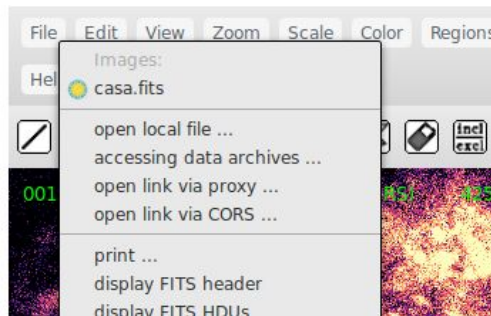


Navigating JS9

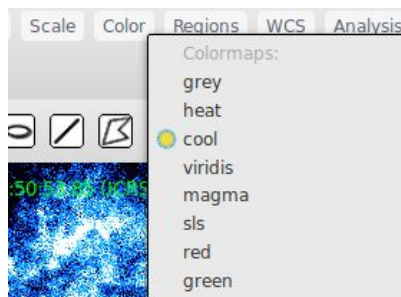
What is JS9? JS9 is an online tool for doing analysis of astronomical data and images. You load an image or data file into the tool; then, you can visualize the image in different ways, perform analysis on different regions of the image, etc.

How does it relate to Science Olympiad? This year, tournaments are encouraged to write questions based off of JS9 image analysis. Competitors are expected to be able to look at *screenshots* of JS9 images/analyses and draw conclusions about the object in the image. A good way to prepare for this is to practice using JS9 to see what it can do and what it can tell you!

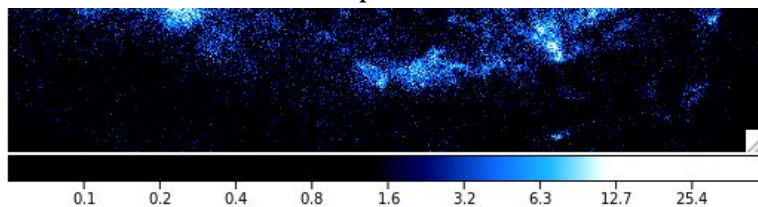
1. Go to <https://js9.si.edu/>.
2. Click *File* in the menu bar. You should see that the default selected image is **casa.fits**. The .fits file extension represents astronomical image data; casa refers to the Cassiopeia A supernova remnant. Indeed, what you see in the window is an image of Cas A.



3. Click *Color* in the menu bar. By default, the selected colormap is chosen randomly. Change the selected colormap to **cool**. You should see the color scheme change to a gradient from black to blue to white.



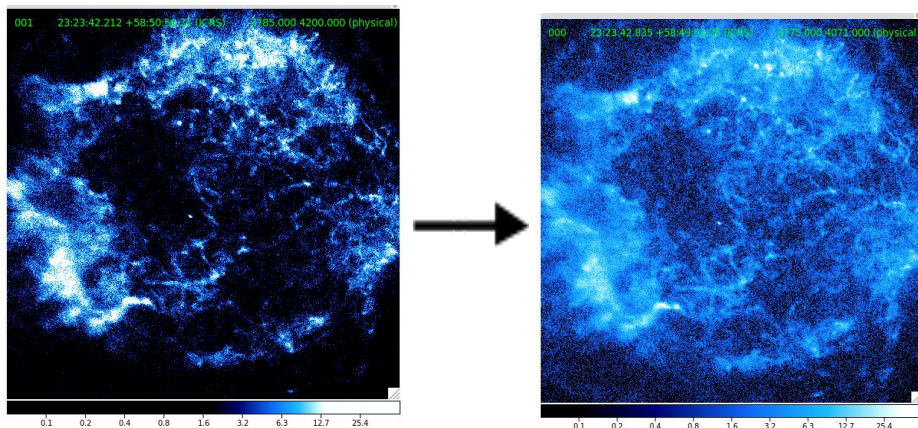
You can see the gradient in a bar below the image. It may not look *exactly* like this, depending on the random initial colormap.



