Summary of the Results of the Radioastronomical Observations by the Students of the Course M2-UE7e

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Observing sessions

Two observing sessions were held: in the mornings of 24 Jan 2013 and 7 Feb 2013. In the first session of 3 hours, each of the two two-student teams had two runs of about 45 min. with each of the two telescopes. They observed the Sun with both telescopes, took an elevation profile of the sky background at 12.5 GHz, and obtained spectra of the HI 21 cm emission at various positions in the inner Galactic Plane in order to derive the Galactic rotation curve. Unfortunately the ESA-Haystack could only be used in simulation mode because the mechanical troubles with the azimuth and elevation drives could not yet be resolved.

The second session was organized in a less formal way, combining observations and the analysis of the data. Each of the two pairs used the ESA-Dresden to take a sky elevation profile and to obtain drift scans of the Sun and the Moon. Since the sky was only mildly overcast, observations of the moon were possible, and both teams secured good data. Everybody stayed between 09:00 and about 16:30 with an appropriate lunch break.

In both sessions the solar drift scans were affected by strong winds moving the antenna.

Data reduction sessions

Following the first observing session, one session was held about the reduction and analysis of the spectra at 1.42 GHz. The entire process from raw data to baseline-subtracted emission profiles, and the deduction of the rotational velocity was explained and executed for a single galactic plane position. Since the teams had used the ESA-Haystack in simulation mode only, they were given files with real data taken earlier.

During the second observing/analysing session the team reduced their data from both ESA-Dresden and ESA-Haystack instruments while having available all necessary explanations and help.

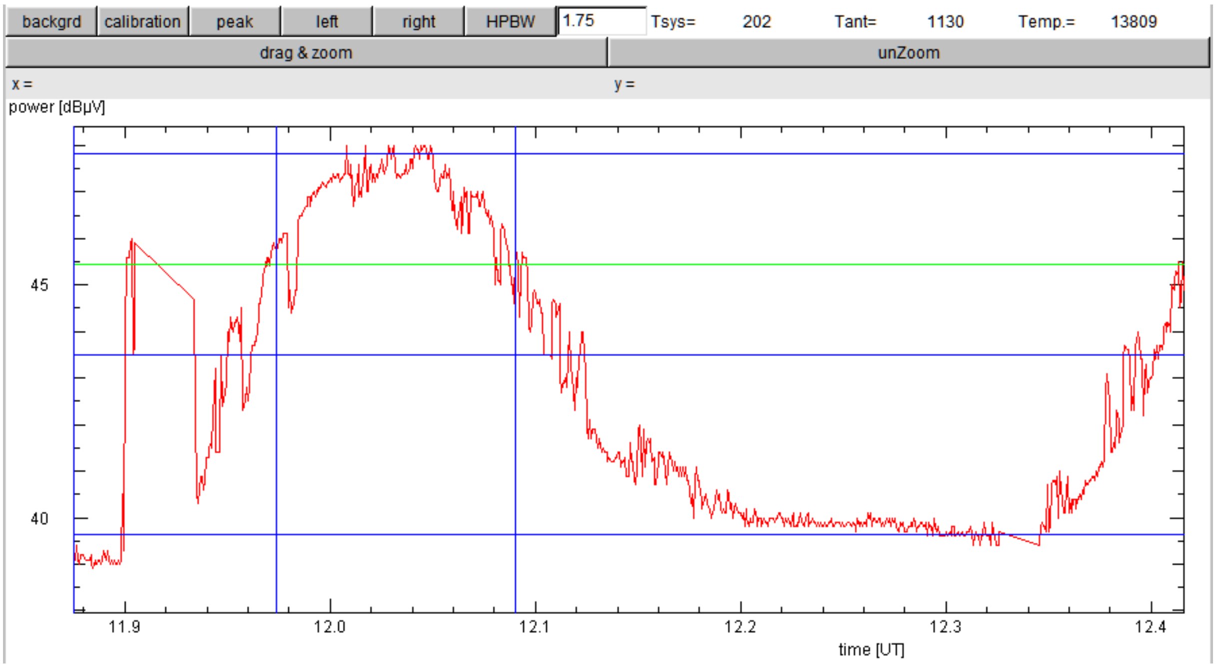
Solar observations on 12.5 and 1.42 GHz

With the ESA-Dresden telescope on 12.5 GHz, partial solar drift scans were taken of the sun by each team, giving these results:

