Storytelling with Uniview #12:
H II Regions

May 15, 2014

Ka Chun Yu
kcyu@dmns.org

H II regions are star-forming regions, so named because they contain bubbles of hot (10,000 K) ionized gas: neutral hydrogen is H I, while ionized hydrogen is H II. The ionization occurs because massive stars that have formed nearby are emitting prodigious amounts of ultraviolet (UV) radiation which is energetic enough to knock loose a hydrogen atom's lone electron. Many of the well-known emission nebula with spectacular imagery from Hubble and other telescopes are H II star forming regions. Here are some of them from Milky Way→Deep Sky Objects (Lagoon, Eagle, Omega, Trifid):

And also one that has its own 3D model Milky Way→Nebulae→Orion Nebula Model:

Star formation occurs in molecular clouds: cold clouds (with temperatures typically 10-50 K) where the gas is mostly molecular hydrogen (H_2), and which can be some of the largest structures in the galaxy (tens of light years across for the largest, with a mass up to several 100,000 times that of the Sun). Only these clouds are dense and large enough for gas cores within the cloud to collapse into protostars. Because they are so dense, they can completely block out background visible starlight. The dark lanes in the Milky Way consist of molecular clouds. And since these clouds tend to be crowded along the spiral arms, H II regions will show up as bright emission regions also along the arms of a spiral galaxy.

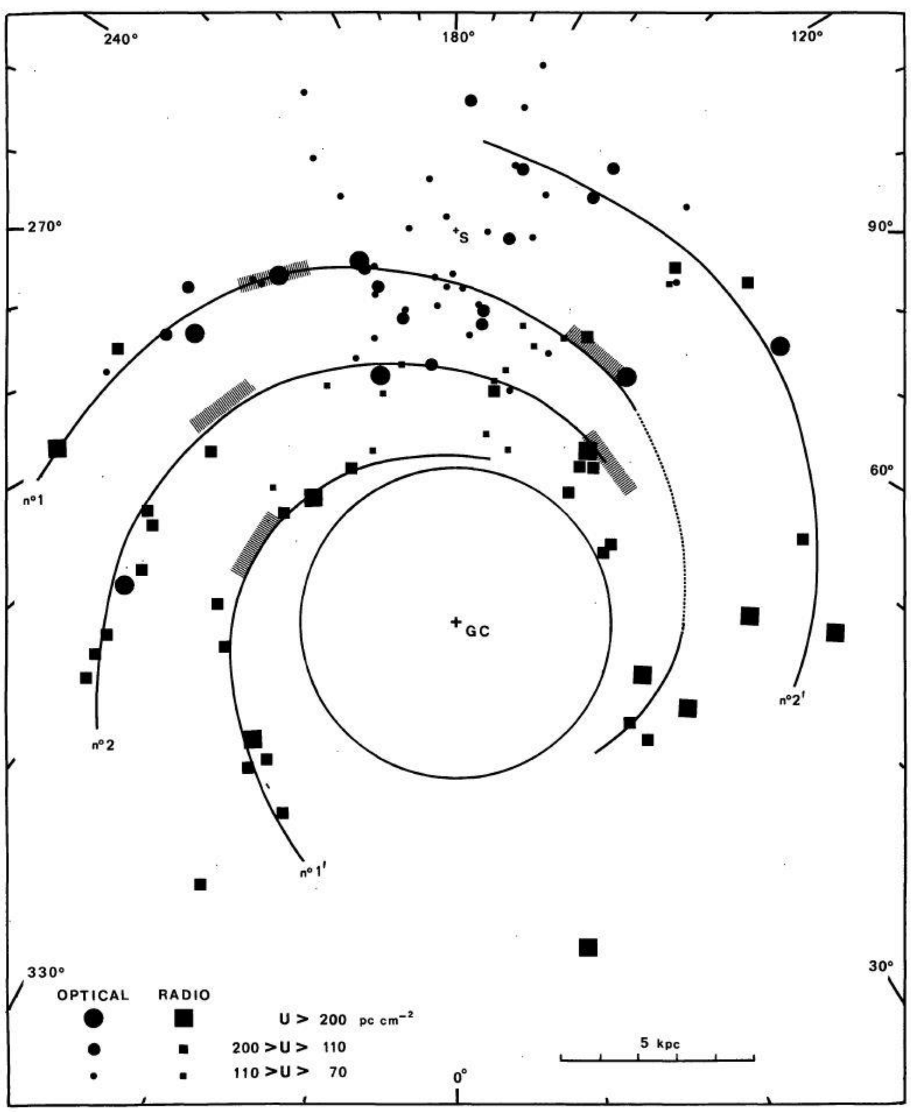
Although star formation can take place in small molecular clouds, most stars in the Milky Way Galaxy formed in giant molecular clouds (GMC) where many thousands of stars are born over a period of millions of years. Small stars are found more frequently than larger stars. But in a star-forming region with thousands of protostars, there will likely be at least one that is massive enough that it pumps out predominantly UV photons. An H II region is therefore a star-forming region where a massive star has turned on, and is slowly obliterating the GMC from the inside out via radiation and stellar winds. (The fact that we can see H II regions as emission nebulae, like the Orion Nebula, is a testament to the disruptive power of massive stars which destroy the thick molecular gas that would have shielded the young stars at visible wavelengths from our sight.) Over time, the gas in the GMC continues to be disrupted from massive stars as well as weaker winds from low mass stars, with the ultimate disruption coming from a massive star going supernova. Since massive stars don't live for more than a few million years, the longevity of a GMC is constrained by when a massive star appears on the scene. Given all of these factors, most of the GMC gas is actually returned to the interstellar medium; only a few percent of the original GMC mass is actually turned into stars.

