Radioastronomy at school

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inspired by the exercise developed by Cathy Horellou, Daniel Johansson and Christer Andersson
(Onsala Observatory, Sweden)

Outline

1. Introduction

- Current status of small radiotelescopes for education and plans
- Radio domain
- HI hyperfine transition

2. Our current knowledge of Milky Way

3. EU-HOU exercises

4. On-line demonstration of radio observations

Basics to know

Units :

1 parsec = 1 pc = 3.086 x 10^{16} m = 3,26 ly = 2,063 x 10^4AU

1 light-year = 1 ly = 9.46 x 10^{15} m = 0.3066 pc = 6.32x10^4AU

1 AU = 149,6 x 10^9 m

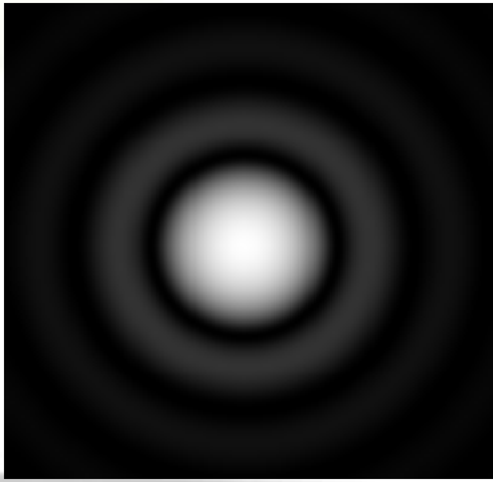
1 solar mass = 1 M_O = 1,99 x 10^{30} kg

Wavelength/Frequency of the HI line:

1420 MHz ⟷ 21,1 cm

At λ=21.1cm, $\Delta\nu$=1MHz ⟷ 211km/s

Resolution of a radiotelescope: diffraction limit (Airy pattern)



$\theta \sim \sin\theta = 1.22$ rad λ/D [$=70$ deg λ/D]

$\theta \sim \sin\theta = 1.03$ rad λ/D ➔ FWHM/HWFP

SALSA: Such A Lovely Small Antenna
Onsala Observatory, Sweden

- Diameter 2.3m
- Angular resolution :

7 degrees at 1420 MHz

- Radio receiver (9,4kHz/chan)
  - Bandwidth 2.4 Mhz
  - 256 frequency channels

Development of a new radiotelescope in Paris (not operational yet!)

SRT(Small Radiotelescope) Haystack Observatory Cassi Corps/USA

Work in progress

Diametre: 2.1m

Resolutions:

spatial: 7deg.

spectral: 40kHz

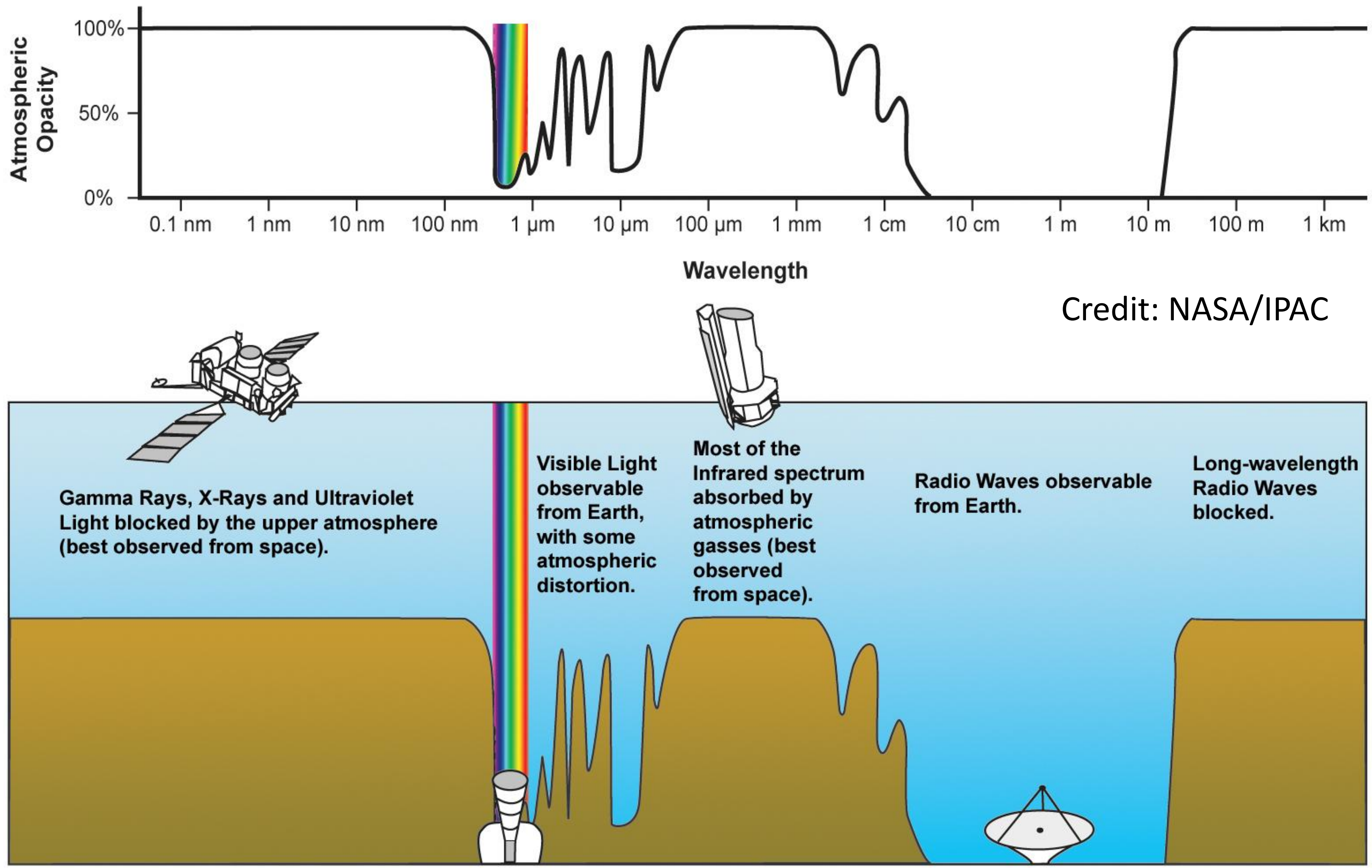
Perspective (2010-2012): Development of European network of radiotelescopes

Comenius multilateral proposal submitted to the European Commission (response due in June 2010)
Belgium, Cyprus, France, Germany, Greece, Poland, Portugal, Romania, Spain, UK

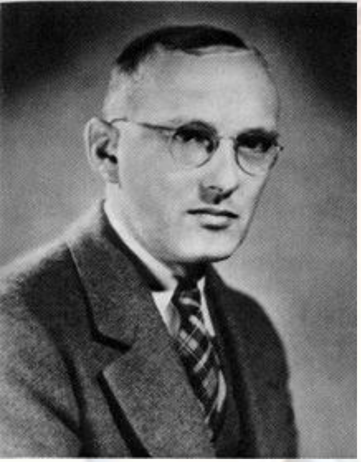
SRT radiotelescopes are planned to be installed in :
France, Poland, Portugal, Roumania, Spain
and will be remotely controlled by European classrooms through Internet.

More information will be posted on the EUHOU web site http://www.euhou.net

Atmospheric transparency

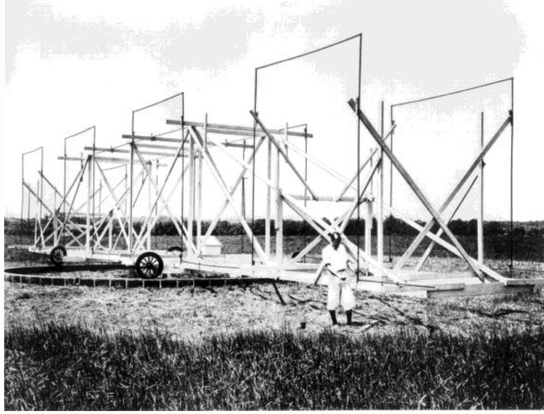


Credit: NASA/IPAC

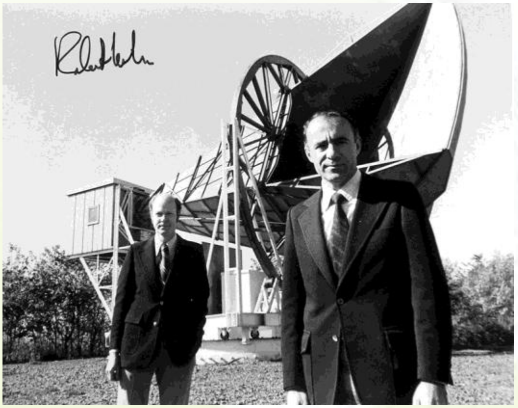


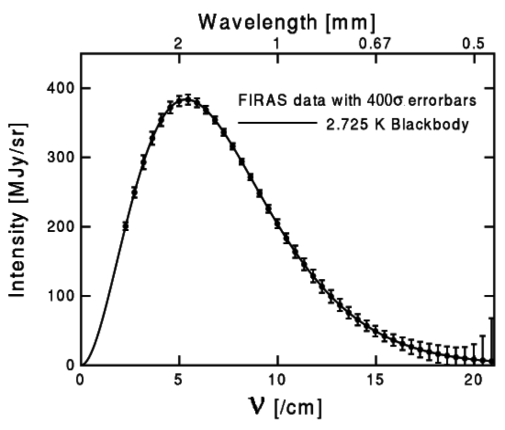
Birth of radioastronomy:

Karl Jansky (1905-1950) detected radio emission from the Galactic center using this antenna in 1932. (The antenna operated at a wavelength of 14.5 m) 1 Jansky = 10^{-26} W/m^2/Hz



