A Mysterious Shell in the Outskirts of the Milky Way

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Abstract: At the edge of the Milky Way lies a region known as the Galactic Anti-center, which contains neutral hydrogen (HI) gas at unusually high velocities. This gas appears as a shell-like structure (the Anti-center shell) and its origin is currently unknown. The goal of this project is to characterize properties of the Anti-center shell and understand what events were likely key in its inception. Using new HI data from the GALFA-HI survey, we are measuring the mass of Hydrogen in this region and the velocity of expansion for the shell. These measurements suggest that this shell to big to be created by supernovae explosions and was most likely created when a high velocity cloud collided with the Milky Way's disk..

Observations

The observations for this research were made by the Arecibo radio telescope. It is a single dish 305 m radio telescope in Puerto Rico. The data used are part of the recent GALFA-HI survey, which mapped the neutral hydrogen (HI) emission across the whole Arecibo sky. Radio telescopes like Arecibo work by surveying the sky, receiving and interpreting the light that is collected. The GALFA-HI survey was centered around 1420MHz, which corresponds to the famous transition of Hydrogen atoms occurring in predominantly atomic interstellar gas. Using the Doppler Effect, computers can compile the data into cubes with one axis being radial velocity. With these data cubes, astronomers can study gas structure based on its velocity with respect to Earth. Using these cubes, images like the one below can be created and calculations can be completed.

Project Motivation

Large gas structures like the Anti-center shell are pretty common throughout the universe, but it is not entirely clear what processes are key in their creation. Bruhweiler et al. (1980) and Tomisaka, Habe and Ikeuchi (1981) explain these structures as being created initially by the stellar winds of massive stars. As massive stars end their lives in supernova explosions, the energy input of these events lead to further gas expansion and the formation of a their formation (McCray & Kafatos 1987). The Anti-center shell, which was found by Heiles (1984), is around 30° in diameter. Its large size and a large mass of the swept up atomic hydrogen gas have called for alternative ideas for shell formation. One such scenario involves a collision of a high velocity cloud (HVC) with the Milky way disk. The recent large-scale, high resolution neutral hydrogen (HI) survey, GALFA-HI (Peek et al. 2011), allows us to re-examine the Anti-center shell and investigate its possible formation scenarios.

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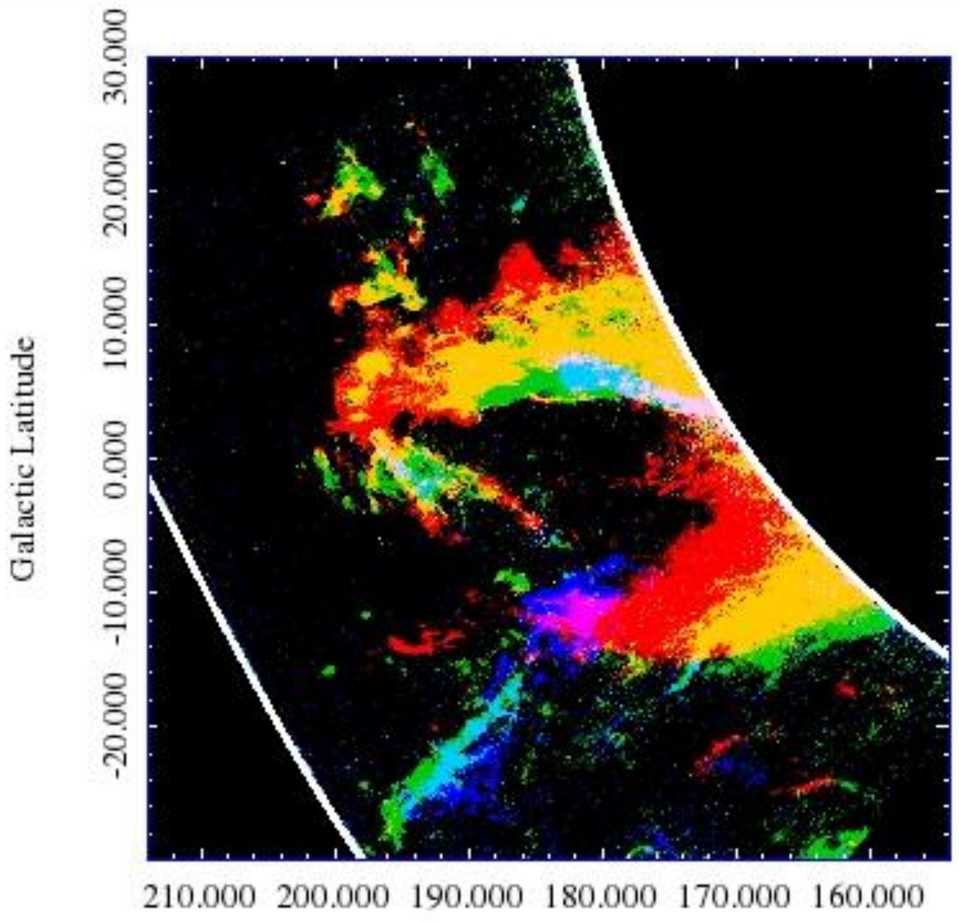

