**Binary Orbits**

Stars also orbit each other in binary and multiple star systems. Review the multiple star orbits at the website <http://www.atlasoftheuniverse.com/orbits.html>.

Then explore the orbital parameters (semi-major axis and eccentricity) of several nearby binary star systems, available on the website <http://www.solstation.com/orbits.htm>. Good examples are Alpha Centauri AB, Sirius AB, 61 Cygni AB, and 36 Ophiuchi AB.

What values of eccentricity are typical for binary star systems? Are circular orbits common or rare?

**Part 8: Beyond the Solar System –** Gravity dominates not only the planets of the Solar System, but all of the bodies of the Universe – stars, galaxies, even clusters of galaxies. Each small group will consider ONE of the following problems to discuss with the class. Circle the number of the problem you think about, and describe the solution below.

1. **Black hole in the center of the Milky Way** – A massive black hole can be found at the center of the Milky Way. The black hole has a mass of about 4 million times the mass of the Sun. Many young stars orbit around this massive black hole. “S2,” the star that passes closest to the black hole, has an orbital period of about 15.6 years, and a semi-major axis of about 1000 AU. What is the mass of the black hole?  *(S2 approaches to within 150 AU of the black hole!)*
2. **Binary Neutron Stars** – Two neutron stars, with masses of 1.6 and 2.4 solar masses, respectively, orbit each other in a circular orbit with a period of 3 hours (3.5 x 10-4 years!). What is the semi-major axis of the orbit? How does the semi-major axis of their orbit compare to the diameter of the Sun (1.4 x 106 km)?
3. **Orbit of the Sun around the Galaxy** – The Sun orbits around the center of the Milky Way with an orbital speed of 220 km s-1. Assume it follows a circular orbit, and the distance from the Galactic Center is a mere 26,000 light years (2.4 x 1017 km or 1.7 x 109 AU). How many times has the Sun circled the Galaxy since the Sun formed 4.6 billion years ago? Estimate the mass of the Milky Way from the Sun’s orbit.
4. **The Impact of Andromeda and the Milky Way** - The Andromeda and Milky Way galaxies are moving toward each other at a speed of 300 km s-1. The two galaxies are currently separated by 2.54 x 106 LY (2.4 x 1019 km = 1.6 x 1011 AU). The eccentricity of the Milky Way’s orbit around Andromeda is not known. However, if the orbit were circular, and if the orbital speed were 300 km s-1, how long would one complete orbit take? Assume both galaxies have masses of 1011 solar masses. Would the two galaxies have completed one full orbit during the age of the Universe?
5. **Falling toward Virgo** - The Local Group of galaxies, including the Milky Way and the Andromeda Galaxy, are falling toward the Virgo Supercluster of Galaxies at a speed of 600 km s-1. The distance to the Virgo Supercluster is about 50 x 106 light years (about 5 x 1020 km = 3 x 1012 AU). If the Local Group is following a circular orbit around the Virgo Supercluster, how long would one orbit take? Assume the mass of the Virgo Supercluster is 1015 times the mass of the Sun.