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)
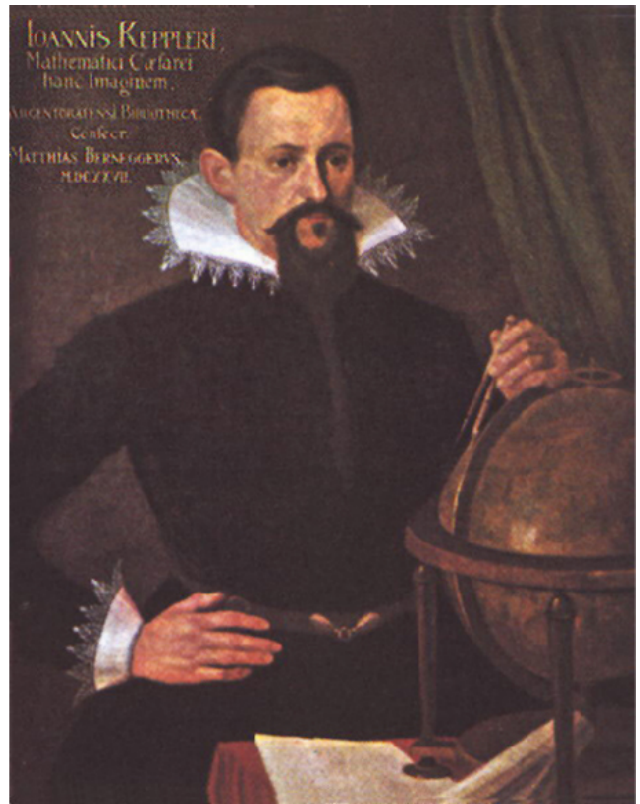
(b)

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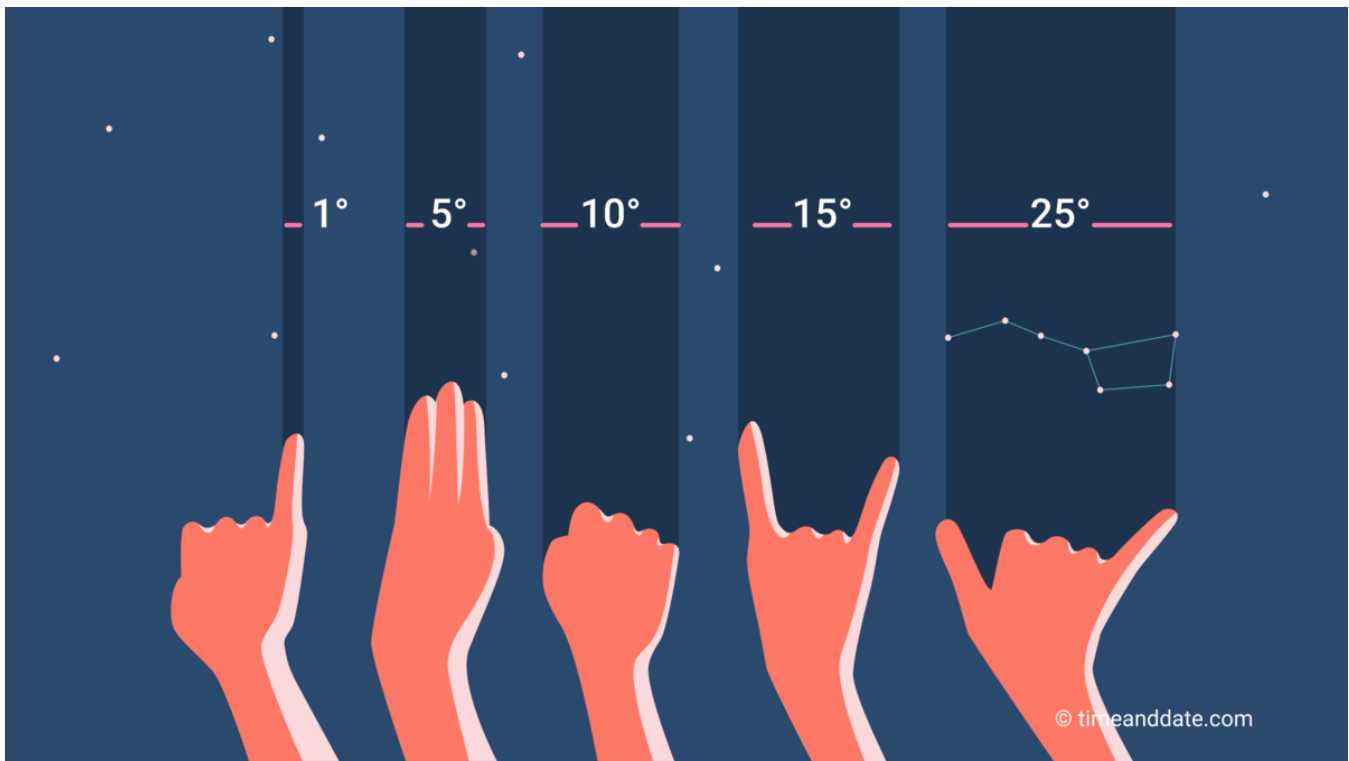
You can even approximately estimate your lattitude on Earth by measuring the altitude of Polaris from the horizon by simply using your fist!

