Measurement of Galactic Rotation Curve with JRT

Job's Radio Telescope

-and describe existence of Dark Matter-

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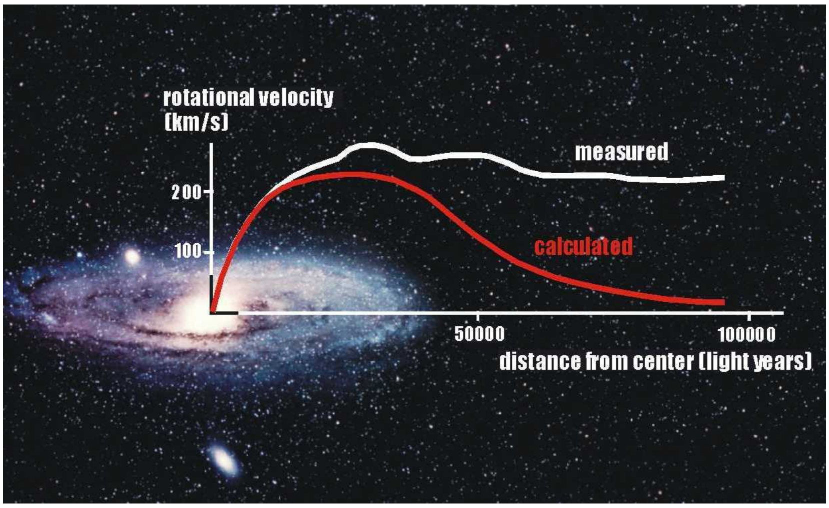


ROTATION CURVE OF THE MILKY WAY GALAXY

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.

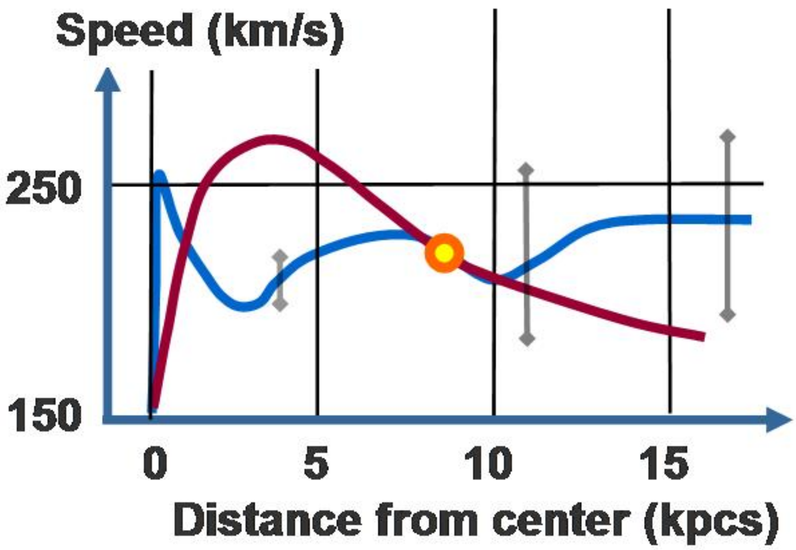
The galaxy rotation problem is the discrepancy between observed galaxy rotation curves and the theoretical prediction, assuming a centrally dominated mass associated with the observed luminous material. When mass profiles of galaxies are calculated from the distribution of stars in spirals and mass-to-light 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.

https://commons.wikimedia.org/w/index.php?title=File%3AGalaxy_rotation_under_the_influence_of_dark_matter.ogv

(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.



(red = expected, blue is measured)

THEORY

Time to check that with JRT.

