"PHOTOMETRIC STUDY OF NORTH CELESTIAL POLE FIELD"

submitted to

MAHATMA GANDHI UNIVERSITY, KOTTAYAM

In partial fulfillment of the requirement for the award of

Master of Science (Space Science)

By

JYOTHY K PRAKASH

(REG NO. 200011024026)

Under the Guidance of

Dr. MARGARITA SAFONOVA

INDIAN INSTITUTE OF ASTROPHYSICS, KORMANGALA

BANGLORE

2020-2022

CERTIFICATE

This is to certify that the project report submitted by Ms. Jyothi K. Prakash (Reg No. 200011024026), 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

Dr. Margarita Safonova
DST Woman Scientist,
Indian Institute of Astrophysics
Bangalore-560034, India

Plagiarism Checker X - Report

Originality Assessment

Overall Similarity: **7%**

Date: Sep 27, 2022
Statistics: 190 words Plagiarized / 2678 Total words
Remarks: Low similarity detected, check your supervisor if changes are required.

DECLARATION

I, **JYOTHY K PRAKASH** do hereby declare that this project report entitled **"PHOTOMETRIC STUDY OF NORTH CELESTIAL POLE 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   **JYOTHY K PRAKASH**

Date:

ACKNOWLEDGEMENT

First and foremost, I thank God the almighty, who has showered his blessings upon me to complete this project successfully.

My sincere gratitude is expressed to Dr. Shainy Palatty, Principal Bharata Mata College, Thrikkakara, for her permission and help extended for the accomplishment of this work.

I would like to covey my deep regards to our project supervisor Margarita safonova, DST scientist, Indian institute of Astrophysics. I thank her for her patience, guidance, regular monitoring of the work and inputs, without which this work could have never come to a success. Indeed, the experience of working under her is one of that I will cherish forever.

I would like to thank the entire Department of Physics Bharata Mata College, Thrikkakara for their support in making this work a success. They were with me in every difficulty that I have faced and their encouragement was tremendous sources of inspiration.

I am thankful to Indian Institute of Astrophysics for their assistance in completing this work.

I also thanks to my parents, brother, friends, classmates, teachers of Bharath Mata College, Thrikkakara, for their kind cooperation and for

JYOTHY K PRAKASH

CONTENTS

Abstract

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 TAUVEX. 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.
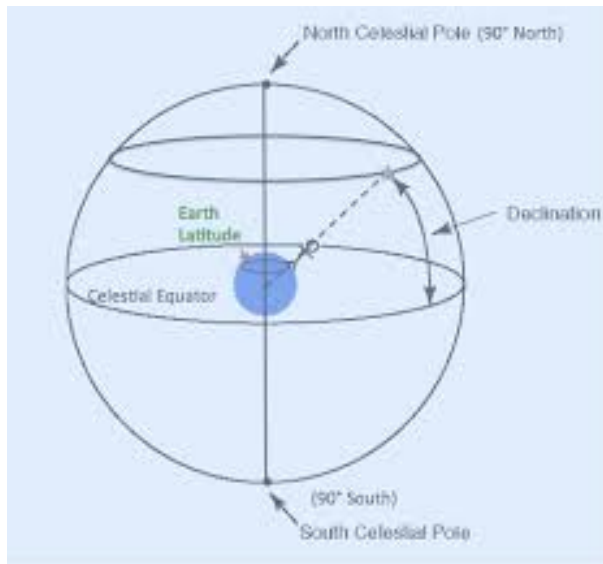
Figure 1: North Celestial Pole

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-

3

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.    softools.    vo.
      dbms.        lists.       plot.        system.
      images.      noao.        proto.       utilities.

