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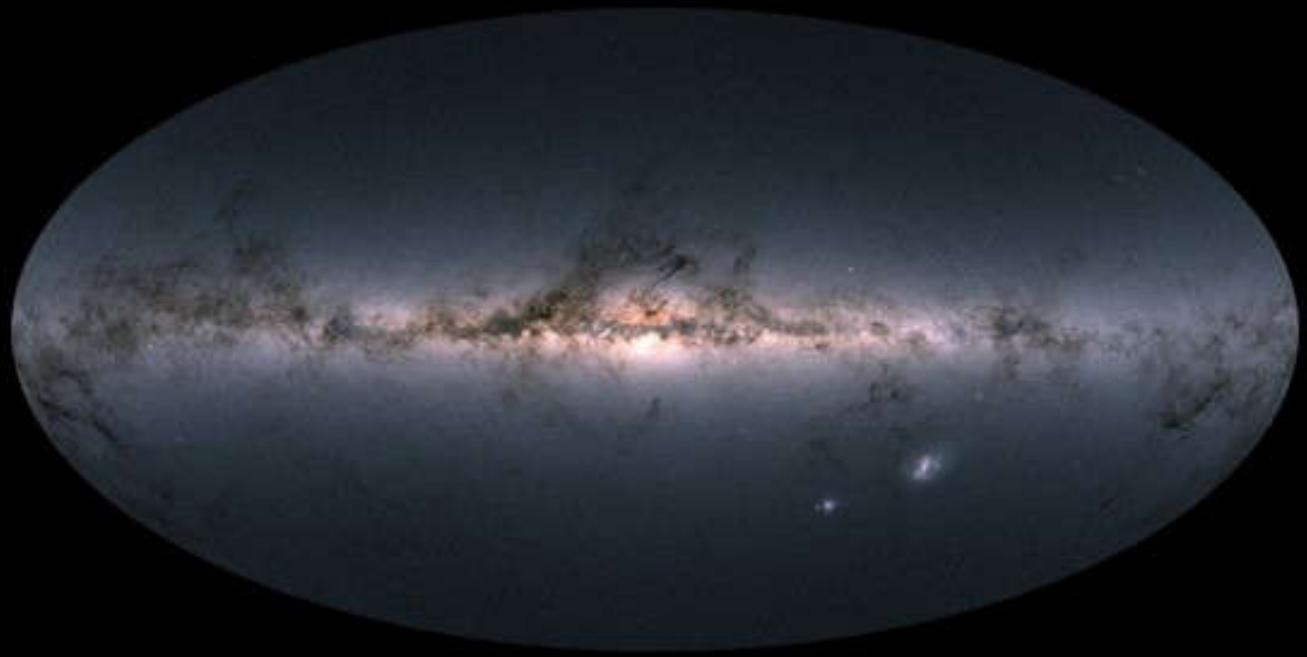
Midden Nederland

Making a map of the Milky way

Andries Boone



Star observatory ‘Midden-Nederland’
Amersfoort, Netherlands

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Making a map of the Milky way

our radio group

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Situation Eucara 2016, Dwingeloo (NL):

We received a signal, confirmed to be the ‘hydrogen line’ (H1)
To make a chart of the Milky way we needed:

- More reliable and weather-proof hardware and more ‘smart’ software
- Accurate pointing of the dish to capture a specific part of the Milky way
- A table that calculates the distance of that part to the galactic centre

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OUR H1 RECEIVER

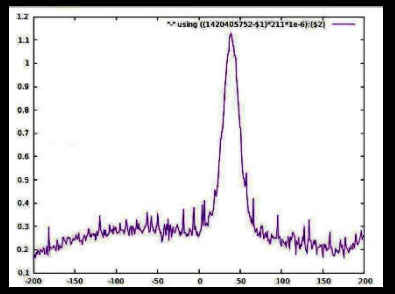
Receiver (RTL SDR):
TCXO dongle, 8 bits, Noolec

Low noise amplifier (LNA):
G4DDK building-kit VLNA21
Noise figure: 0,3 dB @ 1420 MHz

Interdigital bandpass filter (BPF):
1420 MHz, low loss (PA2DOL)

Inline amplifiers (Amp):
TV sat, 18 dB

PC Software
RA_RTL_power FFTW



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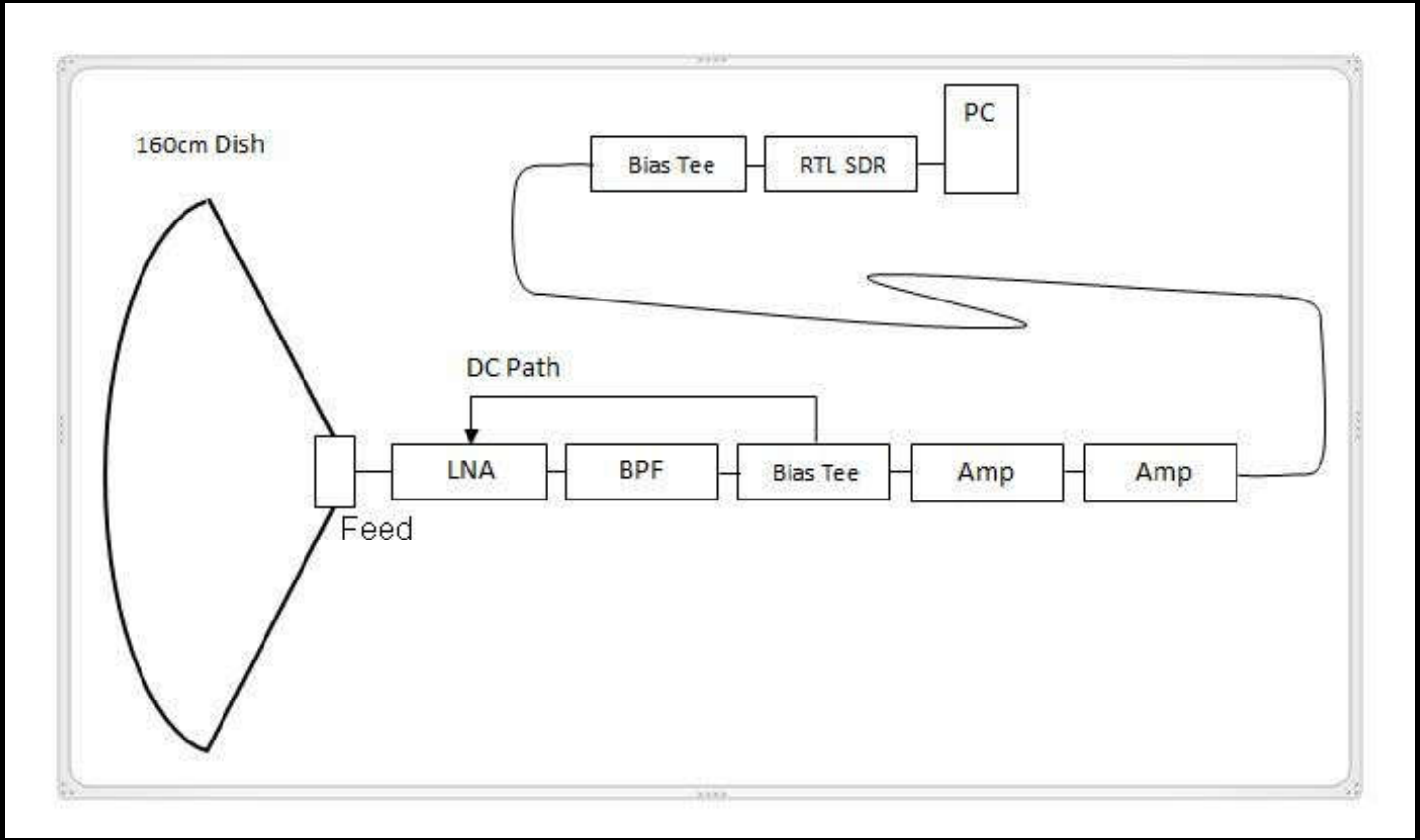
SETUP remains the same:

- 150 cm dish f/D=0,5
- software defined radio (SDR) @1420 MHz
- band with approx. 50 MHz



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WHAT'S NEW?

