Introduction

In this Lab you will determine when Cassiopeia A's Supernova occurred. You will either obtain an actual image from an observatory (LCOGT, or Chandra) or from a provided image in the folder. Using the image (which will be in an Astronomical Image format called FITTS) you will learn how we can use its data and laws of physics to determine its size, how fast the supernova remnants are expanding, and finally determine how long ago the supernova occurred. I would like to thank the LCOGT team specifically Haley Gomez and Sarah Eve Roberts for access to their observatory data for use in this lab.

Materials

- FITS (or fz) file of a supernova remnant
- A computer with ds9 image editing software installed

Background Science

**Supernovae**

A blindingly bright star bursts into view in a corner of the night sky — it wasn't there just a few hours ago, but now it burns like a beacon. That bright star isn't actually a star, at least not anymore. The brilliant point of light is the explosion of a star that has reached the end of its life, otherwise known as a supernova.

Supernovas can briefly outshine entire galaxies and radiate more energy than our sun will in its entire lifetime. They're also the primary source of heavy elements in the universe. According to NASA, supernovae are “the largest explosion that takes place in space.”

On average, a supernova will occur about once every 50 years in a galaxy the size of the Milky Way. Put another way, a star explodes every second or so somewhere in the universe, and some of those aren't too far from Earth. About 10 million years ago, a cluster of supernovae created the “Local Bubble,” a 300-light-year long, peanut-shaped bubble of gas in the interstellar medium that surrounds the solar system.

Exactly how a star dies depends in part on its mass. Our sun, for example, doesn't have enough mass to explode as a supernova (though the news for Earth still isn't good, because once the sun runs out of its nuclear fuel, perhaps in a couple billion years, it will swell into a red giant that will likely vaporize our world, before gradually cooling into a white dwarf). But with the right amount of mass, a star can burn out in a fiery explosion.

A star can go supernova in one of two ways:
• **Type I supernova**: star accumulates matter from a nearby neighbor until a runaway nuclear reaction ignites.

• **Type II supernova**: star runs out of nuclear fuel and collapses under its own gravity.

**Supernova Remnants**

No matter whether it is a Type Ia or Type II supernova, the enormous explosions from these stars eject material into the surroundings at very high velocities, sweeping up the surrounding interstellar gas into a shell or a giant bubble. This is known as a **supernova remnant**. The ejected material and the swept-up compressed gas are very hot. The shell (or bubble) shines at different wavelengths, mainly in the X-ray, optical and radio.

Supernova remnants are studied at many different wavelengths from optical light to X-rays. Different things are happening in different wavelengths; when we observe in, say the X-ray, we are looking at the bits of the shell that are much hotter than the bits shining in the optical.

In this activity we will concentrate on the **optical** emission that comes from the interaction between the outward moving shell and the interstellar material that surrounds the supernova. The material is compressed and heated to **10 thousand degrees Kelvin**. In the optical we can see the shocks caused by the expanding material as it sweeps outwards at high velocities. Using the H-alpha filter we will specifically see hydrogen gas.

**Cassiopeia A**

Cassiopeia A is the brightest radio object in the sky so it’s images are intently studied by a variety of observatories around the world.

**The Lab**

What you are about to do is determine how long-ago supernova Cassiopeia A exploded. We will be using a variety of calculation to determine this value. Each step (indicated by a ▶ symbol) will guide you through the process, and you will be recording values of some of those calculations along the way. Think about each step and how we are actually using mathematics from a grade 11 level to determine the final answer.
Preparation

In this project you will obtain a FITS (or fz, a compressed FITS format) image of Cassiopeia A (Cas A).

- You can use an image obtained for you in the folder: Cas A.fz or Cassiopeia A.fz
- You can obtain an image from Las Cumbres Observatory
- You can obtain an image from Chandra ACIS X-ray Imager
- You can locate a FITS image from another observatory on your own

How to obtain an image from Las Cumbres Observatory

➢ Visit the observatory's website: http://lcogt.net/observations

The following window should appear:

➢ Type in Cassiopeia A in the Search Box and hit the Search button.