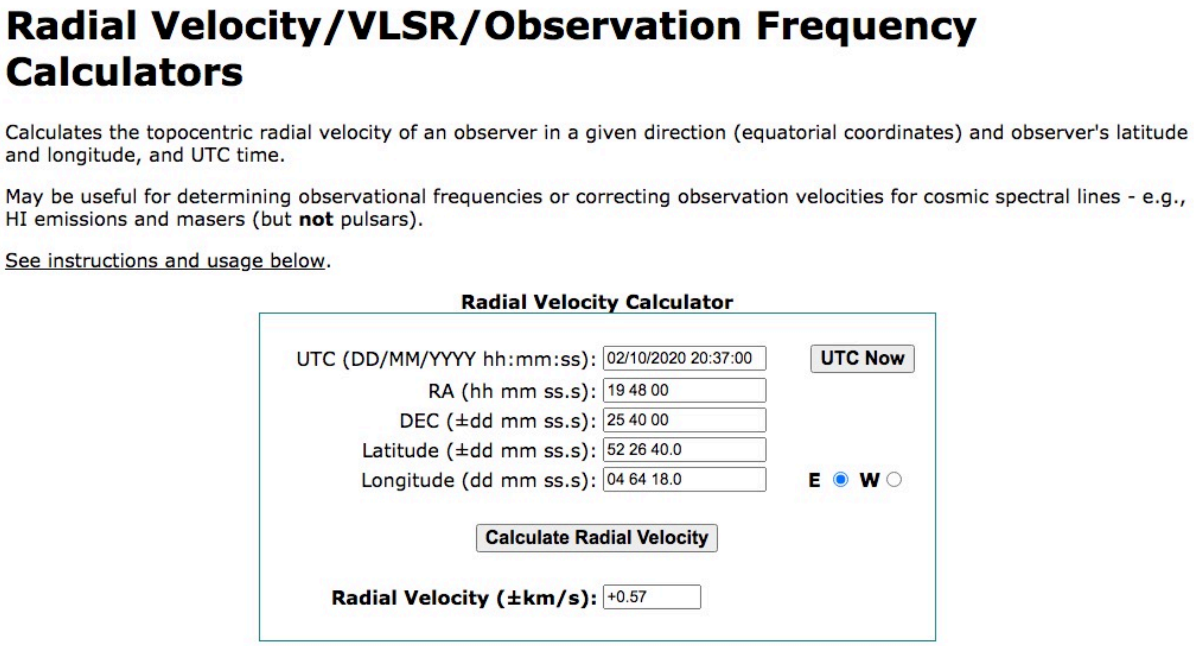
Besides the hardware, we need software and some mathematics to compute the velocities.

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:

$VrE = 30.0 \cos \beta \sin \lambda \cos \lambda - \cos \beta \cos \lambda \sin \lambda = 30.0 \cos \beta \sin(\lambda - \lambda)$.

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



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

V=(1420.406-f)*Vc/1420.406-Vlsr

Where f is the highest found red shift frequency and Vc 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=sin(l)*8.5

where l is longitude.

In these pictures you can check it out (if you want to):