Hardware

•Dish

- 150 cm RF Hamdesign prime-focus dish on the roof
- weather-proof housing of LNA and filter-box

•Azimuth and elevation rotors, remote controlled

•Temperature controlled SDR-dongle (TCXO)

•Raspberry Pi (reception and capture (data-processing)

•Remote control of the whole H1-station @ home

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OUR DISH

Prime focus or offset?
Our choice: prime focus,
RF Hamdesign 150 cm dish

Rotor(s)
Azimuth: old TV Stolle rotor
-modified: pulse counter
Elevation: Sat TV actuator
-modified: pulse counter

Feed
Waveguide ‘Cantenna’, home-built

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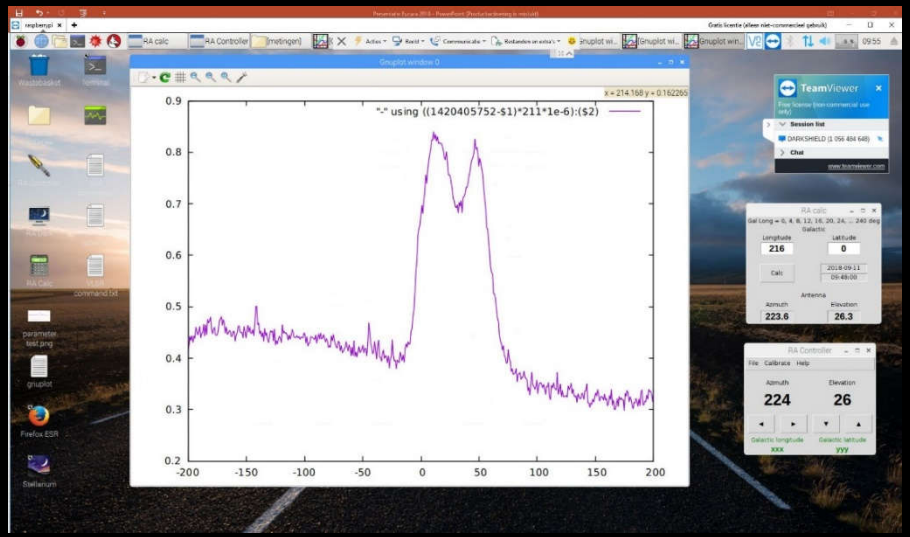
WHAT'S New)
Software improvements:

- File name in galactic degrees
- Integration time 150 sec.
- GNU-plot H1-profile appears on screen after capture:

x = Doppler-shift y = field strength

- Calculation tool galactic degrees→ Az & El



View of the control-screen from the Raspberry Pi

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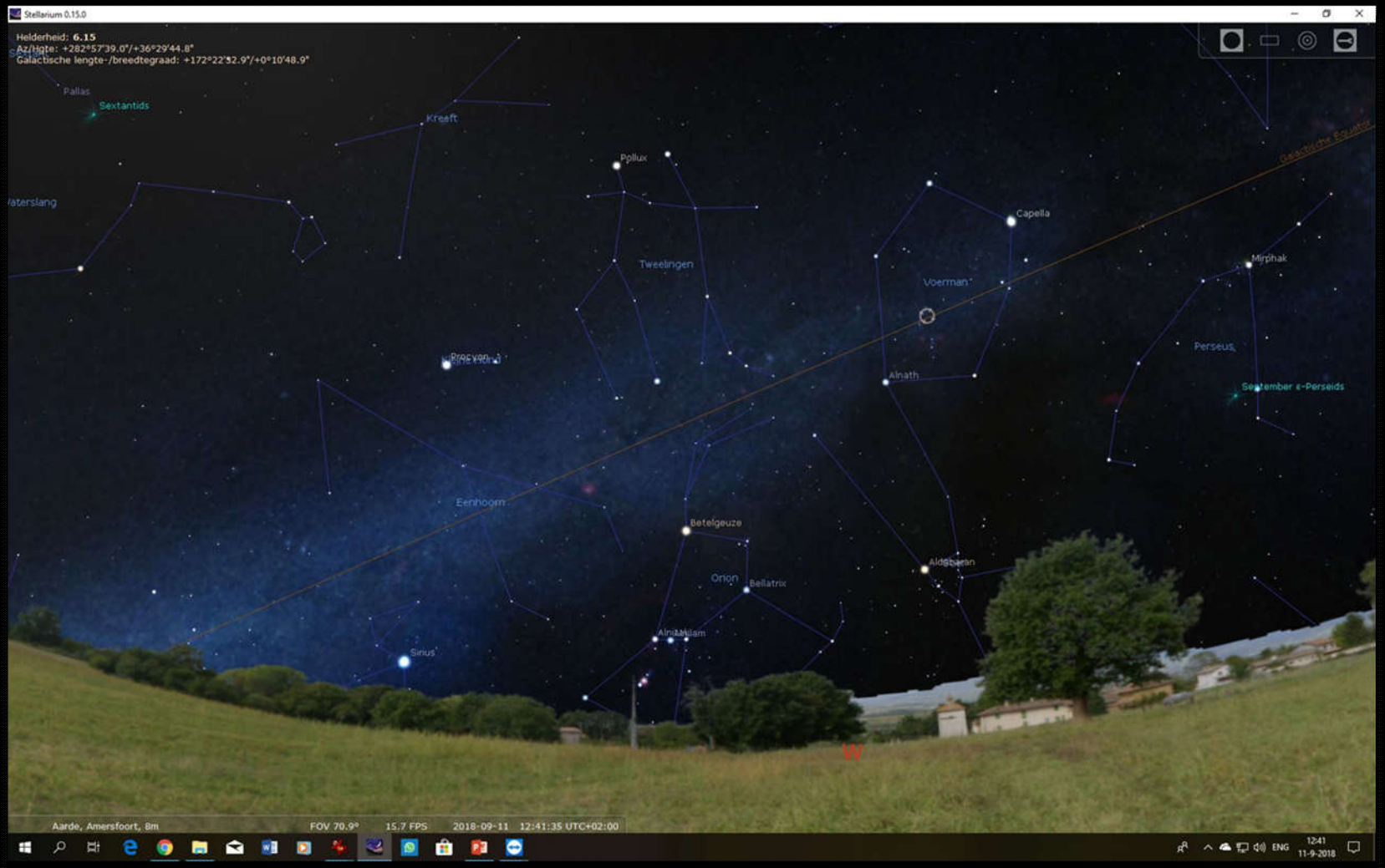
MAKING RECORDINGS

- We use ‘Stellarium’ to plan a series of records along the galactic equator
- In steps of 4 degrees, from 0-240 degrees (0,4, 8, 12, 16 etc.)



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THE THEORY BEHIND THE MAP

You find it at Salsa, Onsala Sweden
https://vale.oso.chalmers.se/salsa/welcome

SALSA
such a lovely small antenna

Username * Password *

Create new account Request new password

Log in

Welcome | Live webcam | Observe | Telescope schedule | Software | Documentation and support

Welcome to SALSA

SALSA means "Such a lovely small antenna" (or in Swedish: "Sicken Attans Liten Söt Antenn") and refers to our small (2.3m) radio telescopes situated at Onsala Space Observatory in Sweden. Anyone may control these telescopes via internet for free. SALSA is a part of the European Hands-On Universe project, EU-HOU, to bring front-line interactive astronomy to the classroom. Most SALSA users observe emission from hydrogen in the spiral arms of our galaxy, the Milky Way. These observations can be done via your webbrowser during day-time as well as night-time, and even in bad weather. Using SALSA you can make a rough map of the spiral structure of our galaxy by yourself. You may also find evidence for dark matter! For more information on how to use the telescope, please see the documentation available at this page.

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THE THEORY BEHIND THE MAP

The theory behind the Milky Way

2.1 Preliminary calculations

Let us imagine that we point our radio telescope towards a gas cloud in the Galaxy. In Figs 2.1 and 2.2 we see that the actual velocity of the cloud (V) makes an angle with the line-of-sight. Thus, we will measure merely *a projection of the cloud's velocity on the line-of-sight* (V_{los}).

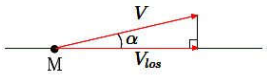


Figure 2.1: The velocity of the cloud projected on the line-of-sight.

