

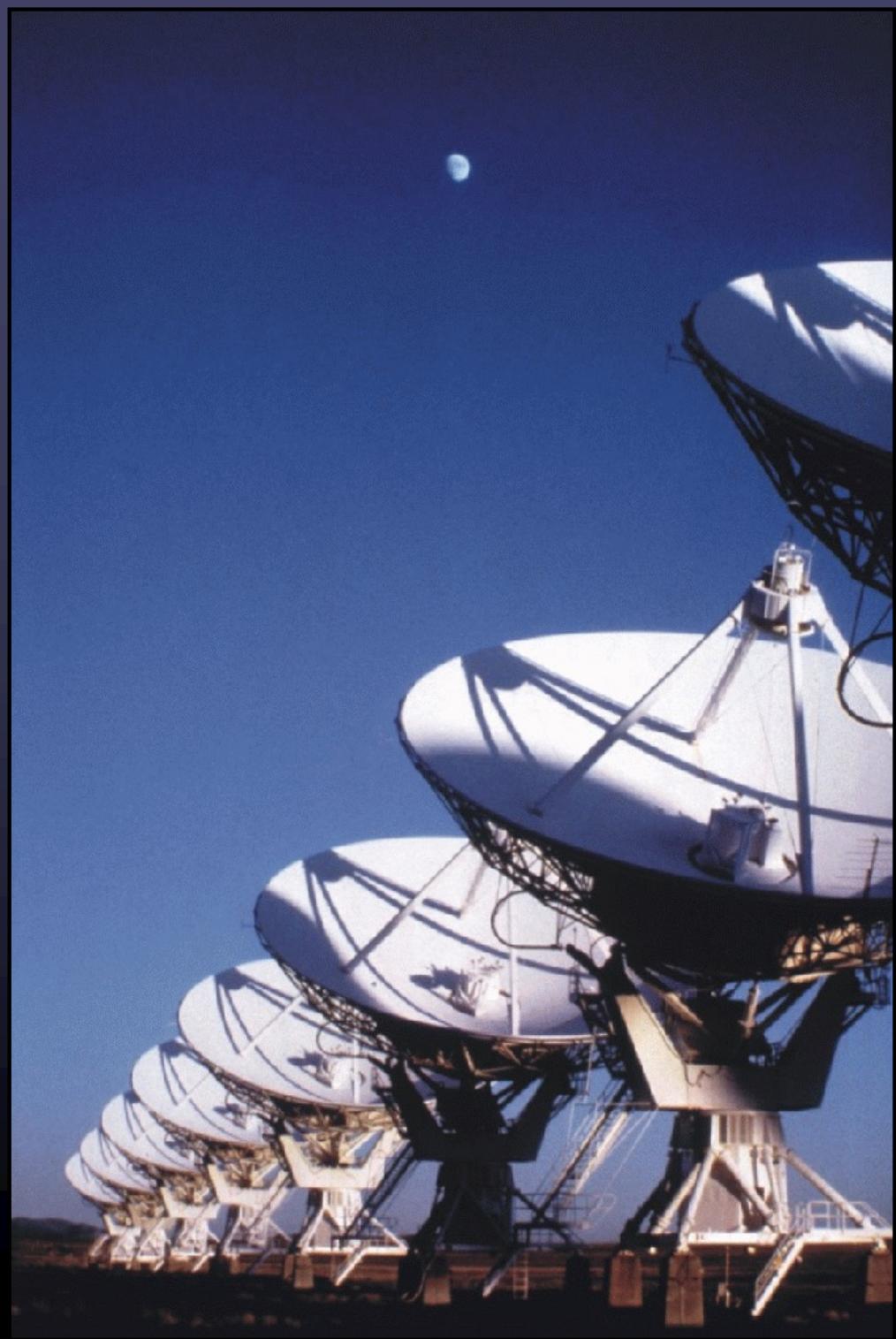


Non-thermal sources

Greg Taylor

University of New Mexico

Astronomy 423 at UNM
Radio Astronomy

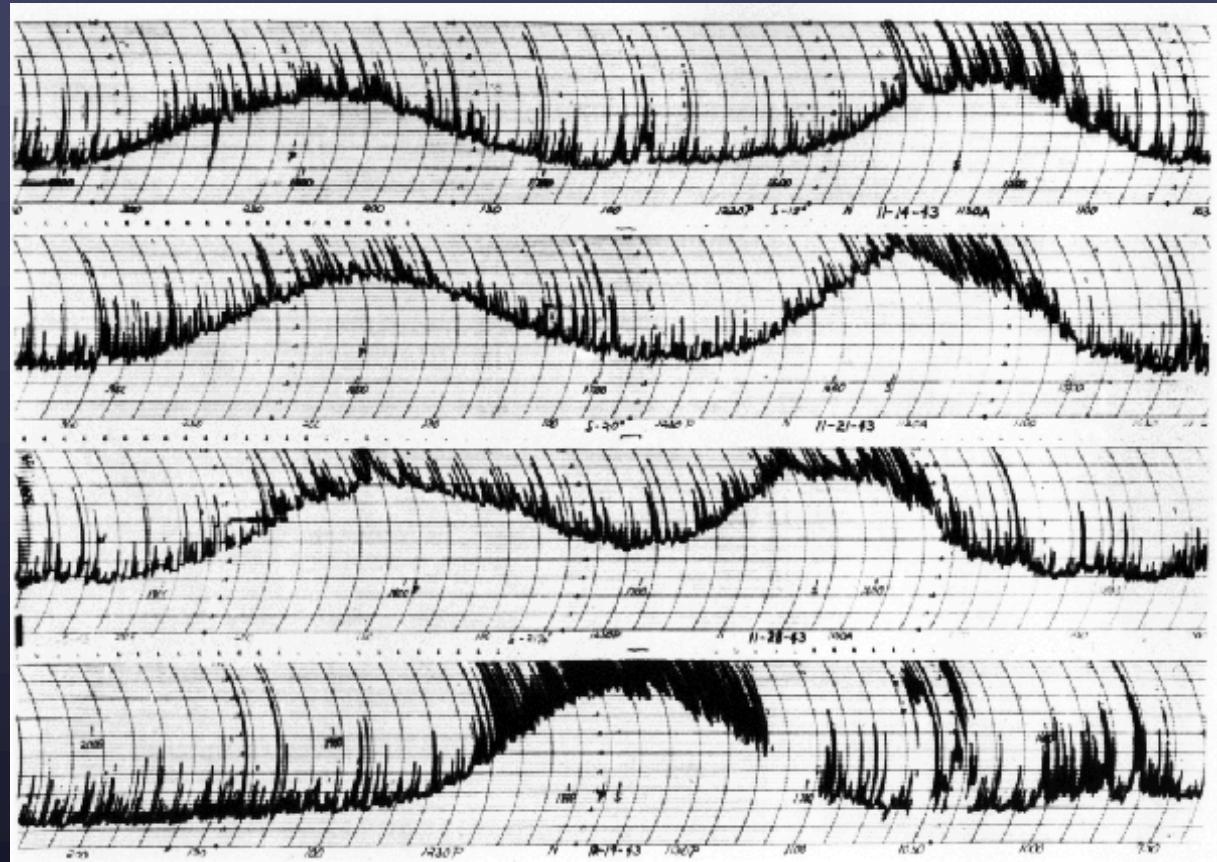
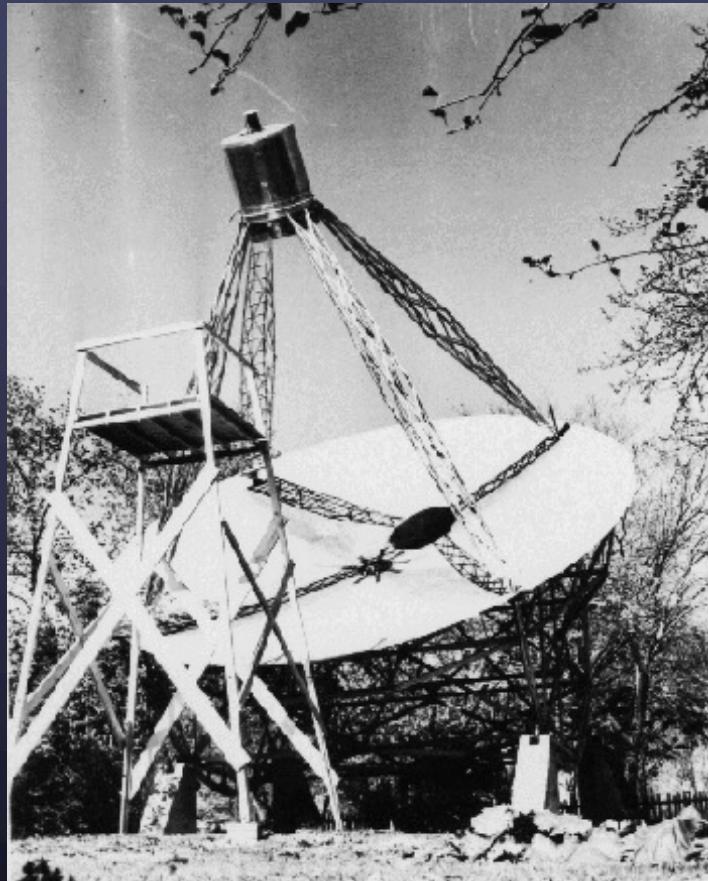


Announcements – The Sprint to the Finish

- HW9 is due on Monday, April 21
- April 21 - Thermal sources + short review on Monday
- April 23 – Exam 2 on Wednesday
- May 5; teams CasA and CygA
- May 7; teams Sag A and M87
- May 14; teams Jupiter1, Jupiter2, Starlink
- Presentations should use slides (powerpoint, keynote, etc.) and aim for 21+10 (talk + Q&A)
Everybody in the group needs to take a turn speaking
- May 16 - Written reports due



Non-Thermal Sources



Grote Reber's telescope and Radio Frequency Interference in 1938

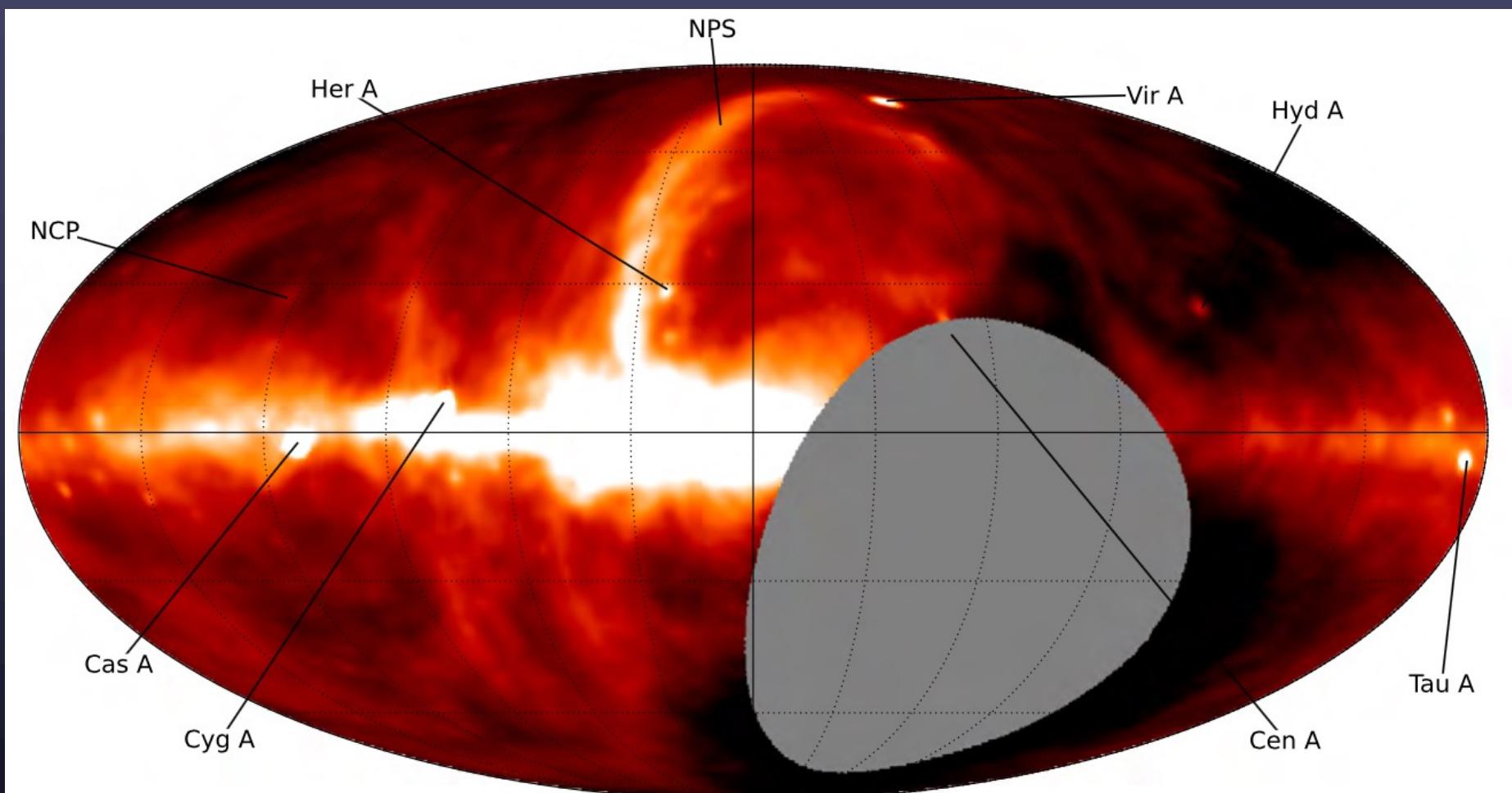


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The Milky Way at 74 MHz from LWA1



Dowell et al. 2017



The Radio Sky



5 GHz image from 300 ft, Condon et al.

G. Taylor, Astr 423 at UNM



radio continuum (408 MHz)

atomic hydrogen

radio continuum (2.5 GHz)

