# “CYGNUS LOOP”

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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**(REG NO. 200011024027)**


Under the Guidance of

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**INDIAN INSTITUTE OF ASTROPHYSICS, KORMANGALA**

**BANGLORE**

**2020-2022**

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22nd Sept. 2022.

To: Whomsoever it may concern.

This is to certify that the material presented in the project report, on the UV study of some Southern and Eastern segments of the Cygnus loop, titled "CYGNUS LOOP" by Linta Premkumar, was carried out under my supervision at the Indian Institute of Astrophysics, Bangalore, India, during Apr-Jun 2022.

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Summary

# DECLARATION

I, **LINTA PREMKUMAR** do hereby declare that this project report entitled **"A STUDY ON SOUTHERN LIMB OF CYGNUS LOOP"** 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. Firoza Sutaria**. This work hasn't been undertaken or submitted elsewhere in connection with any academic course.

Place: Thrikkakara **LINTA PREMKUMAR**

Date: 26/9/2022

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I would like to covey my deep regards to our project supervisor Firoza Sutaria, Assistant Professor, 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, friends, classmates, teachers of Bharata Mata College, Thrikkakara, for their kind cooperation

LINTA PREMKUMAR

# CONTENT

# ABSTRACT

A study on southern limb and 28' diameter segment of the eastern limb of the cygnus loop is presented here. The UVIT images of this area are processed using two software developed for processing UVIT images-JUDE and CCDLAB. A comparison of these software is studied which helps the observer to use suitable software for their studies on UVIT images. The images are studies carefully to observe whether any changes occurred in these areas over time. A change is observed in NGC6995, so it is studies more to analyze the changes.

# INTRODUCTION

Cygnus loop is a large supernova remnant located in the northern constellation of Cygnus. It is 725 ± 15 pc away [1]. Supernova remnant(SNR) are remains of a supernova explosion, and their structure and evolution is determined by interaction of the supernova shock with stellar as well as interstellar matter. It enriches space with heavy elements. It also plays an important role in stellar evolution. It compresses interstellar gas which triggers new star formation.

ASTROSAT is India's first multi-wavelength space telescope. It was launched into a circular orbit which is 650km above the earth and has an inclination of about 6◦ relative to the equatorial plane. On board ASTROSAT have five payloads. One of them is UVIT or ultra-violet imaging telescope. It is a 3 in 1 imaging telescope which can observe simultaneously in the visible, far ultra-violet (FUV) and near-ultraviolet (NUV). It consists of two Ritchey-Chretian telescopes, with UV capable optics. Of these, one observes the far ultraviolet (1350 – 1800˚A) band while the other is equipped with beam splitter, which permits observations in both the near ultraviolet (1800– 3200˚A) and visible (3200 – 9000˚A) pass bands. In front of each detector a filter wheel is provided to select required spectral range. The band pass and central effective wavelength of all the filters used in this project is give below (table 1)

| **FUV** | | |
|---|---|---|
| FILTER | BANDPASS ($A^0$) | Central Effective Wavelength |
| BaF2 | 1330 – 1830 | 1555.81 |
| Sapphire | 1450 – 1810 | 1602.36 |
| Silica | 1600 – 1790 | 1718.03 |
| **NUV** | | |
| NUVN2 | 2750 – 2850 | 2792.37 |

Table 1: Filter specifications for the Astrosat/UVIT-FUV and UVIT-NUV bands used in these observations [2]

UVIT imaging data of southern limb, as well as a single, 28′ diameter segment of eastern limb of the Cygnus loop is brought under study here. To study a region it is important to study images which are processed perfectly. Image registration on the level1 UVIT data was carried out using two separate softwares, JUDE and CCDLAB and the resulting images were calibrated using calibrations reported by [6] and [2]. Then the broad band images are compared with the archival IUE spectroscopic data and UIT archival UIT images are used to trace the loci of the shock fronts embedded within the cooler, UV emitting gasses. Here, Observation of CYGNUS-S-I, CYGNUS-S-VIII and NGC6995 are made.

# OBSERVATION AND DATA ANALYSIS

` The raw data from ASTROSAT (labeled level0) is telemetered from the satellite to the terrestrial receiving stations, and is sent to ASTORSAT data processing centre and data archive at the Indian Space Science Data Centre (ISSDC). Here level0 is processed in to level1, correctly accounting for the satellite parameters, and assigned to the correct instruments, in the process. Now, the post processing data is called level1 data. The level 1 data of Cygnus-S-I, Cygnus-S-VIII and NGC6995 are obtained from the Astrosat data archive. The level1 data is an zipped archive for each of the observations. They are all in the form of Flexible Image Transport System (FITS) binary tables. The first step is to process these binary tables to obtain images in the same format. This is the level 2 data.

Here we'll use two software to obtain the level 2 data, Jayant's UVIT data Explorer (JUDE) data pipeline software and CCDLAB, developed by Canadian space agency. Both softwares are developed for processing and reducing Ultra-violet Imaging Telescope data.

JUDE [3] is a software written in IDL/GDL data language. Following the methodology given in [4] To convert level 1 data to level 2 data we first have to run the IDL/GDL utility process uvit.com from the terminal. This will (a) merge data, and discard repetitive time stamps, (b) create event list and, (c) create images. Displaying the images shows that the frames even with a single observation, are not aligned properly and the stellar streaks trace the wobble of the satellite in the orbit. To register the images properly, we run the JUDE IDL/GDL task interactive.com. Following the methodology in [4] then certain questions will be asked for which inputs are to be given along with it a window with image appear.(fig 1)

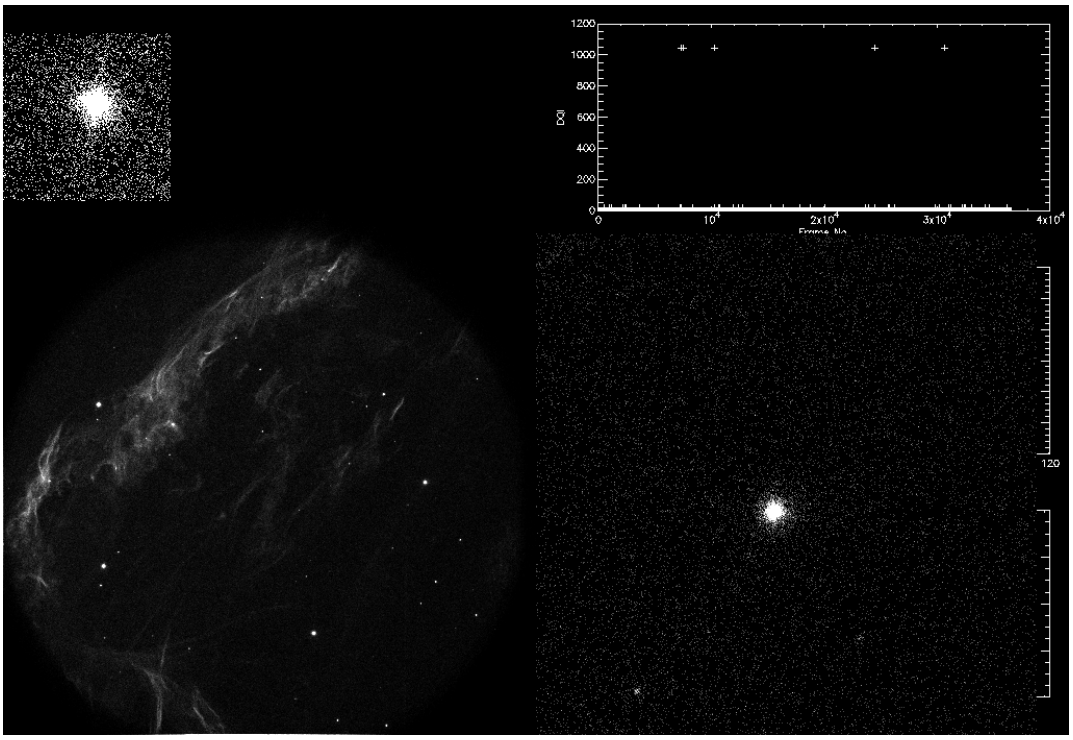


Figure 1: JUDE processing CYG-S-VIII

It is to be noted that in the level 2 data sets, generated in JUDE, for a single filter more than one image is created.

[5]CCDLAB is a Canadian UVIT pipeline used for UVIT data reduction. Level1 obtained is extracted from CCDLAB. Then the process of extraction, digestion etc.. will be carried out automatically. All the conditions for this will be selected by default.

After this automated process we have to register the images. For that we have to select two bright opposite stars to avoid translation and rotation, and registration is done. After the registration the images are merged and images from each filter is obtained. Then PSF optimization is done and final product is obtained.

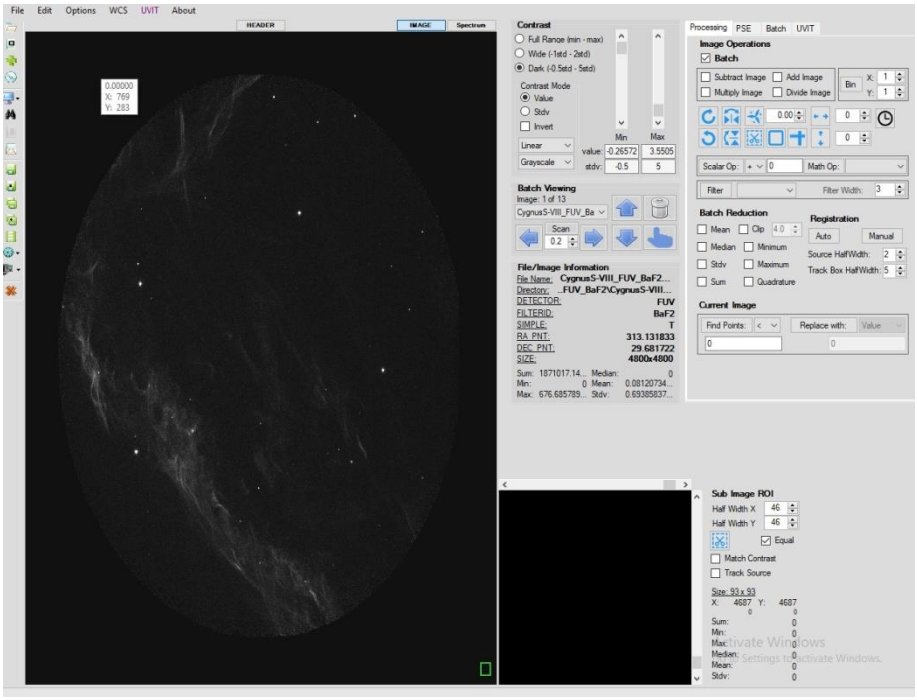


Figure 2: CCDLAB set up

Through these processes every data set is processed to obtain level 2 data. The images of S-VIII for FUV BaF2 filters obtained from JUDE and CCDLAB is given below.

