

**U BAND PHOTOMETRIC STUDIES
OF
THE NORTH CELESTIAL POLE (NCP) FILED**

submitted to

MAHATMA GANDHI UNIVERSITY, KOTTAYAM
In partial fulfillment of the requirement for the award of

**Master of Science (Space Science)
By**

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Under the Guidance of

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BANGALORE
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भारतीय ताराभौतिकी संस्थान
INDIAN INSTITUTE OF ASTROPHYSICS

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CERTIFICATE

This is to certify that the project report submitted by Ms. Akhila Chandran (Reg No. 200011024021), a student of Bharata Mata College, Trikkakara, Kochi, Kerala, titled “U-band photometric studies of the North Celestial Pole (NCP)” is a record of project work carried out by her during the period April – June 2022 under my supervision in fulfillment for the award of Master of Science in Space Sciences.

I hereby confirm the originality of work.

Place: Bangalore, Karnataka
Date: 26-09-2022

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DECLARATION

I, **AKHILA CHANDRAN** do hereby declare that this project report entitled “**U BAND PHOTOMETRIC STUDIES OF THE NORTH CELESTIAL POLE(NCP) FIELD**” is a bona-fide record of work submitted to Mahatma Gandhi University in partial fulfillment of the requirement for the award of the degree of MSc. in Space Science carried out by me under the guidance of **Dr. MARGARITA SAFONOVA**. This work hasn't been undertaken or submitted elsewhere in connection with any academic course.

Place: Thrikkakara

AKHILA CHANDRAN

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PHYSICS

BHARATA MATA COLLEGE

TRIKKAKARA

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AKHILA CHANDRAN

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ABSTRACT

Study of north celestial pole in 2009 with a 2-m HANLE telescope as part of the proposed u-v satellite related observation. It is in the U filter. Here are the u-band images obtained on the HCT over 6 nights in 2009 as part of the TAUVEK. This will include learning the data reduction and preprocessing of HCT images.

Chapter 1

INTRODUCTION

The celestial equatorial coordinate system is based on the concept of the celestial sphere, which is an imaginary sphere of an infinite radius surrounding the Earth. The locations of objects in the sky are given by projecting their locations onto this sphere. The celestial sphere is fixed with respect to the universe, and since the earth rotates from west to east, the celestial sphere appears to rotate from east to west according to an observer on Earth. The North Celestial Pole (NCP) is the point in the sky about which all the stars seen from the Northern Hemisphere rotate. The North Star, Polaris, is located almost exactly at this point in the sky. The NCP is directly above the Earth's north pole.

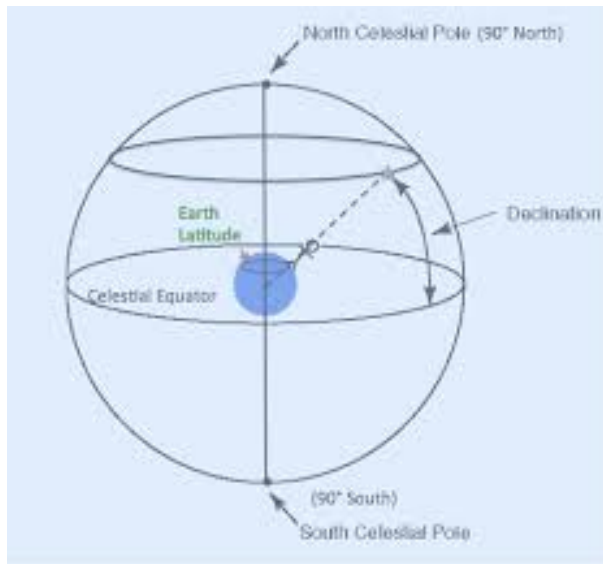


Figure 1: North Celestial Pole

The study of stars includes a detailed understanding of their brightness, distance, luminosity, and so on. There are several methods, like photometry, spectroscopy, etc., for determining the properties of stars. And when we would like to study the motions, measurements of the positions, and magnitudes of stars, then it refers to another branch called Astrometry. The measurement of the amount of flux received from an object or source is referred to as photometry.