molecular hydrogen

infrared

mid-infrared

near infrared

optical

x-ray

gamma ray

<http://adc.gsfc.nasa.gov/mw>



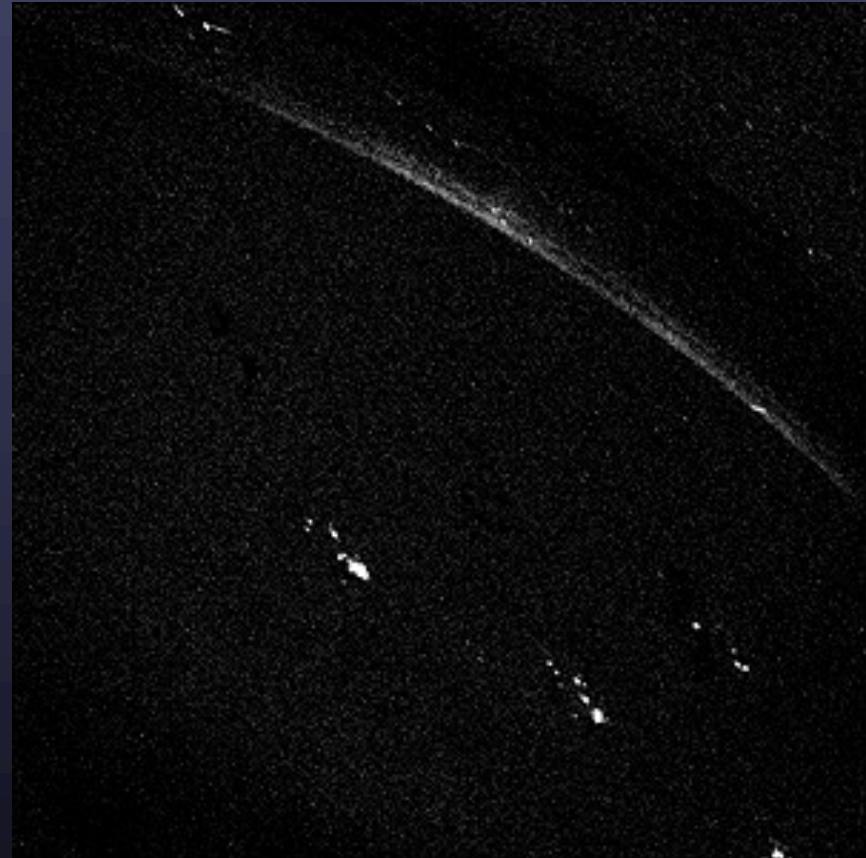
Multiwavelength Milky Way

Lightning

On Earth



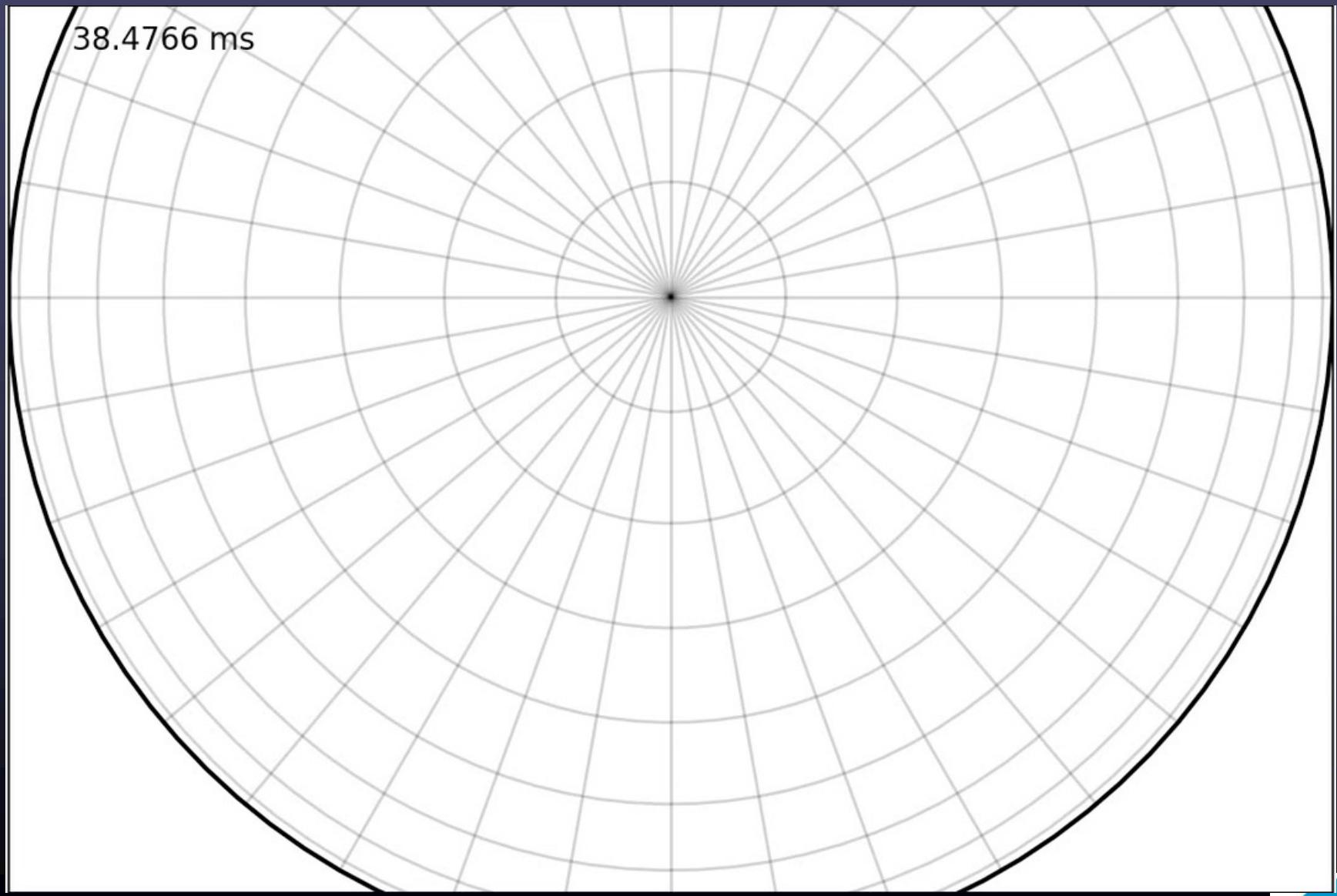
On Jupiter



G. Taylor, Astr 423 at UNM



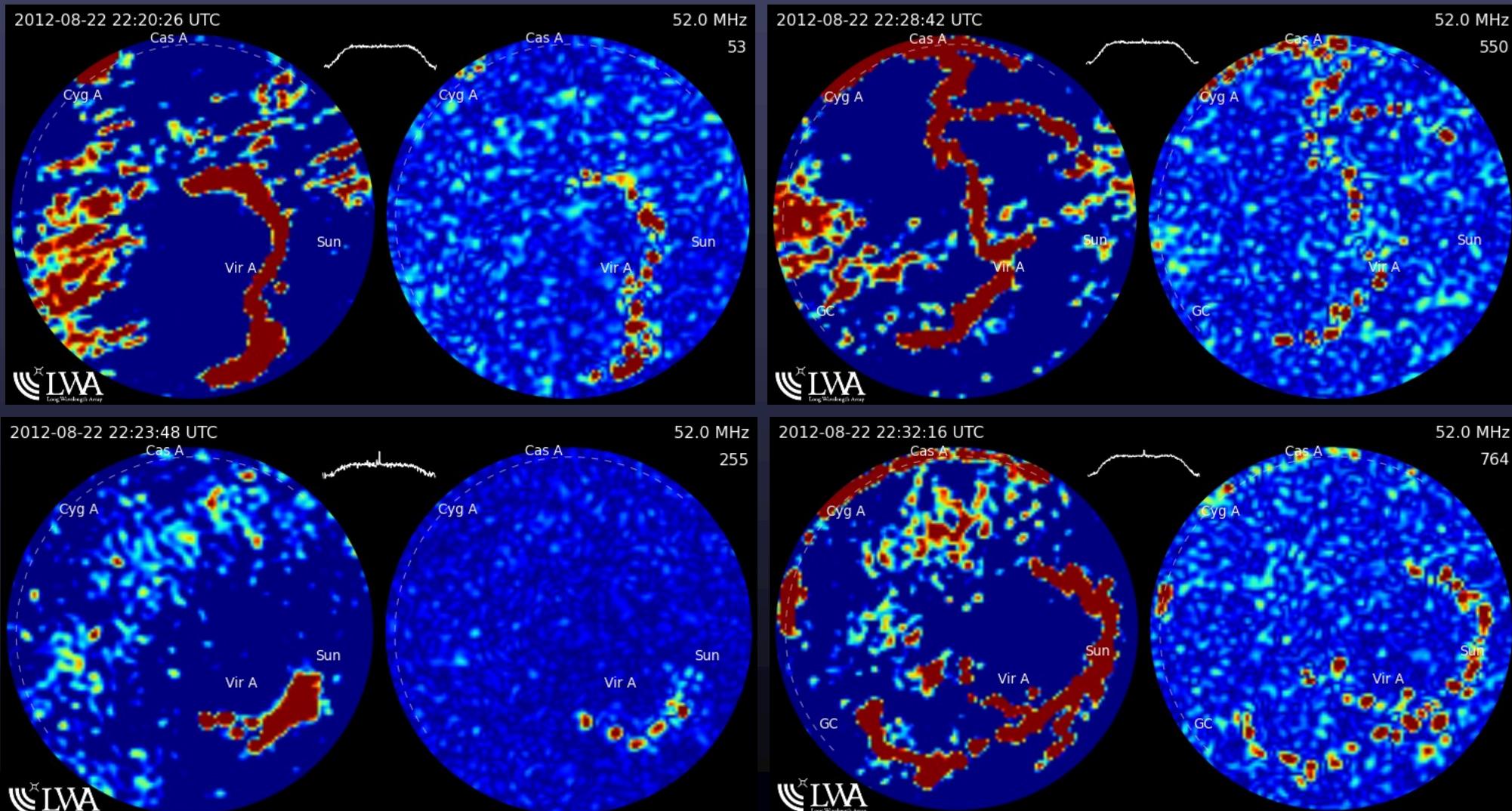
The University of New Mexico



G. Taylor, Astr 423 at UNM

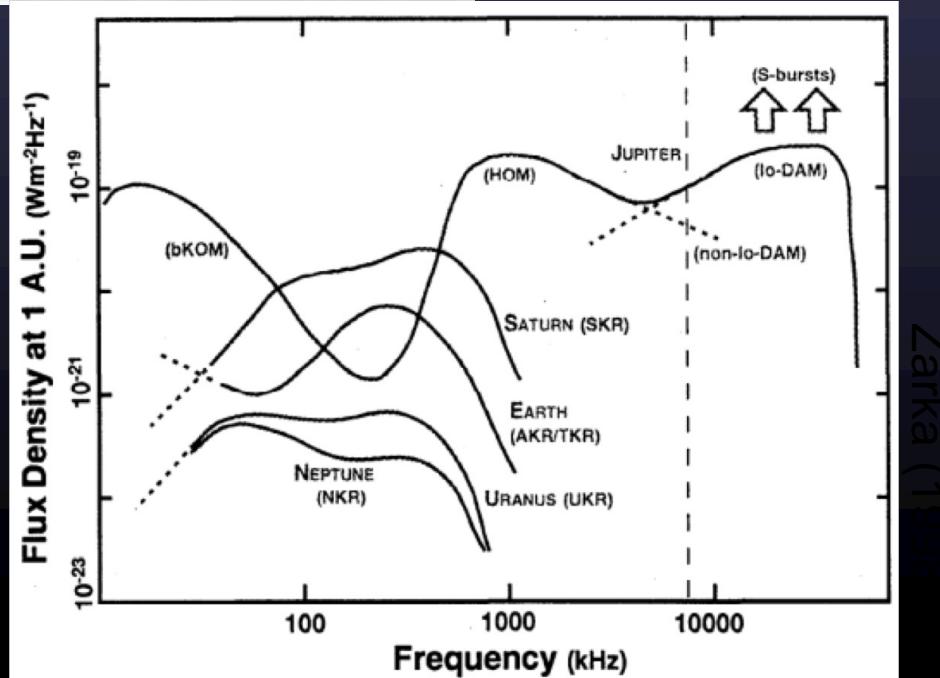
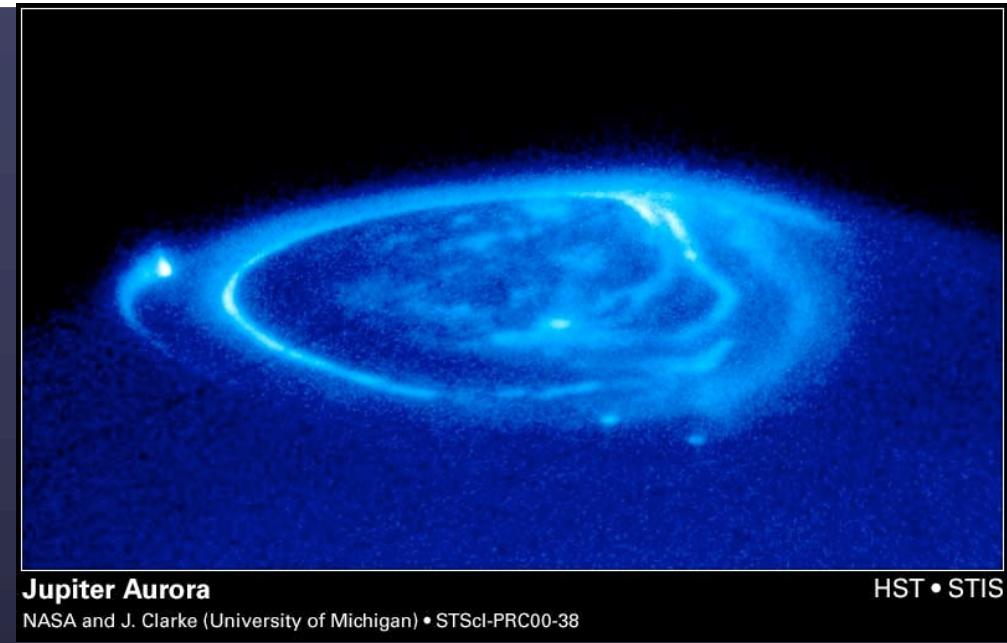
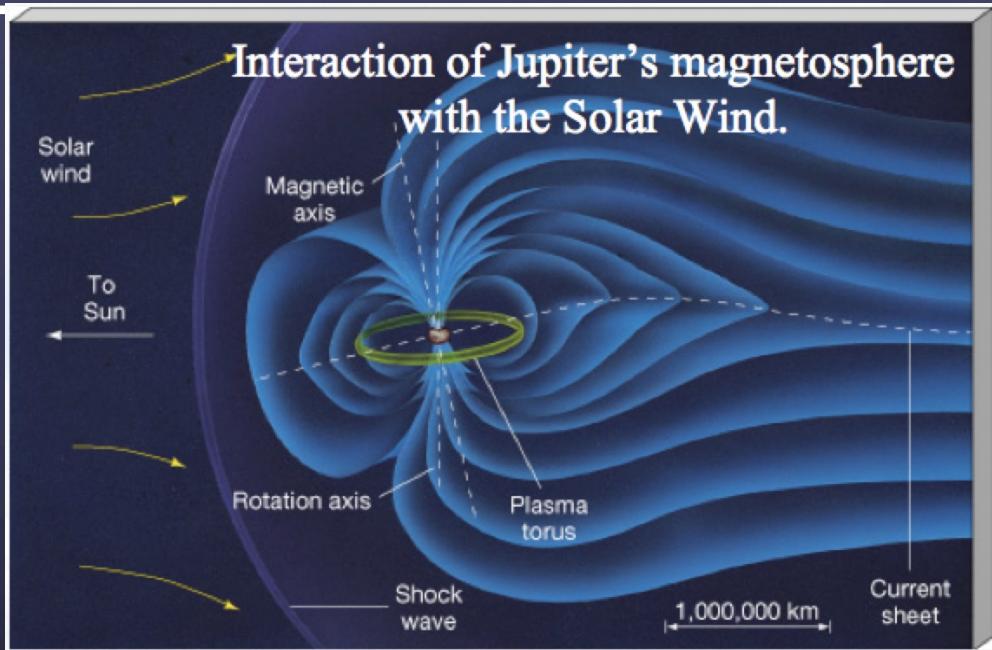