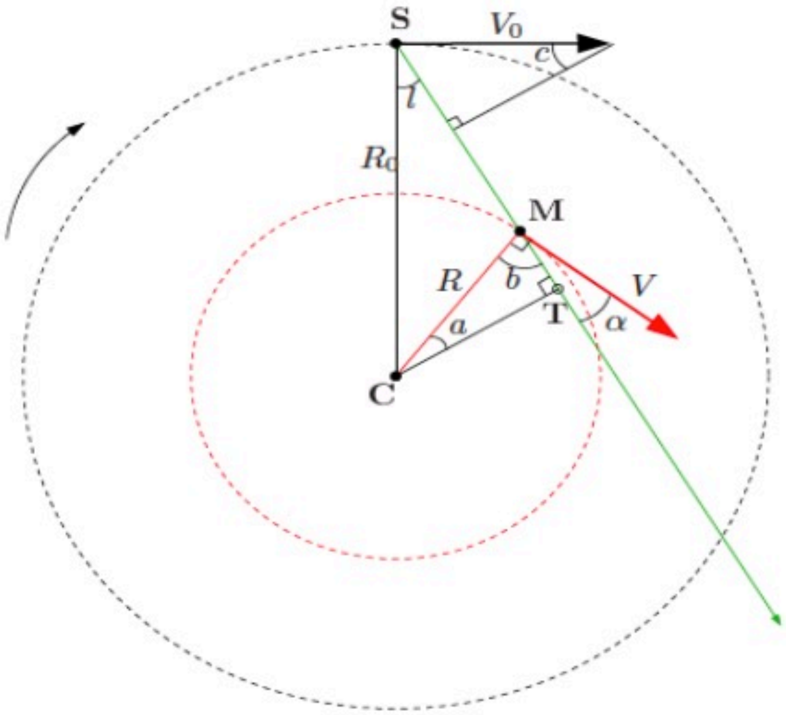


Figure 3. Diagram for the rotation of the Milky Way

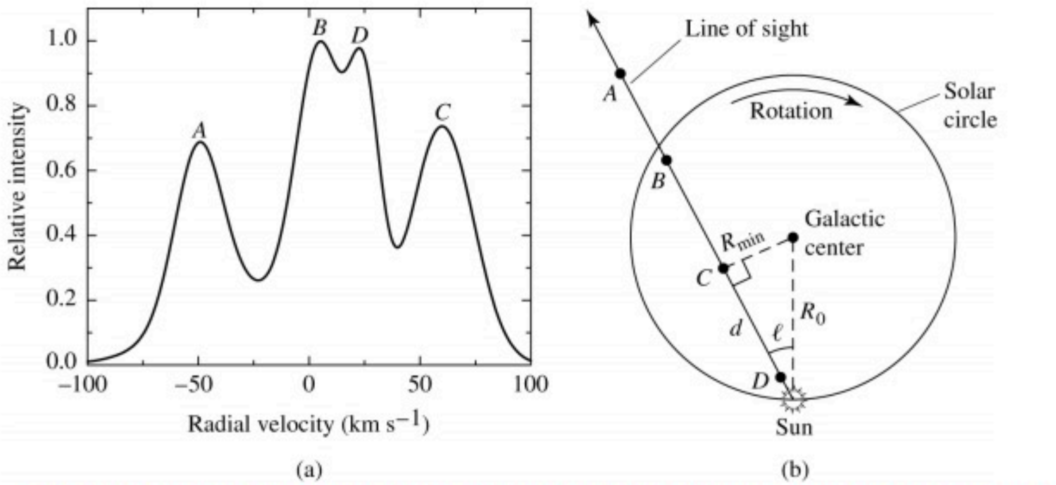


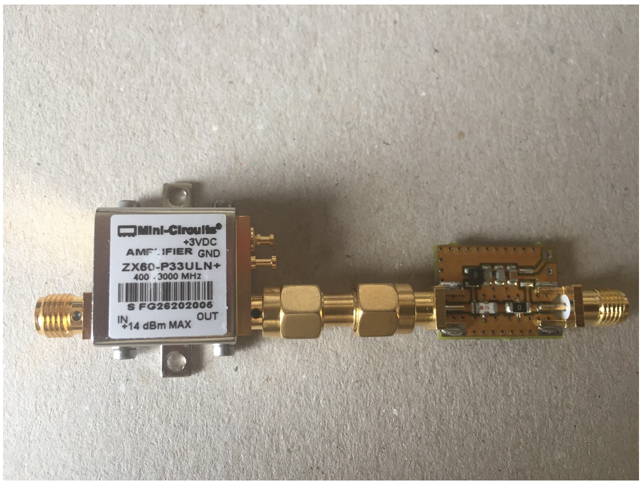
Figure 4. (a) Plot of Hydrogen 21-cm emission along a line-of -sight from the Sun. (b) A diagram showing the positions of the 4 Hydrogen clouds (A,B,C,D) relative to the Sun. Note that the cloud with the smallest *R* (cloud C) has the largest radial velocity

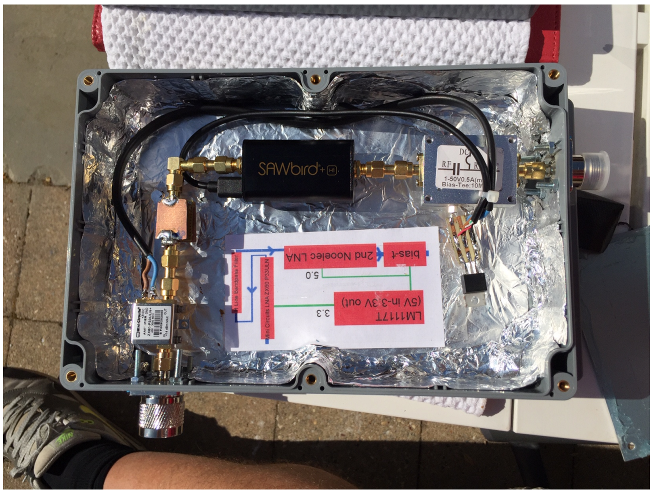
THE HARDWARE

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.


Mini-Circuits
+3VDC
GND
ZX60-P33ULN+
400 - 3000 MHz
S FG26202005
IN
OUT
+14 dBm MAX

