

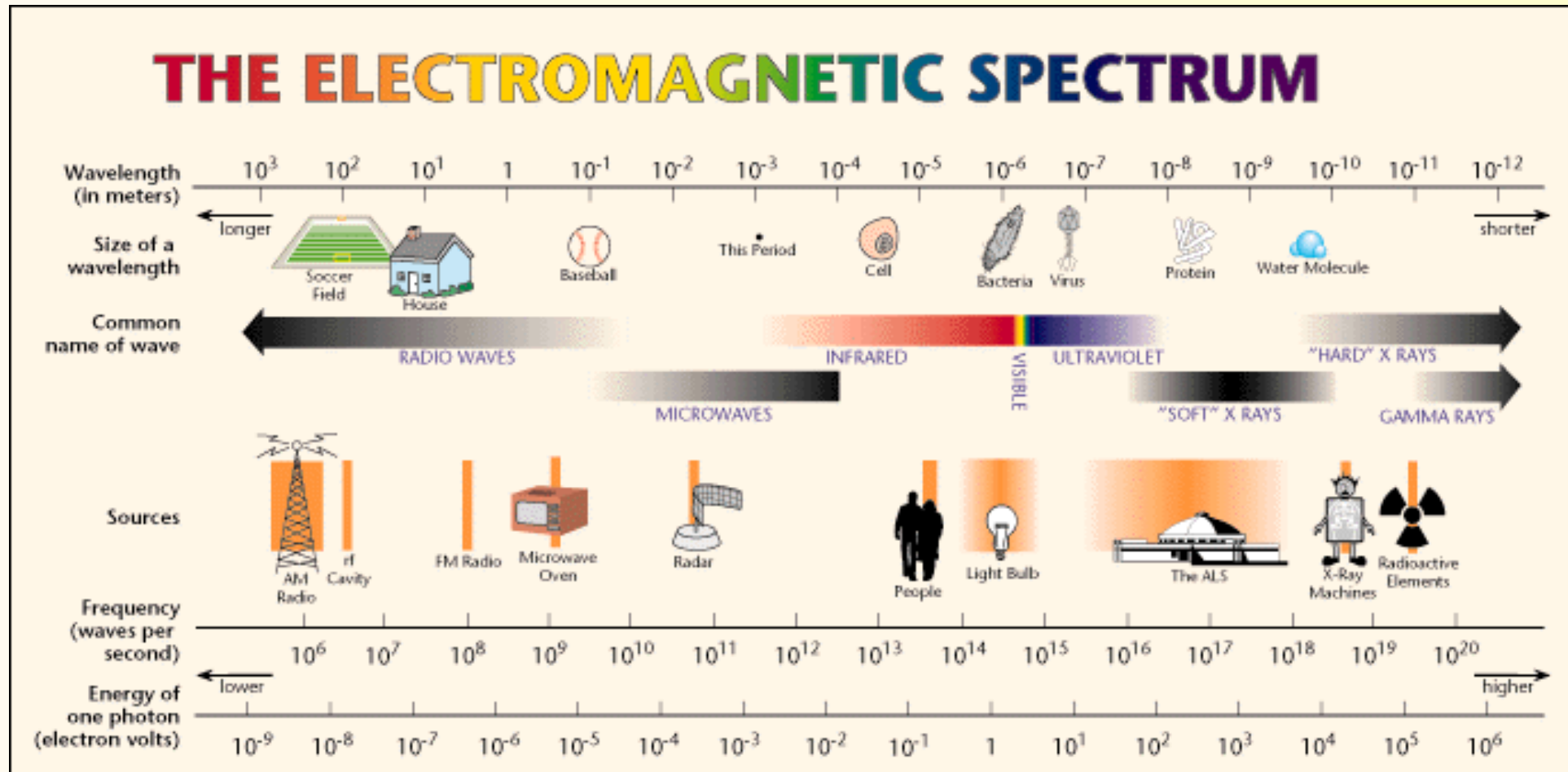
A view of the radio universe



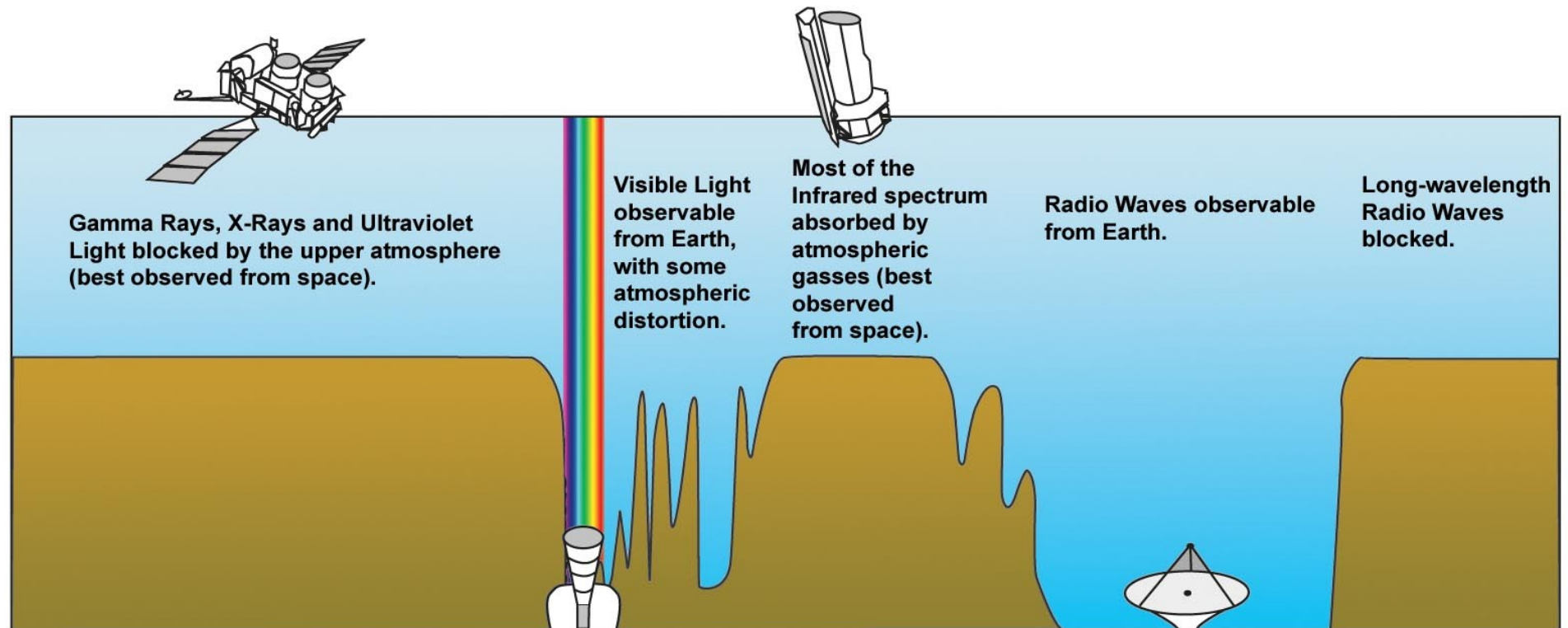
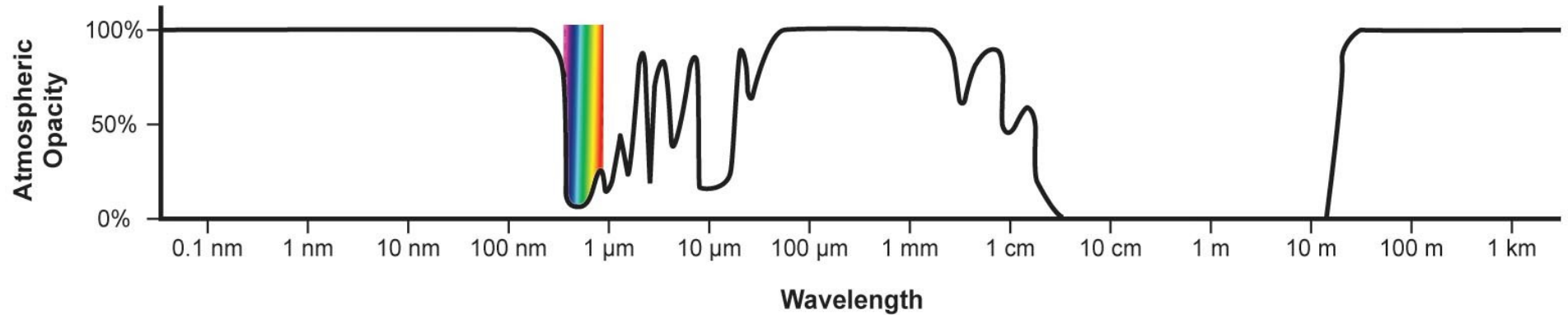
Outline

- Electromagnetic spectrum
 - Effects of the atmosphere
- Radio emission mechanisms
 - Continuum
 - Black body (planets, Moon)
 - Free-free (HII regions)
 - synchrotron (SNRs, radio galaxies, quasars, nanoquasars)
 - Spectral lines
 - 21 cm hydrogen
 - Thermal molecular lines
 - masers (star formation, old stars)
 - Other
 - Pulsars (maybe curvature emission)

