🟣 **See Chandru Grading Comments from 11/4/23 below**

1. Nice work!

✅ **You have a 100% grade on this notebook**

✅ **Correct Any Errors identfied above for an improved grade**

Measuring Astronomical Objects

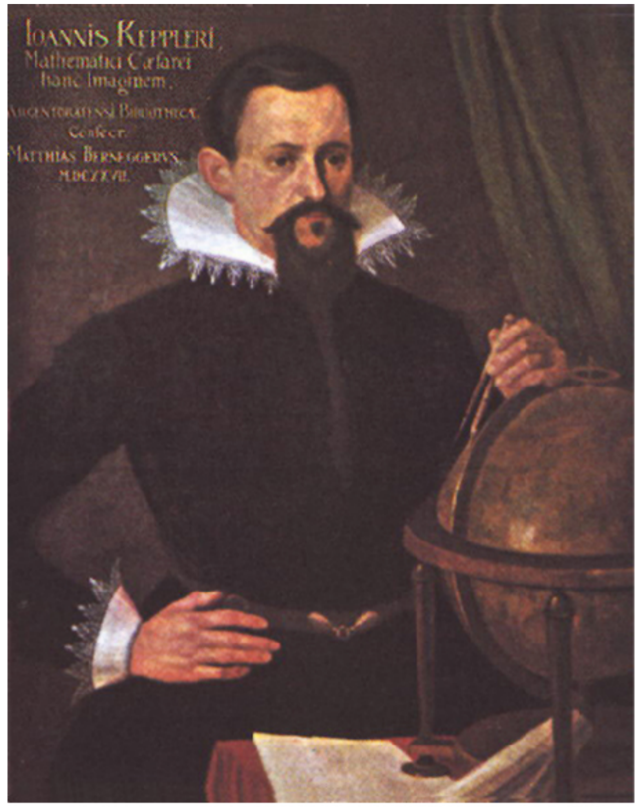
Tycho Brahe's Observatory

Three years after the publication of Copernicus' De Revolutionibus, Tycho Brahe was born to a family of Danish nobility. He developed an early interest in astronomy and, as a young man, made significant astronomical observations. Among these was a careful study of what we now know was an exploding star that flared up to great brilliance in the night sky. His growing reputation gained him the patronage of the Danish King Frederick II, and at the age of 30, Brahe was able to establish a fine astronomical observatory on the North Sea island of Hven (Figure 3.2). Brahe was the last and greatest of the pre-telescopic observers in Europe.

Johannes Kepler

Johannes Kepler was born into a poor family in the German province of Württemberg and lived much of his life amid the turmoil of the Thirty Years' War (see Figure 3.2). He attended university at Tubingen and studied for a theological career. There, he learned the principles of the Copernican system and became converted to the heliocentric hypothesis. Eventually, Kepler went to Prague to serve as an assistant to Brahe, who set him to work trying to find a satisfactory theory of planetary motion—one that was compatible with the long series of observations made at Hven. Brahe was reluctant to provide Kepler with much material at any one time for fear that Kepler would discover the secrets of the universal motion by himself, thereby robbing Brahe of some of the glory. Only after Brahe's death in 1601 did Kepler get full possession of the priceless records. Their study occupied most of Kepler's time for more than 20 years.

