

The above image of the globular cluster NGC-6266 was taken by the Chandra Satellite and shows only the stars in the cluster that are producing X-rays. Each spot is a binary star in which one of the members is a dense neutron star which is consuming gas from its normal star companion to produce x-rays. The field is 66.8 arcseconds wide.

Problem 1 - Measure the width of the image in millimeters, and calculate the image scale in arcseconds per millimeter.

Problem 2 - About what is the smallest separation between stars in the picture in: A) millimeters? B) arcseconds?

Problem 3 - What is the diameter of the densest part of the x-ray cluster in: A) millimeters? B) arcseconds?

Problem 4 - The distance to the cluster is 22,500 light years. What is: A) the smallest star separation and B) the diameter of the x-ray cluster?

Astronomers measure the sizes of objects in the sky in terms of their angular size. For instance, the moon appears to be about 1/2 degree in diameter. The planet Venus, when it is closest to Earth, appears to be even smaller - only about 1/60 of a degree. This small angle is called the arc-minute. There are 60 arcminutes in one degree.

What we really would like to know is, physically, how big something is in kilometers, instead of how big it appears to be in angular measure. To get this information, all we need to know is how far away the object is from us.

The moon is 324,000 kilometers away, and Venus is about 40 million kilometers away from Earth at its closest distance. The following formula lets us convert angles into kilometers:

$$\text{Size} = \text{Distance} \times \text{Diameter in degrees} / 57.3 \text{ degrees}$$

With the data for the Moon and Venus we get

$$\begin{aligned} \text{Moon} &= 324,000 \text{ km} \times (0.5) / 57.296 = 2,800 \text{ km} \\ \text{Venus} &= 40 \text{ million km} \times (1/60) / 57.296 = 11,600 \text{ km.} \end{aligned}$$

For more distant objects, we use a slightly different formula. Instead of an angular size measured in degrees, we use angles measured in arcseconds. There are 60 arcseconds in one arc minute, so one arcsecond is $1/60 \times 1/60 = 1/3600$ degree, so we get:

$$\text{Diameter} = \text{distance} \times \text{Size} / (3600 \times 57.296)$$

which becomes

$$\text{Diameter} = \text{distance} \times \text{Size} / (206,265)$$

The binary star system P Eridani is 26.6 light years from Earth. Its two stars have a maximum separation of 11.8 arcseconds, which will occur in the year 2048. How far apart will they be if 1 light year (LY) equals 6 trillion kilometers?

$$\text{Separation} = 26.6 \times 11.8 / 206265 = 0.0015 \text{ LY.}$$

This equals $0.0015 \text{ LY} \times 6 \text{ trillion km/LY} = 9 \text{ billion kilometers}$, or twice the distance to Pluto!

For more on angular size, and an interactive calculator, visit the NASA, Chandra website:
http://chandra.harvard.edu/photo/scale_distance.html

Answer Key:

Problem 1 - Measure the width of the image in millimeters, and calculate the image scale in arcseconds per millimeter.

Answer: 58 millimeters corresponds to 66.8 arcseconds, so the scale is $66.8/58 = 1.2$ arcseconds / millimeter.

Problem 2 - About what is the smallest separation between stars in the picture in A) millimeters? B) arcseconds?

Answer: Students answers may vary depending on which stars they choose: A) **About 2 mm** B) $2 \text{ mm} \times 1.2 \text{ arcsec/mm} = 2.4$ arcseconds.

Problem 3 - What is the diameter of the densest part of the x-ray cluster in A) millimeters? B) arcseconds?

Answer: Students answers may vary: A) **10 millimeters**; B) $10 \text{ mm} \times 1.2 \text{ arcsec/mm} = 12$ arcseconds.

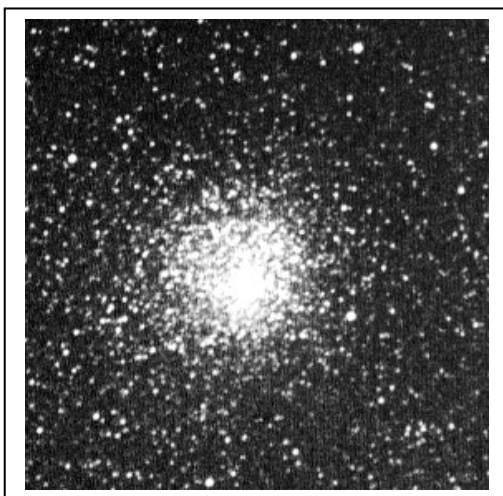
Problem 4 - The distance to the cluster is 22,500 light years. What is A) the smallest star separation and B) the diameter of the x-ray cluster?

Answer:

A) Separation = $22,500 \text{ light years} \times (2.4 \text{ arcseconds}) / 206265 = 0.26$ light years.

B) Diameter = $22,500 \text{ light years} \times (12 \text{ arcseconds}) / 206265 = 1.3$ light years.

Students estimates will differ depending on which star pairs or diameters they measure.



NGC-6266 is also called Messier-62 and is located in the constellation Ophiuchus. Here is a picture of the entire cluster. The diameter of the star cluster in this image is 15 arcminutes. At a distance of 22,500 light years, its diameter is

$$22,500 \text{ LY} \times (15/60)/57.296 = 98 \text{ light years!}$$

The Chandra image is only a very small part of the center of this cluster!