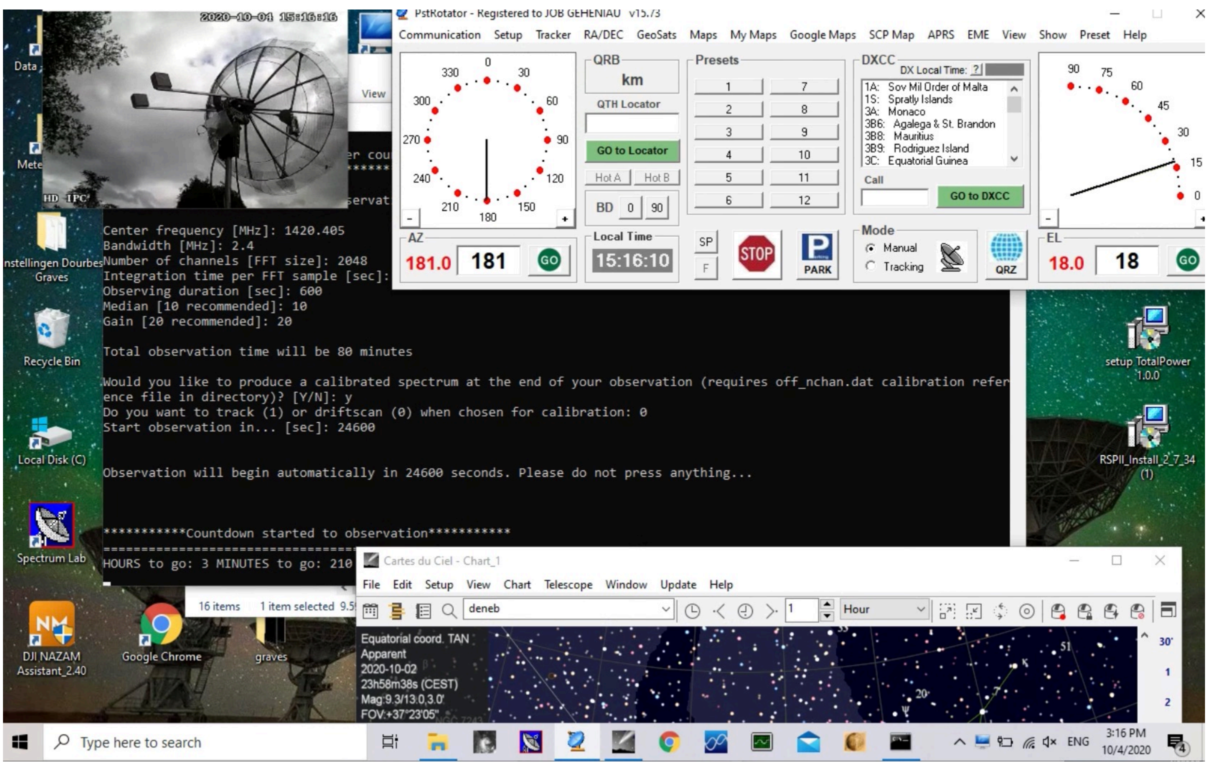

SAWbird+

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 whishes.
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

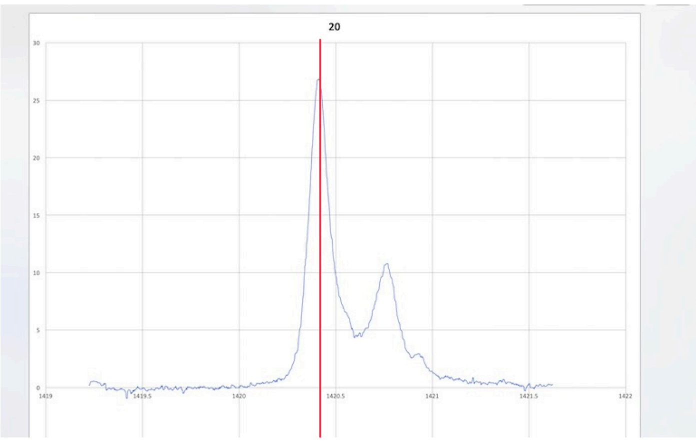
So how to obtain the data?

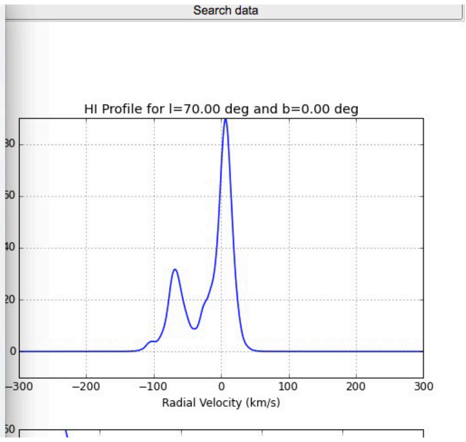
1) Compute RA DEC coordinates with my own Python script. In this case 37 points.

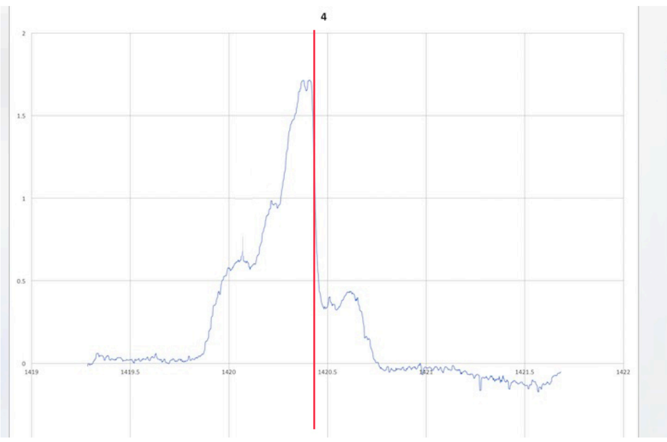
2) Let VIRGO run and gather full automatic 37 spectra from longitude 0 to 90 steps 2.5 degrees. Every spectrum 10 minutes.

