# JS9 Science Olympiad Problems and Solutions

Cornell, 2019

## M100 and GK Per

23. M100 resides in the Virgo cluster of galaxies. It is estimated that its distance from us is about 16 Mpc. It has a radial velocity of 1525 km/s relative to our galactic center.

    (a) What methods or techniques can be used to derive a distance to this object? List at least two, and explain qualitatively how you would use them.

    (b) Using a Hubble constant of 67.8 km/sec/Mpc, estimate the distance to M100. Does this answer surprise you? Why or why not?

    (c) What explanation do you have for your answer to part (b)?

    (d) What does this tell you about using Hubble's law to derive distances to nearby galaxies?

    (e) Image 42 shows a Palomar image of this galaxy, displayed using JS9. The selected region encompasses nearly the entire visible galaxy, so it can be used to estimate the size of M100. If the radius of the green circular region is 3.166' (as indicated on the screen shot), what is the physical size of M100 (in light years)?

    (f) How does the size of M100 compare to the size of the Milky Way?

24. We know that the end points of stellar evolution in normal galaxies are white dwarfs and neutron stars. But how can we tell them apart? X-ray light curves can provide some clues. First, let us consider the light curve (a plot of counts vs. time) for GK-Per, taken with the Chandra X-ray Observatory. Using JS9, we show the entire observation and a zoomed-in portion in images 43 and 44.

    (a) Using image 44, guess the approximate period of variability of GK-Per, in seconds. It is not obvious!

    (b) But now we can use the entire observation and make a "power spectrum"! See image 45. How does a power spectrum differ from an energy spectrum?

    (c) Convert the frequency of the maximum in the zoomed in portion of the power spectrum shown in image 46 into a period in seconds. What is the period of variability of GK Per? How close was your guess from part (a)?

(d) Show that the centripetal gravitational acceleration at the surface of this object is sufficient to hold it together if it is a white dwarf rotating with the period given in (c). Use a radius of 7000 km, for a 1 solar mass white dwarf.

# Solutions

## 23.

a) Cepheid period-luminosity relationship, the Tully-Fisher relation, SN Ia brightnesses, SN II brightnesses, novae brightness, brightest stars, Hubble's Law. The latter doesn't work, as we shall now show!

b) V= H x d → d= 1525/67.8 Mpc = 22.5 Mpc. Considerably different from 16 Mpc! A surprise?

c) Galaxies have their own peculiar velocities, which differ from the Hubble flow. Especially at close distances, this can lead to substantial errors.

d) You have to be careful! Other methods need to be given greater weight.