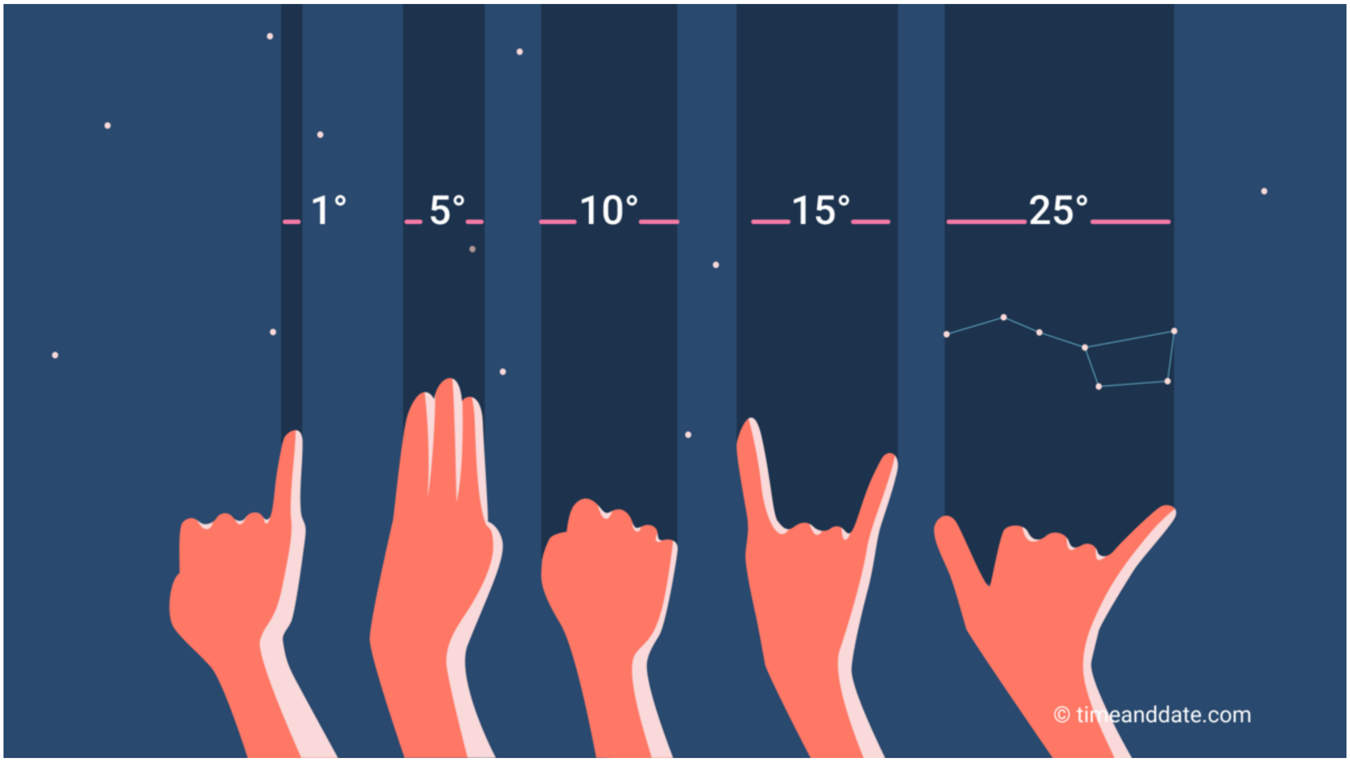
(a)



(b)

In this project we will learn how to roughly measure Astronomical objects in the sky. When we look at the stars, we can use our eyes, out hands and our fingers to approximately estimate the angular extent of objects in the sky in degrees, minutes and seconds of arc. If you already know the distance to the object, you can estimate its actual size in distance measures such as light years or even km in the case of the sun, moon.

A Handy Guide to Measuring the Sky



You can even approximately estimate your lattitude on Earth by measuring the altitude of Polaris from the horizon by simply using your fist!

But, wait! You can do a lot more from a **FITS (Flexible Image Transport System)** image you can obtain from a telescope. We will be measuring the extents of Galaxies, Nebulae, Globular Clusters, and Double Stars from the images we obtainted through the Bush Telescope!