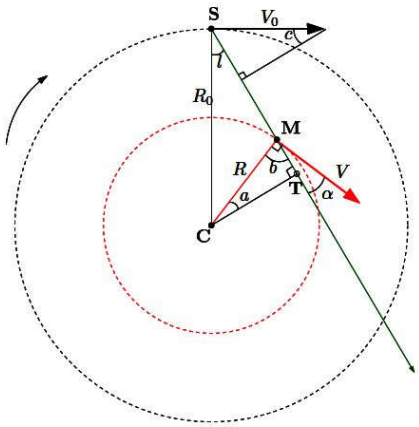
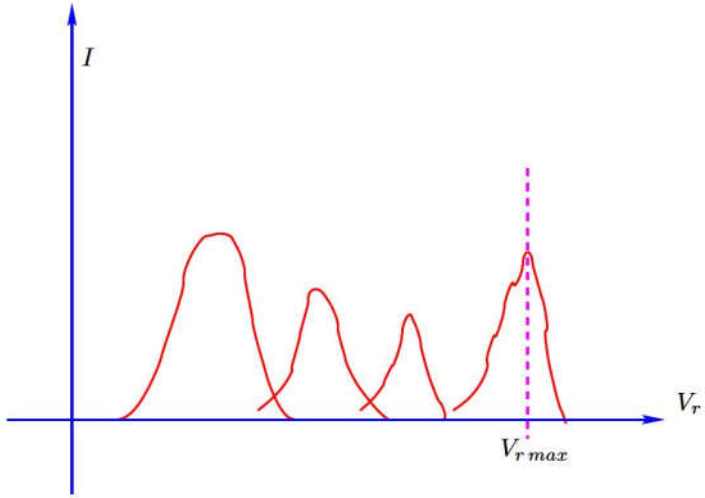


Figure 2.2: Geometry of the Galaxy.

- H1-clouds are concentrated in the spiral arms
- Each peak corresponds to a cloud with some relative velocity
- We look for peaks in the H1-profile we receive on 'the line of sight'



There can be multiple velocity components in the observed spectrum, each peak corresponds to a cloud with some relative velocity.

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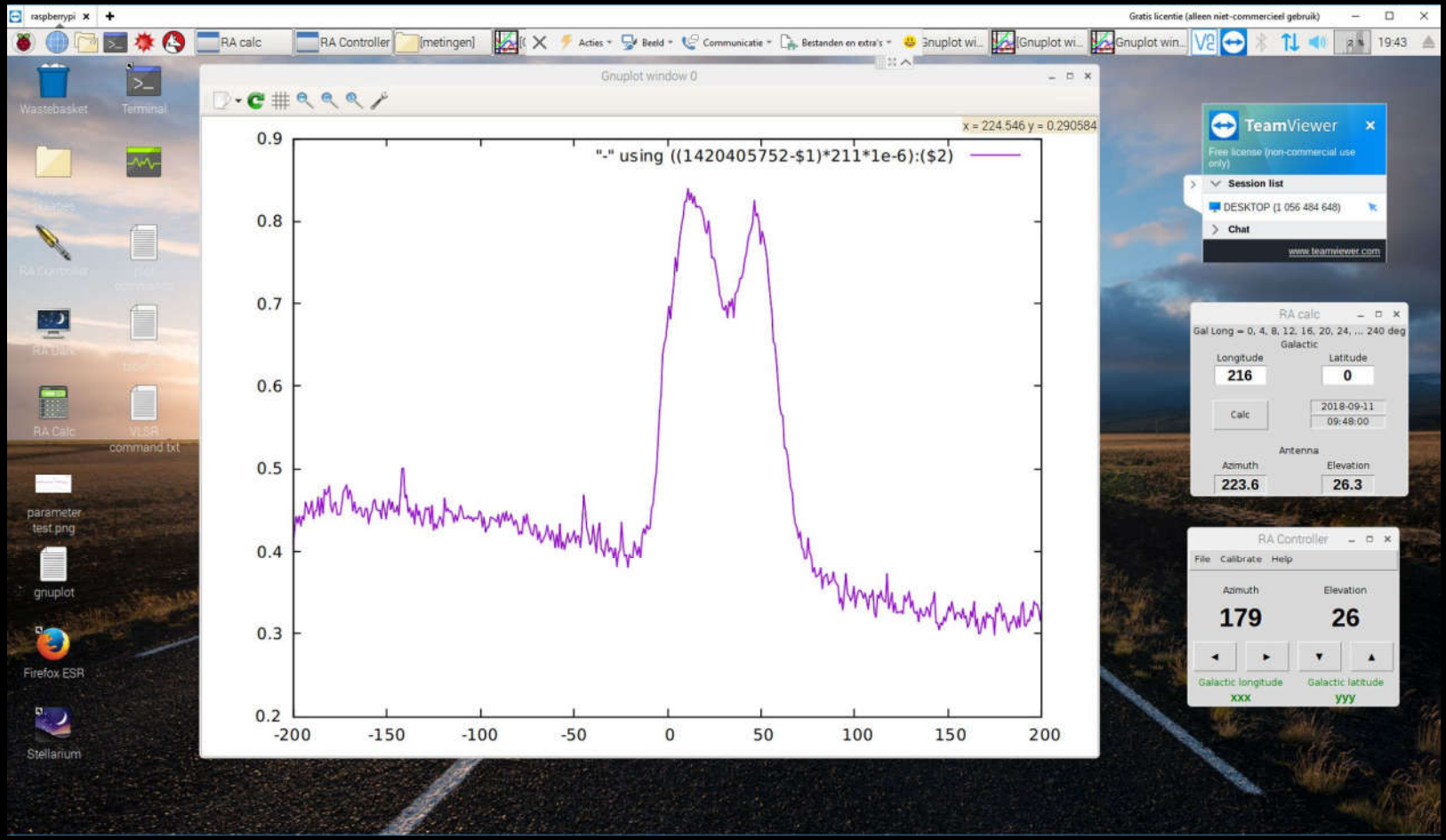
OUR RESULTS 1

We translate the desired galactic length into Az&El, point the antenna to that direction and record



Result: Received H1-profile on the control panel in a remote session

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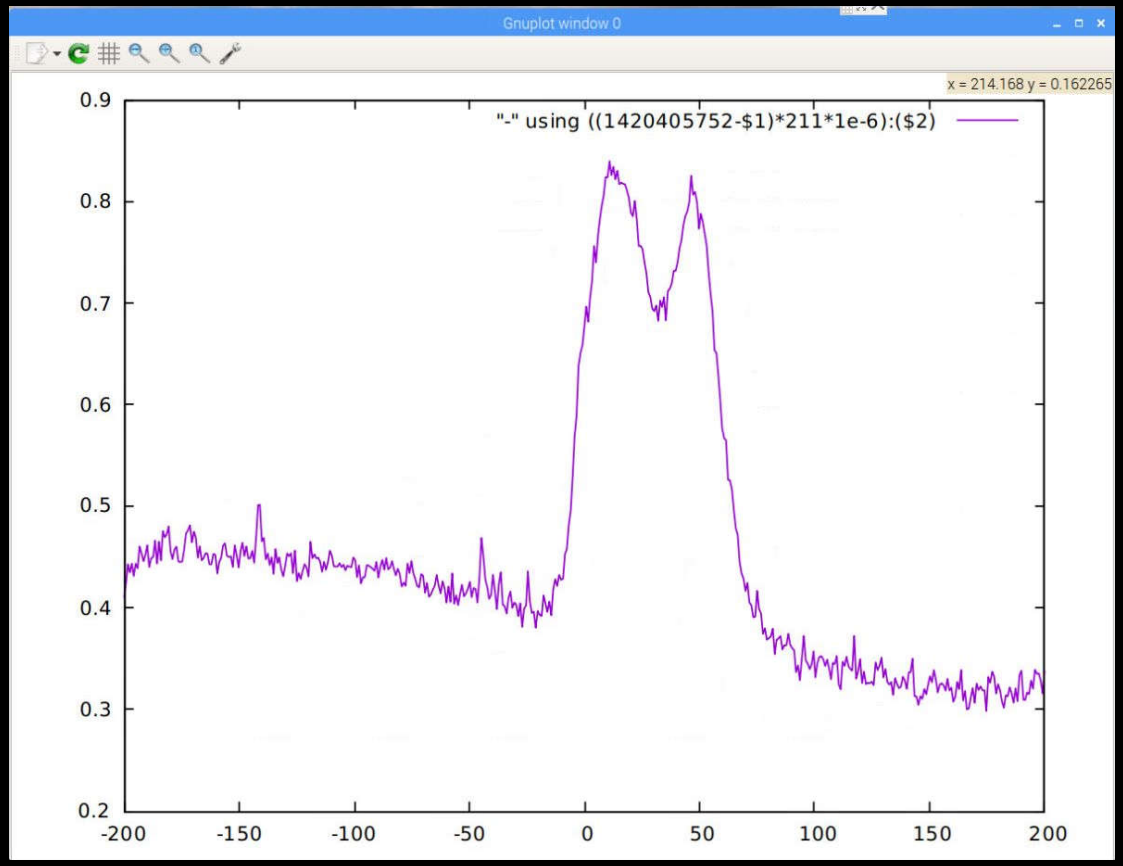
OUR RESULTS 2