You will be presented with a set of images of Cassiopeia A taken by various institutions.
Choose an image (Click on it) and you will be be presented with a larger view with a details panel on the right side.

You want to make sure that the image has a FITS line in the Data Column, and preferably using the red (R-band, Bessell R) or H-alpha filter.

➢ Click on the FITS word and the image file will be **downloaded** to your computer.

*The file format (.fz) is in a lossless compressed FITS structure. The FITS structure contains information about the image such as telescope parameters that can be used to determine other properties when uses by a FITS viewer (see Appendix 1).*

How to obtain an image from Chandra Telescope

➢ Start the ds9 Imaging Software
➢ Go to **Analysis>>Virtual Observatory** from the top tabs

➢ Choose any one of the two site Sites to open up a web window
➢ Choose ObsID number 114 (ACIS image of CAS A) from the list.

Our Standard Chandra-Ed Observations

[NB: To use this Web page, ds9 must be running and connected to this site via the Analysis->Virtual Observatory menu option.]

The following observations are available in the Chandra-Ed image directory. These data are (or will be) used in Chandra-Ed activities. Click on the Title of an observation to load it into ds9.

<table>
<thead>
<tr>
<th>ObsID</th>
<th>RA</th>
<th>Dec</th>
<th>Observer</th>
<th>Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>114</td>
<td>23:23:40.278</td>
<td>58:47:34.152</td>
<td>STEPHEN HOLT</td>
<td>ACIS OBSERVATION OF CAS A (first 5K seconds only)</td>
</tr>
<tr>
<td>115</td>
<td>0:25:07.339</td>
<td>64:09:42.660</td>
<td>STEPHEN HOLT</td>
<td>ACIS OBSERVATIONS OF TYCHO AND KEPLER</td>
</tr>
<tr>
<td>117</td>
<td>19:11:01.507</td>
<td>9:06:06.127</td>
<td>STEPHEN HOLT</td>
<td>ACIS OBSERVATION OF W49B</td>
</tr>
<tr>
<td>126</td>
<td>11:24:53.849</td>
<td>-59:15:37.271</td>
<td>GORDON GARMIRE</td>
<td>G692 0-1.8: A REMARKABLE OXYGEN-RICH SUPERNOVA REMNANT</td>
</tr>
<tr>
<td>129</td>
<td>2:05:35.437</td>
<td>64:46:18.069</td>
<td>STEPHEN MURRAY</td>
<td>SEARCH FOR PULSARS (3c-58)</td>
</tr>
<tr>
<td>303</td>
<td>0:42:42.590</td>
<td>41:16:12.235</td>
<td>STEPHEN MURRAY</td>
<td>M31 MONITORING (FOLLOWUP)</td>
</tr>
</tbody>
</table>

The ds9 software will automatically download the image into its imaging section. Once image is downloaded, you can close-down the web window and click on the Close button from the virtual observatory. You should see the image in the ds9 window.
How to load an image into ds9

If you are using either of the provided images (Cas A or Cassiopeia A) or have obtained an image from the Las Cumbres Observatory or another observatory, we need to load it into ds9. If you are using the Chandra image, it is already loaded into the software.

Let’s use the ds9 FITS view software.

➢ Start **ds9 if you have not already done so.**
➢ Click on **File>Open** and choose the Cassiopeia remnant FITS file you have chosen to work with.
➢ Your image may appear black to begin with, try out different options in the toolbars. You are looking for an image that shows as much detail as possible of the supernova remnant. You should see a faint bubble-like structure. I want you to experiment here on your own, as most software no longer comes with user-manuals.

Hint use **Zoom>Fit to Frame** to see full size.

This image of Cas A is shown demonstrating the following values: **scale > linear > 99%, colour > cool**
You will now determine the diameter of the remnant by placing a circle over the shell. This will tell you the angular size of the remnant.

➢ Go to **Region > Shape > Circle**
➢ Draw a circle over the supernova, marking out the shape of the shell. Aim to be as exact as possible.

