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Multiwavelength study of the inner regions of the Milky Way Galaxy

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Abstract. The inner regions of the Milky Way have received a lot of attention in recent years. Multiwavelength observations have been made at varying spatial, temporal and spectral resolutions. We have studied the inner regions of the Milky Way using data from the Infrared Space Observatory at mid infrared wavelengths, DENIS and 2MASS at near infrared wavelengths, etc. In the present contribution, we summarize results obtained from these studies. We discuss in particular the M16 star forming region for which complementary near infrared observations were made using the PRL NICMOS array on the 1.2m telescope at the Mt Abu IR Observatory.

Keywords : The Galaxy – extinction – galactic structure – stellar populations

1. Introduction

The inner regions of the Milky Way Galaxy have been the subject of surveys at several wavelengths at varying spatial and spectral resolutions. Large scale general sky surveys provide low resolution information while some selected areas have been studied by more powerful instruments / techniques to greater depth.

The DENIS (Deep Near Infrared Southern sky survey) and 2MASS (2 Micron All Sky Survey) surveys provide coverage at near infrared wavelengths (I,J and K_S for DENIS, and J,H and K_S for 2MASS) of the Milky Way galaxy. The resolution is limited by the pixel

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size of the detectors (1" in the I band, 3" pixels in J and K_S for DENIS, 2" for 2MASS in J, H and K_S) and by the crowdedness of the fields being observed. Using the DENIS survey of the Galactic Bulge extinction maps have been built (Schultheis, et al., 1999, Ganesh et al., in prep) by making use of the detection of the red giant/asymptotic giant branch in the K_S vs J-K_S colour-magnitude diagrams. Closer to the Galactic center, one finds large number of stars detected at K_S without detections at shorter wavelengths. Longer wavelength data provide confirmation of the genuineness of the detections at K_S hence one considers that the shorter wavelength (J band) data are not complete in detecting all sources detected at K_S. In order to remedy this situation we carried out deeper surveys at near infrared wavelengths from Mt Abu and elsewhere. One of the fields surveyed included the famous M16 region. These observations and a few results are discussed in the following section.

Towards the galactic nuclear bulge simultaneous J, H and K_S surveys were carried out by our group using the SIRIUS (Simultaneous InfraRed Imager for Unbiased Surveys) camera on the InfraRed Survey Facility's 1.4m telescope at South Africa and these provide the deepest views (over the scale of 5 degrees) of the nuclear bulge to date. Results from this survey are in preparation for publication elsewhere.

The mid infrared data from the ISOGAL project provide a rich set of observations of a large variety of stars mostly obscured by interstellar dust and gas. Some results (Omont et al., 2003 and references therein) and a point source catalog (Schuller et al., 2003) have been published.

2. The M16 region

2.1 Near infrared observations from Mt Abu

Near infrared observations were obtained using the 256x256 NICMOS-III array camera mounted on the 1.2m Mt Abu Telescope. Multiple observations were taken at each location in J and H band and coadded later on. Sky frames were constructed from the image frames themselves. Flat fielding was done using a normalized sky frame with large signal. Photometry was done for the frames at each location and then standardized using the observations of known standards. For the astrometry we used the USNO-A2 positions for the bright stars in each image and applied the corrections accordingly. Stars in the overlaps between images were considered by visual inspection. For each star in the overlap area average value of the corrected world coordinates were taken as also the average of the photometric values. The raster scan procedure employed for these observations is described below.

2.1.1 *Implementation of raster mapping*

The NICMOS array control PC communicates via an RS-232 link with the telescope control system. A plain text file is prepared with the coordinates of the location to be observed alongwith observational parameters such as filters, integration times and number of frames at each location. A typical schedule file is shown below:

```
RA=12:54:32.5 DEC=-01:33:07   UT=00:00:00  OBJECT=DUMMY
        I0=000.500 I1=002.000 F1=2 F2=8 IT=02 DS=10001 DT= star
RA=12:54:42.5 DEC=-01:23:07   UT=00:00:00  OBJECT=SD1254
        I0=000.500 I1=040.000 F1=2 F2=8 IT=05 DS=20001 DT= star
  =12:54:42.5    =-01:23:07   UT=00:00:00  OBJECT=SD1254
        I0=000.500 I1=020.000 F1=3 F2=8 IT=05 DS=30001 DT= star
```