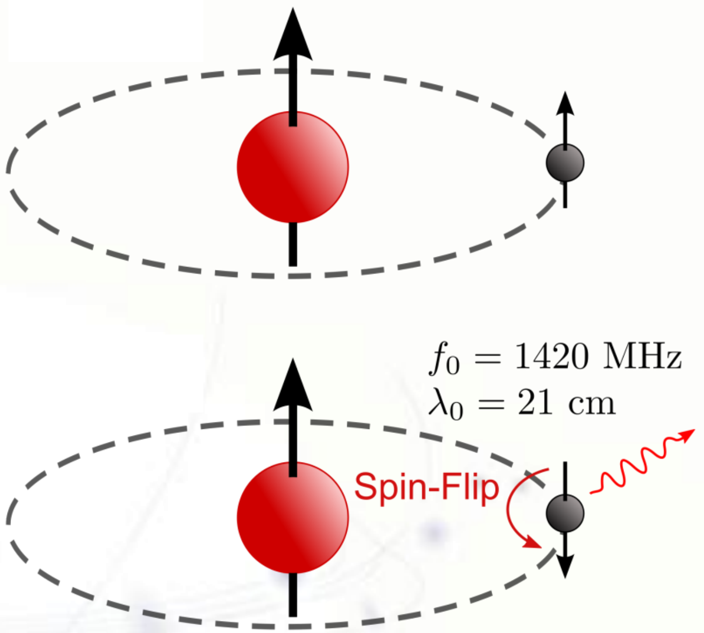
One of the greatest discoveries of radio astronomy





- Cosmologists had predicted a background radiation
- The Cosmic Microwave Background (CMB) – all-sky blackbody radiation at 3 K
- Discovered in 1964 by A. A. Penzias & R. W. Wilson
- Nobel Prize in Physics 1978
- Big Bang theory

Hydrogen 21 cm line



Spin flips probability:

once every ten million years

➔ should be hard to detect

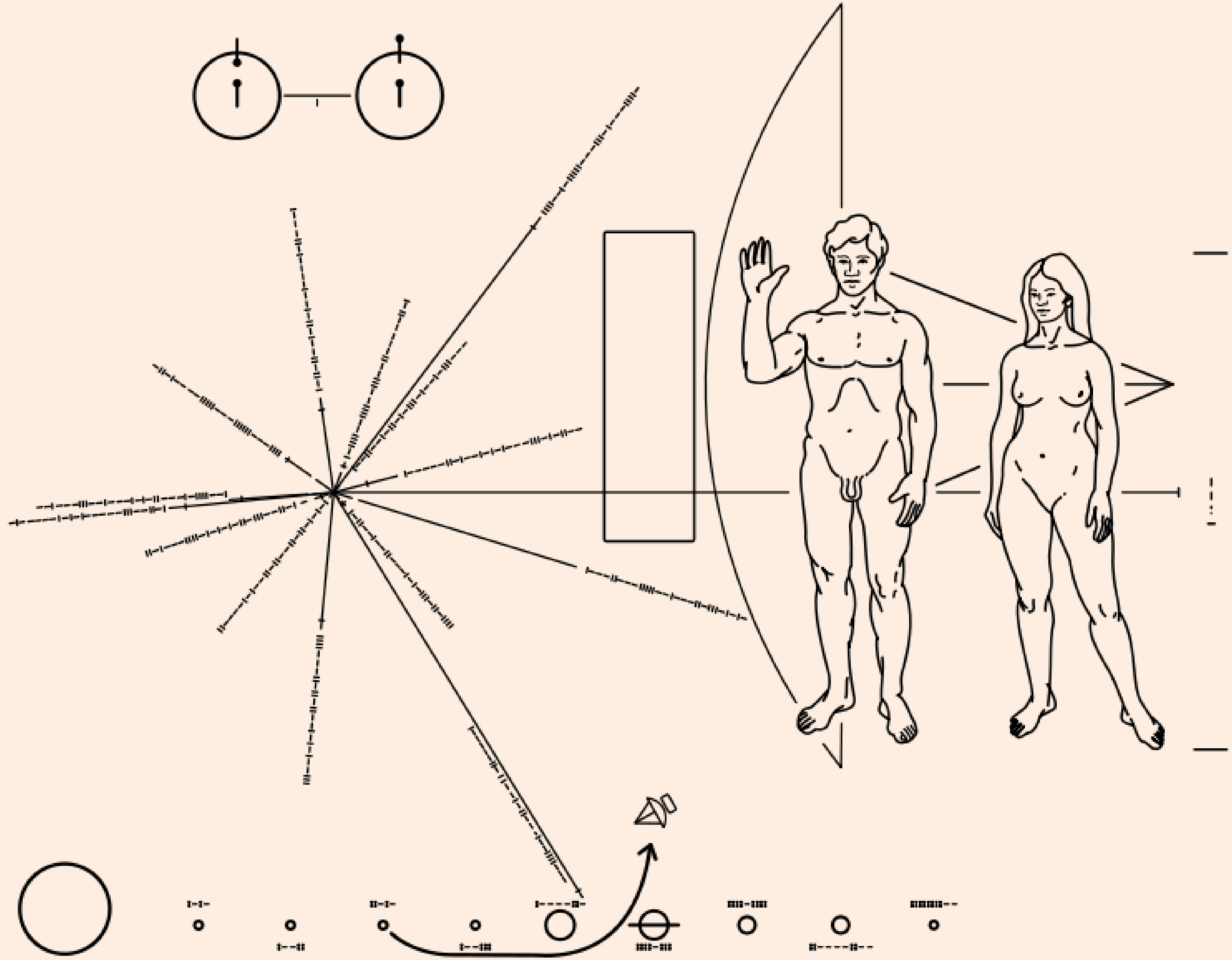
But:

- Huge amounts of atomic hydrogen in the Galaxy
- Makes the 21 cm line easy to detect

Theoretical prediction: H.C. van de Hulst (1944)

Observational discovery

- Ewen & Purcell (USA) 1951
- Muller & Oort (Holland) 1951



Plaque on board Pioneer spacecraft

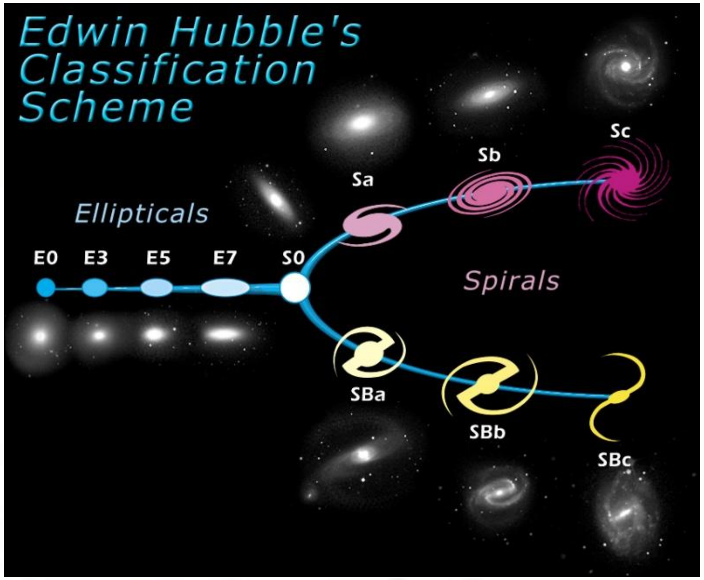
Cover of the Voyager Golden record

What is the Milky Way?

- A spiral galaxy (type b) with a bar

90% of HI in well-defined thin disk

-It contains (Kalberla et al. 2007) within 60kpc:

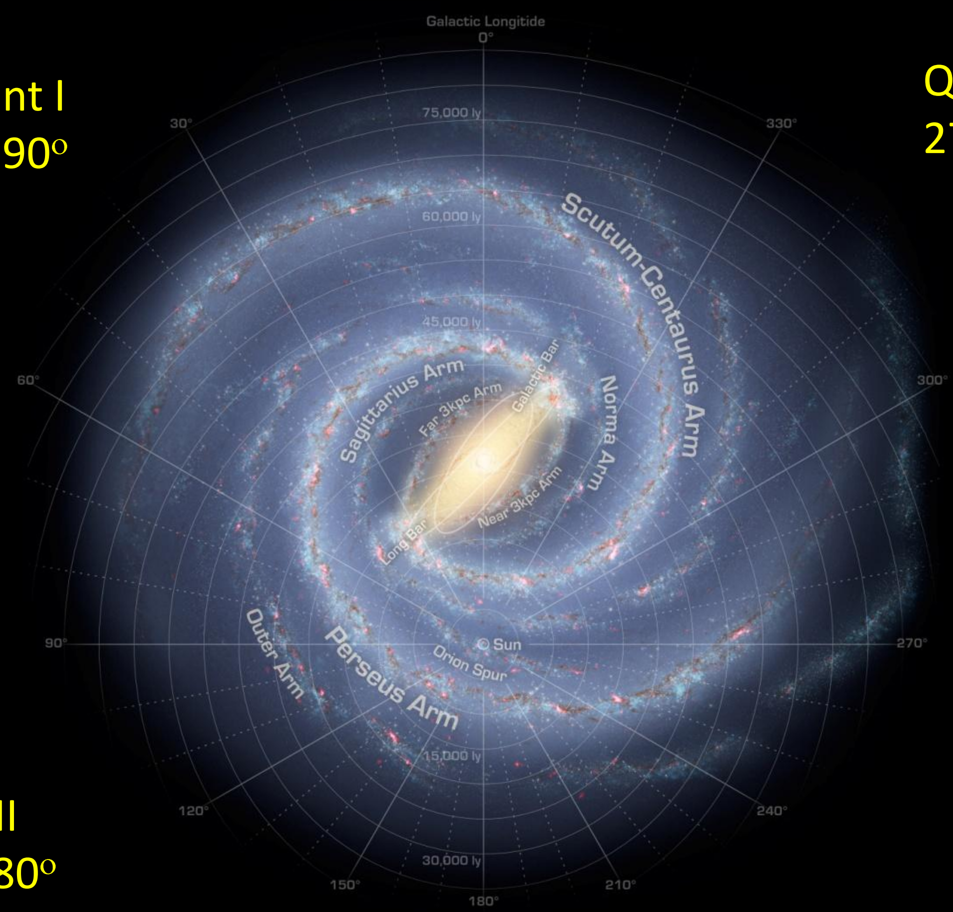


Stellar mass:	$8.26 \times 10^{10} M_O$ (87%)
Gas mass:	$1.23 \times 10^{10} M_O$ (13%)
Total Baryon mass:	**$9.50 \times 10^{10} M_O$ (20%)**
DM mass:	**$3.65 \times 10^{11} M_O$ (80%)**
Total mass:	**$4.6 \times 10^{11} M_O$**

A realistic view of the Milky Way?

