JS9 Science Olympiad Problems and Solutions
MIT, 2020

A Gravitational Lens

41. Gravitational lensing.

Use JS9 to analyze an observation of an Einstein ring around a massive lensing object.

    (a) Use JS9 to determine the diameter of the ring in pixels.

    (b) Convert the previous answer to arcseconds. Use the "counts in regions" tool.

    (c) You determine that the distance to the central object is 9.2 megaparsecs. What is the diameter of the ring, in parsecs? Hint: convert the answer from part b) to radians and use the small angle approximation. (Remember: 3600 arcseconds in a degree.) Ignore cosmological effects.

    (d) How are the answers to parts b) and c) related to the mass of the lensing object?

    (e) Which object appears brighter in the sky, the ring or the lensing object? Use two concentric circular regions and the "counts in regions" tool.

Solutions

When this problem was given, the observation was pre-loaded into JS9. Since then, we have developed a very slick drag-and-drop procedure by which you can load *any* FITS file into JS9. This is the procedure we will use here, and you can expect to see it often in future NSO events.

1. If you haven't already, open: https://chandra.harvard.edu/js9/index.html

2. To retrieve the observation, go to: http://www.physics.rutgers.edu/~matilsky/JS9/Data/

3. **Click, hold, and drag** the "lens.fits" file onto the tab that you opened for step 1. When that page opens, drag the cursor onto the JS9 window. Release, and voila! The observation appears in the JS9 window.

Now, we can answer the questions….

a) Go to: **Regions → circle** and position and resize the region so it matches the lens image. (It might be helpful to review the JS9 "Guide" that is available on the JS9 page, if you haven't before.). It also might be helpful to make the image larger. Go to: **Zoom → 4** and then use **View → Panner** to re-center the image. There are many ways to obtain the pixel diameter, but the easiest is to go to: **Analysis → Region Stats** and you can read off the "box width" directly. (If the statistics do not appear immediately, just click inside the region, move it slightly and then reposition it. Then the region stats will appear.) Can you think of another method to obtain the value? Your answer should be close to "65" pixels.

b) Go to: **Analysis → Counts in Regions** and you can read of the *radius* of the region in arc-seconds. That should be about 1.3". So the answer is about 2.6"

c) diameter = 9.2 Mpc x 2.6/206265 = 116 pc

d) The mass of the lensing object determines how much light rays "bend" around the object. So there is a relationship between the ring radius (i.e. impact parameter), the mass, and the angular deflection.

e) Setting up two circular regions as suggested should yield a display similar to:
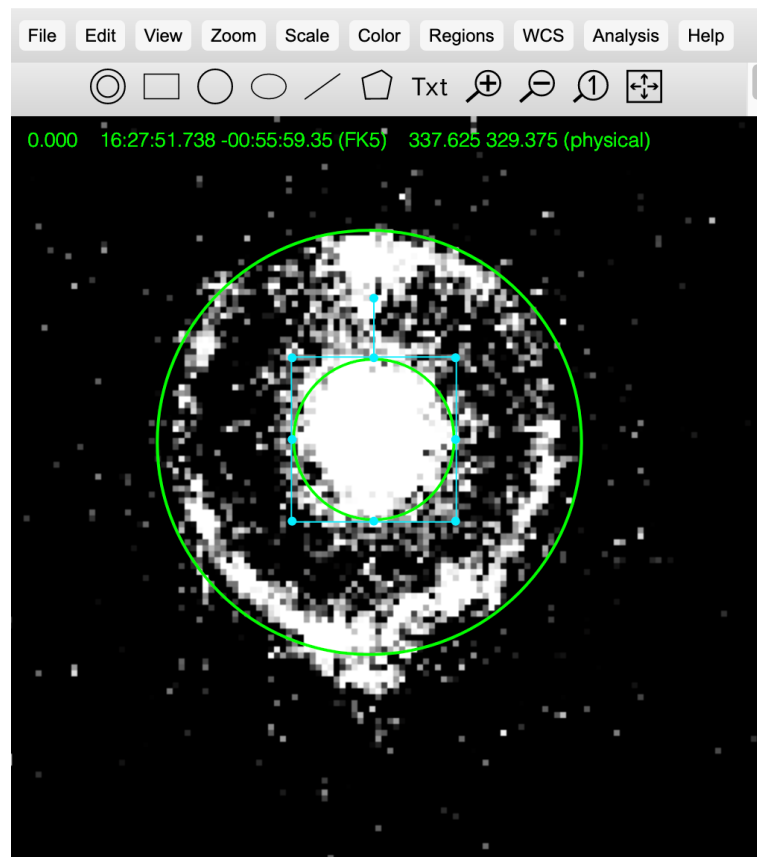
Now, go to **Regions → select all**, and then **Analysis → Counts in Regions**

Which will yield results similar to:

The lensing object is brighter than the ring. You can see this by looking at the total counts in each region. If you do a careful narrow selection of a region encompassing only the ring, you find that the surface brightness of the ring is also less than that of the lensing object.