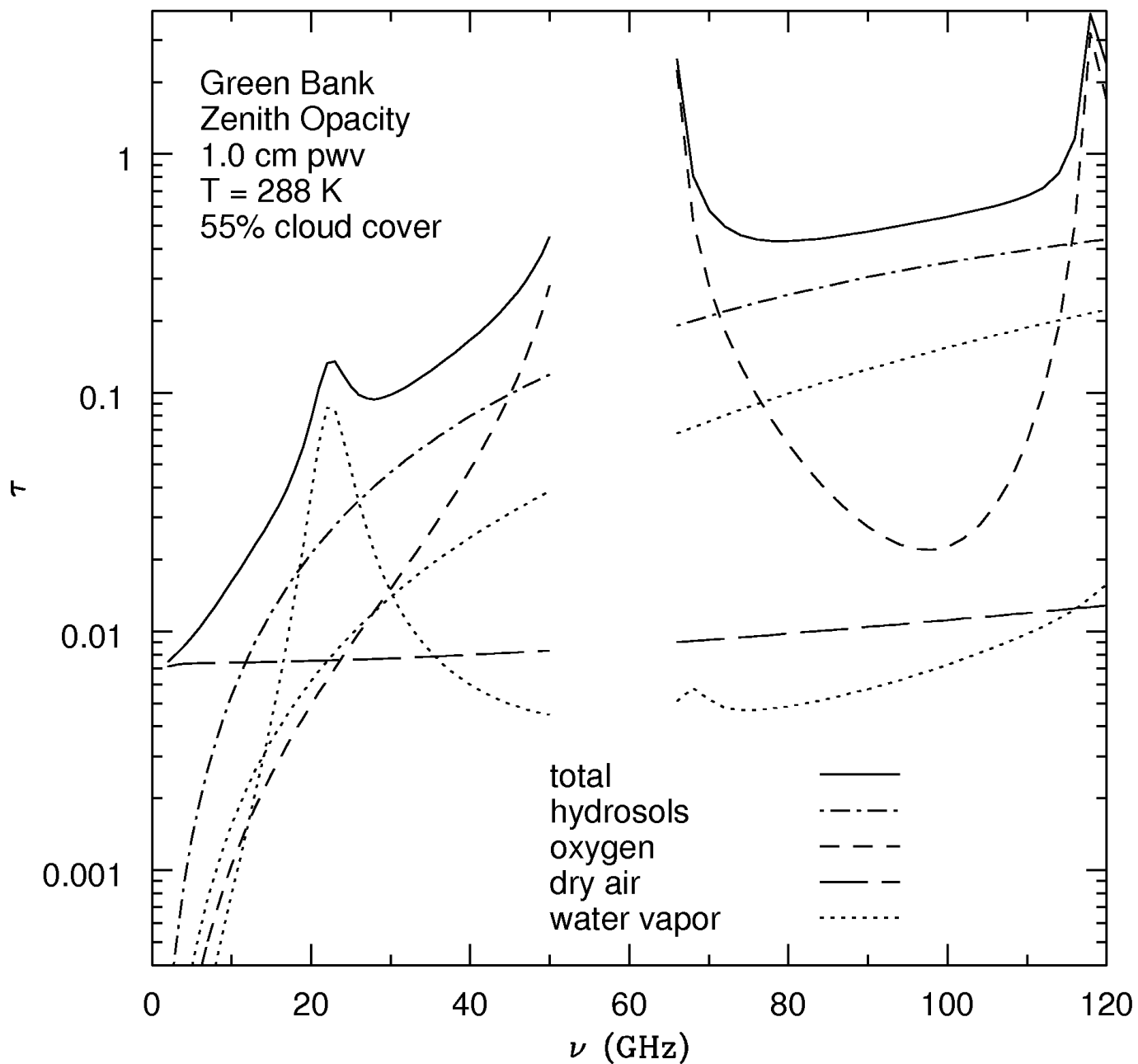
Spectrum



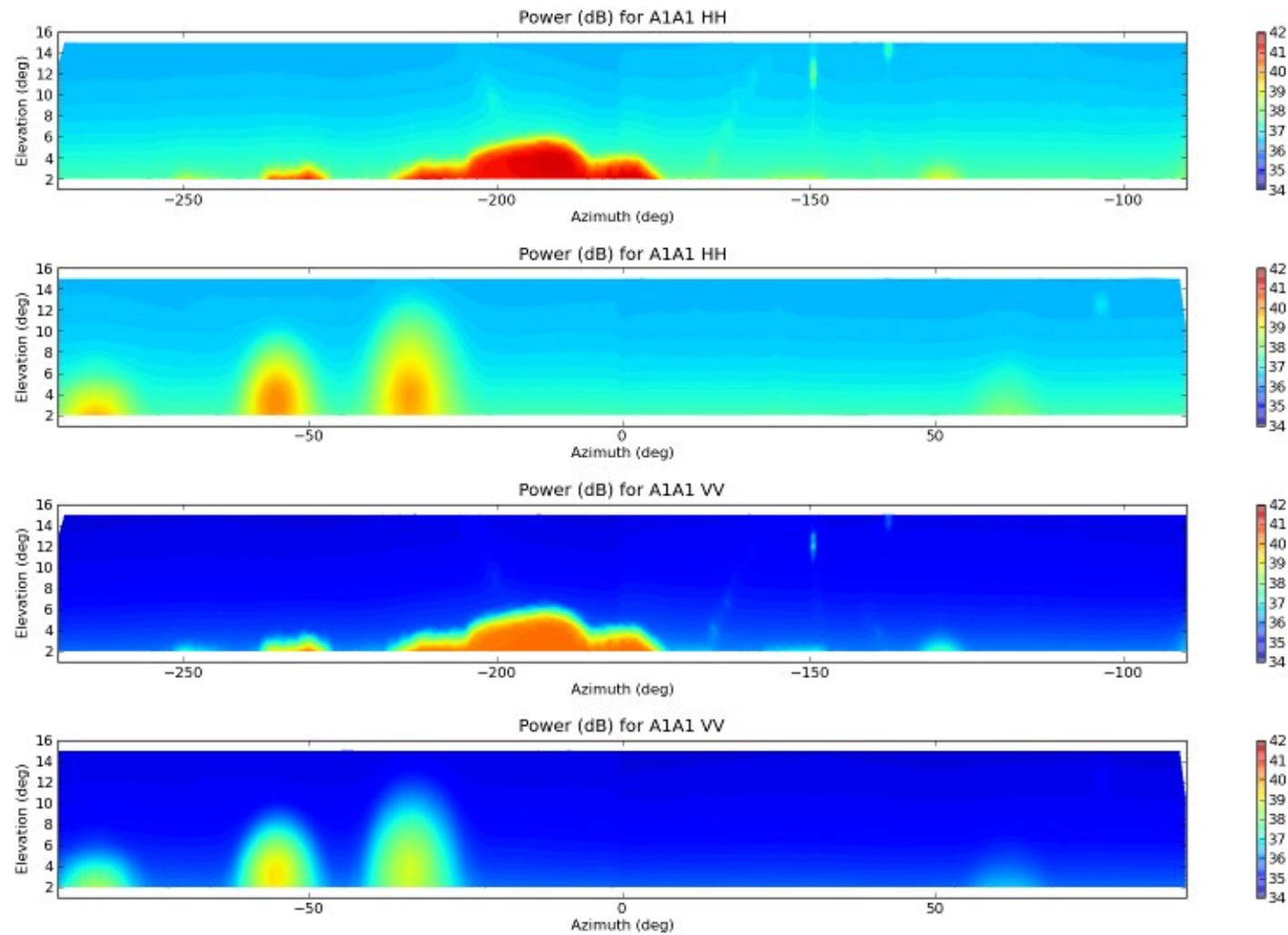
Atmospheric Window



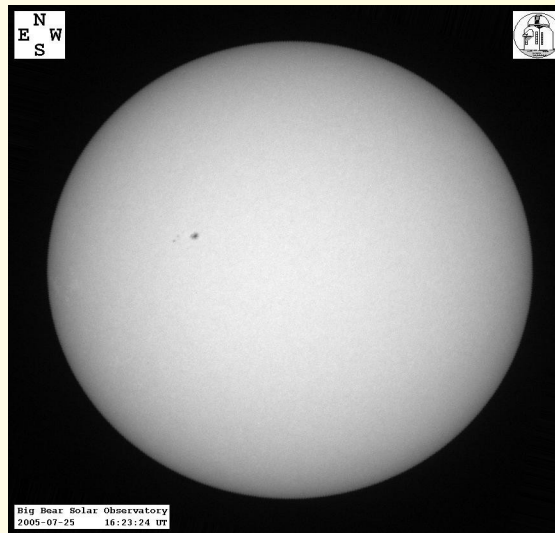
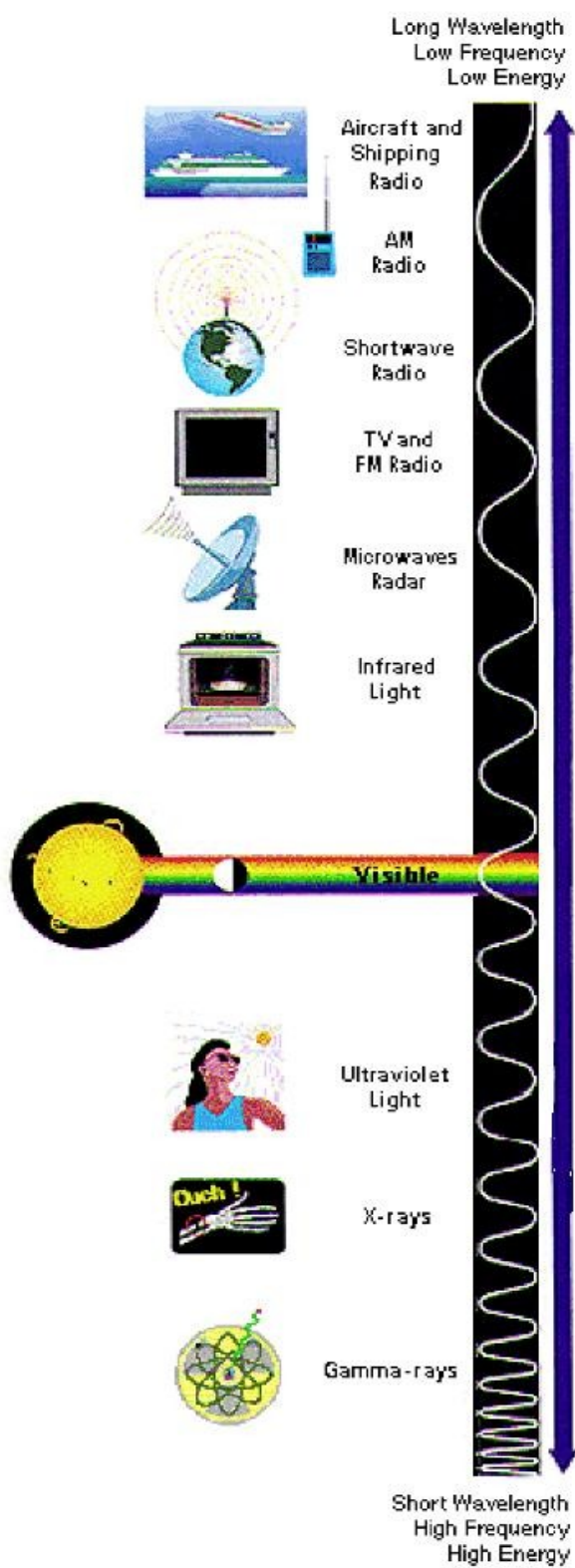
Opacity at Green Bank



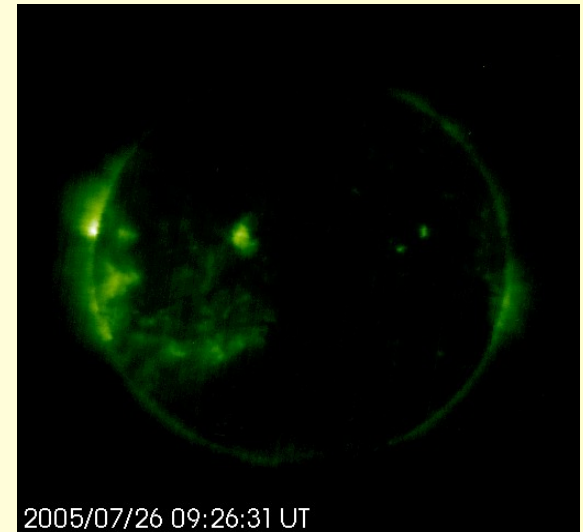
KAT-7 Horizon maps



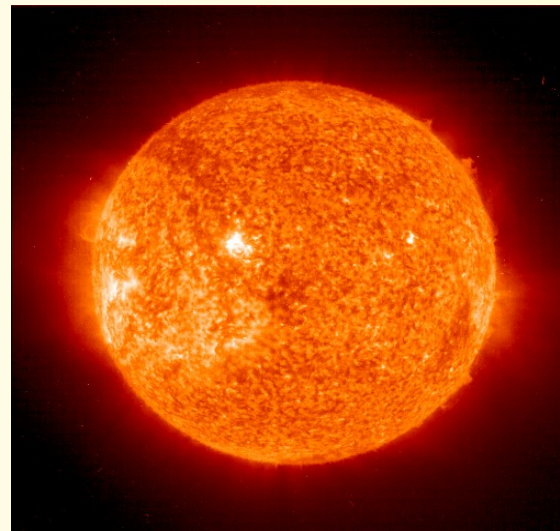
The sun on 25/26 July 2005



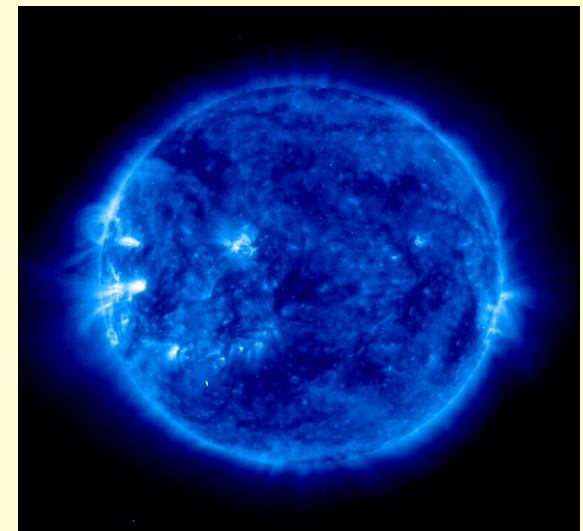
Visible light



X-ray

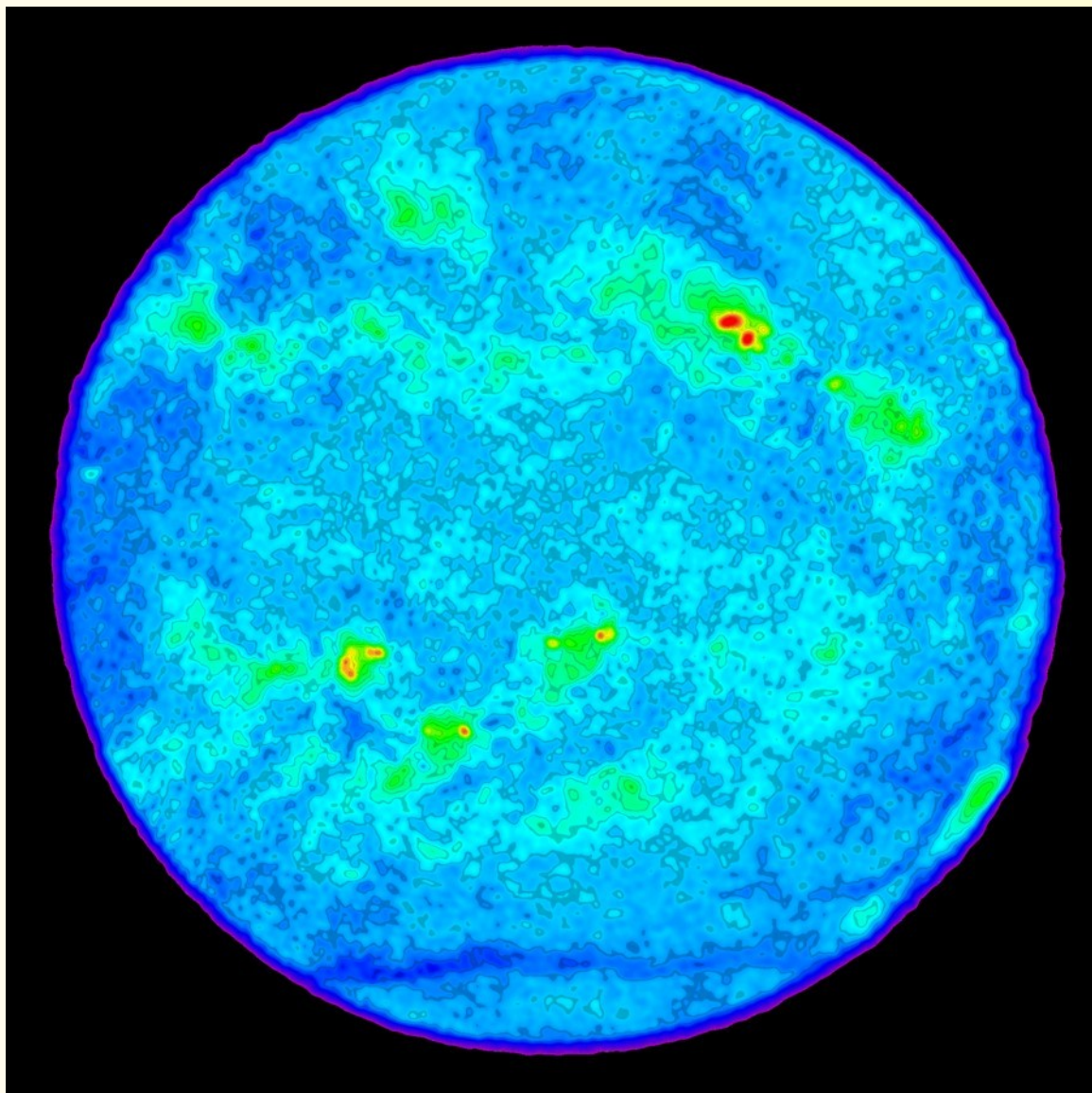


UV - He II



UV - Fe XII

The sun at 5 GHz (VLA)

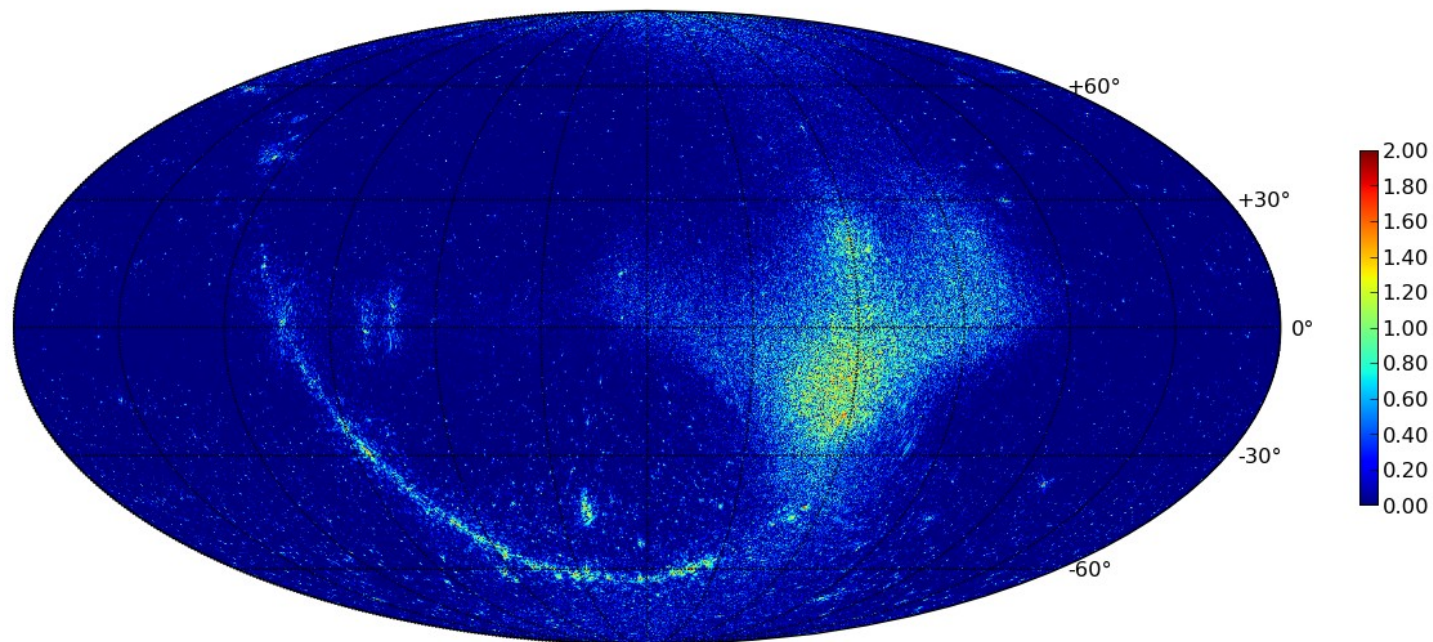


Common radio astronomy bands

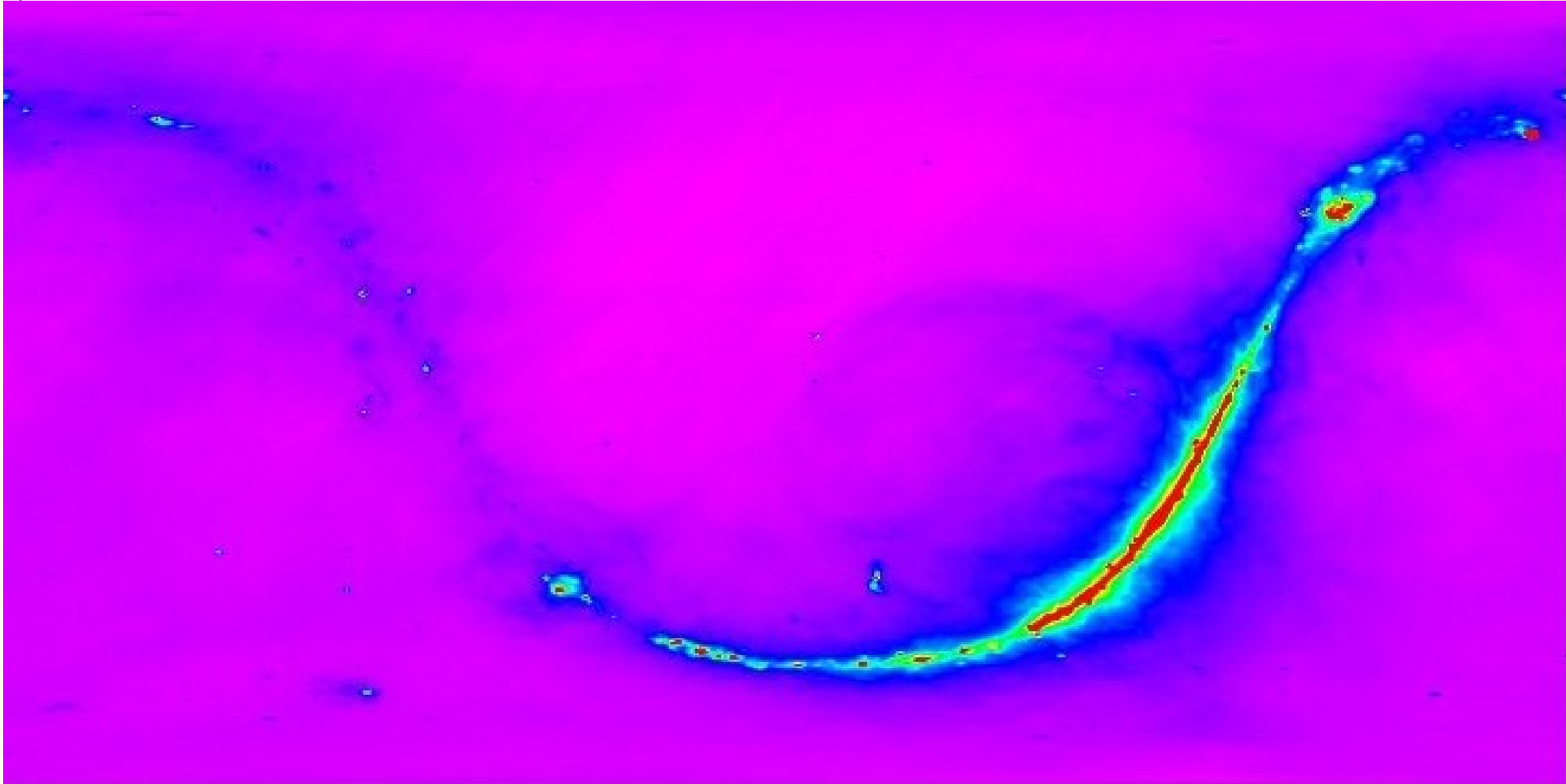
Band	Wavelength	Frequency
P-band	90 cm	327 MHz
L-band	20 cm	1.4 GHz
C-band	6.0 cm	5 GHz
X-band	3.6 cm	8.5 GHz
U-band	2.0 cm	15 GHz
K-band	1.3 cm	23 GHz
Q-band	7 mm	45 GHz

The sky (RA/Dec)