Lightning



The University of New Mexico

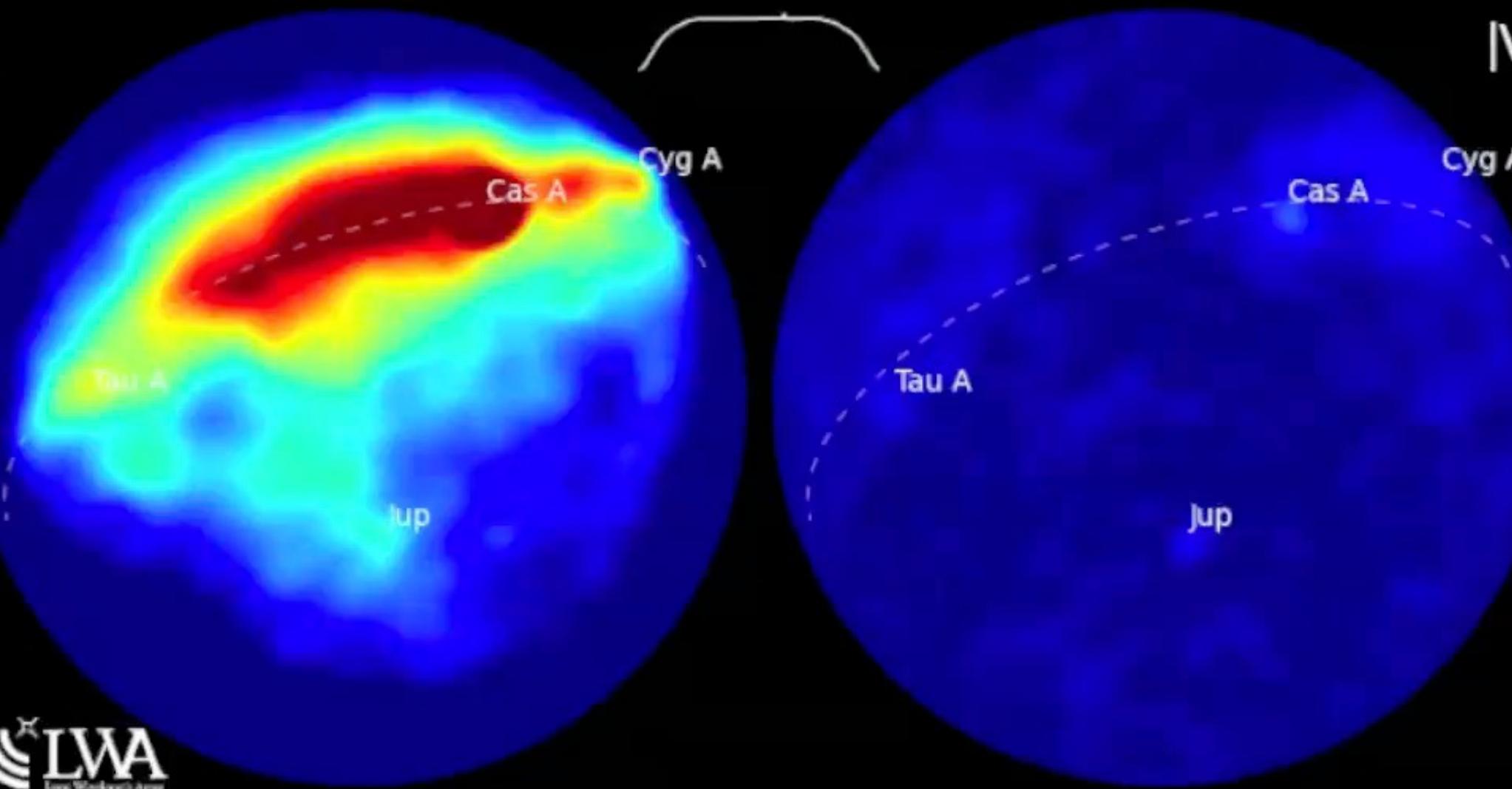
Jupiter



2011 Dec 31

2011-12-31 02:46:30 UTC

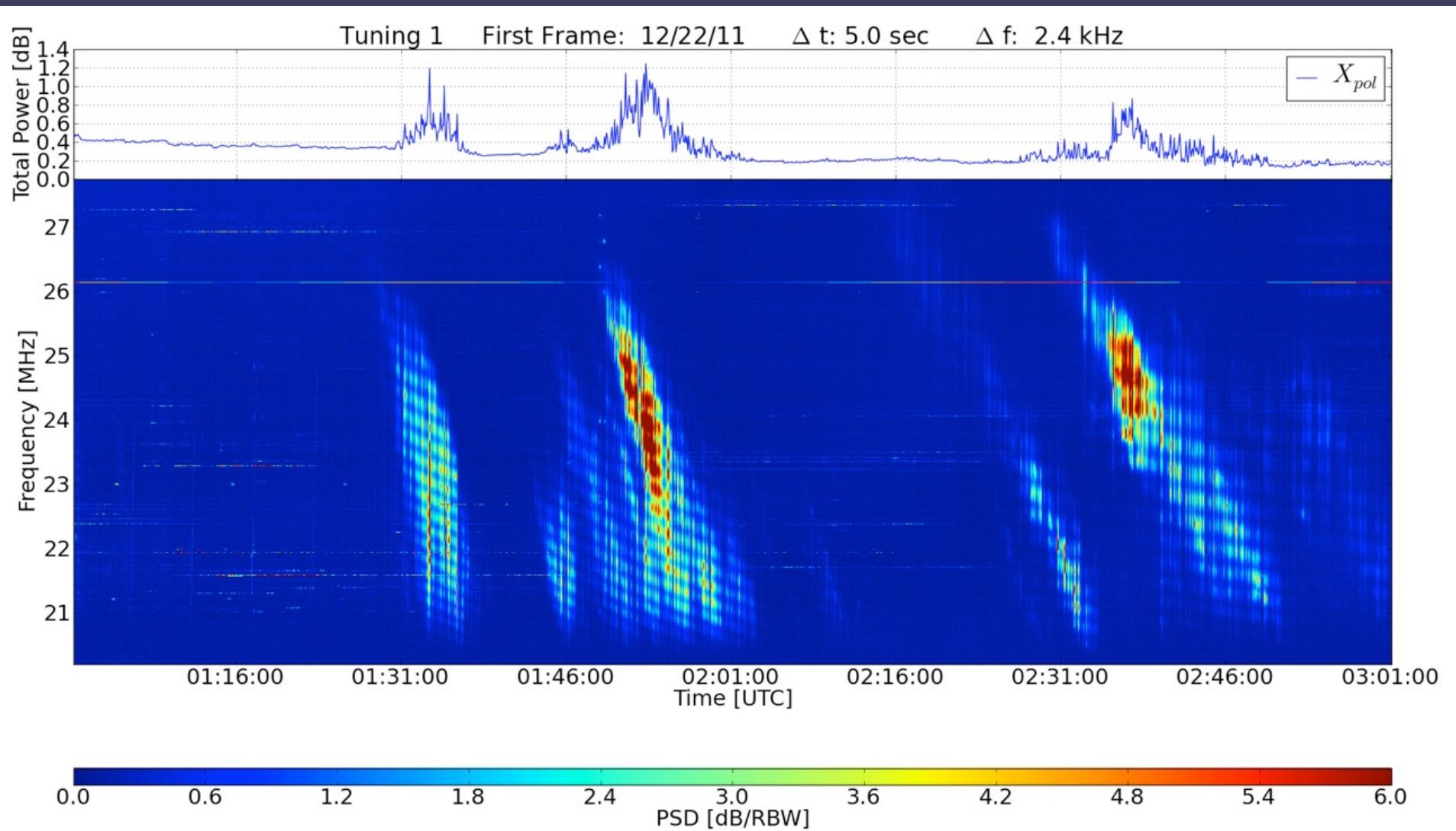
25.6 MHz



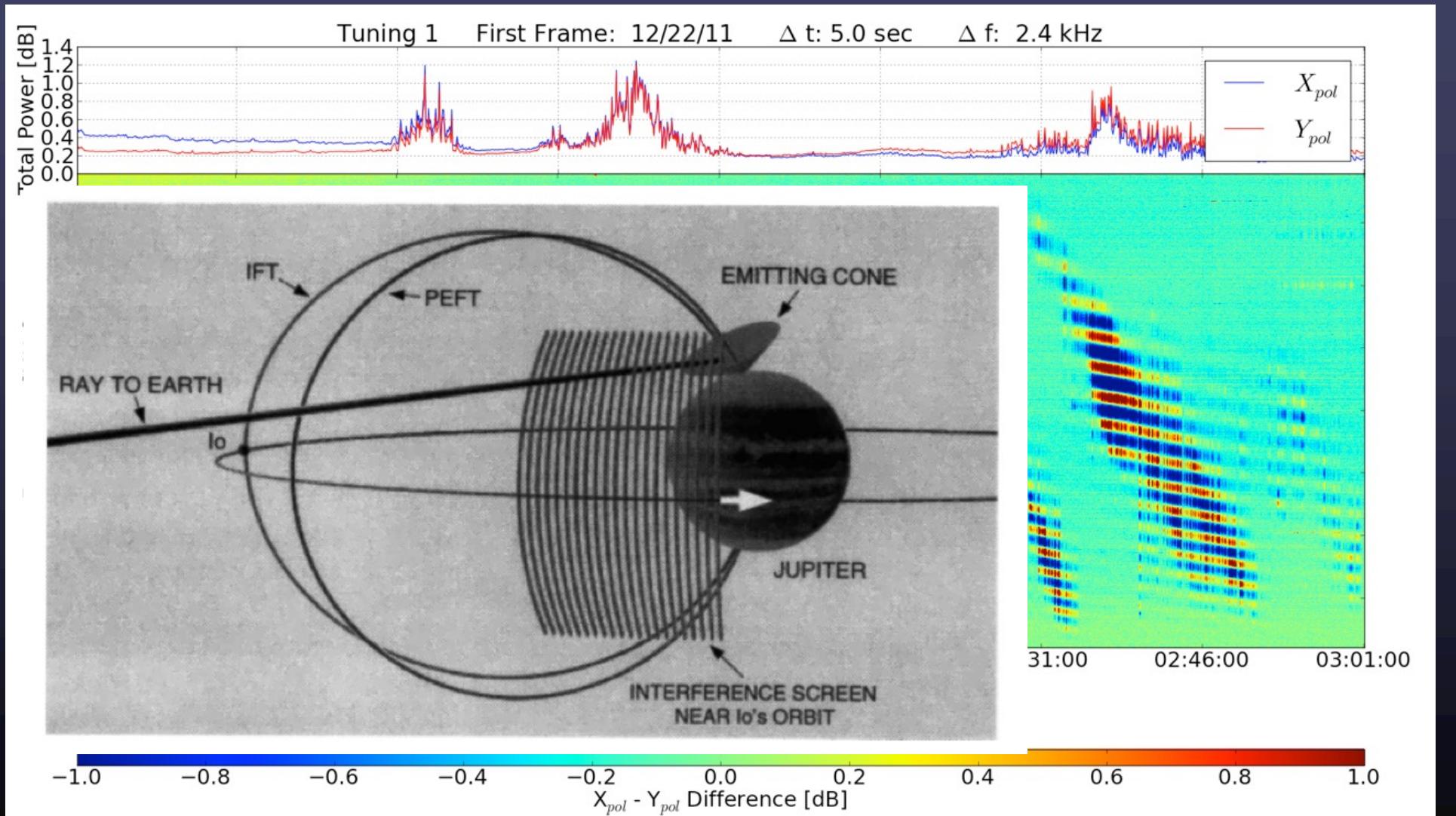
Jovian Bursts



Decametric Jovian Emission



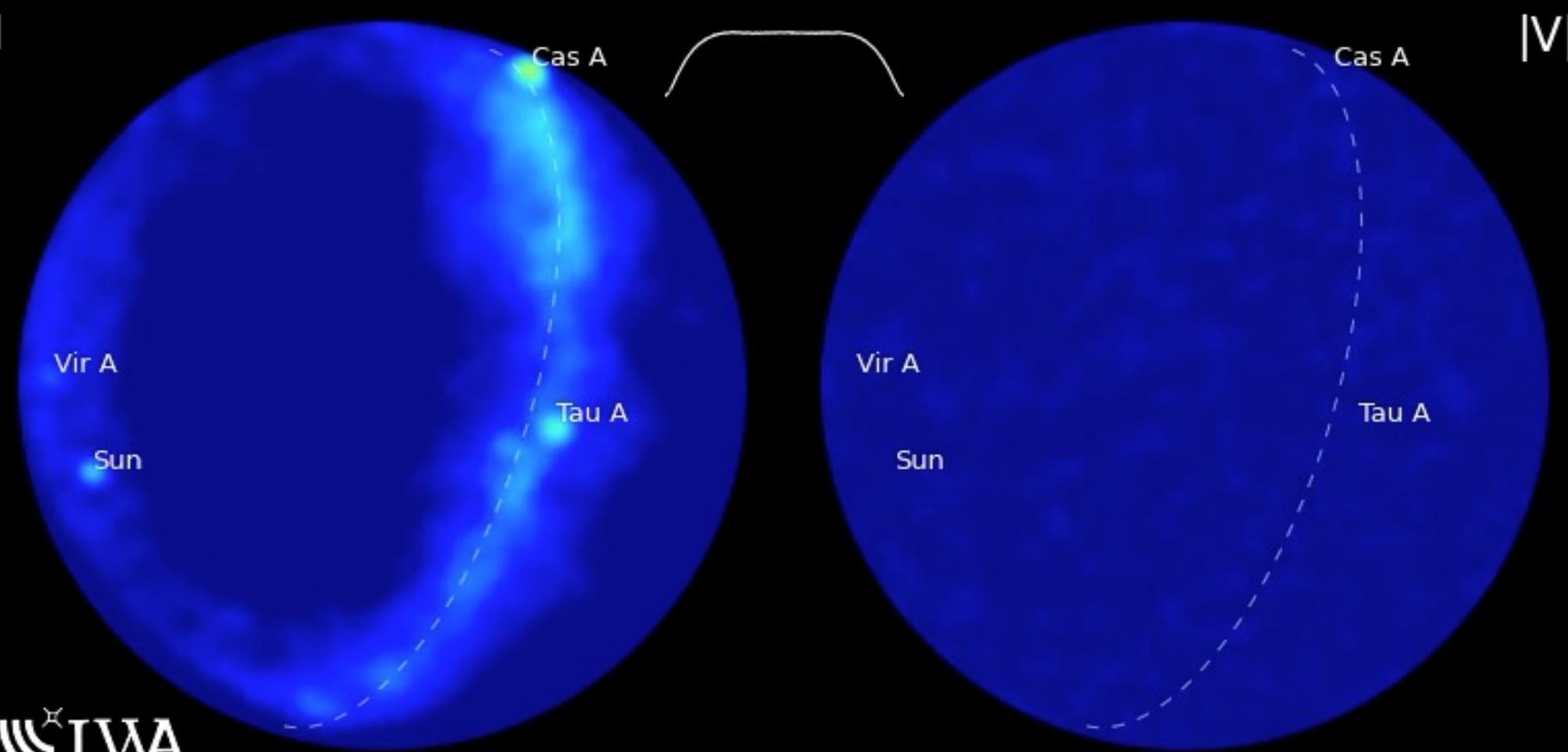
Decametric Jovian Emission



Solar activity in the radio

2017-09-12 15:28:04 UTC

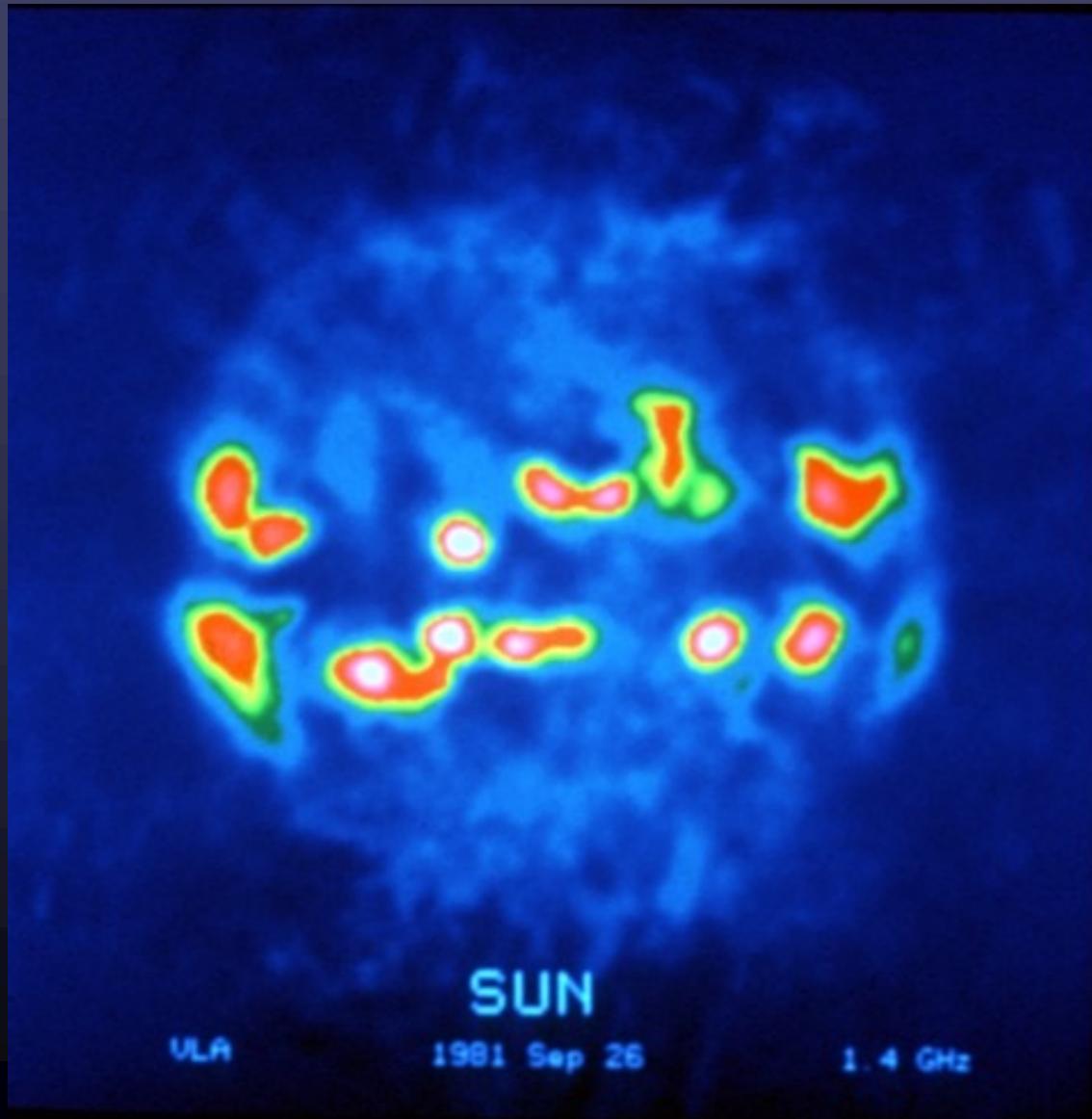
38.10 MHz



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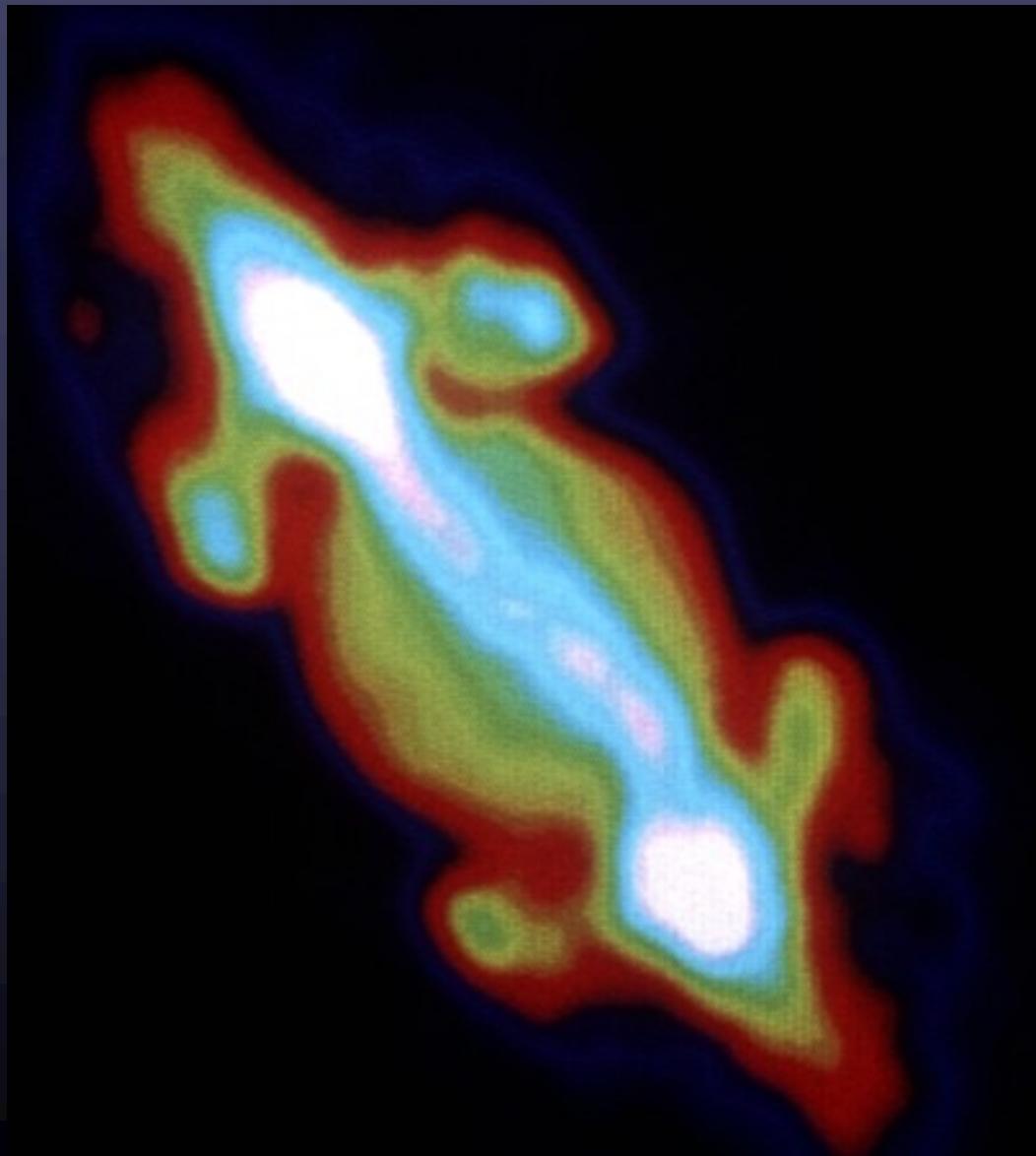
Solar activity in the radio



G. Taylor, Astr 423 at UNM



Picture of Jupiter in the radio with the VLA



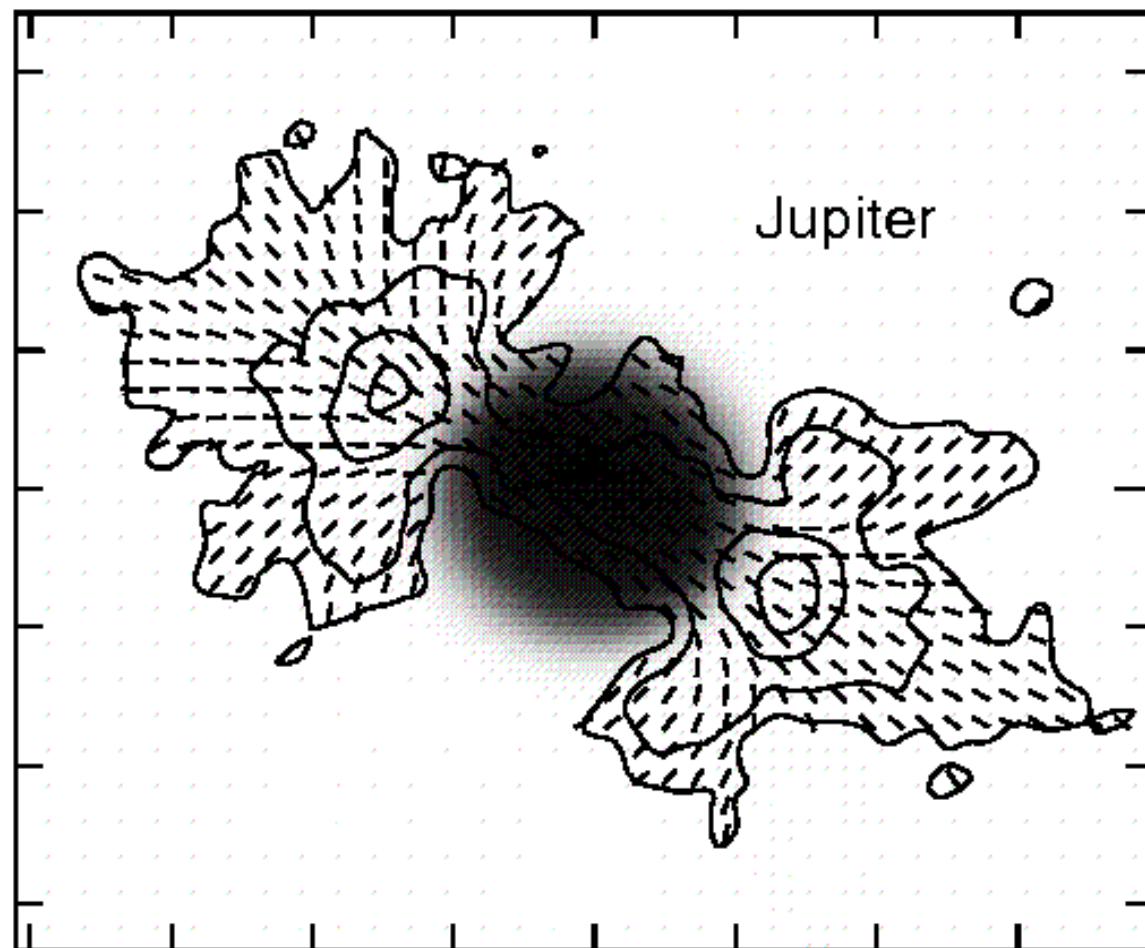
detection of the
magnetic belts around
Jupiter

synchrotron emission
from energetic particles
in magnetic fields



>SNTHS IMAGN SUMMR SCHUL

17



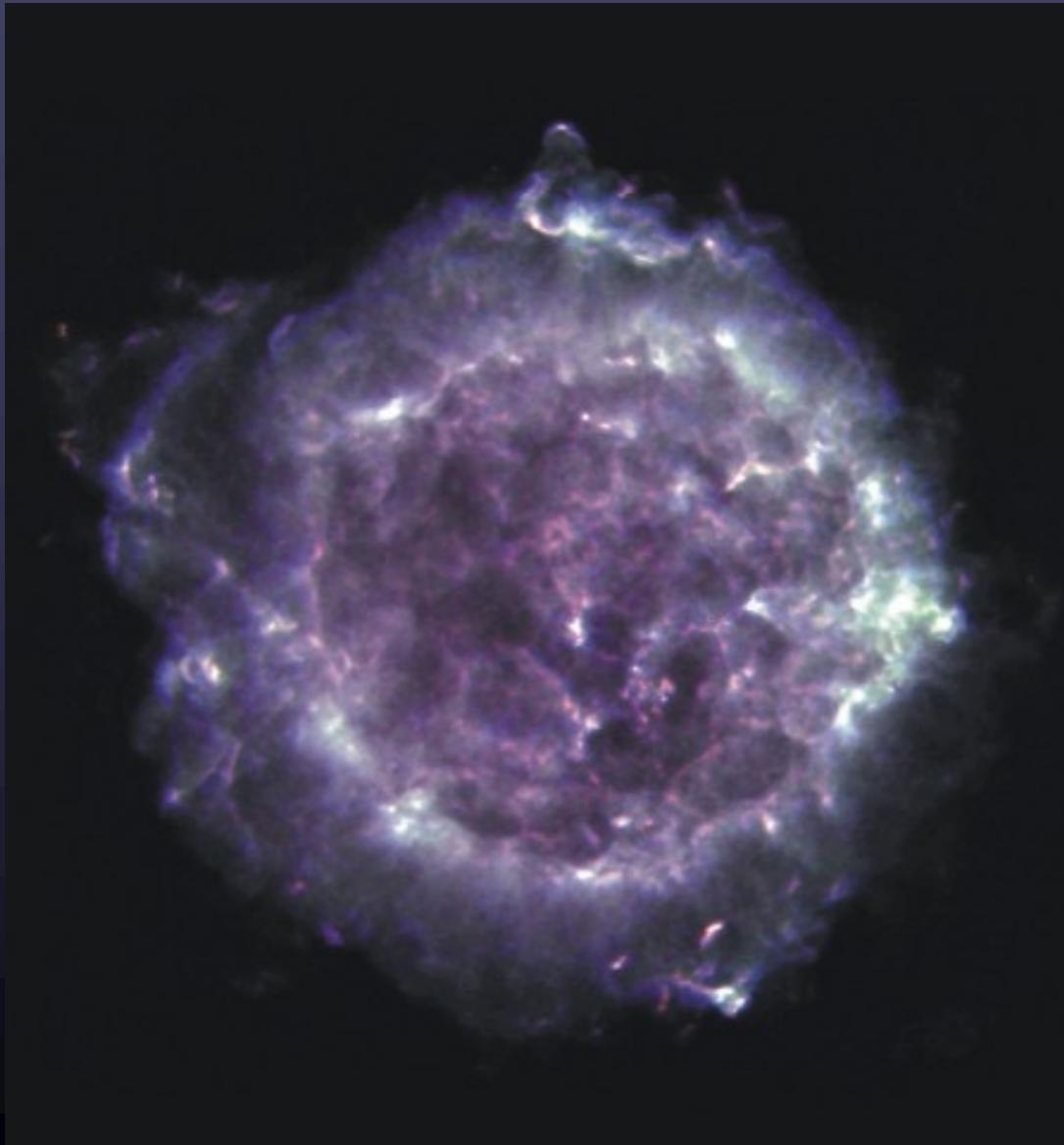
June 20-27, 2000
Socorro, NM, USA

G. Taylor, Astr 423 at UNM



Supernovae

18



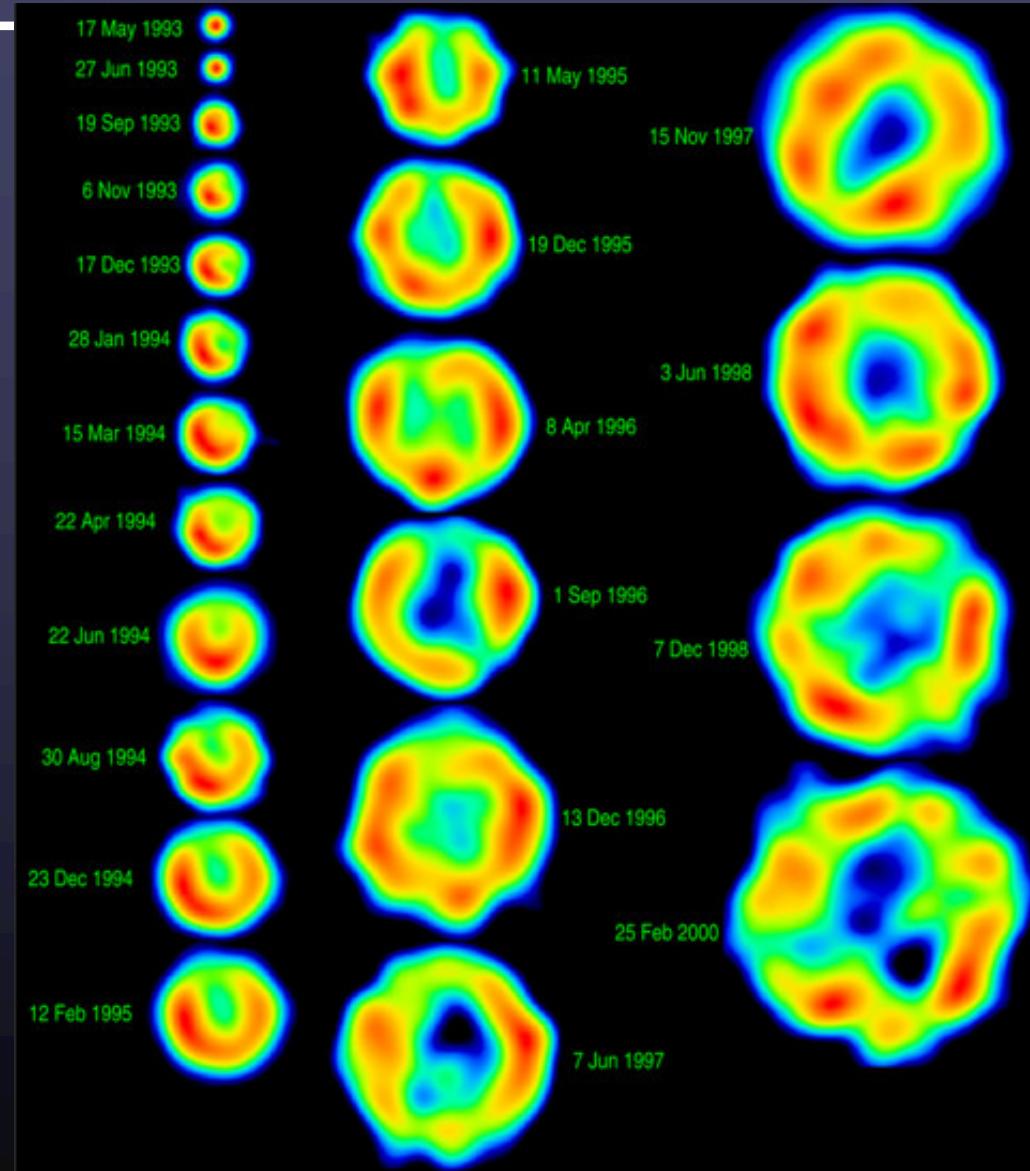
Cass A
Rudnick et al.