To do this we will download specific images obtained by you during our observing sessions via the Bush Telescope in September 2023 from the **Bush Astro Dropbox** below. We will also be using The School's Observatory's **Astrolab Stellar** application generously offered to our class from the Liverpool John Moores University

Bush Astro Drop Box

Astrolab Stellar Viewer

Project: Measure Size of Astronomical Target

1. Each team of 4 will measure 4 separate targets. Each of you will measure your target and capture a screenshot from Astrolab Stellar application and embed in your Jupyterlab notebook. Please collaborate and obtain help from each other on your team in completing this. You need to do these in your own individual notebook.

2. The camera we used to obtain these images has a pixel size in microns (micrometer or 1-millionth of a meter. We will need this to convert pixels to an angle (arc-seconds) in the sky. We will also

need the focal length of the telescope. All of these can be obtained from the Astrolab Stellar application by taking a screenshot of the FITS header.

3. The 2 steps above are shown in the video linked here.

4. Then create a code cell with the formula below to calculate Image Scale (use variable name image_scale) and print it out as a f-string.

5. Image scale [arc-sec/pixel] = 206.265 * Pixel size[µm] / Focal length[mm]

6. You will then look up the actual target in Sky Safari app on your phone or wikipedia to find the distance to the object in light years. Create a variable (target_distance) and set it equal to the distance in light years.

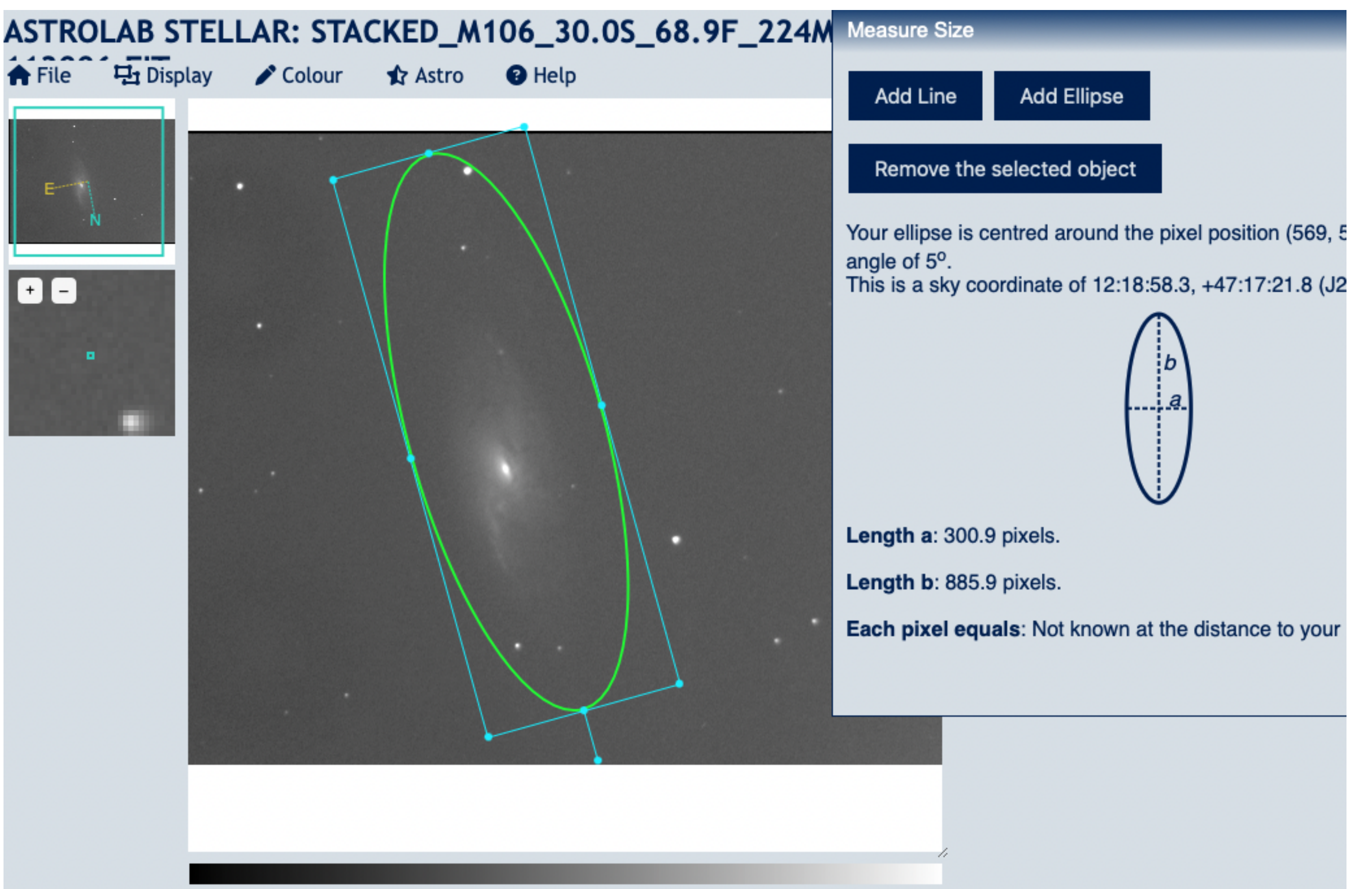
7. Then create another variable (target_angular_extent) to calculate the angular extent of your target (embed the jpg image of this in your notebook). As you have seen before from the measuring the diameter of the Sun project, the distance is easily obtained by first converting the 'target_angular_extent' from degrees to radians and multiplying that by target_distance. This is your final result - the extent of your astronomical target! You can verify this and calculate a %error estimate by looking it up in Wikipedia!