Quadrant I
$0^o < l < 90^o$

Quadrant IV
$270^o < l < 360^o$



Galactic rotation

Quadrant II
$90^o < l < 180^o$

Quadrant III
$180^o < l < 270^o$

Illustration courtesy: NASA/JPL-Caltech/R. Hurt

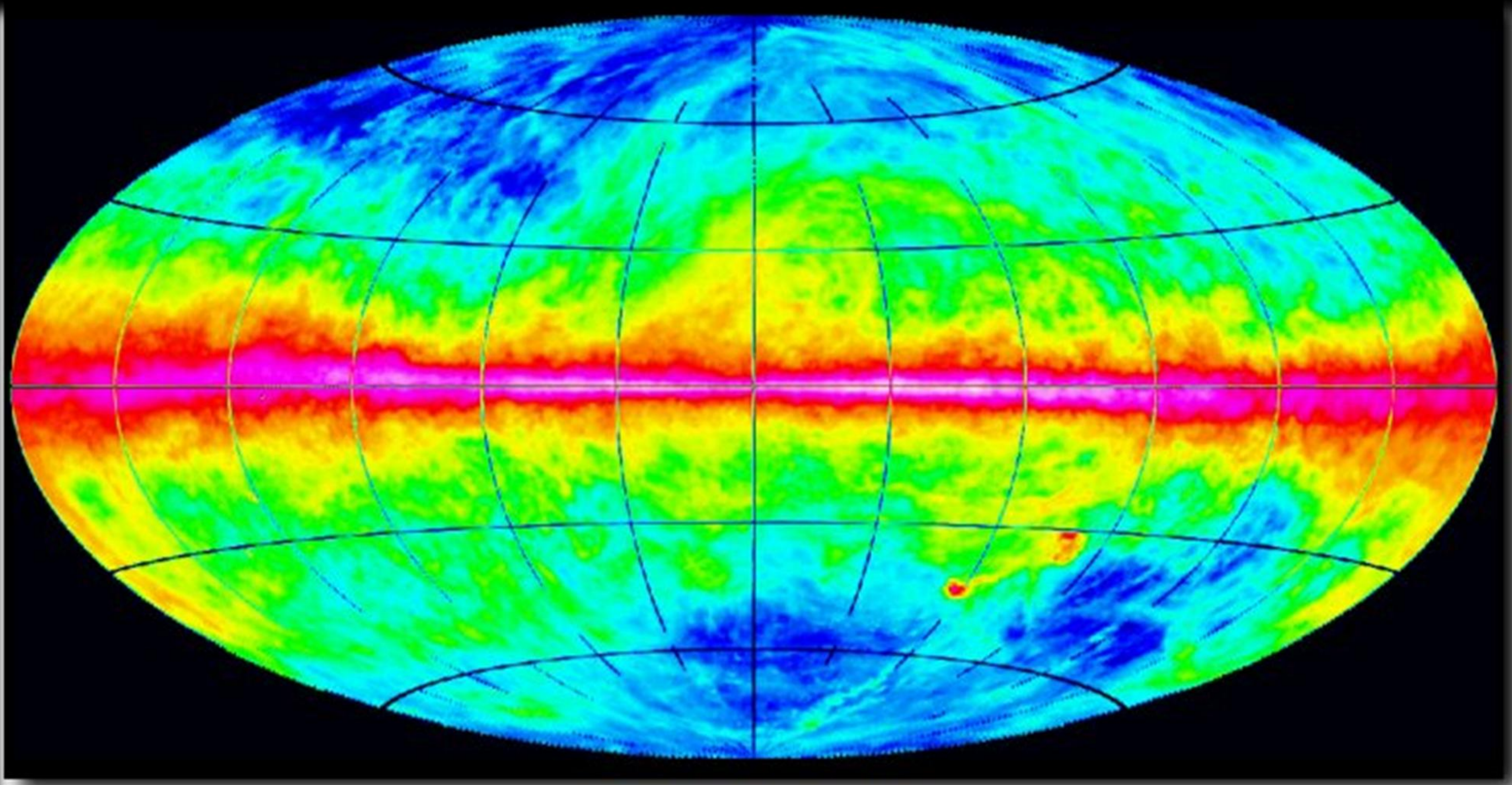
Real observations: the Milky Way seen from Paranal

360 degrees view !

The Milky Way as seen in the optical

ESO/S. Brunier

Observations at 21cm



Leiden/Argentine/Bonn Galactic H I Survey

Search the LAB Survey

With the form on this page you can extract the H I column density and the complete spectrum for any position on the sky from the LAB Survey. Please specify below the desired position in either equatorial or Galactic coordinates. For additional help please click on the corresponding labels next to the fields.