G. Taylor, Astr 423 at UNM



A Young Supernova

19



SN 1993J
Rupen et al.

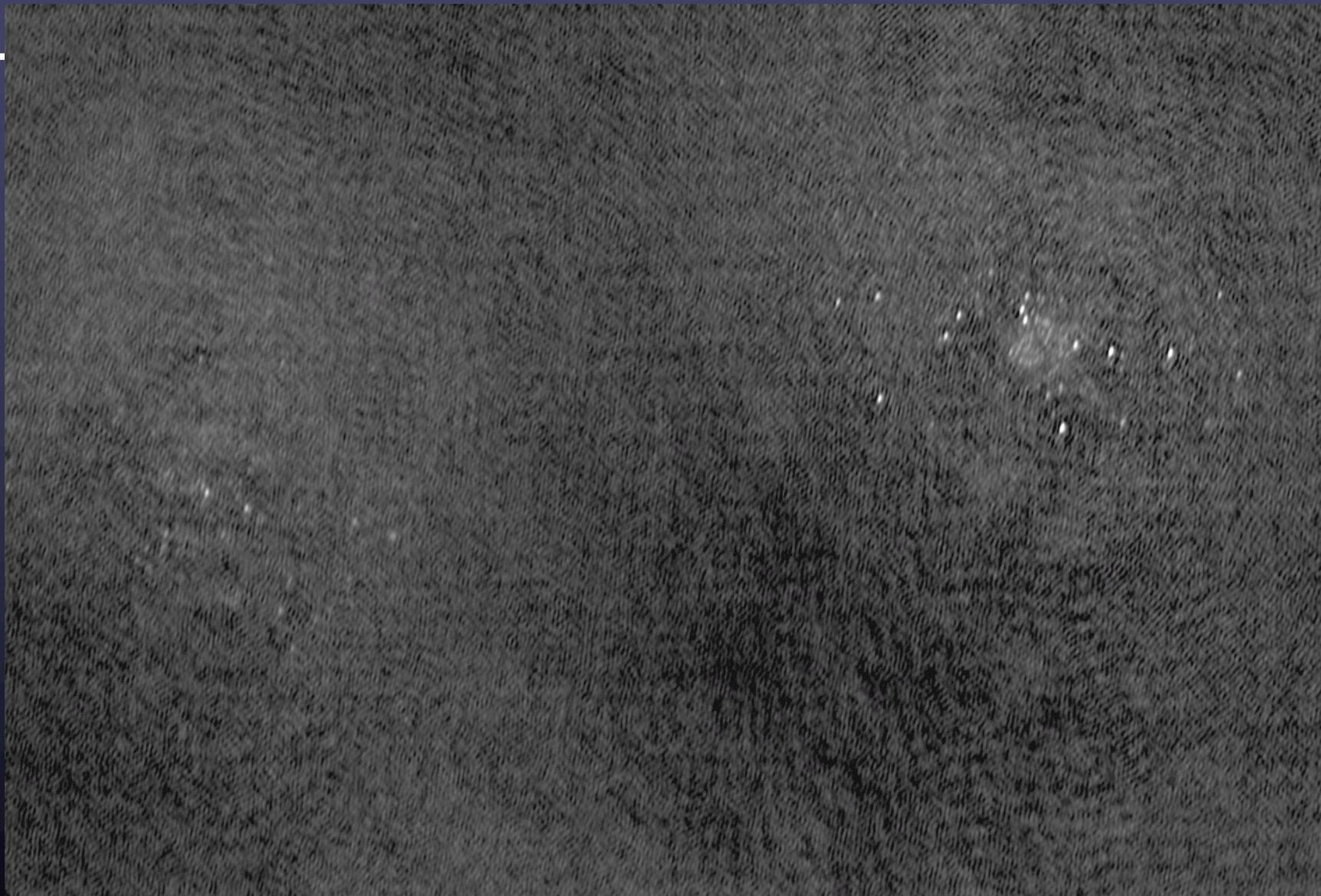


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Arp 220 - A starburst Galaxy

20



VLBA Image of the core of Arp 220 at 1.4 GHz - Lonsdale et al. in prep

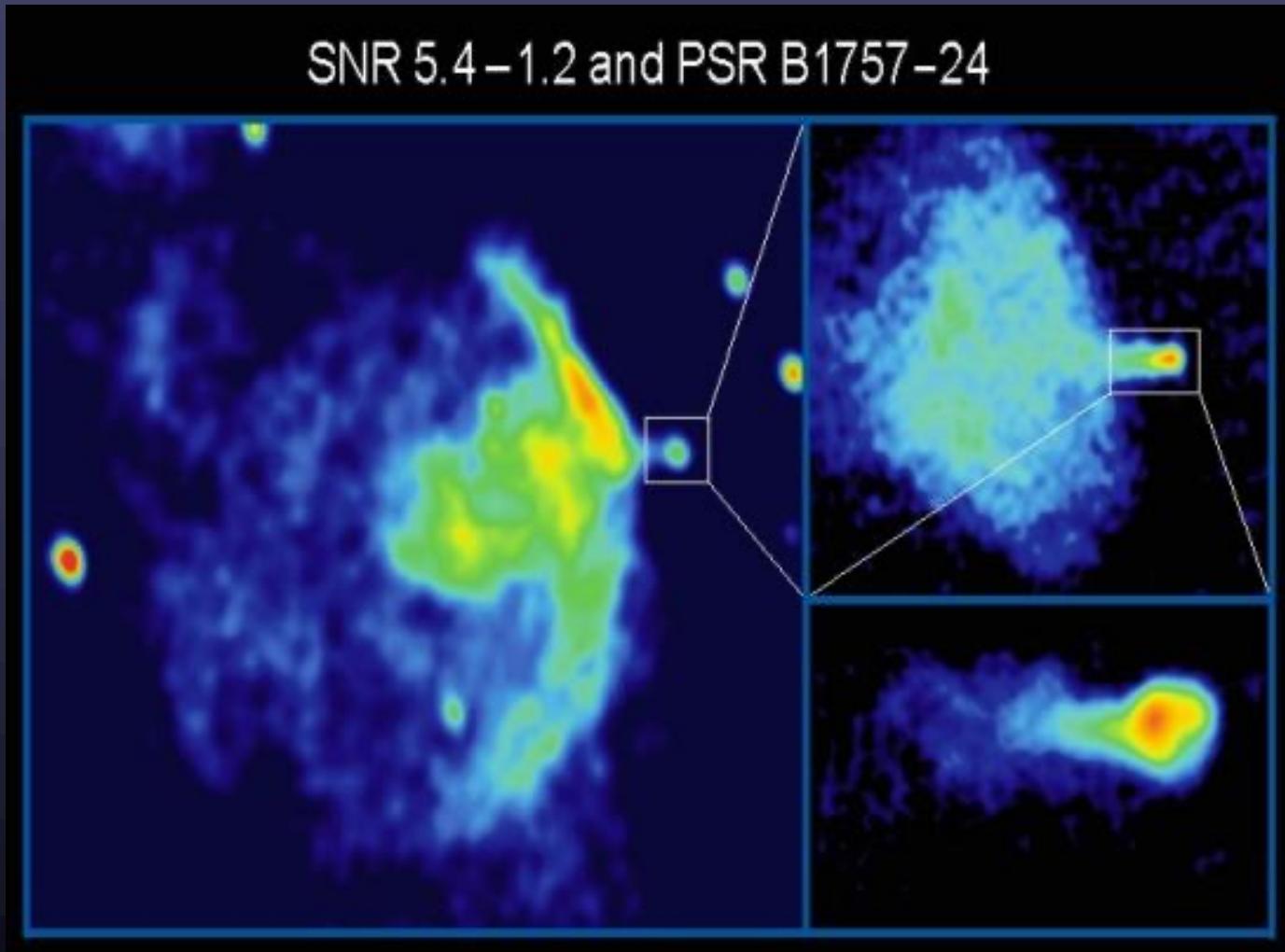


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The Duck

21



Gaensler et al.

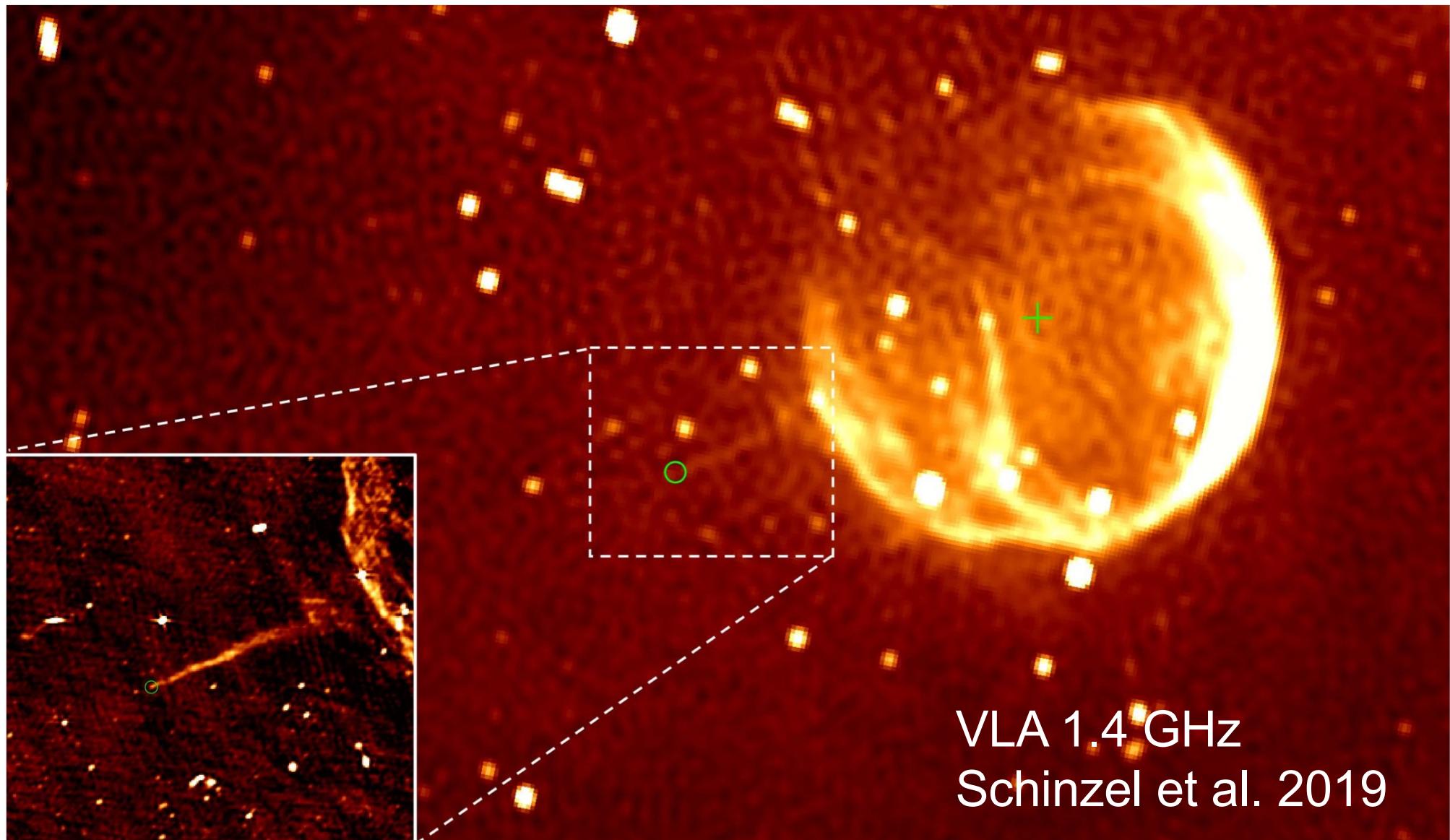


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The Cannonball Pulsar J0002+6216 and SNR CTB 1