Team	HPBW [°]	T_system [K]	T_antenna [K]	T_sun [K]
F+S	1.7 (assumed)	195	1118	12928
L+N	1.75	181	1161	14157
F (+O) (7 feb)	1.95	171	1078	16438
L+S (7 feb)	1.75	202	1130	13809

NB: The solar sky motion was not corrected for the actual solar declination, which would affect the HPBW. For the solar surface temperature the current solar angular diameter of 0.54° was taken.

Only the observation F (7feb) was without perturbations by the wind. But despite strong perturbations, useful results were obtained (L+S on 7 feb):

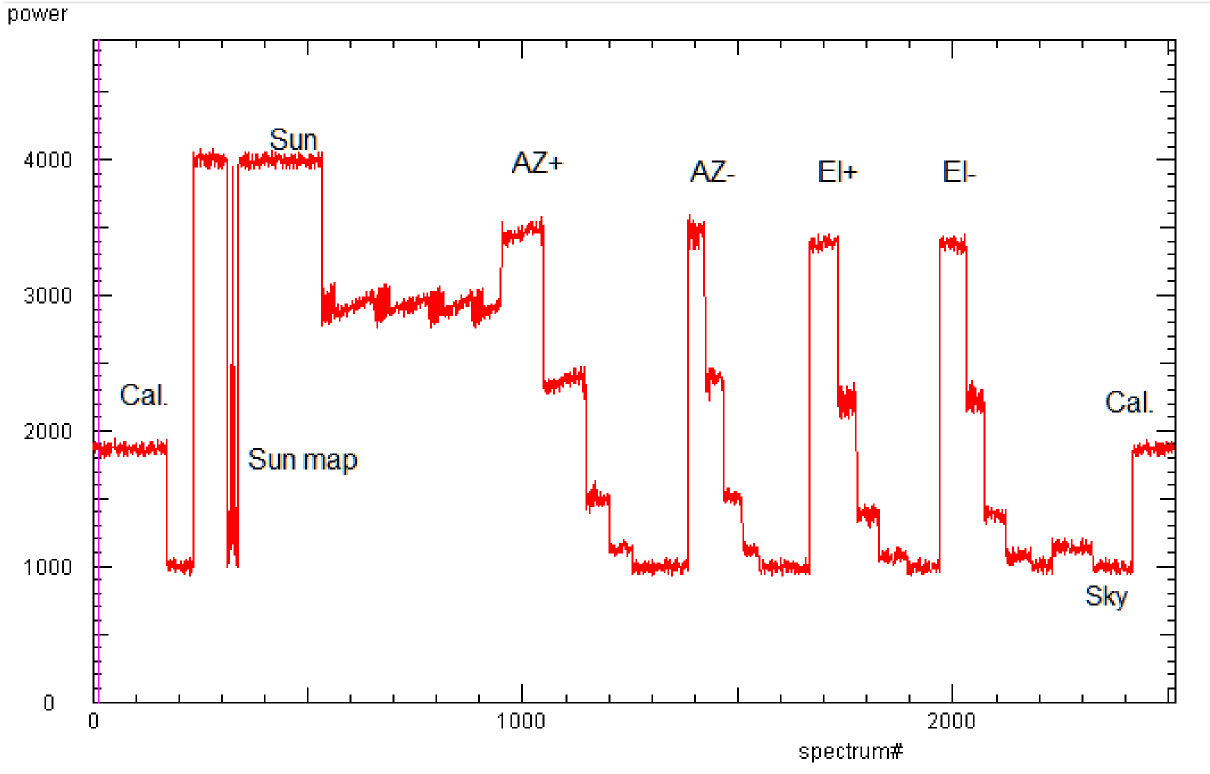


The Sun was also observed on 1.42 GHz with the ESA-Haystack telescope in simulation mode. Each team performed a mapping of the region about the Sun, which did give zero pointing offsets in azimuth and elevation for the telescope.