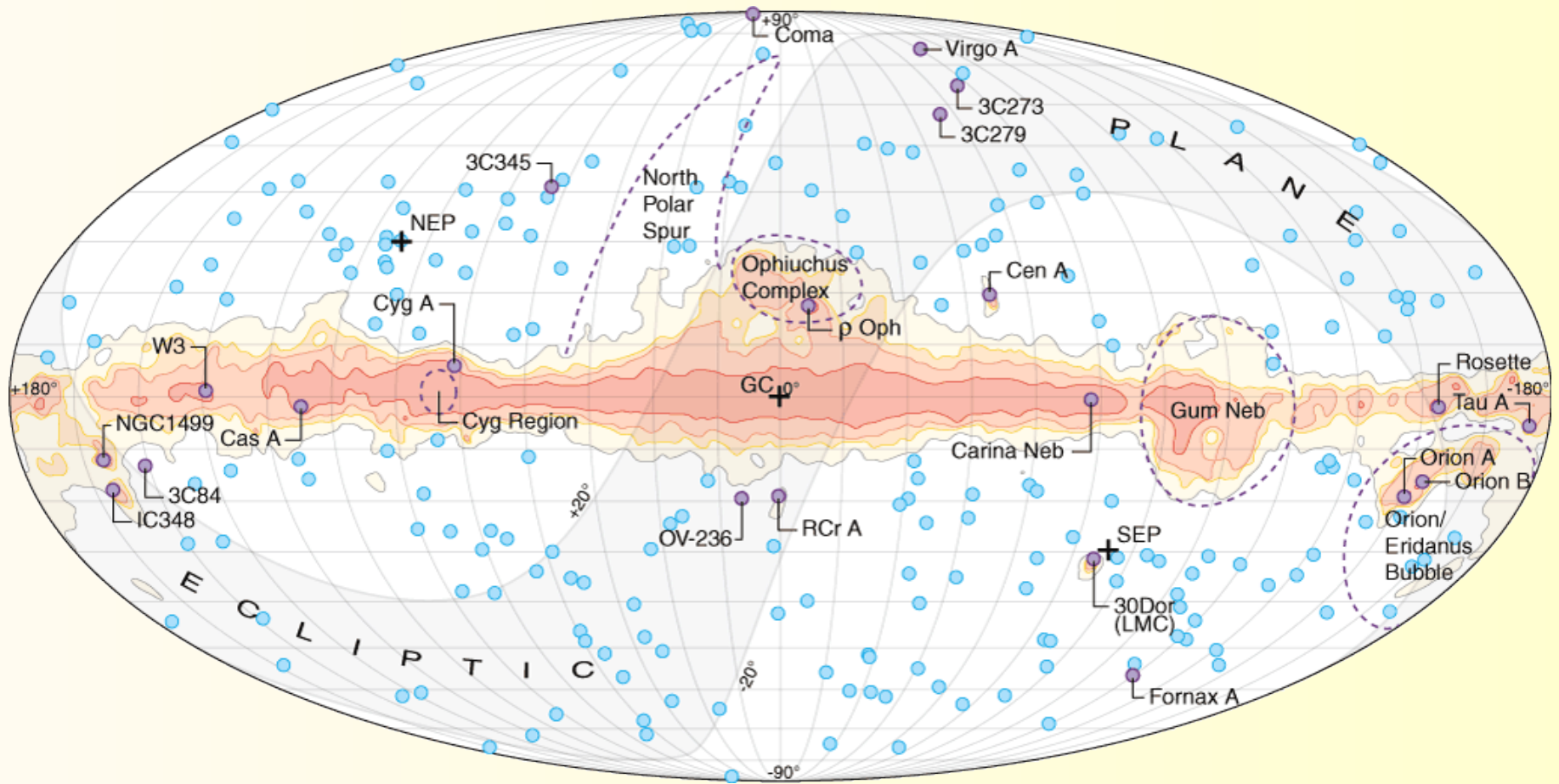
- From PAPER north and south 150MHz



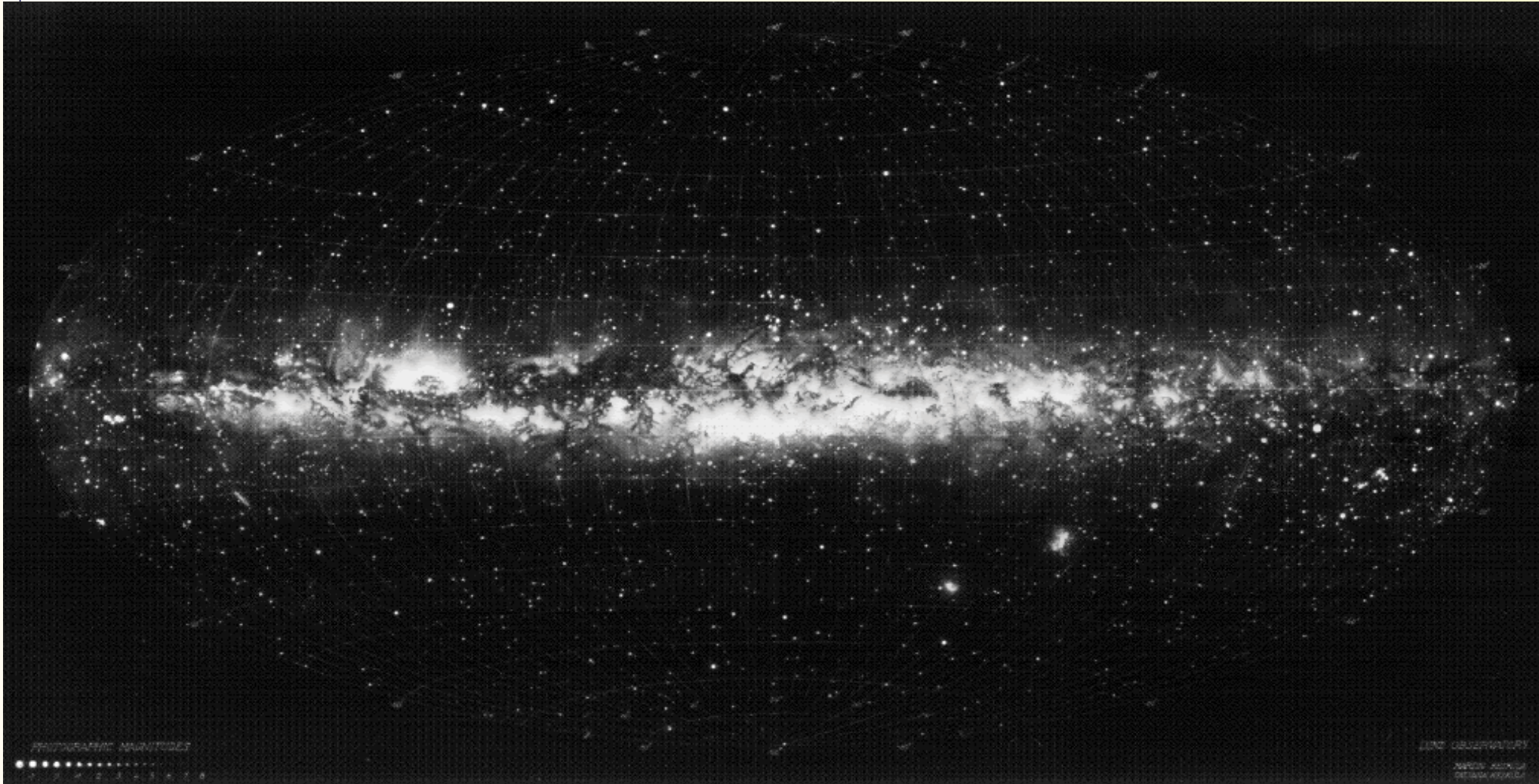
Sky at 408MHz (Jodrell/Parkes)



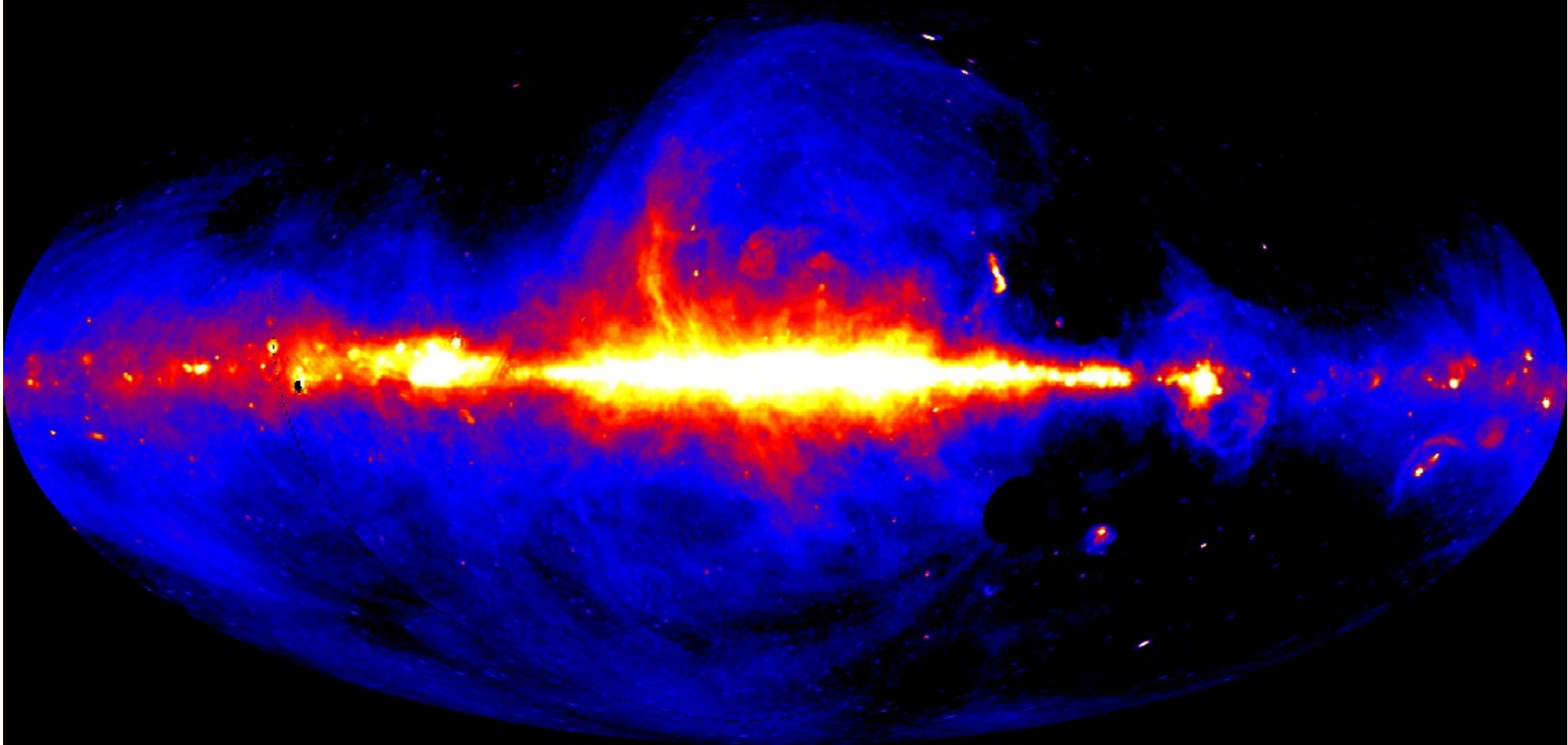
Overview (Galactic coordinates)



The galaxy as our eyes see it



The galaxy as radio telescopes see it



Emission at radio frequencies

– **Any time you accelerate a charged particle it radiates**

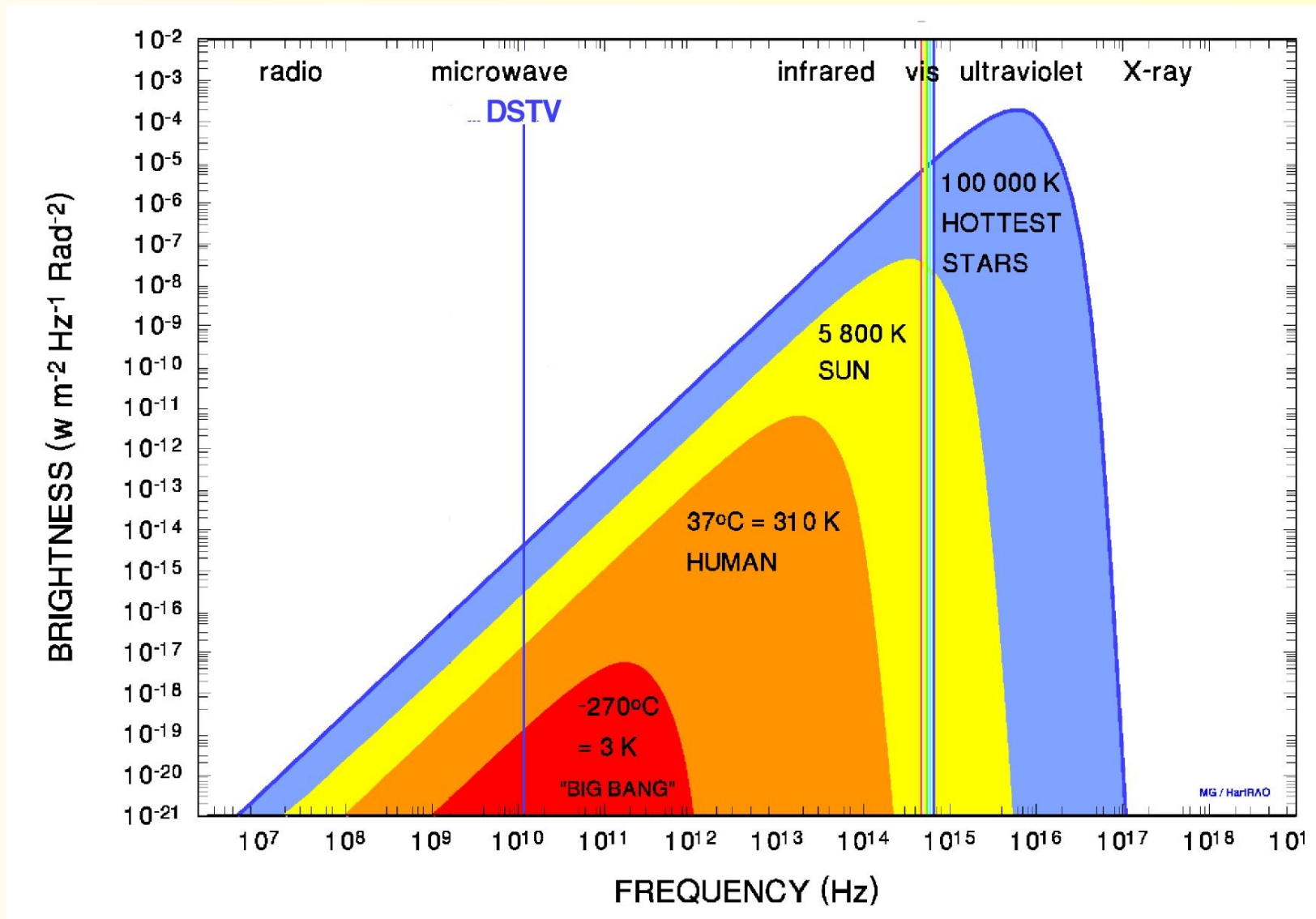
- Black body radiation (thermal motion)
- Free-free emission
- Synchrotron and cyclotron radiation

There are also spectral lines in radio

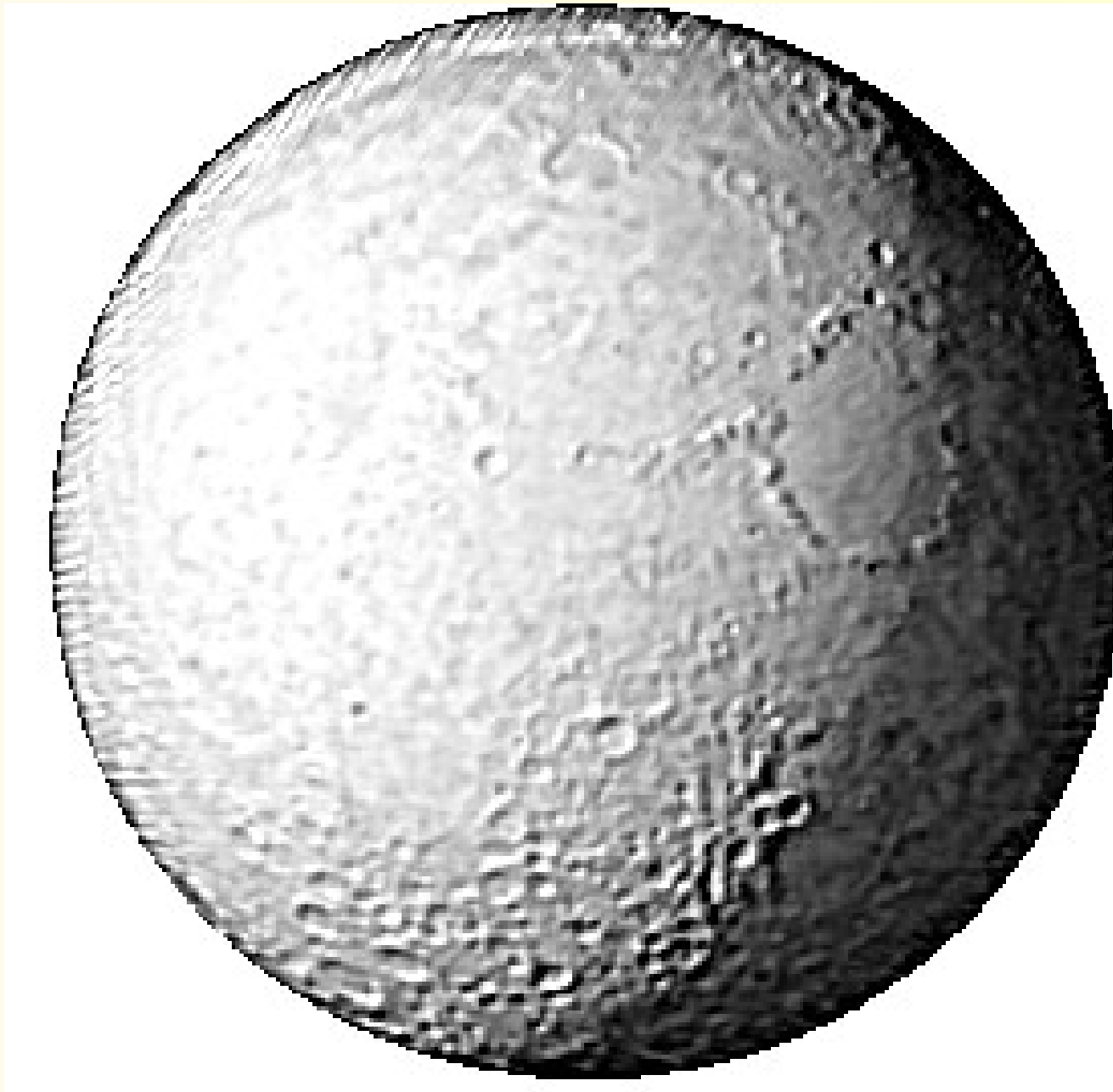
- 21cm hydrogen line radiation
- Molecular lines
 - Cosmic masers

....and the list goes on ...