22



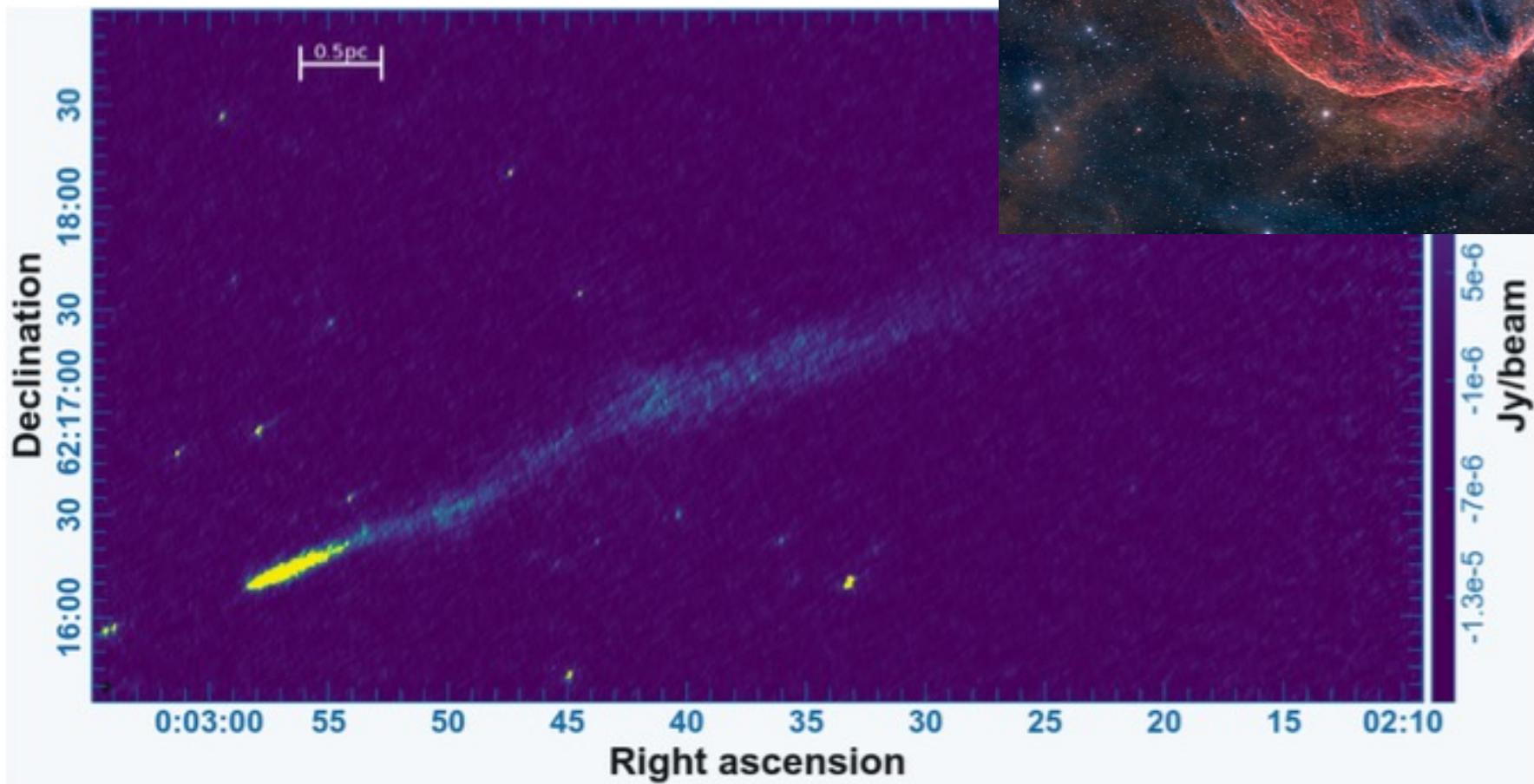
G. Taylor, Astr 423 at UNM



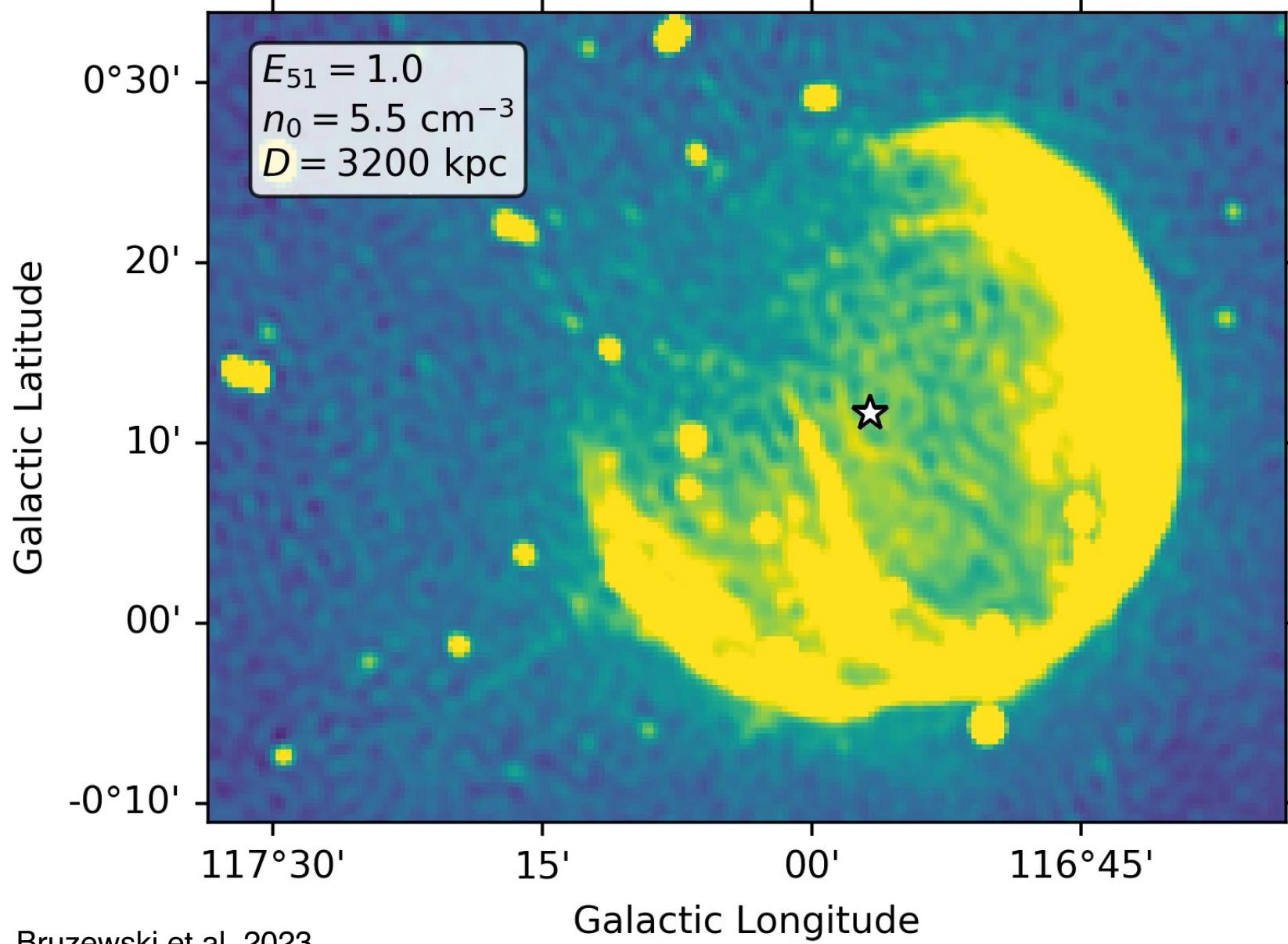
Cannonball J0002+6216 and SNR CTB-1

Kumar et al. 2022 VLA 6 GHz

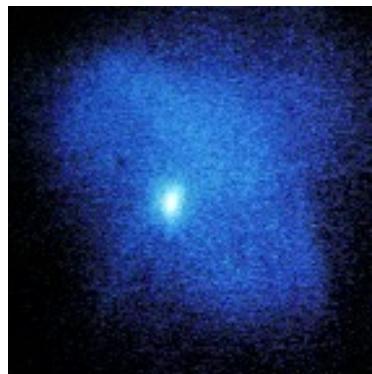
Optical



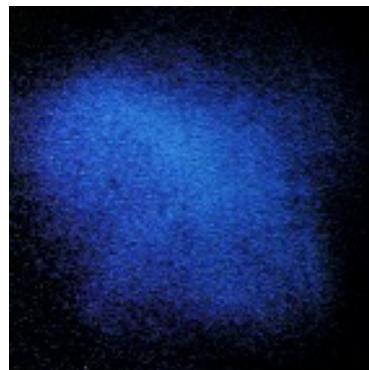
Cannonball J0002+6216 and SNR CTB-1



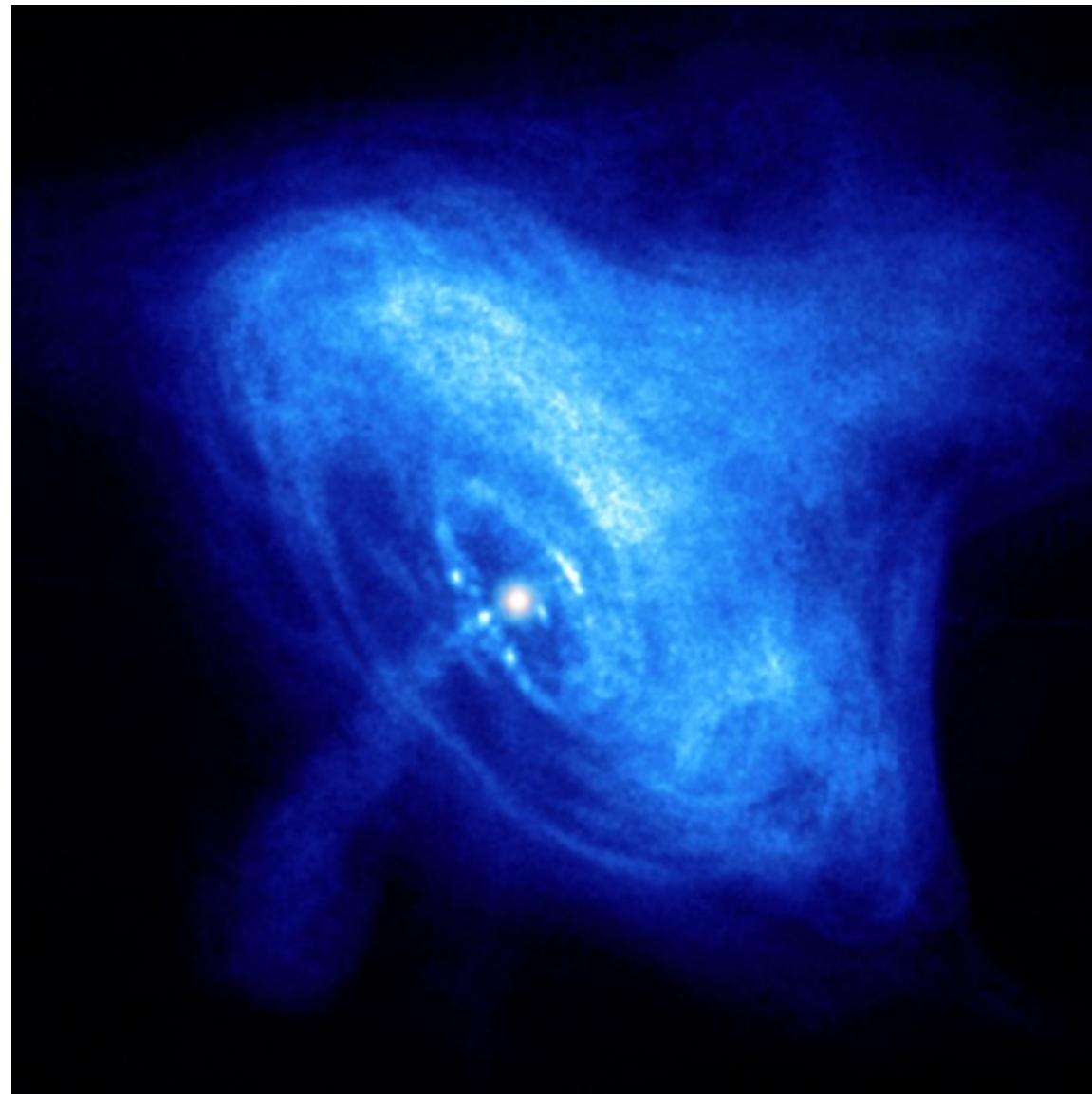
The Crab Pulsar



On



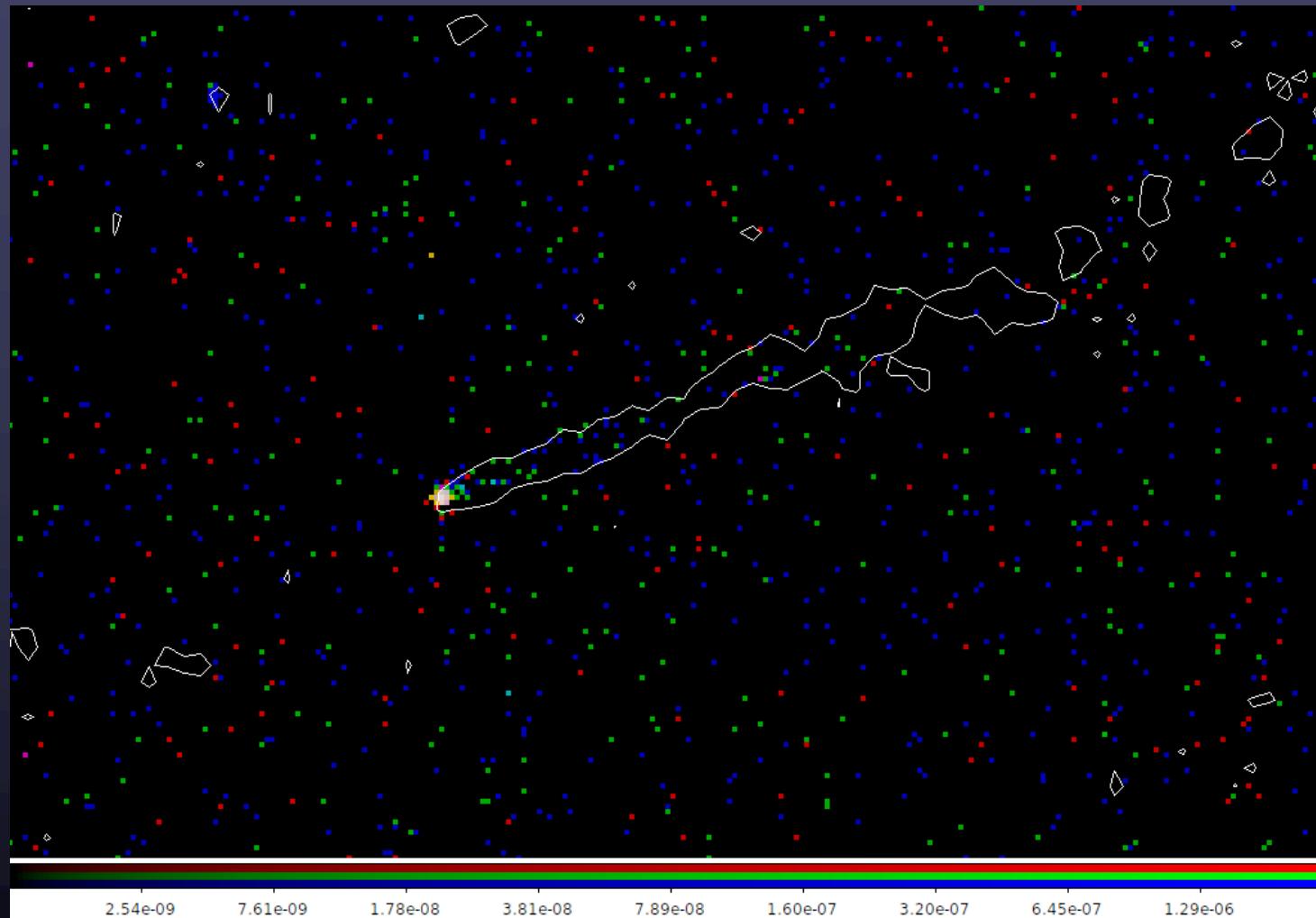
Off



Chandra
X-ray
image

The Cannonball Pulsar J0002+6216 and SNR CTB 1

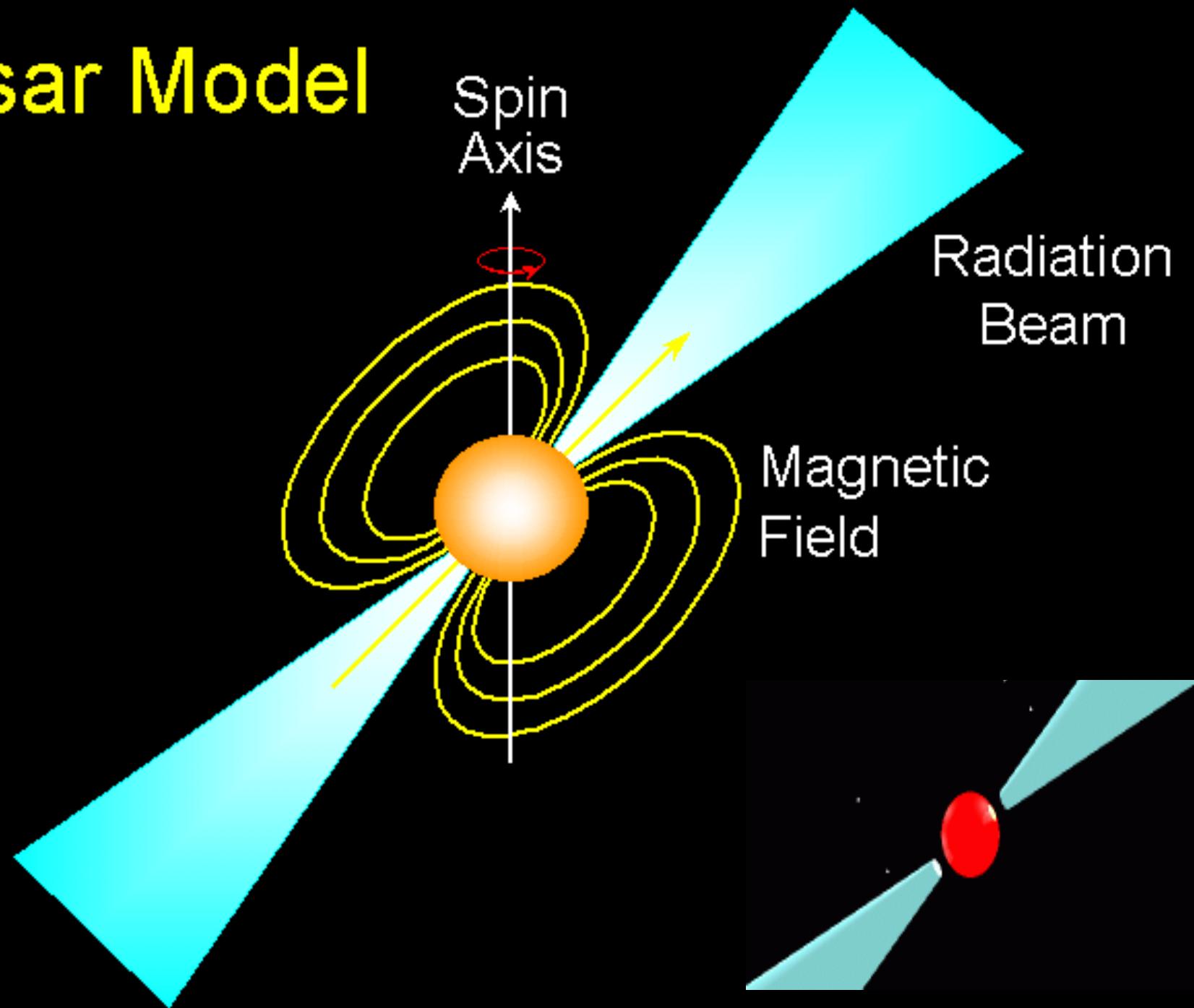
26



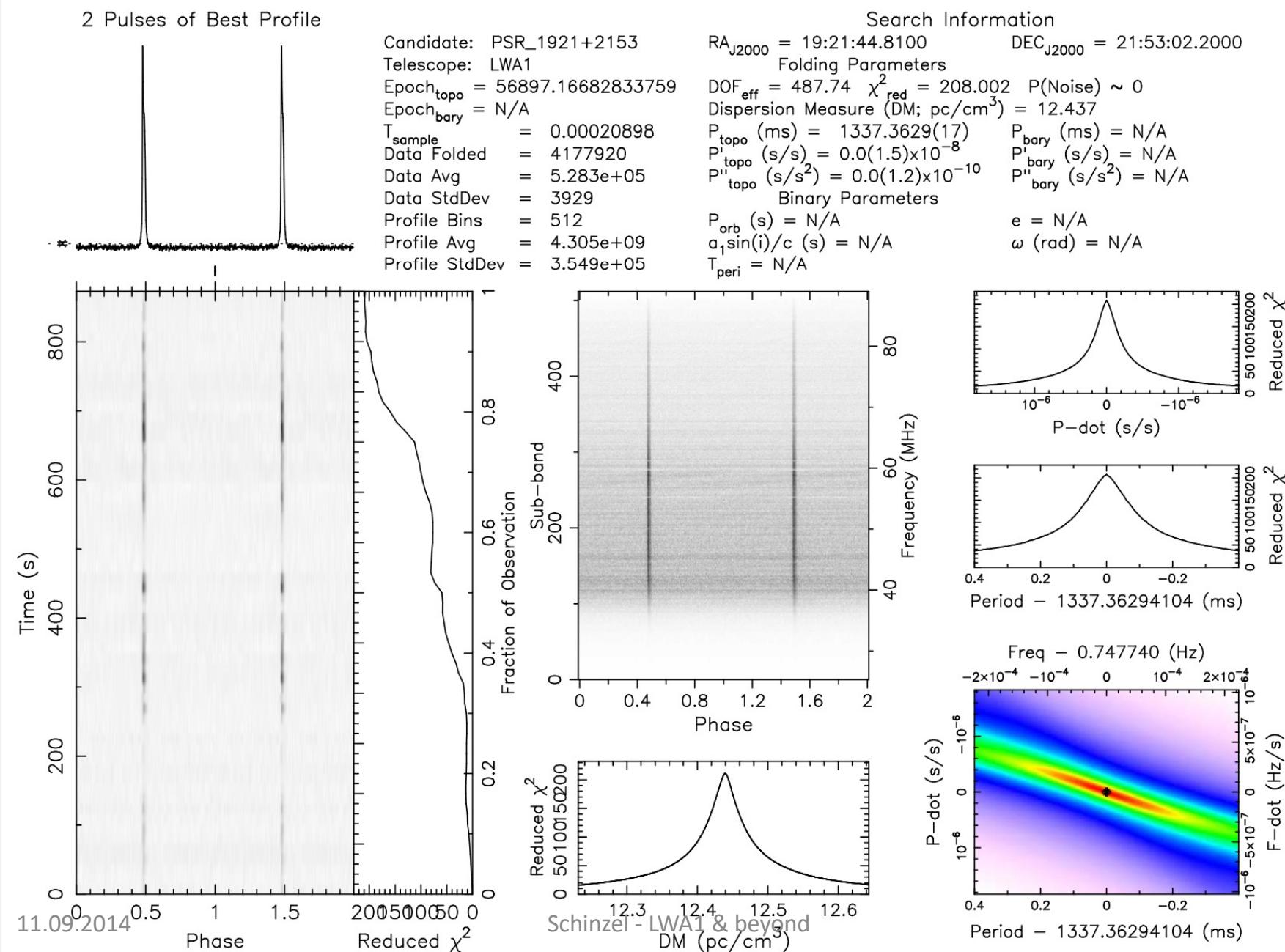
G. Taylor, Astr 423 at UNM



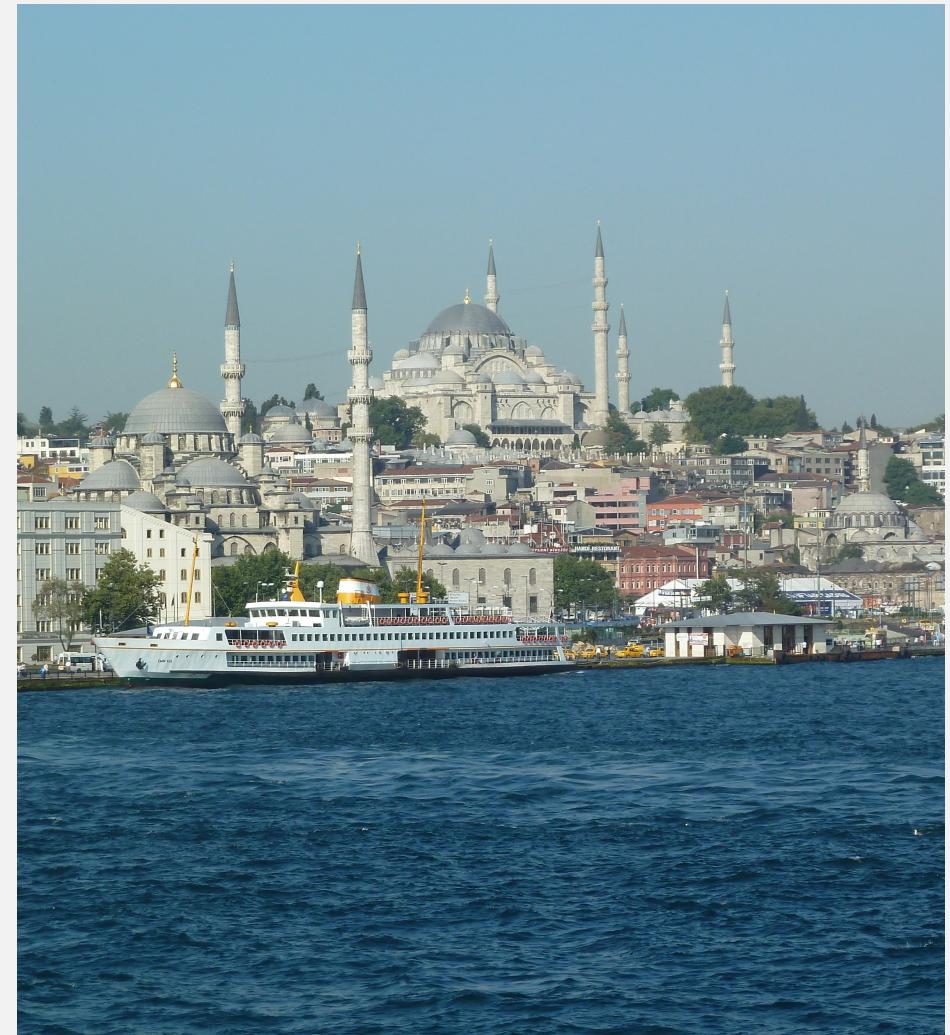
Pulsar Model



Typical LWA Observation of a Pulsar

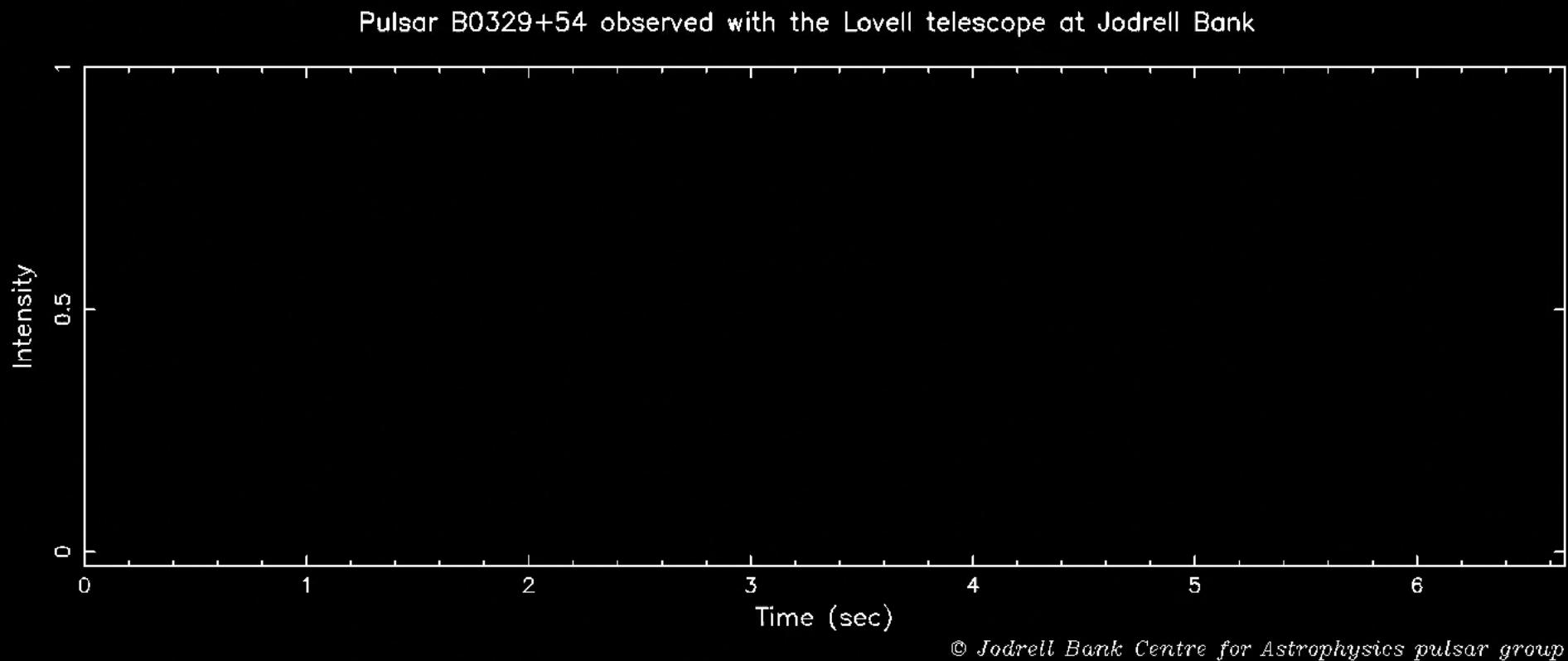


Study the Universe, See the World



Jocelyn Bell and Alan Rogers at URSI-2011 meeting in
Istanbul

