Radio Astronomy Intro, part 2

Some Possible LWA Observing Projects

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University of New Mexico

Astronomy 423 at UNM

Radio Astronomy

Announcements

National Radio Astronomy Observatory

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Summer Student Research Assistantships

Applications are now open for the 2025 summer student program at NRAO. The application deadline is February 1, 2025.

Please read the instructions before applying.

- On-line Application Form
- Submit Reference Letter

Reference letters may be submitted by faculty members or other contacts who feel qualified to recommend the student. Each application should include at least one reference letter, and as many as three may be submitted. We encourage those who are writing reference letters to submit by the Feb 1 deadline, but we will continue to accept reference letters after that date until all positions are filled.

Please direct questions to: sstudents at nrao dot edu.

- What and Where are the NRAO and GBO?
- What is Radio Astronomy?
- What are NRAO Summer Student Research Assistantships?
- What types of summer research positions are available?
- Would I be paid?
- Are research positions remote or in person, and where would I live?
- When would I start, and how long is the program?
- Where can I find more information on NRAO Summer Students?
- Application Instructions
- When will I hear about summer offers?
- Other Astronomy Programs

Celebrating More Than Six Decades of Training Young Scientists

Since its inception in 1959, the NRAO Summer Student Research Assistantship program has engaged over 1,000 young people in scientific research, and many of our summer students have gone on to distinguished careers in astronomy, physics, and other sciences. The list of former NRAO summer students includes people who represent a wide range of careers, research interests, geographic locations, and backgrounds.

ngvla Next Generation Very Large Array

The University of New Mexico

Announcements

- Observing proposals for LWA time due on Monday, Feb 3 by 4pm – send by e-mail to gbtaylor@unm.edu.
- You can use today's suggestions but you will need to do a little research to flesh them out
  - Strongly advise against "detection experiments"
- Books for the course are available in electronic editions from me (see e-mail with Dropbox link).

What are the benefits to doing radio astronomy?

1. can do it easily from the ground, day and night!