Image 1: The HI emission from the Anti-center shell. Red gas is moving from –54.47 km/s to –72.14 km/s. Green is moving from –76.56 km/s to –111.89 km/s. Blue is moving from –116.31 km/s to –178.14 km/s.

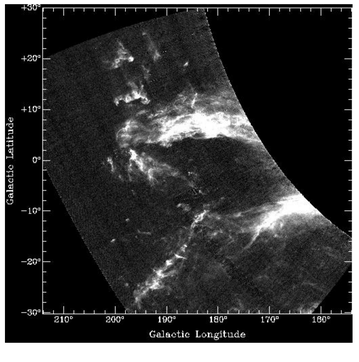

Image 2: The Anti-center shell. HI emission was integrated from –63.31 km/s to –178.14 km/s.

Arecibo Telescope in Puerto Rico

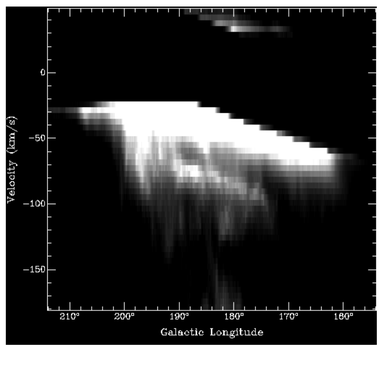

Image 3: Velocity vs. Longitude image of the shell.

Images

Image 1: demonstrates the differences in velocity of within the shell. Blue represents gas that is moving towards Earth the fastest. Red gas is the slowest. All other colors and in between, green being the middle. The image shows just how diverse the shell is in velocities.

Image 2: a combination of gas traveling at all velocities that the shell is seen. This image was used to calculated the mass of the shell.

Image 3: A view of the shell with respect to velocity and longitude. The lowest gas in the image can be paired up with the blue gas in Image 1. Near the top of the image is a blacked out region, which was done using an equation that removed gas present in the galactic disk. We can do this because galactic disk gas moves within a predictable range.

Results

We have applied a velocity cut-off to exclude the HI gas right within the Milky Way disk and select the HI contribution from the Anti-center shell only.
The HI mass of the shell was measured and found to be $7.75 * 10^5$ solar masses. The age of the shell was found the age to be 10 million years. To find this age the equation $t = \frac{3}{5}\frac{r}{v}$ was used. Using these results and the size of the shell, with the radius being around $1.67 * 10^{16}$ km (540 parsecs), it was possible to calculate a value for the energy needed to create the shell, which was found to be $4.7 * 10^{52}$ ergs. Knowing the energy of the shell and the fact that a supernova generally releases 10^{49} ergs when it explodes, it can be concluded that it would take 4700 supernovae to create this shell. This is an incredibly large number, suggesting that the supernova origin of the shell is not very likely. This means that the most likely cause for creation was collision with a high velocity cloud.

References

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