



FAULKES TELESCOPE

Galaxies

Scale in the Universe and Star Life Cycles

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Author: Richard Beare

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Measuring objects in the Solar System



Jupiter

image width 2.45 arcmin

distance 4.59 AU

1. Click the Get new image button and import this image of Jupiter.
2. Enter the name Jupiter, the image image width and the distance of Jupiter from the telescope into the JPEG Viewer, making sure that you choose the correct units.
3. Now measure the diameter of Jupiter as follows:
 - a. click the green solid line shape button on the toolbar
 - b. drag the green line that appears on the image across the image until one end is on the left hand edge of Jupiter
 - c. drag the handle at the other end of the line until it is directly opposite the other end (i.e. the line is a diameter)
 - d. make any adjustments you need to in order to get the line in exactly the right position
 - e. finally click the Measure button
 - f. read off the angular diameter of Jupiter in arcminutes and also its actual diameter in km
4. The procedure you have just used is the same for all four shapes (solid line, dotted line, rectangle/square and ellipse/circle). Use the ellipse/circle shape to find the diameter of Jupiter.

Hint: If you hold down the shift key while resizing the ellipse/circle shape it will stay as a circle.
5. Compare the sizes of the Earth, Saturn and the Sun using the Show comparison object button.

Hint: You can drag a comparison object across the image.
6. How wide are the belts and zones on Jupiter compared with the Earth?



The Moon

total image width 46.0 arcmin

distance 352 000 km

7. Use the circle shape to measure the diameter of the Moon. Is the image exactly circular?
8. Measure some of the craters and other features on the Moon.

Hint: You can use the Zoom in button to get a magnified view, and the Reset image position button to see the whole Moon again.



Saturn and its rings

image width 2.3 arcmin

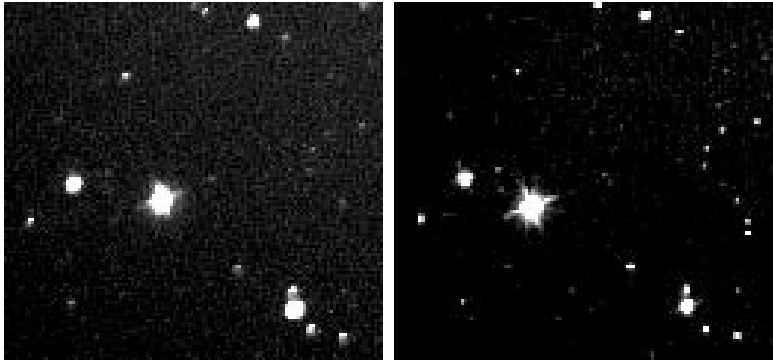
distance 8.45 AU

9. Measure the diameter of the outermost visible ring of Saturn (the A ring) by using an ellipse.

Hint: You will need to drag the handles on the ellipse to give approximately the right shape, and then rotate it. To rotate it, make sure that the shape is still selected, click the Rotate button and then drag the handles.

When you are satisfied with the fit, click the Measure button. The ring diameter will be given by the long axis of the ellipse. The angle of tilt will be given by the 'viewing angle' of the ellipse (i.e. a viewing angle of 90 degrees is edge on and zero degrees would be face on).

10. Measure the diameter of the planet. Before you do so, look carefully at where the planet blocks the light from the rings at the bottom. This will help you to know more accurately where the edge of the planet is (it being quite faint and hard to see otherwise).
11. Compare the size of the Earth. Use two straight lines to estimate how many times Saturn is bigger than the Earth.



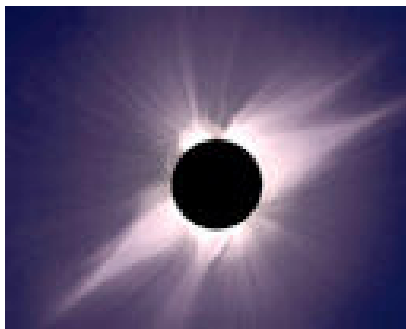
**Two images containing
the asteroid Vesta**

image width 4.6 arcmin

distance unknown

1. Blink the two images and identify the asteroid. Instructions for doing this are as follows:
 - a. Use the Get new image button to import the first image and the Get second image button to import the second one.
 - b. Click the Blink button repeatedly and look for the object in the image which moves.