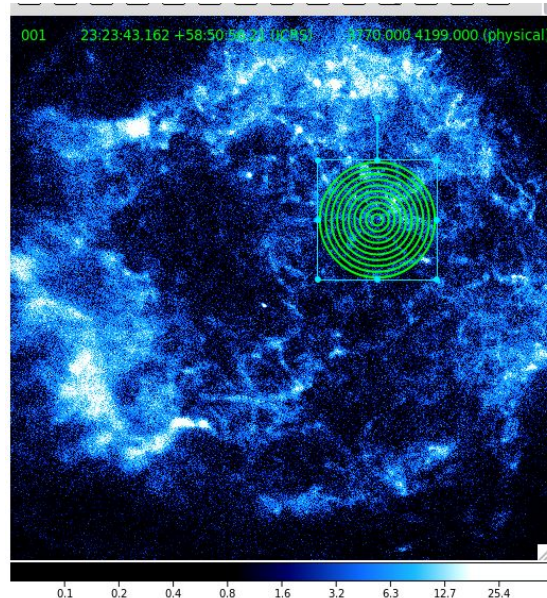
- a. What do the numbers on the gradient bar mean? In a **.fits** image, each pixel is assigned a value representing the brightness of that pixel. As you move your mouse over the picture, notice the green number in the top left corner -- that is the brightness of the pixel you're currently hovering over. The numbers below the

gradient bar correspond to these brightness values -- the colormap is a mapping between the brightness values and a color to display. In this colormap, black represents dark pixels, and white represents bright pixels.

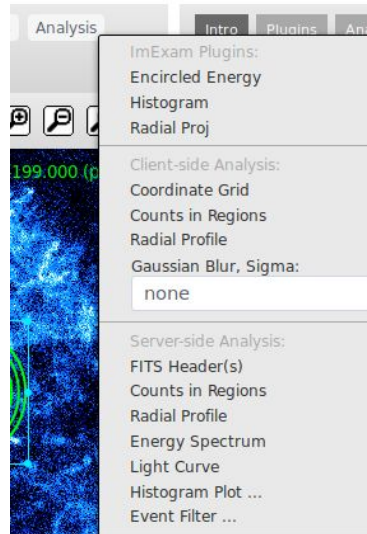
- b. Remember that the brightness of a pixel corresponds to how much light the telescope received from that point in space (restricted to whatever wavelengths the telescope was measuring in -- in this case, X-rays).
 - c. Notice that the number scale is not linear at all. In fact, by default, it's logarithmic. You can change this by clicking *Scale* in the menu bar and changing the scaling algorithm. Personally I think the logarithmic scale is the most versatile and I don't change it.
4. You can fine tune the colormap by clicking on the image and dragging the mouse around. You should see the colormap bar on the bottom (and the image itself) respond accordingly. Vertical motion of the mouse changes the "standard deviation" of the gradient, whereas horizontal motion changes the position of the colors with respect to the numerical scale.



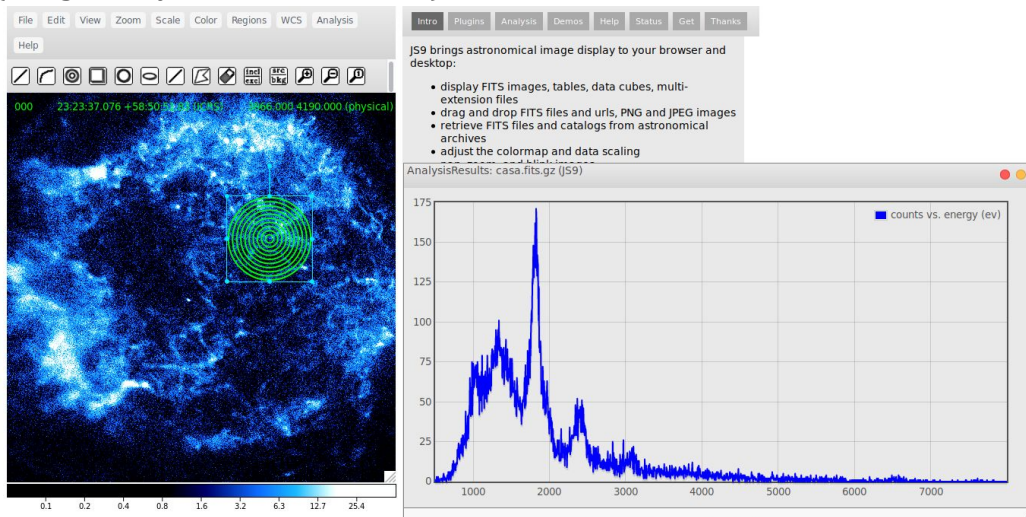
5. In the icon bar below the menu bar, click the annulus icon (looks like a target, 3rd icon from the left). A green annulus should show up in the middle. This is known as a region (the annulus is one type of region; you can have a circle, square, polygon, etc instead). You can perform data analysis on regions. You can also move/stretch/rotate the regions on the image by clicking on the region and modifying the shape and location.