Sky position

RA / l: 120

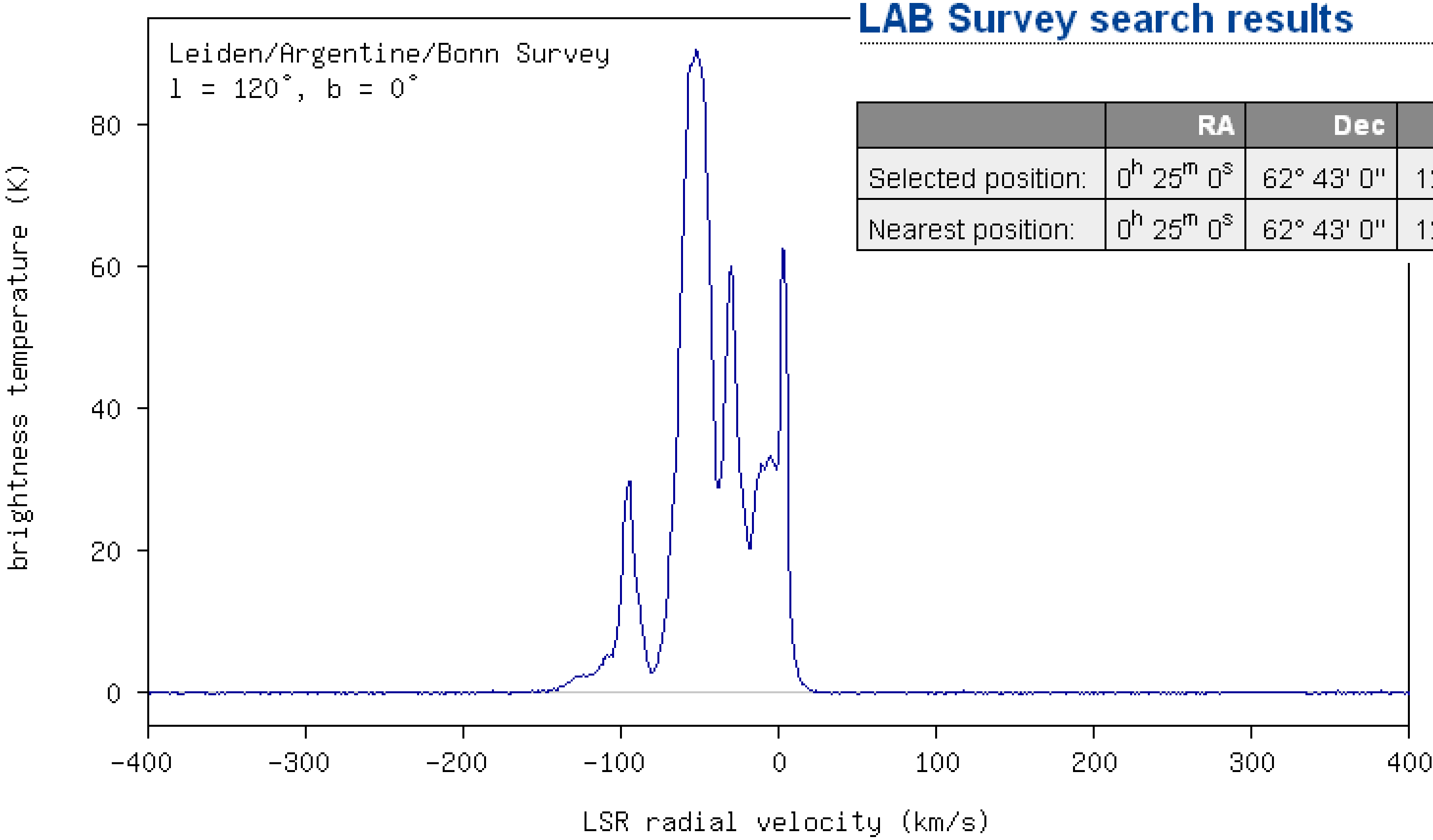
Dec / b: 0

Submit

http://www.astro.uni-bonn.de/~webaiub/english/tools_labsurvey.php

LAB Survey search results

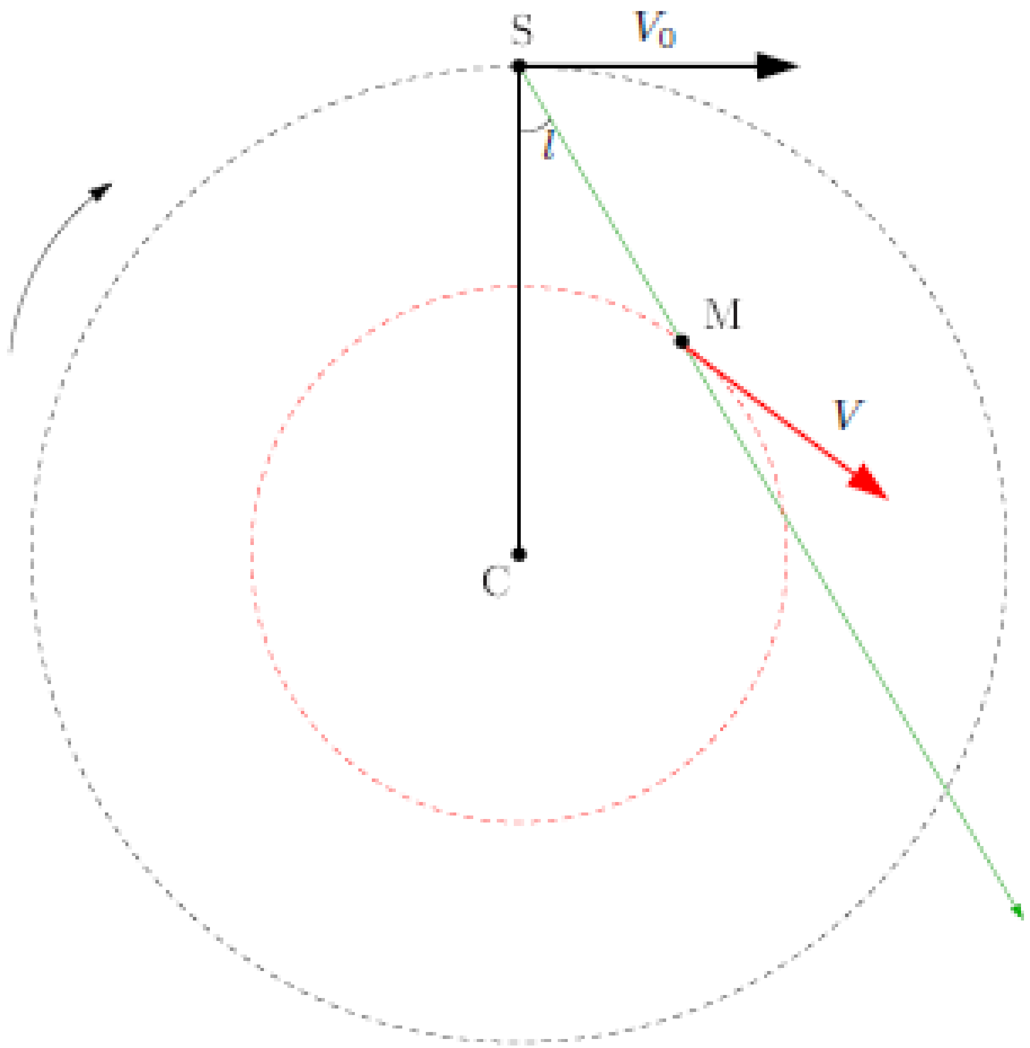
	RA	Dec	*l*	*b*	$N_{H\,I}$
Selected position:	$0^h\ 25^m\ 0^s$	62° 43' 0"	120.00°	0.00°	$0.765 \cdot 10^{22}$ cm^{-2}
Nearest position:	$0^h\ 25^m\ 0^s$	62° 43' 0"	120.00°	0.00°	$0.765 \cdot 10^{22}$ cm^{-2}



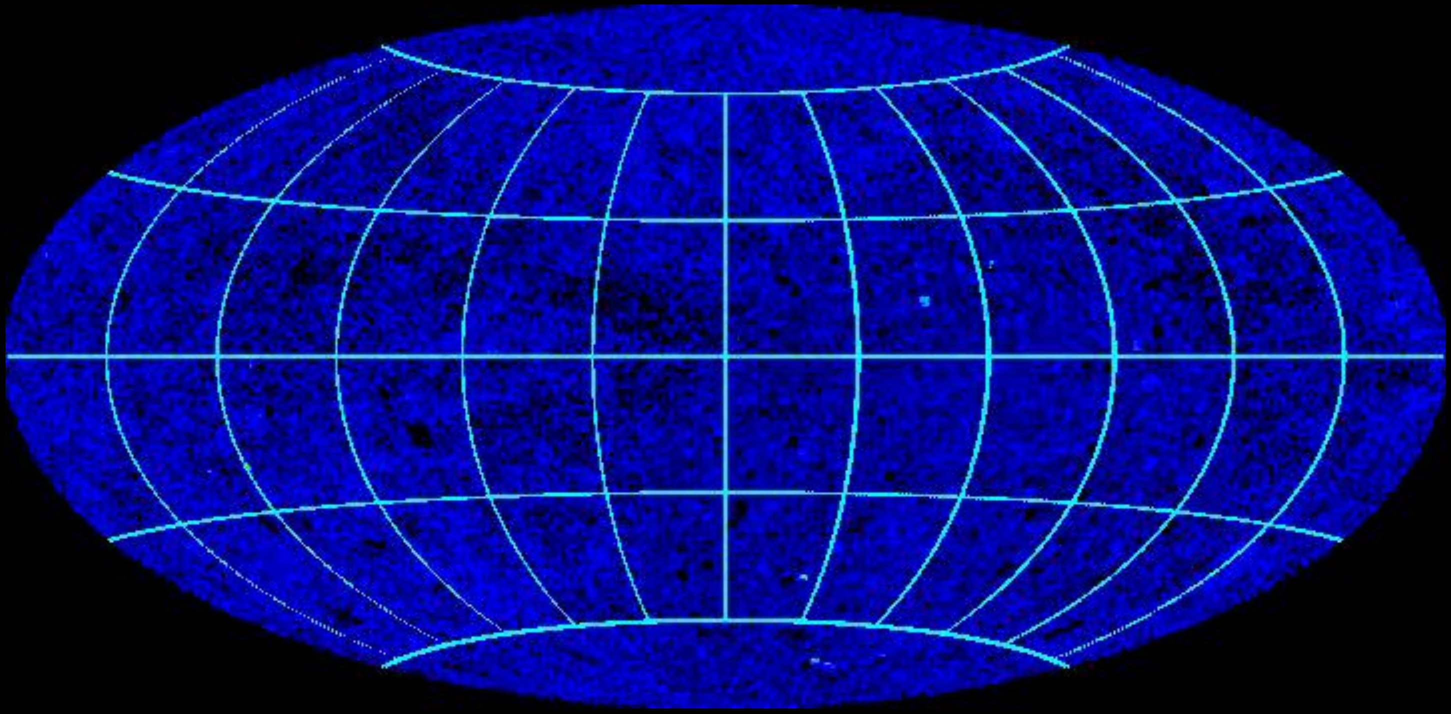
What do we detect?

Usual assumption:

- Circular orbits

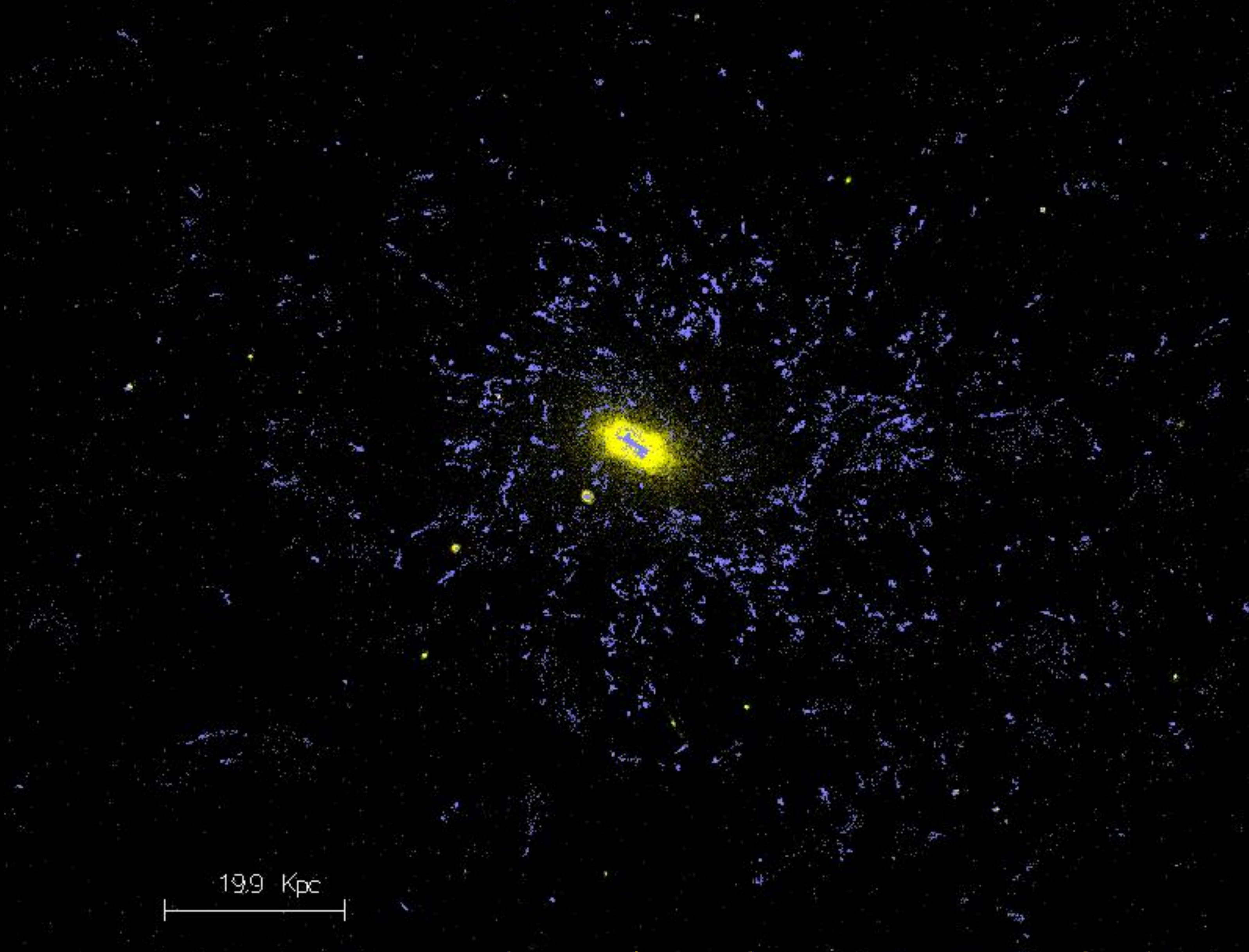


Towards the Galactic Centre: Velocities from -400 to 400 km/s



LAB survey, Kalberla et al. (2005)