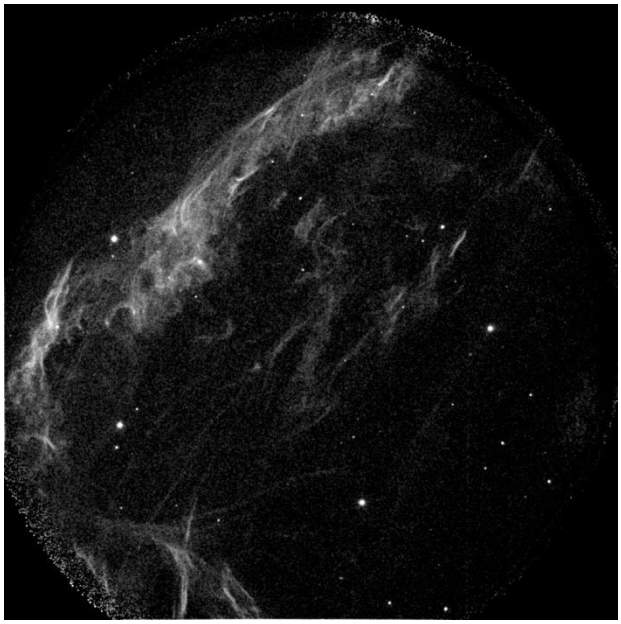

Figure 3: image0 CYG-S-VIII (BaF2) images from JUDE

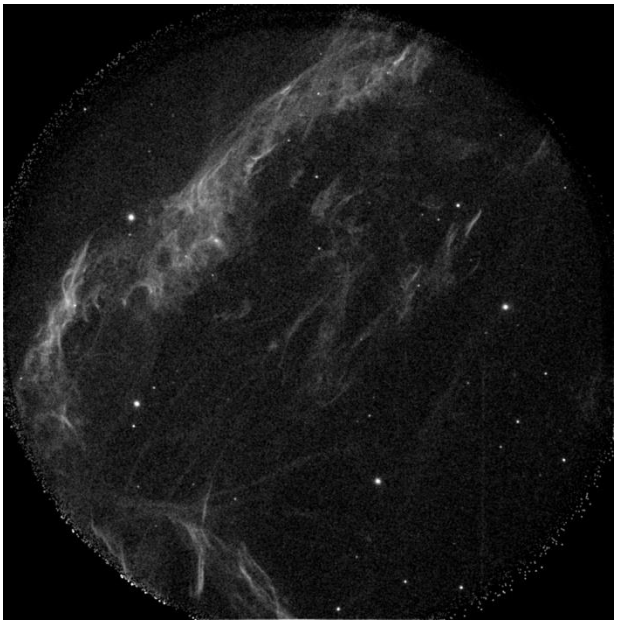

Figure 4: Image 1 CYG-S-VIII (BaF2) images from JUDE

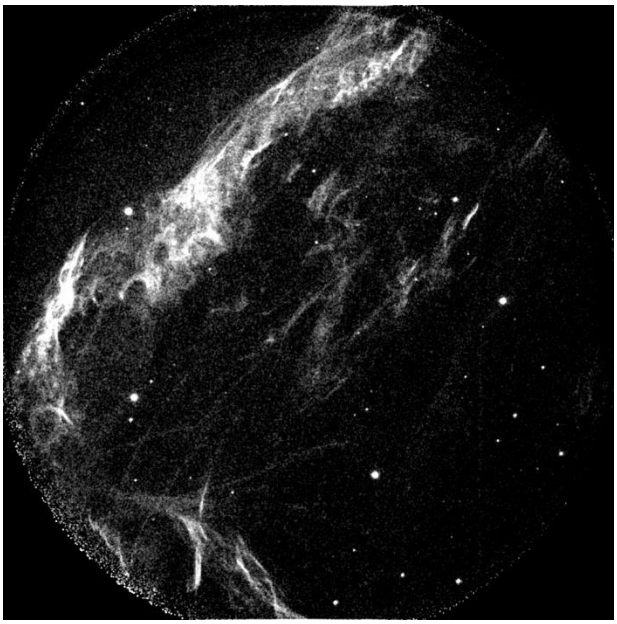

Figure 5:Image 2 CYG-S-VIII (BaF2) images from JUDE

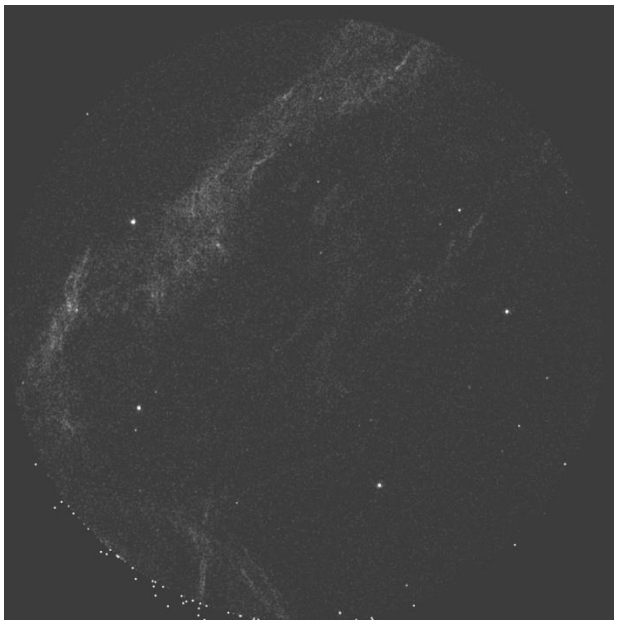

Figure 6: Image 3 CYG-S-VIII (BaF2) images from JUDE

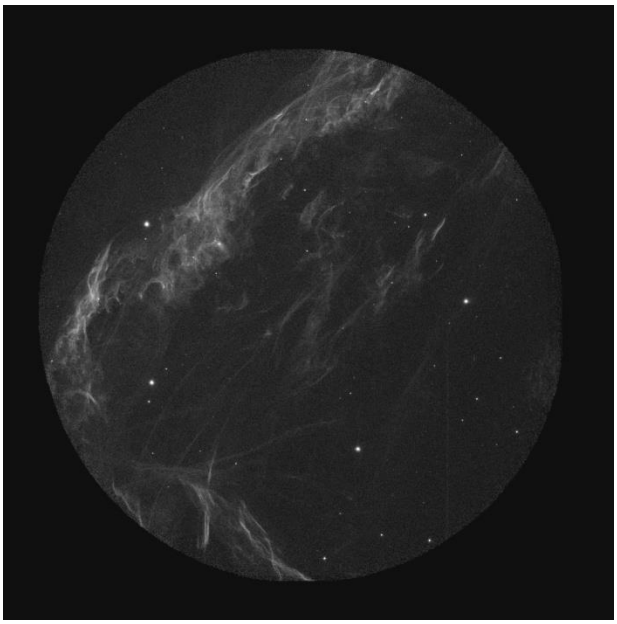

Figure 7:CYG-S-VIII (BaF2) images from CCDLAB

# ASTROMETRY

After obtaining level 2 data for further study we need to measure the position (Ra and dec ) of each point in the region. The process of identifying the location of celestial objects is known as Astrometry. For this we need to find which telescopes previously observed our region. From the MAST(Mikulski Archive for Space Telescopes) website to carry out astrometry the GALEX image for the required area is downloaded by specifying the Ra PNT and Dec PNT. Along with it catalogue is also downloaded.

Now for camparison with the GALEX images bright points in level 2 images are marked. They are compared with GALEX image and the same points are indentified and plotted in GALEX image (figure 4).

Then from the catalogue is opened and using catalogue tool the Ra and Dec of these bright points are obtained and noted.

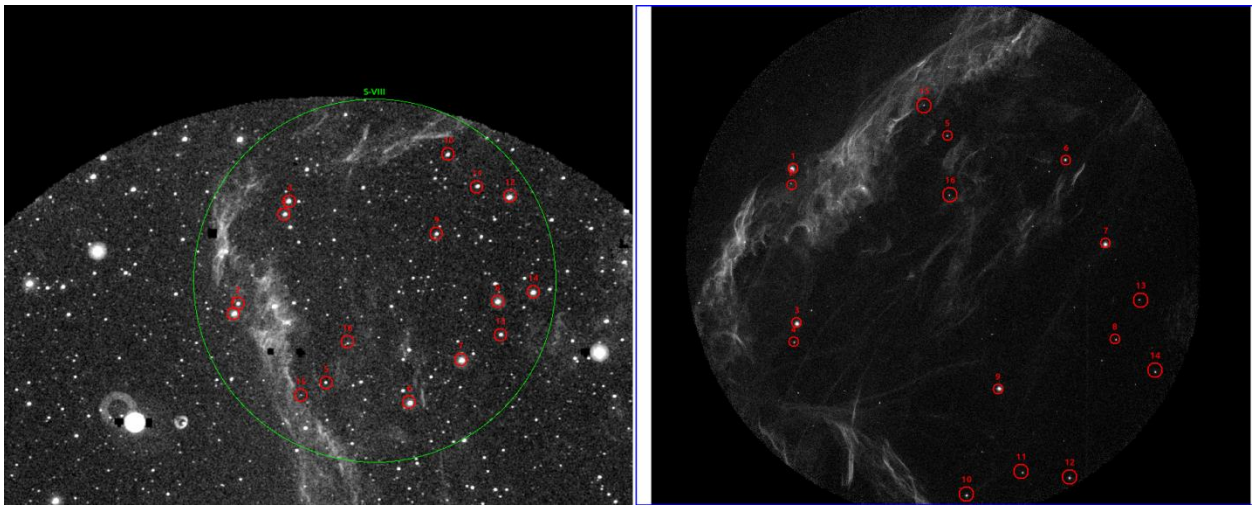

Figure 8:Bright points are plotted in GALEX image corresponding to Cyg-S-VIII BaF2 Image

Further steps of Astrometry is carried out using IRAF. Using imexam utility centroid of the stars are found by typing  a on the selected stars. Then a file is created with rows x stars, y stars, ra J2000, dec J2000(astrom.in) . The last two are taken from the reference catalogue. The above procedure for each data is given below.

CYGNUS_S_I

CygnusS-1_FUV_BaF2_astrom.in

| | | | |
|---|---|---|---|
| 2025.54 | 2867.77 | 312.826738212 | 29.18388881325 |
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| 2149.81 | 2813.98 | 312.8419424395 | 29.17572465176 |
| 2482.09 | 2765.69 | 312.8848278091 | 29.16448583446 |
| 2364.15 | 2670.08 | 312.867386785 | 29.15539131306 |
| 2343.81 | 2459.81 | 312.8606210361 | 29.13161475386 |
| 1102.53 | 2639.73 | 312.701575563 | 29.1728039716 |
| 619.41 | 2619.92 | 312.6364244147 | 29.17778008036 |
| 828.61 | 3252.20 | 312.6773098563 | 29.24814938776 |
| 1139.04 | 3434.34 | 312.7215269764 | 29.26376387846 |
| 1310.50 | 3243.91 | 312.7401785614 | 29.23902118788 |
| 1732.76 | 3577.79 | 312.8022546615 | 29.27008414082 |
| 1868.57 | 3506.04 | 312.8185824439 | 29.25962551231 |
| 2151.82 | 3525.99 | 312.8560759546 | 29.25700182731 |
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| 1655.30 | 4148.78 | 312.8031065992 | 29.33676572211 |
| 1143.93 | 1223.53 | 312.6792925781 | 29.01030489847 |
| 1336.54 | 1063.70 | 312.7016081006 | 28.98871036269 |
| 1337.32 | 873.83 | 312.7083177968 | 28.94136898305 |
| 3864.68 | 1284.09 | 313.0368164094 | 28.97092760254 |
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| 2215.49 | 1528.96 | 312.8251760379 | 29.02705579287 |
| 2264.31 | 1477.36 | 312.8312820595 | 29.02046581798 |
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| 1932.08 | 1382.22 | 312.7861861805 | 29.01482725266 |

CygnusS-1_FUV_Sapphire_astrom.in

| | | | |
|---|---|---|---|
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| 2149.94 | 2813.81 | 312.8419424395 | 29.17572465176 |
| 2482.31 | 2765.70 | 312.8848278091 | 29.16448583446 |
| 2364.13 | 2670.00 | 312.867386785 | 29.15539131306 |
| 2343.51 | 2459.44 | 312.8606210361 | 29.13161475386 |
| 1102.48 | 2639.82 | 312.701575563 | 29.1728039716 |
| 619.59 | 2620.14 | 312.6364244147 | 29.17778008036 |
| 829.18 | 3252.36 | 312.6773098563 | 29.24814938776 |
| 1139.86 | 3434.97 | 312.7215269764 | 29.26376387846 |
| 1310.67 | 3243.74 | 312.7401785614 | 29.23902118788 |
| 1733.57 | 3577.80 | 312.8022546615 | 29.27008414082 |
| 1868.63 | 3506.04 | 312.8185824439 | 29.25962551231 |
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| 1751.35 | 4078.82 | 312.8143987663 | 29.32724581331 |
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| 1143.78 | 1223.63 | 312.6792925781 | 29.01030489847 |
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| 2214.55 | 1528.19 | 312.8251760379 | 29.02705579287 |
| 2264.21 | 1477.38 | 312.8312820595 | 29.02046581798 |
| 2358.11 | 1423.50 | 312.8423586257 | 29.01242171099 |
| 1932.14 | 1382.12 | 312.7861861805 | 29.01482725266 |

CygnusS-1_FUV_Silica_astrom.in

| | | | |
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| 2364.40 | 2669.94 | 312.867386785 | 29.15539131306 |
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| 1102.62 | 2639.97 | 312.701575563 | 29.1728039716 |
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| 1752.46 | 4078.60 | 312.8143987663 | 29.32724581331 |
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CYGNUS_S_VIII

CygnusS-VIII_FUV_BaF2_astrom.in

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| 3318.29 | 3162.46 | 313.0797017335 | 29.5247570091 |
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| 4037.19 | 1468.89 | 312.8970081089 | 29.66636152459 |
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CygnusS-VIII_FUV_Sapphire_astrom.in

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| 1147.51 | 1705.30 | 313.2591367308 | 29.78405135254 |
| 2371.76 | 3355.64 | 313.2047253949 | 29.55098469257 |
| 3318.42 | 3162.53 | 313.0797017335 | 29.5247570091 |
| 3637.99 | 2487.59 | 313.0029895472 | 29.57962323539 |
| 3723.58 | 1726.41 | 312.9492442289 | 29.65486526147 |
| 2788.81 | 1335.55 | 313.0399717563 | 29.74188402526 |

| | | | |
|---|---|---|---|
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| 3909.23 | 2046.04 | 312.9451747086 | 29.6123533115 |
| 4037.02 | 1469.15 | 312.8970081089 | 29.66636152459 |
| 2185.24 | 3598.28 | 313.2412665284 | 29.5347139121 |
| 2389.64 | 2881.35 | 313.1719971878 | 29.60139076827 |

CygnusS-VIII_FUV_Silica_astrom.in

| | | | |
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| 1170.21 | 1853.37 | 313.2648892324 | 29.76725024348 |
| 1147.67 | 1705.19 | 313.2591367308 | 29.78405135254 |
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NGC6995