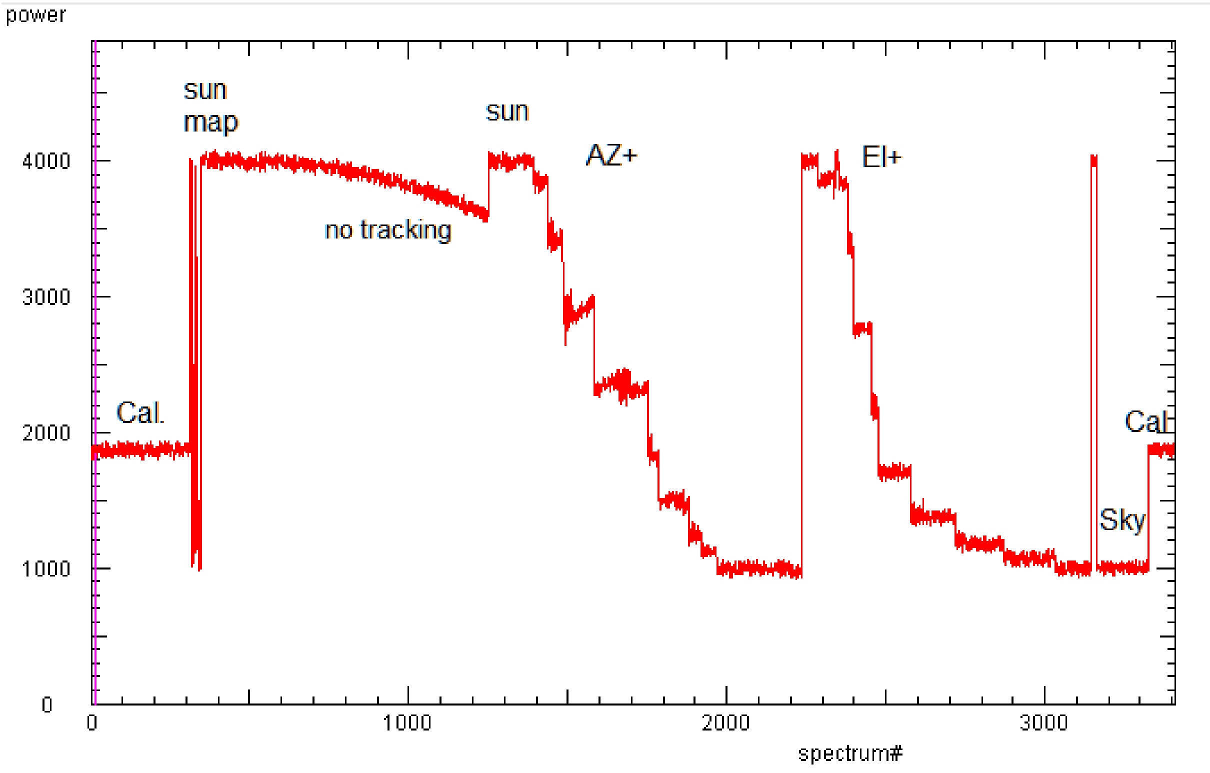
Then, the solar flux was measured by direct pointing, and along a measurement of the empty sky at the same elevation as well as the wall of ISU library for the flux calibration, results (assuming an HPBW=6°, taken from the solar mapping) were obtained that are as expected form the simulation.:

Furthermore, the flux was measured at several positions offset in azimuth and elevation, in order to measure the half power beam width in a different way.

