JS9 Science Olympiad Problems and Solutions
On-line, 2021

Galex, Spitzer and Chandra observations

Images B1, B2, and B3 below are three observations displayed in JS9 showing a pair of galaxies in collision. They are from the Chandra, Galex, and Spitzer satellite observatories. Please use these images to answer the following questions.
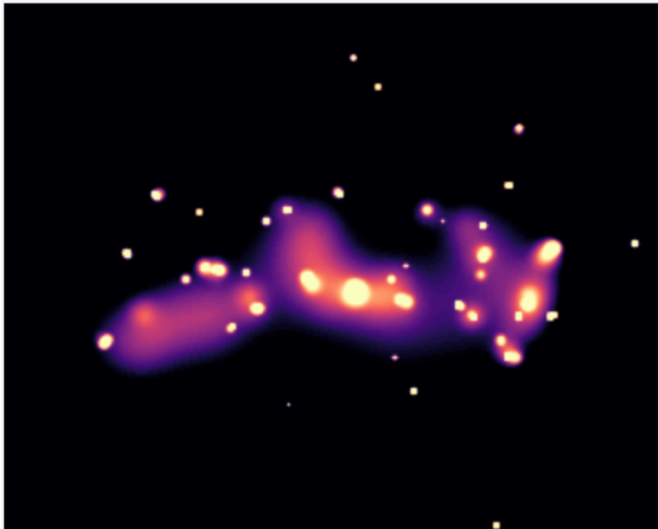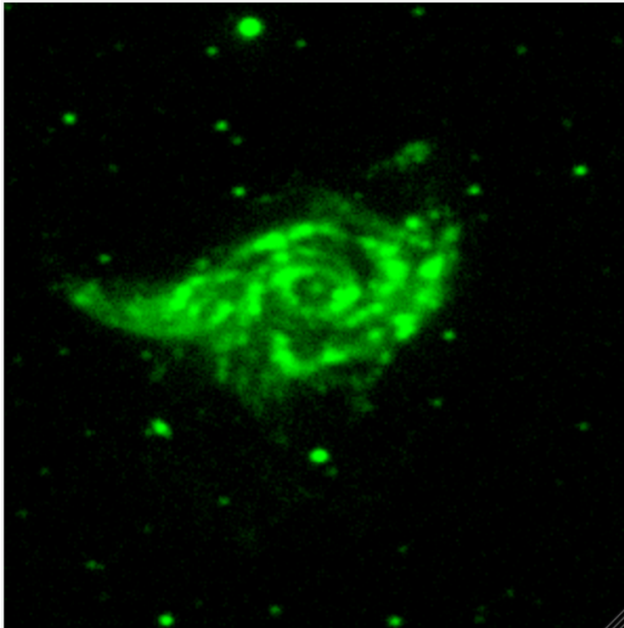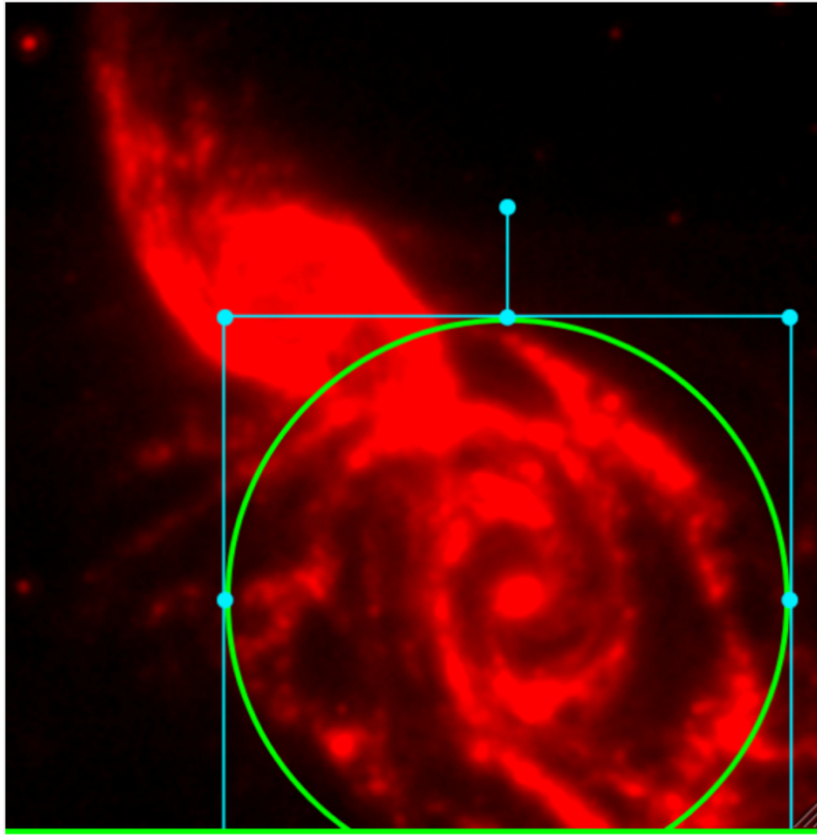
Image B1:

Image B2:

Image B3:

60) In your haste, you have downloaded FITS data from these three observations, but have forgotten which images goes to which satellite! What file can you examine in JS9 that will quickly tell you which is which?

Ans: The FITS header record contains these data. In JS9, go to: **File → display → FITS header.**

61) Whew! That was a close call! But now you know that B1 is from Chandra, B2 is from Galex, and B3 is from Spitzer. Based on image appearance alone, which observation would you examine first if you were looking for periodic time variability? Why?

Ans: The X-ray Chandra observation. Periodic variability requires compact sources, which are most easily seen in the x-ray regime.

62) Tidal stripping is a common mechanism at work when galaxies collide. Which image should show this phenomenon to the fullest extent possible? Why?

Ans: The Spitzer IR observation. Interacting ("starburst") galaxies emit up to 98% in the IR, since the gas and dust is predominantly cool.

63) Using spectra from the ordinary stars in these galaxies objects, we measure a radial velocity of about 2700 km/sec. Using a Hubble constant $H_0 = 70$ km/sec/Mpc, what is the approximate distance to these galaxies in Mpc?

Ans: $d = v/H_0 = 2700/70$ Mpc = 39 Mpc.

64) What is another type of distance indicator that can be utilized to measure their distances?

Ans: Type Ia Supernovae

65) What common type of astronomical distance indicating objects will *not* work for these galaxies? Why?

 Ans: Cepheid variable stars. They are too faint to be seen at these distances.

66) Image B3 has a region set down that encompasses much of the larger galaxy. The region parameters are: FK5; circle(06:16:22.093,-21:22:24.486,60.940135") Using this plus your answer to 63) above, estimate the physical extent of this galaxy in kpc.

Ans: The last number in the set of region parameters is the angular *radius* of the green region. Thus, the angular extent of the galaxy is about 122". So the size of the galaxy is:
122"/206,265"/radian x 39 Mpc = 23 kpc

Image B4, shown below, is a stunning UV observation of M31, the closest spiral galaxy to our Milky Way. Your friend is curious to compare the size of this object on the sky to the size of the full moon. So you lay down a "line" region as shown in the image that spans most of the galaxy. The region has the following attributes:

FK5; line(00:46:56.783,+40:31:45.910,00:38:18.137,+41:57:08.839)
{"size":2.159855,"units":"degrees","posang":41.2294,"posunits":"degrees"}

Image B4:

Regions: skv14689644727506.fits (JS9)

FK5; line(00:46:56.783,+40:31:45.910,00:38:18.137,+41:57:08.839)
{"size":2.159855,"units":"degrees","posang":41.2294,"posunits":"degrees"}