]

The above-mentioned flux can be measured by just adding up all the fluxes in each pixel in the selected region of the object. But this method may not end with an accurate measurement because there may be light from other sources too. The so-called external light should be subtracted to get the adequate value of flux. A detector, say, a CCD placed inside the telescope, records raw im-

ages to the computer. For a detailed and effective study, we will need to proceed with processed or reduced images. Image reduction can be done with the help of various image processing software, and one among them is IRAF (Image Reduction and Analysis Facility). IRAF is a software collection written at the National Optical Astronomy Observatory (NOAO) for AstroImage reduction in pixel array form.

0.1 CCD

CCD is referred to as the charged coupled device. An integrated circuit etched onto a silicon surface forms light-sensitive elements called pixels. Each pixel consists of information regarding the image. The light coming from distant stars is passed through the telescope and collected on a CCD chip. In the CCD, photons are converted into electrons. When the photons incident on this surface generate electrons due to a photoelectric effect, that can be read by electronics and turned into a digital copy of the patterns falling on the device.

]

If the CCD is at 100electron. When we get the count of electrons, it represents how much light is coming from the object. Several noises interrupt the process of image capturing. One such noise is caused by cosmic rays. That noise can be removed by certain software. Different pixels have different sensitivity to light, so the problem that arises due to this can be reduced by flat fielding. The sensitivity of a CCD is determined by its quantum efficiency.

0.2 Software and Tools

In the course of our project, we have used different software packages and tools to analyze the obtained data. Most of these are quite commonly used in astronomical research.

0.2.1 IRAF

The basic optical astronomical data package used is IRAF (Image Reduction and Analysis Facility) developed by National Optical Astronomical Observatories(NOAO).

```
NOAO/IRAF PC-IRAF Revision 2.16 EXPORT Thu May 24 15:41:17 MST 2012
This is the EXPORT version of IRAF V2.16 supporting PC systems.

Welcome to IRAF. To list the available commands, type ? or ??. To get
detailed information about a command, type `help <command>'. To run a
command or load a package, type its name. Type `bye' to exit a
package, or `logout' to get out of the CL. Type `news' to find out
what is new in the version of the system you are using.

Visit http://iraf.net if you have questions or to report problems.

The following commands or packages are currently defined:
Initializing SAMP .... No Hub Available

    dataio.    language.  obsolete.  softtools.  vo.
    dbms.     lists.      plot.      system.
    images.   noao.      proto.     utilities.

voc1> □
```

Figure 2: IRAF window

0.3 TOOLS

0.3.1 DS9

SAOimage ds9 is an astronomical image displaying application. It helps to display FITS format astronomical images. If our fits image has specified a world coordinate system the Ra and DEC of the particular position will be displayed as the cursor moves.

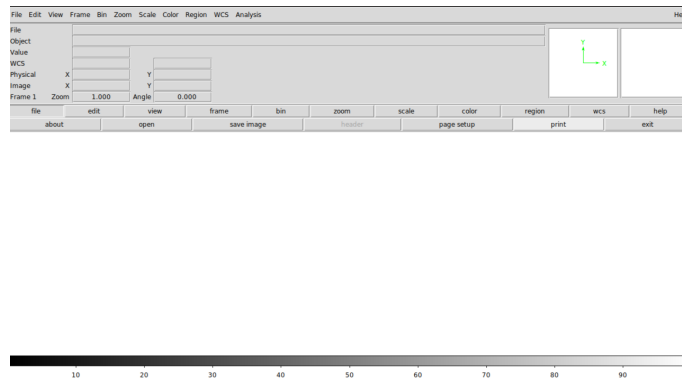


Figure 3: Ds9

0.4 Aladin

Aladin - An interactive software sky atlas. It visualizes digitized astronomical images and helps to access data and information related to the image from the SIMBAD-database and so on. We here use Aladdin to plot the observed stars.