The team F+S measured several positions on either side of the lobe centre, which shows that the (simulated) antenna pattern is well symmetric:



The team L+N choose to explore the antenna pattern to large offsets, which would reveal the assumed Gaussian shape of the main lobe:



Solar fluxes and telescope efficiencies

From the antenna temperatures of the sun and the geometric cross section of the antenna one can derive the solar fluxes at the two frequencies

$$\text{Flux} = 2\ k_B\ T_{antenna} / A_{geom}$$

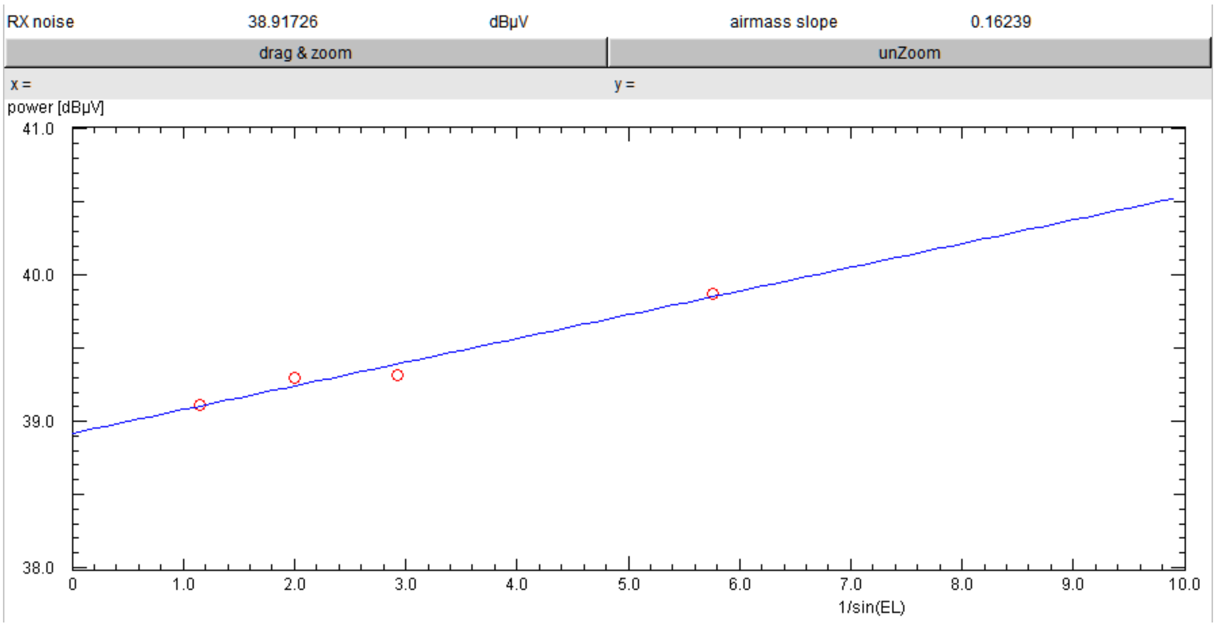
Comparison with the data from daily observations published by NOAA, the efficiencies of the telescopes can be determined $\eta = \text{Flux} / \text{Flux\_NOAA}$:

Freq. [GHz]	Team	T_antenna [K]	Power [W]	Flux [SFU]	Efficiency
12.5	F+S	1104	1.52 E-20	339	0.81
12.5	L+N	1185	1.63 E-20	363	0.86
8.8	NOAA (San Vito)	---	---	236	---
15.4	NOAA (San Vito)	---	---	523	---
1.42	NOAA (San Vito)	---	---	87	---

The values obtained are very reasonable and within what could be expected from such a simple approach.