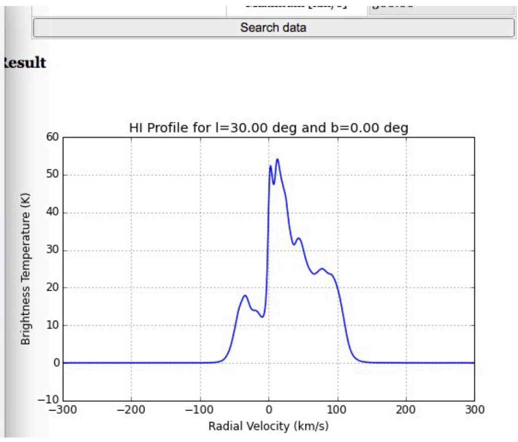
3) Compare some samples with https://www.astro.uni-bonn.de/hisurvey/euhou/LABprofile/

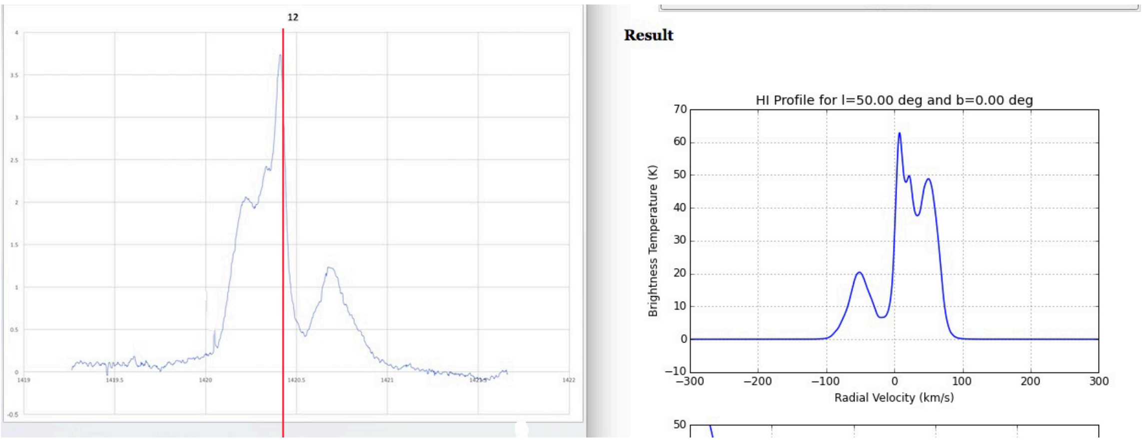
   These are in reverse because its the frequency and not the speed. Red line is 1420.405 Mhz, HI.