File

0.0944   00:38:51.963 +42:06:46.63 (FK5)   4125.000 4437.000 (physical)
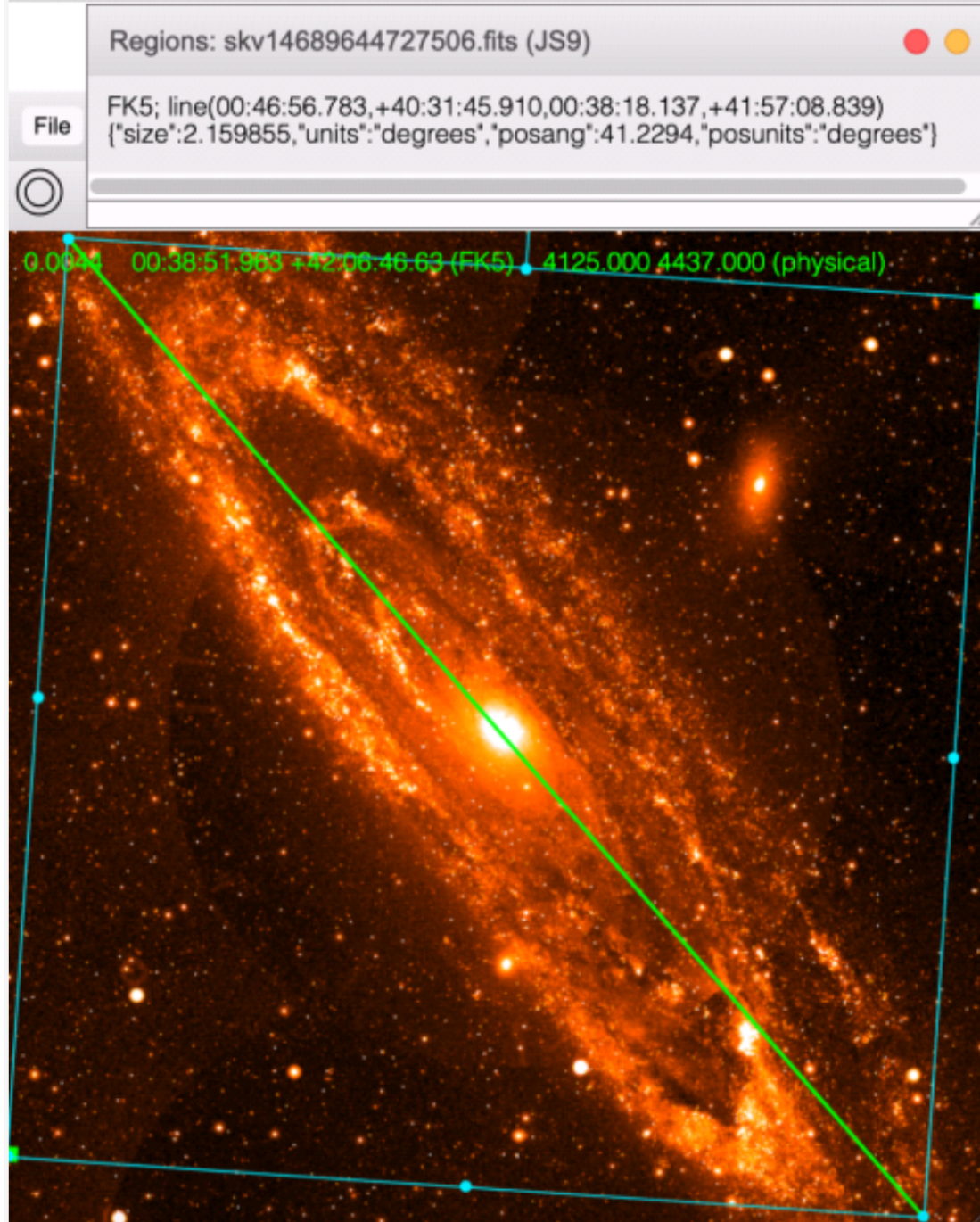
67) How many side-by-side full moons would you have to place on the sky to cover the part of the galaxy shown?

Ans: 4. The region is about 2 degrees in extent and the Moon takes up about 1⁄2 degree in sky.

68) Now, your friend wants to know how far away the galaxy is? Can you use the same techniques that you did for the set of questions above using the Hubble constant? Why or why not?

Ans: No. Nearby galaxies have significant individual ("peculiar") velocities relative to the Milky Way. So the Hubble flow is not established at the distance of M31.

69) What other distance indicator can be used to obtain an answer?

Ans: Cepheid variables, Type 1a supernovae (either one accepted)

70) Our best estimate for the distance to M31 is about 2.5×10^6 l.y. What is the actual extent in light years of the part of the galaxy that is shown in Image B4?

Ans: 2.16 deg/57.3 deg/radian x 2.5×10^6 light years $= 9.4 \times 10^4$ l.y.

71) The radial velocity of M31 is measured to be -110 km/sec. Using that value, what is the amount of time that will elapse until M31 collides with the Milky Way?

Ans: 1 ly $= 3 \times 10^5$ km/sec x 3.16×10^7 sec/yr $= 9.5 \times 10^{12}$ km. So, traveling at 110 km/sec, it would take 9.5×10^{12} x 2.5×10^6 / 110   sec $= 2.1 \times 10^{17}$ sec $= 6.6 \times 10^9$ yr.

72) Why is this number so different from the accepted time of collision of about 4.5 billion years from now?

Ans: We have neglected the effect of gravitational acceleration between the galaxies.

73) Why is just measuring the radial velocity insufficient to predict whether or not there will be a collision?

Ans: If there is a significant tangential component to the motion, the galaxies may not necessarily collide.