Atmospheric noise on 12.5 GHz

Every team took measurements of the sky background signal at elevations of 10, 20, 30, and 60°. Linear Regression of these data, as a function of the abscissa 1/sin(elevation) permits to separate the constant contribution to the noise from the receiver (and the cosmic microwave background) from the elevation-dependent atmospheric noise:



Observers	RX noise level [dBµV]	Slope [dB]	Weather
JK (19 jun 2011)	+38.62	0.127	Blue skies
JK (15 nov 2011)	+39.08	0.166	Fair
T+C (7 dec 2011)	+38.34	0.455	Overcast+rainy *)
JB+F (7 dec 2011)	+38.71	0.367	Overcast+rainy *)
G+PA(7 dec 2011)	+38.64	0.346	Overcast+rainy
JB+F (4 jan 2012)	+38.39	0.151	Slight overcast
PA+T (4 jan 2012)	+38.72	0.132	Slight overcast
JK (25 jan 2012)	+38.52	0.128	Fair, some clouds
JK (3 feb 2012)	+39.28	0.103	Clear skies
JK (24 jan 2013)	+38.73	0.140	Overcast
F+S (24 jan 2013)	+38.80	0.170	Overcast
L+N (24 jan 2013)	+38.70	0.213	Overcast
JK (7 feb 2013)	+38.58	0.160	Light overcast
F (7 feb 2013)	+38.95	0.170	Light overcast
L+S (7 feb 2013)	+38.92	0.162	Light overcast
JK (7 feb 2013)	+38.89	0.150	Light overcast

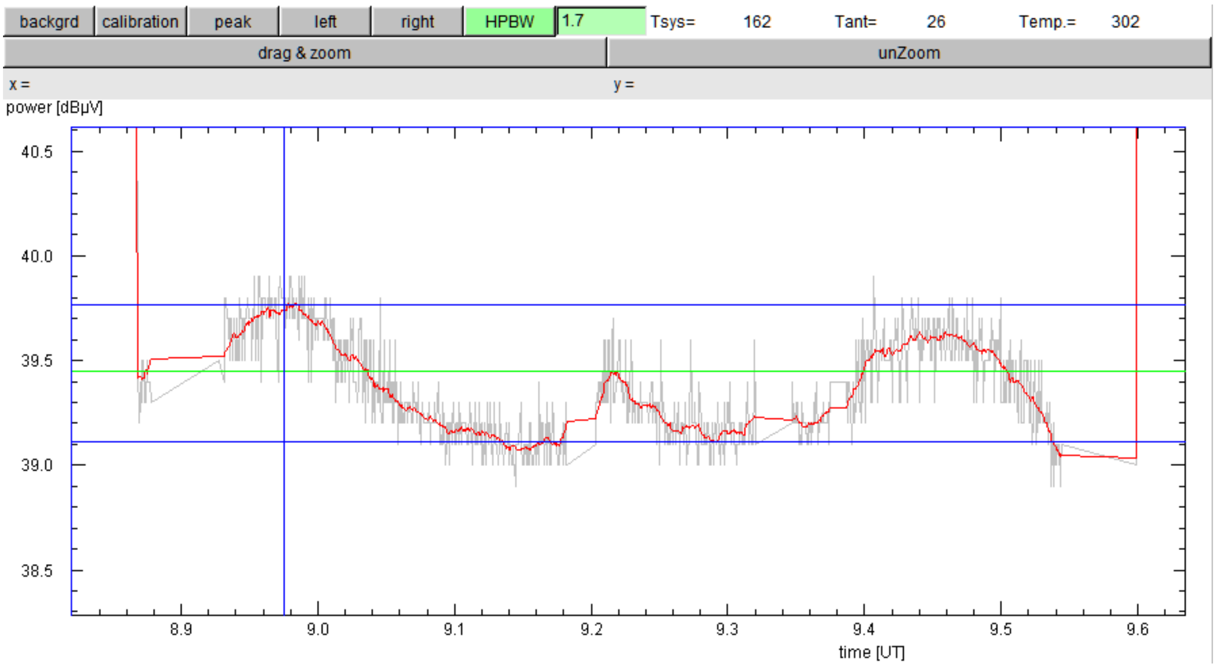
*) these teams noted that the noise level varied during observation at a fixed position. This would be caused by individual heavy clouds passing through the antenna beam.

The measurements are consistent with data taken at other times and during last year's MS2 class. Also, we had no difficulty to observe the moon on 7 feb, which indicates low atmospheric opacity. All these observations show that the slope of the relation is well-correlated with the amount and thickness of clouds in the sky, i.e. the amount of water vapour.