vocl> ▯
```

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.
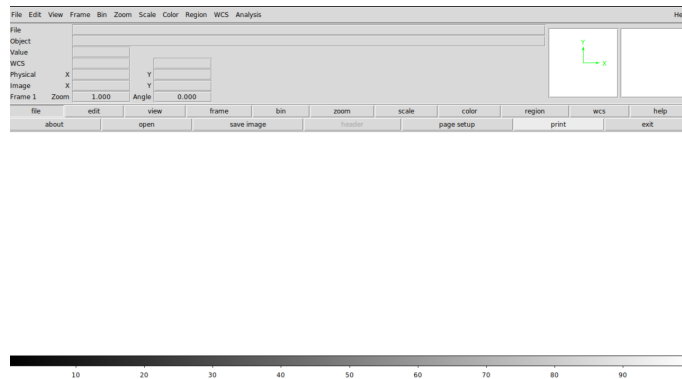

Figure 3: Ds9

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 TAUVEX. 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.

Figure 5: Nov data

Figure 6: December data

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.
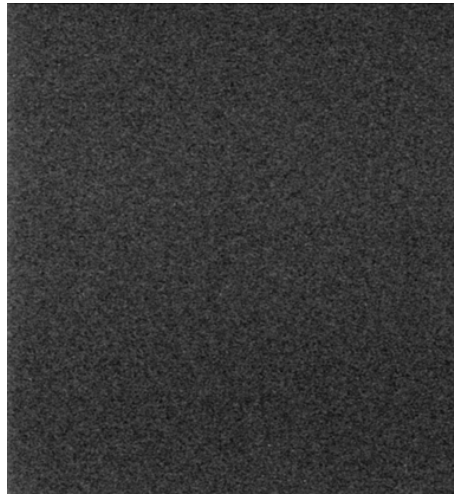

Figure 8: MasterBias frame

```
                                                              IRAF
                                                         I R A F
                                            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 this 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 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.
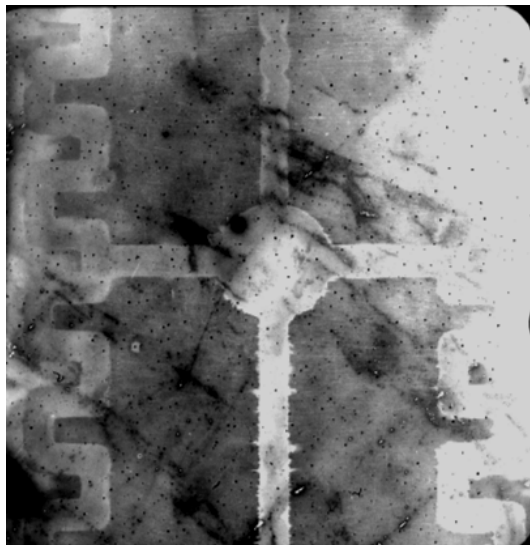