- a. Once you've adjusted the region and placed it where you want it, click on *Analysis* in the menu bar. There are 3 types of analysis: Plugins, Client-Side, and Server-Side. The difference between them is not very important, except to note the following: If you run a plugin and then change the region (move/stretch/rotate), the plugin will automatically update. However, client-side and server-side analysis DO NOT update automatically; you have to rerun the analysis.



- b. Of particular importance are the energy spectrum and light curve analyses. Play around with these and see if you can find anything interesting. Notice that the energy spectrum is given in units of electron-Volts (eV). This unit is common in particle physics. You can convert these units to the familiar wavelength units of light (Google it if you're not sure how).



Those are the basics for JS9! Play around with it and see what other cool things you can do.

JS9 Sample Question Section

Image 1

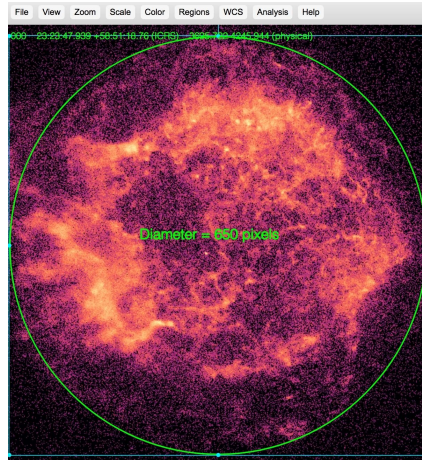


Image 2

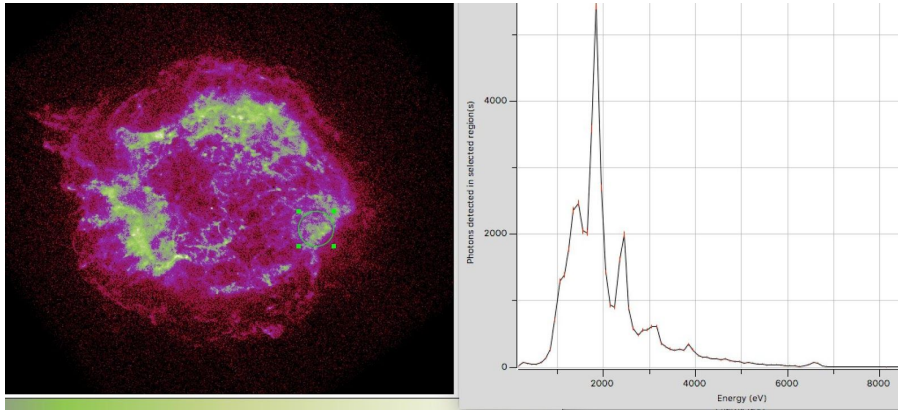


Image 3

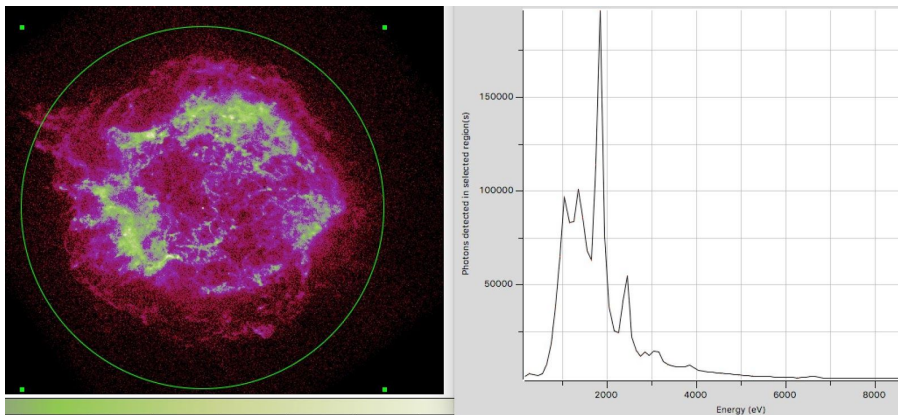
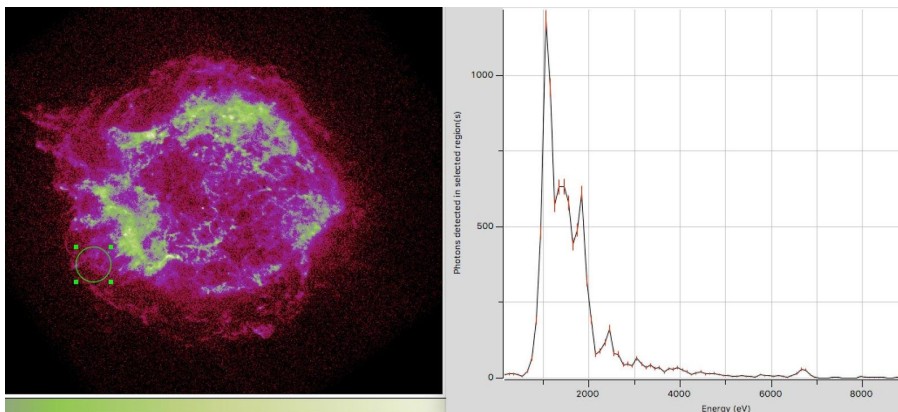


Image 4



1. Cas A is a Type II supernova remnant, which happens to be the strongest extra-solar radio wavelength source in the sky (at high frequencies). An X-ray observation from the Chandra satellite is shown in Image 1 using JS9. We will set out to explore this fascinating object in depth.
 - a. First, we want to find out what the actual physical diameter (in km or parsecs) of this object is. To allow us to calculate this, what two fundamental measurements/determinations do you need to make?
 - b. The Chandra satellite has an image resolution of $0''.5$ per pixel. How can you use that number to determine one of the two parameters needed in part a)?
 - c. The second parameter is trickier to get, but fortunately, some interesting data about Cas A has been collected over the years that document the remnant's expansion. Fast moving knots of gas have been observed over decades to be moving at about 5000 km/sec. What phenomenon allows us to determine this velocity?