NGC6995_FUV_BaF2_astrom.in

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| 2679.66 | 3615.40 | 314.1900520153 | 31.34677255347 |
| 2368.30 | 3590.29 | 314.147975762 | 31.35010843532 |
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| 2586.27 | 1505.28 | 314.1294394935 | 31.1080051292 |
| 2596.08 | 1374.76 | 314.1278263283 | 31.09294663442 |
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NGC6995_FUV_Sapphire_astrom.in

| | | | |
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| 2796.31 | 3572.26 | 314.2047257487 | 31.33963830351 |
| 2679.62 | 3615.33 | 314.1900520153 | 31.34677255347 |
| 2368.10 | 3590.50 | 314.147975762 | 31.35010843532 |
| 1478.58 | 3158.19 | 314.0192141257 | 31.31810819942 |
| 1202.28 | 2968.28 | 313.9780814974 | 31.30196374071 |
| 3365.82 | 3928.65 | 314.2888242114 | 31.36916508199 |
| 3282.13 | 1620.38 | 314.2250567428 | 31.10765809102 |
| 3305.50 | 1467.49 | 314.2245101863 | 31.08971537867 |
| 2873.87 | 1395.22 | 314.1652767521 | 31.08974601444 |
| 2586.85 | 1505.35 | 314.1294394935 | 31.1080051292 |

2596.38 1374.89 314.1278263283 31.09294663442
2559.30 1371.05 314.1227162242 31.09321996334

NGC6995_FUV_Silica_astrom.in

2836.37 4283.37 314.2263574057 31.42018340304
2011.32 3849.62 314.1061594582 31.38675823179
2796.31 3573.20 314.2047257487 31.33963830351
2679.67 3615.29 314.1900520153 31.34677255347
2368.03 3590.31 314.147975762 31.35010843532
1478.15 3158.30 314.0192141257 31.31810819942
1202.28 2968.57 313.9780814974 31.30196374071
3366.09 3928.66 314.2888242114 31.36916508199
3282.36 1620.56 314.2250567428 31.10765809102
3305.70 1468.02 314.2245101863 31.08971537867
2873.69 1395.63 314.1652767521 31.08974601444
2586.66 1505.47 314.1294394935 31.1080051292
2596.33 1374.86 314.1278263283 31.09294663442
2559.25 1371.17 314.1227162242 31.09321996334

NGC6995_NUV_NUVN2_astrom.in

2836.08 4283.21 314.2263574057 31.42018340304
2011.39 3849.47 314.1061594582 31.38675823179
2796.08 3572.22 314.2047257487 31.33963830351
2679.38 3614.71 314.1900520153 31.34677255347
2368.15 3590.20 314.147975762 31.35010843532
1477.88 3158.49 314.0192141257 31.31810819942
1202.21 2968.93 313.9780814974 31.30196374071
3365.75 3928.26 314.2888242114 31.36916508199
3282.11 1620.58 314.2250567428 31.10765809102
3306.03 1468.01 314.2245101863 31.08971537867
2873.75 1395.64 314.1652767521 31.08974601444

| | | | |
|---|---|---|---|
| 2586.61 | 1505.50 314 | 1294394935 | 31.1080051292 |
| 2596.19 | 1374.88 314 | 1278263283 | 31.09294663442 |
| 2559.26 | 1371.22 314 | 1227162242 | 31.09321996334 |

To obtain the transformation to j2000 coordinates we ran ccmap on iraf. After that the stars are fitted so that the wcs rms values are less than 1 arc sec. At last ccsetwcs is used to fit the solution to the frame.

CYG-S-I

BaF2

PACKAGE = imcoords
  TASK = ccmap

input  = CygnusS-1_FUV_BaF2_astrom.in  The input coordinate files
database= CygnusS-1_FUV_BaF2.db  The output database file
(solutio= CygnusS-1_FUV_BaF2.sol) The database plate solution names
(images = CygnusS-1_FUV_BaF2___MASTER_IMAGE_CYG-S-I_COSMIC_RAY_REJECTED.fits) The input images
(results= CygnusS-1_FUV_BaF2.sum) The optional results summary files
(xcolumn=  1) Column containing the x coordinate
(ycolumn=  2) Column containing the y coordinate
(lngcolu=  3) Column containing the ra / longitude
(latcolu=  4) Column containing the dec / latitude
(xmin  =  INDEF) Minimum logical x pixel value
(xmax  =  INDEF) Maximum logical x pixel value
(ymin  =  INDEF) Minimum logical y pixel value
(ymax  =  INDEF) Maximum logical y pixel value
(lngunit=  deg) Input ra / longitude units

```
(latunit=                deg) Input dec / latitude units
(insyste=               j2000) Input celestial coordinate system
(refpoin=              coords) Source of the reference point definition
(xref   =              INDEF) Reference point in x
(yref   =              INDEF) Reference point in y
(lngref =               INDEF) Reference point ra / longitude telescope coordinate
(latref =              INDEF) Reference point dec / latitude telescope coordinate
(refsyst=               INDEF) Reference point telescope coordinate system
(lngrefu=                    ) Reference point ra / longitude units
(latrefu=                    ) Reference point dec / latitude units
(project=                tan) Sky projection geometry
(fitgeom=            general) Fitting geometry
(functio=         polynomial) Surface type
(xxorder=                  2) Order of xi fit in x
(xyorder=                  2) Order of xi fit in y
(xxterms=               half) Xi fit cross terms type
(yxorder=                  2) Order of eta fit in x
(yyorder=                  2) Order of eta fit in y
(yxterms=               half) Eta fit cross terms type
(maxiter=                  0) The maximum number of rejection iterations
(reject =                3.) Rejection limit in sigma units
(update =                 no) Update the image world coordinate system ?
(pixsyst=             logical) Input pixel coordinate system
(verbose=                 yes) Print messages about progress of task ?
(interac=                yes) Fit the transformation interactively ?
(graphic=            stdgraph) Default graphics device
(cursor =                    ) Graphics cursor
(mode   =                  ql)

Refsystem: j2000  Coordinates: equatorial FK5
   Equinox: J2000.000 Epoch: J2000.00000000 MJD: 51544.50000
Insystem: j2000  Coordinates: equatorial FK5
   Equinox: J2000.000 Epoch: J2000.00000000 MJD: 51544.50000
```

Coords File: CygnusS-1_FUV_BaF2_astrom.in  Image: CygnusS-1_FUV_BaF2___MASTER_IMAGE_CYG-S-I_COSMIC_RAY_REJECTED.fits
   Database: CygnusS-1_FUV_BaF2.db  Solution: CygnusS-1_FUV_BaF2.sol
Coordinate mapping status
   Ra/Dec or Long/Lat fit rms: 0.478  0.49   (arcsec  arcsec)
Coordinate mapping parameters
   Sky projection geometry: tan
   Reference point: 312:48:15.60  29:08:32.56  (degrees  degrees)
   Reference point: 1910.242  2489.507  (pixels  pixels)
   X and Y scale: 0.417  0.417  (arcsec/pixel  arcsec/pixel)
   X and Y axis rotation: 8.408  8.426  (degrees  degrees)
Wcs mapping status
   Ra/Dec or Long/Lat wcs rms: 0.478  0.49   (arcsec  arcsec)
vocl>

PACKAGE = imcoords
  TASK = ccsetwcs

images  = CygnusS-1_FUV_BaF2___MASTER_IMAGE_CYG-S-I_COSMIC_RAY_REJECTED.fits  The input images
database= CygnusS-1_FUV_BaF2.db  The input database file
solution= CygnusS-1_FUV_BaF2.sol  The input plate solutions
(xref   =              INDEF) The x reference pixel
(yref   =              INDEF) The y reference pixel
(xmag   =                INDEF) The x axis scale in arcsec / pixel
(ymag   =                INDEF) The y axis scale in arcsec / pixel
(xrotati=               INDEF) The x axis rotation angle in degrees
(yrotati=               INDEF) The y axis rotation angle in degrees
(lngref =               INDEF) The ra / longitude reference coordinate in lngunits
(latref =              INDEF) The dec / latitude reference coordinate in latunits
(lngunit=                    ) The ra / longitude reference coordinate units
(latunit=                   ) The dec / latitude reference coordinate units
(transpo=                  no) Transpose the computed image wcs ?
(project=                 tan) The sky projection geometry

(coosyst= j2000) The celestial coordinate system
(update = yes) Update the image world coordinate system ?
(pixsyst= logical) The input pixel coordinate system
(verbose= yes) Print messages about actions taken by the task ?
(mode = ql)

Image: CygnusS-1_FUV_BaF2___MASTER_IMAGE_CYG-S-I_COSMIC_RAY_REJECTED.fits Database: CygnusS-1_FUV_BaF2.db Solution: CygnusS-1_FUV_BaF2.sol
Coordinate mapping parameters
Sky projection geometry: tan
Reference point: 312:48:15.60 29:08:32.56 (degrees degrees)
Ra/Dec logical image axes: 1 2
Reference point: 1910.242 2489.507 (pixels pixels)
X and Y scale: 0.417 0.417 (arcsec/pixel arcsec/pixel)
X and Y coordinate rotation: 8.408 8.426 (degrees degrees)
Updating image header wcs
vocl>

Sapphire

PACKAGE = imcoords
TASK = ccmap

input = CygnusS-1_FUV_Sapphire_astrom.in The input coordinate files
database= CygnusS-1_FUV_Sapphire.db The output database file
(solutio= CygnusS-1_FUV_Sapphire.sol) The database plate solution names
(images = CygnusS-1_FUV_Sapphire___MASTER_IMAGE_CYG-S-I_COSMIC_RAY_REJECTED.fits) The input images
(results= CygnusS-1_FUV_Sapphire.sum) The optional results summary files
(xcolumn= 1) Column containing the x coordinate
(ycolumn= 2) Column containing the y coordinate
(lngcolu= 3) Column containing the ra / longitude
(latcolu= 4) Column containing the dec / latitude

(xmin = INDEF) Minimum logical x pixel value
(xmax = INDEF) Maximum logical x pixel value
(ymin = INDEF) Minimum logical y pixel value
(ymax = INDEF) Maximum logical y pixel value
(lngunit= deg) Input ra / longitude units
(latunit= deg) Input dec / latitude units
(insyste= j2000) Input celestial coordinate system
(refpoin= coords) Source of the reference point definition
(xref = INDEF) Reference point in x
(yref = INDEF) Reference point in y
(lngref = INDEF) Reference point ra / longitude telescope coordinate
(latref = INDEF) Reference point dec / latitude telescope coordinate
(refsyst= INDEF) Reference point telescope coordinate system
(lngrefu= ) Reference point ra / longitude units
(latrefu= ) Reference point dec / latitude units
(project= tan) Sky projection geometry
(fitgeom= general) Fitting geometry
(functio= polynomial) Surface type
(xxorder= 2) Order of xi fit in x
(xyorder= 2) Order of xi fit in y
(xxterms= half) Xi fit cross terms type
(yxorder= 2) Order of eta fit in x
(yyorder= 2) Order of eta fit in y
(yxterms= half) Eta fit cross terms type
(maxiter= 0) The maximum number of rejection iterations
(reject = 3.) Rejection limit in sigma units
(update = no) Update the image world coordinate system ?
(pixsyst= logical) Input pixel coordinate system
(verbose= yes) Print messages about progress of task ?
(interac= yes) Fit the transformation interactively ?
(graphic= stdgraph) Default graphics device
(cursor = ) Graphics cursor
(mode = ql)

Refsystem: j2000  Coordinates: equatorial FK5
    Equinox: J2000.000 Epoch: J2000.00000000 MJD: 51544.50000
Insystem: j2000  Coordinates: equatorial FK5
    Equinox: J2000.000 Epoch: J2000.00000000 MJD: 51544.50000

Coords File: CygnusS-1_FUV_Sapphire_astrom.in  Image: CygnusS-1_FUV_Sapphire___MASTER_IMAGE_CYG-S-I_COSMIC_RAY_REJECTED.fits
    Database: CygnusS-1_FUV_Sapphire.db  Solution: CygnusS-1_FUV_Sapphire.sol
Coordinate mapping status
    Ra/Dec or Long/Lat fit rms: 0.493  0.504   (arcsec  arcsec)
Coordinate mapping parameters
    Sky projection geometry: tan
    Reference point: 312:48:15.60  29:08:32.56  (degrees  degrees)
    Reference point: 1910.080  2489.500  (pixels  pixels)
    X and Y scale: 0.417  0.417  (arcsec/pixel  arcsec/pixel)
    X and Y axis rotation: 8.395  8.399  (degrees  degrees)
Wcs mapping status
    Ra/Dec or Long/Lat wcs rms: 0.493  0.504   (arcsec  arcsec)
vocl>

PACKAGE = imcoords
   TASK = ccsetwcs

images  = CygnusS-1_FUV_Sapphire___MASTER_IMAGE_CYG-S-I_COSMIC_RAY_REJECTED.fits  The input images
database= CygnusS-1_FUV_Sapphire.db  The input database file
solution= CygnusS-1_FUV_Sapphire.sol  The input plate solutions
(xref   =              INDEF) The x reference pixel
(yref   =              INDEF) The y reference pixel
(xmag   =                INDEF) The x axis scale in arcsec / pixel
(ymag   =                INDEF) The y axis scale in arcsec / pixel
(xrotati=               INDEF) The x axis rotation angle in degrees
(yrotati=               INDEF) The y axis rotation angle in degrees
(lngref =               INDEF) The ra / longitude reference coordinate in lngunits

(latref = INDEF) The dec / latitude reference coordinate in latunits
(lngunit= ) The ra / longitude reference coordinate units
(latunit= ) The dec / latitude reference coordinate units
(transpo= no) Transpose the computed image wcs ?
(project= tan) The sky projection geometry
(coosyst= j2000) The celestial coordinate system
(update = yes) Update the image world coordinate system ?
(pixsyst= logical) The input pixel coordinate system
(verbose= yes) Print messages about actions taken by the task ?
(mode = ql)