- Clear H1-profile in range 20-240 galactic degrees
  (every 4 degrees on the galactic equator from 0-240)



@ Galactic length 216 degrees: 2 Doppler-shifts (without Gaussian fit)

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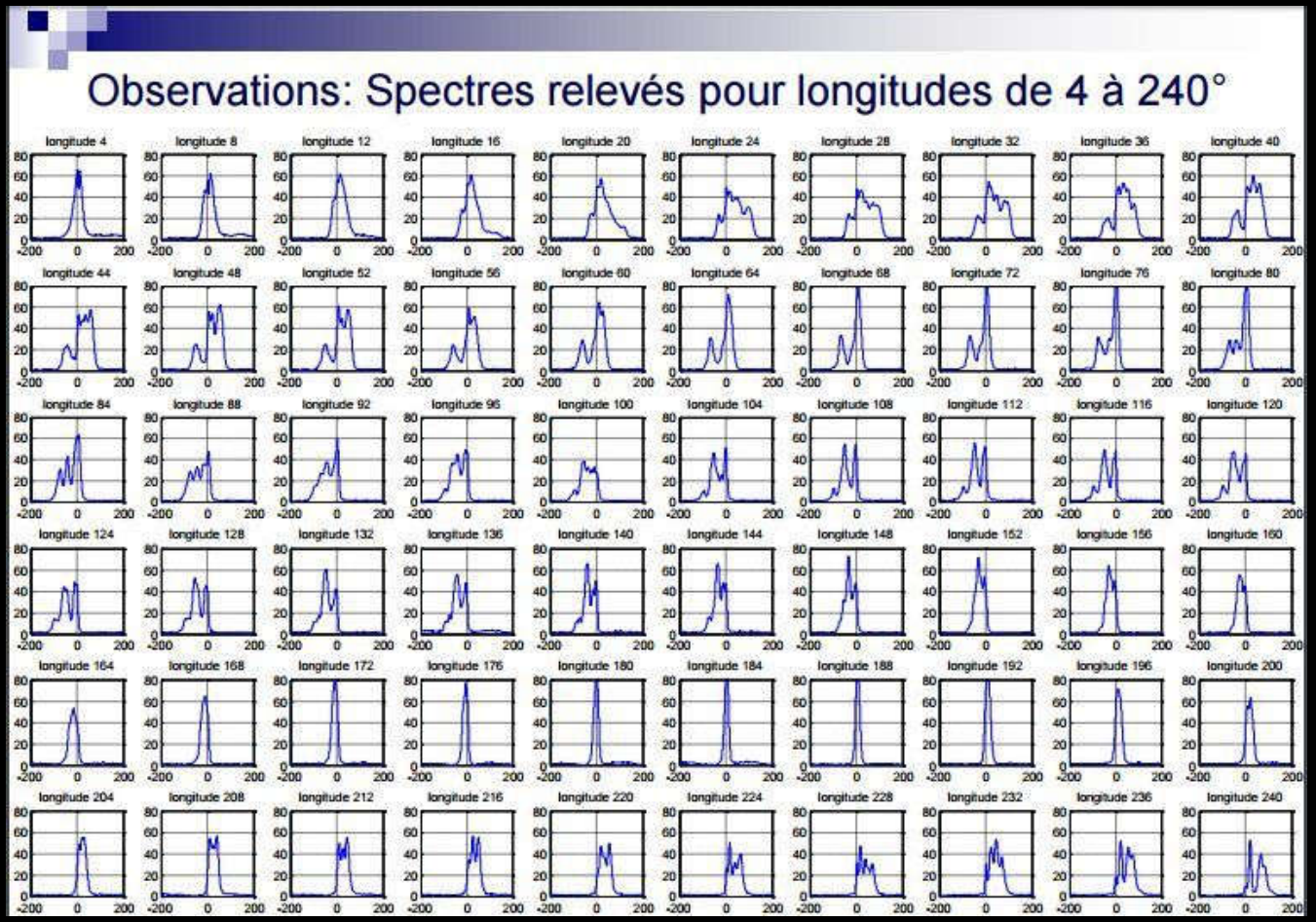
REFERENCES

1. Sun noise measurement: 4 dB above noise level
2. Every galactic length has its own ‘fingerprint’



- you can compare these H1-profiles with your own results! (source: F1EHN)
- you can also collect these data online @Salsa (Onsala, Sweden)

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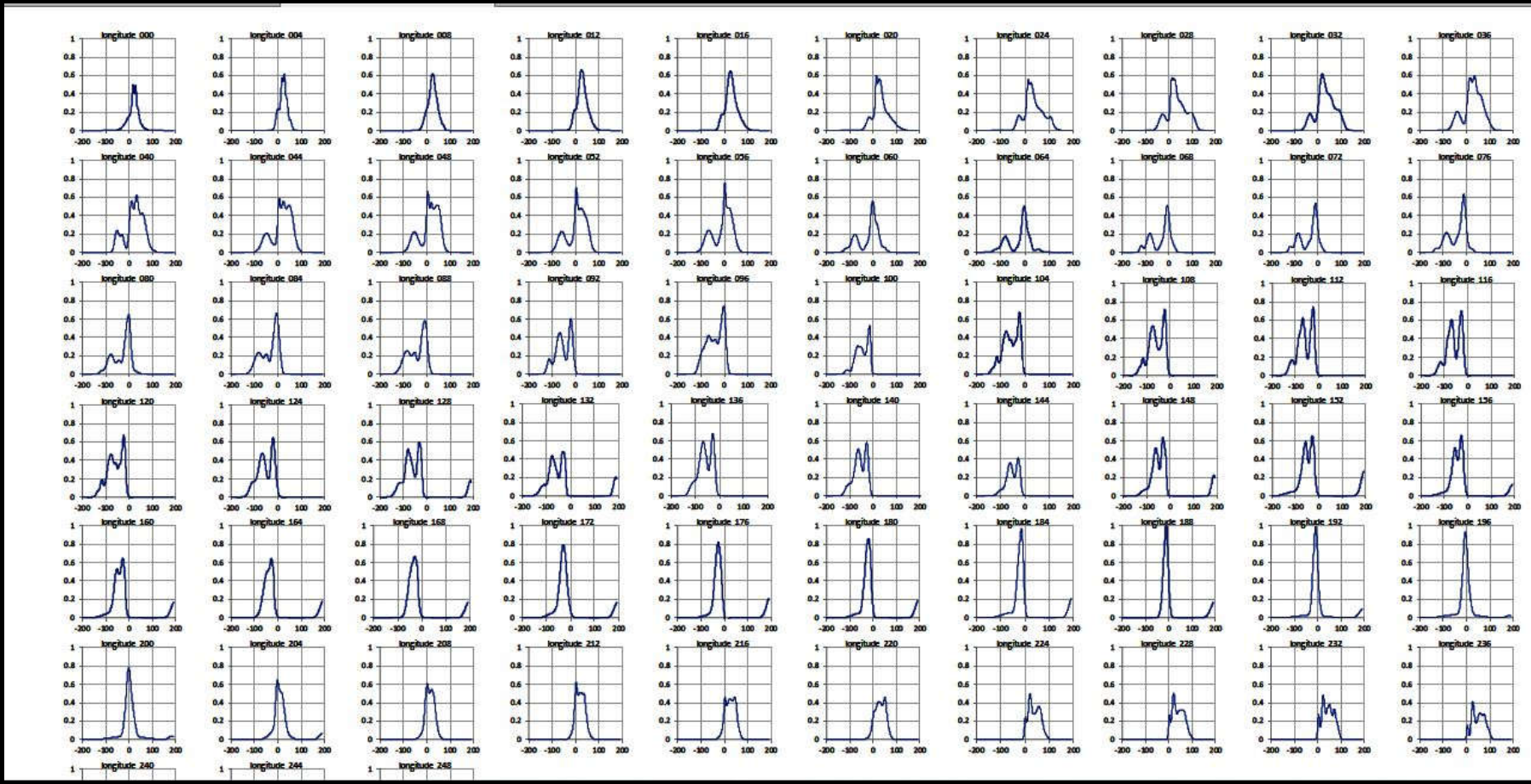
OUR OWN H1-PROFILES (000-240 Degrees)