**Note:** Click in your circle will allow you to select it (4 squares will appear). You can now resize the circle by **left-click** and **dragging** a square, or **left-click** inside the circle to move it around.
➢ Click on Region > Get Information

A window will open up providing you with information about the material the circle surrounds.

➢ First ensure that beside the Radius value, the word says degrees (if not change the scale value to degrees). Record the value of the Radius in the table at the end of the Lab. The example above shows the radius = 0.0305016 degrees.

You can now close the software as we have obtained the crucial piece of information. Cassiopeia A spans a distance in the sky of 2 times the radius or 0.061 degrees in our example.

Now that you know the angular size of Cassiopeia, you will calculate the age of the supernova remnant and find out when its source star exploded.

**How to convert the Angular Radius to a distance in metres.**

For these calculations we will be using the distance of 11,100 ly as the distance from Cassiopeia A to Earth (obtained from Astronomical sites, but we could have used the techniques used in calculating supernova distances in another lab).

➢ Determine the distance to Cassiopeia A in metres (recall that one light year contains about $9.5 \times 10^{15}$ metres). Enter this value into the table.
Our next step is to work out the radius of the supernova remnant in metres by calculating the radius $r$.

- Perform this calculation using the equation below and then record the radius value that is in metres in the table below:

$$ r = D \tan (\theta) $$

$D$ = distance to remnant in metres
$r$ = radius of remnant in metres
$\theta$ is the radius angle on the sky in degrees (from ds9).

*see above figure to understand where this equation comes from.*

Now that you have the radius in metres, you can work out the volume of your supernova remnant.

- Use the following equation; Where $V$ is volume (in cubic metres) and the $r$ is the radius in metres, and $\pi$ can be approximated by 3.1416. Determine the volume and record this value in your table.

$$ V = \frac{4}{3} \pi r^3 $$

*Note: During the initial collapse and rebound of the star's core when a supernova occurs, the outer layers of the star's material are ejected, yet most of the gas in a supernova remnant is not from the star but is collected afterward. As the remnant expands, it sweeps up the surrounding interstellar medium, material which builds up around the edge of the shockwave. The volume through which the remnant has expanded, and the density of the interstellar medium can be used to calculate the mass of the remnant.*

In the space between the stars, the density of material is very low - there isn’t much out there! In fact, the average density in space is about $1 \times 10^{-21}$ kg m$^{-3}$.

This is the density value we will be using in the calculations to determine the mass (M) for Cassiopeia A's supernova remnant.

Since you know both the Volume and the density of Cassiopeia A's supernova remnant, you can calculate the mass of your supernova remnant using the following formula:

$$ \text{Mass} = \text{density} \times \text{volume} $$

- Determine the Mass of the remnant and enter this value into the table below.
The next step is to calculate the velocity that the material in your supernova remnant is moving away from the initial star that when supernova (the core of that star is now a neutron star). A typical supernova explosion will eject about $1 \times 10^{44}$ Joules of Energy (KE) into the surroundings. About one-quarter of that energy is the kinetic energy of the moving remnants. This is the value you will use for kinetic energy. Use the following equation, where $M$ is mass that you previously found (can you determine where the formula came from?):

$$v = \sqrt{\frac{2 \times \left(1 \times 10^{44}\right)}{M}}$$

- Determine the velocity of the ejected material, and enter it into the Table below.

The final step in your calculation is to determine the age of the Cassiopeia A supernova. You can do this using the distance that the supernova remnant has travelled (radius) and its expansion velocity. You will use the following equation:

$$\text{Time} = \frac{\text{Distance}}{\text{Velocity}} = \frac{\text{radius (m)}}{\text{velocity}}$$

Distance is actually the size of the remnant (i.e. the distance the shell has travelled since the explosion, this is your radius in metres)) and the resultant time is actually the age of the remnant (how long it has been expanding).

- Determine the time (duration).

Your result will be in seconds, you will need to convert it to years.

Recall: 1 year contains about $60 \times 60 \times 24 \times 365$ seconds

- Determine the time in years, and record this time in the table

This time value tells us how long ago that Cassiopeia A exploded. We could use that time to look back in history (if mankind was around at that time) to see if anybody recorded the event.

