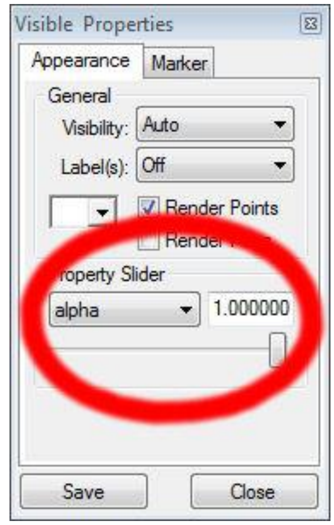
Storytelling with Uniview #02:
Structure of the Milky Way

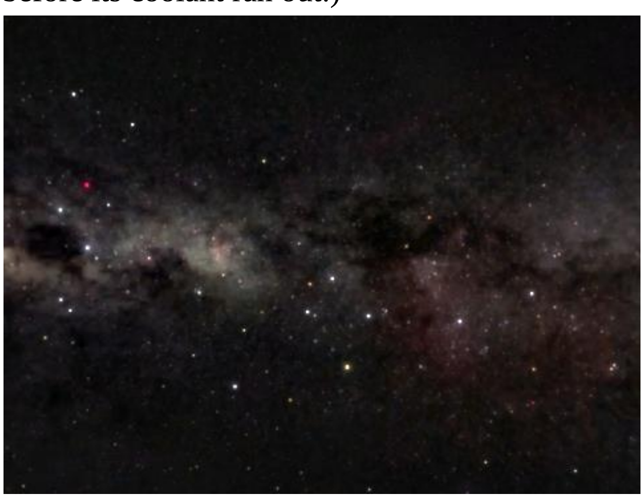
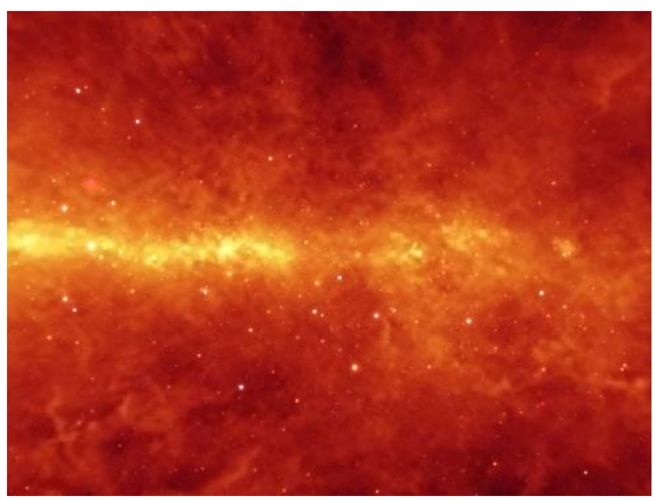
February 27, 2014

Ka Chun Yu
kcyu@dmns.org



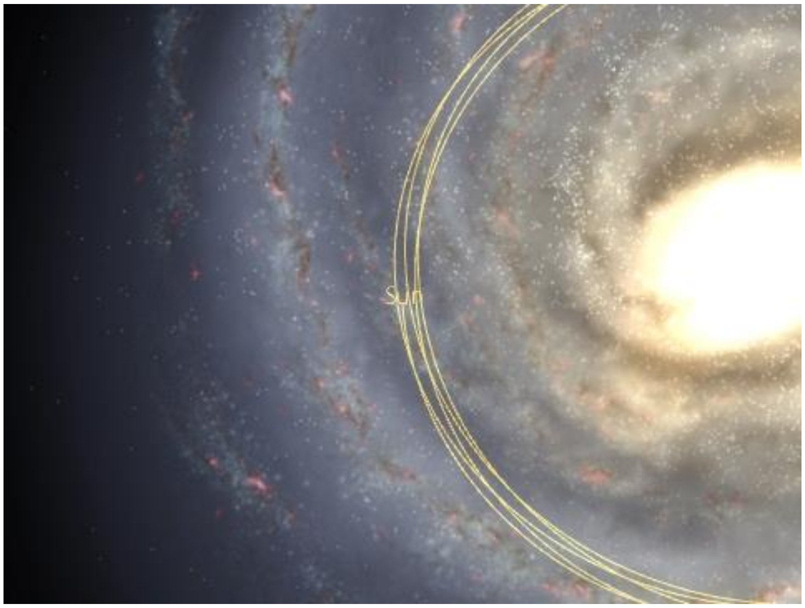
For our first column last week, we looked at distances in the Solar System. For today, let's go and understand the layout of our home galaxy, the Milky Way, which is a collection of 200 billion stars including our Sun, all bound together via their collective gravity. You don't have to fly far before showing the Milky Way: you can do so inside the Solar System by pointing out the faint band of clumpy light encircling the sky. (You can make this more visible by selecting Milky Way→All-Sky Surveys→Visible in the Object Tree, then going to the *Properties* menu, selecting the *alpha* parameter in the *Properties Slider*, and dragging it the right to make the visible sky layer brighter.) Because the Sun lies inside the disk of the Milky Way, we see our home galaxy as a band encircling around us. However because of intervening cold, dense molecular clouds (full of molecular hydrogen gas and dust), the Milky Way appears dark to us, with only patches of light poking through (consisting of the aggregated glow from many millions of stars). Hence we are not seeing an absence of stars when we look at a dark region in the band of the Milky Way, but merely the obscuration of stars by foreground clouds.