60 ‘Tiles’ (note: we get smooth H1-profiles after Gaussian fit)



Note: field strength is lower at 000 and 232/236 due to low elevations

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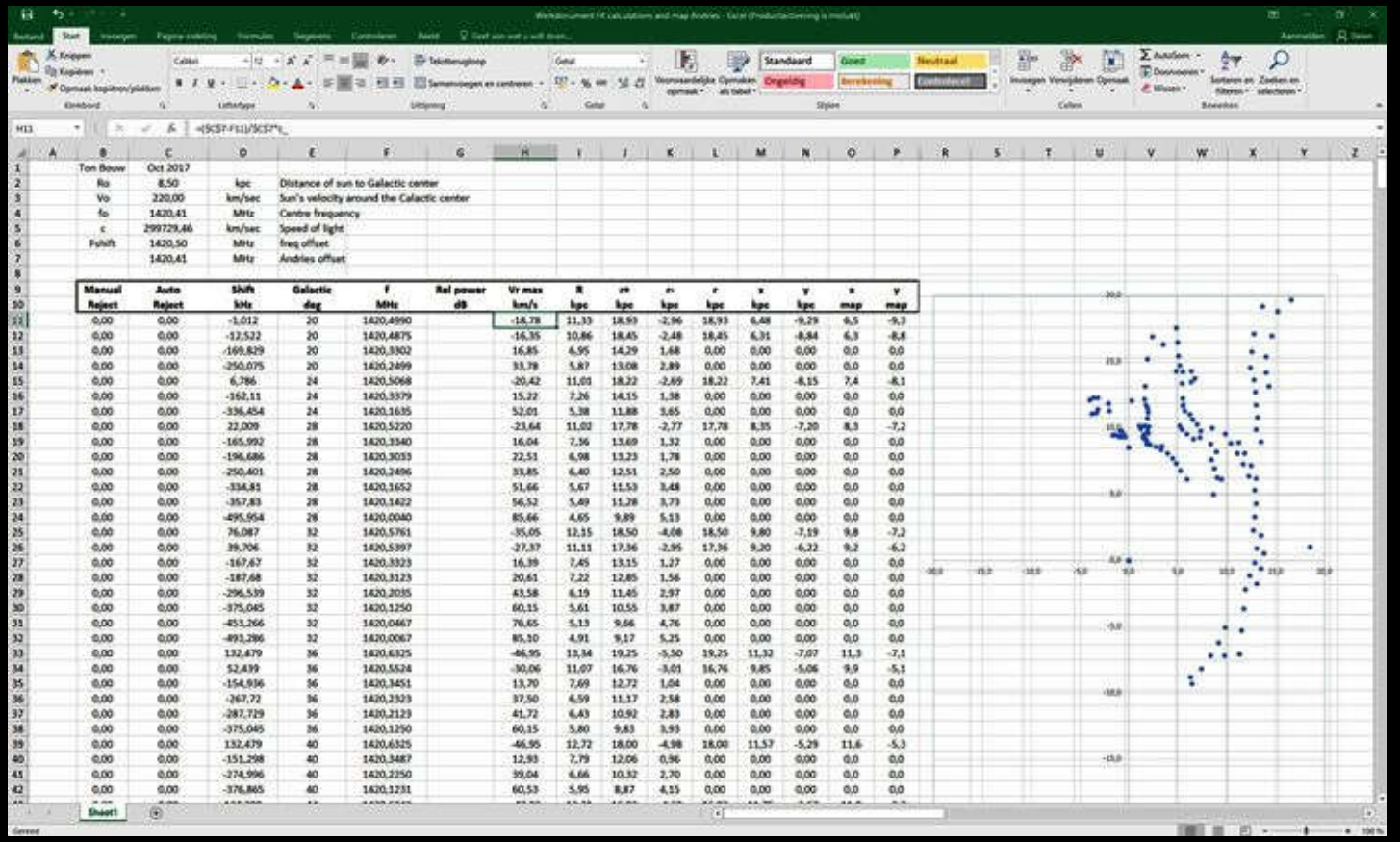
TRANSLATING DOPPLER-SHIFTS INTO DISTANCE

1.Smooth the H1-profile by a Gaussian fit
2.Determine the Doppler-shift(s) for each substantial, ‘convincing’ peak;
3.Each peak represents the intersection of a spiral arm with the line of sight
(the galactic direction where to the dish is pointed at the galactic equator)
4.Enter these shifts into a translation table (Excel)
5.As a result you get a map of the Milky Way as if you are looking on it from above



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LEGEND OF MILKY WAY MAPS

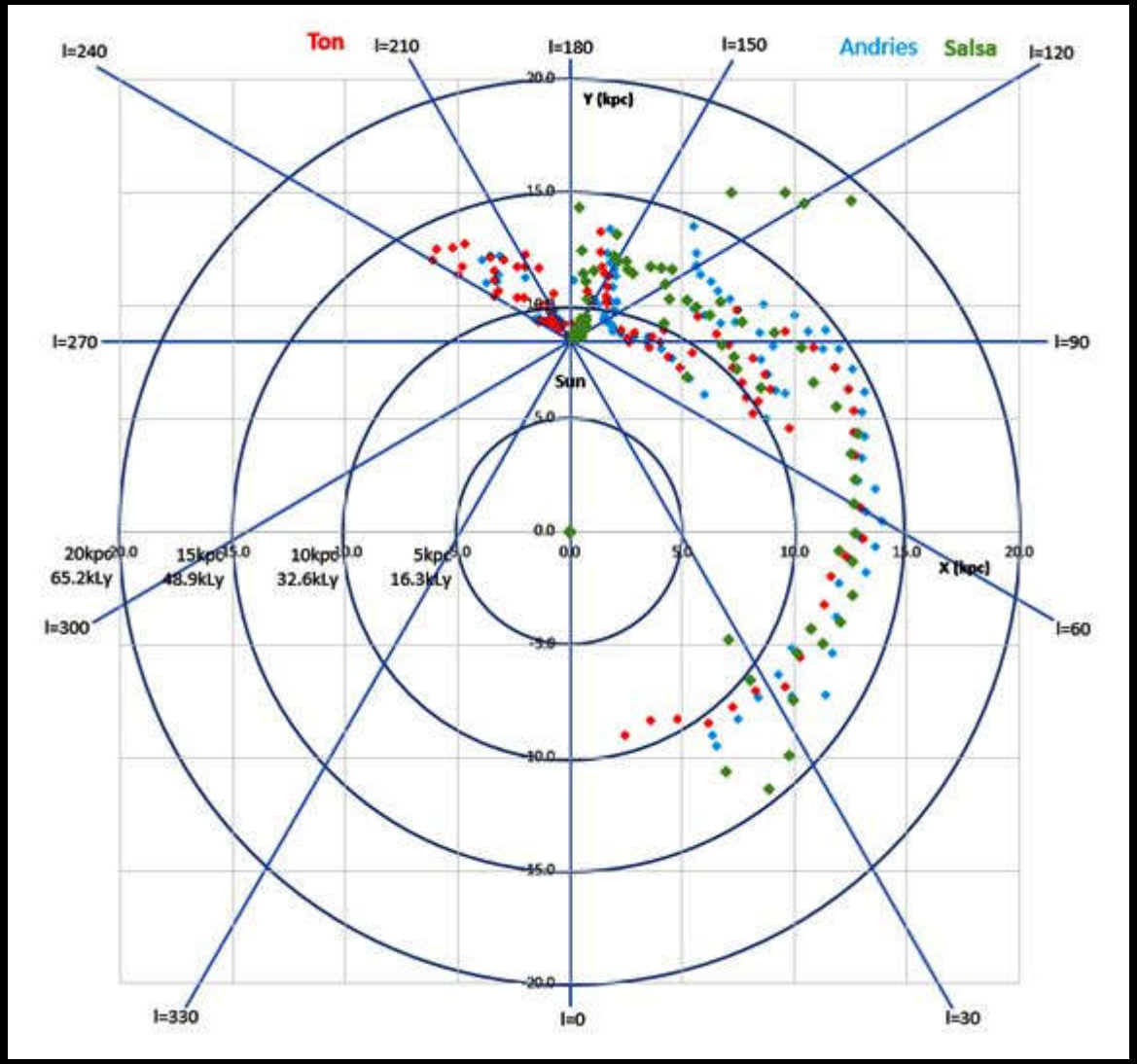
Legend:

Orientation degrees:
0 degrees: starting at the bottom, increasing anti-clockwise to 360