 - d. If, in 10 years, a knot has been observed to move $3''$ across our line of sight, use your answer to part c), and estimate the second fundamental quantity necessary for our size calculation.
 - e. Now, using the pixel diameter shown on the JS9 image 1, estimate how big the remnant is at this time in its evolution. Display your answer in parsecs.
 - f. Suppose this same knot is now $100''$ from the center of the remnant. Approximately when did the supernova explode? What approximation (if any) did you use to answer this?
2. Let us now turn to an analysis of the X-ray energy spectrum emitted from this object. Image 2 shows the total energy output from the encircled region, out to an energy of 9000 eV (9 keV).
 - a. This is the same observation as we explored in the previous question. Why does this image show such different colors?
 - b. What do the various peaks in this plot tell us?
 - c. Why does the energy emitted almost disappear past 7 keV?
 - d. Now look at the two energy spectra shown in Images 3 and 4. These correspond to X-ray radiation associated with the small encircled regions displayed. What do you notice immediately in these spectra?
 - e. What does this tell you about the supernova explosion that produced this remnant?

Answer KEY: Section C (2 points each, 22 total)

1. Answers

- a. Angular size and distance
- b. Multiply the number of pixels subtended by the object by resolution (0.5" per pixel) to get angular diameter.
- c. The Doppler effect.
- d. 2.5 - 4.5 kilo-parsecs
- e. 4.6 - 6.6 parsecs
- f. 266 - 400 years, Assuming: Assuming a constant velocity of expansion

2. Answers

- a. X-ray images are always displayed in "false-color," since the eye is not sensitive to X-rays. You can choose any color-map you wish to display the data.
- b. The peaks correspond to emission from different atomic species.
- c. The remnant is not hot enough to produce much radiation beyond 7 keV.
- d. The spectra are quite different, with one displaying enhanced emission at about 1 keV, corresponding to the element iron.
- e. The explosion was not uniform (which is usually what we assume in our models). Our knowledge of the exact nature of the explosions is really quite primitive.