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
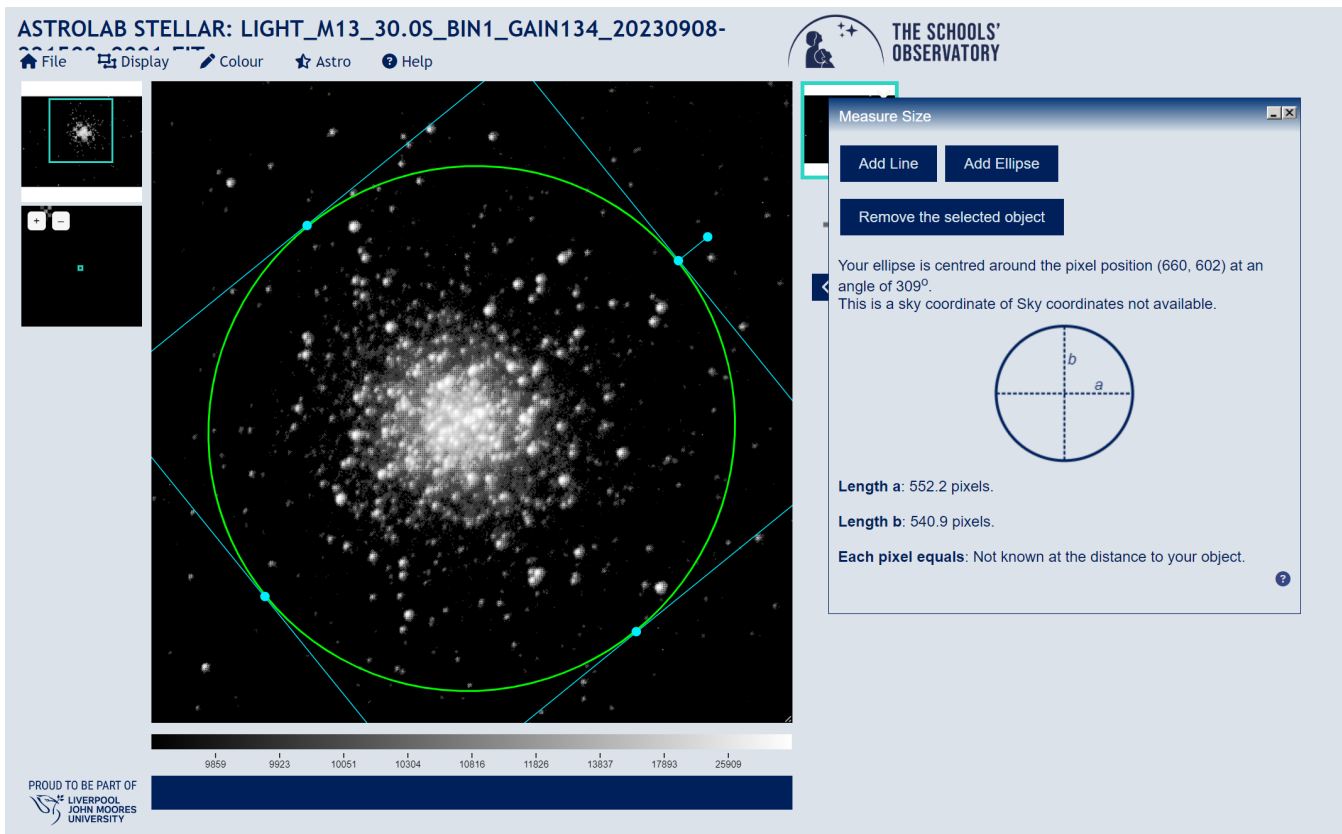
Project: Measure Size of Astronomical Target