Note: this time assumes that the exploding material has been travelling outwards at a constant speed.

Thinking question: research when professional astronomers believe Cassiopeia A actually went nova, how does your answer compare. What could we have done to improve our answer?

Want another challenge: how long ago did the E0102 72 supernova occur?
<table>
<thead>
<tr>
<th>Radius (degrees)</th>
<th>Distance Cas A (metres)</th>
<th>Radius (metres)</th>
<th>Volume (metres$^3$)</th>
<th>Mass (kg)</th>
<th>Velocity (m/s)</th>
<th>Age (years)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Appendix 1

FITS Data encoded in an image

The following list what else is encoded inside a single FITS image. As you can see programs can use this date to determine information about the image. Ds9 used some of the data to determine the radius angle in degrees of our circle.

Image #1
SIMPLE = T / 
BITPIX = -64 / 
NAXIS = 2 / 
NAXIS1 = 2045 / Axis Length 
NAXIS2 = 2013 / Axis Length 
DATADICTV= 'LCOGT-DIC.FITS-0.11.0' / Version number of the data dictionary 
HDRVER = 'LCOGT-HDR-1.4.0' / Version number of the headers 
ORIGIN = 'LCOGT' / Organization responsible for the data 
SITEID = 'coj' / ID code of the Observatory site 
SITE = 'LCOGT node at Siding Spring Observatory' / Site of the Observatory 
ENCID = 'clma' / ID code of the Enclosure 
ENCLOSURE= 'Clamshell-02' / Building containing Telescope 
TELUID = '2m0a' / ID code of the Telescope 
TELESCOP= '2m0-02' / The Name of the Telescope 
LATITUDE= -31.2728196 / [deg North] Telescope Latitude 
LONGITUDE= 149.0708466 / [deg East] Telescope Longitude 
HEIGHT = 1130.000 / [m] Altitude of Telescope above sea level 
OBSEOFX= -666032.414 / [m] Cartesian X co-ord of telescope (WGS84) 
OBSEOFY= 2804939.432 / [m] Cartesian Y co-ord of telescope (WGS84) 
OBSEOFZ= -3292370.526 / [m] Cartesian Z co-ord of telescope (WGS84) 
OBSTYPE = 'EXPOSE' / Observation type 
FRAMENUM= 4 / Running frame number 
MOLTYPE = 'EXPOSE' / Molecule type 
MOLNUM = 4 / Molecule number 
MOLFRNUM= 1 / Exposure number within molecule 
FRMTOTAL= 1 / Total number of exposures within molecule 
ORIGNOME= 'coj2m002-fs01-20170223-0004-e00.fits' / Fname written by ICS 
OBSTELEM= 'N/A' / Link to observation telemetry 
TIMESYS = 'UTC' / Time system used 
DATE = '2017-02-23' / [UTC] Date this FITS file was written 
DATE-OBS = '2017-02-23T11:13:22.408' / [UTC] Start date and time of the observati 
DAY-OBS = '20170223' / [UTC] Date at start of local observing night 
UTSTART = '11:13:22.408' / [UTC] The start time of the observation 
UTSTOP = '11:16:22.433' / [UTC] The finish time of the observation 
MJD-OBS = 57807.4676150 / [UTC days] Start date/time (Modified Julian Dat 
EXPTIME = 180.0000000 / [s] Exposure length 
FILTER1 = 'H-Alpha' / The first filter wheel filter type 
FILTER1I = 'NBND-HA-008' / The first filter wheel filter id 
FILTER2 = 'air' / The second filter wheel filter type 
FILTER2I = 'air' / The second filter wheel filter id 
FILTER3 = 'air' / The third filter wheel filter type 
FILTER3I = 'air' / The third filter wheel filter id 
FILTER = 'H-Alpha' / Filter used 
FWID = 'fw75a-02' / Filter Wheel ID 
INSTRUME= 'fs01' / Instrument used 
INSTATE= 'OKAY' / The instrument status 
ICSVER = 'origin/master@0xda67b008' / Version number of the ICS software 
CONFMODE= 'N/A' / Camera mode configuration 
CONFNAME= 'N/A' / The instrument configuration used 
DETECTOR= 'UNKNOWN' / Detector type 
DETECTID= 'DS-81' / Detector serial number 
GAIN = 1.0 / [electrons/count] Pixel gain 
RDNOISE = 11.1800000 / [electrons/pixel] Read noise 