Figure 4: Aladin

The task that was used for this project

noao

- imred: Image Reduction package.
- ccdred: Used for generic CCD reductions

CHAPTER 2

1 OBSERVATION AND DATA REDUCTION

1.1 Observation

Observing the North Celestial Pole in 2009 with a 2-m HANLE telescope as part of the proposed u-v satellite-related observation .It is in the U filter. Here are the u-band images obtained on the HCT over 6 nights in 2009 as part of the TAUVEK. This will include learning the data reduction and Preprocessing of the HCT images. we will have to reduce the data and look for transients and also for pulsars. Photometry of this data will help us to find if there are any interesting objects in polar regions. The central 2048×2048 pixel region was used for imaging, with a pixel scale of $0.296''$ / pixel and a FOV of $10' \times 10'$. The readout noise, gain, and readout time of the CCD are 4.87 e, and 1.22 e/ADU respectively.

1.2 DATA

A CCD raw image includes many types of signals other than source signals such as bias signals, thermal signals, and noise. Readout noise, Dark current, sky background, and cosmic rays are some of the noises. The very first signal coming out of CCD before exposure is the bias signal and thermal signal which is due to the thermal activity of the semiconductor and can be reduced by cooling the CCD or by lowering the temperature of CCD to very low. For analyzing the data the raw images cannot be used directly .so they need to be calibrated and cleaned

of noise. For calibration, we use preprocessing and calibration frames.

```

voc1> cd 2009-11-21
voc1> ls
sk210001.fits sk210010.fits sk210019.fits sk210028.fits sk210037.fits sk210046.fits sk210055.fits sk210098.f
sk210002.fits sk210011.fits sk210020.fits sk210029.fits sk210038.fits sk210047.fits sk210056.fits sk210099.f
sk210003.fits sk210012.fits sk210021.fits sk210030.fits sk210039.fits sk210048.fits sk210057.fits sk210100.f
sk210004.fits sk210013.fits sk210022.fits sk210031.fits sk210040.fits sk210049.fits sk210058.fits sk210101.f
sk210005.fits sk210014.fits sk210023.fits sk210032.fits sk210041.fits sk210050.fits sk210059.fits sk210102.f
sk210006.fits sk210015.fits sk210024.fits sk210033.fits sk210042.fits sk210051.fits sk210060.fits sk210103.f
sk210007.fits sk210016.fits sk210025.fits sk210034.fits sk210043.fits sk210052.fits sk210061.fits sk210104.f
sk210008.fits sk210017.fits sk210026.fits sk210035.fits sk210044.fits sk210053.fits sk210096.fits sk210105.f
sk210009.fits sk210018.fits sk210027.fits sk210036.fits sk210045.fits sk210054.fits sk210097.fits sk210106.f

```

Figure 5: Nov data

```

voc1> cd 2009-12-22
voc1> ls
sl220001.fits sl220014.fits sl220027.fits sl220040.fits sl220053.fits sl220066.fits sl220079.fits sl220092.f
sl220002.fits sl220015.fits sl220028.fits sl220041.fits sl220054.fits sl220067.fits sl220080.fits sl220093.f
sl220003.fits sl220016.fits sl220029.fits sl220042.fits sl220055.fits sl220068.fits sl220081.fits sl220094.f
sl220004.fits sl220017.fits sl220030.fits sl220043.fits sl220056.fits sl220069.fits sl220082.fits sl220095.f
sl220005.fits sl220018.fits sl220031.fits sl220044.fits sl220057.fits sl220070.fits sl220083.fits sl220096.f
sl220006.fits sl220019.fits sl220032.fits sl220045.fits sl220058.fits sl220071.fits sl220084.fits sl220097.f
sl220007.fits sl220020.fits sl220033.fits sl220046.fits sl220059.fits sl220072.fits sl220085.fits sl220098.f
sl220008.fits sl220021.fits sl220034.fits sl220047.fits sl220060.fits sl220073.fits sl220086.fits sl220099.f
sl220009.fits sl220022.fits sl220035.fits sl220048.fits sl220061.fits sl220074.fits sl220087.fits sl220100.f
sl220010.fits sl220023.fits sl220036.fits sl220049.fits sl220062.fits sl220075.fits sl220088.fits sl220101.f
sl220011.fits sl220024.fits sl220037.fits sl220050.fits sl220063.fits sl220076.fits sl220089.fits sl220102.f
sl220012.fits sl220025.fits sl220038.fits sl220051.fits sl220064.fits sl220077.fits sl220090.fits sl220103.f
sl220013.fits sl220026.fits sl220039.fits sl220052.fits sl220065.fits sl220078.fits sl220091.fits sl220104.f