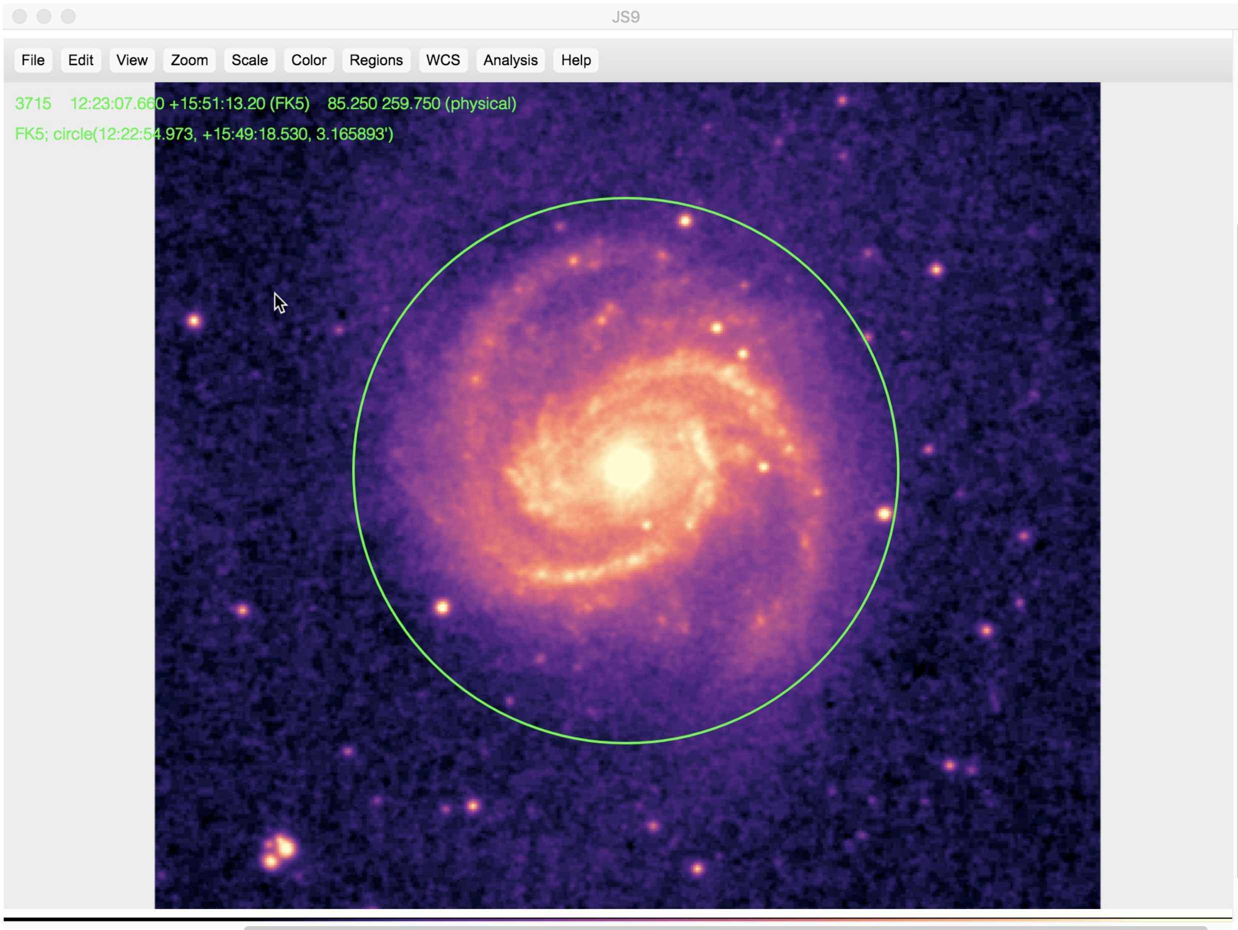


Image 42

e) Size= Distance x subtended angle =16 Mpc x (6.33 arc-min)/(3438 arc-min/radian) = 29.5 Kpc = 96,000 l.y.

f) This is about the same size as the Milky Way.

24.

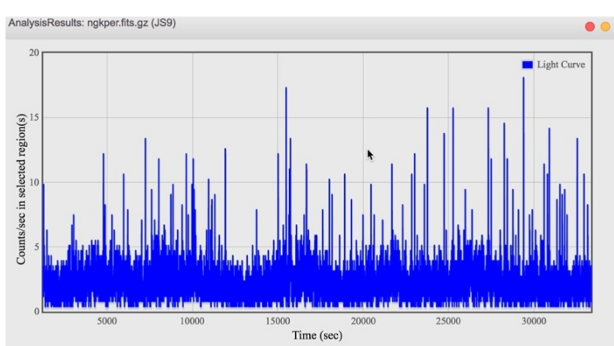

Image 43

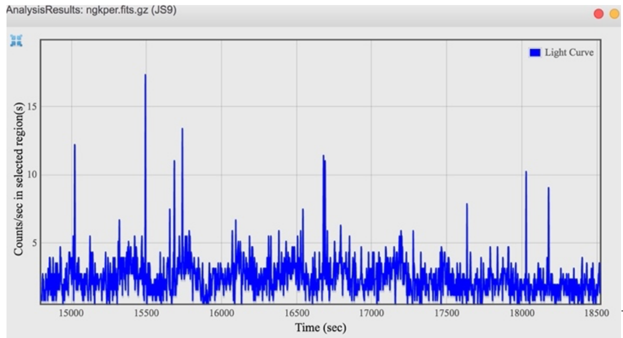

Image 44

a) 300-400 seconds. Count peaks and times, etc. Other possibilities are acceptable. It's a guess! We need something more accurate!

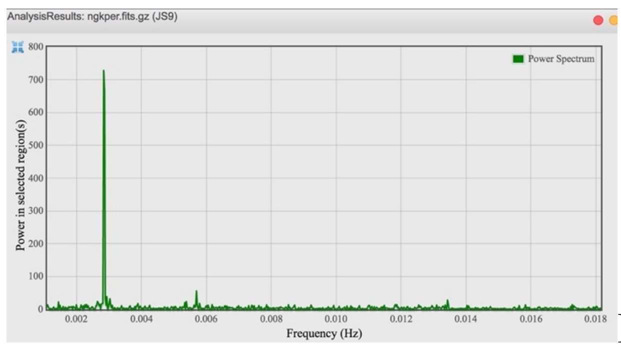

Image 45

b) An energy spectrum shows intensity vs. wavelength or frequency of the emitted light. A power spectrum fits sine waves of different frequency to a light curve to see if there is a period to the variability. It is the distribution of the energy of a waveform among its different frequency components.

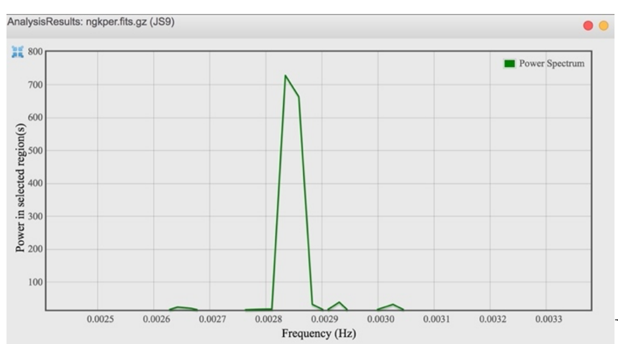

Image 46

c) P = 1/f = 1/.00284 = 352 seconds

d) GM/r**2 is greater than v**2/r, where v=2πr/P. (Do the math yourself!). Therefore, stable.