DARKCURR= 0.0000000 / [electrons/pixel/s @ 200K] Dark current 
SATURATE= 512006.000000001 / [ADU] Saturation level 
MAXLIN = 512006.000000001 / [ADU] Non-linearity level
RDSPEED = 400.0000000 / [kpix/s] Readout speed used
DETSIZE = '[1:0,1:0]' / [pixel] Detector size
AMPNAME = 'default' / Amplifier name
CCDSEC = 'UNKNOWN' / [pixel] Region of CCD read
CCDSUM = '2 2' / CCD on-chip summing/binning
BIASSEC = '[2048:2080,1:2048]' / [binned pixel] Section of bias/overscan data
DATASEC = '[1:2048,1:2048]' / [binned pixel] Data section
TRIMSEC = '[11:2055,19:2031]' / [binned pixel] Section of useful data
ROI = 'UNKNOWN' / [binned pixel] Region of interest or MULTIPLE
DETSEC = 'UNKNOWN' / [binned pixel] Section of useful data
CCDXPIXE = 0.0000000150 / [m] Size of pixels, in X
CCDYPIXE = 0.0000000150 / [m] Size of pixels, in Y
PIXSCALE = 0.3040000 / [arcsec/pixel] Nominal pixel scale on sky
CCDSTEMP = -100.0000000 / [deg C] CCD required temperature
CCDATEMP = -101.0000000 / [deg C] CCD actual temperature
CCDSESSIG = 'N/A' / [mK] CCD temp control servo error signal
TELMODE = 'AUTOMATIC' / Telescope mode
TAGID = 'FTP' / Time Allocation Group ID
USERID = 'fraser_lewis1' / User ID
PROPID = 'FTP2014A-004' / Proposal ID
GROUPID = 'FL-SN1987A' / Group ID
OBSD = 'UNSPECIFIED' / Observation ID
OBSTEL = 'FRASER' / Observation Note
SCHEDNAME = 'POND' / Name of scheduler in control
TRACKNUM = '0000347772' / Request DB tracking number
REQNUM = '0000967653' / Request DB request number
MOLUID = '297669051' / Molecule unique ID
BLKTYPE = 'POND' / Group type
BLKID = '126276363' / Group unique ID
BLKDATE = '2017-02-23T11:09:23' / [UTC] Block start date
BLKEDATE = '2017-02-23T11:20:25' / [UTC] Block end date
BLKNOMEX = 662.0000000 / [s] Block nominal exec time
BLKMNDST = 30.0000000 / [deg] Minimum lunar distance required
BLKSECC = 'N/A' / Minimum transparency required
BLKAIRCO = '2.0' / Maximum airmass required
SCHEDULE = 'N/A' / [arcsec] Estimated seeing when group scheduled
SCHEDTRN = 'N/A' / [0-1] Estimated transparency when group scheduled
TRIGGER = 'N/A' / External trigger ID
OBRM = 'N/A' / Observing Recipes required/used
PCRECIP = 'N/A' / Processing Recipes required/used
PPRECIP = 'N/A' / Post-Processing Recipes required/used
RA = '05:35:26.2955' / [HH:MM:SS.sss] RA where telescope is pointing
DEC = '-69:16:06.991' / [DD:MM:SSss] Dec where telescope is pointing
RECSYS = 'ICRS' / [[FK5,ICRS] Fundamental coord. system of the object
LST = '07:23:48.22' / [HH:MM:SS.ss] LST at start of current observation
CAT-RA = '05:35:28.020' / [HH:MM:SS.ss] Catalog RA of the object
CAT-DEC = '-69:16:11.07' / [DD:MM:SSss] Catalog Dec of the object
OFFST-RA = '05:35:28.020' / [HH:MM:SS.ss] Catalog RA plus pointing offsets
OFFST-DEC = '-69:16:11.07' / [DD:MM:SSss] Catalog Dec plus pointing offset
TPT-RA = '05:33:15.756' / [HH:MM:SS.ss] Telescope demand RA
OBJECT = 'SN1987a' / Object name
SRCID = 'EXTRASOLAR' / Source type
PM-RA = 0.0000000 / [sec/year] Proper motion in RA of the object
PM-DEC = 0.0000000 / [arcsec/year] Proper motion in Dec of the object
PARALLAX = 0.0000000 / [arcsec] Parallax of the object
RADVEL = 0.0000000 / [km/s] Radial velocity of the object
RATRACK = 0.0000000 / [arcsec] Non-sidereal tracking in RA
DECTRACK = 0.0000000 / [arcsec] Non-sidereal tracking in Dec
TELSTATE = 'WARNING' / Current telescope status
ENGSTATE = 'UNSPECIFIED' / Engineering override state
TCSSTATE = 'OKAY' / TCS state
TCSVER = '0.4' / Version number of the TCS software
TPNMODL = '20150306140204' / Version number of the pointing model
UT1-UTC = 0.5250900 / [s] UT1-UTC