Image: CygnusS-1_FUV_Sapphire___MASTER_IMAGE_CYG-S-I_COSMIC_RAY_REJECTED.fits Database: CygnusS-1_FUV_Sapphire.db Solution: CygnusS-1_FUV_Sapphire.sol
Coordinate mapping parameters
Sky projection geometry: tan
Reference point: 312:48:15.60 29:08:32.56 (degrees degrees)
Ra/Dec logical image axes: 1 2
Reference point: 1910.080 2489.500 (pixels pixels)
X and Y scale: 0.417 0.417 (arcsec/pixel arcsec/pixel)
X and Y coordinate rotation: 8.395 8.399 (degrees degrees)
Updating image header wcs
vocl>

Silica

PACKAGE = imcoords
TASK = ccmap

input = CygnusS-1_FUV_Silica_astrom.in The input coordinate files
database= CygnusS-1_FUV_Silica.db The output database file
(solutio= CygnusS-1_FUV_Silica.sol) The database plate solution names
(images = CygnusS-1_FUV_Silica___MASTER_IMAGE_CYG-S-

I_COSMIC_RAY_REJECTED.fits) The input images
(results= CygnusS-1_FUV_Silica.sum) The optional results summary files
(xcolumn= 1) Column containing the x coordinate
(ycolumn= 2) Column containing the y coordinate
(lngcolu= 3) Column containing the ra / longitude
(latcolu= 4) Column containing the dec / latitude
(xmin = INDEF) Minimum logical x pixel value
(xmax = INDEF) Maximum logical x pixel value
(ymin = INDEF) Minimum logical y pixel value
(ymax = INDEF) Maximum logical y pixel value
(lngunit= deg) Input ra / longitude units
(latunit= deg) Input dec / latitude units
(insyste= j2000) Input celestial coordinate system
(refpoin= coords) Source of the reference point definition
(xref = INDEF) Reference point in x
(yref = INDEF) Reference point in y
(lngref = INDEF) Reference point ra / longitude telescope coordinate
(latref = INDEF) Reference point dec / latitude telescope coordinate
(refsyst= INDEF) Reference point telescope coordinate system
(lngrefu= ) Reference point ra / longitude units
(latrefu= ) Reference point dec / latitude units
(project= tan) Sky projection geometry
(fitgeom= general) Fitting geometry
(functio= polynomial) Surface type
(xxorder= 2) Order of xi fit in x
(xyorder= 2) Order of xi fit in y
(xxterms= half) Xi fit cross terms type
(yxorder= 2) Order of eta fit in x
(yyorder= 2) Order of eta fit in y
(yxterms= half) Eta fit cross terms type
(maxiter= 0) The maximum number of rejection iterations
(reject = 3.) Rejection limit in sigma units
(update = no) Update the image world coordinate system ?
(pixsyst= logical) Input pixel coordinate system

(verbose= yes) Print messages about progress of task ?
(interac= yes) Fit the transformation interactively ?
(graphic= stdgraph) Default graphics device
(cursor = ) Graphics cursor
(mode = ql)

Refsystem: j2000 Coordinates: equatorial FK5
Equinox: J2000.000 Epoch: J2000.00000000 MJD: 51544.50000
Insystem: j2000 Coordinates: equatorial FK5
Equinox: J2000.000 Epoch: J2000.00000000 MJD: 51544.50000

Coords File: CygnusS-1_FUV_Silica_astrom.in Image: CygnusS-1_FUV_Silica___MASTER_IMAGE_CYG-S-I_COSMIC_RAY_REJECTED.fits
Database: CygnusS-1_FUV_Silica.db Solution: CygnusS-1_FUV_Silica.sol
Coordinate mapping status
Ra/Dec or Long/Lat fit rms: 0.406 0.408 (arcsec arcsec)
Coordinate mapping parameters
Sky projection geometry: tan
Reference point: 312:48:15.82 29:08:03.39 (degrees degrees)
Reference point: 1921.438 2420.165 (pixels pixels)
X and Y scale: 0.417 0.417 (arcsec/pixel arcsec/pixel)
X and Y axis rotation: 8.403 8.381 (degrees degrees)
Wcs mapping status
Ra/Dec or Long/Lat wcs rms: 0.406 0.408 (arcsec arcsec)
vocl>

PACKAGE = imcoords
TASK = ccsetwcs

images = CygnusS-1_FUV_Silica___MASTER_IMAGE_CYG-S-I_COSMIC_RAY_REJECTED.fits The input images
database= CygnusS-1_FUV_Silica.db The input database file
solution= CygnusS-1_FUV_Silica.sol The input plate solutions

(xref = INDEF) The x reference pixel
(yref = INDEF) The y reference pixel
(xmag = INDEF) The x axis scale in arcsec / pixel
(ymag = INDEF) The y axis scale in arcsec / pixel
(xrotati= INDEF) The x axis rotation angle in degrees
(yrotati= INDEF) The y axis rotation angle in degrees
(lngref = INDEF) The ra / longitude reference coordinate in lngunits
(latref = INDEF) The dec / latitude reference coordinate in latunits
(lngunit= ) The ra / longitude reference coordinate units
(latunit= ) The dec / latitude reference coordinate units
(transpo= no) Transpose the computed image wcs ?
(project= tan) The sky projection geometry
(coosyst= j2000) The celestial coordinate system
(update = yes) Update the image world coordinate system ?
(pixsyst= logical) The input pixel coordinate system
(verbose= yes) Print messages about actions taken by the task ?
(mode = ql)

Image: CygnusS-1_FUV_Silica___MASTER_IMAGE_CYG-S-I_COSMIC_RAY_REJECTED.fits Database: CygnusS-1_FUV_Silica.db Solution: CygnusS-1_FUV_Silica.sol
Coordinate mapping parameters
Sky projection geometry: tan
Reference point: 312:48:15.82 29:08:03.39 (degrees degrees)
Ra/Dec logical image axes: 1 2
Reference point: 1921.438 2420.165 (pixels pixels)
X and Y scale: 0.417 0.417 (arcsec/pixel arcsec/pixel)
X and Y coordinate rotation: 8.403 8.381 (degrees degrees)
Updating image header wcs
vocl>

CYG-S-VIII

BaF2

PACKAGE = imcoords
  TASK = ccmap

input   = CygnusS-VIII_FUV_BaF2_astrom.in  The input coordinate files
database= CygnusS-VIII_FUV_BaF2.db  The output database file
(solutio= CygnusS-VIII_FUV_BaF2.sol) The database plate solution names
(images = CygnusS-VIII_FUV_BaF2___MASTER_IMAGE_CYG-S-VIII.fits) The input images
(results= CygnusS-VIII_FUV_BaF2.sum) The optional results summary files
(xcolumn=                1) Column containing the x coordinate
(ycolumn=                2) Column containing the y coordinate
(lngcolu=                3) Column containing the ra / longitude
(latcolu=                4) Column containing the dec / latitude
(xmin   =           INDEF) Minimum logical x pixel value
(xmax   =           INDEF) Maximum logical x pixel value
(ymin   =           INDEF) Minimum logical y pixel value
(ymax   =           INDEF) Maximum logical y pixel value
(lngunit=             deg) Input ra / longitude units
(latunit=             deg) Input dec / latitude units
(insyste=           j2000) Input celestial coordinate system
(refpoin=          coords) Source of the reference point definition
More
Refsystem: j2000  Coordinates: equatorial FK5
   Equinox: J2000.000 Epoch: J2000.00000000 MJD: 51544.50000
Insystem: j2000  Coordinates: equatorial FK5
   Equinox: J2000.000 Epoch: J2000.00000000 MJD: 51544.50000

Coords File: CygnusS-VIII_FUV_BaF2_astrom.in  Image: CygnusS-VIII_FUV_BaF2___MASTER_IMAGE_CYG-S-VIII.fits
   Database: CygnusS-VIII_FUV_BaF2.db  Solution: CygnusS-VIII_FUV_BaF2.sol
Coordinate mapping status
   Ra/Dec or Long/Lat fit rms: 0.278  0.256   (arcsec  arcsec)

Coordinate mapping parameters
    Sky projection geometry: tan
    Reference point: 313:06:13.82  29:40:18.46  (degrees  degrees)
    Reference point: 2613.487  2088.148  (pixels  pixels)
    X and Y scale: 0.417  0.416  (arcsec/pixel  arcsec/pixel)
    X and Y axis rotation: 154.861  154.780  (degrees  degrees)
Wcs mapping status
    Ra/Dec or Long/Lat wcs rms: 0.278  0.256   (arcsec  arcsec)
vocl>

PACKAGE = imcoords
   TASK = ccsetwcs

images  = CygnusS-VIII_FUV_BaF2___MASTER_IMAGE_CYG-S-VIII.fits  The input images
database= CygnusS-VIII_FUV_BaF2.db  The input database file
solution= CygnusS-VIII_FUV_BaF2.sol  The input plate solutions
(xref   =              INDEF) The x reference pixel
(yref   =              INDEF) The y reference pixel
(xmag   =                INDEF) The x axis scale in arcsec / pixel
(ymag   =                INDEF) The y axis scale in arcsec / pixel
(xrotati=               INDEF) The x axis rotation angle in degrees
(yrotati=               INDEF) The y axis rotation angle in degrees
(lngref =               INDEF) The ra / longitude reference coordinate in lngunits
(latref =              INDEF) The dec / latitude reference coordinate in latunits
(lngunit=                    ) The ra / longitude reference coordinate units
(latunit=                   ) The dec / latitude reference coordinate units
(transpo=                   no) Transpose the computed image wcs ?
(project=                  tan) The sky projection geometry
(coosyst=                 j2000) The celestial coordinate system
(update =                  yes) Update the image world coordinate system ?
(pixsyst=              logical) The input pixel coordinate system
(verbose=                   yes) Print messages about actions taken by the task ?
(mode   =                   ql)

Image: CygnusS-VIII_FUV_BaF2___MASTER_IMAGE_CYG-S-VIII.fits  Database: CygnusS-VIII_FUV_BaF2.db  Solution: CygnusS-VIII_FUV_BaF2.sol
Coordinate mapping parameters
    Sky projection geometry: tan
    Reference point: 313:06:13.82  29:40:18.46  (degrees   degrees)
    Ra/Dec logical image axes: 1  2
    Reference point: 2613.487  2088.148  (pixels  pixels)
    X and Y scale: 0.417  0.416  (arcsec/pixel  arcsec/pixel)
    X and Y coordinate rotation: 154.861  154.780  (degrees  degrees)
Updating image header wcs
vocl>

Sapphire

PACKAGE = imcoords
  TASK = ccmap

input   = CygnusS-VIII_FUV_Sapphire_astrom.in  The input coordinate files
database= CygnusS-VIII_FUV_Sapphire.db  The output database file
(solutio= CygnusS-VIII_FUV_Sapphire.sol) The database plate solution names
(images = CygnusS-VIII_FUV_Sapphire___MASTER_IMAGE_CYG-S-VIII.fits) The input images
(results= CygnusS-VIII_FUV_Sapphire.sum) The optional results summary files
(xcolumn=                1) Column containing the x coordinate
(ycolumn=                2) Column containing the y coordinate
(lngcolu=                3) Column containing the ra / longitude
(latcolu=                4) Column containing the dec / latitude
(xmin   =           INDEF) Minimum logical x pixel value
(xmax   =           INDEF) Maximum logical x pixel value
(ymin   =           INDEF) Minimum logical y pixel value
(ymax   =           INDEF) Maximum logical y pixel value
(lngunit=             deg) Input ra / longitude units

```
(latunit=                deg) Input dec / latitude units
(insyste=               j2000) Input celestial coordinate system
(refpoin=              coords) Source of the reference point definition
(xref   =              INDEF) Reference point in x
(yref   =              INDEF) Reference point in y
(lngref =               INDEF) Reference point ra / longitude telescope coordinate
(latref =              INDEF) Reference point dec / latitude telescope coordinate
(refsyst=               INDEF) Reference point telescope coordinate system
(lngrefu=                    ) Reference point ra / longitude units
(latrefu=                    ) Reference point dec / latitude units
(project=                tan) Sky projection geometry
(fitgeom=            general) Fitting geometry
(functio=         polynomial) Surface type
(xxorder=                  2) Order of xi fit in x
(xyorder=                  2) Order of xi fit in y
(xxterms=               half) Xi fit cross terms type
(yxorder=                  2) Order of eta fit in x
(yyorder=                  2) Order of eta fit in y
(yxterms=               half) Eta fit cross terms type
(maxiter=                  0) The maximum number of rejection iterations
(reject =                3.) Rejection limit in sigma units
(update =                 no) Update the image world coordinate system ?
(pixsyst=            logical) Input pixel coordinate system
(verbose=                 yes) Print messages about progress of task ?
(interac=                yes) Fit the transformation interactively ?
(graphic=           stdgraph) Default graphics device
(cursor =                    ) Graphics cursor
(mode   =                  ql)

Refsystem: j2000  Coordinates: equatorial FK5
   Equinox: J2000.000 Epoch: J2000.00000000 MJD: 51544.50000
Insystem: j2000  Coordinates: equatorial FK5
   Equinox: J2000.000 Epoch: J2000.00000000 MJD: 51544.50000
```