```

Figure 6: December data

```

voc1> cd 2009-10-27
voc1> ls
list
sj270001.fits sj270007.fits sj270014.fits sj270021.fits sj270028.fits sj270
sj270002.fits sj270008.fits sj270015.fits sj270022.fits sj270029.fits sj270
sj270003.fits sj270009.fits sj270016.fits sj270023.fits sj270030.fits sj270
sj270004.fits sj270010.fits sj270017.fits sj270024.fits sj270031.fits sj270
sj270005.fits sj270011.fits sj270018.fits sj270025.fits sj270032.fits sj270
sj270006.fits sj270012.fits sj270019.fits sj270026.fits sj270033.fits sj270
sj270007.fits sj270013.fits sj270020.fits sj270027.fits sj270034.fits sj270

```

Figure 7: October data

1.3 BIAS FRAME

Bias frames are zero-second exposure time which removes bias signal and readout noise from our sensor. Bias is a constant voltage added to CCD and it cannot be negative. There is an additional component in noise that prevents the CCD from recording a negative value. The Bias voltage is applied to ensure efficient charge transfer and also the detection of low-energy photons. Bias frame defines minimum CCD noise and it must be subtracted from all images. A master bias frame is obtained when we take averaged image of a single bias frame. Then the pixel-by-pixel subtraction of the master bias frame is done by the object frame as well as the Master flat-field frame.

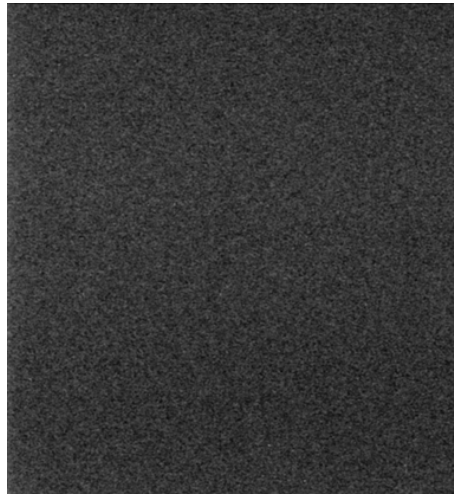


Figure 8: MasterBias frame

```

IRAF
Image Reduction and Analysis Facility
PACKAGE = ccdred
TASK = zerocombine

input = @biases List of zero level images to combine
(output = MasterBias.fits) Output zero level name
(combine= average) Type of combine operation
(reject = minmax) Type of rejection
(ccdtype= ) CCD image type to combine
(process= no) Process images before combining?
(delete = no) Delete input images after combining?
(clobber= no) Clobber existing output image?
(scale = none) Image scaling
(statsec= ) Image section for computing statistics
(nlow = 0) minmax: Number of low pixels to reject
(nhigh = 1) minmax: Number of high pixels to reject
(nkeep = 1) Minimum to keep (pos) or maximum to reject (neg)
(mclip = yes) Use median in sigma clipping algorithms?
(lsigma = 3.) Lower sigma clipping factor
(hsigma = 3.) Upper sigma clipping factor
(rdnoise= 4.87) ccdclip: CCD readout noise (electrons)
(gain = 1.22) ccdclip: CCD gain (electrons/DN)
(snoise = 0.) ccdclip: Sensitivity noise (fraction)
(pclip = -0.5) pclip: Percentile clipping parameter
(blank = 0.) Value if there are no pixels
(mode = ql)

```

Figure 9: MasterBias

From the given data we have to list the bias images and call it as biases. The listing is done by the command "hselect @list I "exptime?=0.000" biases". Then these biases are then used for masterbias. Here we use the command 'epar hedit' to open this window (fig:9) and set the input as @biases and do the MasterBiasing of the biases.