Distance scale:
0-20 kpc (+ & -)

Centre point map:
galactic centre: (x=0, y=0)
sun: (x=0,y=8.5)

Quadrants:
quadrant I: bottom right (0-90)
quadrant II: top right (90-180)
quadrant III: top left (180-270)
quadrant IV: bottom left (270-360)



Map made in Excel (several observers) Green points: records from Salsa

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ANALYSIS OF THE MILKY WAY MAP:

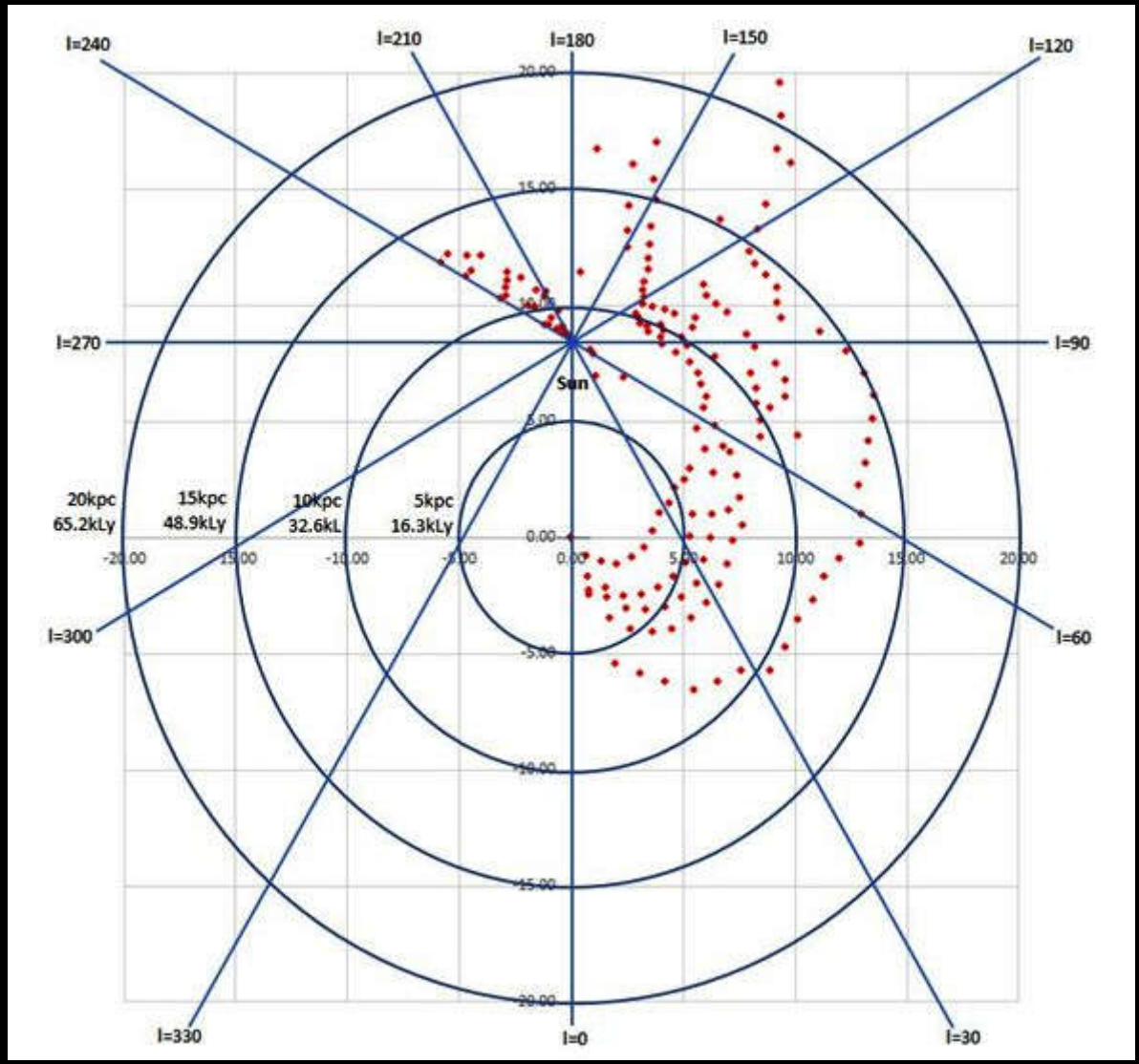
We see spiral arms!!

Arms continue to the galactic centre (x=0, y=0)

Deviations in sector 90-150 degrees ?

Enough resolution??

Note: the wide aperture angle of the antenne and the absence of records around the galactic equator (at galactic latitudes > 0) limit the resolution



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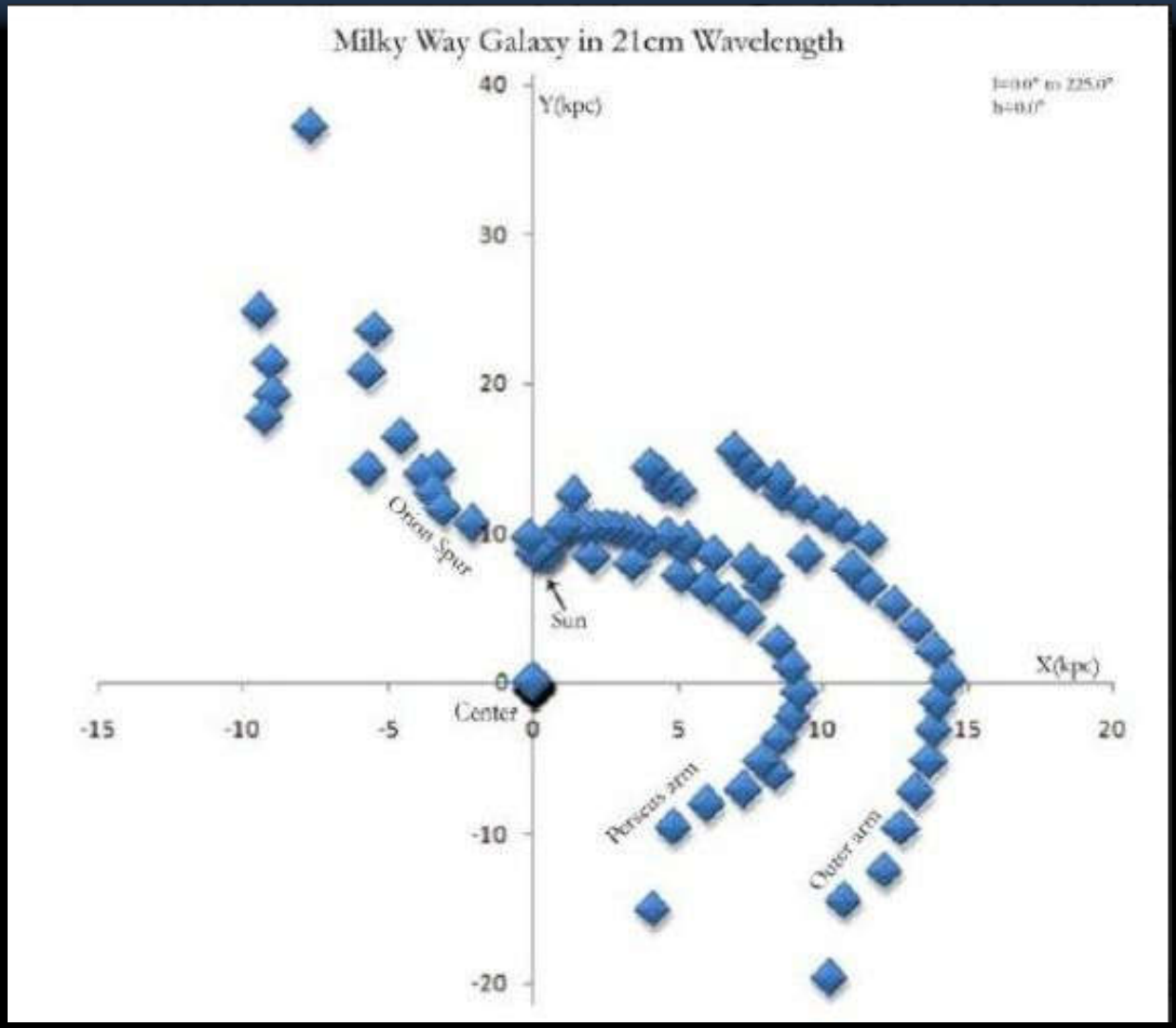
MAKING MAPS OF THE MILKY WAY: OTHER OBSERVERS



