Measurement of Galactic Rotation Curve with JRT
Job’s Radio Telescope
-and describe existence of Dark Matter-

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ROTATION CURVE OF THE MILKY WAY GALAXY

The rotation curve of a disc galaxy (also called a velocity curve) is a plot of the orbital speeds of visible stars or gas in that galaxy versus their radial distance from that galaxy’s centre. It is typically rendered graphically as a plot.

The galaxy rotation problem is the discrepancy between observed galaxy rotation curves and the theoretical prediction, assuming a centrally dominated mass associated with the observed luminous material. When mass profiles of galaxies are calculated from the distribution of stars in spirals and mass-to-light ratios in the stellar disks, they do not match with the masses derived from the observed rotation curves and the law of gravity. A solution is to hypothesize the existence of dark matter and to assume its distribution from the galaxy's center out to its halo.

Animation of the theory.
(wikipedia)

So we would expect that mass further away from the center has a lower velocity than the mass in the centre (like a vortex). But it happens to be a higher almost constant velocity. That means other forces are responsible for this velocity. Nowadays it assumed that the existence of Dark Matter makes the Rotational Velocity Curve look like a horizontal line instead of decreasing speeds.
THEORY

Time to check that with JRT.

Besides the hardware, we need software and some mathematics to compute the velocities.

To start with the hardest part: formulas. It took a lot of time and effort to get the right formules and interprete them. What we need is the values of the highest measured redshift. We need some goniometrics to compute the speed of the measured cloud. And now the hard part, we need to compensate for the movement of the Earth AND the speed of our solar system. This is called Vlsr: Velocity of Local Standard of Reference. Because not only the cloud we observe is moving, but we are also moving i.e. the rotation of the Earth AND the speed of the solar system itself) So some heavy calculations have to be done with formulas like:

\[ V_{rE} = 30.0 \cos \beta \sin \lambda \cos \lambda - \cos \beta \cos \lambda \sin \lambda = 30.0 \cos \beta \sin(\lambda - \lambda). \]
BUT...I was lucky, there is a perfect Internet site which does these calculations for me:

http://neutronstar.joataman.net/technical/radial_vel_calc.html

**Radial Velocity/VLSR/Observation Frequency Calculators**

Calculates the topocentric radial velocity of an observer in a given direction (equatorial coordinates) and observer's latitude and longitude, and UTC time.

May be useful for determining observational frequencies or correcting observation velocities for cosmic spectral lines - e.g., HI emissions and masers (but not pulsars).

See instructions and usage below.

To compute the speed of the observation point, the formula is:

\[ V = \frac{(1420.406 - f) \cdot V_c}{1420.406 - V_{lsr}} \]

Where \( f \) is the highest found red shift frequency and \( V_c \) is the speed of light, 299790 km/s.

So far for the Rotational speed, the Y-axis in the graph we need.

For the X-axis we need to compute the tangential distance from the Galactic center in kpc. That’s easy. That’s sin \( l \) * 8.5

\[ R = \text{sin}(l) \cdot 8.5 \]

where \( l \) is longitude.
In these pictures you can check it out (if you want to):

Figure 3. Diagram for the rotation of the Milky Way

Figure 4. (a) Plot of Hydrogen 21-cm emission along a line-of-sight from the Sun. (b) A diagram showing the positions of the 4 Hydrogen clouds (A,B,C,D) relative to the Sun. Note that the cloud with the smallest R (cloud C) has the largest radial velocity.
THE HARDWARE

The JRT radio telescope is 1.5 meter rf-Hamdesign radio telescope. It is FULLY REMOTE CONTROLLED!

It has 2 LNA’s and a filter.

Lna 1: Mini Circuits ZX60
Filter: 1.420 Ghz filter
Lna 2: Nooelec sawbird
Bias-T feeded with 5 Volt and 3.3 Volt
15 meters of Coax
RTL-SDR Receiver
Laptop
SPX-02 Rotator
Netfilter
13.8 Volt 10 Ampere Power Supply
all remote and viewable by webcam.
THE SOFTWARE

To receive the data from the RTLSDR I use 2 applications, SDR# and VIRGO. But since VIRGO is written in Python I can adjust the software to my wishes.
For tracking I use PsT Rotator which is connected via Cartes du Ciel with Virgo.

Links:

PsT: https://www.qsl.net/yo3dmu/index_Page346.htm
Hamdesign: http://www.rfhamdesign.com
Cartes du Ciel: https://ap-i.net/skychart/en/start
Virgo: https://github.com/0xCoto/VIRGO
THE PLANNING, GATHERING AND RESULTS

So how to obtain the data?

1) Compute RA DEC coordinates with my own Python script. In this case 37 points.

2) Let VIRGO run and gather full automatic 37 spectra from longitude 0 to 90 steps 2.5 degrees. Every spectrum 10 minutes.

3) Compare some samples with https://www.astro.uni-bonn.de/hisurvey/euhou/LABprofile/

These are in reverse because its the frequency and not the speed. Red line is 1420.405 Mhz, HI.
4) Look for highest red shift/velocity (lowest frequency start of detection)

5) Compute $V_r$

\[
V=(1420.406-f)\times V_c/1420.406-V_{lsr}
\]

6) Plot the distance against rotational velocity in Excel

\[
R=\sin(l)\times 8.5
\]
The calculations in Excel

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Column 1 Longitude
Column 2 Sinus in RAD
Column 3 Measured highest Red Shift Frequency
Column 4 Speed of Cloud
Column 5 Distance of Cloud to Center
Column 6 Vlsr
Column 7 Sinus L *8.5 as formula
Column 8 Rotational Velocity as formula
Column 9 Sinus L *8.5 as value
Column 10 Rotational Velocity as value
FINAL RESULT!

**Rotation Curve Milky Way Job Gehniau 1.5 Meter Dish**

*Figures show data from the Milky Way's rotation curve using a 1.5-meter dish. The measured curve suggests the presence of dark matter, as indicated by the expected curve.*
So we expect a curve down of Neutral Hydrogen Clouds which move slower, but it happens to be a flat curve. One of the assumptions is that Dark Matter (unknown matter) is generating the extra “pull”.

All this was nog possible without help of many people. But I am happy that this result is possible with JRT.

Special thanks to Eskil Varenius, Apostolos Spanakis Misirlis, Eduard Mol, Simon Bijlsma

Job Geheniau – october 2020

More info:

https://en.wikipedia.org/wiki/Galaxy_rotation_curve
https://www.youtube.com/watch?v=-UrzmAa62ho
https://astronomy.swin.edu.au/cosmos/r/rotation+curve
https://www.youtube.com/watch?v=Hcc0dToHf18
https://www.youtube.com/watch?v=_eMNRa-KEiQ
https://ned.ipac.caltech.edu/level5/March01/Battaner/node9.html