The NICMOS control software then processes this file line by line and if there is a change in location it passes on a string with the new RA and DEC coordinates via the serial port to the telescope control system. It also changes the filters as per requirement and once the telescope has reached the target the integration is started. The telescope control system provides status messages over the serial port with information including current RA, DEC, airmass, UT, as well as some status characters indicating whether the telescope is still moving towards the target or has started tracking the target. A typical string sent by the telescope control system is shown below:

```
RA 14:39:20.4 DEC +19:26:34 NTLST 16:18:35.91 UT 22:23:24.53 HRA 01:39:15.4
   AM 1:090  SM 31:08 AZ 262:16 EL 66:45 DOM 262:0 DAY 097   C G T
```

With each data file (binary) that is saved, a text file containing the observing parameters is also saved by the NICMOS control pc and a sample of such a file is shown below:

```
SIMPLE  =                    T
BITPIX  =                   32
NAXIS   =                    2
NAXIS1  =                  256
NAXIS2  =                  256
OBJECT  = 'mrk501             '
ORIGIN  = 'PRL-NIC3'
DATE-OBS= '2002-03-19T21:20:25'
UT      = '21:18:47'
I0      =                0.500
I1      =                1.000
F1POS   =                    5
```

```
F2POS   =                    8
RA      = '16:53:37.0'
DEC     = '+39:43:00'
DATA-TYP= star
DATA-SET=50401
NIT     =                   22
FOV     =                    4
END
```

Using simple *IRAF* scripts, the two files are combined during analysis to create the corresponding fits image file. Availability of the different keywords makes the analysis procedure amenable to scripting for automated initial reductions.

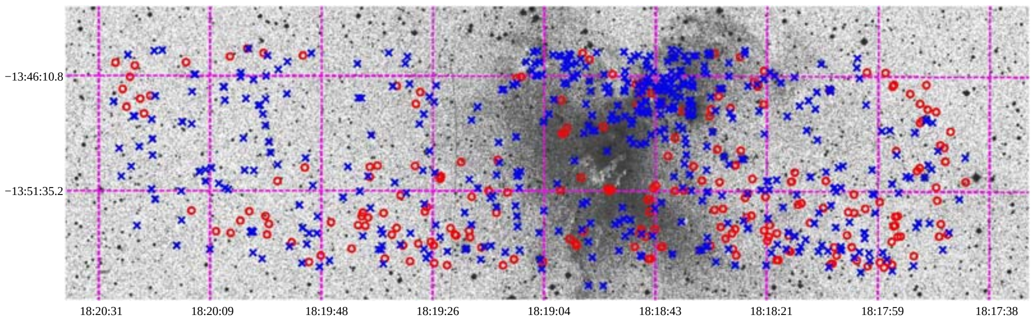

Figure 1. Region covered by the Mt Abu observations overlaid on a DSS view of the M16 star forming region. Crosses mark the blue young stars while open circles mark the reddened stars of the CMD. Note the strong clustering of young stars.

For the M16 observations, the schedule files were created with difference of 1.8' (center to center distance) and the rastering procedure followed this schedule file first moving in RA and then repeating the RA range with different DEC positions. The M16 region is a region with relatively low extinction and a large number of bright stars are in the field which complicate automated reductions/source extraction techniques as employed in large scale surveys such as DENIS. In order to compensate for this we used short integrations of 1sec for each frame in both J and H band filters. A total of 16 frames were taken at each map position in J and 50 in H. Thus a total of 16 and 50 second integration times are available per source in our surveyed field of about 10' by 40' size. Typical photometric accuracy is better than 0.1 mag. Astrometric accuracy is better than 1" thanks to the USNO-A2 catalog used for calibration.