1.4 FLAT FIELD FRAME

A Flat field is a technique used to improve quality in digital imaging. The last calibration image is a at frame and it is the only calibration frame where the shutter is opened. A uniform signal will create a uniform output if a detector has been properly flat-fielded. A Master-flat image is obtained when we take an average image of many single flat-field frames.

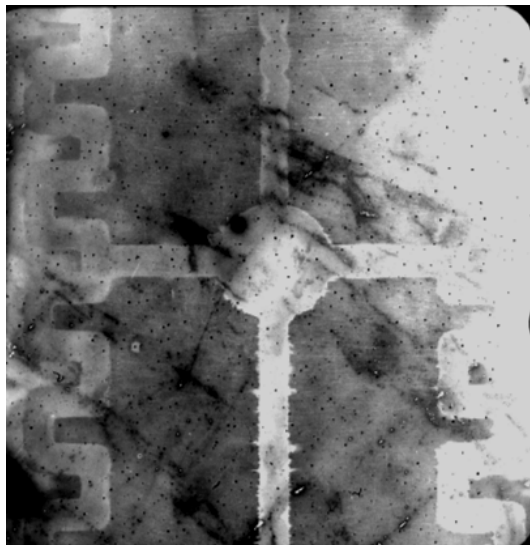


Figure 10: NMasterflat frame

```

IRAF
IRAF
Image Reduction and Analysis Facility

PACKAGE = ccdred
TASK = flatcombine

input = [] @flats List of flat field images to combine
(output = MasterFlat.fits) Output flat field root name
(combine= median) Type of combine operation
(reject = avsigclip) Type of rejection
(ccdtype= ) CCD image type to combine
(process= no) Process images before combining?
(subsets= no) Combine images by subset parameter?
(delete = no) Delete input images after combining?
(clobber= no) Clobber existing output image?
(scale = mode) Image scaling
(statsec= ) Image section for computing statistics
(nlow = 1) minmax: Number of low pixels to reject
(nhigh = 1) minmax: Number of high pixels to reject
(nkeep = 1) Minimum to keep (pos) or maximum to reject (neg)
(mclip = yes) Use median in sigma clipping algorithms?
(lsigma = 3.) Lower sigma clipping factor
(hsigma = 3.) Upper sigma clipping factor
(rdnoise= 4.87) ccdclip: CCD readout noise (electrons)
(gain = 1.22) ccdclip: CCD gain (electrons/DN)
(snoise = 0.) ccdclip: Sensitivity noise (fraction)
(pclip = -0.5) pclip: Percentile clipping parameter
(blank = 1.) Value if there are no pixels
(mode = );

```

Figure 11: Masterflat frame

Now the MasterFlat is created and we have to normalise it and create NMasterFlat. For that we initially check the mean value and divide the MasterFlat with this mean value to get NMasterFlat. We use the command "imstat MasterFlat.fits" to check the mean.

```

ccdred> imstat MasterFlat.fits
#      IMAGE      NPIX      MEAN      STDDEV      MIN      MAX
      MasterFlat.fits  4194304  25262.  3784.  0.  54512.
ccdred> []

```

Figure 12: Mean of MasterFlat

We have to normalise the mean value so use 'epar imarith' and give the input, output and operation to execute as shown in the following

```

                                I R A F
                                Image Reduction and Analysis Facility
PACKAGE = imutil
TASK = imarith

operand1=   Masteflat.fits  Operand image or numerical constant
op         =                /      Operator
operand2=   25262          Operand image or numerical constant
result    =   NMasterFlat.fits  Resultant image
(title    =                ) Title for resultant image
(divzero  =   0.)          Replacement value for division by zero
(hparams  =                ) List of header parameters
(pixtype  =                ) Pixel type for resultant image
(calctype =                ) Calculation data type
(verbose  =   yes)         Print operations?
(react   =   no)          Print operations without performing them?
(mode    =                ql)

```

Figure 13: epar imarith

```

IMARITH:
Operation = /
Operand1 = MasterFlat.fits
Operand2 = 25262
Result = NMasterFlat.fits
Result pixel type = real
Calculation type = real
Replacement value for division by zero = 0.
ccdred> imstat NMasterFlat.fits
#      IMAGE      NPIX      MEAN      STDDEV      MIN      MAX
      NMasterFlat.fits  4194304      1.      0.1498      0.      2.158
ccdred>

```

Figure 14: Normalised mean

1.5 Object frame

The astronomical object of interest is included in object frames. Each object frame is influenced by an object, CCD readout Variation, sky, and cosmic rays. The exposure time depends on the brightness of the object. As there are several pixels, each pixel responds to the incident light in a different way hence the object frame is needed to be flat-fielded.