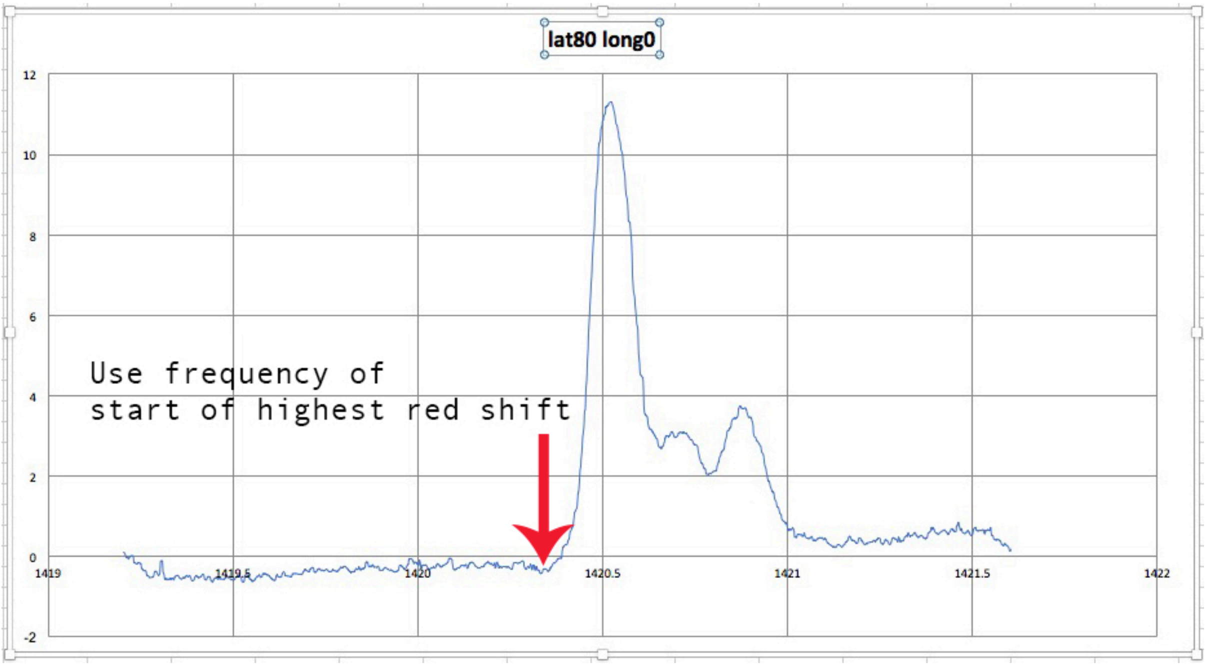








4) Look for highest red shift/velocity (lowest frequency start of detection)



5) Compute Vr

   V=(1420.406-f)*Vc/1420.406-Vlsr

6) Plot the distance against rotational velocity in Excel

   R=sin(l)*8.5

The calculations in Excel

	A	B	C	D	E	F	G	H	I	J	K
3				Speed of cloud	Distance from	11 min per observation				GRAPH X	GRAPH Y
4	Degrees	Sinus calculation	Higest redshift	Vr	Galactic Center	Vlsr	sin l * 8.5 (kpc)	Vr+220 * sin l		Column G as Value	Column H as Value
5	Longitude	Rad	Frequency in Hertz	km/s	kpc	km/s	Rotation Curve X-axis	Rotation Curve Y-axis		Kpc	km/s
7	0	0	1420245000	52.38055908	0	-18.4	0	52.38055908		0	52.38055908
8	2.5	0.087155743	1420100000	82.49416819	0.000543585	-17.91	0.732108239	101.6684316		0.732108239	101.6684316
9	5	0.087155743	1420096000	82.90840568	1.596561301	-17.48	0.732108239	102.0826691		0.732108239	102.0826691
10	7.5	0.130526192	1420050000	91.99713685	2.022020689	-16.86	1.096420015	120.7128991		1.096420015	120.7128991
11	10	0.173648178	1420010000	100.0595118	2.348597821	-16.48	1.458644692	138.2621109		1.458644692	138.2621109
12	12.5	0.216439614	1419995000	102.7954024	2.690887443	-16.05	1.818092757	150.4121174		1.818092757	150.4121174
13	15	0.258819045	1419784000	146.6489301	2.377296067	-15.37	2.174079979	203.58912		2.174079979	203.58912
14	17.5	0.3007058	1419776000	147.8474051	2.627629909	-14.88	2.525928716	214.002681		2.525928716	214.002681
15	20	0.342020143	1419771000	148.182702	2.862578318	-14.16	2.872969204	223.4271335		2.872969204	223.4271335
16	22.5	0.382683432	1419809000	139.6424458	3.197109698	-13.64	3.214540832	223.8328009		3.214540832	223.8328009
17	25	0.422618262	1419778000	145.3452863	3.316095273	-12.8	3.549993399	238.3213039		3.549993399	238.3213039
18	27.5	0.461748613	1419841000	131.4885458	3.704714896	-12.24	3.878688351	233.0732408		3.878688351	233.0732408
19	30	0.5	1419850000	128.6890115	3.91723102	-11.34	4.2	238.6890115		4.2	238.6890115
20	32.5	0.537299608	1419870000	123.327824	4.159875455	-10.2	4.51331671	241.5337379		4.51331671	241.5337379
21	35	0.573576436	1419914000	113.6612116	4.47194812	-9.82	4.818042065	239.8480276		4.818042065	239.8480276
22	37.5	0.608761429	1419900000	115.9860428	4.555110515	-9.19	5.113596004	249.9135572		5.113596004	249.9135572