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POLARMOX = 0.0042000 / [arcsec] Polar motion X
POLARMOY = 0.3087000 / [arcsec] Polar motion Y
EOPSRC = 'IERS BULL. A 2017/02/16' / Source of the EOP Values
ROLLERD= 0.0000000 / [rad] Driven roller encoder angle
ROLLERND= 0.0000000 / [rad] Non-driven roller encoder angle
AZDMD = 194.2378456 / [deg] Azimuth axis demand
AZIMUTH = 194.2378470 / [deg] Azimuth axis position
AZSTAT = 'WARNING ' / Azimuth axis state
ALTDMD = 49.0103688 / [deg] Altitude axis demand
ALTITUDE= 49.0103633 / [deg] Altitude axis position
ALTSTAT = 'OKAY ' / Altitude axis state
ROTYPE = 'CASSEGRAIN' / Selected image derotator
ROTMODE = 'SKY ' / Rotator mode
ROTDMD = 117.8793252 / [deg] Rotator axis demand
ROTANGLE= 117.8761019 / [deg] Rotator axis position
ROTSKYPA= 0.0000000 / [deg] Rotator position angle
ROTSTAT = 'OKAY ' / Rotator axis state
AIRMASS = 1.3254939 / Effective mean airmass
AMSTART = 1.3238836 / Airmass at start of observation
AMEND = 1.3271042 / Airmass at end of observation
ENC1STAT= 'OPEN ' / Enclosure shutter 1 state
ENC2STAT= 'OPEN ' / Enclosure shutter 2 state
ENCAZ = 0.0000000 / [deg] Enclosure azimuth
ENCWLIGT= 'UNKNOWN ' / Enclosure white lights state
ENCRLIGT= 'UNKNOWN ' / Enclosure red lights state
FOLDSTAT= 'N/A ' / Fold mirror state
FOLDPORT= 'CASSEGRAIN' / Fold mirror port
FOLDPOSN= -0.0078130 / [mm] Fold mirror position (r, theta)
FOCAFOFF= -0.3279936 / [mm] Autofocus offset in focal plane
FOCFLOFF= -0.1300000 / [mm] Filter focus offset in focal plane
FOCSTAT = 'HALTED ' / Focus state
M1HRTMN = 'UNKNOWN ' / M1 Hartmann screen state
M2PITCH = -32.2947112 / [arcsec] M2 tilt about vertex in pitch direction
M2ROLL = 9.3821432 / [arcsec] M2 tilt about vertex in roll direction
AUXROLL = 5.2474327 / [arcsec] Auxiliary pointing corrections in roll
AUXPITCH= -17.2371902 / [arcsec] Auxiliary pointing corrections in pitch
CTYPE1 = 'RA---TAN' / Type of WCS Projection
CRPIX1 = 1023 / [pixel] Coordinate of reference point (axis 1)
CRPIX2 = 1007 / [pixel] Coordinate of reference point (axis 2)
CRVAL1 = 83.8595645046 / [deg] RA at the reference pixel
CRVAL2 = -69.2686086678 / [deg] Dec at the reference pixel
CUNIT1 = 'deg ' / Units of RA
CUNIT2 = 'deg ' / Units of Dec
CD1_1 = -8.3717256245799E-05 / WCS CD transformation matrix
CD1_2 = -4.93177782495E-07 / WCS CD transformation matrix
CD2_1 = -4.93177782495E-07 / WCS CD transformation matrix
CD2_2 = 8.3717256245799E-05 / WCS CD transformation matrix
WMSSTATE= 'OKAY ' / WMS system state
WMSHUMID= 28.3000000 / [%] Current percentage humidity
WMSTEMP = 23.8000000 / [deg C] External temperature
WMSPPRES = 894.0000000 / [mbar] Atmospheric pressure
WINDSPEE= 14.0364000 / [km/h] Windspeed
WINDDIR = 252.0000000 / [deg E of N] Wind direction
WMSRAIN = 'CLEAR ' / Rain alert
WMSMOIST = 5000.0000000 / [mV] Moisture level
WMSDEWPT= 4.4000000 / [deg C] Dewpoint
WMSCLD= -34.6380000 / [deg C] Boltwood sky temperature
WMSKKYRB= 22.0000000 / [mag/arcsec^2] Measured sky brightness
SKYMAG = 22.0000000 / [mag/arcsec^2] Computed (expected) sky brightness
Cassiopeia A Supernova - Lab

