**SMALL RADIO TELESCOPE PROBES DARK MATTER**

Adam Birenbaum, Ryan Bossler, Tenzin Choedak, Felipe Gutierrez, Daniel Hesse, Briana Indahl, Nathan Oster, Jessie Otradovec, Pooja Rawat, Snezana Stanimirovic, Claire Murray.

Affiliation: University of Wisconsin-Madison
Astronomy
Department

---

**GALACTIC ROTATION CURVE**

- **Definition:** Orbital speed of stars and gas clouds as a function of distance from the galactic center

- **Importance:**
  1. Provides estimate of the total mass in the Milky Way
     
     \[ M(< R) = \frac{RV^2}{G} \]

---

NASA/JPL/R. Hunt
2. Tells us how fast clouds/stars in the Milky Way move toward/away from us (radial velocity component).

3. Allows us to measure dark matter profile.

- The predicted orbital velocity due to visible mass different from observed velocity.
- There must be additional (DARK) matter

Assume that hydrogen clouds move on circular orbits around the Galactic center.

\[ V_r = R_\odot \sin(l)(V/R - V_\odot/R_\odot) \]

- Measure radial velocities of HI clouds at a known distance from the GC to estimate orbital velocities.
- Objects of known GC radius found only in the inner Galaxy. (0°<l<90°, 270°<l<360°)

- Applied the Tangent Point Method for 20°<l<75°.
- For clouds at tangent points: \( R = R_\odot \sin(l) \)
  \[ V = V_r + V_\odot \sin(l) \]

**The Telescope**

SRT (Small Radio Telescope)

- Located on the roof of Sterling Hall
- 2.3 meter aperture
- Developed by the Haystack Observatory/MIT
- Operational since early 2013
- Detect emission lines from atomic hydrogen at a frequency of 1420.405 MHz.
- Integration time ~20 sec per position
Multiply the Artificial Intensity Units by 0.1 to convert to Brightness Temperature.

We used the Doppler Equation to convert from frequency to radial velocity:
\[ f = \left( \frac{c + v_r}{c} \right) f_0 \]

The first step is to average all the spectra at a certain point.
The next step is to perform a linear fit to the data to remove the background (sky + electronics) contribution.
Our results show good agreement with Brand & Blitz (1993)'s best fit of their observations. We have large error bars, but we see no indication of a drop in velocity at higher radii. In fact, we observe a relatively constant rotation curve.
We compare our results with D’Onghia et al. (2012) theoretical model for an exponential stellar disk with $4 \times 10^{10} \, M_\odot$.

We observe that the stellar disk does not contribute enough to the rotation curve.

The extra contribution must be from the dark matter halo, mass $\sim 10^{12} \, M_\odot$.

Calculated rotation curve:
- Relatively constant at 200-220 km/sec
- Agrees with other published results
- Suggests presence of a large amount of dark matter in the outskirts of the Milky Way
- Estimated total mass of the Milky Way within 8 kpc is roughly $10^{11} \, M_\odot$ or $2 \times 10^{41} \, kg$
Redo the experiment by increasing observing time. This would better define the hydrogen peaks in the spectra and allow more precise measurements.

Reduction of background radio interference. A second SRT has been installed at Pine Bluff, a rural setting 15 miles west of Madison where the interference is much lower than on campus. Error bars on data points will be significantly reduced.