Simulation of galaxy formation



Credit: Benoît Semelin LERMA, UPMC & Obs. de Paris

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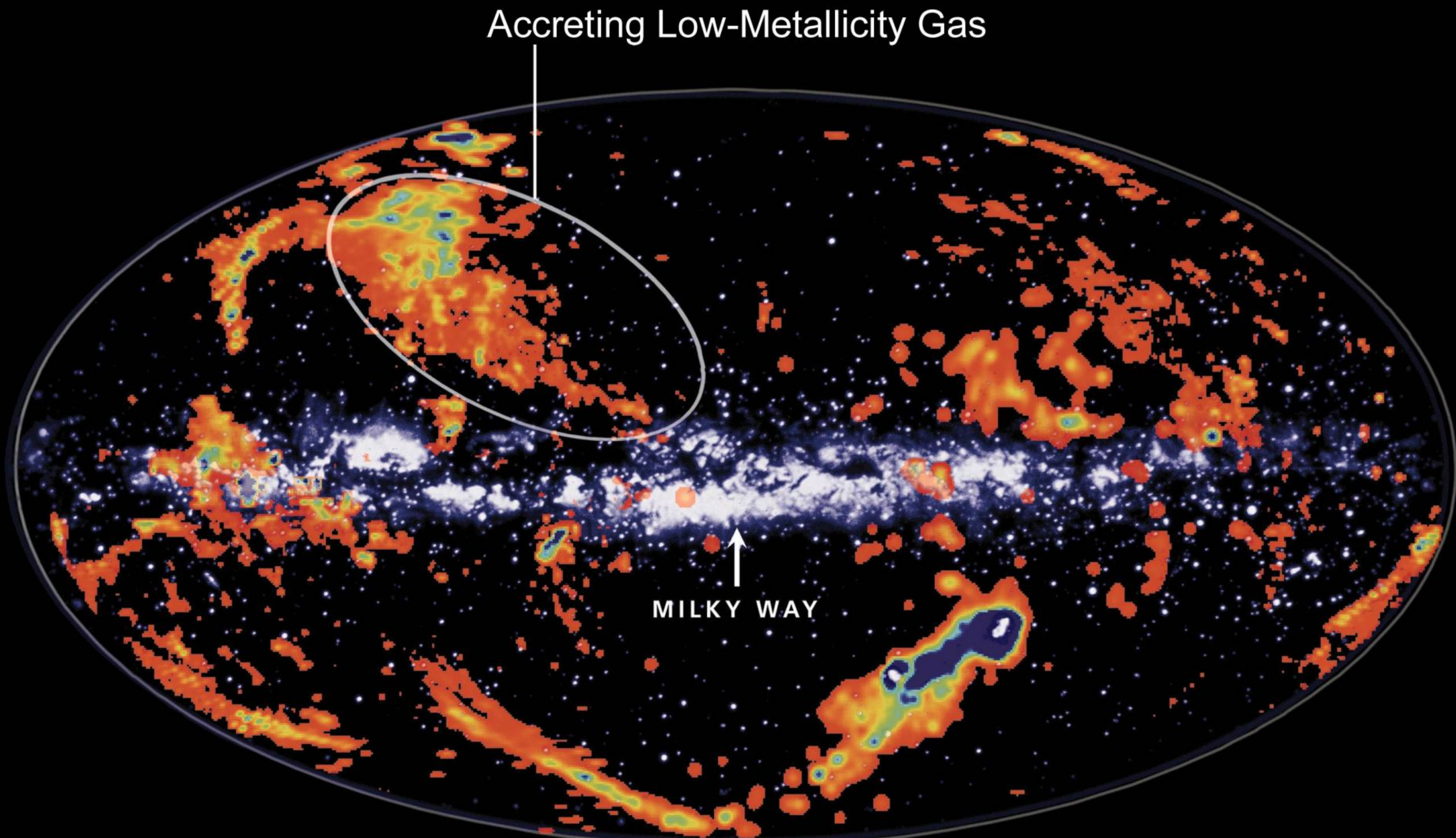