It was noticed by Sarah during the first session that the datum at 20° elevation is significantly below the recursion line. Inspection of all data set taken this year shows that this is present more or less strongly in all data sets. Furthermore it is independent of the azimuth at which the profile is obtained. One possibility could be that the data at 10° (1/sin(EL) = 5.8) is stronger than expected, for instance because of pickup of ground radiation. This could be tested by measurements at 15°, say.

Lunar observations on 12.5 GHz

During the second session the moon could be observed. Like for the Sun, a partial drift scan was done after the Moon had been found by carefully moving the telescope to the position of maximum signal. The figure below shows one good lunar scan, followed by a partial miss, and another good scan:



As the lunar signal is only 0.5 dB above the sky, and the fluctuations of the individual measurements are about 0.3 dB, this procedure is somewhat delicate. But after very few tries, the teams mastered the technique and obtained valid data. The deduced lunar surface temperatures are acceptable, although a bit high.

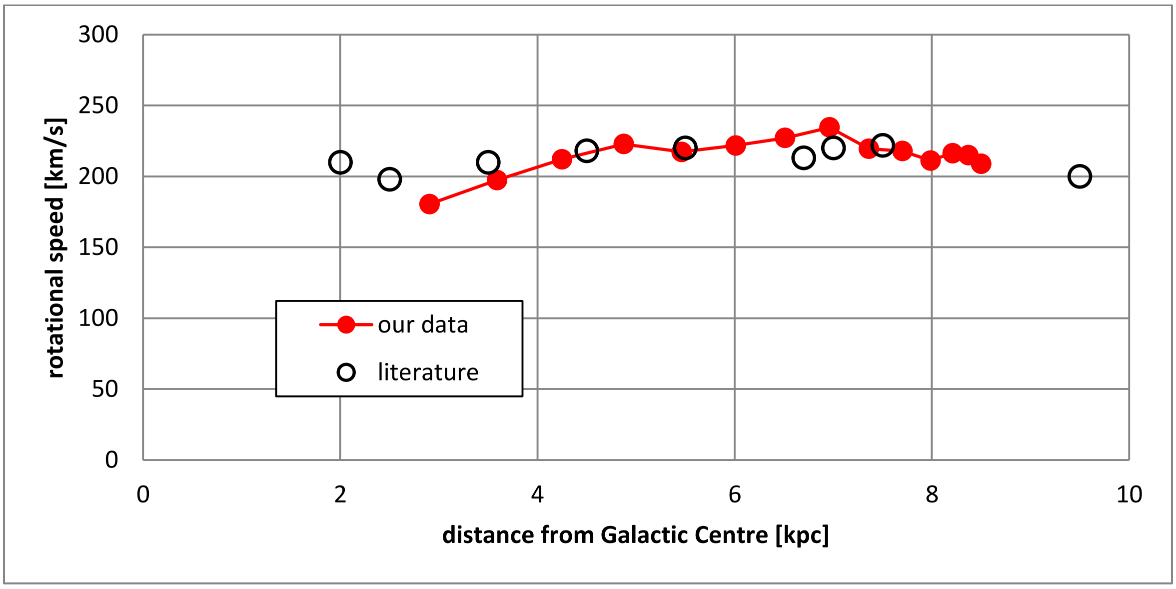
Team	T_system [K]	T_antenna [K]	T_moon [K]
F (+O)	162	26	302
F +(O)	162	19	228
L+S	189	26	304

Since the sky was partially overcast and changing, it is quite probable that the observations done at different times captured different levels of the sky background – perhaps influenced by a passing denser cloud.