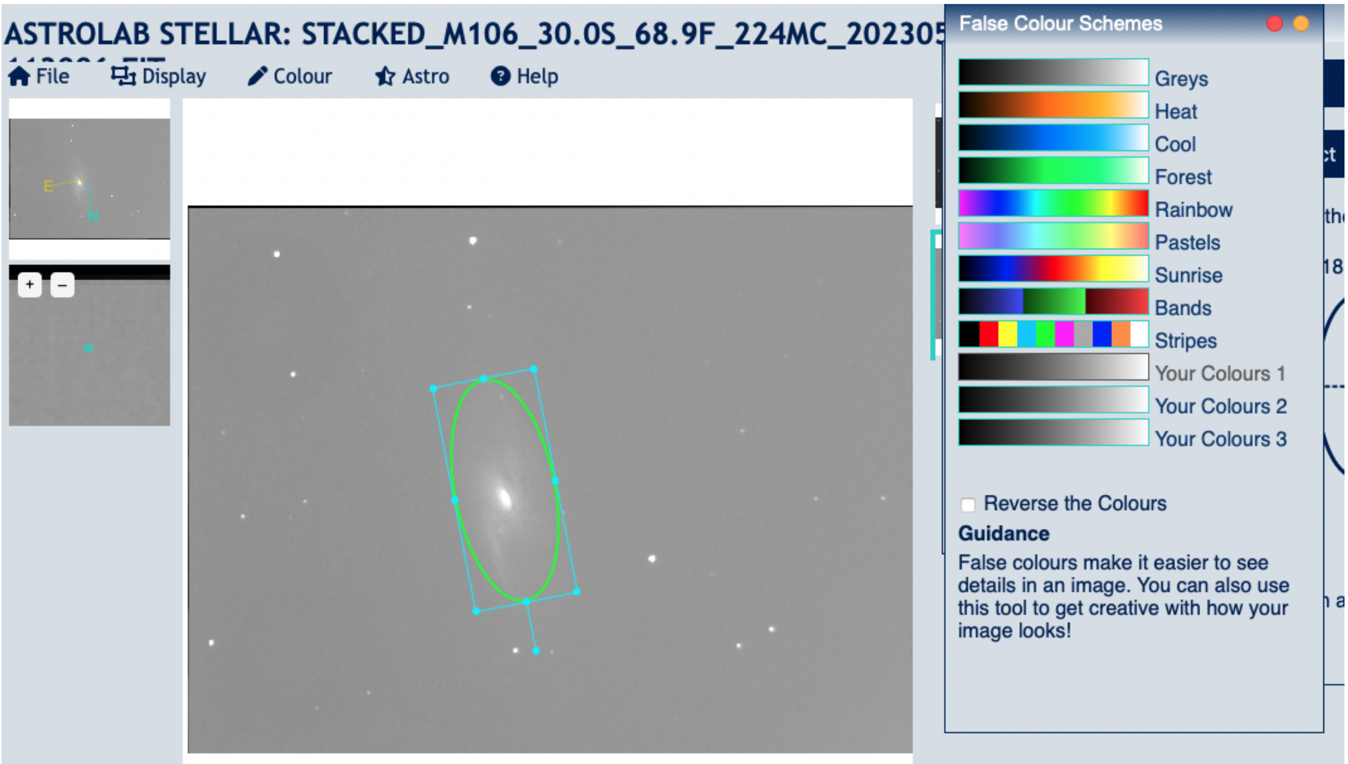
8. Follow my example below!