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 M13 - A Globular Cluster

File · Display · Colour · Astro · Help

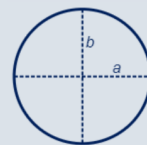THE SCHOOLS' OBSERVATORY
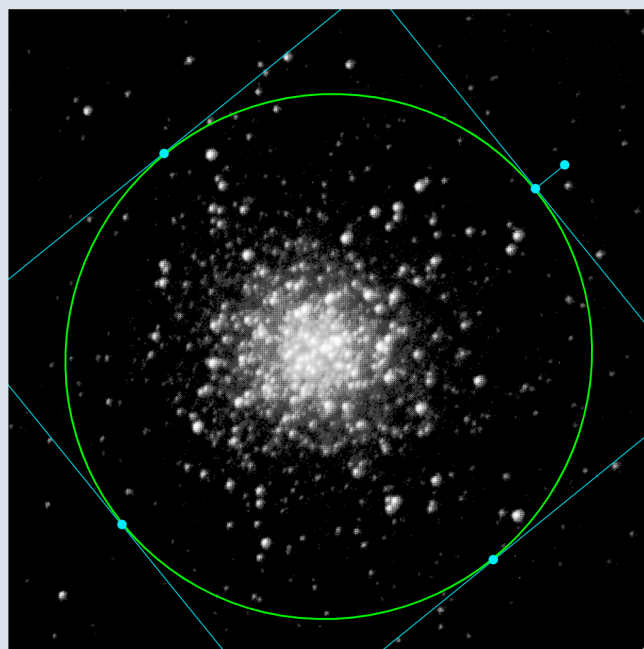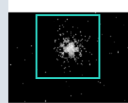
Measure Size

Add Line   Add Ellipse

Remove the selected object

Your ellipse is centred around the pixel position (660, 602) at an angle of 309°.
This is a sky coordinate of Sky coordinates not available.

Length a: 552.2 pixels.

Length b: 540.9 pixels.

Each pixel equals: Not known at the distance to your object.

9859   9923   10051   10304   10816   11826   13837   17893   25909

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FITS Header - details of the observation

YBINNING	1	Camera Y Bin
CCDXBIN	1	Camera X Bin
CCDYBIN	1	Camera Y Bin
XPIXSZ	3.75	pixel size in microns (with binning)
YPIXSZ	3.75	pixel size in microns (with binning)
IMAGETYP	Light	Type of image
EXPOSURE	30.	Exposure time in seconds
EXPTIME	30.	Exposure time in seconds
CCD-TEMP	18.6000003814697	sensor temperature in C
RA	250.6365	Object Right Ascension in degrees
DEC	36.4169	Object Declination in degrees
DATE-OBS	2023-09-09T05:14:37.738642	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
END		

Measured extent of M13 = 1093.1 pixels
Image Scale = 0.9668671875 arc-sec/pixel
M13 measured extent of M13 = 1056.88 arc-sec or 17.61 arc-min or 0.005123911063093091 degrees

Messier 13

Globular cluster Messier 13 in Hercules

Observation data (J2000 epoch)	
Class	V[1][2]
Constellation	Hercules
Right ascension	16^h 41^m 41.24^s[3]
Declination	+36° 27' 35.5″[3]
Distance	22.2 kly (6.8 kpc)[4]
Apparent magnitude (V)	5.8[5]
Apparent dimensions (V)	20 arcminutes

Physical characteristics	
Absolute magnitude	−8.5
Mass	6×10^{5}[6] $M_\odot$
Radius	84 ly[7]

Metallicity	$[Fe/H] = -1.33$ dex
Estimated age	11.65 Gyr[8]
Notable features	One of the best-known clusters of the Northern Hemisphere
Other designations	NGC 6205[5]

See also: Globular cluster, List of globular clusters

M13 is 22180 Light Years away!

Diameter of M13 = 113.65 Light Years

'Percent Error = 21.62%'