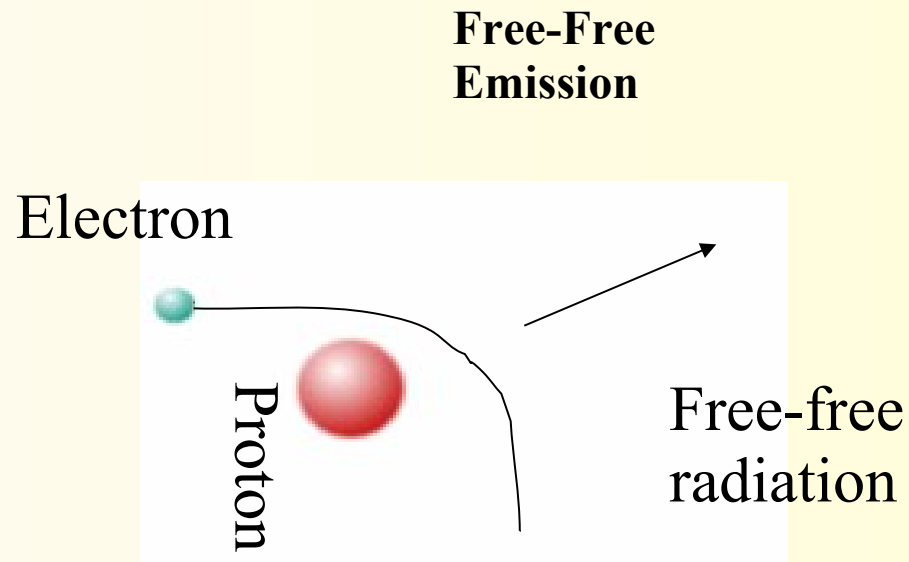
Thermal emission



The moon at 0.85mm (JCMT)



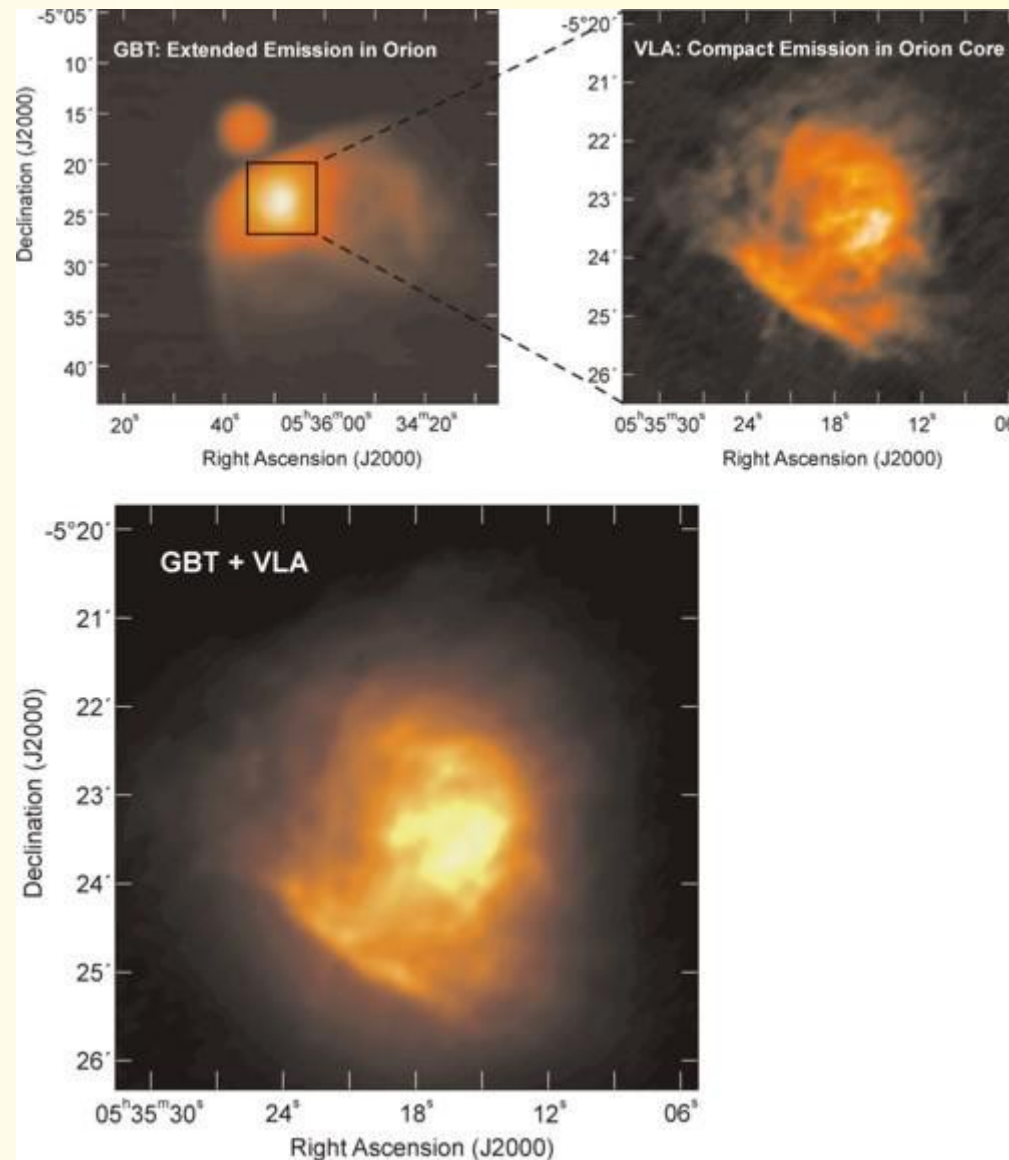
Free-free radiation in an ionised gas (bremsstrahlung)



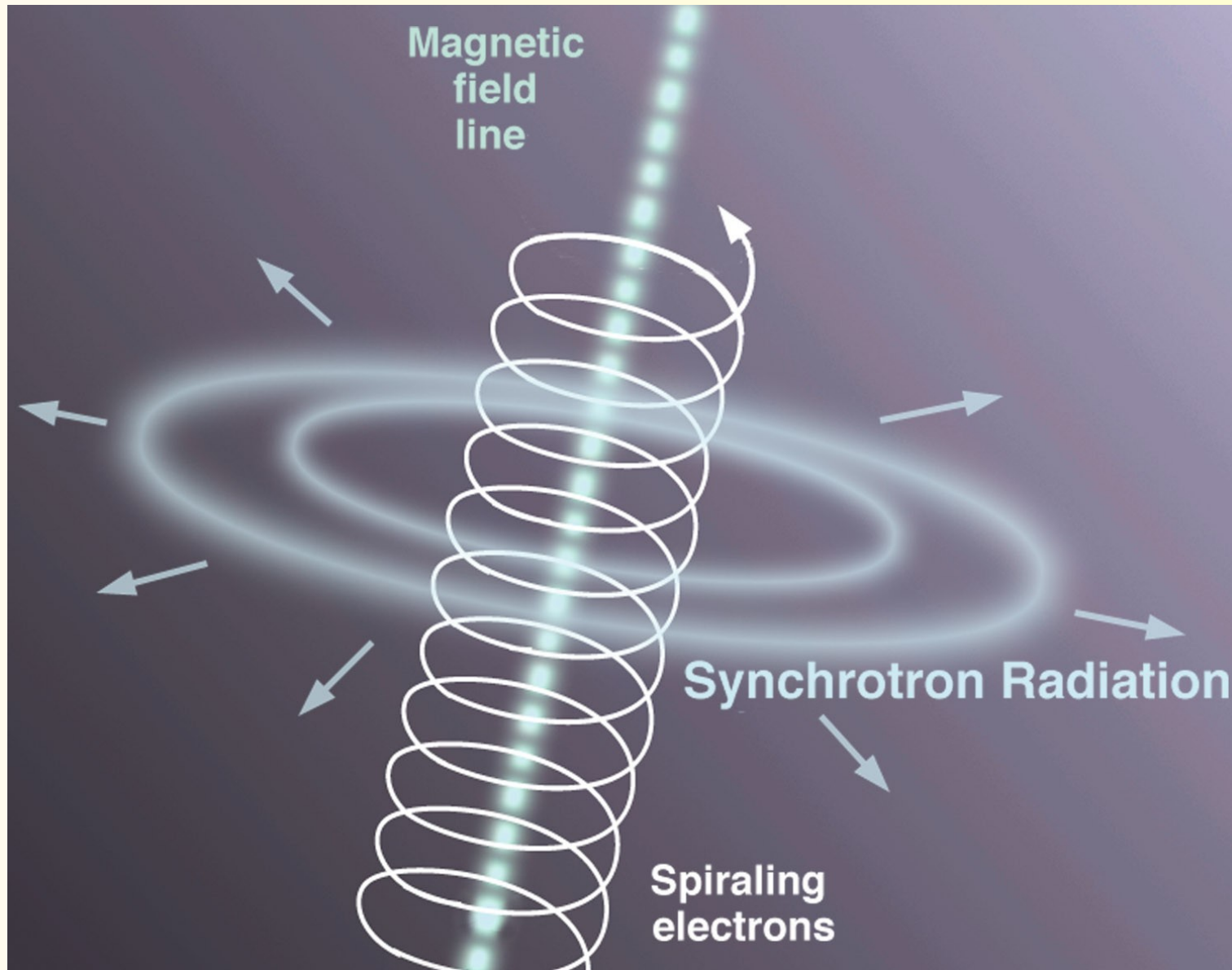
Orion Nebula (HST)



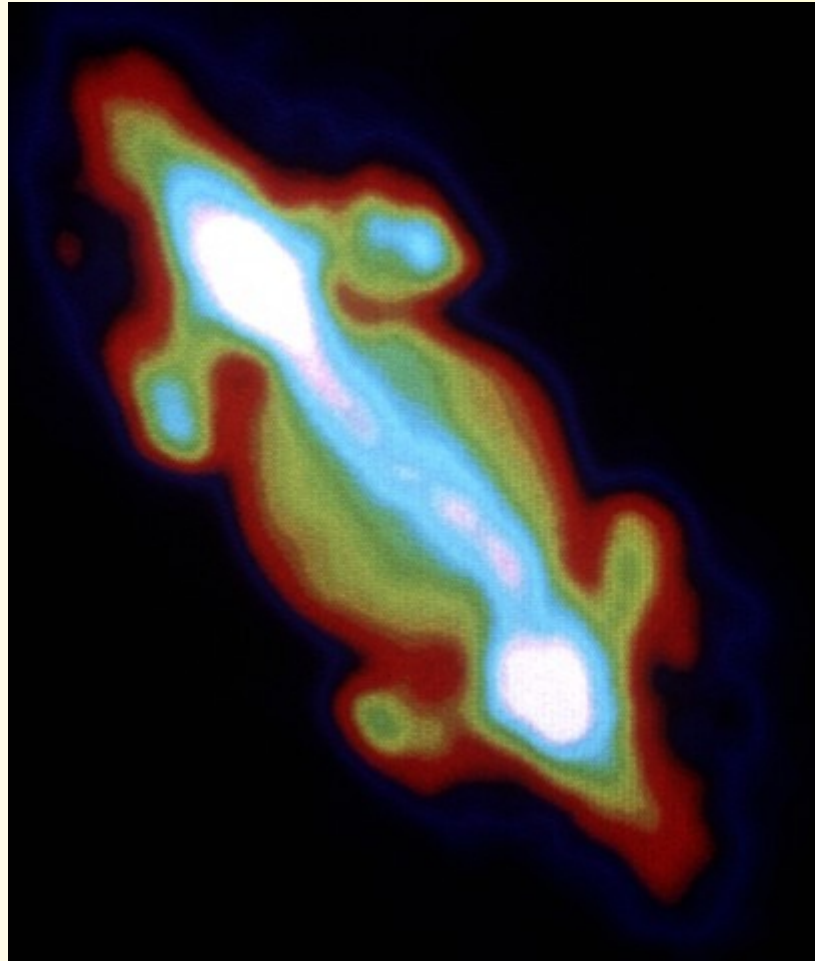
Orion (radio)