Source: Tarif Rashid Santo (Salsa)

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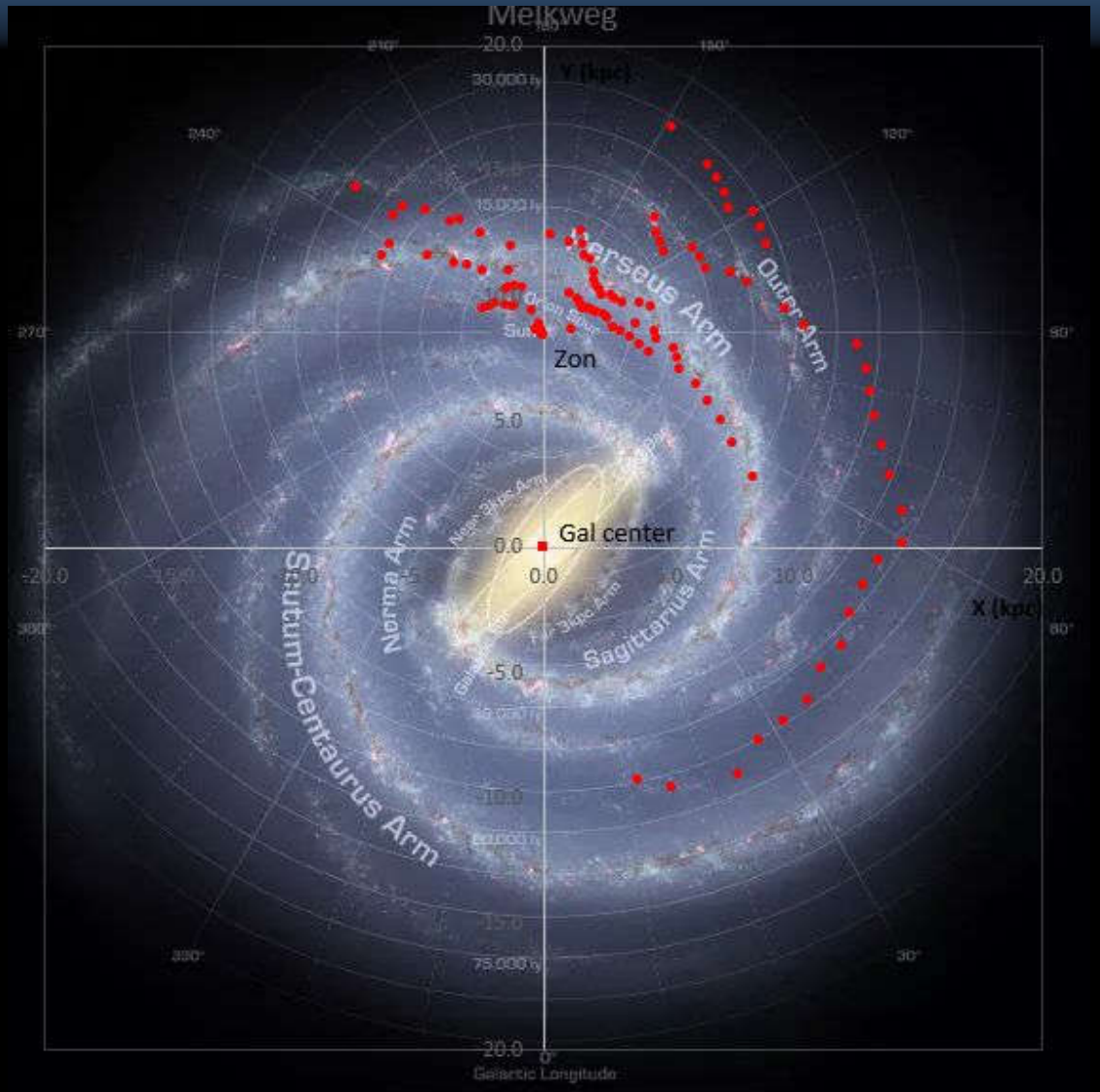
OUR MAP ON A NASA MILKY WAY BACKGROUND!



Why is the Sagittarius arm not filled in quadrant I ?

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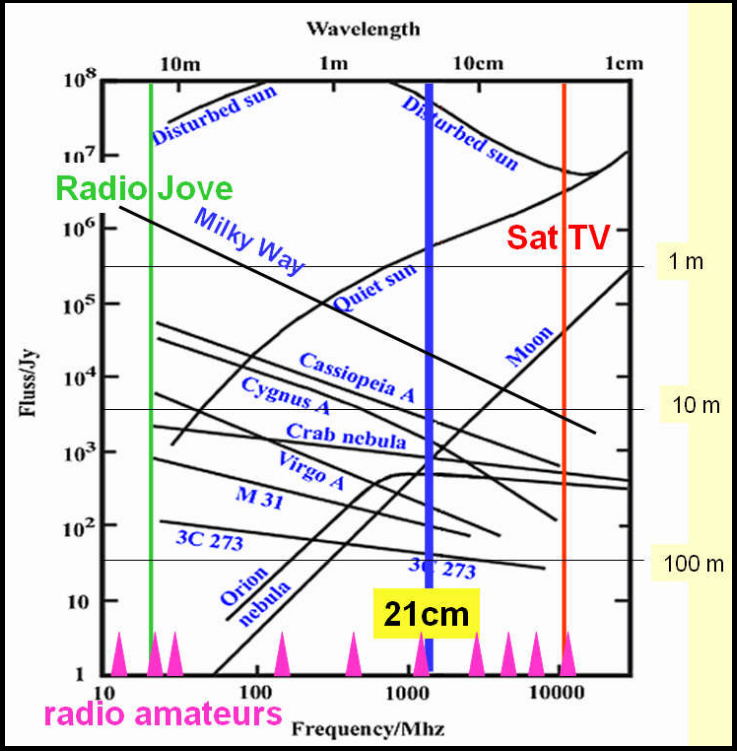
FOLLOW-UP: WEAK SOURCES?



We want to receive much weaker sources like Cas. A

Conditions:
- dish > 3 meter, SPID rotor, heavy mounting

As a result we need :
- (much) more money to invest than we have
- permission of local government (our location is in a protected area)

Solutions:
- Fundraising
- Alliances with other observatories, universities and others

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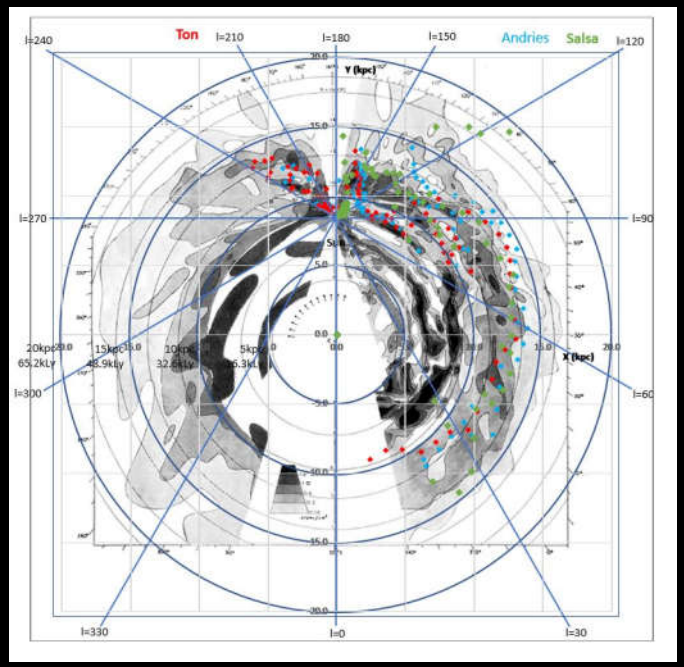
WE CONSOLIDATE THE H1-PROJECT

- Shortly we start a national project on H1-reception
- - in collaboration with several other observatories in The Netherlands and Belgium
  - with support from the Royal Netherlands Association for Meteorology and astronomy (KNVWS)
- This is an Example project to make a map of the Milky Way on the basis of our experiences (with a small antenna)
- Sharing knowledge, especially on hardware and software pitfalls in H1-reception



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THANK YOU FOR YOUR ATTENTION!

Any questions??
All suggestions and help are welcome!!