The Sound of Pulsars



B0329+54, A bright pulsar with period 0.714520 sec

The Sound of Pulsars



47 Tucanae, A globular cluster with 22 millisecond pulsars

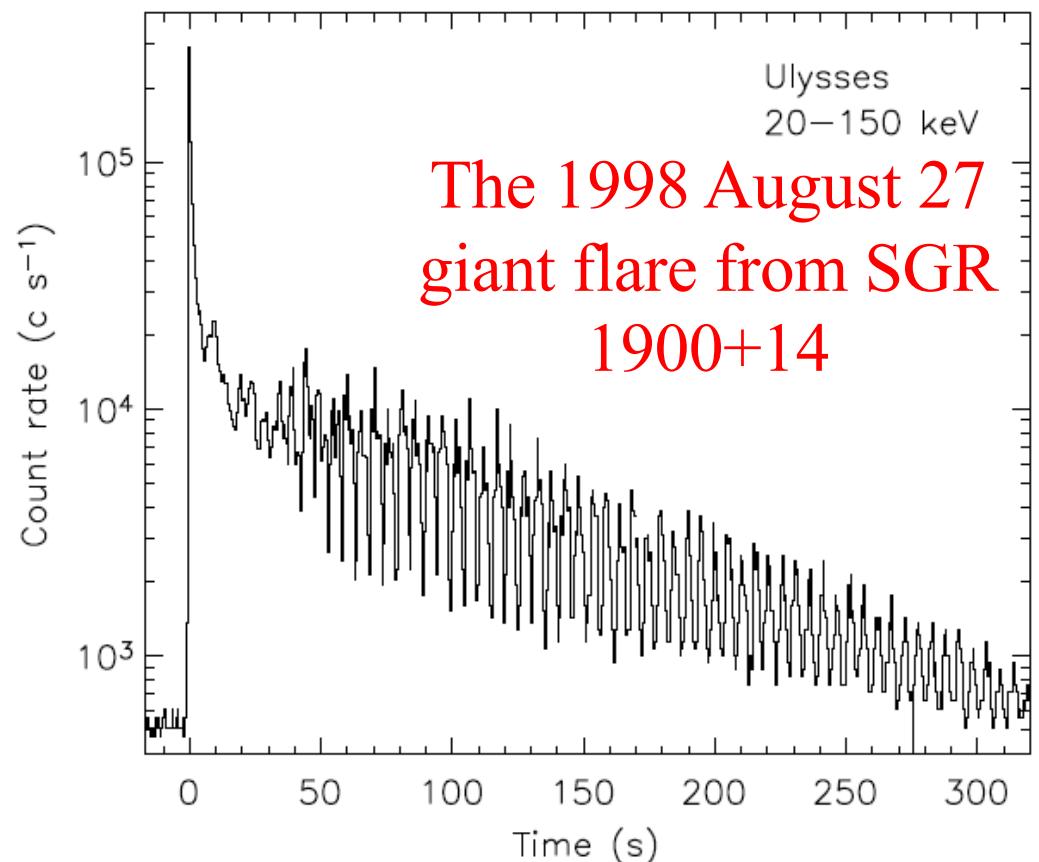
Giant Flares from SGRs

- Initial spike: $\Delta t \sim 0.3$ s , $E_{\text{iso}} \sim \text{a few } 10^{44}$ erg

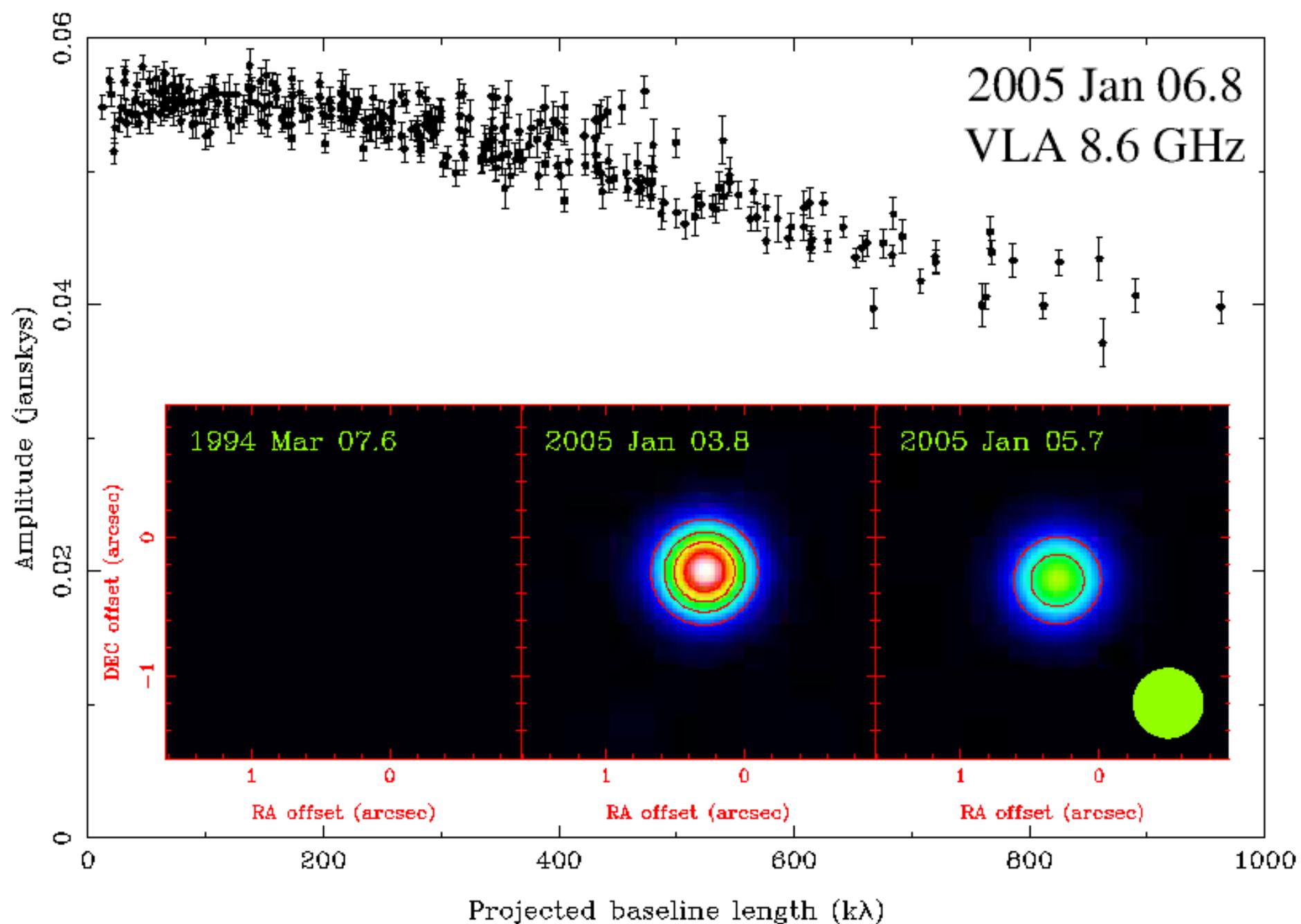
- o hard spectrum
- o \sim ms rise time

- Pulsating tail

- o Lasts a few min.
- o Modulated at the NS rotation period
- o Softer spectrum



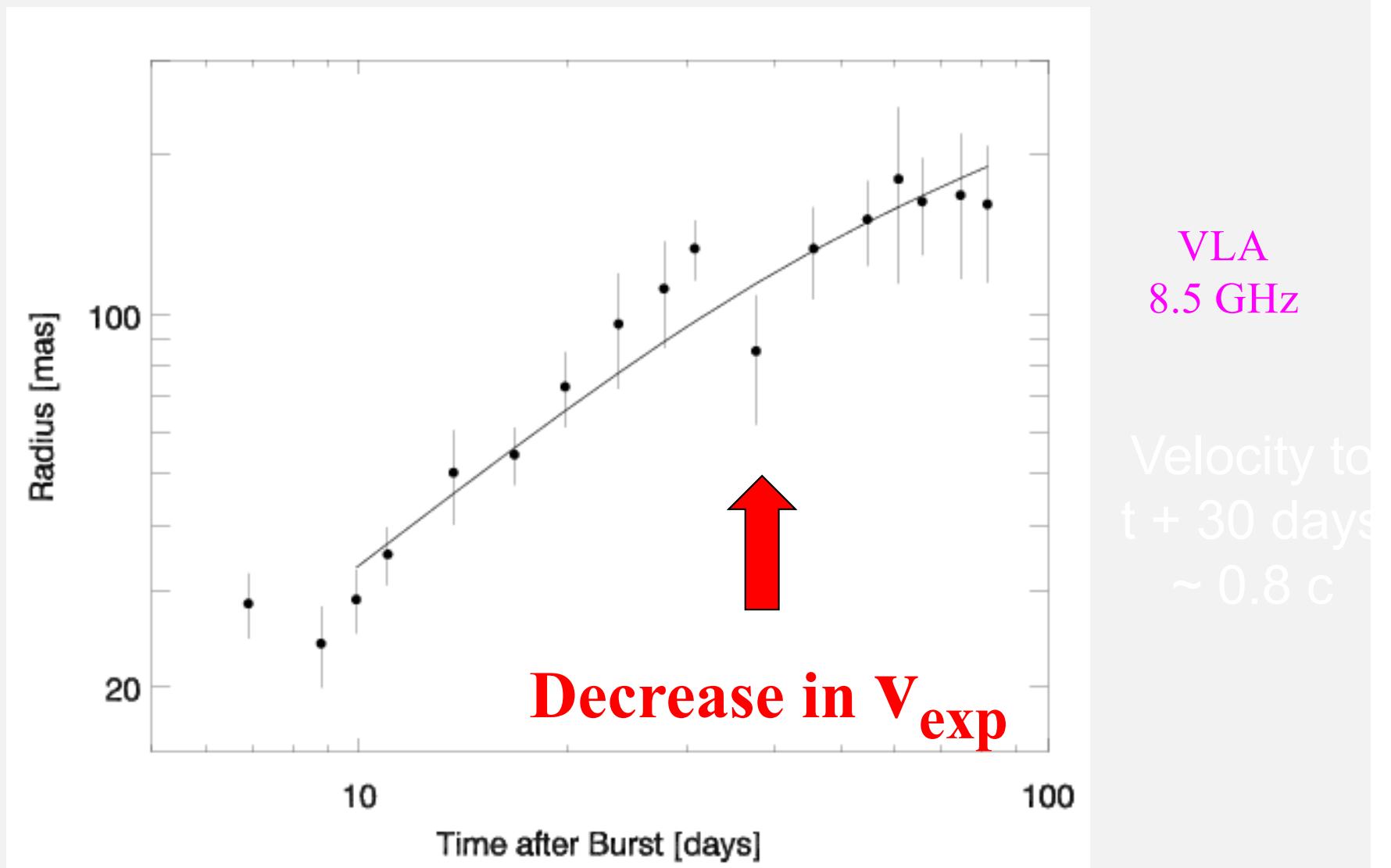
- Only 2 previous events ever recorded: in 1979 (SGR 0526-66 in LMC) & 1998 (SGR 1900-14)



Gaensler et al 2005

Growth of the Radio Afterglow

Size at
t+7 days
 10^{16} cm
(1000 AU)



Taylor et al 2005

Magnetar burst sequence

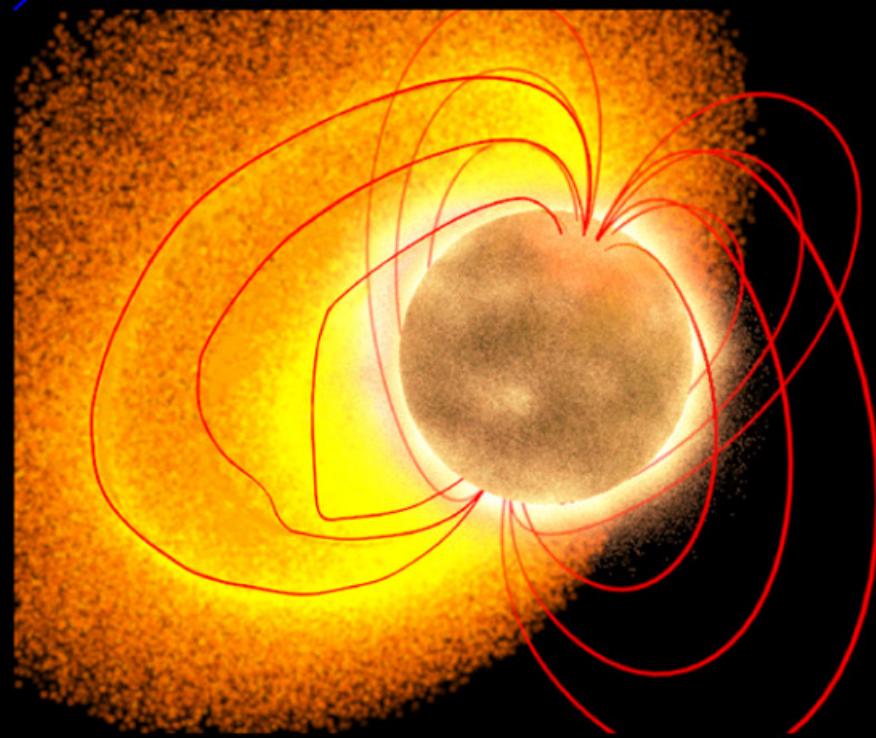
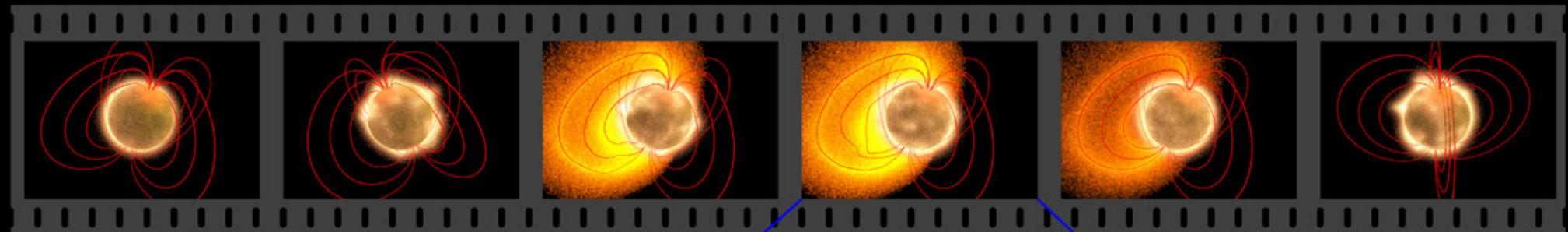