NASA and B. Wakker (University of Wisconsin-Madison) • STScI-PRC99-46

Rotation curves and dark matter

Circular velocity V as function of radius R

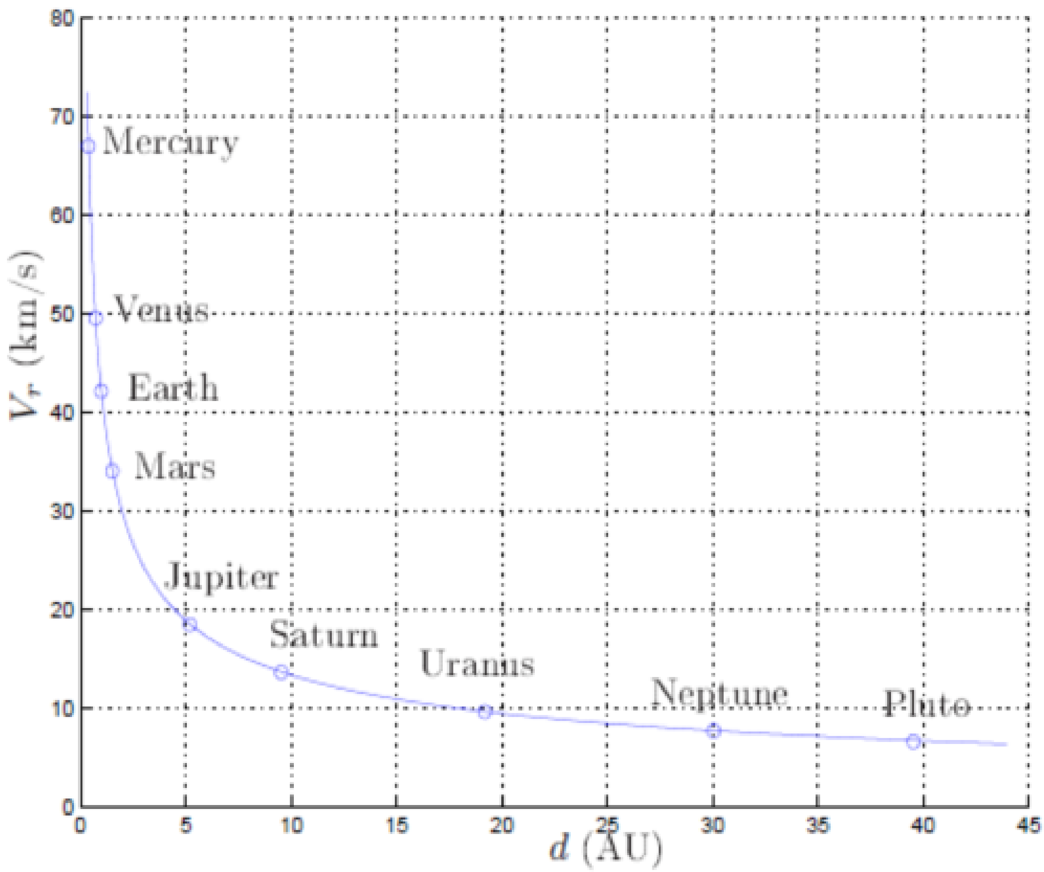
Solid-body rotation: a CD-rom

Ω = V/R = Constant; V α R

Keplerian rotation:
Solar System

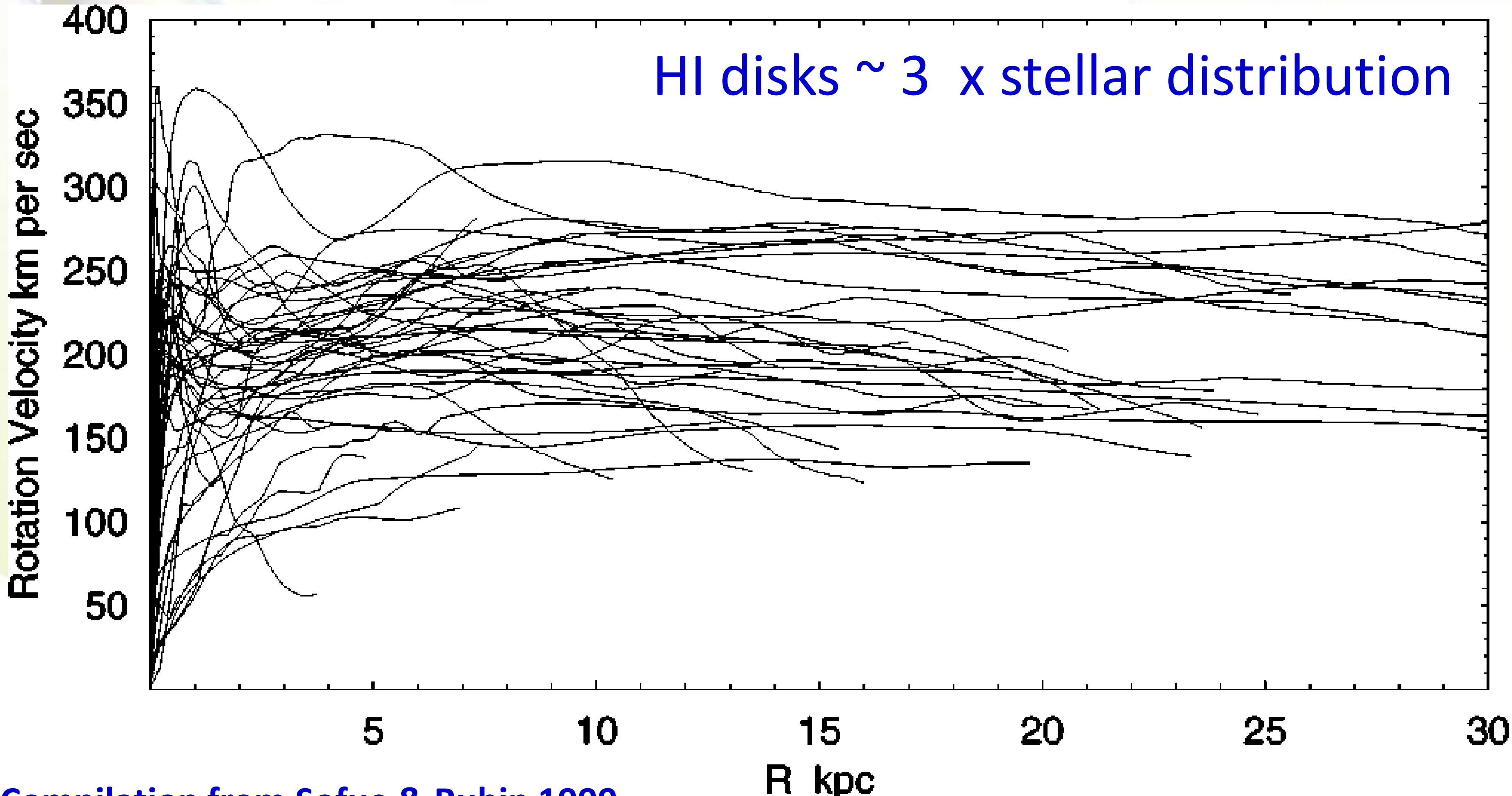
$V^2/R = GM/R^2$

$V = (GM/R)^{1/2}$



Rotation curves and dark matter

What happens for galaxies?



Compilation from Sofue & Rubin 1999

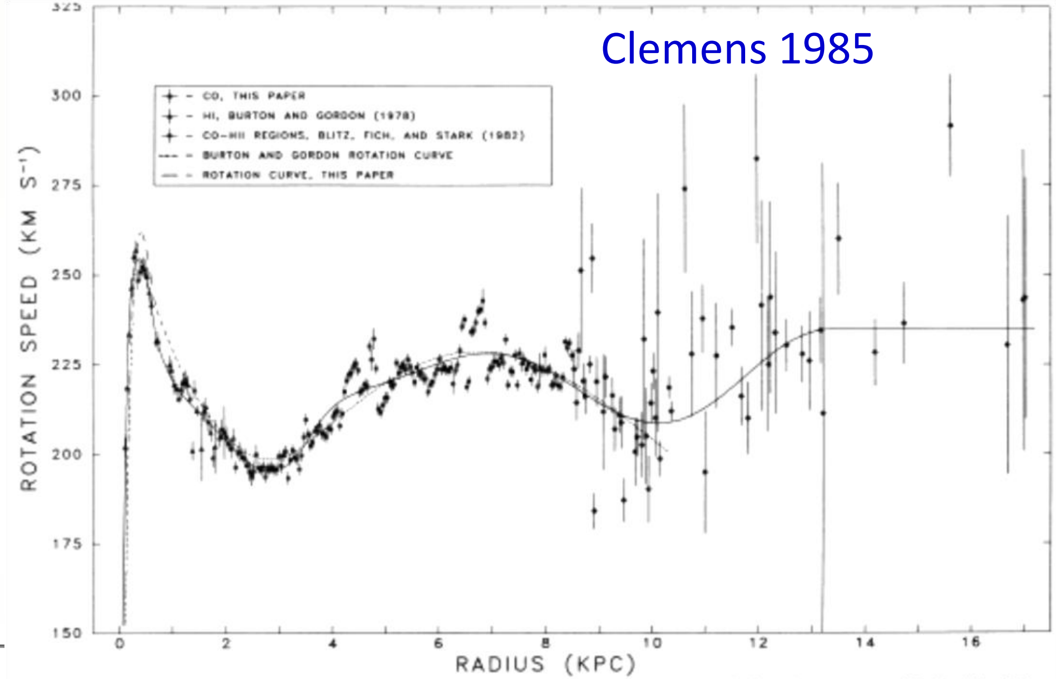
Rotation curves and dark matter

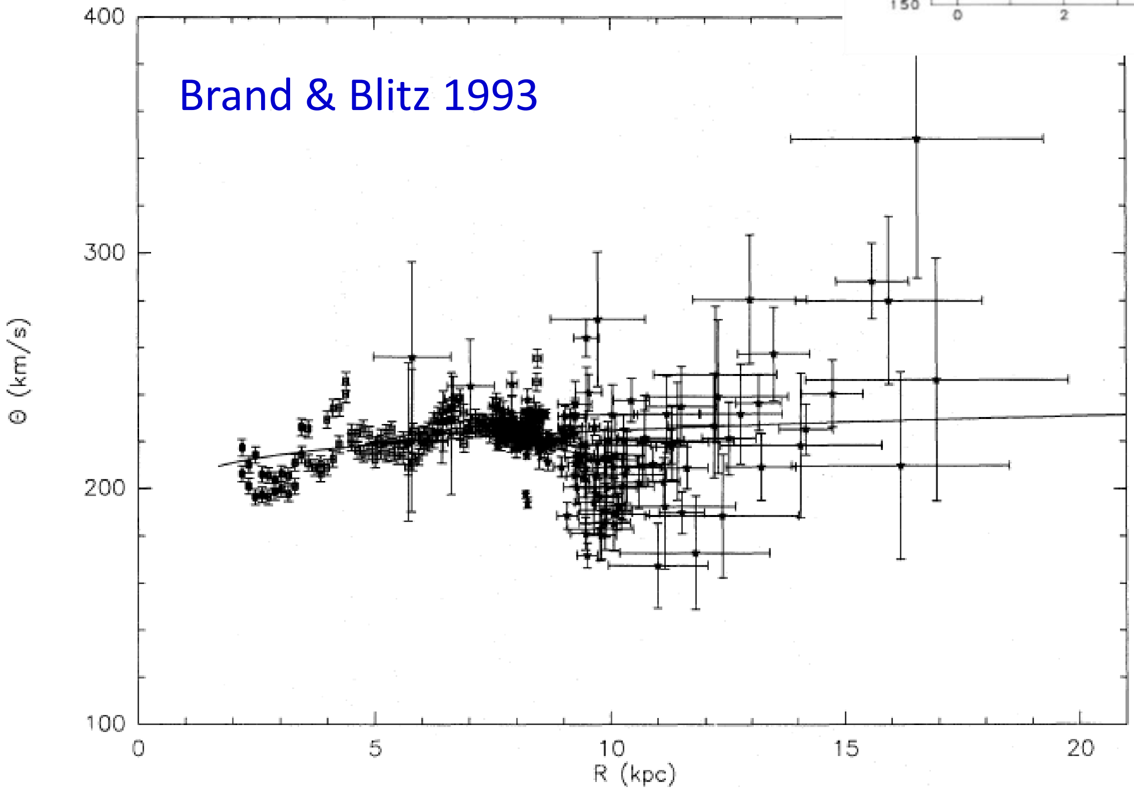
What happens for galaxies?

V=constant ; $\Omega \propto 1/R$

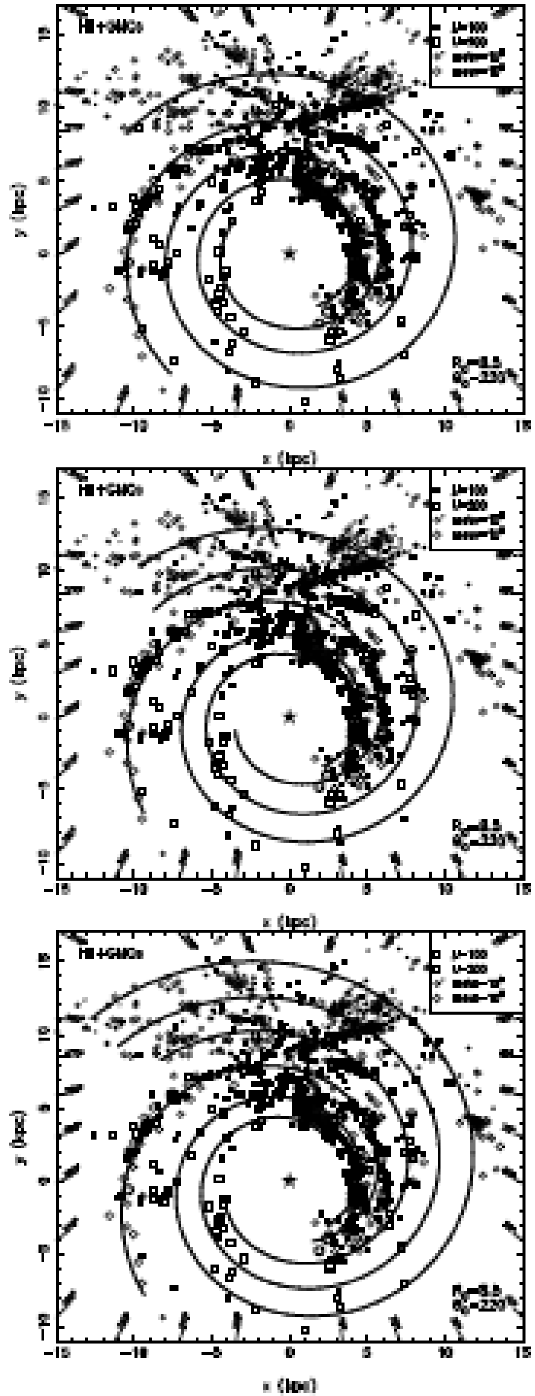
- ➔ **More matter than seen**
- ➔ **So-called dark matter**