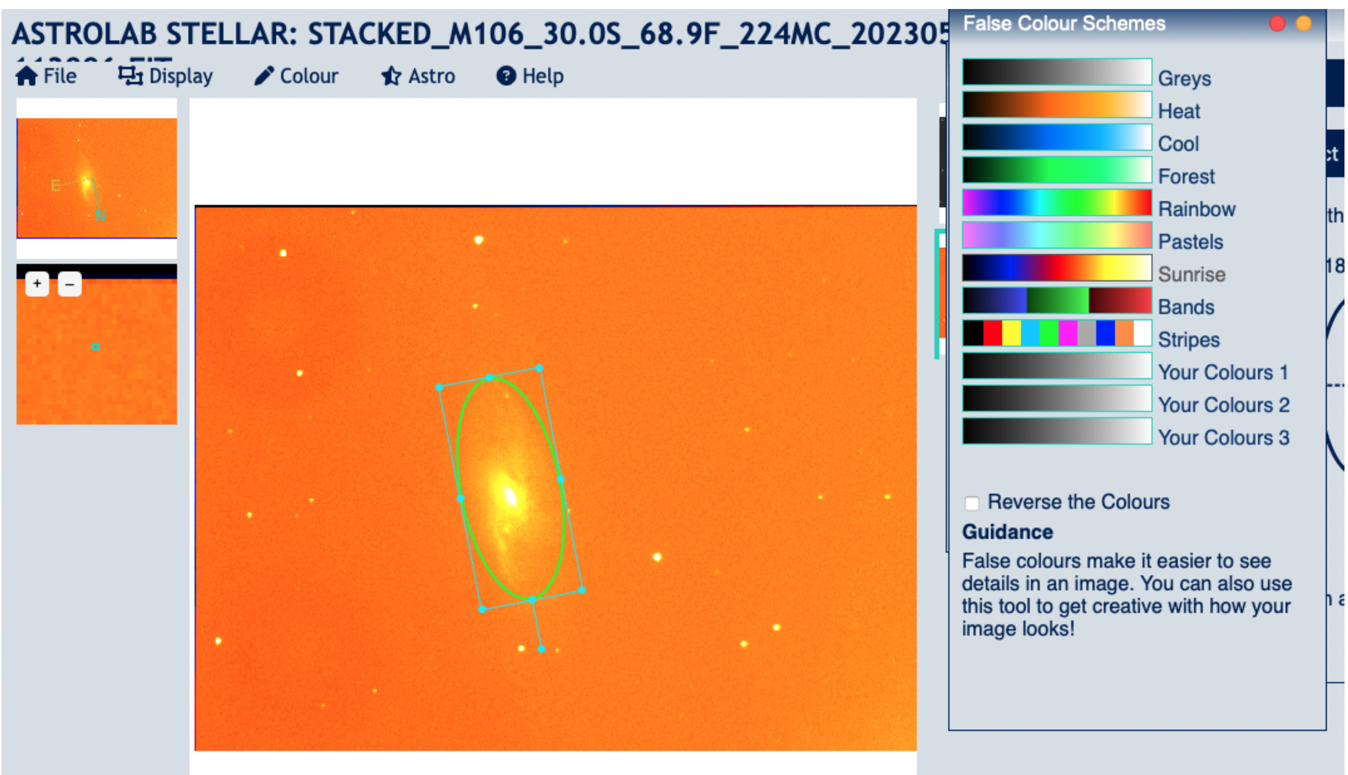
Target is M106 - A Spiral Galaxy in Canes Venatici 23.7 MLY distant