23	40	0.64278761	1419981000	97.9102336	5.022543926	-8.21	5.399415921	239.3235077		5.399415921	239.3235077
24	42.5	0.675590208	1420000000	93.25010551	5.223060787	-7.56	5.674957744	241.8799512		5.674957744	241.8799512
25	45	0.707106781	1420000000	92.23010551	5.336254427	-6.54	5.939696962	247.7935974		5.939696962	247.7935974
26	47.5	0.737277337	1420042000	82.68561183	5.629987406	-5.86	6.193129629	244.8866259		6.193129629	244.8866259
27	50	0.766044443	1420030000	84.17832431	5.668607767	-4.82	6.434773322	252.7081018		6.434773322	252.7081018
28	52.5	0.79335334	1420021000	85.37785867	5.707894344	-4.12	6.664168058	259.9155935		6.664168058	259.9155935
29	55	0.819152044	1420065000	75.03124625	6.001356137	-3.06	6.880877172	255.244696		6.880877172	255.244696
30	57.5	0.843391446	1420103000	66.30099007	6.262299437	-2.35	7.084488145	251.8471081		7.084488145	251.8471081
31	60	0.866025404	1420112000	63.33145571	6.379446779	-1.28	7.274613392	253.8570445		7.274613392	253.8570445
32	62.5	0.887010833	1420055000	74.64183998	6.14828487	-0.56	7.450890999	269.7842233		7.450890999	269.7842233
33	65	0.906307787	1420132000	57.31026825	6.602294075	0.52	7.612985411	256.6979814		7.612985411	256.6979814
34	67.5	0.923879533	1420120000	59.12298073	6.584640284	1.24	7.760588073	262.3764779		7.760588073	262.3764779
35	70	0.939692621	1420147000	52.35437765	6.78238147	2.31	7.893418015	259.0867542		7.893418015	259.0867542
36	72.5	0.953716951	1420140000	53.12179326	6.782741071	3.02	8.011222386	262.9395224		8.011222386	262.9395224
37	75	0.965925826	1420200000	39.38823087	7.170858628	4.09	8.113776941	251.8919127		8.113776941	251.8919127
38	77.5	0.976296007	1420240000	30.24585595	7.450786639	4.79	8.20088646	245.0309775		8.20088646	245.0309775
39	80	0.984807753	1420244000	28.36161845	7.516103086	5.83	8.272385125	245.0193241		8.272385125	245.0193241
40	82.5	0.991444861	1420248000	26.82738096	7.569046092	6.52	8.328136836	244.9452505		8.328136836	244.9452505
41	85	0.996194698	1420250000	25.38526221	7.617659338	7.54	8.368035464	244.5480958		8.368035464	244.5480958
42	87.5	0.999048222	1420275000	19.45877788	7.808672786	8.19	8.392005061	239.2493866		8.392005061	239.2493866
43	90	1	1420270000	19.52407475	7.807148413	9.18	8.4	239.5240748		8.4	239.5240748