These dust and gas clouds can actually be made visible. Again in the Milky Way→All-Sky Surveys part of the Object Tree, you will see toggles for **IRAS Far Infrared** and **IRAS Composite**. These are created from data sent back from IRAS (Infrared Astronomical Satellite), launched in 1983, which was the first satellite to map the sky in the mid- and far infrared (specifically the 12, 25, 60, and 100 micron bands). These dark molecular clouds are too cold—down to 10-20 degrees Kelvin at their cores—to emit in any radiation with wavelengths shorter than the infrared. But the dust particles positively glow at infrared wavelengths, and the band of the Milky Way shines brightly. (These layers also show triangular-ish black strips of missing data, which were parts of the sky that were not mapped by IRAS before its coolant ran out.)

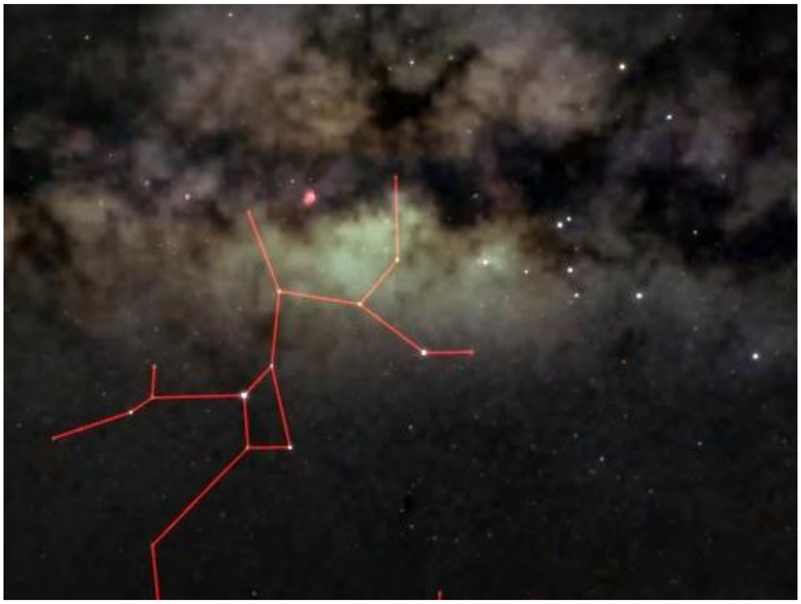



The Milky Way as it appears in visible light (*Left*) and in the far infrared (*Right*).

The dominant source of gravity in the Solar System is the Sun. Jupiter can have a perturbing effect on the orbits of asteroids, comets, and even other planets, but to first order, you can determine the orbit of any non-moon body by assuming the Sun to be the only source of gravity. This is not the case in the Milky Way: the orbital motion of a star or gas cloud is due to the collective gravity of everything else in the Galaxy. However the stars and gas clouds in the disk do tend to orbit in the same direction. But because the disk is not smooth but filled with irregularities—like the traffic jams of molecular clouds and stars at the spiral arms—orbits are not neat circles. Stars can speed up as they approach areas with increased mass density in the disk, and slow down when they leave them for less dense regions. If you turn on the orbital path of the Sun (Milky Way→Stars→Star Orbits→Sun) you can see that the Sun does not trace exactly the same trajectory with each 225-250 million year-long loop around the Galactic Center.