TUBETEMP= 24.6380000 / [deg C] Temperature of the telescope tube
M1TEMP = 'UNKNOWN ' / [deg C] Primary mirror temperature
FOCTEMP = 24.6380000 / [deg C] Focus temperature
ISSTEMP = 'UNKNOWN ' / [deg C] ISS temperature
REFPRES = 894.0000000 / [mbar] Pressure used in refraction calculation
REFTEMP = 23.8000000 / [deg C] Temperature used in refraction calculation
REFHUMID= 28.3000000 / [%] Humidity used in refraction calculation
AGSTATE = 'ACQUIRING' / Autoguider software state
AGCAM = 'kb34    ' / Camera used for autoguiding
AGLCKFRC= 0.00 / [%] Fraction of time AG locked
AGMODE = 'MAYBE   ' / Autoguider mode
AGRA = 'UNKNOWN ' / [deg] RA of guide star
AGDEC = 'UNKNOWN ' / [deg] Dec of guide star
AGGMAG  = 'UNKNOWN ' / [mag] Autoguider guide star mag
AGFWHM  = 'UNKNOWN ' / [arcsec] Autoguider FWHM
AGMIRDMD= 'UNKNOWN ' / [mm] Autoguider mirror demand
AGMIRPO= '00.0, N/A' / Autoguider mirror position
AGMIRST = 'DEPLOYED' / Autoguider mirror state
AGFOCDMD= 12.0000000 / [mm] Autoguider focus demand
AGFOCUS = 12.0000000 / [mm] Autoguider focus position
AGFOCOFF= 0.0000000 / [mm] Autoguider relative focus offset
AGFOCST = 'In position' / Autoguider focus state
AGFILTER= 'BL,     ' / Autoguider filter
AGFILTID= 'RGBL-B1-004,' / Autoguider filter id
AGFLIT= 'Enabled' / Autoguider filter state
MOONSTAT= 'DOWN    ' / [UP, DOWN] Moon position at obs start
MOONFRAC= 0.1079295 / [(0-1)] Lunar Illuminated Fraction
MOONDIST= 90.3639225 / [deg] Lunar distance from target
MOONALT = -41.335998 / [deg] Lunar altitude
SUNDIST = 86.8335998 / [deg] Solar distance from target
SUNALT  = -29.9236967 / [deg] Solar altitude
CHECKSUM= 'Hj9VIh8VHh8VHh8V'