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

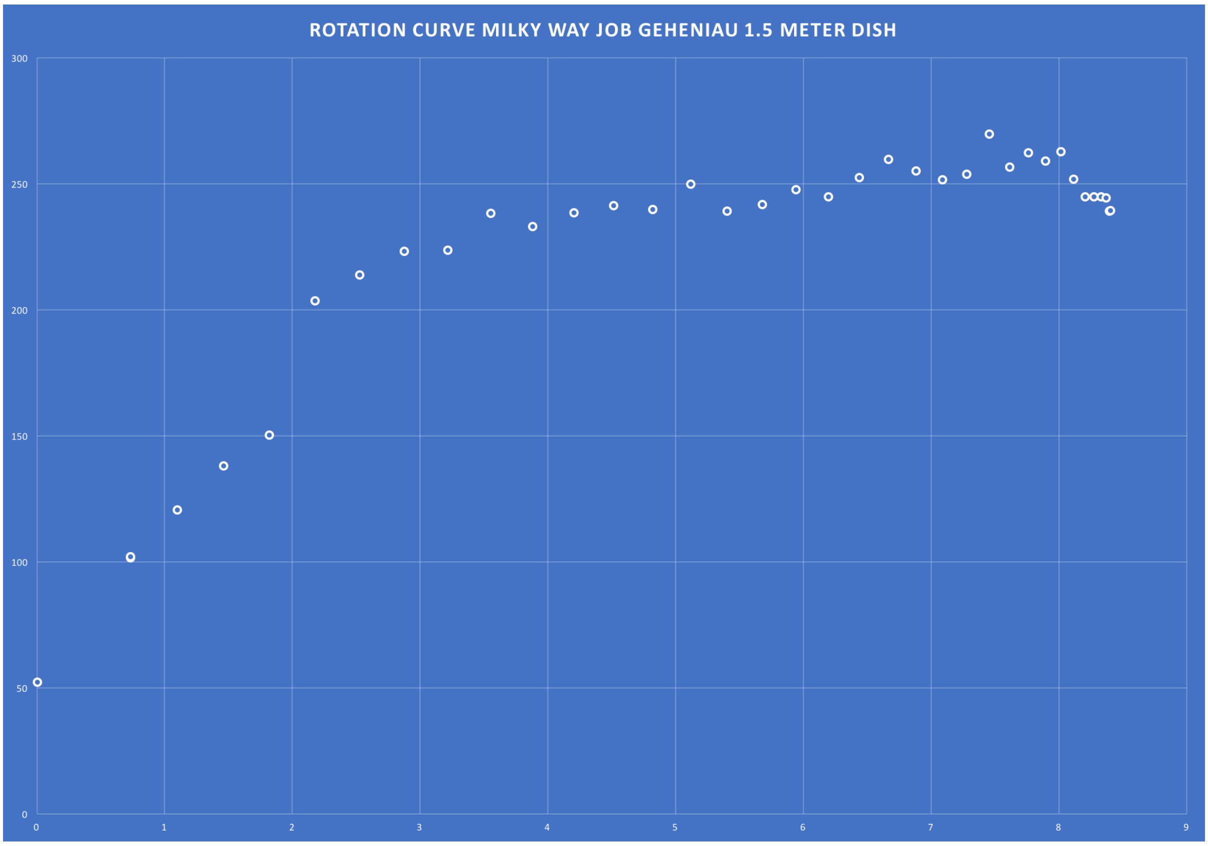
Column 7 Sinus L *8.5 as formula

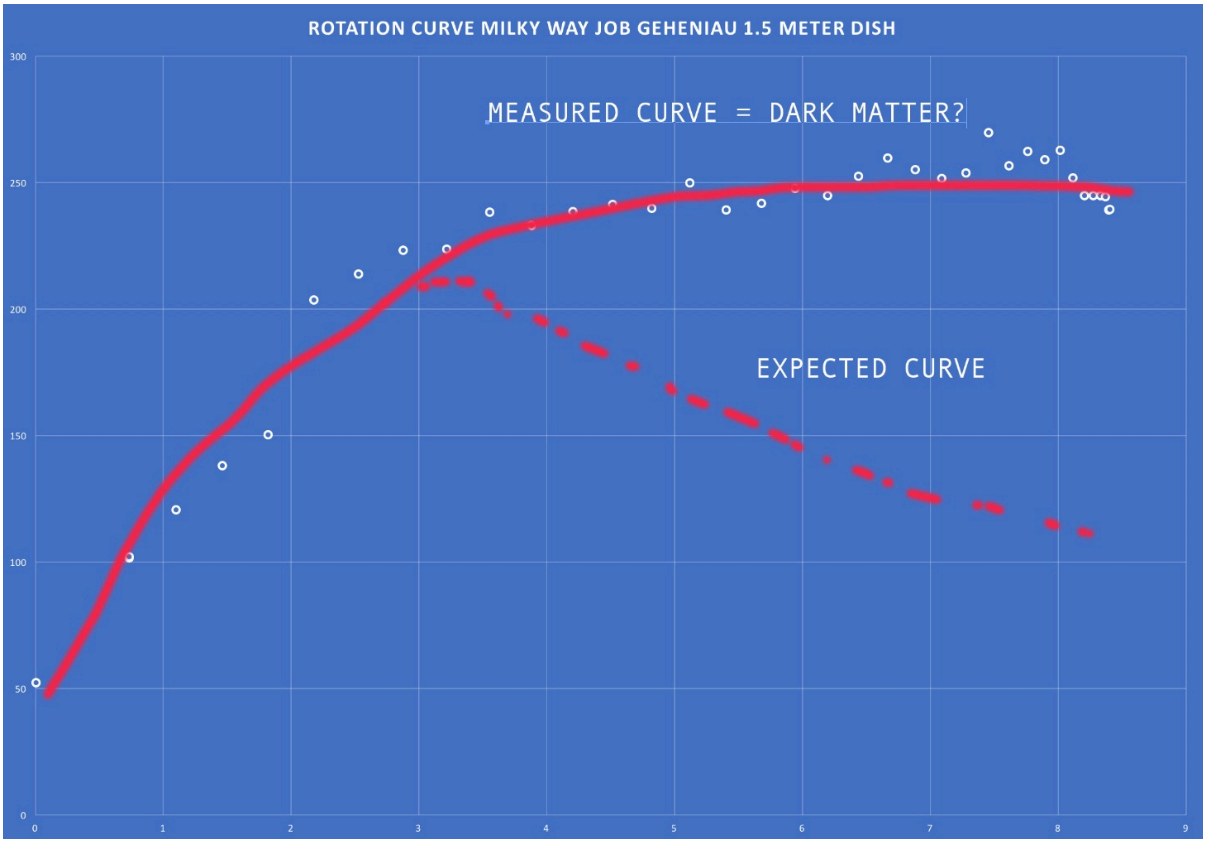
Column 8 Rotational Velocity as formula

Column 9 Sinus L *8.5 as value

Column 10 Rotational Velocity as value

FINAL RESULT !





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
http://www.se.euhou.net/docupload/files/handbook/radiosweden.pdf
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