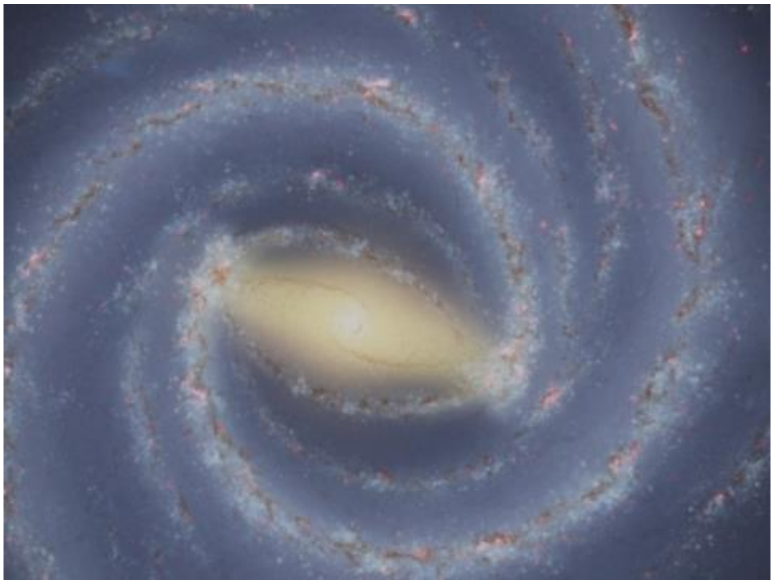
The Sun orbits at a distance of roughly 25,000 light years from the Galactic Center (there are quite a number of uncertainties and you will see slightly different numbers quoted in the literature). This is about half-way from the center to the edge of the disk, meaning the visible Galactic disk is 100,000 light years across from one end to the other. Even when you are in or just outside the Solar System, you can point out the Galactic Center. If you turn on the constellations (or just the zodiacal ones), look for the "teapot" in Sagittarius. The center of the Milky Way is located just to the right of the tip of the spout of the kettle. You can tell that there is a brightening of the Milky Way band in this part of the sky. If you zoom out to see the entire Galaxy from the outside, you can confirm that the Galactic Center is in that direction.



There are three distinct components to the visible mass of the Milky Way: the disk, the bulge, and the halo. The disk and the bulge are the most apparent when you fly clear out of the Milky Way. When you do this, make sure you point out to audiences that we have never sent a spacecraft that far out; what they are seeing is a visualization based on our best scientific data. (Remember from last week that many members of the public are confused about how far we have sent spacecraft.)

The disk is blue-ish and contains the spiral arms lined with dark molecular gas and dust clouds. These clouds are where young stars form, including the blue-white O and B stars. It's the light of these massive young stars (the largest of which can outshine the Sun by a factor of a million) that give the disk its blue-ish tint. The gas clouds also show up when you view the Milky Way edge on instead of face-on. The density of stars and gas decreases smoothly as you go from the center to the edge, and from the mid-plane of the disk out along the Galactic north and south directions. So the thickness of the disk is much greater near the center than it is out in the suburbs where we are, and keeps dropping as you go out (making it somewhat difficult to define a hard edge). But a good rule-of-thumb for the thickness of the disk is roughly 1000 light years where the Sun orbits.

The bulge in contrast is orange-ish, restricted towards the middle third of the volumetric Uniview Galaxy, and appropriately enough, "bulges" out from the disk. The orange glow is from a population of stars that is relatively older (most of the young blue stars have died off), and consists of about a tenth of all the stars in the Milky Way. There is a recognition in recent years that the Milky Way is not just a spiral galaxy, but a barred spiral. So you will actually see the bulge containing a bar shape connecting two of the main spiral arms in the glow of the volumetric model in Uniview.[1]



Finally the halo is a very low density population of stars whose orbits can take them far from the disk and bulge. Although containing only 10% of the stars in the Galaxy, they are spread out over a huge volume. You can view a vector model of this by turning on Milky Way→Milky Way Model→Halo, and a sphere 133,660 light years in radius will show up. This makes the extent of the halo more than twice that of the disk. (You will also find diagrammatic versions of the **Bar** and **Bulge** in that same twig of the Object Tree containing the halo.) The **Globular Clusters** also orbit in the halo. The 150 that have been discovered tend to be relatively close to the Galactic disk, but the furthest currently lies far outside the halo vector sphere.

Reference

Henbest, N., & Couper, H. 1994, *The Guide to the Galaxy*, New York, NY: University of Cambridge.

[1] An analogy I've given in the past for the disk and bulge to cement a mental model in a visitor's head is a thin crust pizza with two hamburger buns stuck in the center on either side. But given a barred center, maybe it should be more parallelogram-like pieces of baklava or other pastries.