Figure 10: NMasterflat frame

```
                                                          IRAF

                                            I R A F
                               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 NMasteFlat.For that we initally 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

15

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

Figure 13: epar imarith

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 'fbobject'

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.
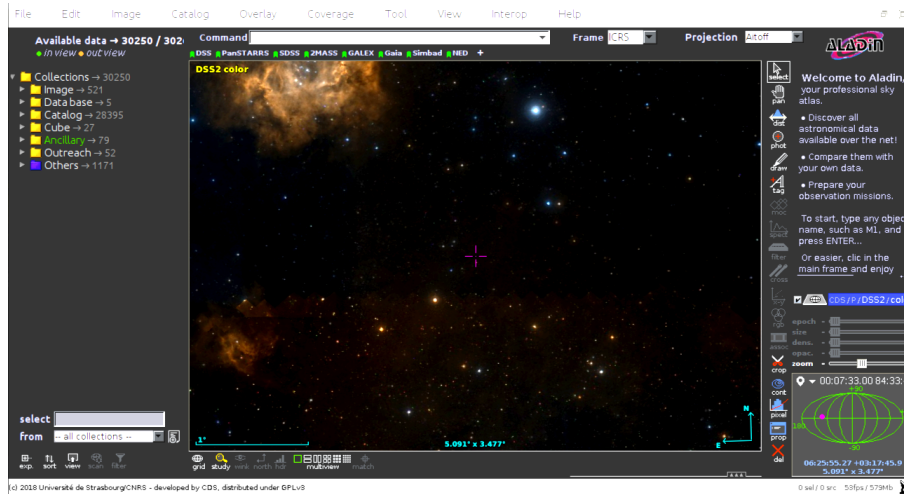¿Select DSS from the displayed window.

Figure 17: ALADIN DSS

¿ 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.
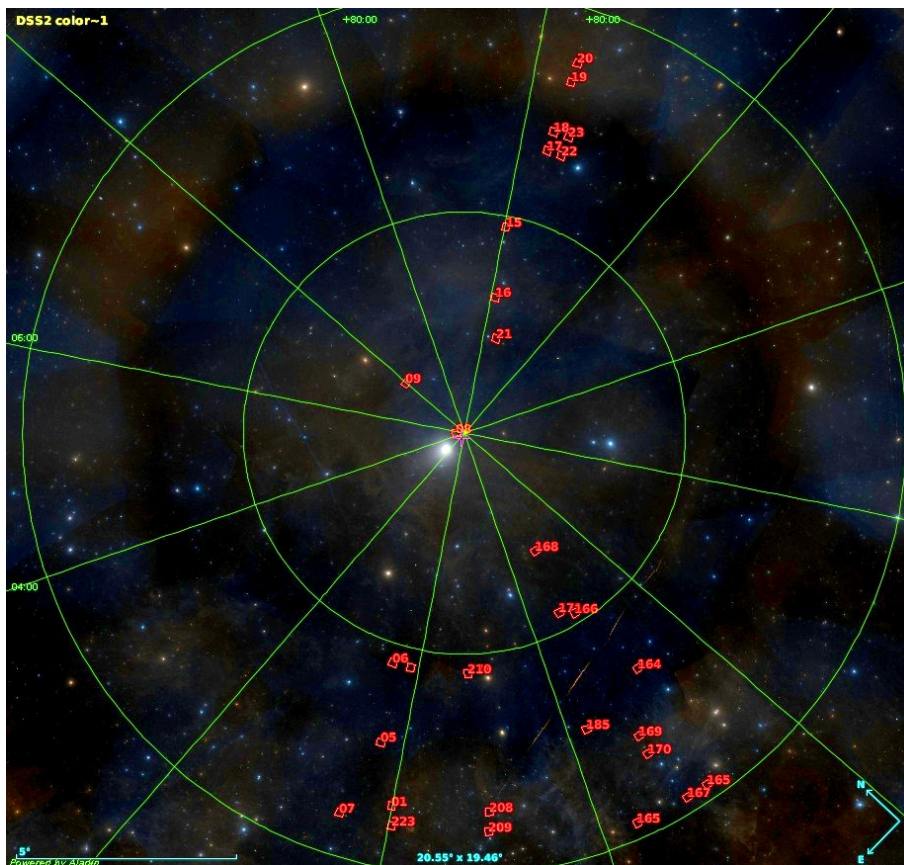

Figure 18: plotting of stars

2.2 RA and DEC

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

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

Command¿ draw box(00:16:37 82:45:47 10arcmin 10arcmin 0deg)

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

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

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

Command¿ draw box(07:57:26 88:15:40 10arcmin 10arcmin 0deg)

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

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

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

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

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

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

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

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

10arcmin 0deg)

Command¿ draw box(12:33:47.00 82:54:12.00 10arcmin 10arcmin 0deg)

Command¿ draw box(20:50:18 83:23:44 10arcmin 10arcmin 0deg)

Command¿ draw box(20:57:40 80:21:07 10arcmin 10arcmin 0deg)

Command¿ draw box(21:09:47 85:13:53 10arcmin 10arcmin 0deg)

Command¿ draw box(21:10:18 80:21:12 10arcmin 10arcmin 0deg)

Command¿ draw box(21:12:35 86:53:50 10arcmin 10arcmin 0deg)

Command¿ draw box(21:16:26 82:06:06 10arcmin 10arcmin 0deg)

Command¿ draw box(21:17:05 81:39:09 10arcmin 10arcmin 0deg)

Command¿ draw box(21:24:41.00 85:25:01.00 10arcmin 10arcmin 0deg)

Command¿ draw box(21:40:36 80:21:14 10arcmin 10arcmin 0deg)

Command¿ draw box(21:46:36 82:45:20 10arcmin 10arcmin 0deg)

Command¿ draw box(23:01:09.00 81:24:52.00 10arcmin 10arcmin 0deg)

Command¿ draw box(23:02:02.00 80:57:54.00 10arcmin 10arcmin 0deg)

Command¿ draw box(23:12:35.00 84:33:52.00 10arcmin 10arcmin 0deg)

Command¿ 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 celes-
tial pole but here we conclude our work by plotting the
observed stars due to errors in the given data.