Coords File: CygnusS-VIII_FUV_Sapphire_astrom.in  Image: CygnusS-VIII_FUV_Sapphire___MASTER_IMAGE_CYG-S-VIII.fits
   Database: CygnusS-VIII_FUV_Sapphire.db  Solution: CygnusS-VIII_FUV_Sapphire.sol
Coordinate mapping status
   Ra/Dec or Long/Lat fit rms: 0.401  0.312   (arcsec  arcsec)
Coordinate mapping parameters
   Sky projection geometry: tan
   Reference point: 313:06:13.82  29:40:18.46  (degrees  degrees)
   Reference point: 2613.750  2088.134  (pixels  pixels)
   X and Y scale: 0.417  0.416  (arcsec/pixel  arcsec/pixel)
   X and Y axis rotation: 154.858  154.779  (degrees  degrees)
Wcs mapping status
   Ra/Dec or Long/Lat wcs rms: 0.401  0.312   (arcsec  arcsec)
vocl>

PACKAGE = imcoords
  TASK = ccsetwcs

images  = CygnusS-VIII_FUV_Sapphire___MASTER_IMAGE_CYG-S-VIII.fits  The input images
database= CygnusS-VIII_FUV_Sapphire.db  The input database file
solution= CygnusS-VIII_FUV_Sapphire.sol  The input plate solutions
(xref   =              INDEF) The x reference pixel
(yref   =              INDEF) The y reference pixel
(xmag   =                INDEF) The x axis scale in arcsec / pixel
(ymag   =                INDEF) The y axis scale in arcsec / pixel
(xrotati=               INDEF) The x axis rotation angle in degrees
(yrotati=               INDEF) The y axis rotation angle in degrees
(lngref =               INDEF) The ra / longitude reference coordinate in lngunits
(latref =              INDEF) The dec / latitude reference coordinate in latunits
(lngunit=                    ) The ra / longitude reference coordinate units
(latunit=                   ) The dec / latitude reference coordinate units
(transpo=                   no) Transpose the computed image wcs ?

(project= tan) The sky projection geometry
(coosyst= j2000) The celestial coordinate system
(update = yes) Update the image world coordinate system ?
(pixsyst= logical) The input pixel coordinate system
(verbose= yes) Print messages about actions taken by the task ?
(mode = ql)

Image: CygnusS-VIII_FUV_Sapphire___MASTER_IMAGE_CYG-S-VIII.fits Database:
CygnusS-VIII_FUV_Sapphire.db Solution: CygnusS-VIII_FUV_Sapphire.sol
Coordinate mapping parameters
Sky projection geometry: tan
Reference point: 313:06:13.82 29:40:18.46 (degrees degrees)
Ra/Dec logical image axes: 1 2
Reference point: 2613.750 2088.134 (pixels pixels)
X and Y scale: 0.417 0.416 (arcsec/pixel arcsec/pixel)
X and Y coordinate rotation: 154.858 154.779 (degrees degrees)
Updating image header wcs
vocl>

Silica

PACKAGE = imcoords
TASK = ccmap

input = CygnusS-VIII_FUV_Silica_astrom.in The input coordinate files
database= CygnusS-VIII_FUV_Silica.db The output database file
(solutio= CygnusS-VIII_FUV_Silica.sol) The database plate solution names
(images = CygnusS-VIII_FUV_Silica___MASTER_IMAGE_CYG-S-VIII.fits) The input images
(results= CygnusS-VIII_FUV_Silica.sum) The optional results summary files
(xcolumn= 1) Column containing the x coordinate
(ycolumn= 2) Column containing the y coordinate
(lngcolu= 3) Column containing the ra / longitude
(latcolu= 4) Column containing the dec / latitude

(xmin = INDEF) Minimum logical x pixel value
(xmax = INDEF) Maximum logical x pixel value
(ymin = INDEF) Minimum logical y pixel value
(ymax = INDEF) Maximum logical y pixel value
(lngunit= deg) Input ra / longitude units
(latunit= deg) Input dec / latitude units
(insyste= j2000) Input celestial coordinate system
(refpoin= coords) Source of the reference point definition
(xref = INDEF) Reference point in x
(yref = INDEF) Reference point in y
(lngref = INDEF) Reference point ra / longitude telescope coordinate
(latref = INDEF) Reference point dec / latitude telescope coordinate
(refsyst= INDEF) Reference point telescope coordinate system
(lngrefu= ) Reference point ra / longitude units
(latrefu= ) Reference point dec / latitude units
(project= tan) Sky projection geometry
(fitgeom= general) Fitting geometry
(functio= polynomial) Surface type
(xxorder= 2) Order of xi fit in x
(xyorder= 2) Order of xi fit in y
(xxterms= half) Xi fit cross terms type
(yxorder= 2) Order of eta fit in x
(yyorder= 2) Order of eta fit in y
(yxterms= half) Eta fit cross terms type
(maxiter= 0) The maximum number of rejection iterations
(reject = 3.) Rejection limit in sigma units
(update = no) Update the image world coordinate system ?
(pixsyst= logical) Input pixel coordinate system
(verbose= yes) Print messages about progress of task ?
(interac= yes) Fit the transformation interactively ?
(graphic= stdgraph) Default graphics device
(cursor = ) Graphics cursor
(mode = ql)

Refsystem: j2000  Coordinates: equatorial FK5
    Equinox: J2000.000 Epoch: J2000.00000000 MJD: 51544.50000
Insystem: j2000  Coordinates: equatorial FK5
    Equinox: J2000.000 Epoch: J2000.00000000 MJD: 51544.50000

Coords File: CygnusS-VIII_FUV_Silica_astrom.in  Image: CygnusS-VIII_FUV_Silica___MASTER_IMAGE_CYG-S-VIII.fits
    Database: CygnusS-VIII_FUV_Silica.db  Solution: CygnusS-VIII_FUV_Silica.sol
Coordinate mapping status
    Ra/Dec or Long/Lat fit rms: 0.328  0.292   (arcsec  arcsec)
Coordinate mapping parameters
    Sky projection geometry: tan
    Reference point: 313:06:13.82  29:40:18.46  (degrees  degrees)
    Reference point: 2613.578  2088.304  (pixels  pixels)
    X and Y scale: 0.417  0.416  (arcsec/pixel  arcsec/pixel)
    X and Y axis rotation: 154.862  154.793  (degrees  degrees)
Wcs mapping status
    Ra/Dec or Long/Lat wcs rms: 0.328  0.292   (arcsec  arcsec)
vocl>

PACKAGE = imcoords
  TASK = ccsetwcs

images  = CygnusS-VIII_FUV_Silica___MASTER_IMAGE_CYG-S-VIII.fits  The input images
database= CygnusS-VIII_FUV_Silica.db  The input database file
solution= CygnusS-VIII_FUV_Silica.sol  The input plate solutions
(xref   =              INDEF) The x reference pixel
(yref   =              INDEF) The y reference pixel
(xmag   =                INDEF) The x axis scale in arcsec / pixel
(ymag   =                INDEF) The y axis scale in arcsec / pixel
(xrotati=               INDEF) The x axis rotation angle in degrees
(yrotati=               INDEF) The y axis rotation angle in degrees
(lngref =               INDEF) The ra / longitude reference coordinate in lngunits

(latref = INDEF) The dec / latitude reference coordinate in latunits
(lngunit= ) The ra / longitude reference coordinate units
(latunit= ) The dec / latitude reference coordinate units
(transpo= no) Transpose the computed image wcs ?
(project= tan) The sky projection geometry
(coosyst= j2000) The celestial coordinate system
(update = yes) Update the image world coordinate system ?
(pixsyst= logical) The input pixel coordinate system
(verbose= yes) Print messages about actions taken by the task ?
(mode = ql)

Image: CygnusS-VIII_FUV_Silica___MASTER_IMAGE_CYG-S-VIII.fits Database: CygnusS-VIII_FUV_Silica.db Solution: CygnusS-VIII_FUV_Silica.sol
Coordinate mapping parameters
Sky projection geometry: tan
Reference point: 313:06:13.82 29:40:18.46 (degrees degrees)
Ra/Dec logical image axes: 1 2
Reference point: 2613.578 2088.304 (pixels pixels)
X and Y scale: 0.417 0.416 (arcsec/pixel arcsec/pixel)
X and Y coordinate rotation: 154.862 154.793 (degrees degrees)
Updating image header wcs
vocl>

## BaF2

PACKAGE = imcoords
  TASK = ccmap

input   = NGC6995_FUV_BaF2_astrom.in  The input coordinate files
database=  NGC6995_FUV_BaF2.db  The output database file
(solutio= NGC6995_FUV_BaF2.sol) The database plate solution names
(images = NGC6995_FUV_BaF2___MASTER_IMAGE_CYG-S-VIII.fits) The input images
(results= NGC6995_FUV_BaF2.sum) The optional results summary files
(xcolumn=                1) Column containing the x coordinate
(ycolumn=                2) Column containing the y coordinate
(lngcolu=                3) Column containing the ra / longitude
(latcolu=                4) Column containing the dec / latitude
(xmin   =           INDEF) Minimum logical x pixel value
(xmax   =           INDEF) Maximum logical x pixel value
(ymin   =           INDEF) Minimum logical y pixel value
(ymax   =           INDEF) Maximum logical y pixel value
(lngunit=             deg) Input ra / longitude units
(latunit=             deg) Input dec / latitude units
(insyste=           j2000) Input celestial coordinate system
(refpoin=          coords) Source of the reference point definition
(xref   =           INDEF) Reference point in x
(yref   =           INDEF) Reference point in y
(lngref =           INDEF) Reference point ra / longitude telescope coordinate
(latref =           INDEF) Reference point dec / latitude telescope coordinate
(refsyst=           INDEF) Reference point telescope coordinate system
(lngrefu=                ) Reference point ra / longitude units
(latrefu=                ) Reference point dec / latitude units
(project=              tan) Sky projection geometry
(fitgeom=          general) Fitting geometry
(functio=       polynomial) Surface type

(xxorder= 2) Order of xi fit in x
(xyorder= 2) Order of xi fit in y
(xxterms= half) Xi fit cross terms type
(yxorder= 2) Order of eta fit in x
(yyorder= 2) Order of eta fit in y
(yxterms= half) Eta fit cross terms type
(maxiter= 0) The maximum number of rejection iterations
(reject = 3.) Rejection limit in sigma units
(update = no) Update the image world coordinate system ?
(pixsyst= logical) Input pixel coordinate system
(verbose= yes) Print messages about progress of task ?
(interac= yes) Fit the transformation interactively ?
(graphic= stdgraph) Default graphics device
(cursor = ) Graphics cursor
(mode = ql)

Refsystem: j2000 Coordinates: equatorial FK5
Equinox: J2000.000 Epoch: J2000.00000000 MJD: 51544.50000
Insystem: j2000 Coordinates: equatorial FK5
Equinox: J2000.000 Epoch: J2000.00000000 MJD: 51544.50000

Coords File: NGC6995_FUV_BaF2_astrom.in Image:
NGC6995_FUV_BaF2___MASTER_IMAGE_CYG-S-VIII.fits
Database: NGC6995_FUV_BaF2.db Solution: NGC6995_FUV_BaF2.sol
Coordinate mapping status
Ra/Dec or Long/Lat fit rms: 0.15 0.121 (arcsec arcsec)
Coordinate mapping parameters
Sky projection geometry: tan
Reference point: 314:09:13.93 31:14:38.20 (degrees degrees)
Reference point: 2566.037 2693.865 (pixels pixels)
X and Y scale: 0.417 0.417 (arcsec/pixel arcsec/pixel)
X and Y axis rotation: 9.790 9.718 (degrees degrees)
Wcs mapping status
Ra/Dec or Long/Lat wcs rms: 0.15 0.121 (arcsec arcsec)

PACKAGE = imcoords
  TASK = ccsetwcs

images  =  The input images
database=  NGC6995_FUV_BaF2.db  The input database file
solution= NGC6995_FUV_BaF2.sol  The input plate solutions
(xref   =             INDEF) The x reference pixel
(yref   =             INDEF) The y reference pixel
(xmag   =               INDEF) The x axis scale in arcsec / pixel
(ymag   =               INDEF) The y axis scale in arcsec / pixel
(xrotati=              INDEF) The x axis rotation angle in degrees
(yrotati=              INDEF) The y axis rotation angle in degrees
(lngref =              INDEF) The ra / longitude reference coordinate in lngunits
(latref =             INDEF) The dec / latitude reference coordinate in latunits
(lngunit=                  ) The ra / longitude reference coordinate units
(latunit=                 ) The dec / latitude reference coordinate units
(transpo=                 no) Transpose the computed image wcs ?
(project=                tan) The sky projection geometry
(coosyst=               j2000) The celestial coordinate system
(update =                yes) Update the image world coordinate system ?
(pixsyst=            logical) The input pixel coordinate system
(verbose=                 yes) Print messages about actions taken by the task ?
(mode   =                 ql)