Figure 15: objectframe

The objects consist of images under observation and we have to subtract biases and flat from them by using 'epar imarith'. After the subtraction the objects are listed as 'fboject'

```
fbsk210049.fits  
fbsk210050.fits  
fbsk210051.fits  
fbsk210052.fits  
fbsk210053.fits  
fbsk210058.fits  
fbsk210059.fits  
fbsk210060.fits  
fbsk210061.fits
```

Figure 16: fboject

CHAPTER 3

2 DATAANALYSIS

There are different modules of data analysis and one among them we used here is

- ∫ Pre-processing Module which calibrates the science images and removes cosmic-rays.
- ∫ This module includes astrometry and photometry.

2.1 Pre-processing Module

In this module, we run the code “preprocessing. cl”. It can be executed by typing “cl ∫ preprocessing. cl” in the IRAF terminal in the ccdred package. After the code had run, the raw images will get calibrated. The calibration includes the creation of a master bias frame and master flat-field frame which can be used to correct the raw object images. IRAF tasks “Zerocombine” and “Flatcombine” are combined and used to do the raw object image corrections and then observed images are pre-processed using the ‘ccdproc’ task.

2.1.1 How to plot?

Here we start by opening the terminal and type
;type Aladin
Then the aladin window will display.
;Select DSS from the displayed window.

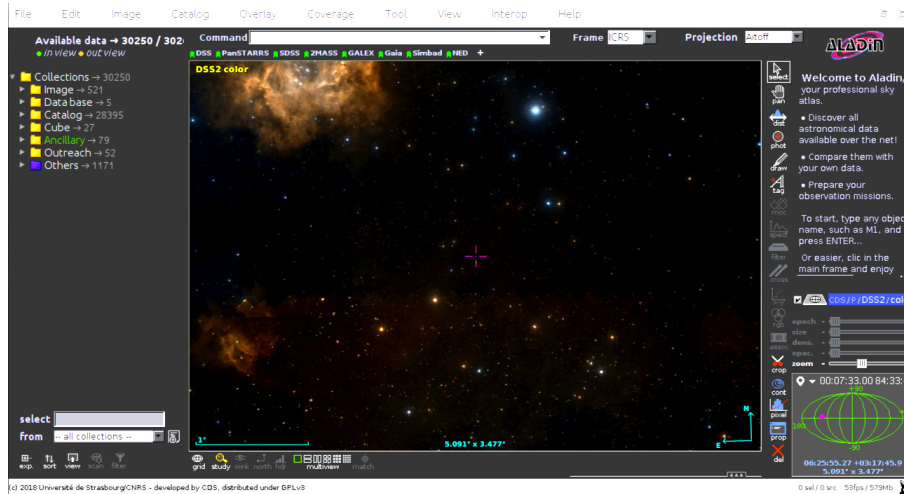


Figure 17: ALADIN DSS

ı Now adjust the cursor to the North-Pole . Then enter the codes that is the coordinates of each stars , in the terminal command box and run .Each stars plotted and displayed as small red squares .After entering all the co-ordinates we get the final plotted image of the whole stars we observed.