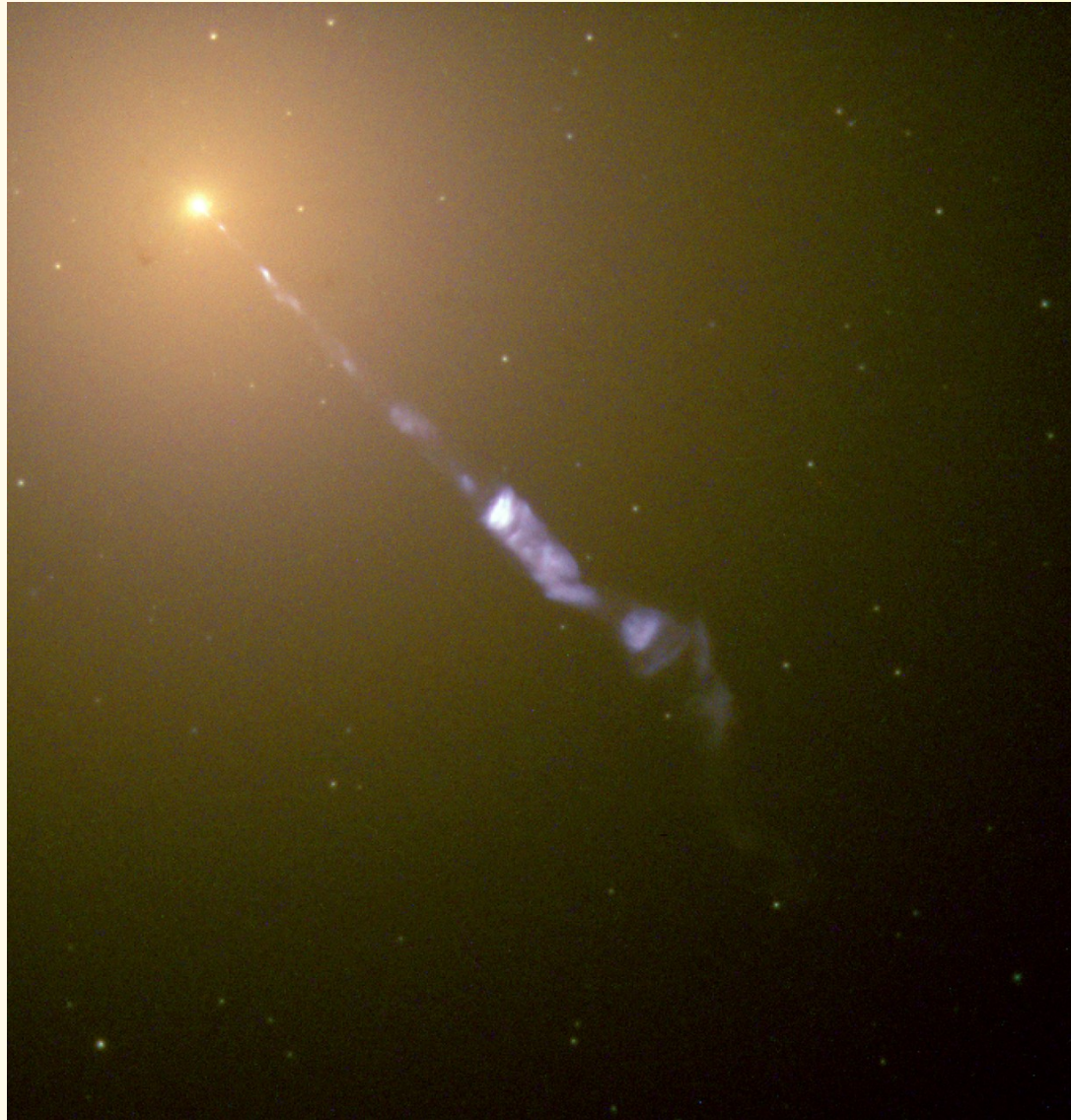
Synchrotron radiation



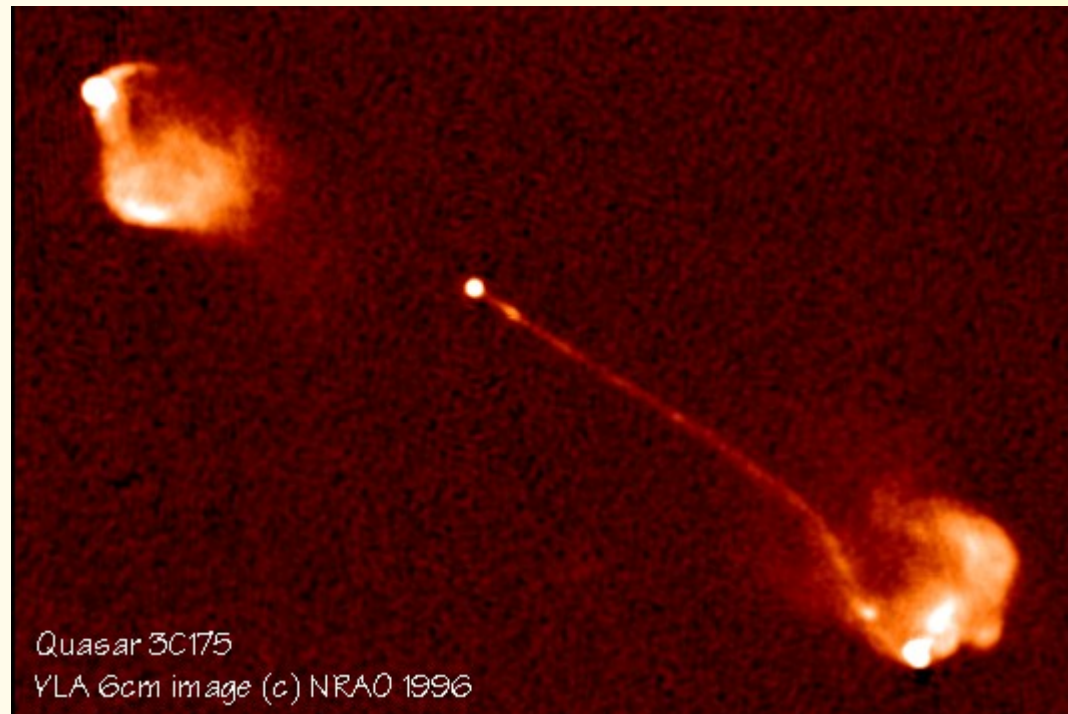
Jupiter



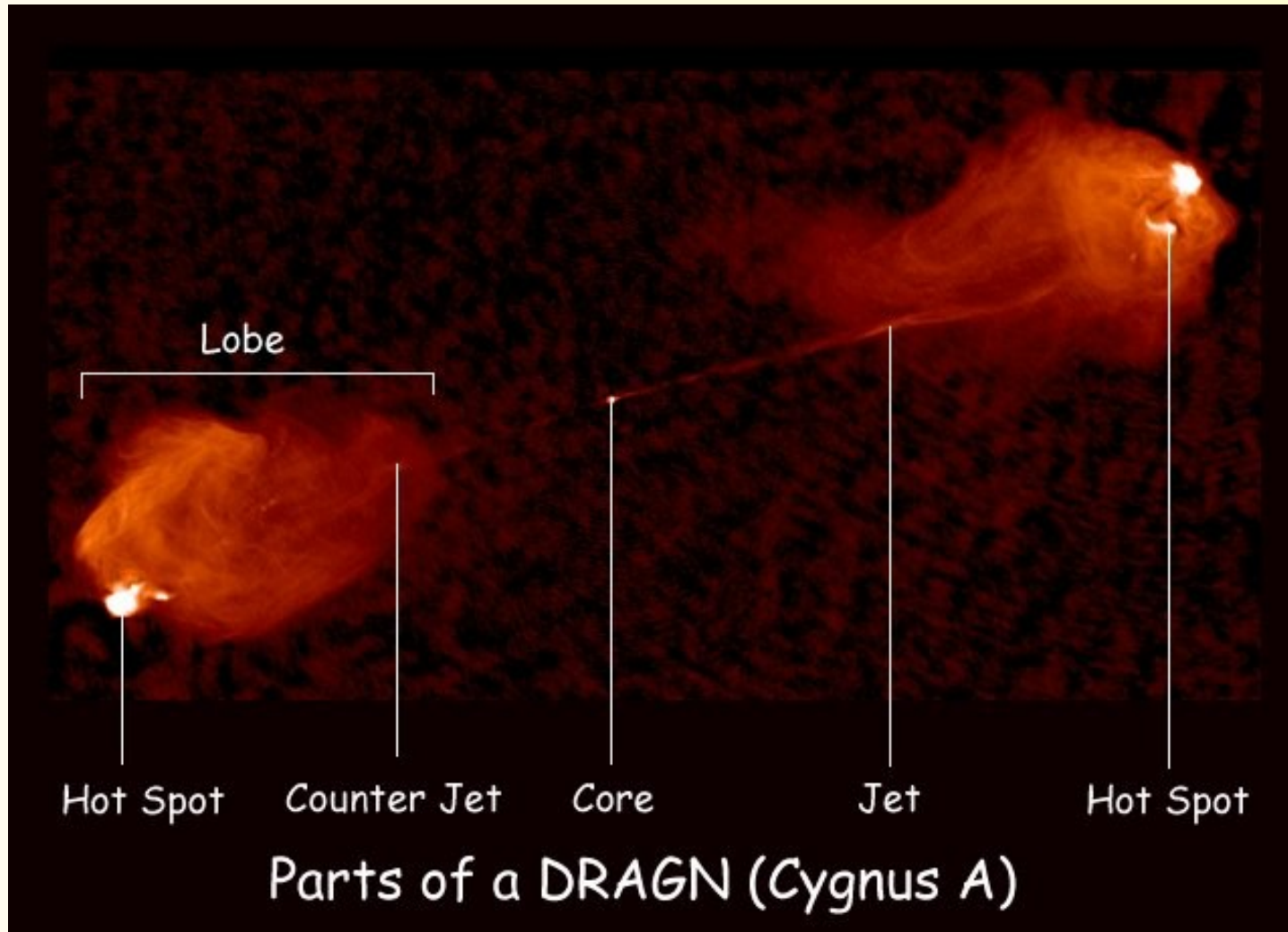
Synchrotron radiation



Quasar 3C175



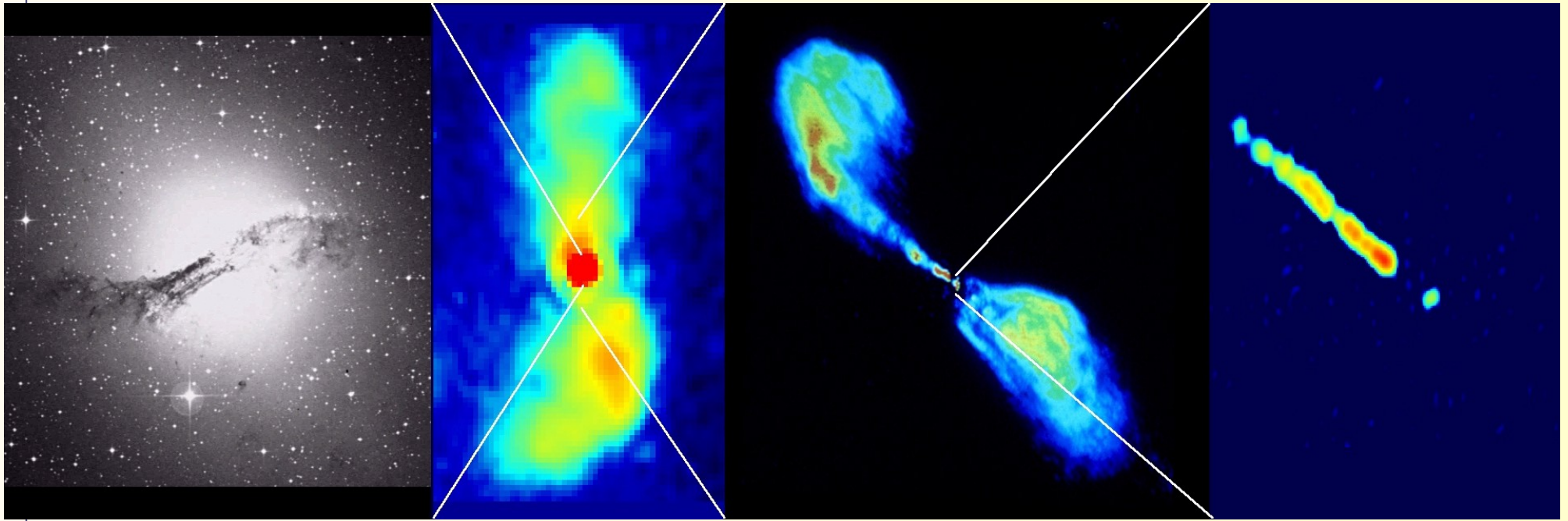
Cygnus A



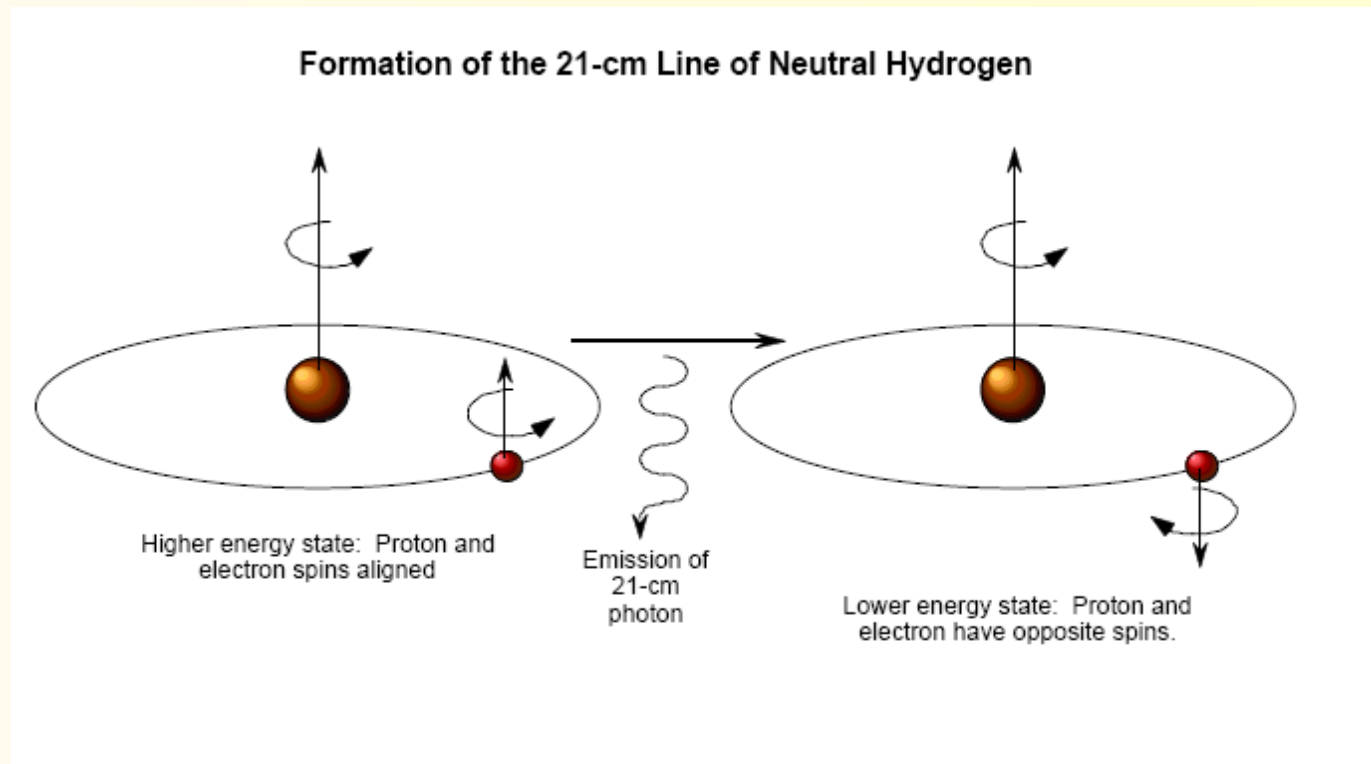
Centaurus A



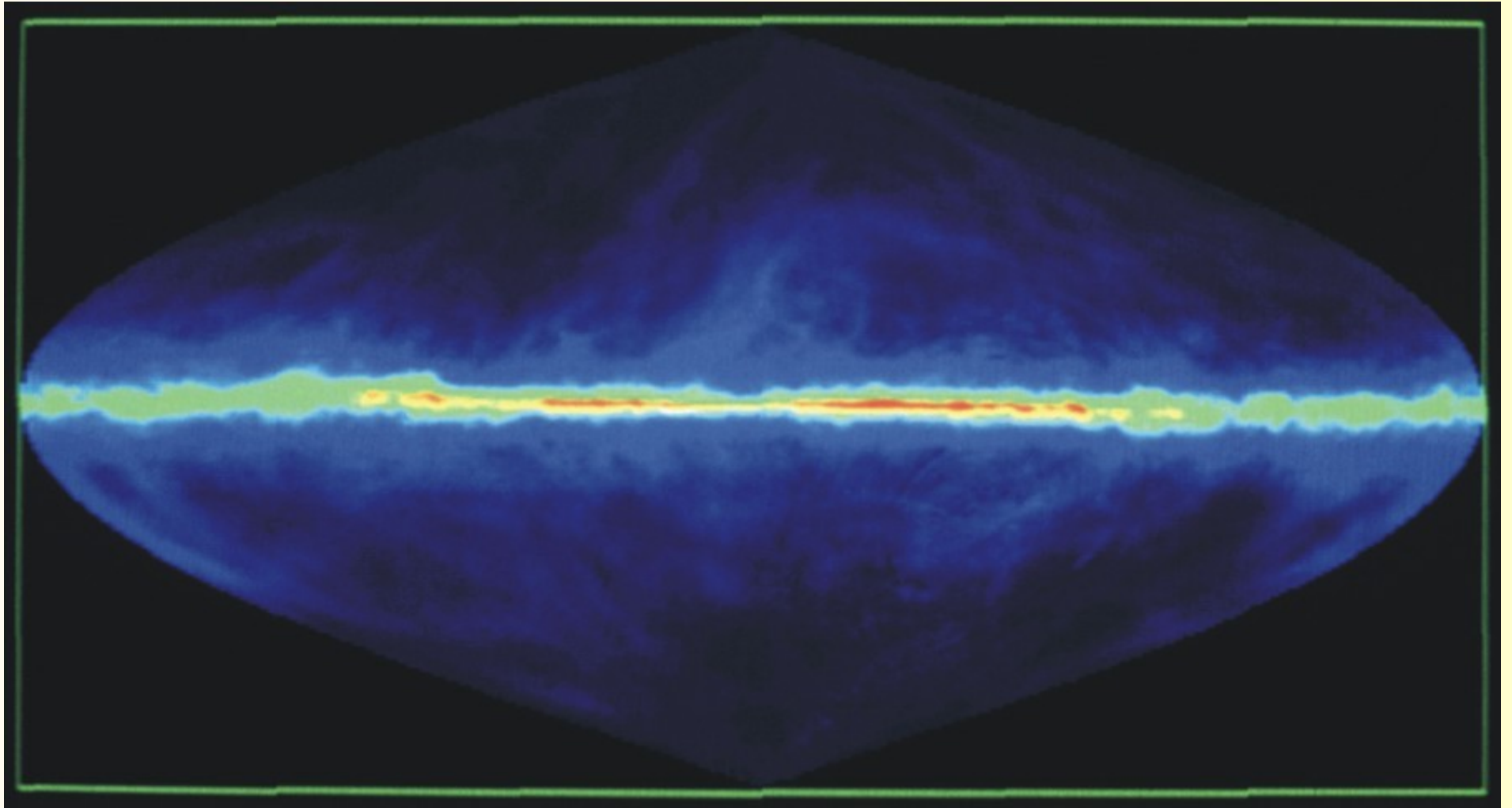
Centaurus A



21-cm spectral line radiation



The HI sky -galactic coordinates

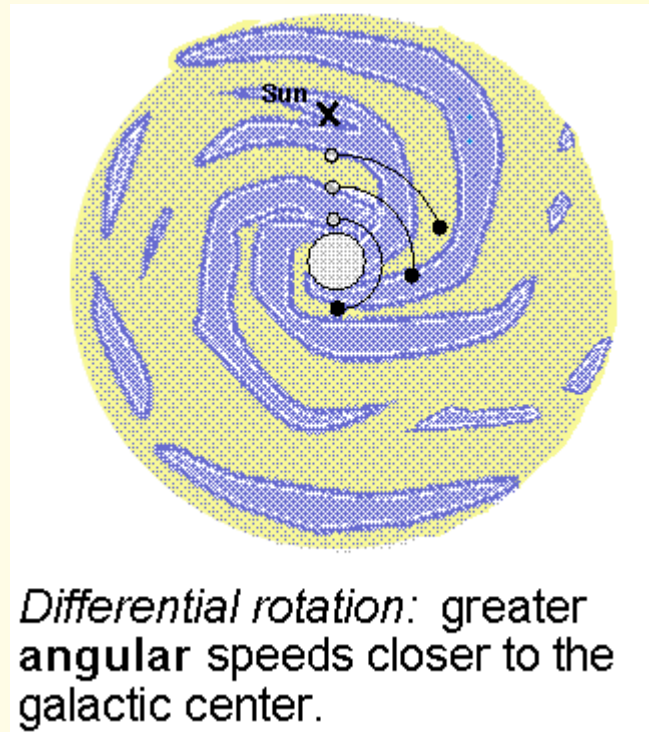


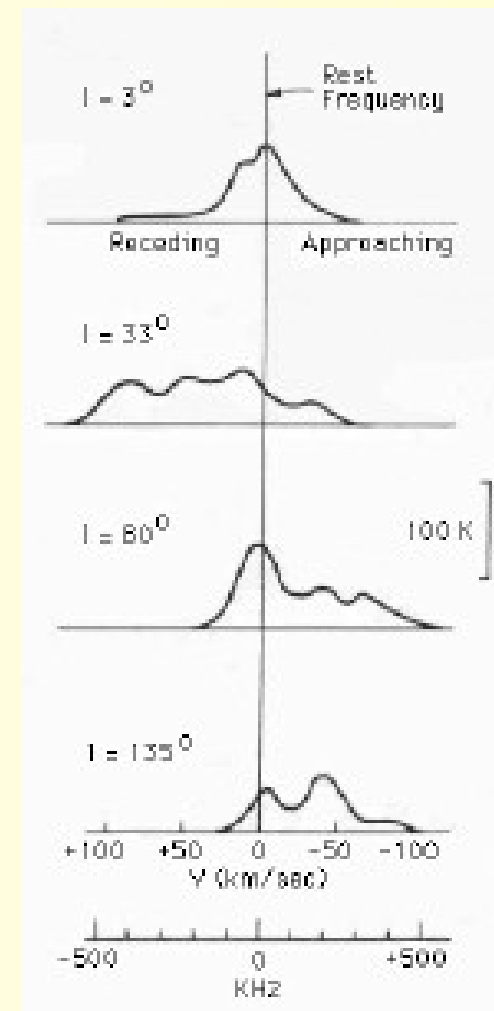
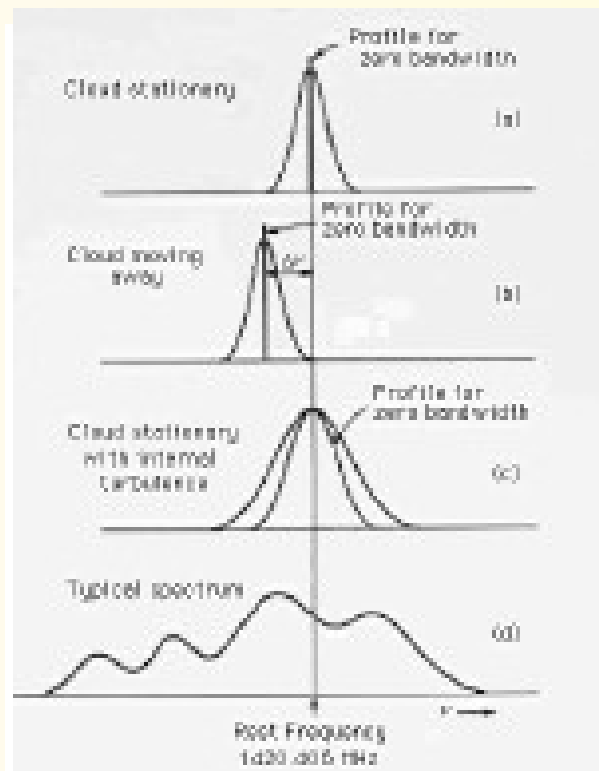
The 21cm line can be used to map galaxies