Image: NGC6995_FUV_BaF2___MASTER_IMAGE_CYG-S-VIII.fits  Database:
NGC6995_FUV_BaF2.db  Solution: NGC6995_FUV_BaF2.sol
Coordinate mapping parameters
   Sky projection geometry: tan
   Reference point: 314:09:13.93  31:14:38.20  (degrees   degrees)
   Ra/Dec logical image axes: 1  2
   Reference point: 2566.037  2693.865  (pixels  pixels)
   X and Y scale: 0.417  0.417  (arcsec/pixel  arcsec/pixel)

X and Y coordinate rotation: 9.790  9.718  (degrees  degrees)
Updating image header wcs
noao>

Sapphire

PACKAGE = imcoords
TASK = ccmap

input   = NGC6995_FUV_Sapphire_astrom.in  The input coordinate files
database= NGC6995_FUV_Sapphire.db  The output database file
(solutio= NGC6995_FUV_Sapphire.sol) The database plate solution names
(images = NGC6995_FUV_Sapphire___MASTER_IMAGE_CYG-S-VIII.fits) The input images
(results= NGC6995_FUV_Sapphire.sum) The optional results summary files
(xcolumn=                1) Column containing the x coordinate
(ycolumn=                2) Column containing the y coordinate
(lngcolu=                3) Column containing the ra / longitude
(latcolu=                4) Column containing the dec / latitude
(xmin   =           INDEF) Minimum logical x pixel value
(xmax   =           INDEF) Maximum logical x pixel value
(ymin   =           INDEF) Minimum logical y pixel value
(ymax   =           INDEF) Maximum logical y pixel value
(lngunit=             deg) Input ra / longitude units
(latunit=             deg) Input dec / latitude units
(insyste=           j2000) Input celestial coordinate system
(refpoin=          coords) Source of the reference point definition
(xref   =           INDEF) Reference point in x
(yref   =           INDEF) Reference point in y
(lngref =           INDEF) Reference point ra / longitude telescope coordinate
(latref =           INDEF) Reference point dec / latitude telescope coordinate
(refsyst=           INDEF) Reference point telescope coordinate system
(lngrefu=                ) Reference point ra / longitude units

(latrefu=                ) Reference point dec / latitude units
(project=              tan) Sky projection geometry
(fitgeom=          general) Fitting geometry
(functio=       polynomial) Surface type
(xxorder=                2) Order of xi fit in x
(xyorder=                2) Order of xi fit in y
(xxterms=             half) Xi fit cross terms type
(yxorder=                2) Order of eta fit in x
(yyorder=                2) Order of eta fit in y
(yxterms=             half) Eta fit cross terms type
(maxiter=                0) The maximum number of rejection iterations
(reject =              3.) Rejection limit in sigma units
(update =               no) Update the image world coordinate system ?
(pixsyst=          logical) Input pixel coordinate system
(verbose=              yes) Print messages about progress of task ?
(interac=              yes) Fit the transformation interactively ?
(graphic=       stdgraph) Default graphics device
(cursor =                ) Graphics cursor
(mode   =                ql)

Refsystem: j2000  Coordinates: equatorial FK5
   Equinox: J2000.000 Epoch: J2000.00000000 MJD: 51544.50000
Insystem: j2000  Coordinates: equatorial FK5
   Equinox: J2000.000 Epoch: J2000.00000000 MJD: 51544.50000

Coords File: NGC6995_FUV_Sapphire_astrom.in  Image:
NGC6995_FUV_Sapphire___MASTER_IMAGE_CYG-S-VIII.fits
   Database: NGC6995_FUV_Sapphire.db  Solution: NGC6995_FUV_Sapphire.sol
Coordinate mapping status
   Ra/Dec or Long/Lat fit rms: 0.148  0.161   (arcsec  arcsec)
Coordinate mapping parameters
   Sky projection geometry: tan
   Reference point: 314:09:13.93  31:14:38.20  (degrees  degrees)

```
    Reference point: 2566.180  2693.859  (pixels  pixels)
    X and Y scale: 0.417  0.417  (arcsec/pixel  arcsec/pixel)
    X and Y axis rotation: 9.767  9.724  (degrees  degrees)
Wcs mapping status
    Ra/Dec or Long/Lat wcs rms: 0.148  0.161   (arcsec  arcsec)
noao>

PACKAGE = imcoords
   TASK = ccsetwcs


images  = NGC6995_FUV_Sapphire___MASTER_IMAGE_CYG-S-VIII.fits  The input images
database= NGC6995_FUV_Sapphire.db  The input database file
solution= NGC6995_FUV_Sapphire.sol  The input plate solutions
(xref   =              INDEF) The x reference pixel
(yref   =              INDEF) The y reference pixel
(xmag   =                INDEF) The x axis scale in arcsec / pixel
(ymag   =                INDEF) The y axis scale in arcsec / pixel
(xrotati=               INDEF) The x axis rotation angle in degrees
(yrotati=               INDEF) The y axis rotation angle in degrees
(lngref =               INDEF) The ra / longitude reference coordinate in lngunits
(latref =              INDEF) The dec / latitude reference coordinate in latunits
(lngunit=                    ) The ra / longitude reference coordinate units
(latunit=                   ) The dec / latitude reference coordinate units
(transpo=                   no) Transpose the computed image wcs ?
(project=                  tan) The sky projection geometry
(coosyst=                 j2000) The celestial coordinate system
(update =                  yes) Update the image world coordinate system ?
(pixsyst=             logical) The input pixel coordinate system
(verbose=                   yes) Print messages about actions taken by the task ?
(mode   =                   ql)

Image: NGC6995_FUV_Sapphire___MASTER_IMAGE_CYG-S-VIII.fits  Database:
NGC6995_FUV_Sapphire.db  Solution: NGC6995_FUV_Sapphire.sol
```

Coordinate mapping parameters
    Sky projection geometry: tan
    Reference point: 314:09:13.93  31:14:38.20  (degrees   degrees)
    Ra/Dec logical image axes: 1  2
    Reference point: 2566.180  2693.859  (pixels  pixels)
    X and Y scale: 0.417  0.417  (arcsec/pixel  arcsec/pixel)
    X and Y coordinate rotation: 9.767  9.724  (degrees  degrees)
Updating image header wcs
noao>

Silica

PACKAGE = imcoords
  TASK = ccmap

input   = NGC6995_FUV_Silica_astrom.in  The input coordinate files
database= NGC6995_FUV_Silica.db  The output database file
(solutio= NGC6995_FUV_Silica.sol) The database plate solution names
(images = NGC6995_FUV_Silica___MASTER_IMAGE_CYG-S-VIII.fits) The input images
(results= NGC6995_FUV_Silica.sum) The optional results summary files
(xcolumn=                1) Column containing the x coordinate
(ycolumn=                2) Column containing the y coordinate
(lngcolu=                3) Column containing the ra / longitude
(latcolu=                4) Column containing the dec / latitude
(xmin   =           INDEF) Minimum logical x pixel value
(xmax   =           INDEF) Maximum logical x pixel value
(ymin   =           INDEF) Minimum logical y pixel value
(ymax   =           INDEF) Maximum logical y pixel value
(lngunit=             deg) Input ra / longitude units
(latunit=             deg) Input dec / latitude units
(insyste=           j2000) Input celestial coordinate system
(refpoin=          coords) Source of the reference point definition

(xref  =  INDEF) Reference point in x
(yref  =  INDEF) Reference point in y
(lngref =  INDEF) Reference point ra / longitude telescope coordinate
(latref =  INDEF) Reference point dec / latitude telescope coordinate
(refsyst=  INDEF) Reference point telescope coordinate system
(lngrefu=  ) Reference point ra / longitude units
(latrefu=  ) Reference point dec / latitude units
(project=  tan) Sky projection geometry
(fitgeom=  general) Fitting geometry
(functio=  polynomial) Surface type
(xxorder=  2) Order of xi fit in x
(xyorder=  2) Order of xi fit in y
(xxterms=  half) Xi fit cross terms type
(yxorder=  2) Order of eta fit in x
(yyorder=  2) Order of eta fit in y
(yxterms=  half) Eta fit cross terms type
(maxiter=  0) The maximum number of rejection iterations
(reject =  3.) Rejection limit in sigma units
(update =  no) Update the image world coordinate system ?
(pixsyst=  logical) Input pixel coordinate system
(verbose=  yes) Print messages about progress of task ?
(interac=  yes) Fit the transformation interactively ?
(graphic=  stdgraph) Default graphics device
(cursor =  ) Graphics cursor
(mode  =  ql)

Refsystem: j2000  Coordinates: equatorial FK5
  Equinox: J2000.000 Epoch: J2000.00000000 MJD: 51544.50000
Insystem: j2000  Coordinates: equatorial FK5
  Equinox: J2000.000 Epoch: J2000.00000000 MJD: 51544.50000

Coords File: NGC6995_FUV_Silica_astrom.in  Image:
NGC6995_FUV_Silica___MASTER_IMAGE_CYG-S-VIII.fits
  Database: NGC6995_FUV_Silica.db  Solution: NGC6995_FUV_Silica.sol

Coordinate mapping status
    Ra/Dec or Long/Lat fit rms: 0.136  0.14   (arcsec  arcsec)
Coordinate mapping parameters
    Sky projection geometry: tan
    Reference point: 314:09:13.93  31:14:38.20  (degrees  degrees)
    Reference point: 2566.300  2693.728  (pixels  pixels)
    X and Y scale: 0.417  0.417  (arcsec/pixel  arcsec/pixel)
    X and Y axis rotation: 9.782  9.721  (degrees  degrees)
Wcs mapping status
    Ra/Dec or Long/Lat wcs rms: 0.136  0.14   (arcsec  arcsec)
noao>

PACKAGE = imcoords
  TASK = ccsetwcs

images  = NGC6995_FUV_Silica___MASTER_IMAGE_CYG-S-VIII.fits  The input images
database= NGC6995_FUV_Silica.db  The input database file
solution= NGC6995_FUV_Silica.sol  The input plate solutions
(xref   =              INDEF) The x reference pixel
(yref   =              INDEF) The y reference pixel
(xmag   =                INDEF) The x axis scale in arcsec / pixel
(ymag   =                INDEF) The y axis scale in arcsec / pixel
(xrotati=               INDEF) The x axis rotation angle in degrees
(yrotati=               INDEF) The y axis rotation angle in degrees
(lngref =               INDEF) The ra / longitude reference coordinate in lngunits
(latref =              INDEF) The dec / latitude reference coordinate in latunits
(lngunit=                    ) The ra / longitude reference coordinate units
(latunit=                   ) The dec / latitude reference coordinate units
(transpo=                  no) Transpose the computed image wcs ?
(project=                 tan) The sky projection geometry
(coosyst=                j2000) The celestial coordinate system
(update =                  yes) Update the image world coordinate system ?
(pixsyst=             logical) The input pixel coordinate system

(verbose= yes) Print messages about actions taken by the task ?
(mode = ql)

Image: NGC6995_FUV_Silica___MASTER_IMAGE_CYG-S-VIII.fits Database:
NGC6995_FUV_Silica.db Solution: NGC6995_FUV_Silica.sol
Coordinate mapping parameters
Sky projection geometry: tan
Reference point: 314:09:13.93 31:14:38.20 (degrees degrees)
Ra/Dec logical image axes: 1 2
Reference point: 2566.300 2693.728 (pixels pixels)
X and Y scale: 0.417 0.417 (arcsec/pixel arcsec/pixel)
X and Y coordinate rotation: 9.782 9.721 (degrees degrees)
Updating image header wcs
noao>

NGC6995

PACKAGE = imcoords
TASK = ccmap

input = NGC6995_NUV_NUVN2_astrom.in The input coordinate files
database= NGC6995_NUV_NUVN2.db The output database file
(solutio= NGC6995_NUV_NUVN2.sol) The database plate solution names
(images = NGC6995_NUV_NUVN2___MASTER_IMAGE_CYG-S-VIII.fits) The input images
(results= NGC6995_NUV_NUVN2.sum) The optional results summary files
(xcolumn= 1) Column containing the x coordinate
(ycolumn= 2) Column containing the y coordinate
(lngcolu= 3) Column containing the ra / longitude
(latcolu= 4) Column containing the dec / latitude
(xmin = INDEF) Minimum logical x pixel value
(xmax = INDEF) Maximum logical x pixel value
(ymin = INDEF) Minimum logical y pixel value

(ymax =  INDEF) Maximum logical y pixel value
(lngunit=  deg) Input ra / longitude units
(latunit=  deg) Input dec / latitude units
(insyste=  j2000) Input celestial coordinate system
(refpoin=  coords) Source of the reference point definition
(xref =  INDEF) Reference point in x
(yref =  INDEF) Reference point in y
(lngref =  INDEF) Reference point ra / longitude telescope coordinate
(latref =  INDEF) Reference point dec / latitude telescope coordinate
(refsyst=  INDEF) Reference point telescope coordinate system
(lngrefu=  ) Reference point ra / longitude units
(latrefu=  ) Reference point dec / latitude units
(project=  tan) Sky projection geometry
(fitgeom=  general) Fitting geometry
(functio=  polynomial) Surface type
(xxorder=  2) Order of xi fit in x
(xyorder=  2) Order of xi fit in y
(xxterms=  half) Xi fit cross terms type
(yxorder=  2) Order of eta fit in x
(yyorder=  2) Order of eta fit in y
(yxterms=  half) Eta fit cross terms type
(maxiter=  0) The maximum number of rejection iterations
(reject =  3.) Rejection limit in sigma units
(update =  no) Update the image world coordinate system ?
(pixsyst=  logical) Input pixel coordinate system
(verbose=  yes) Print messages about progress of task ?
(interac=  yes) Fit the transformation interactively ?
(graphic=  stdgraph) Default graphics device
(cursor =  ) Graphics cursor
(mode =  ql)