Note: *The object you have identified is the asteroid Vesta. In general, however, you need at least three images to make a positive identification of an asteroid.*



**the solar eclipse of 11th
July 1991**

image width 2.3 degrees

distances: Sun 152 000 000
km,

Moon 356 000 km

13. It is an amazing fact that the Sun and Moon appear to be almost exactly the same size in the sky (about half a degree), so that when the Moon exactly passes in front of the Sun the Sun's light is just blocked out and no more.

Using the distances given find:

- a. the diameter of the Sun in km,
- b. the diameter of the Moon in km



**Comet Gehrels on
Nov 8th 2004**

image width 4.6 arcmin

distance 153 000 000 km

14. How large is the coma of the comet?

**spiral galaxy M99**

image width
4.6 arcmin

distance
44.7 Mly

**lenticular galaxy
M60 (top left)****and spiral galaxy
NGC4647 (bottom
right)**

image width
4.6 arcmin

distance
44.7 Mly

**edge-on spiral galaxy
NGC 4565**

image width
4.6 arcmin

distance
86.4 Mly

**Sombrero Galaxy
(M104)**

image width
4.6 arcmin

distance
43.0 Mly

15. A typical spiral galaxy like M99 contains one hundred thousand million stars like our own Sun, some smaller, some larger and some similar in size to our Sun. Given that number of stars, you would expect galaxies to be pretty big!

- a. Measure the diameter of M99 in thousands of light years (kly).

[How big is a light year? $1 \text{ kly} = 9.46 \times 10^{12} \text{ km}$ - just under ten million million km!]

- b. Measure the diameter of the bright central bulge. Roughly how much smaller is the bulge than the whole visible galaxy in the case of M99?

16. Compare the sizes of the following objects:

- our own Milky Way galaxy,
- the nearest star distance from us,
- the Sun.

Are these three results what you expected? Why is this?

17. The three other images above show four more galaxies. Measure them and find out which are larger than the Milky Way Galaxy and which smaller.

Clusters of galaxies



Part of the Coma Cluster of galaxies

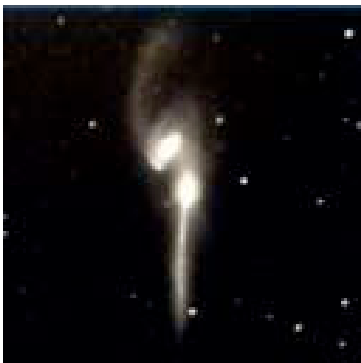
image width 4.6 arcmin

distance 300 Mly

18. Here we can see part of the Coma Cluster of Galaxies, with the large elliptical galaxy NGC 4889 at the centre.

- What diameter is this large central galaxy?
- How far apart would the individual galaxies be on average, if they were all in a single plane perpendicular to the line of sight? (Of course this will not be true, since individual galaxies will be arranged in a three dimensional cluster.)

Interacting galaxies



**Two colliding galaxies:
The 'Mice'**

image width 4.6 arcmin

distance 300 Mly

19. This image shows two galaxies in the Coma Cluster (nicknamed the 'Mice') that have come so close that the gravitational field of each is distorting the other and pulling stars off it. Although not visible in this image, the distortion of each galaxy will also be compressing regions of it and causing new star formation to be triggered.

- how large are the two galaxies?
- assuming that they are lying in a plane perpendicular to us, how far apart are they?
- with the assumption, how long are the tails of stars?

Globular clusters



**globular cluster NGC2419
(the Intergalactic Wanderer)**

image width 4.6 arcmin

distance 275 kly

20. The Sombrero Galaxy has a very large halo - the bright region on either side of the disc that gives it its sombrero appearance. The halo contains stars and compact 'balls' of stars called globular clusters. A globular cluster is a cloud of a million or so stars, all orbiting around a common centre of mass, rather like a swarm of bees. You can see quite a few globular clusters in the 'halo' surrounding the Sombrero Galaxy in the image above. Many of them just look like single stars, but with greater magnification you would see that they were in fact clusters of stars.

Compare the size of the globular cluster M13, which orbits the Milky Way. (You will have to look carefully to see the tiny red circle.) How big would you say a globular cluster was in comparison with a galaxy?

