. (1998) and Wallace et al. (1997, 2000). From these validity checks, it can be confirmed that the GIRT stellar spectral database may serve the scientific community working in the field of stellar population synthesis. Lastly, possible future work based on the information available in GIRT database is discussed.