Refsystem: j2000  Coordinates: equatorial FK5
  Equinox: J2000.000 Epoch: J2000.00000000 MJD: 51544.50000
Insystem: j2000  Coordinates: equatorial FK5

Equinox: J2000.000 Epoch: J2000.00000000 MJD: 51544.50000

Coords File: NGC6995_NUV_NUVN2_astrom.in Image:
NGC6995_NUV_NUVN2___MASTER_IMAGE_CYG-S-VIII.fits
Database: NGC6995_NUV_NUVN2.db Solution: NGC6995_NUV_NUVN2.sol
Coordinate mapping status
Ra/Dec or Long/Lat fit rms: 0.116 0.175 (arcsec arcsec)
Coordinate mapping parameters
Sky projection geometry: tan
Reference point: 314:09:13.93 31:14:38.20 (degrees degrees)
Reference point: 2566.163 2693.420 (pixels pixels)
X and Y scale: 0.417 0.417 (arcsec/pixel arcsec/pixel)
X and Y axis rotation: 9.743 9.727 (degrees degrees)
Wcs mapping status
Ra/Dec or Long/Lat wcs rms: 0.116 0.175 (arcsec arcsec)
noao>

PACKAGE = imcoords
TASK = ccsetwcs

images = NGC6995_NUV_NUVN2___MASTER_IMAGE_CYG-S-VIII.fits The input images
database= NGC6995_NUV_NUVN2.db The input database file
solution= NGC6995_NUV_NUVN2.sol The input plate solutions
(xref = INDEF) The x reference pixel
(yref = INDEF) The y reference pixel
(xmag = INDEF) The x axis scale in arcsec / pixel
(ymag = INDEF) The y axis scale in arcsec / pixel
(xrotati= INDEF) The x axis rotation angle in degrees
(yrotati= INDEF) The y axis rotation angle in degrees
(lngref = INDEF) The ra / longitude reference coordinate in lngunits
(latref = INDEF) The dec / latitude reference coordinate in latunits
(lngunit= ) The ra / longitude reference coordinate units
(latunit= ) The dec / latitude reference coordinate units

(transpo= no) Transpose the computed image wcs ?
(project= tan) The sky projection geometry
(coosyst= j2000) The celestial coordinate system
(update = yes) Update the image world coordinate system ?
(pixsyst= logical) The input pixel coordinate system
(verbose= yes) Print messages about actions taken by the task ?
(mode = ql)

Image: NGC6995_NUV_NUVN2___MASTER_IMAGE_CYG-S-VIII.fits Database: NGC6995_NUV_NUVN2.db Solution: NGC6995_NUV_NUVN2.sol
Coordinate mapping parameters
Sky projection geometry: tan
Reference point: 314:09:13.93 31:14:38.20 (degrees degrees)
Ra/Dec logical image axes: 1 2
Reference point: 2566.163 2693.420 (pixels pixels)
X and Y scale: 0.417 0.417 (arcsec/pixel arcsec/pixel)
X and Y coordinate rotation: 9.743 9.727 (degrees degrees)
Updating image header wcs
noao>

# CALIBRATION

To do the calibration the calibration constants of BaF2, Sapphire, Silica, NUVN2 are found out [6].

| FILTER | CALIBRATION CONSTANT |
|---|---|
| BaF2 | 3.55E-15 |
| Sapphire | 4.392E-15 |
| Silica | 1.075E-14 |
| NUVN2 | 3.55E-15 |

Table 2:caliberation constants for different filters [6]

By running imarith in IRAF, calibration is carried out for all images.

CYG-S-I

vocl> imarith CygnusS-1_FUV_BaF2___MASTER_IMAGE_CYG-S-I_COSMIC_RAY_REJECTED.fits * 3.55e-15 CygnusS-1_FUV_BaF2_calib.fits
vocl> imarith CygnusS-1_FUV_Sapphire___MASTER_IMAGE_CYG-S-I_COSMIC_RAY_REJECTED.fits * 4.392e-15 CygnusS-1_FUV_Sapphire_calib.fits
vocl> imarith CygnusS-1_FUV_Silica___MASTER_IMAGE_CYG-S-I_COSMIC_RAY_REJECTED.fits * 1.074e-14 CygnusS-1_FUV_Silica_calib.fits

CYG-S-VIII

vocl> imarith CygnusS-VIII_FUV_BaF2___MASTER_IMAGE_CYG-S-VIII.fits * 3.55e-15 CygnusS-VIII_FUV_BaF2_calib.fits
vocl> imarith CygnusS-VIII_FUV_Sapphire___MASTER_IMAGE_CYG-S-VIII.fits * 4.392e-15 CygnusS-VIII_FUV_Sapphire_calib.fits
vocl> imarith CygnusS-VIII_FUV_Silica___MASTER_IMAGE_CYG-S-VIII.fits * 1.074e-14 CygnusS-VIII_FUV_Silica_calib.fits
vocl>

NGC6995

vocl> imarith NGC6995_FUV_BaF2___MASTER_IMAGE_CYG-S-VIII.fits * 3.55e-15 NGC6995_FUV_BaF2_calib.fits
vocl> imarith NGC6995_FUV_Sapphire___MASTER_IMAGE_CYG-S-VIII.fits * 4.392e-15 NGC6995_FUV_Sapphire_calib.fits
vocl> imarith NGC6995_FUV_Silica___MASTER_IMAGE_CYG-S-VIII.fits * 1.074e-14 NGC6995_FUV_Silica_calib.fits
vocl> imarith NGC6995_NUV_NUVN2___MASTER_IMAGE_CYG-S-VIII.fits * 3.50e-15 NGC6995_NUV_NUVN2_calib.fits
vocl>

# COMPARISON OF JUDE AND CCDLAB

The total number of frames of images obtained from CCDLAB and JUDE is obtained from the header of the images. For JUDE number of frames of each image in a filter is obtained and added to get the total number of frames. Then the total number of frames (NFRAMES) of two images are compared to find out how many frames JUDE excluded. The comparison of NFRAMES for S-I, S-VIII and NGC6995 images are given below. From the table we can see that the number of frames for images in CCDLAB is greater than the number of frames for images from JUDE. This increase in number of frames is because in CCDLAB frames containing cosmic rays are not removed instead they forms a part of nominal background. In JUDE these frames are removed by setting the count rate to a default threshold value $m+3\sigma$. m is the counts per frame over the entire observation. For UVIT detector $\sigma = \sqrt{m}$. So the level 2 data is processed using CCDLAB by selecting Filter Cosmic Ray Frame option and setting sigma theshold rejection value to 3 so that frames containing cosmic rays can be removed. The number of frames rejected in this way is given in the table below

| **CYG – S – I** | | | |
|---|---|---|---|
| FILTER | JUDE | CCDLAB | DIFFERENCE |
| BaF2 | 102939 | 106541.07 | 3602.07 |
| Sapphire | 71165 | 73823.74 | 2658.74 |
| Silica | 130337 | 146655.45 | 16318.45 |
| CYG-S-VIII | | | |
| BaF2 | 106342 | 111690.090629 | 5348.090629 |
| Sapphire | 77984 | 82249.680682 | 4265.680682 |
| Silica | 134217 | 147991.996971 | 13774.996971 |
| NGC6995 | | | |
| BaF2 | 99489 | 81062.376317 | 18426.6237 |
| Sapphire | 55613 | 56943.370055 | 1280.37 |
| Silica | 155165 | 159136.949803 | 3971.949803 |
| NUVN2 | 299470 | 304019.355146 | 4549.355146 |

Table 3:total number of frames for images in different filter after processed using JUDE and CCDLAB and their comparison

Even though JUDE easily reject cosmic ray frames, the registration in JUDE is poor compared to CCDLAB. So for further study it is decided to use the images from CCDLAB after removing cosmic ray containing frames. The table below gives the number of cosmic ray frames rejected in CCDLAB.

| CYG-S-I | | | |
|---|---|---|---|
| FILTER | NFRAMES with cosmic rays | NFRAMES without cosmic rays | DIFFERENCE |
| BaF2 | 106531.48361 | 96787.001441 | 9744.482176 |
| Sapphire | 73823.739561 | 66030.72112 | 7793.018441 |
| Silica | 146655.450357 | 126093.331715 | 20562.118642 |
| CYG-S-VIII | | | |
| BaF2 | 11690.090629 | 103386.455211 | 8303.635418 |
| Sapphire | 82249.680682 | 76530.546547 | 5719.134135 |
| Silica | 147991.996971 | 133630.912441 | 14361.0843 |
| NGC6995 | | | |
| BaF2 | 81062.376317 | 77588.365959 | 3474.010358 |
| Sapphire | 56943.370055 | 54062.33703 | 2681.033025 |
| Silica | 159136.949803 | 145909.870886 | 13227.078917 |
| NUVN2 | 304019.355146 | 270283.284037 | 33736.071109 |

Table 4:Total number of frames comparison with cosmic ray included images and cosmic ray rejected images

From the above two table we can see that The images are then combined to check whether they are perfectly aligned. For that in DS9 using RGB frame red is given to the longer wavelength filter and blue for shorter wavelength filter. After this we have to combine these images and all the three colours should be perfectly merged. If not we have to register the images again. The three composite images obtained are given below. We can see from below images that CCDLAB gives better registered images.

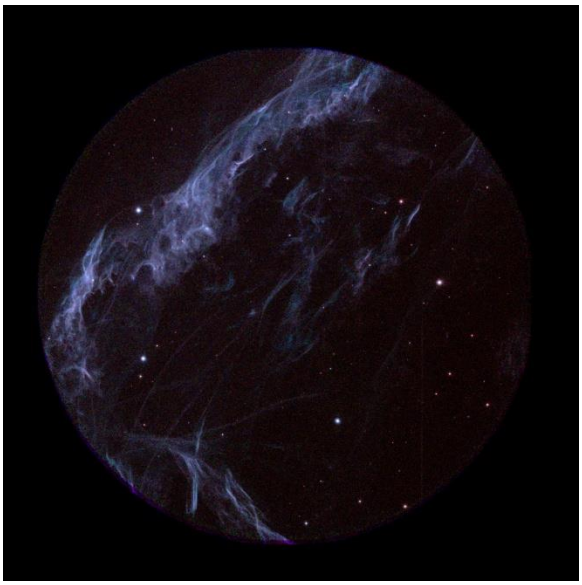

Figure 9: CYG - S – I

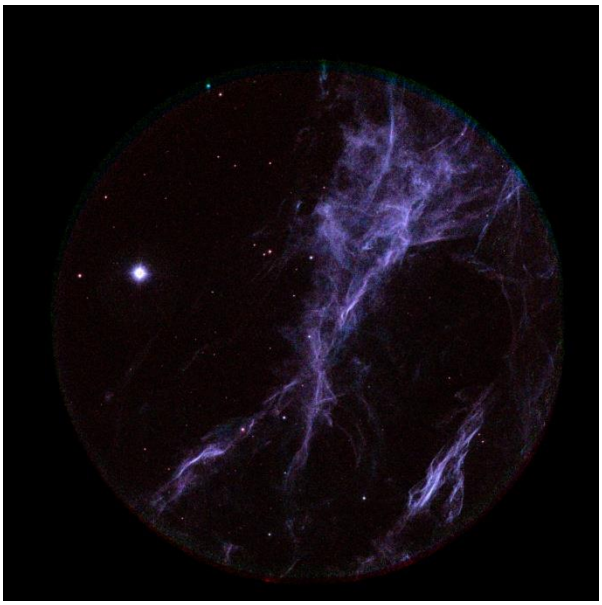

Figure 10: CYG - S – VIII

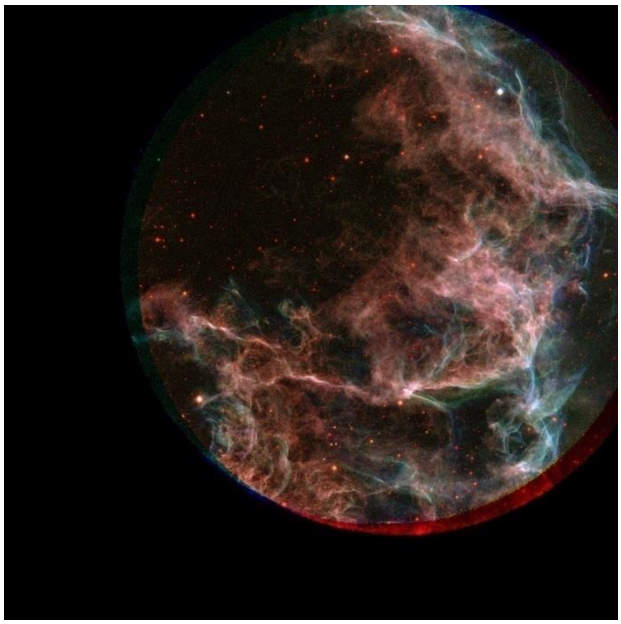

Figure 11:NGC6995

All these images are used for all other studies. Here study of these regions by comparing with previously obtained data from other missions is carried out.