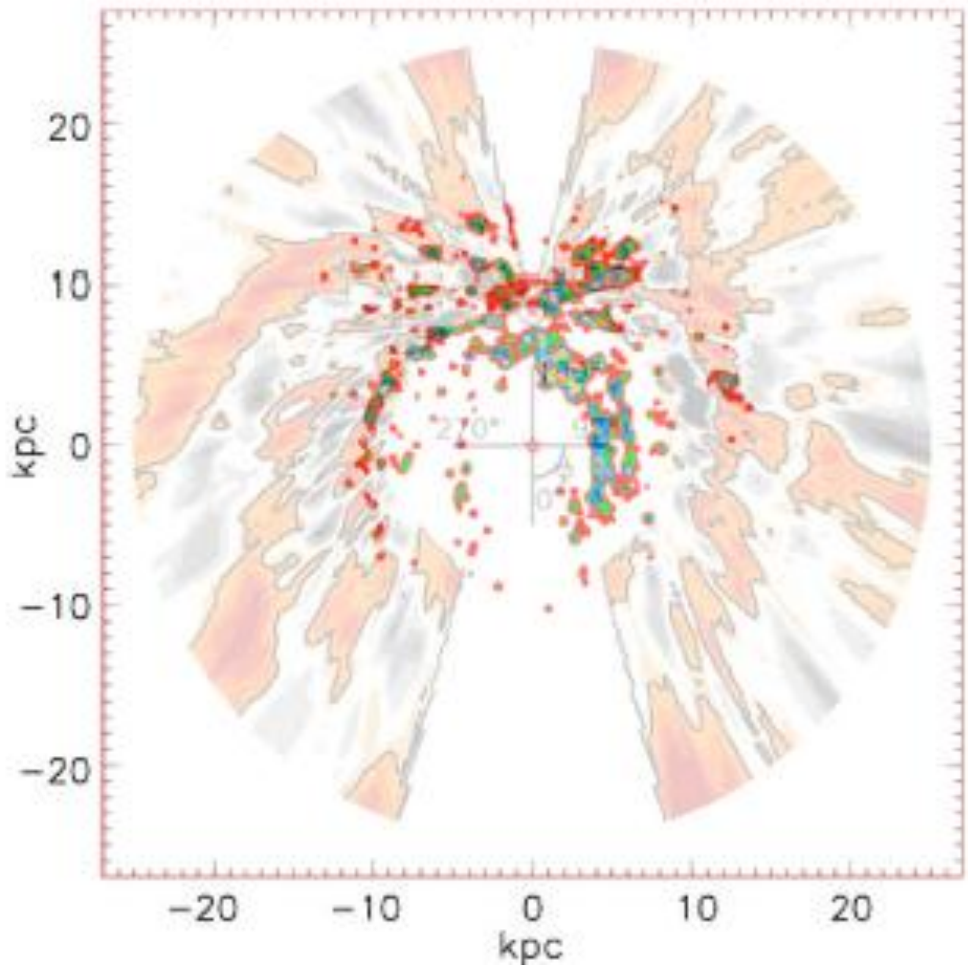
Rotation curves of the Milky Way





Spiral structure of the Milky Way





Hou et al. (2009)

CHALMERS

Hands-On Radio Astronomy

Mapping the Milky Way

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Sweden

Date of last revision: 2009 August 20, CH

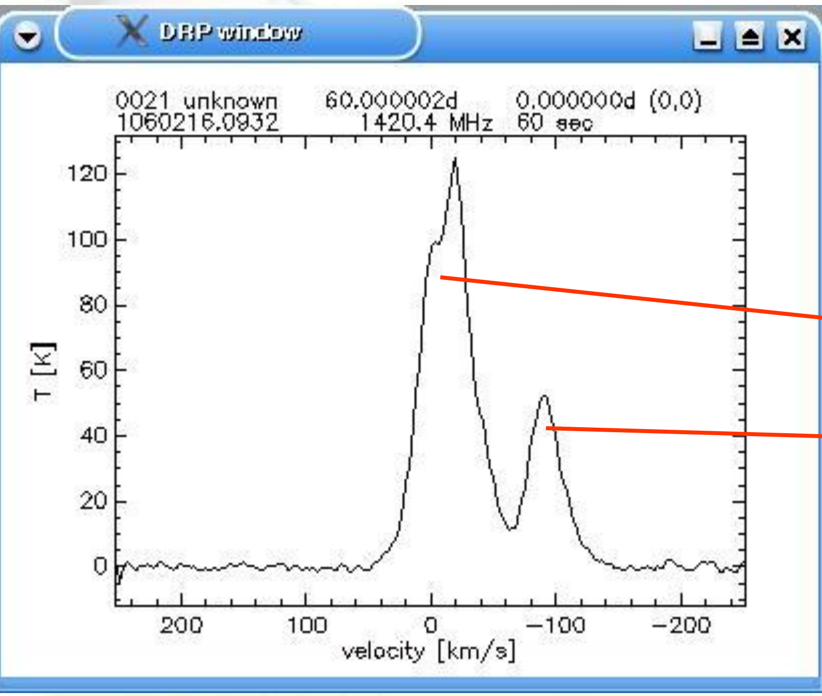
EU-HOU exercises

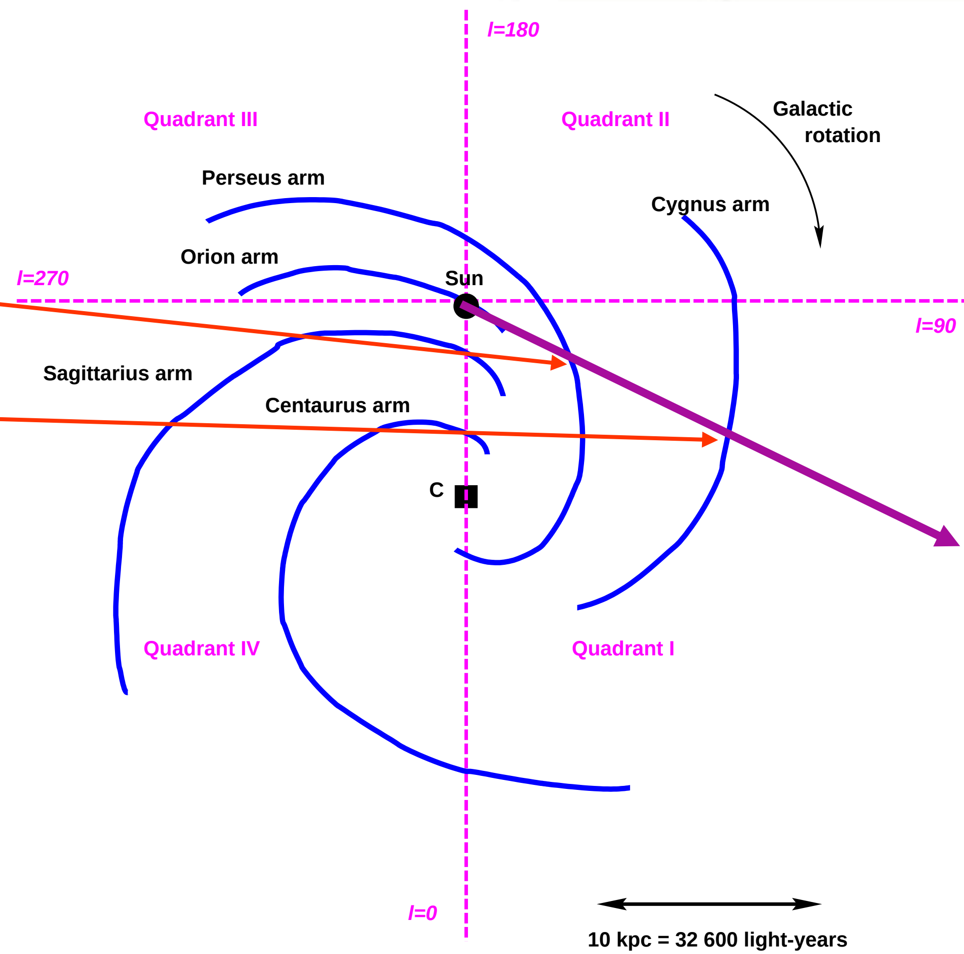
explained into details in the manual (33p.)