FITS Header - details of the observation

XPIXSZ	3.75	pixel size in microns (with binning)
YPIXSZ	3.75	pixel size in microns (with binning)
IMAGETYP	Light	Type of image
EXPOSURE	0.200000002980232	Exposure time in seconds
EXPTIME	0.200000002980232	Exposure time in seconds
CCD-TEMP	16.2999992370605	sensor temperature in C
RA	292.926	Object Right Ascension in degrees
DEC	28.0108	Object Declination in degrees
DATE-OBS	2023-09-23T04:59:34.223905	Image exposure start time
INSTRUME	ZWO ASI224MC	Camera model
GUIDECAM	ZWO ASI120MM Mini	Guide camera model
BAYERPAT	RGGB	Bayer pattern
GAIN	134	Gain Value
TELESCOP	EQMod Mount	Telescope name
CTYPE1	RA---TAN-SIP	TAN (gnomic) projection + SIP distortions
CTYPE2	DEC--TAN-SIP	TAN (gnomic) projection + SIP distortions
CRVAL1	292.745327784	RA of reference point
CRVAL2	27.9429744778	DEC of reference point




ASTROLAB STELLAR: STACKED_M106_30.0S_68.9F_224MC_202305
File
Display
Colour
Astro
Help
False Colour Schemes
Greys
Heat
Cool
Forest
Rainbow
Pastels
Sunrise
Bands
Stripes
Your Colours 1
Your Colours 2
Your Colours 3
Reverse the Colours
Guidance
False colours make it easier to see details in an image. You can also use this tool to get creative with how your image looks!


ASTROLAB STELLAR: STACKED_M106_30.0S_68.9F_224MC_202305
File
Display
Colour
Astro
Help
False Colour Schemes
Greys
Heat
Cool
Forest
Rainbow
Pastels
Sunrise
Bands
Stripes
Your Colours 1
Your Colours 2
Your Colours 3
Reverse the Colours
Guidance
False colours make it easier to see details in an image. You can also use this tool to get creative with how your image looks!

Measured extent of M106 = 885.9 pixels
Image Scale = 0.9668671875 arc-sec/pixel
M106 measured extent of M106 = 856.55 arc-sec or 14.28 arc-min or 0.004152660150758549 d
egrees

Messier 106	
	
M106 and its anomalous arms. Composite of IR (red) and optical light (Credit: NASA, ESA, the Hubble Heritage Team (STScI/AURA), and R. Gendler (for the Hubble Heritage Team))	
Observation data (J2000 epoch)	
Constellation	Canes Venatici
Right ascension	$12^h\ 18^m\ 57.5^s$[1]
Declination	+47° 18′ 14″[1]
Redshift	448 ± 3 km/s[1]
Distance	23.7 ± 1.5 Mly (7 ± 0.5 Mpc)[2][3]
Apparent magnitude (V)	8.4[1]
Characteristics	
Type	SAB(s)bc[1]
Size	135,000 ly (in diameter)[4]
Apparent size (V)	18′.6 × 7′.2[1]
Notable features	Megamaser galaxy,[5] Seyfert II galaxy.[6]
Other designations	
M 106, NGC 4258, UGC 7353, PGC 39600.[1][7]	

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M106 is 2.370e+07 Light Years or 23.7 Million Light Years away!