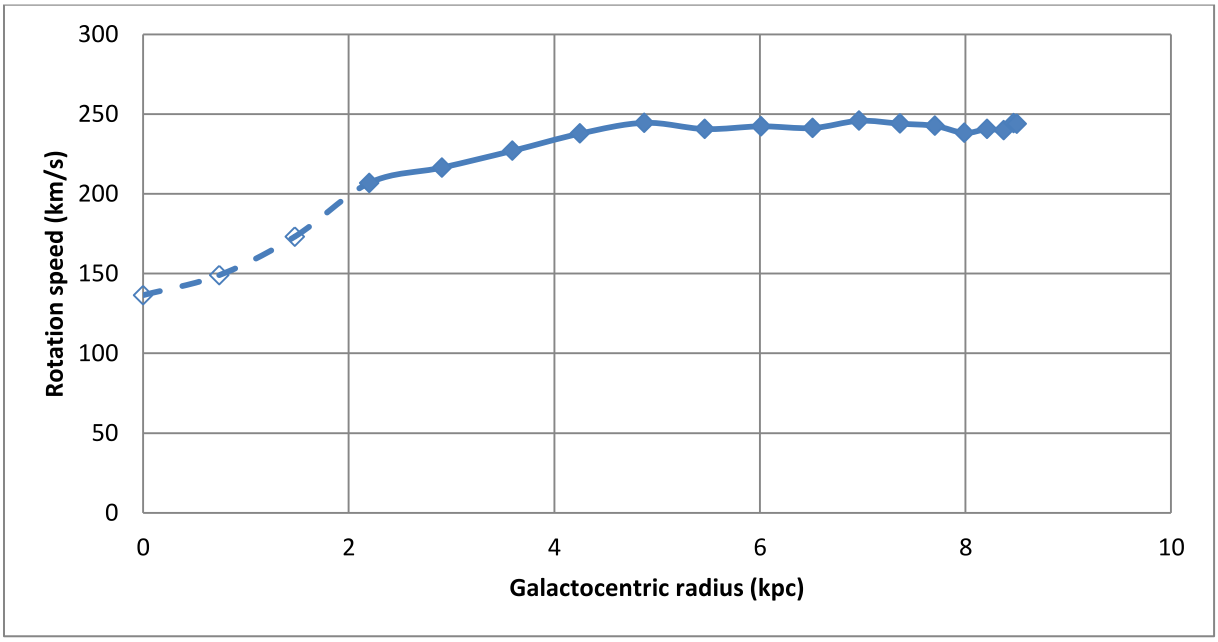
Galactic rotation curve (1.42 GHz)

Since we could not operate the ESA-Haystack but in simulation mode, the students were given real data that had been obtained earlier. They subjected these data to a full analysis, where linear baselines were subtracted from the averaged spectra and the maximum radial velocities were obtained from the reduced spectra.

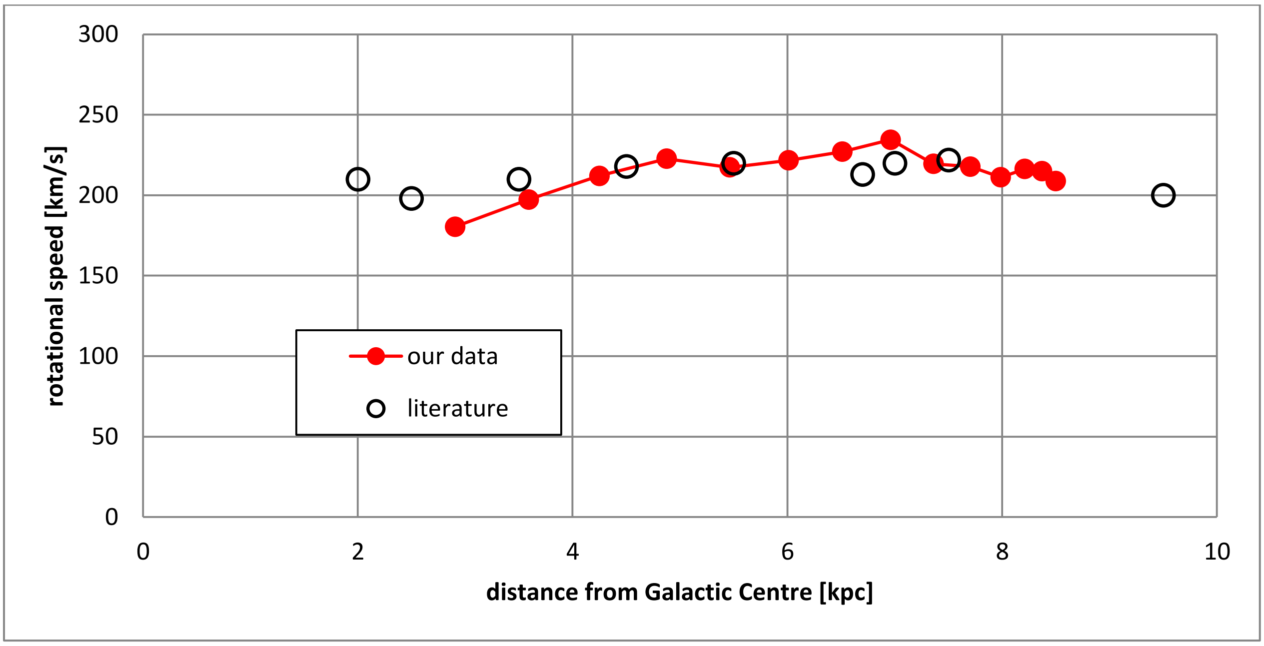
It happened that these spectra were of very good quality, showing also the weak high-velocity emission at low galactic longitudes. Thus the rotation curve could be determined to quite low galactocentric radii, as shown in Nicolas' analysis:



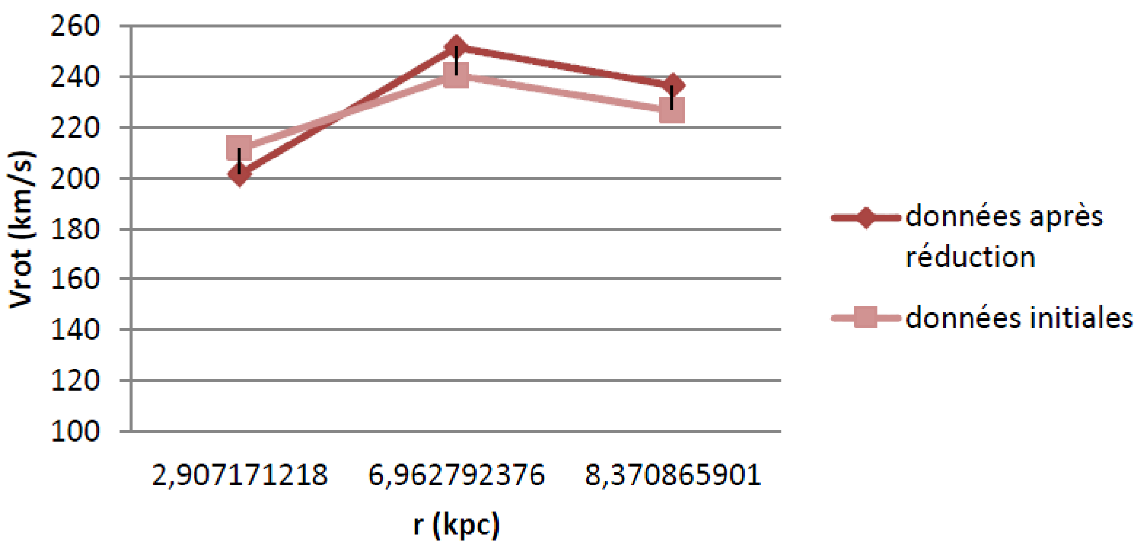
Florie's data set gave very similar results (the innermost 3 data points (l<20°) must be ignored because of the limited sensitivity of the telescope and the difficulty of the baseline subtraction)



Sarah's data set gave practially identical results:



Laura showed for three longitudes (20°, 55°, and 80°) how well the values read off the screen from the simulated data ('données initiales') agree with those derived from a detailed analysis of her set of real data.



All this demonstrates that in our Galaxy we still have the problem of a flat rotation curve, whose explanation requires either Dark Matter or a modification of Newton's law of gravity ...