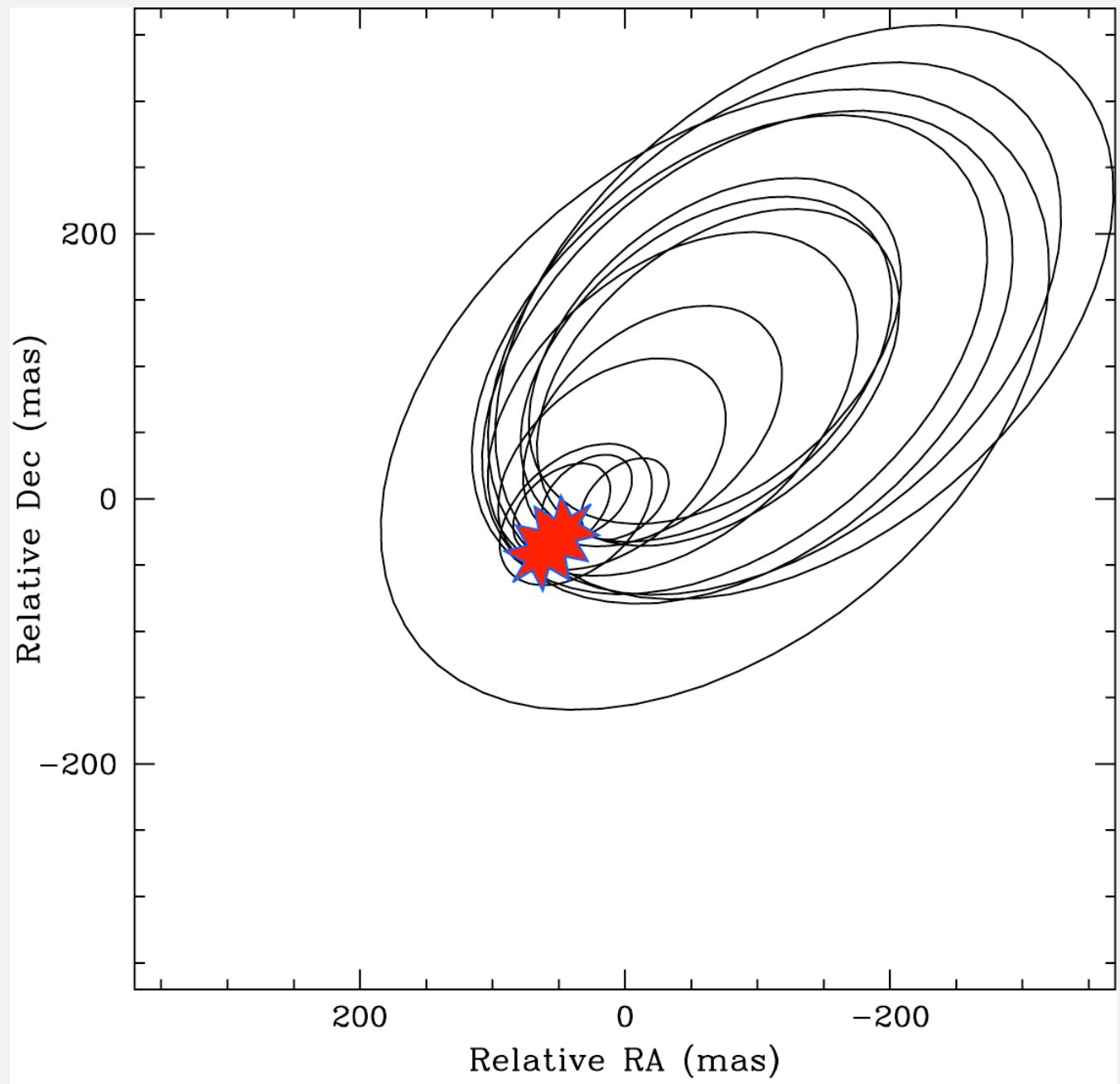
Image Evolution

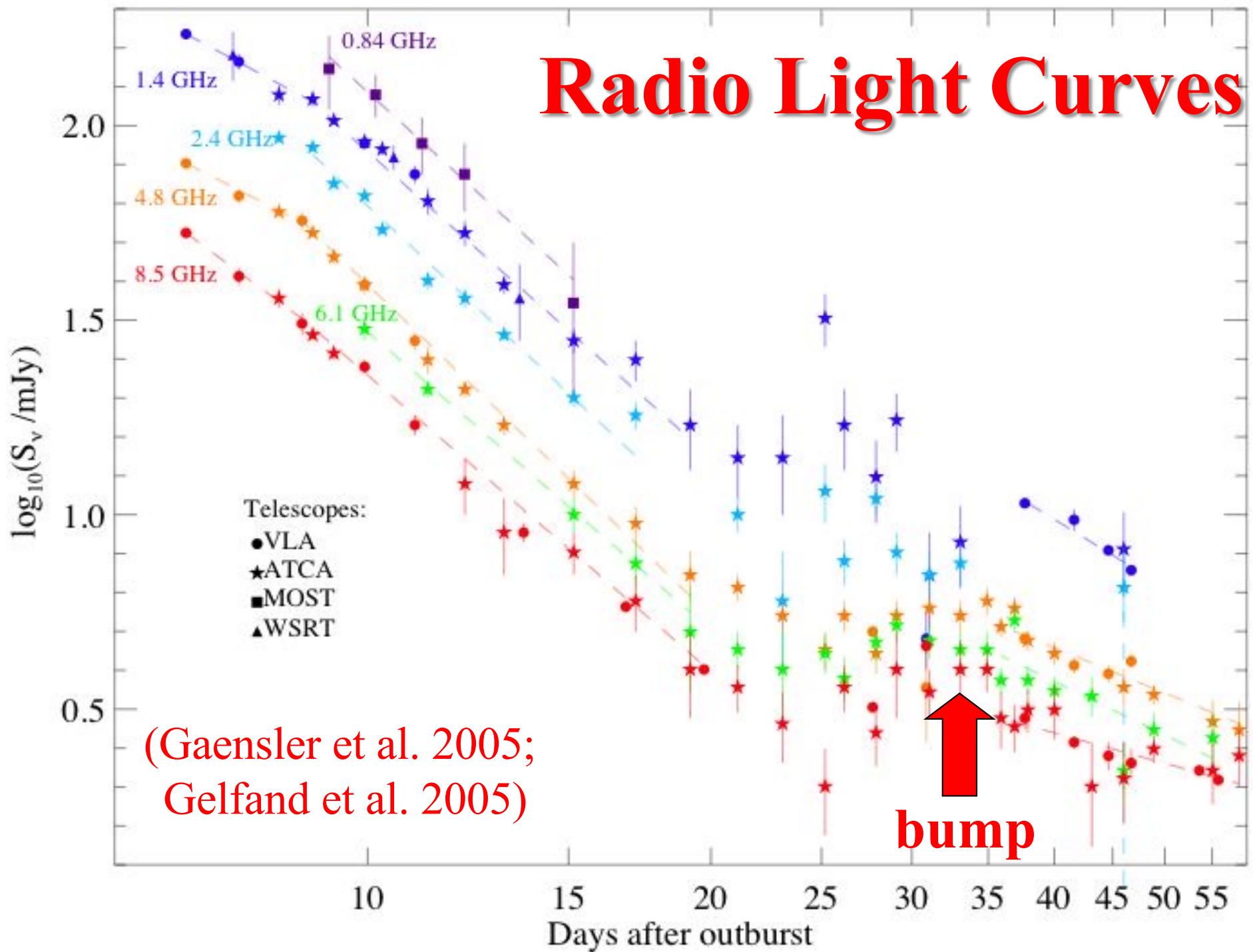
VLA 8.5 GHz

$E \sim 10^{45}$ ergs

One-sided
(anisotropic)
outflow

Taylor et al 2005



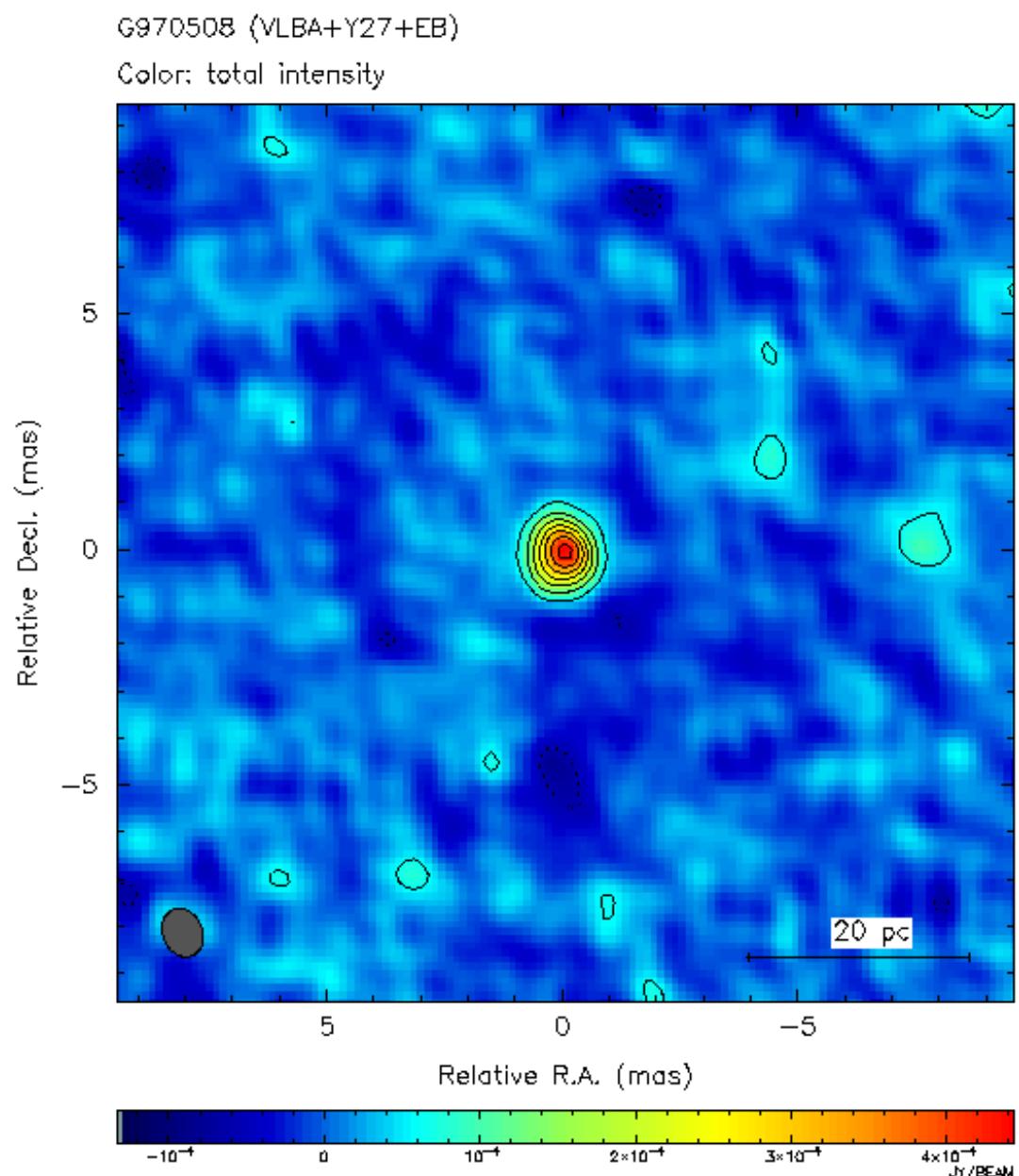


Gamma Ray Bursts

GRB 970508

- First GRB Afterglow detected in the radio
 - absolute position to < 1 mas
 - Size $< 10^{19}$ cm (3 lt years)
 - Distance > 10000 lt years

Taylor et al 1997



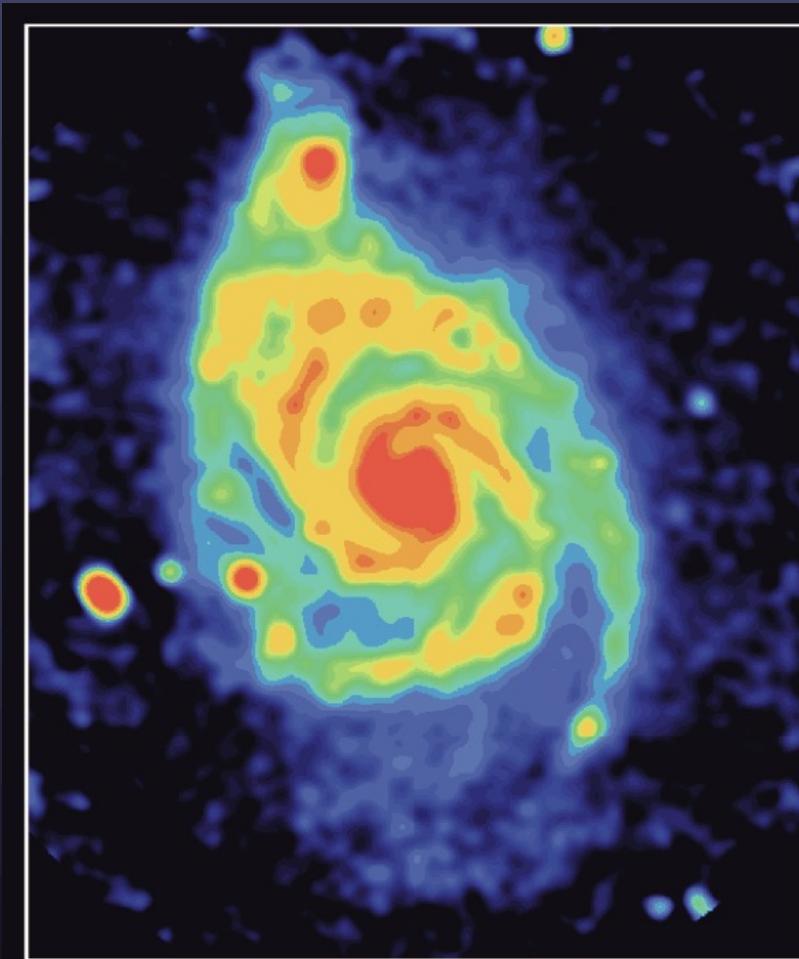
G. Taylor, Astr 423 at UNM



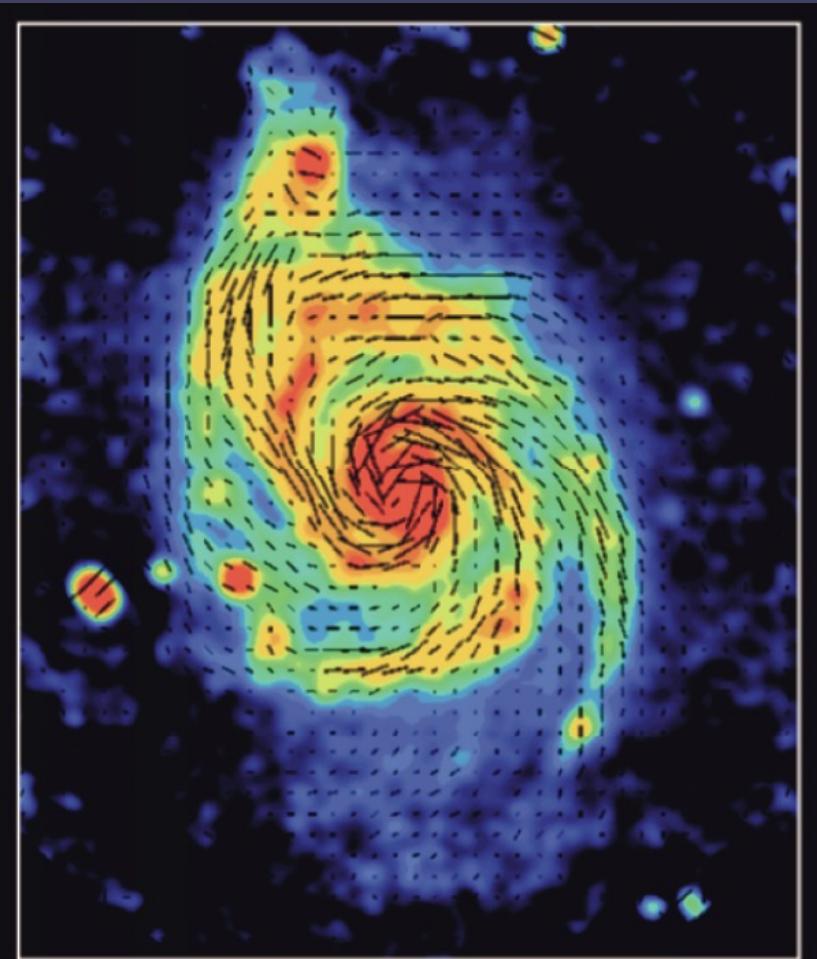
Normal Galaxies

39

M51



Beck et al



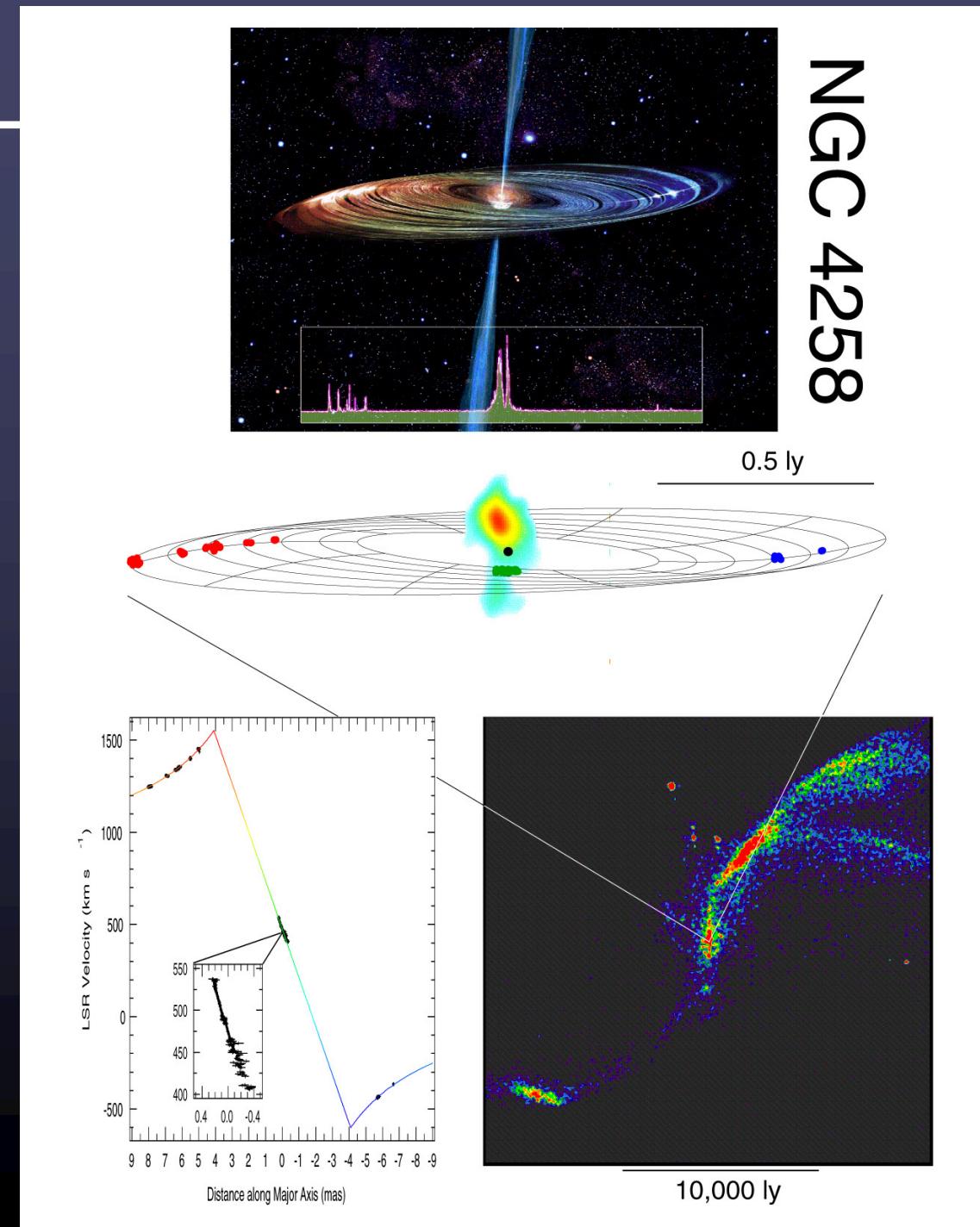
G. Taylor, Astr 423 at UNM

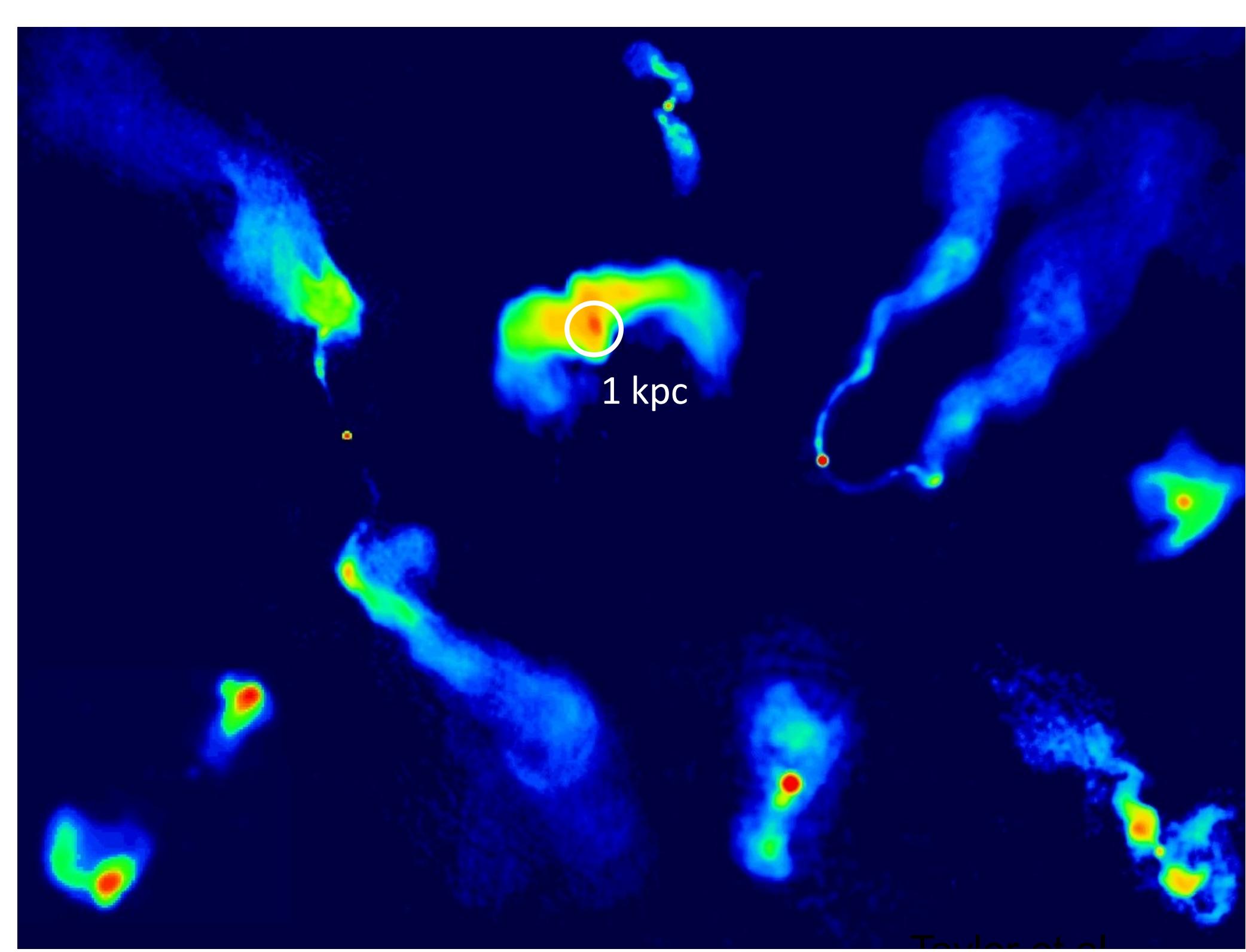


NGC 4258

- ❑ Considered best evidence of a supermassive black hole
- ❑ Can estimate central mass
- ❑ Can estimate distance to host galaxy