21. How big is the Intergalactic Wanderer globular cluster shown in the image above? (It has this strange name because it orbits the Milky Way Galaxy very far out.)

Life Cycles of Stars



spiral galaxy M61

image width 4.6 arcmin

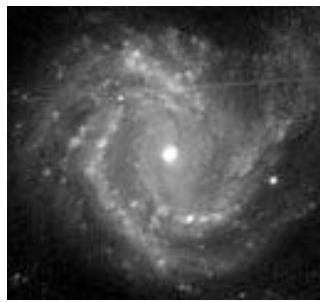
distance 42.7 Mly

22. This image shows the beautiful spiral galaxy M61 (sometimes called the 'Swelling Spiral Galaxy').

Identify the following different features and make estimates of their sizes in kly:

- the central bulge containing older, yellower stars,
- the blue spiral arms containing most of the young, hot, bright, blue stars,
- pinkish emission nebulae ('stellar nurseries') where hydrogen gas is glowing pink due to ultra-violet radiation from bright new stars.

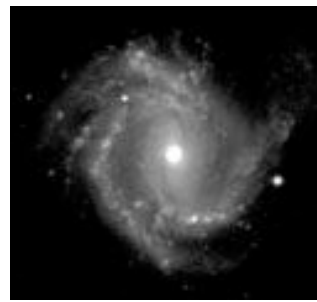
Hint: You can use the Zoom in button to get a magnified view of these regions, and the Reset image position button to see the whole galaxy again.



**spiral galaxy M61
with blue filter**

image width
4.6 arcmin

distance
42.7 Mly



**spiral galaxy M61
with red filter**

image width
4.6 arcmin

distance
42.7 Mly

23. These two images show M61 as seen using blue and red filters.

- Use the Get new image button to import the first image and the Get second image button to import the second one.
- Blink the red and blue images and explain the differences you can see, based on your observations in the previous question.



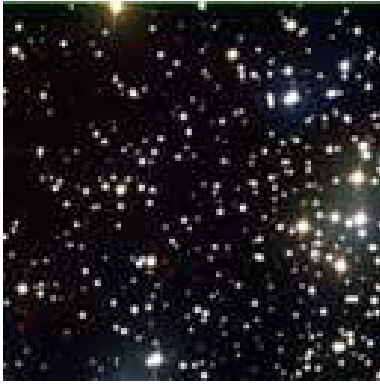
**'Pillars of Creation' in Eagle
Nebula (M16)**

image width 4.6 arcmin

distance 7.0 kly

24. The image shows part of the Eagle Nebula, which is a pinkish star forming region like those you have just been looking at in galaxy M61. New stars and solar systems are being formed out of the fingers of dust and cool hydrogen gas that you can see. The bright glow at the ends of the fingers is due to bright, hot, newly formed stars just out of sight inside the ends of the fingers.

Following a famous Hubble Space Telescope image of them, these fingers of star forming material were dubbed the 'Pillars of Creation'. How long are they?



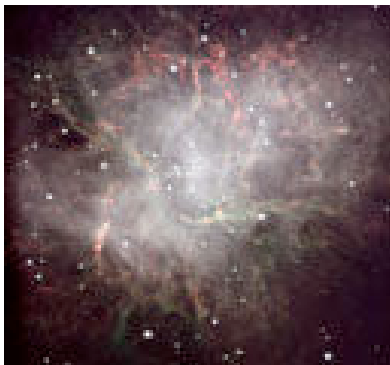
open cluster NGC2506

image width 4.6 arcmin

distance 9.4 kly

25. After a group of stars has formed from a concentration of dust and gas, radiation and supernova explosions blow away the remaining material to leave a loose cluster of stars all about the same age called an 'open cluster'.

Part of one of these is shown in the image. Allowing for the fact that part of the cluster is beyond the edge of the image, what sort of size do you think this open cluster might be?