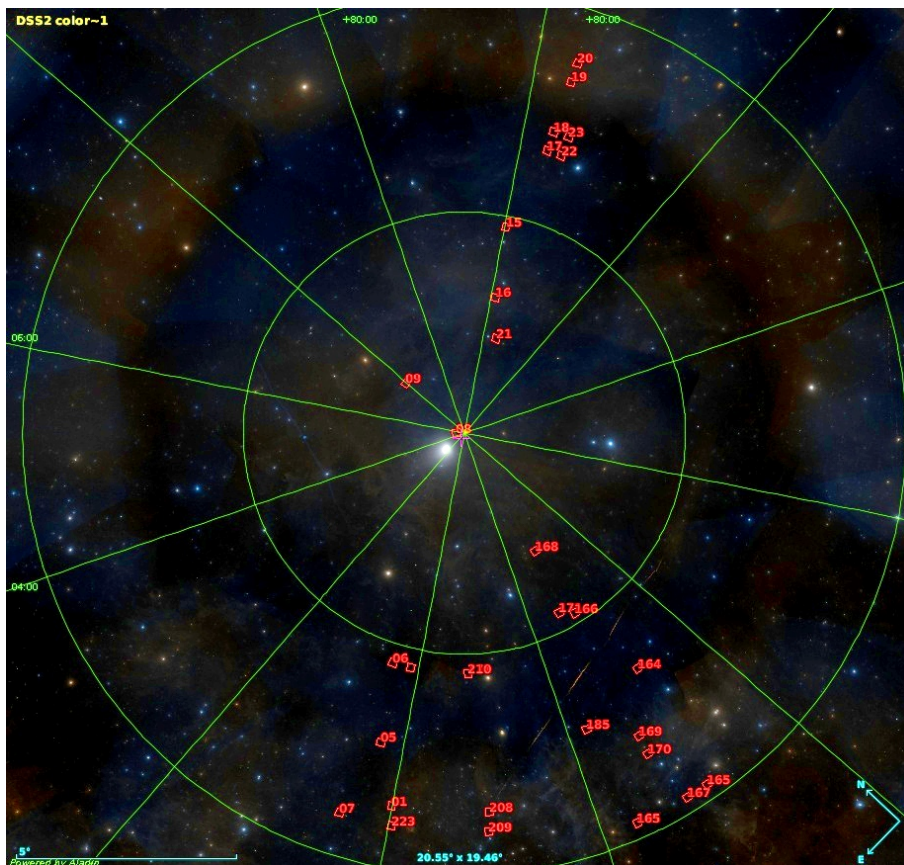


Figure 18: plotting of stars

2.2 RA and DEC

Command_j draw box(00:00:12.00 81:24:48.00 10arcmin
10arcmin 0deg)

Command_i draw box(00:07:33.00 84:33:42.00 10arcmin
10arcmin 0deg)

Command_i draw box(00:16:37 82:45:47 10arcmin 10ar-
cmin 0deg)

Command_i draw box(00:25:19.00 84:33:50.00 10arcmin
10arcmin 0deg)

Command_i draw box(00:28:55.00 80:57:41.00 10arcmin
10arcmin 0deg)

Command_i draw box(05:09:05.00 89:48:54.00 10arcmin
10arcmin 0deg)

Command_i draw box(07:57:26 88:15:40 10arcmin 10ar-
cmin 0deg)

Command_i draw box(12:01:31.00 85:14:56.00 10arcmin
10arcmin 0deg)

Command_i draw box(12:07:18.00 86:51:28.00 10arcmin
10arcmin 0deg)

Command_i draw box(12:21:19.00 83:20:57.00 10arcmin
10arcmin 0deg)

Command_i draw box(12:22:10.00 82:53:58.00 10arcmin
10arcmin 0deg)

Command_i draw box(12:23:41.00 81:41:55.00 10arcmin
10arcmin 0deg)

Command_i draw box(12:24:07.00 81:14:52.00 10arcmin
10arcmin 0deg)

Command_i draw box(12:30:07.00 87:44:48.0 10arcmin
10arcmin 0deg)