# ANALYSIS

For the points of S-VIII, S-I and NGC6995 the corresponding GALEX, IUE, UIT archival datas are downloaded from the MAST website. Mikulski Archive for Space Telescopes (MAST) is a NASA funded project which provides a variety of astronamical data archives, mainly in the optical, ultraviolet, and near-infrared parts of the spectrum. A brief discription of each data used in this project is given below.

The Galaxy Evolution Explorer (GALEX) is a NASA mission. It is led by California Institute of Technology. It observes images in the UV (NUV) and far-UV (FUV) regions of the spectrum. It has a 1.25 degree field-of-view.

| | |
|---|---|
| Telescope Aperture | 50cm |
| Focal Length | 3m |
| Field of View | $1.2^0$ |
| Image quality | $3^0$ |
| Imaging Effective Area | $25cm^2$(FUV), $44cm^2$(NUV) |
| Band | 1350-1750 $A^0$ (FUV), 1750-2800 $A^0$ (NUV) |

Table 5: Instrument specification of GALEX

UIT was one of the three telescope of ASTRO-I mission. It is an f/9 Ritchey-Chretien telescope having an aperture of 38cm and a field of view of 40'[7]. UIT had 2 cameras. one a near-ultraviolet (NUV or "A") camera and the other is a far ultraviolet (FUV or "B") camera. Each camera have 6 filters. The effective wavelength and bandwidth of each filter is given below.
The instrument specification of UIT is given below.

| FILTER | Effective Wavelegth($A^o$) | Bandwidth($A^o$) |
|---|---|---|
| A1 | 2488 | 11477 |
| A2 | 1892 | 412 |
| A3 | 1964 | 173 |
| A4 | 2205 | 244 |
| A5 | 2558 | 456 |
| A6 | | GRATING |
| B1 | 1521 | 354 |
| B2 | 1359 | 160 |
| B3 | 1445 | 256 |
| B4 | 1585 | 129 |
| B5 | 1615 | 255 |
| B6 | 1497 | 404 |

Table 6: effective wavelength and bandwidth of filters of UIT

| | |
|---|---|
| Aperture | 38cm |
| Primary Mirro Focal Length | 144.211cm |
| Primary Mirro Focal Ratio | f/3.8 |
| Effective Focal Length | 342.900 cm |
| System Focal Ratio | f/9.0 |
| Field of View | $40^0$ |
| Angular resolution | $2.5^0$ |
| Wavelenth Range | 1200-3200 $A^0$ |
| Detectors | Image Intensifiers with CsI and Cs2 Te photo cathodes 70,, IIa- O film |

Table 7: Instrument specification of UIT[7]

UIT images are recorded on Kodak IIa-O film. Then these images are digitized with the help of Perkin-Elmer 1010m microdensitometers. These images in the digitized form is then processed by a software called Batch Data Reduction (BDR) system. Thus, a linearized and flat fielded image is obtained in the FITS format.

The international ultraviolet explorer(IUE) launched jointly by NASA, United Kingdom Science Research Council(SRC) and European Space Agency(ESA) is a facility for observing ultraviolet spectra of astronomical sources. A 45 cm Ritchey Chretien f/15 telescope is used in this mission. Secondary electron conduction (SEC) Vidicon cameras are used as detectors here. These are fed to a spectrograph package and covered the spectral range from 1150 to 3250 ˚A. The IUE telescope parameters are given below.

| | |
|---|---|
| Aperture | 45cm |
| Primary Focal Length | 125cm |
| Effective Focal Length | 675cm |
| Focal Ratio | 50cm |
| Field of View | 16’ |
| Image quality | $3^0$ |

Table 8: Instrumentation specification of IUE

First CYG-S-I and CYG-S-VIII is compared with GALEX. This is done in DS9 using RGB frame. GALEX is in the NUV region. Here we have here only FUV data. So I used only silica filter for comparison since it lies close to NUV region. Here GALEX image is taken as red and CYG-S-I and CYG-S-VIII are taken as blue according to wavelength. The images are given below

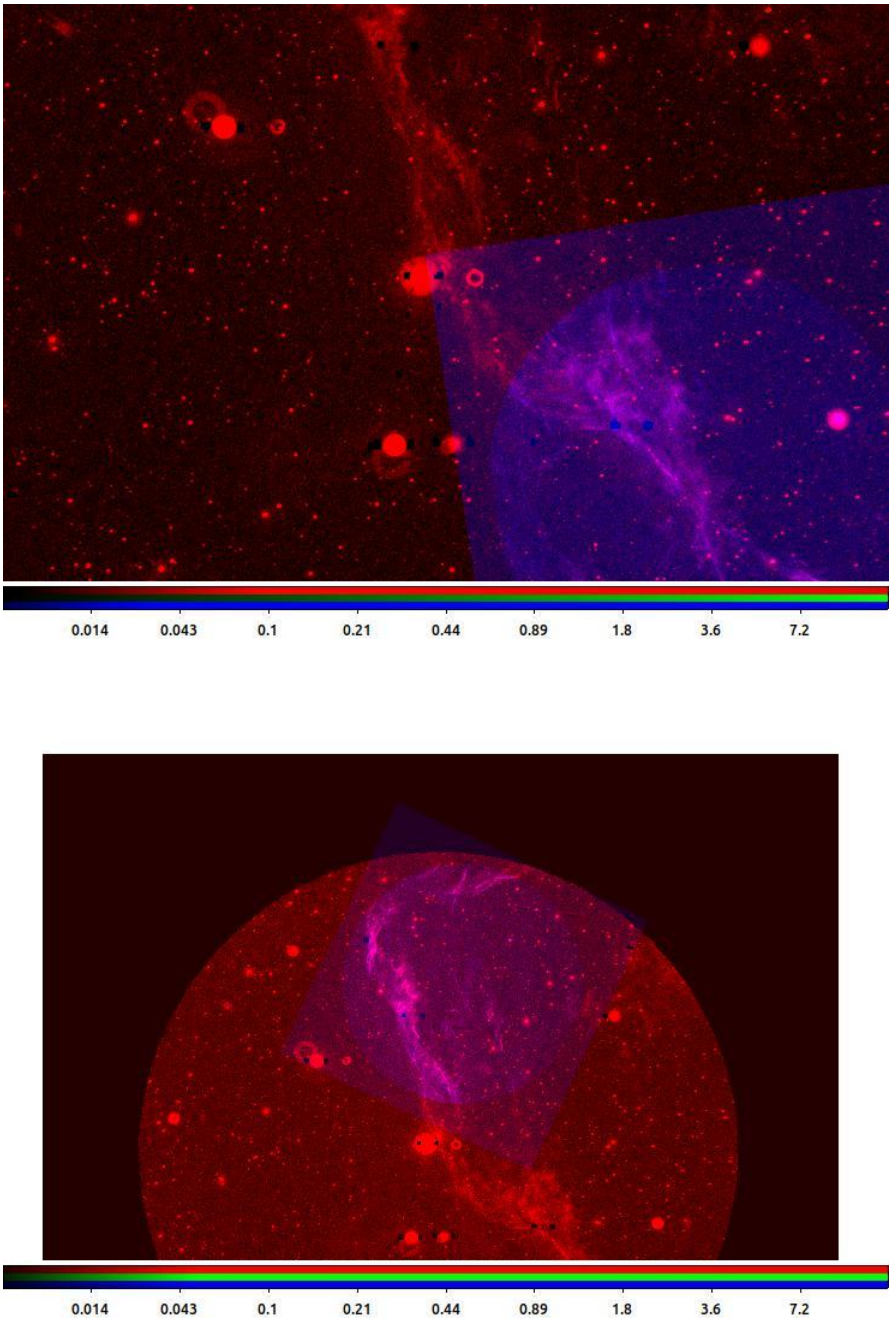


Figure 12: CYG-S-I and CYG-S-VIII compared with GALEX

Further NGC6995 was compared with the UIT images. For this images in same wavelength was selected. Hence, here UIT image FUV2910 and NGC6995 is taken. The image obtained after combining FUV2910 and NGC6995 6995 FUV BaF2 is shown below.

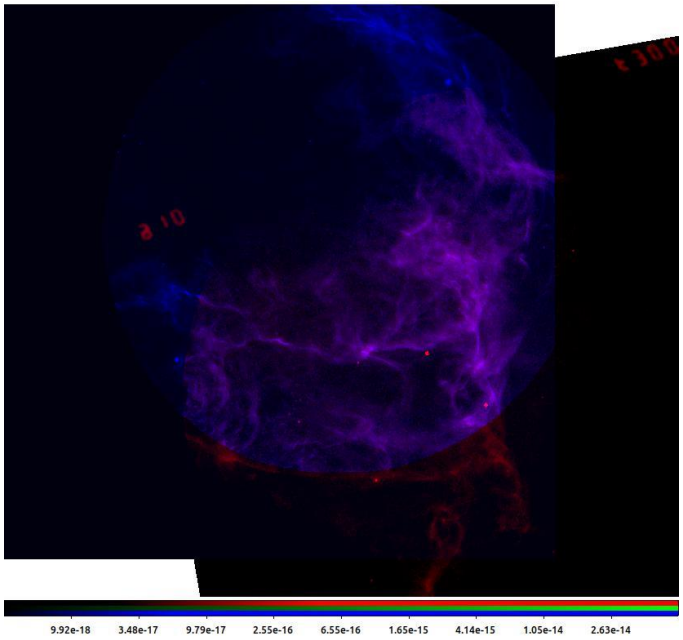


Figure 13: Image of FUV2910 and NGC6995_FUV_BaF2

From this image it is found that there is a shift for NGC6995. This can be marked clearly by plotting contours in ds9.

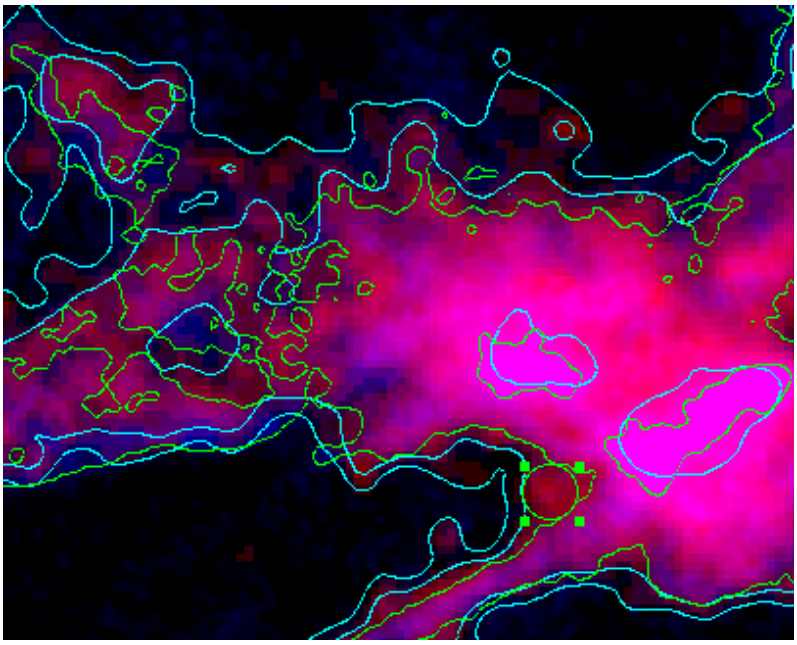

Figure 14: Contour Plotting

From this image by marking a 'region' in one of the knots the angle of shift is calculated to be 0.0010500 degree. The distance of shift is calculated using the equation

$$\text{length of the arc} = \theta \times r$$

Using this equation the distance is calculated to be 0.013188 pc where r is taken to be 720 pc. From the header of UIT2910 the observation date is found to be 17/03/95 and observation date of NGC6995 is 10/10/2016. The difference between two dates are 21 years, 6 months and 23 days. so the velocity with which the shift has occurred can be calculated from the equation distance/time. This is calculated to be 19378055210.428571429km/year which is $19 * 10^9$ km/year.

# CONCLUSION

Cygnus loop, the super nova remnant is an important object of study. Supernova remnants play an important role in stellar evolution. It compresses interstellar matter which helps in star formation. It also enriches the space with heavy elements. In this project I have studied Cygnus loop using CYG-S-I, CYG-S-VIII and NGC6995 regions.

The data for these regions is processed using both JUDE and CCDLAB. There were many limitations in both the software so I did here a comparison of both the software. First in the comparison I found images from CCDLAB contains more number of frames compared to JUDE. From that it was found that the CCDLAB is not rejecting cosmic ray frames. Hence, by changing the settings in CCDLAB I obtained cosmic ray rejected images. The records of the number of frames used for all this process by the software is given in this project report. Registration of images should be done well to obtain a good image. CCDLAB produced well registered images compared with JUDE. Hence for the further comparison I used images from CCDLAB.

There are other missions that observed these regions. In the MAST archival, it is found that UIT observed the regions containing NGC6995 and GALEX observed regions containing CYG-S-I and CYG-S-VIII. In DS9 using RGB frame these images were compared. When I compared NGC6995 and UIT images I observed there is slight shift. I calculated this shift to be 0.013188 pc and also calculated the velocity of the shift. Similarly, Galex images where compared with CYG-S-I and CYG-S-VIII.

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