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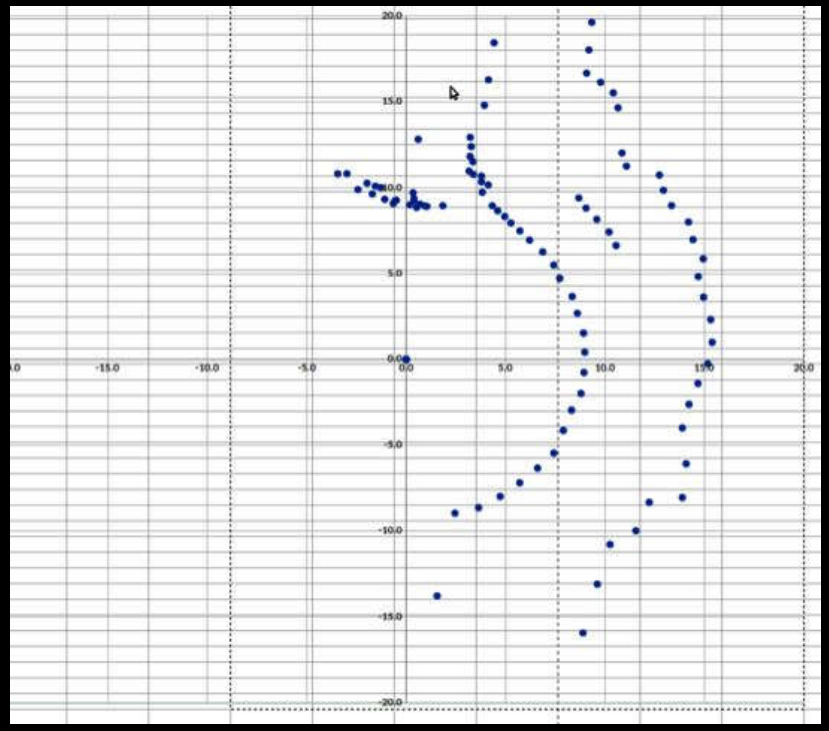
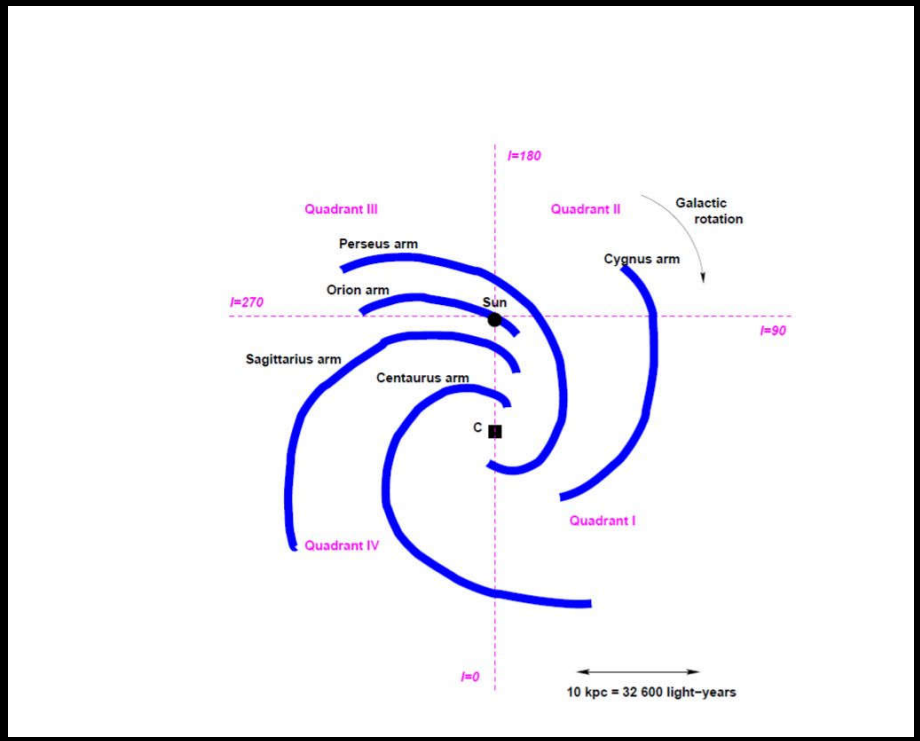
APPENDIX

Other Milky way maps





Map made by our observer Max Hendriks

Map from Salsa documentation

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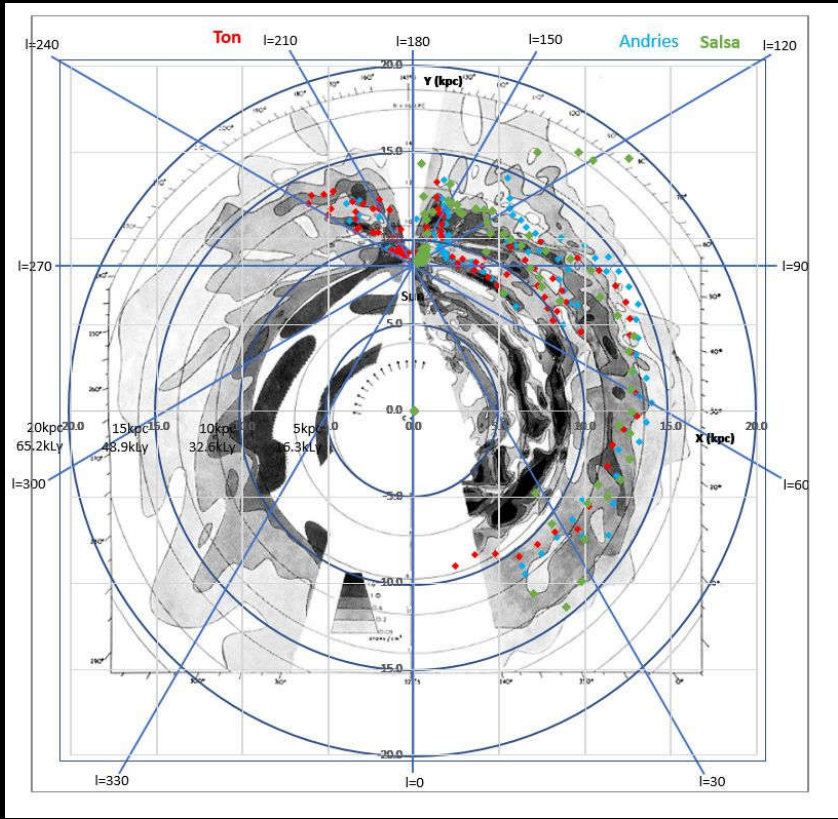
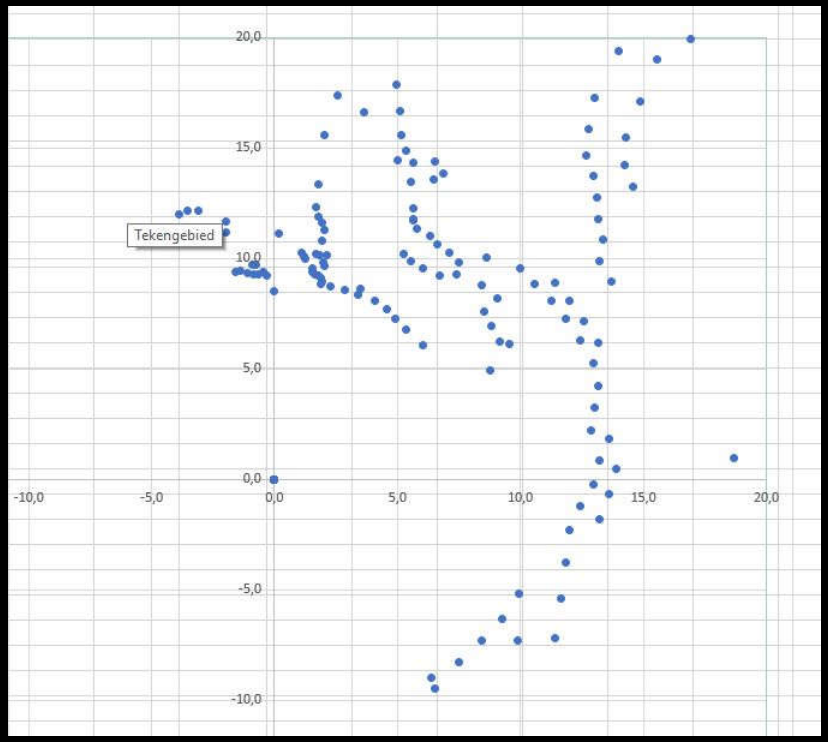
Other Milky way maps





Our maps on background prof. Oort

Map made by our observer Ton Bouw

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