Command_i draw box(12:32:57.00 83:21:20.00 10arcmin

10arcmin 0deg)
 Command_i draw box(12:33:47.00 82:54:12.00 10arcmin
 10arcmin 0deg)
 Command_i draw box(20:50:18 83:23:44 10arcmin 10ar-
 cmin 0deg)
 Command_i draw box(20:57:40 80:21:07 10arcmin 10ar-
 cmin 0deg)
 Command_i draw box(21:09:47 85:13:53 10arcmin 10ar-
 cmin 0deg)
 Command_i draw box(21:10:18 80:21:12 10arcmin 10ar-
 cmin 0deg)
 Command_i draw box(21:12:35 86:53:50 10arcmin 10ar-
 cmin 0deg)
 Command_i draw box(21:16:26 82:06:06 10arcmin 10ar-
 cmin 0deg)
 Command_i draw box(21:17:05 81:39:09 10arcmin 10ar-
 cmin 0deg)
 Command_i draw box(21:24:41.00 85:25:01.00 10arcmin
 10arcmin 0deg)
 Command_i draw box(21:40:36 80:21:14 10arcmin 10ar-
 cmin 0deg)
 Command_i draw box(21:46:36 82:45:20 10arcmin 10ar-
 cmin 0deg)
 Command_i draw box(23:01:09.00 81:24:52.00 10arcmin
 10arcmin 0deg)
 Command_i draw box(23:02:02.00 80:57:54.00 10arcmin
 10arcmin 0deg)
 Command_i draw box(23:12:35.00 84:33:52.00 10arcmin
 10arcmin 0deg)
 Command_i draw box(23:58:16.50 80:58:10.6 10arcmin

10arcmin 0deg)

Command; draw string (05:09:05.00 89:48:54.00 "8")
Command; draw string (05:09:05.00 89:48:54.00 "08")
Command; draw string (07:57:26 88:15:40 "09")
Command; draw string (12:30:07.00 87:44:48.0 "21")
Command; draw string (21:12:35 86:53:50 "168")
Command; draw string (12:07:18.00 86:51:28.00 "16")
Command; draw string (21:24:41.00 85:25:01.00 "171")
Command; draw string (12:01:31.00 85:14:56.00 "15")
Command; draw string (21:09:47 85:13:53 "166")
Command; draw string (23:12:35.00 84:33:52.00 "171")
Command; draw string (23:12:35.00 84:33:52.00 "210")
Command; draw string (00:25:19.00 84:33:50.00 "06")
Command; draw string (20:50:18 83:23:44 "164")
Command; draw string (12:32:57.00 83:21:20.00 "22")
Command; draw string (12:21:19.00 83:20:57.00 "17")
Command; draw string (12:33:47.00 82:54:12.00 "23")
Command; draw string (12:22:10.00 82:53:58.00 "18")
Command; draw string (00:16:37 82:45:47 "05")
Command; draw string (21:46:36 82:45:20 "185")
Command; draw string (12:23:41.00 81:41:55.00 "19")
Command; draw string (23:01:09.00 81:24:52.00 "208")
Command; draw string (21:17:05 81:39:09 "170")
Command; draw string (12:24:07.00 81:14:52.00 "20")
Command; draw string (12:23:41.00 81:41:55.00 "19")
Command; draw string (00:00:12.00 81:24:48.00 "01")
Command; draw string (21:40:36 80:21:14 "165")
Command; draw string (23:02:02.00 80:57:54.00 "209")
Command; draw string (23:58:16.50 80:58:10.6 "223")
Command; draw string (20:57:40 80:21:07 "165")

Command; draw string (21:10:18 80:21:12 "167")
Command; draw string (00:28:55.00 80:57:41.00 "07")
Command; draw string (21:16:26 82:06:06 "169")

RESULT

The stars were identified by eye when flashing through the image sub-frames in ds9. We observed the stars that were distributed along the north celestial pole. Using the astrometrically calibrated reference frame, each of these stars has been identified, their celestial coordinates (RA, DEC) determined and they have been used for the plotting. U band images obtained on HCT over 6 nights observed by Safanova at, 2009 were searched but they were faint stars and were removed during the subtraction. Hence, they were not detected.

CONCLUSION

The observation of the north celestial pole in 2009 with a 2-m Hanle telescope was part of the u-v satellite-related observation. we observe the stars with an u-band filter and identify their position. By identifying the position we plotted the star by Aladin. Astrometric calibration was done by Aladin and IRAF. Our study is based on the u-band photometric study of stars in the north celestial pole but here we conclude our work by plotting the observed stars due to errors in the given data.