Over time, the gas in the GMC is dispersed back into the interstellar medium, where it can collect again back into molecular clouds, and the cycle starts over again. Supernovae also enrich the interstellar medium with heavy elements, thereby providing more of the elements that form planets and life.

In Uniview, the H II regions show up as Milky Way→Nebulae→Star Forming Regions. The naming scheme—S249, S165, etc.—contains objects from a catalog that US astronomer Stewart Sharpless (hence the letter "S" in the names) finalized in 1959. Sharpless surveyed large format photographic plates taken at Mt. Palomar Observatory for emission nebulae, while trying to exclude objects that were not H II regions. Still a few outliers like the Crab Nebula remained in his original catalog (although those are not in the Digital Universe dataset used in Uniview).

The visualization module in Uniview is from a famous 1976 paper by Yvon and Yvonne Georgelin, who measured the radial velocities from hydrogen gas excited by the ionizing radiation in 268 H II regions, as well as radio observations from cold and hot clumps of gas. The radial (or Doppler) velocities tell you how fast something is moving toward (blueshifted) or away (redshifted) from the observer. It turns out that you can use the velocities of H II regions to estimate how far away they are from the Sun. Much of the stars and gas in the disk of the Milky Way, including our Sun, orbit at roughly the same velocity—around 200 km/sec. If most of the mass in the Galaxy was concentrated towards the center (as expected from optical observations), you would expect the orbital velocity to drop with distance from the center. However the velocities plotted in a “rotation curve” are relatively flat, hinting at the existence of substantial amounts of invisible dark matter in the Galactic halo.

Astronomers measure velocities and use spectroscopic parallaxes (or other techniques) of stars to build up a velocity model for the Galactic disk. New radial velocity measurements of an H II region can be used to place that emission region within your Galaxy model if you assume your model velocity map is accurate. There are, of course, substantial uncertainties since we have every reason to believe there is a spread in velocities of any matter orbiting in the Galactic disk. But even with such caveats, the model that Georgelin & Georgelin came up with looks very spiral galaxy-ish (the Sun is marked by the letter *S* near the top center):



This by no means is the last word. There continues to be vigorous debate about the details of our Galaxy’s structure; there are even arguments about whether the Milky Way has two or four spiral arms! But all of this subsequent research follows in the spirit of Georgelin and Georgelin: trying to see the layout of the galactic forest, with all of the confounding trees in the way.

References

Georgelin, Y.M. & Georgelin, Y.P. 1976, “The spiral structure of our Galaxy determined from H II regions,” *Astronomy and Astrophysics*, 49(1), 57-79.

Sharpless, S. 1959, “A Catalogue of HII Regions,” *Astrophysical Journal Supplement*, 4, 257-279.