Diameter of M106 = 98418.05 Light Years
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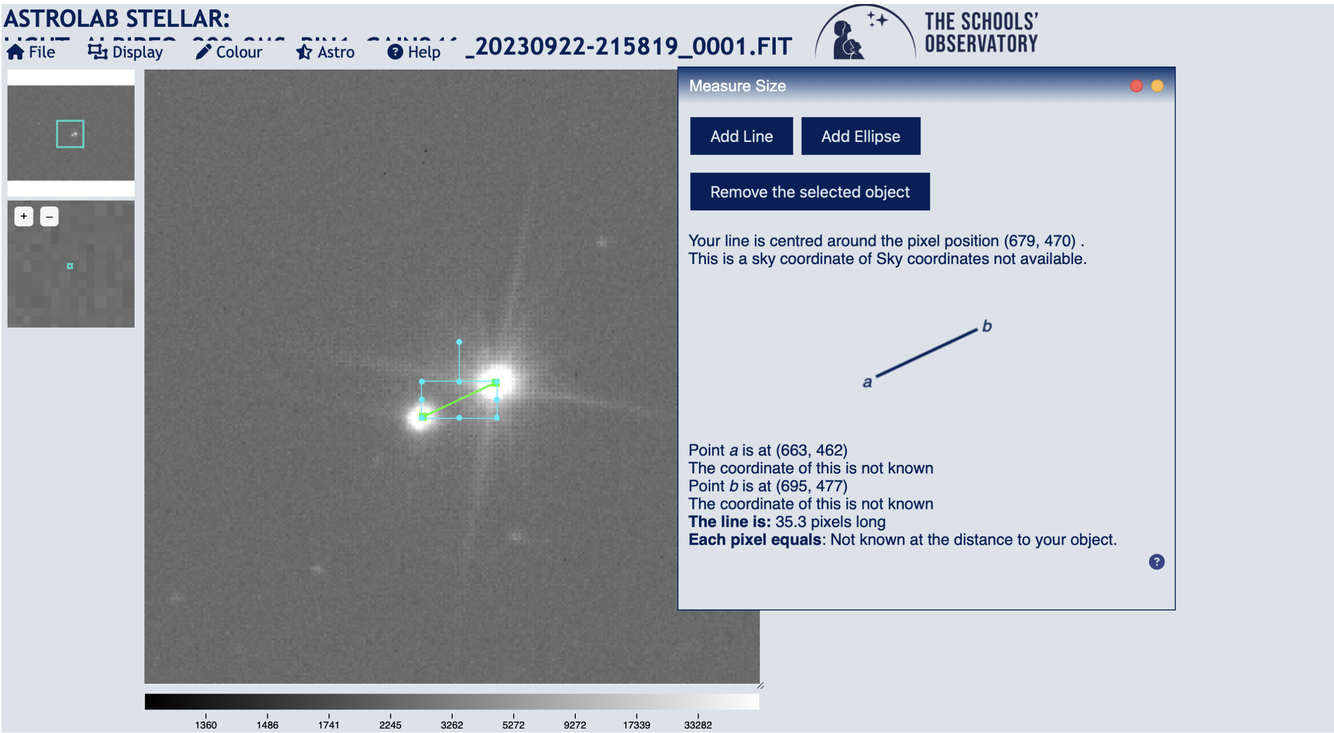


```
Measured extent of Albireo = 35.3 pixels
Image Scale = 0.9668671875 arc-sec/pixel
Albireo measured extent of Albireo = 34.13 arc-sec or 0.57 arc-min or 0.0001654689054315
123 degrees

Albireo is 4.000e+02 Light Years or 0.0004 Million Light Years away!

Diameter of Albireo = 0.07 Light Years
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