Crab Nebula (M1)

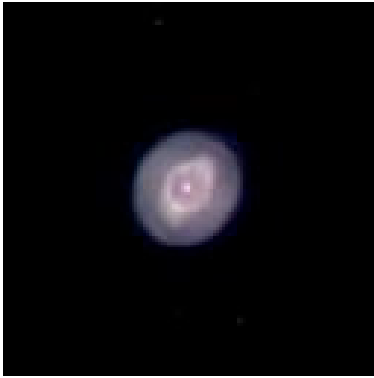
image width 4.6 arcmin

distance 6.3 kly

26. The Crab Nebula is the remains of a massive star which exploded as a supernova when it ran out of 'fuel'. It was seen by the Chinese in 1054 as a bright 'new' star that remained visible for a week or two.

- a. How big is the Crab Nebula?
- b. (A harder question for those that want to try it!) Given that the gas and dust in this image all started in more or less one place about 950 years previously, how fast must it have been travelling outwards after the explosion?

Hint: You will need to know that one light year (ly) = 9.46×10^9 km.



**Ghost of Jupiter
planetary nebula**

image width 4.6 arcmin

distance 1.4 kly

27. Stars about the size of our Sun do not explode when they run out of fuel. Instead they lose their outer layers into space, while the core becomes a white dwarf star. This gives out copious amounts of ultra-violet radiation that causes the surrounding shells of gas to glow with different colours depending on which elements are most abundant.

The result is a beautiful object called a 'planetary nebula' (but it has nothing to do with planets!).

- a. Measure the Ghost of Jupiter planetary nebula.
- b. Can you fit ellipses around the shells of glowing gas seen in the image? If so, how big would these shells be, very approximately?

Measuring spiral arms in galaxies



**spiral galaxy
NGC1232**

image width
4.6 arcmin

distance
85.1 Mly



**spiral galaxy
NGC3938**

image width
4.6 arcmin

distance
71.6 Mly

28. The images show two face-on spiral galaxies. Try fitting log spiral arcs to the spiral arms to see how close the spiral arms are to being logarithmic spirals. You can fit up to five separate spiral arcs. Questions that you can answer for each spiral arm are:

- a. What is the pitch angle?
- b. How long is the spiral arm, i.e. what angle does it subtend at the centre of the galaxy in degrees?
- c. How close is the spiral arm to being a logarithmic spiral? Is it close for its whole length, for part of its length, or for none of its length?

Background: *Pitch angle measures how tightly wound a spirals is. If you drew a series of circles centred on the centre of the galaxy, these would all cut a logarithmic spiral arc at the same angle. This angle is the pitch angle.*

In the Hubble Classification of Galaxies, an Sa galaxy would have tightly wound spiral arms with a pitch angle of about 10 degrees. An Sc galaxy would have spiral arms with pitch angles of 20 degrees, typically, and an Sb galaxy would fall somewhere in between. (There are other aspects of the classification.)

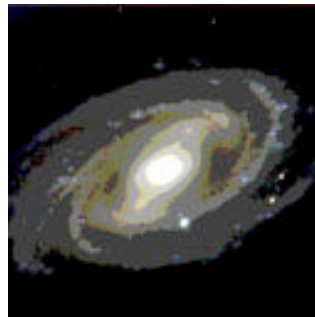
Hint: You do not have to fit the spiral arcs to the whole length of each spiral arms. Try fitting the arc to the part of the spiral arm where it fits best in order to measure the pitch angle. Then if you want to measure the total angle subtended by the spiral arm at the centre, you can re-fit it to the whole length, even though it does not then fit very well.



Spiral galaxy M109

image width 4.6
arcmin

distance 75.3 Mly



**posterised version
of the same image**

29. The left hand image shows the tilted spiral galaxy, M109. The right hand image shows the same image 'posterised' using an image processing package. It has the image altered in such a way that the surface brightness goes up in steps, rather like shading on a contour map. This makes it easier to see the overall shape of the galaxy.

- Open both images (using the Viewer's Get second image button to bring in a second image).
- You can now use the Blink button to switch between the two images.
- Fit an ellipse to the posterised image, click the Measure button, and read off the viewing angle.
- The Viewer now knows what angle of tilt to assume. Try fitting spiral arms as you did previously for the face on galaxies.

Hint: You will probably find when fitting the first spiral arm, that you will get a better fit if you go back to step (c) and increase the angle of tilt somewhat. The remaining arms will probably then fit okay. The reason that step (c) underestimates the true angle of tilt is that the galaxy has a finite thickness, so that when it is tilted it looks rounder than a flat circle would when tilted by the same amount.