By studying the 21 cm line, we learn the following:

- velocity of neutral hydrogen clouds (from Doppler shifts)
- rotation of our galaxy and other galaxies (from Doppler shifts)
- distribution of neutral hydrogen (HI) in our galaxy and in other galaxies (from images)
- tidal interactions between galaxies (from images and Doppler shifts)
- amount of gas in the interstellar medium (from strength of the lines)
- With the SKA we can look at distant galaxies out to extreme distances and learn about dark matter and dark energy from the size and membership of galaxy clusters

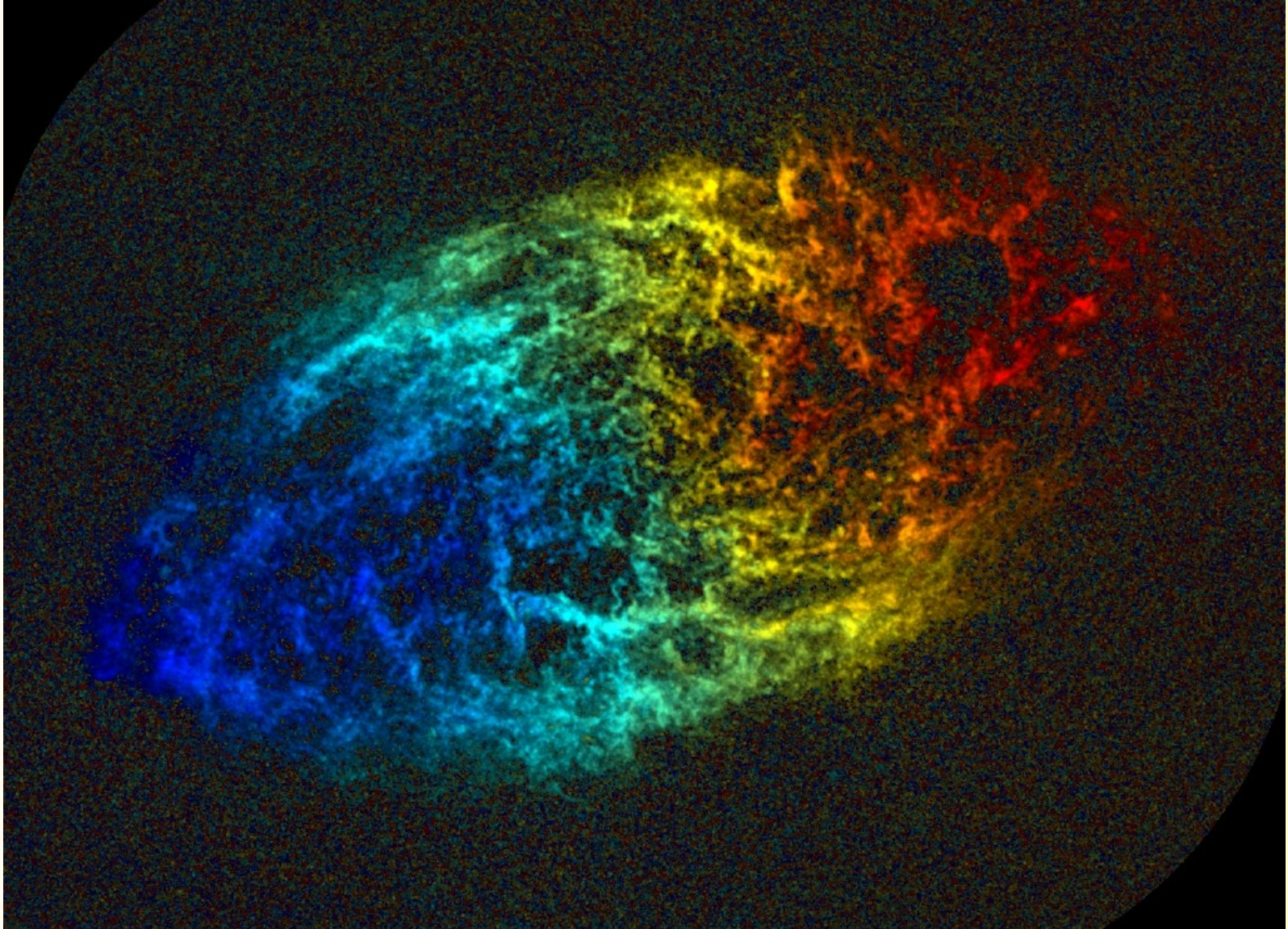
Galactic rotation





Spectra of HI in the Galaxy

M33

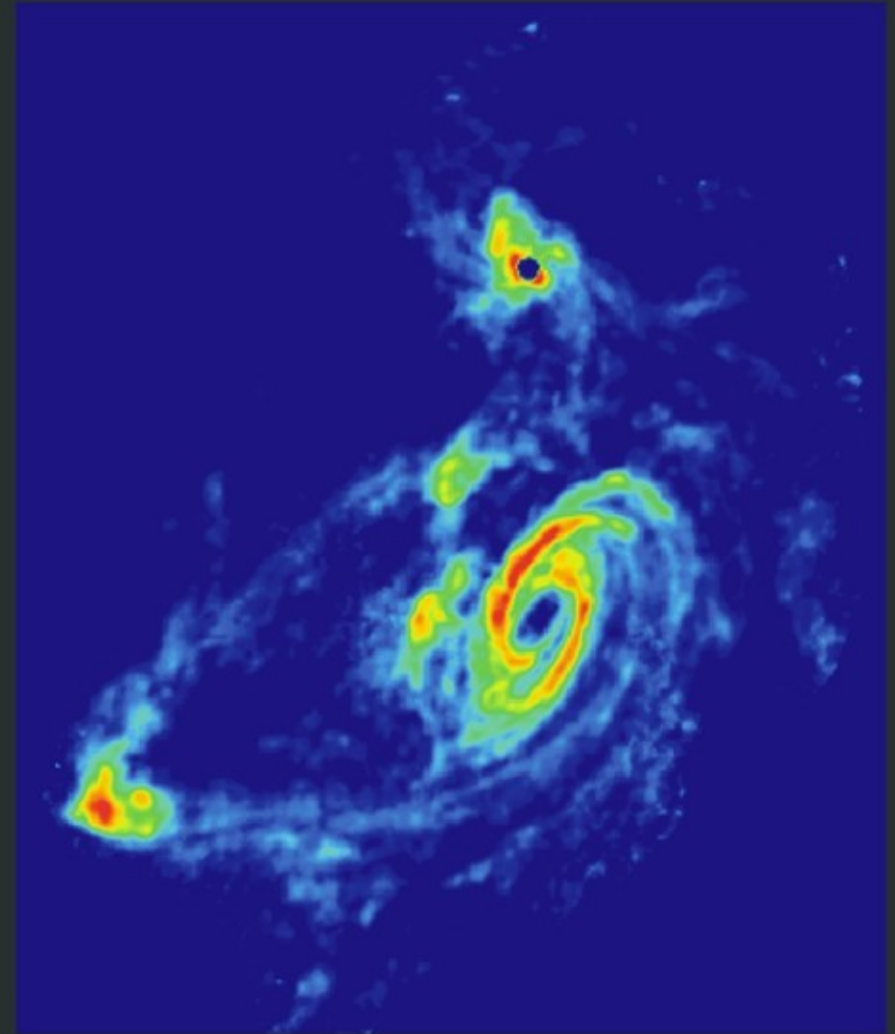


TIDAL INTERACTIONS IN M81 GROUP

Stellar Light Distribution

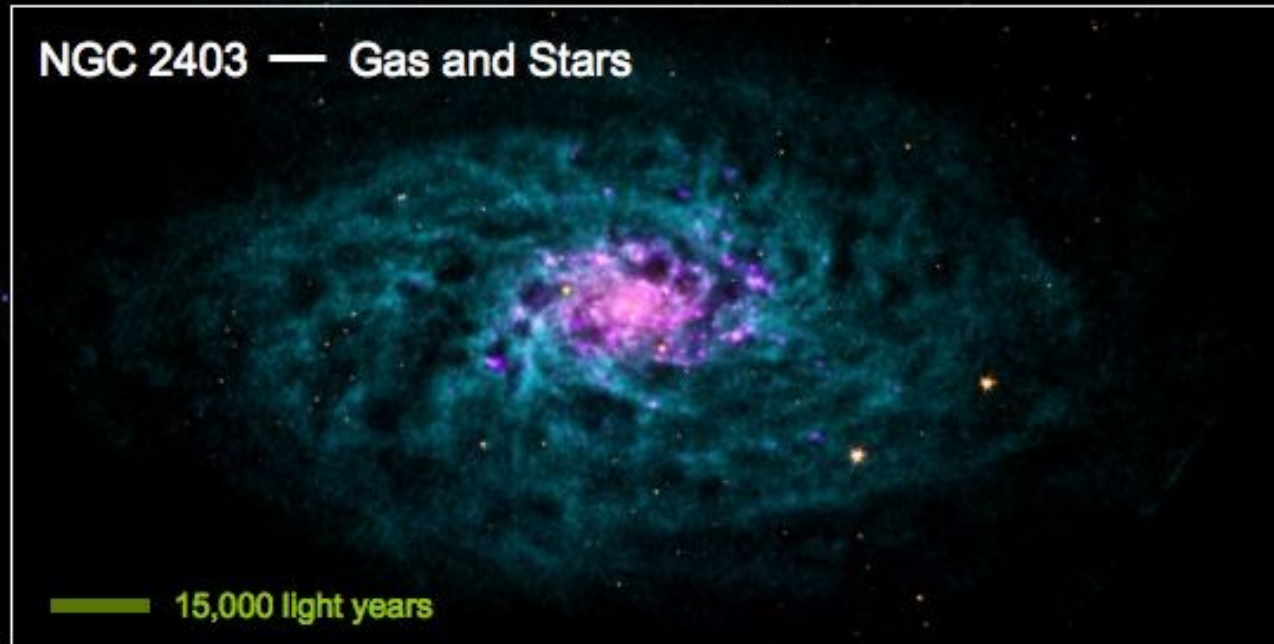


21 cm HI Distribution



Galaxy Dynamics in THINGS — The HI Nearby Galaxy Survey

NGC 2403 — Gas and Stars



THINGS

The HI Nearby
Galaxy Survey

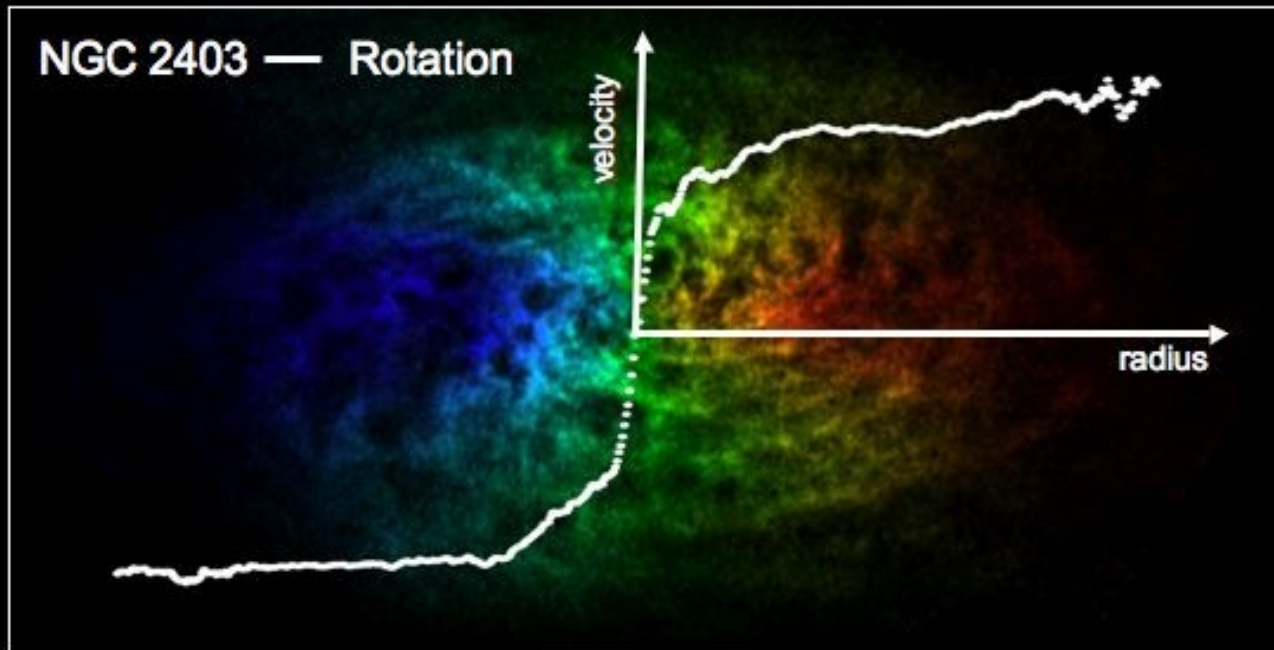
Color Coding:

THINGS Atomic Hydrogen
(*Very Large Array*)

Old stars
(*Spitzer Space Telescope*)

Star Formation
(*GALEX & Spitzer*)

NGC 2403 — Rotation



Color coding:

THINGS HI distribution:

Red-shifted (receding)

Blue-shifted (approaching)

— Rotation Curve



Image credits:

VLA THINGS: Walter et al. 08

Spitzer SINGS: Kennicutt et al. 03

GALEX NGS: Gil de Paz et al. 07

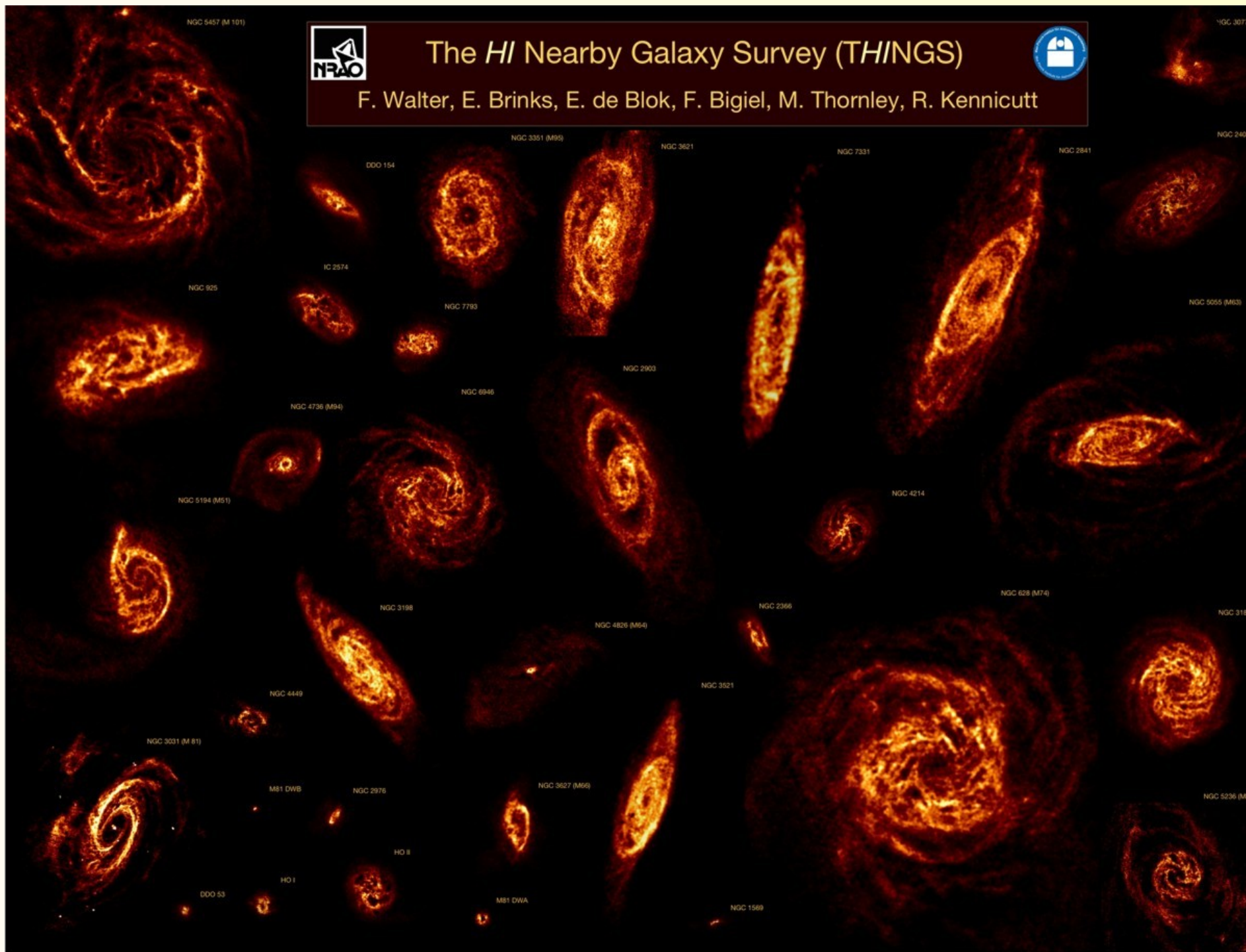
Rotation Curve: de Blok et al. 08



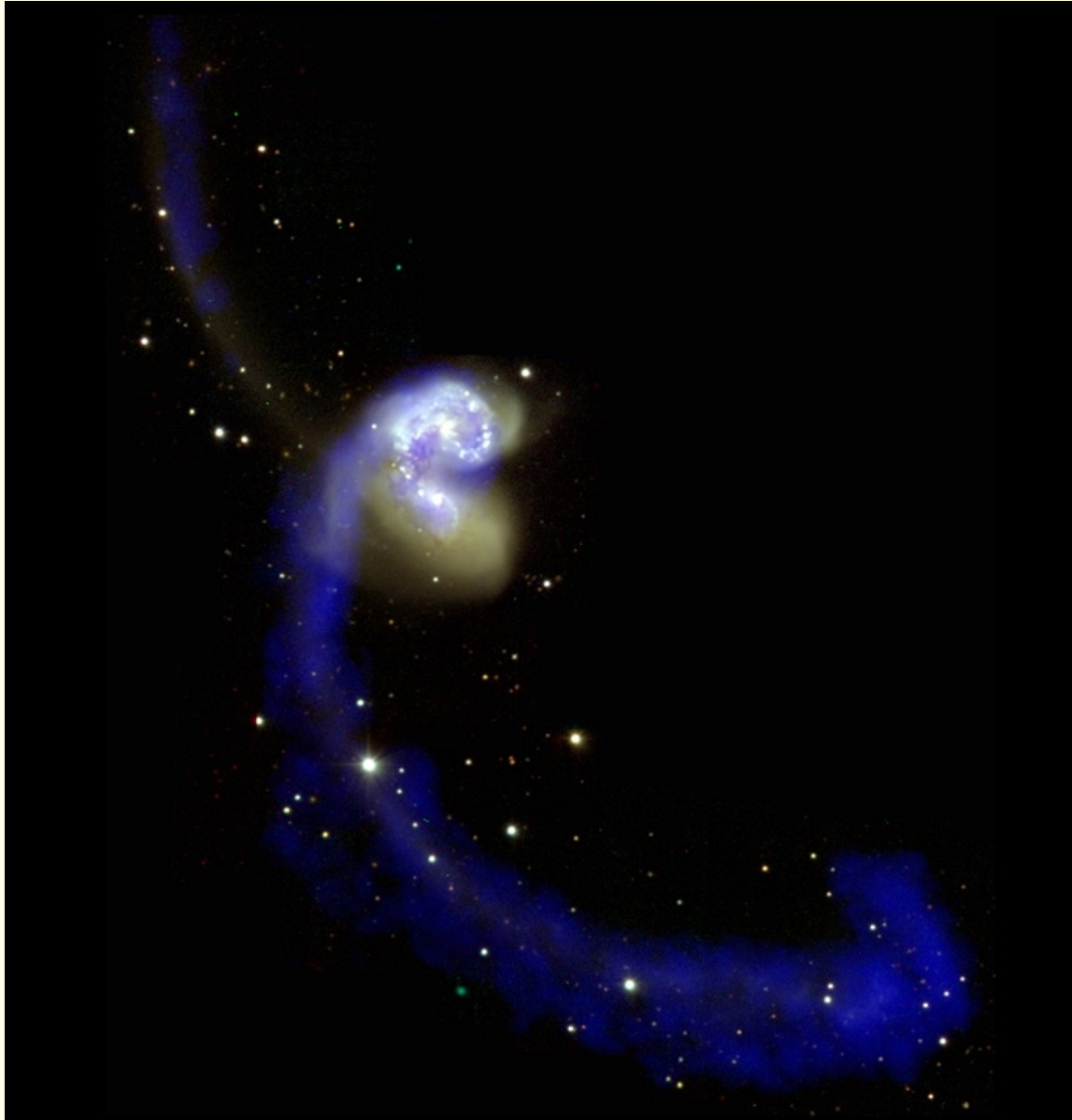
The *HI* Nearby Galaxy Survey (*THINGS*)



F. Walter, E. Brinks, E. de Blok, F. Bigiel, M. Thornley, R. Kennicutt



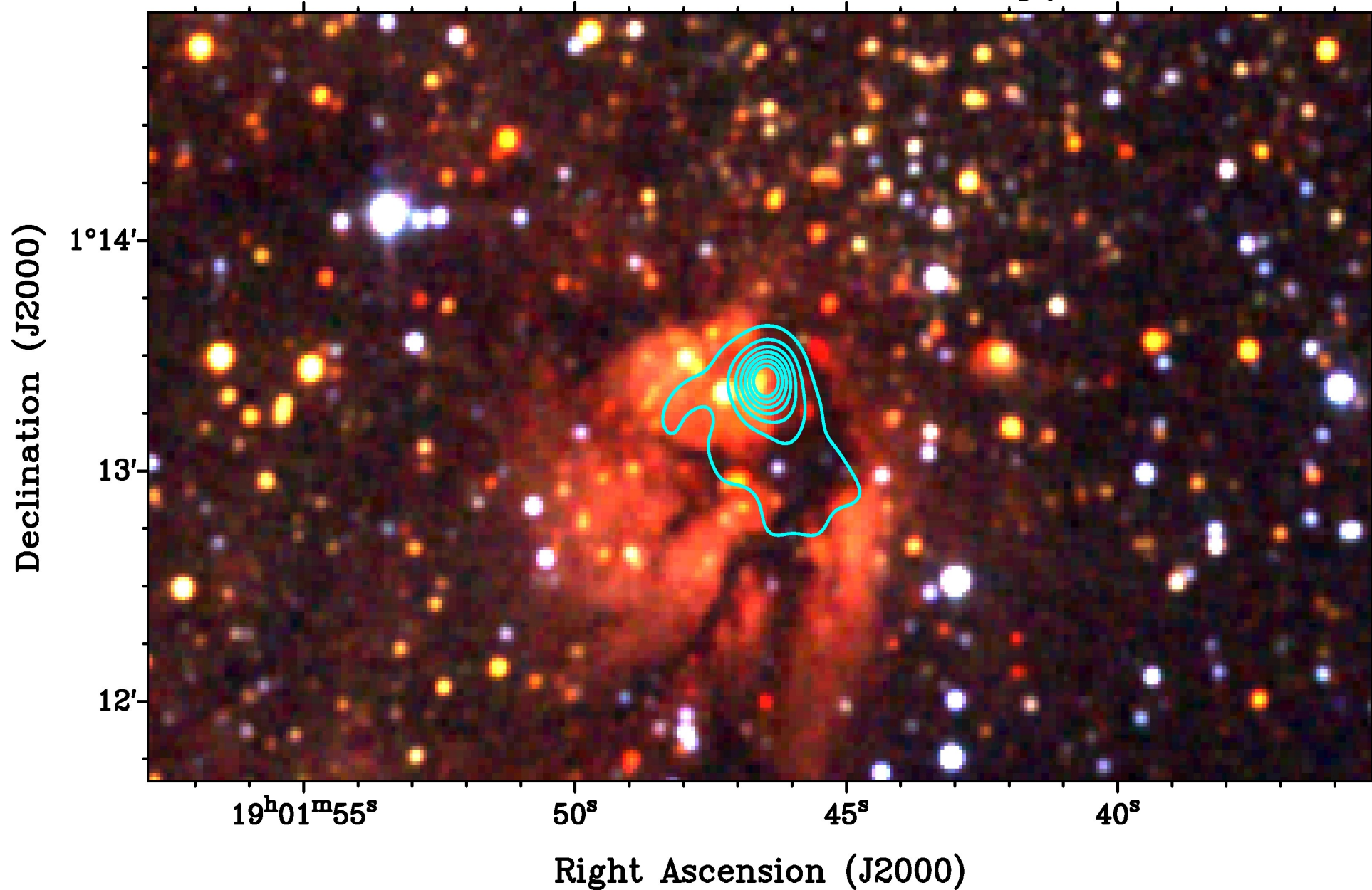
The “antennae”



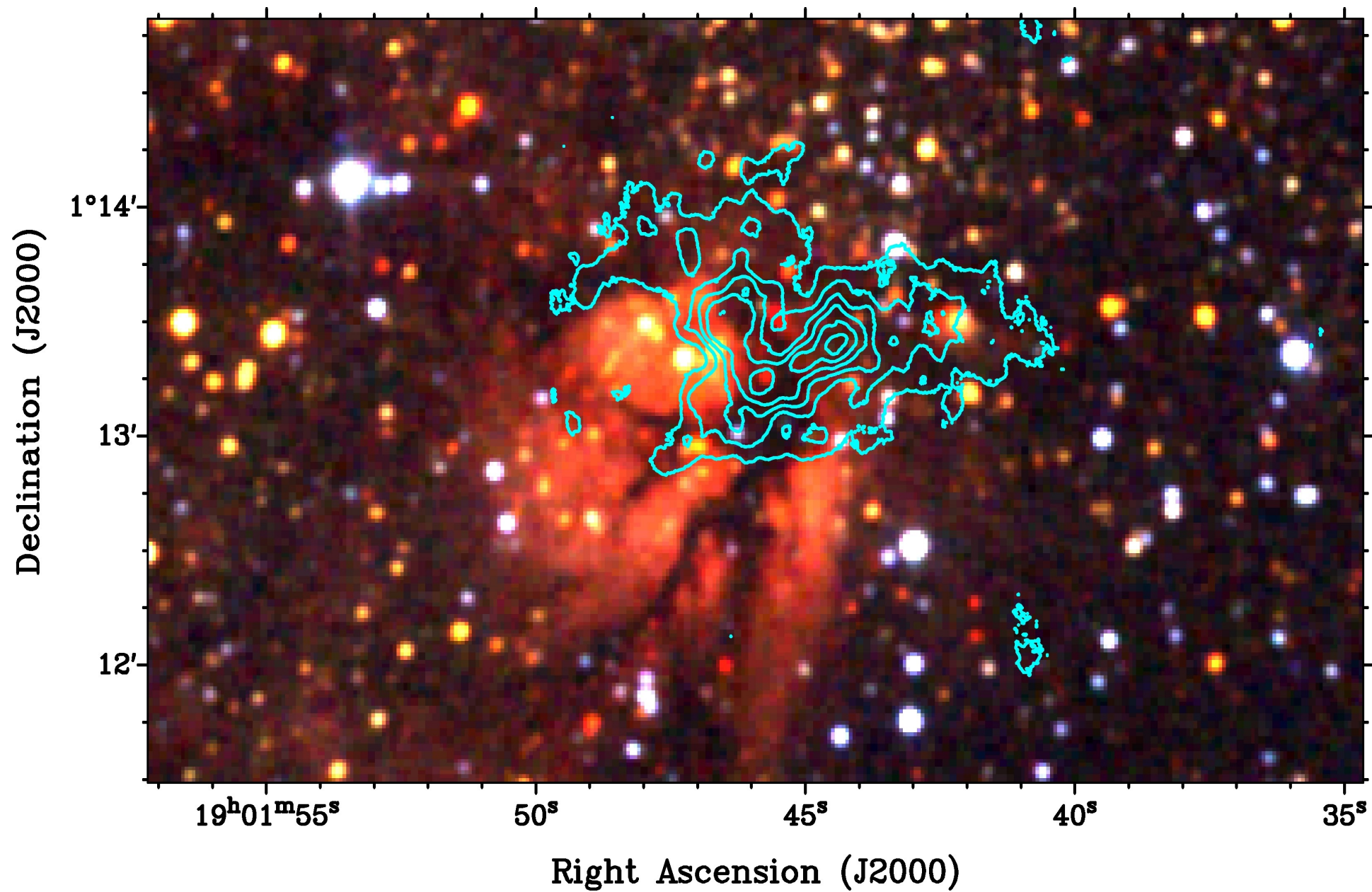
Spectral Lines

- Different molecular lines trace out different chemical and physical conditions
 - For example around ionized gas cloud (HII region)
- Also recombination lines (high energy level versions of Balmer etc.) found around HII regions