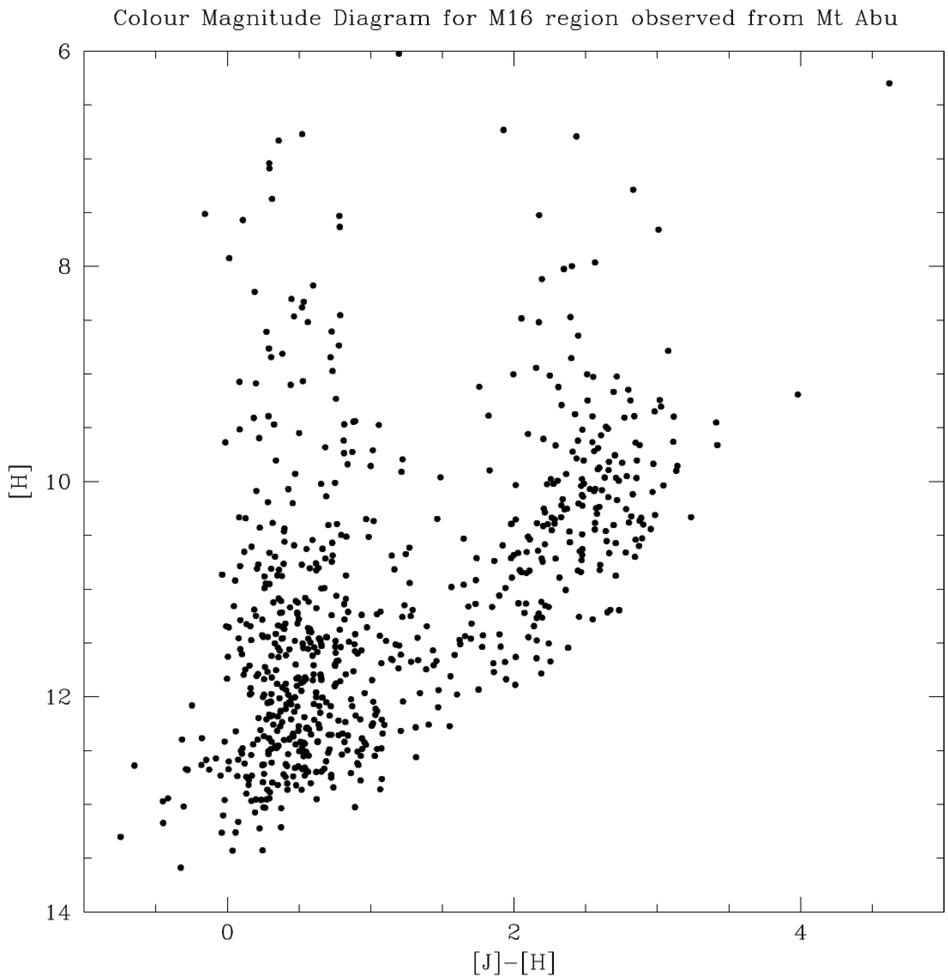

Figure 2. Colour magnitude diagram ([J]-[H] vs [H]) for the field shown in figure 1.

2.2 Results

In figure 1, we show the field covered by our observations overlaid on an optical (DSS) image of the M16 region. The corresponding J-H vs H CMD is shown in figure 2. This has not been corrected for interstellar extinction. A total of 723 sources were detected in both bands and these have been plotted in the figure.

Two distinct stellar populations can be seen. The distribution of the two populations is shown with different symbols in figure 1. The crosses mark the sources that constitute the bluer population. The circles are the sources that appear relatively more extincted. Clearly seen is the central cluster (NGC6611) of blue young stars. Most, but not all, of the redder population is distributed around the fringes of the M16 optical nebulosity. These could be young stars still embedded in the dust they were born in. Some of them could be background stars reddened by interstellar extinction.

A comparative study of the multiwavelength properties of the stars in this region is in progress and will be published separately.

3. Summary

In depth multi-wavelength studies of the inner regions of the Galaxy are being carried out using data from various sources. These are being complemented by followup observations using the Mt Abu telescope and from elsewhere. In this contribution we have summarized the main results of an automated survey using the Mt Abu telescope of about 400 arcmin^2 area of the M16 star forming region. Some results for the M16 region are discussed. We detect two different stellar populations towards this region. Prominently detected is the young cluster of blue stars with small J-H colours. Background sources and other embedded sources are seen with relatively larger reddening. An indepth multi-wavelength study of this field combining data from different surveys is currently in progress.

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References

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