including instructions for on-line observations

translated in several languages

Radio observations of the Milky Way understanding a spectra



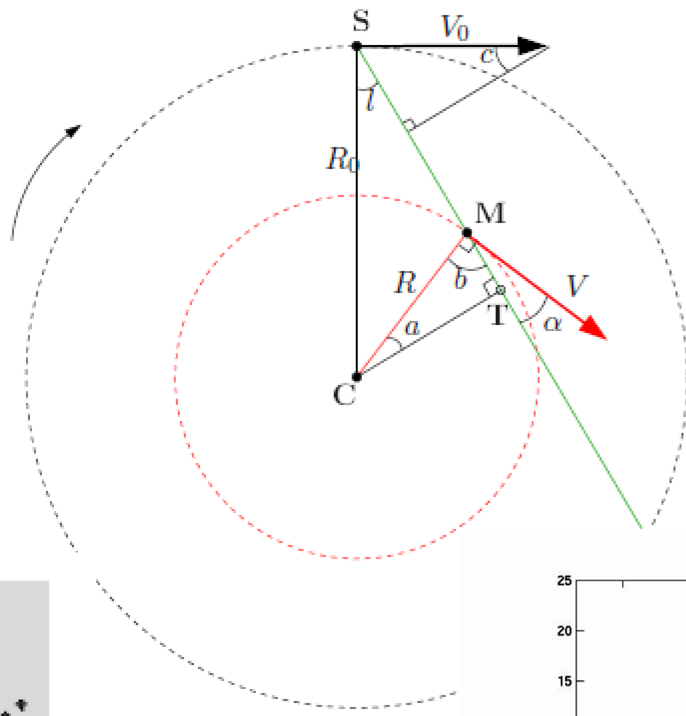


Observations in the Galactic disc

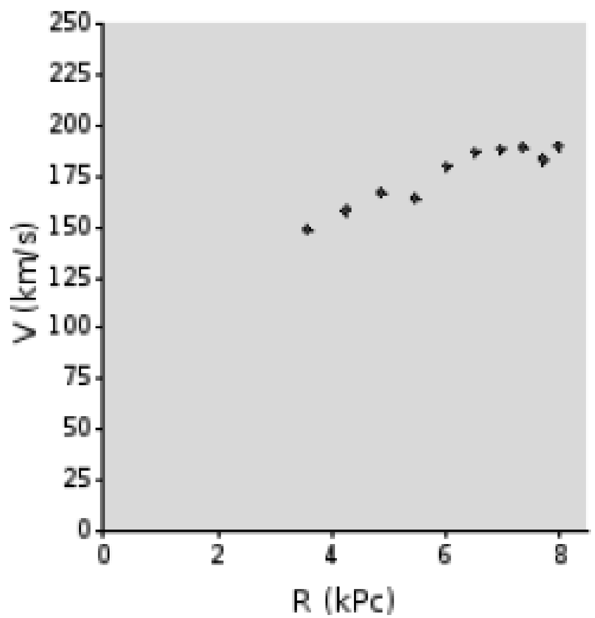
The purple line: line-of-sight

Radio lines correspond to spiral arms

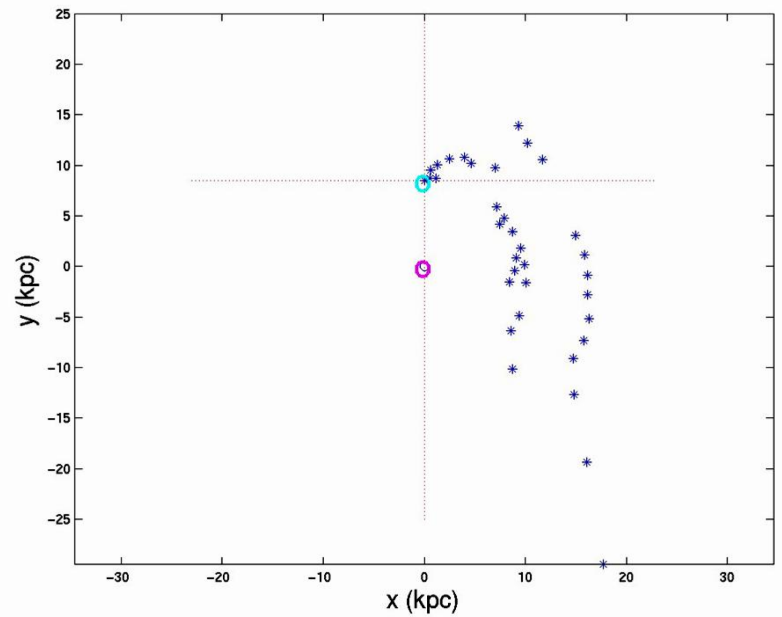
Analysing the spectral data in a classroom
« Pupil's research »



Rotation curve



Spiral arms



EU-HOU exercises and explorations

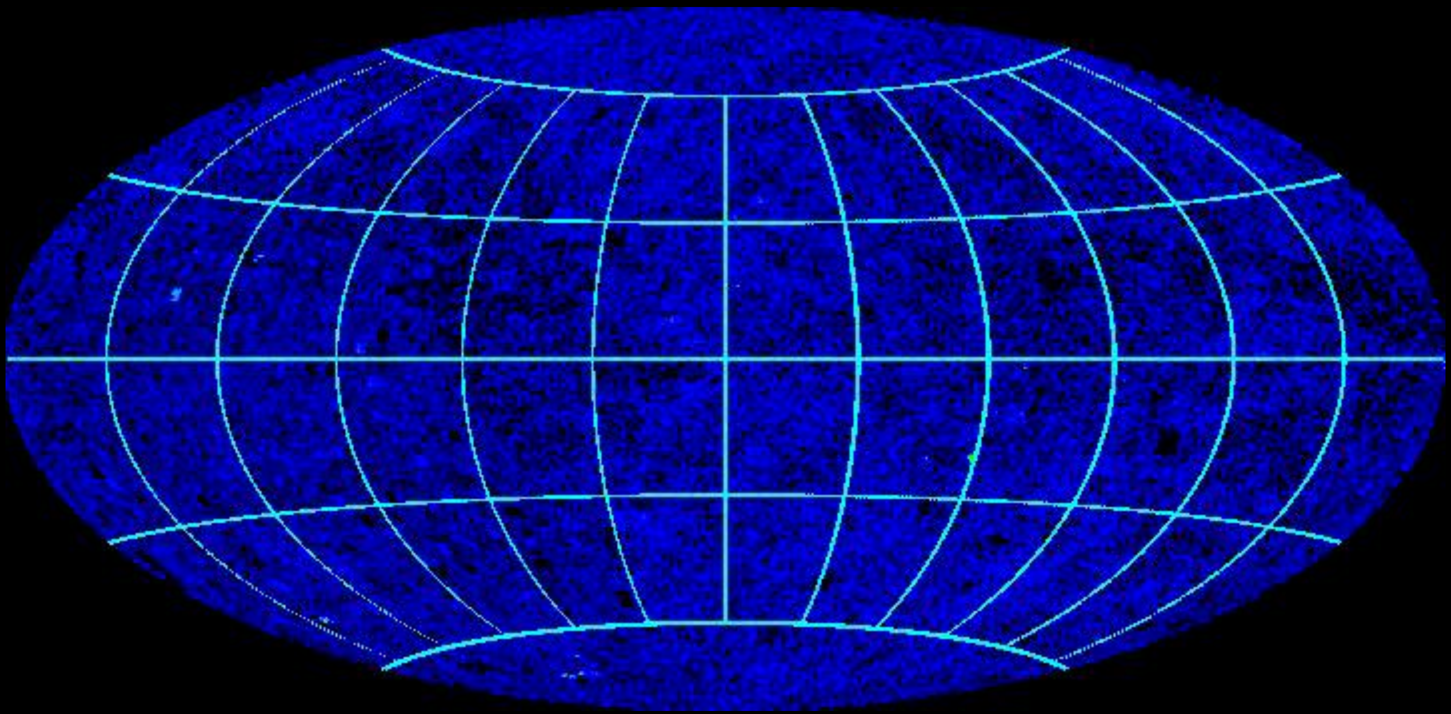
-Comprehensive description of basics in the manual

- Analyse Onsala data available from Web site (excel file)

- Acquire data from Onsala radiotelescope

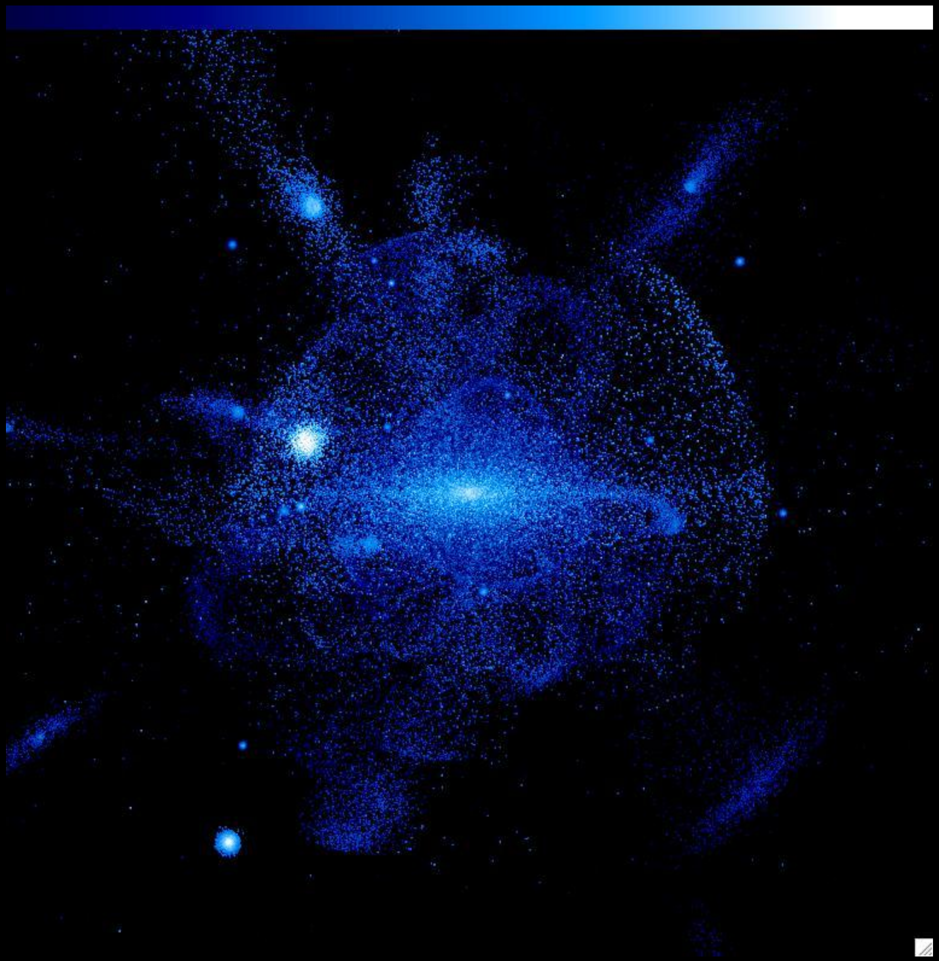
- Use the LAB data base to get high resolution data and explore the Galaxy on your own http://www.euhou.net

Towards the Galactic Anti-Centre: Velocities from -400 to 400 km/s



LAB survey, Kalberla et al. (2005)

Simulation of the Milky Way



Credit: K. Johnston, J. Bullock