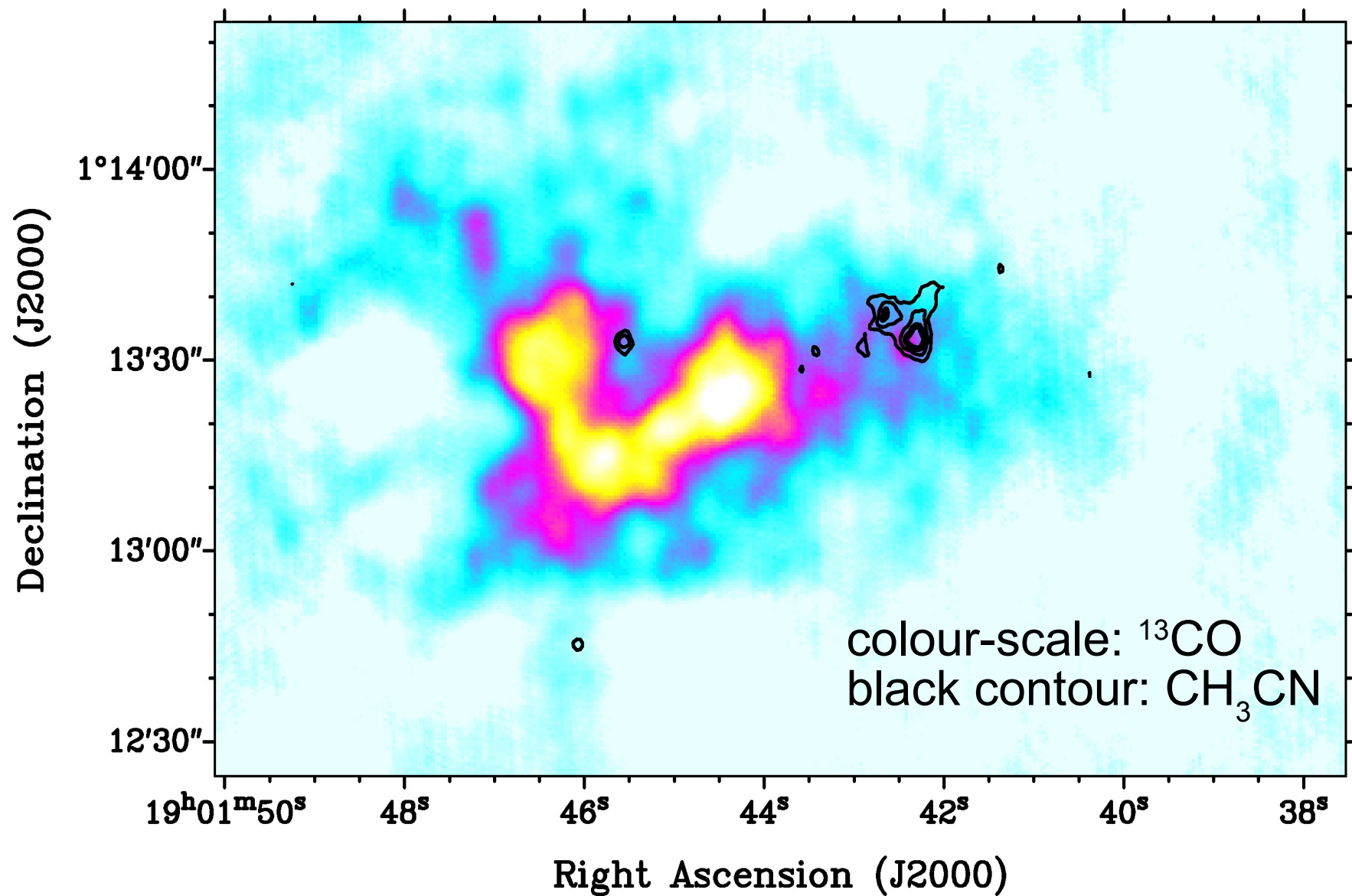
3mm continuum: HII region



^{13}CO



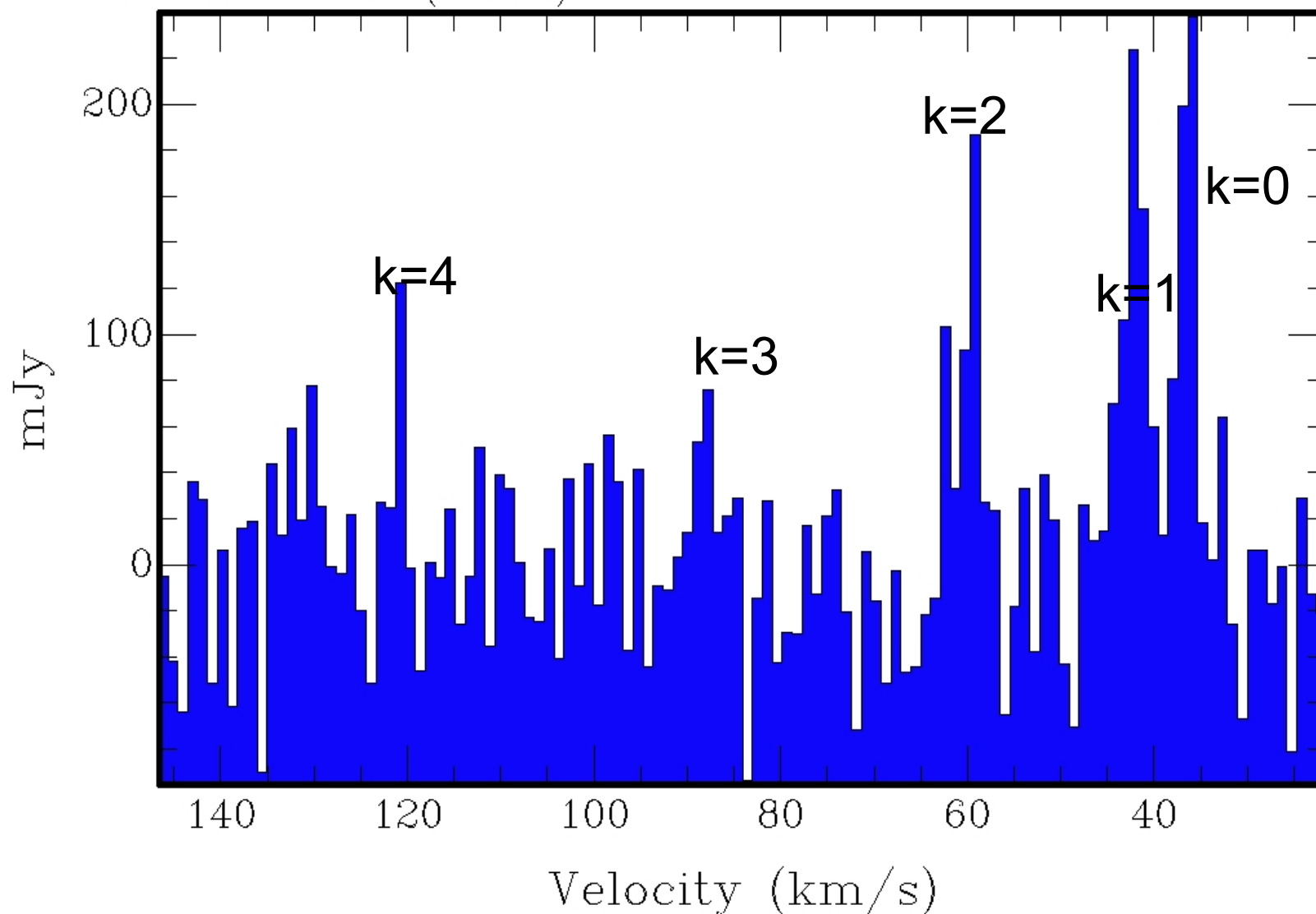
CH_3CN cores



CH₃CN spectrum

Ra: 19^h 01^m 42.61^s (J2000)

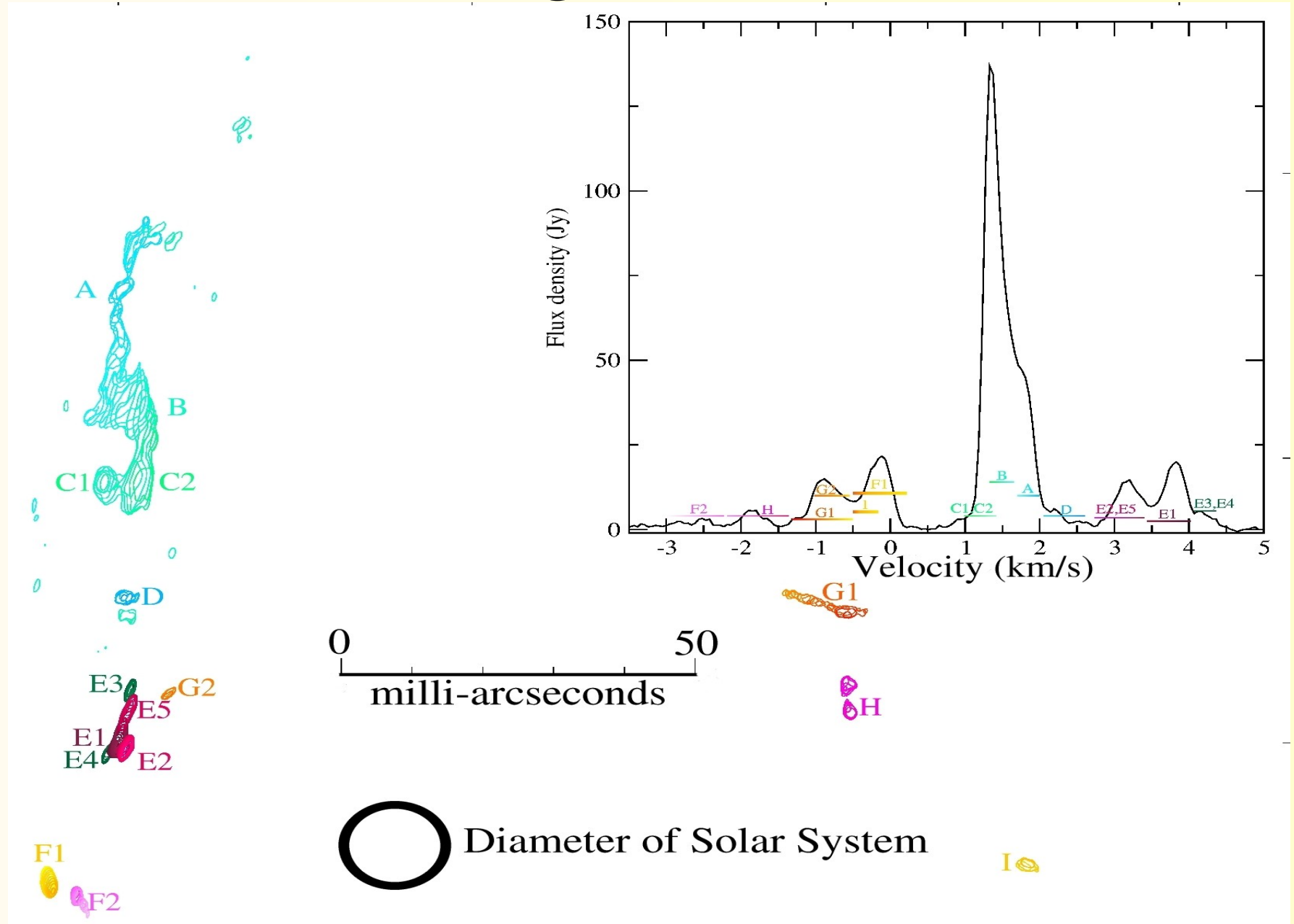
Dec: 01° 13' 36.99" (J2000)



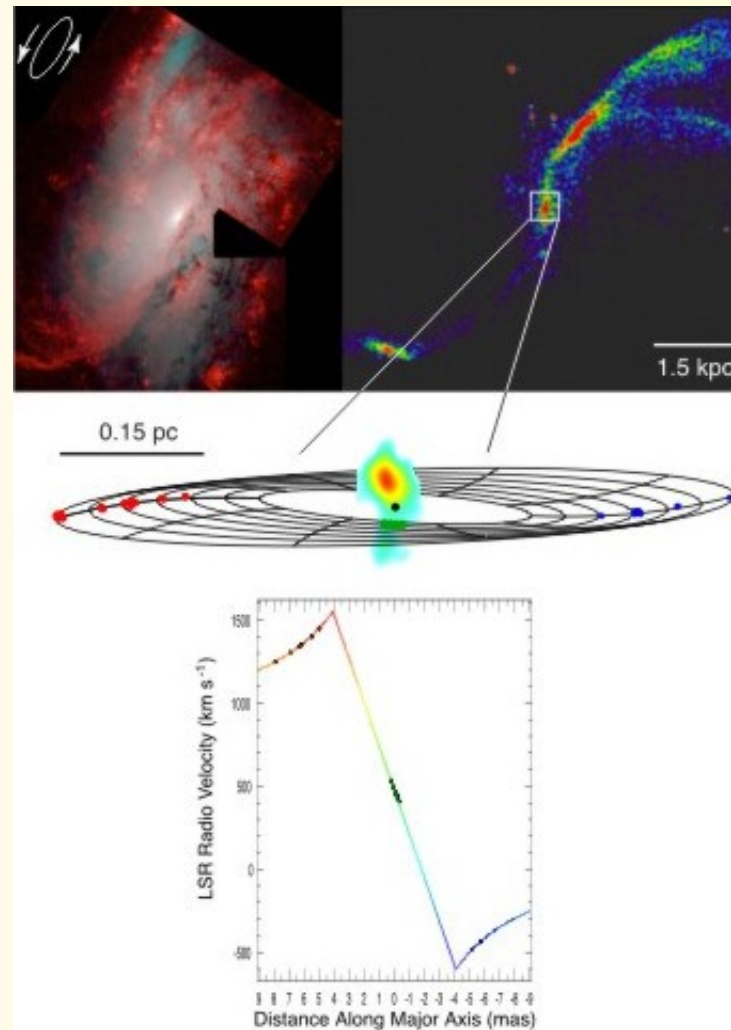
Masers

- Narrow lines (non-thermal)
- Very intense
- Molecular lines – H_2O , OH, CH_3OH , NH_3 , SiO
 - Water, OH radical, methanol, ammonia, silicon monoxide
- Need external 'pump' to force the molecules in a cloud into a meta-stable state
 - They fall to lower state like dominoes- but all at once

Methanol masers in starforming regions



Water maser distribution in NGC 4258



The Crab supernova remnant



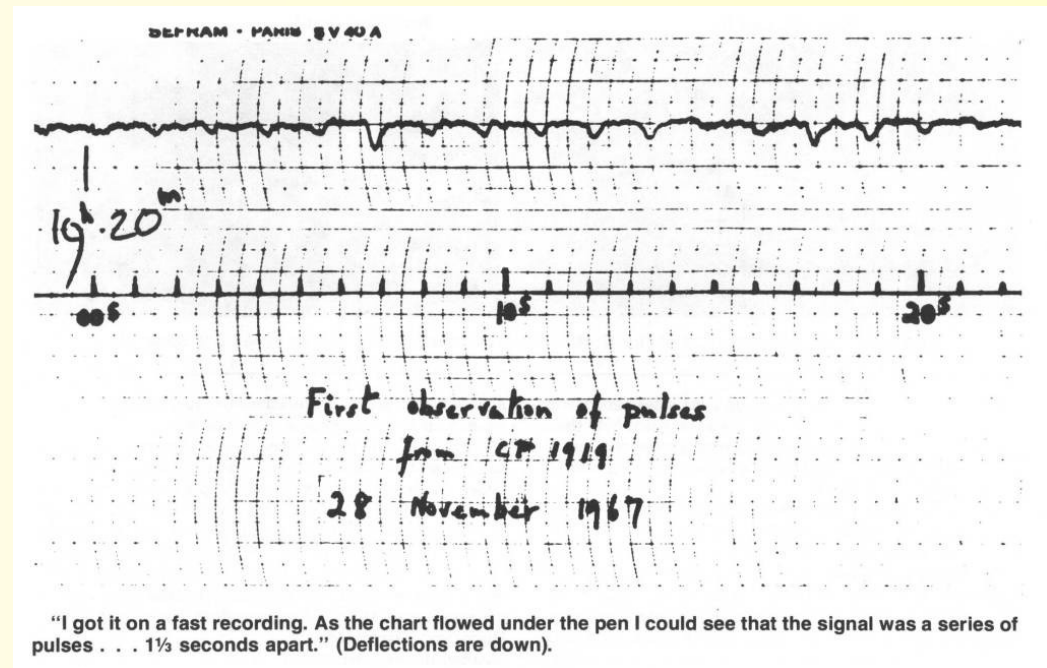
Crab in X-ray, optical & radio



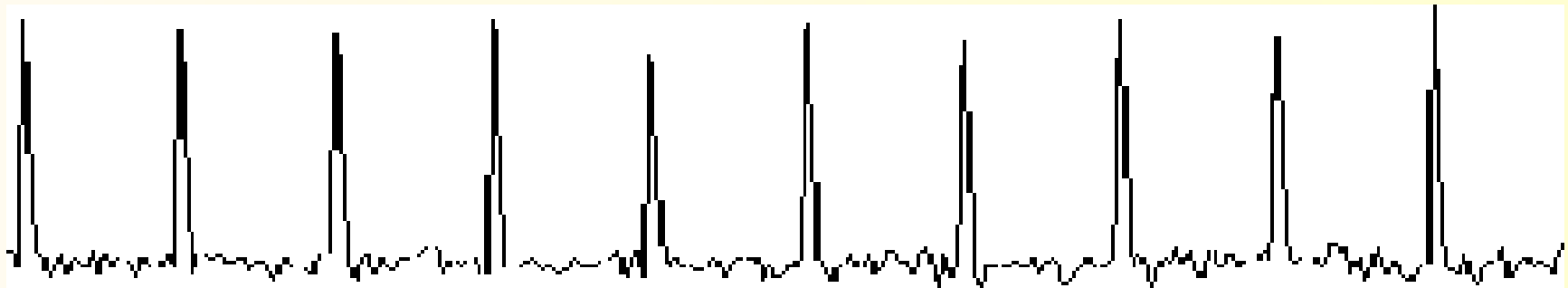
Pulsars

Discovered accidentally by Jocelyn Bell & Tony Hewish in 1967

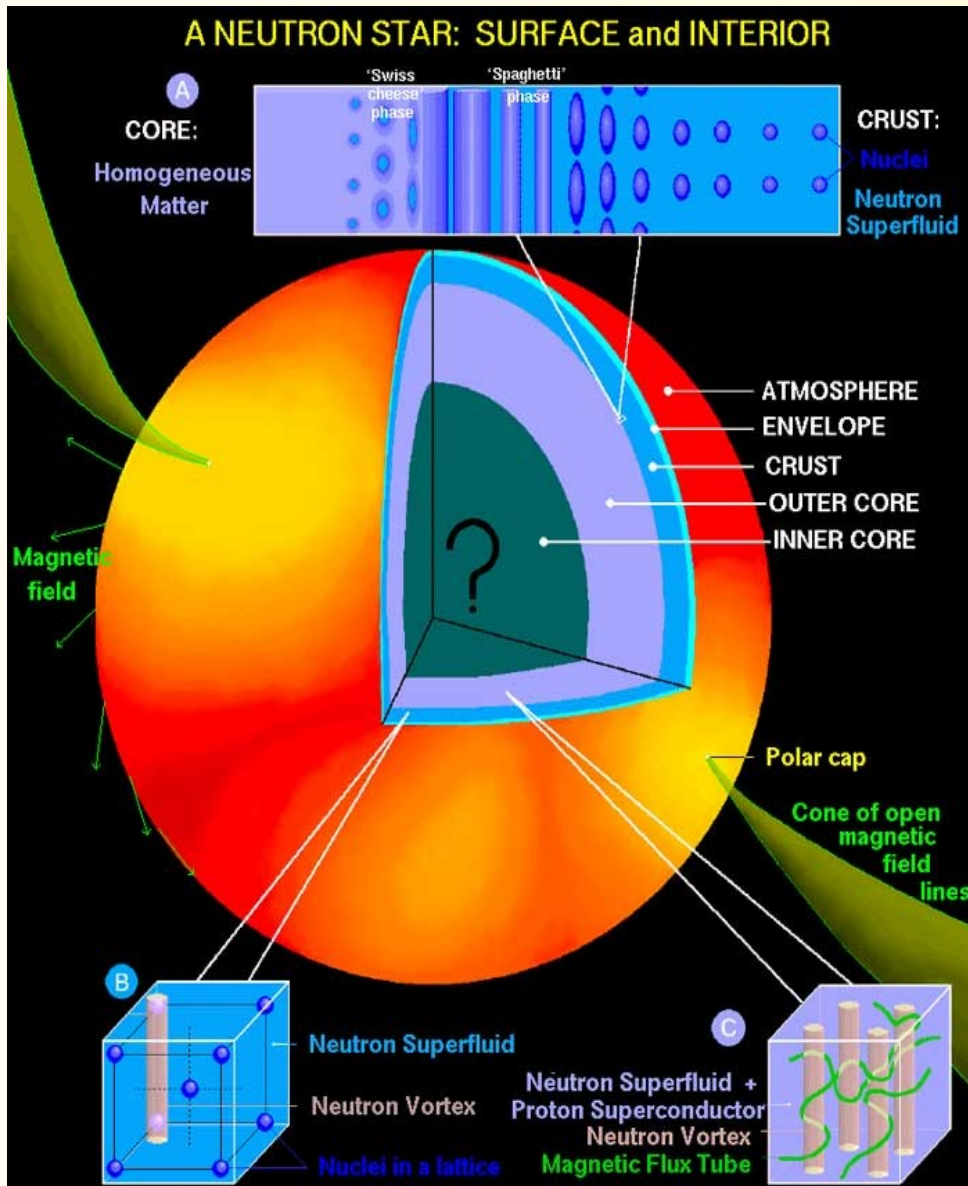
They were looking for scintillation



Pulse train from Vela



Pulsars – rotating neutron stars



Mass $1.4 M_{\text{sun}}$

Radius 10 km

Surface – crystalline solid, density
1 tonne/cc

Outer core – solid with free neutrons

Inner core – neutron superfluid,
 $d=10^8$ tone/cc

Possible solid central core;

Central density 10^9 g/cc