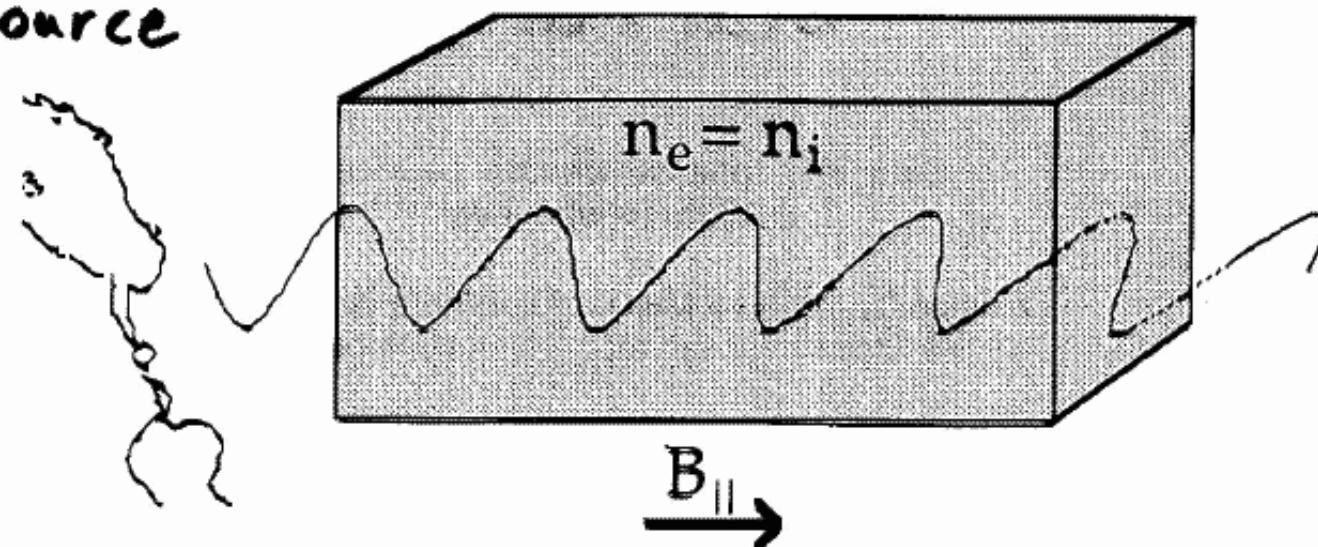
image courtesy Lincoln Greenhill
(see Miyoshi et al 1995
Herrnstein et al 1999)





Faraday Rotation

Polarized
Source

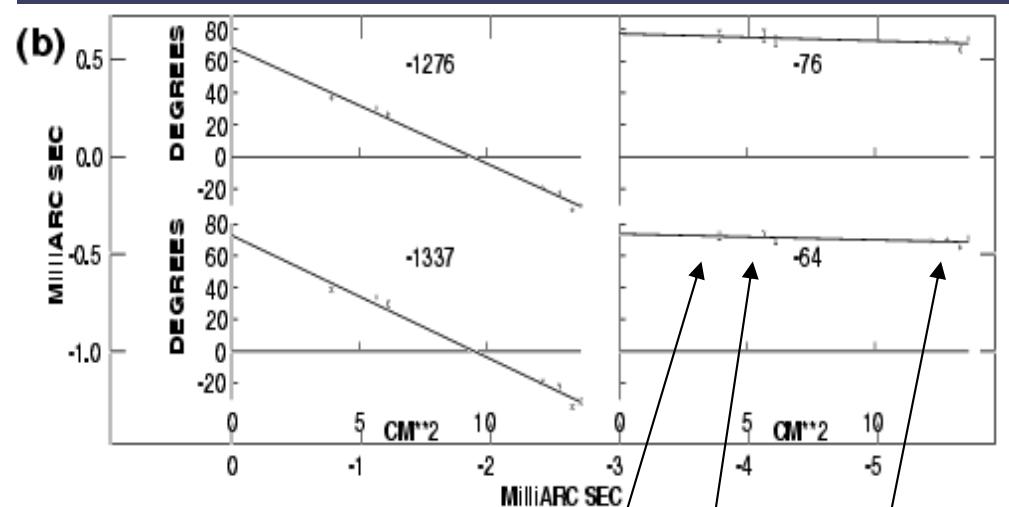
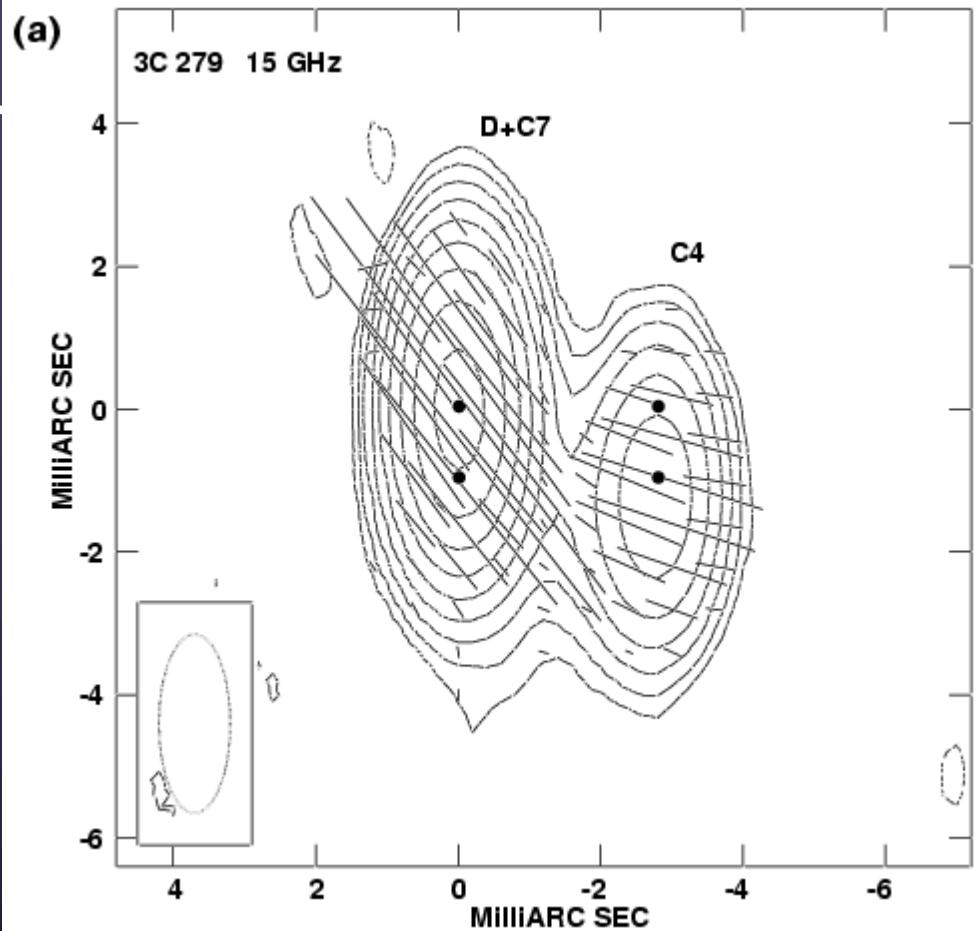


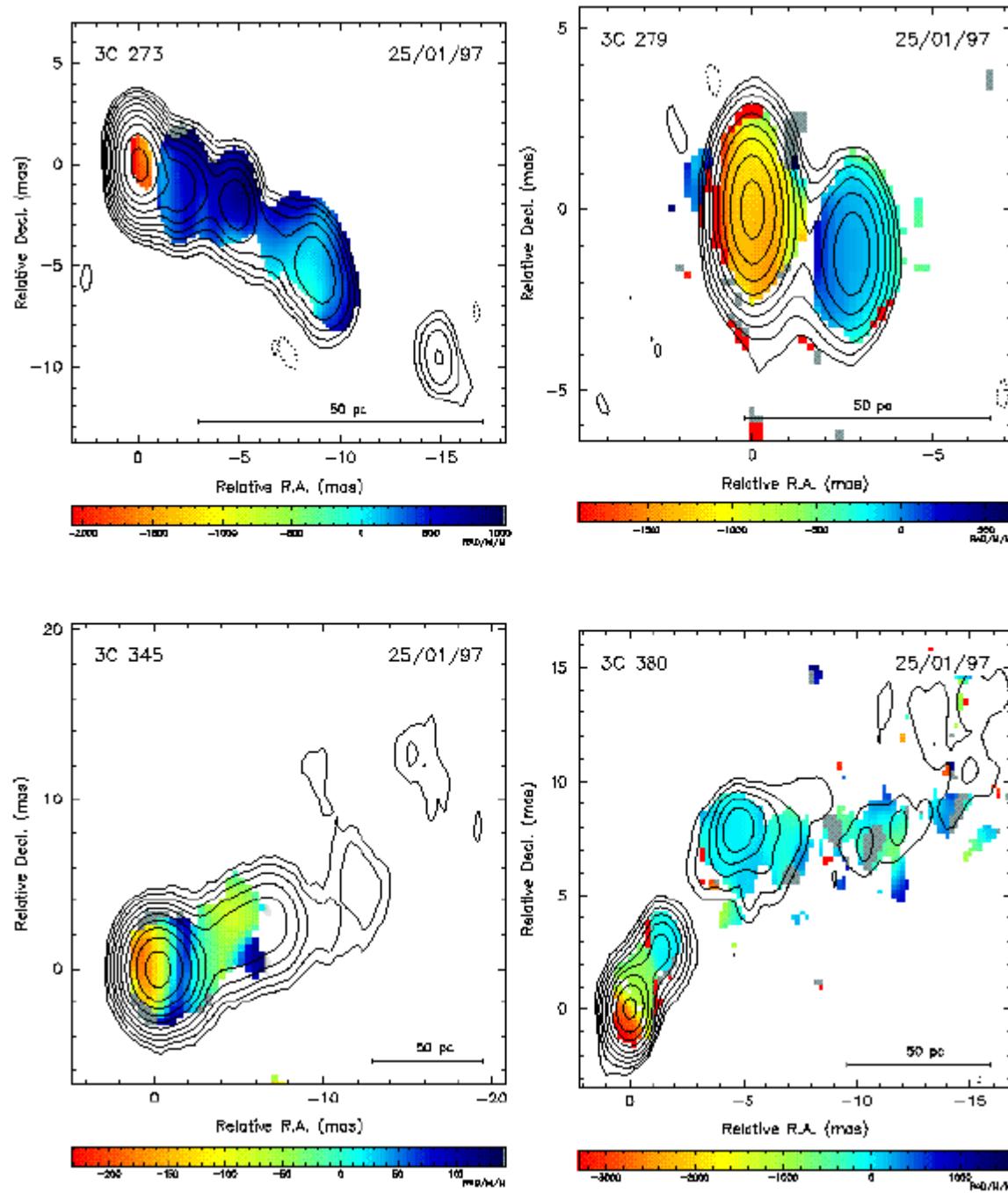
$$\Psi = \Psi_0 + RM \lambda^2$$

$$RM = 812 \int_0^L n_e B_{||} dl \text{ radians/m}^2$$

← kpc ← mGauss
 L cm⁻³





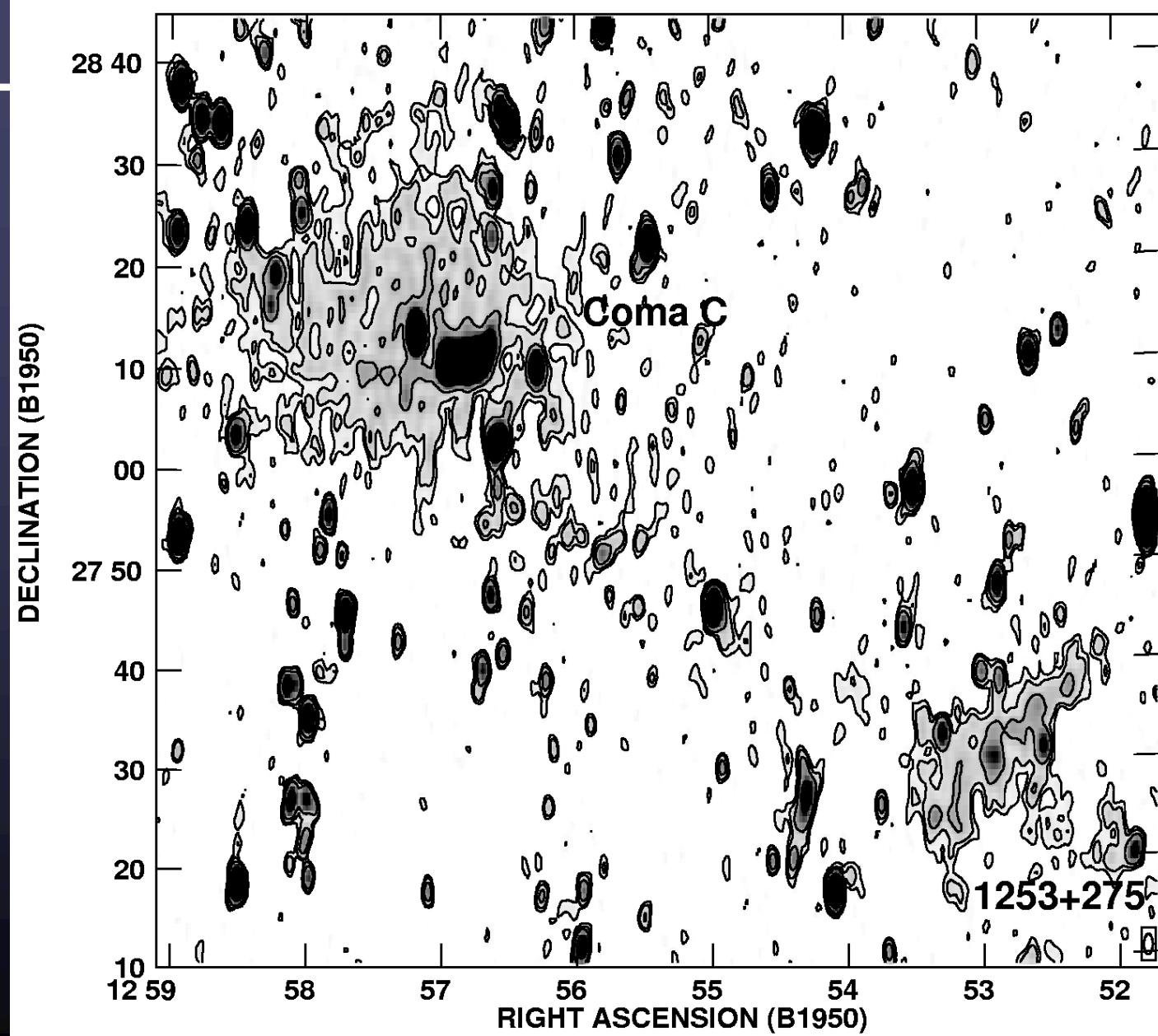


The University of New Mexico

Feretti et al. 1998

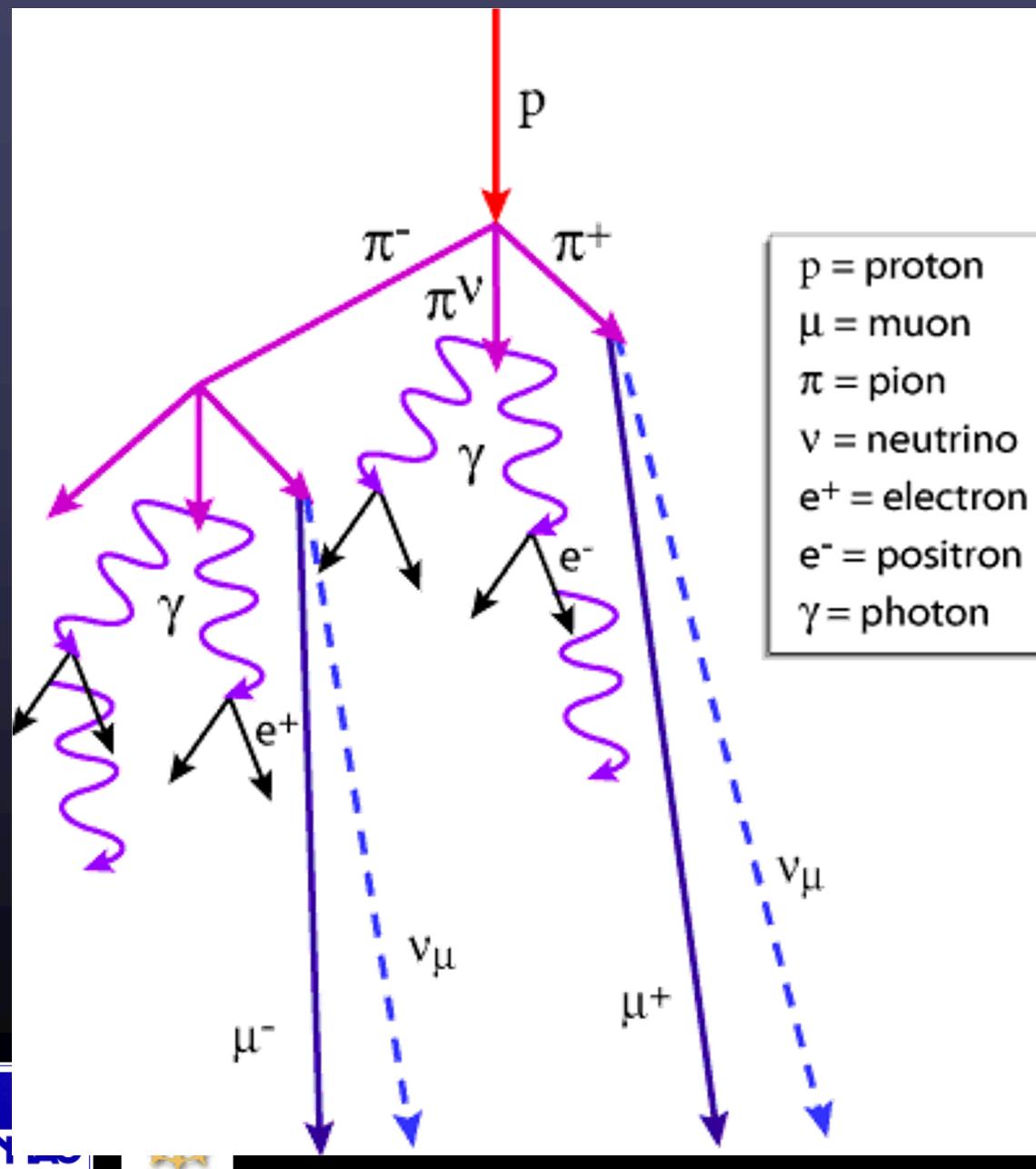
WSRT at 90cm

$B \sim 0.4 \mu\text{G}$

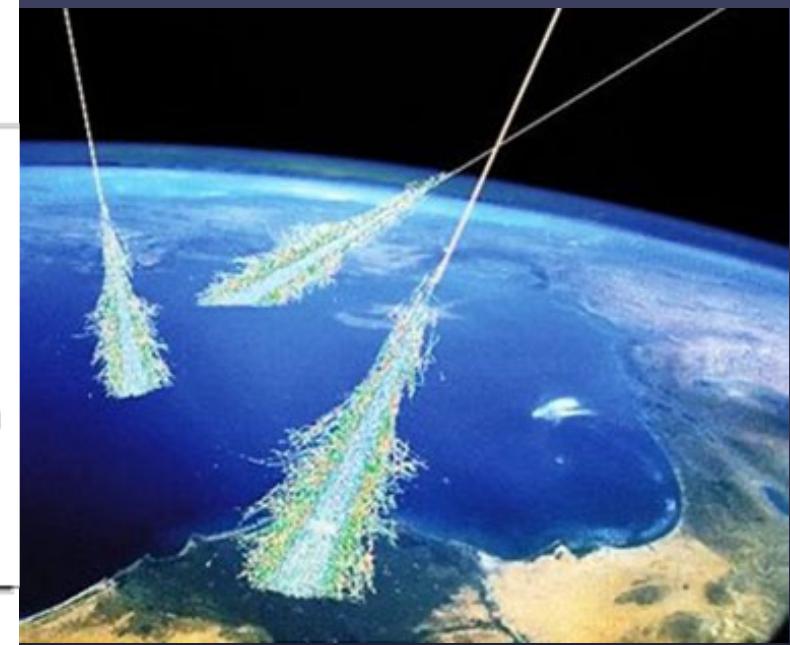


Cosmic Ray Air Showers

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p = proton
 μ = muon
 π = pion
 ν = neutrino
 e^+ = electron
 e^- = positron
 γ = photon



Non-Thermal Sources

- Man-made signals (RFI)
- Cosmic ray air showers
- Solar Flares (Active Sun), also flare stars and brown dwarfs
- Planetary magnetospheres
- Lightning (from storms on planets and locally as RFI)
- Planetary Radar/Spacecraft telemetry
- Supernova Remnants
- Gamma-ray Bursts and their afterglows
- Pulsars
- Magnetar flares
- Masers
- X-ray binaries/microquasars
- Normal galaxies (cosmic ray population)
- Active Galaxies (including Quasars, Blazars, etc.)
- Intracluster medium (halos and relics)
- Dark-matter decay



Further Reading

<http://www.nrao.edu/whatisra/mechanisms.shtml>

<http://www.nrao.edu/whatisra/>

www.nrao.edu

Synthesis Imaging in Radio Astronomy
ASP Vol 180, eds Taylor, Carilli & Perley

This lecture is on the course web page:

<http://www.phys.unm.edu/~gbtaylor/astr423>



G. Taylor, Astr 423 at UNM