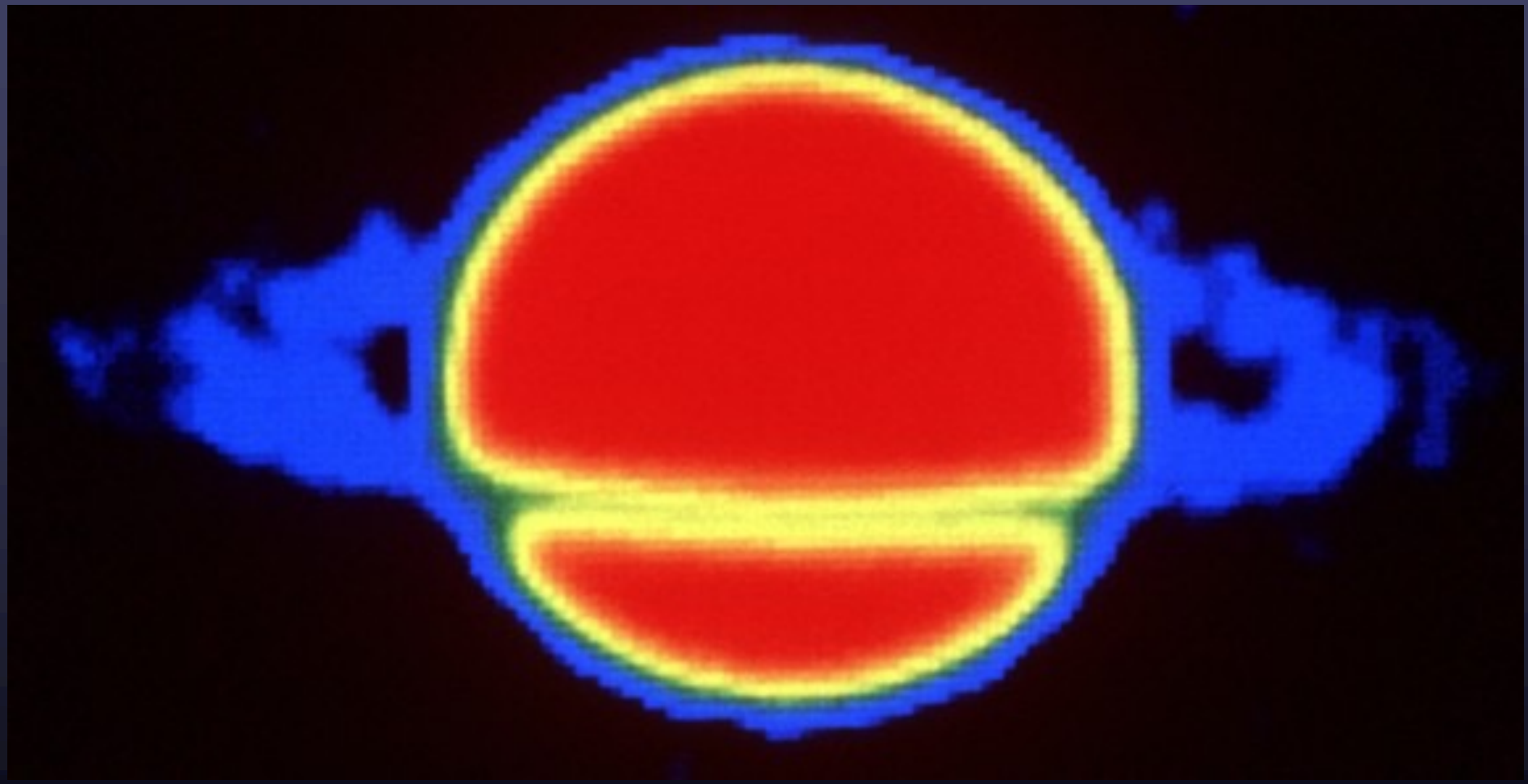
   cheap, easy to repair, upgrade

   round the clock observations – efficient observatories

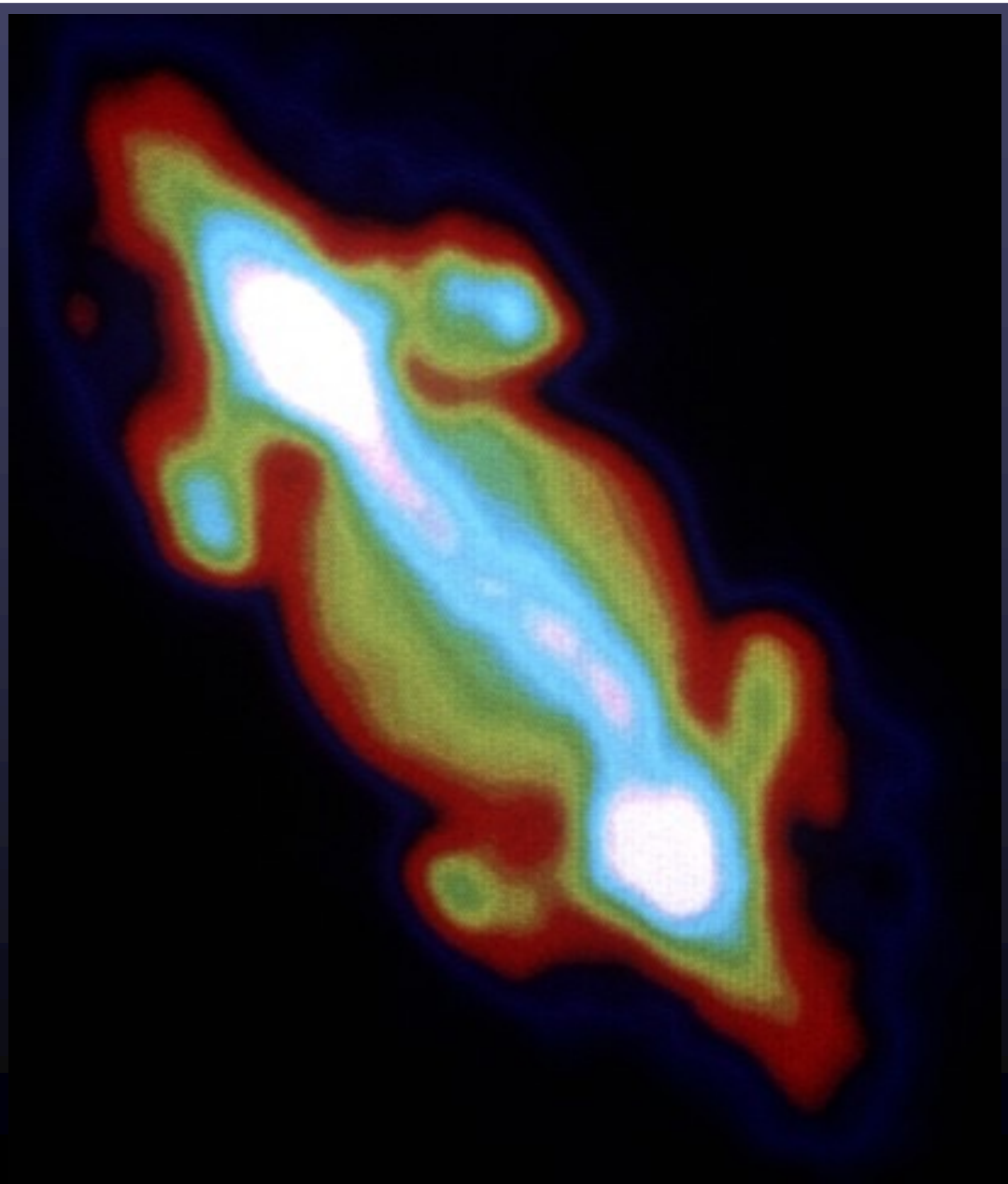
2. some objects/processes are easier to detect in the radio compared to other wavelengths

   - some distant, active galaxies are dominated by radio emission
   - jets from accretion onto a black hole
   - interstellar gas clouds between interacting galaxies
   - magnetic fields
   - coherent emission

Name that object observed in the radio with the VLA



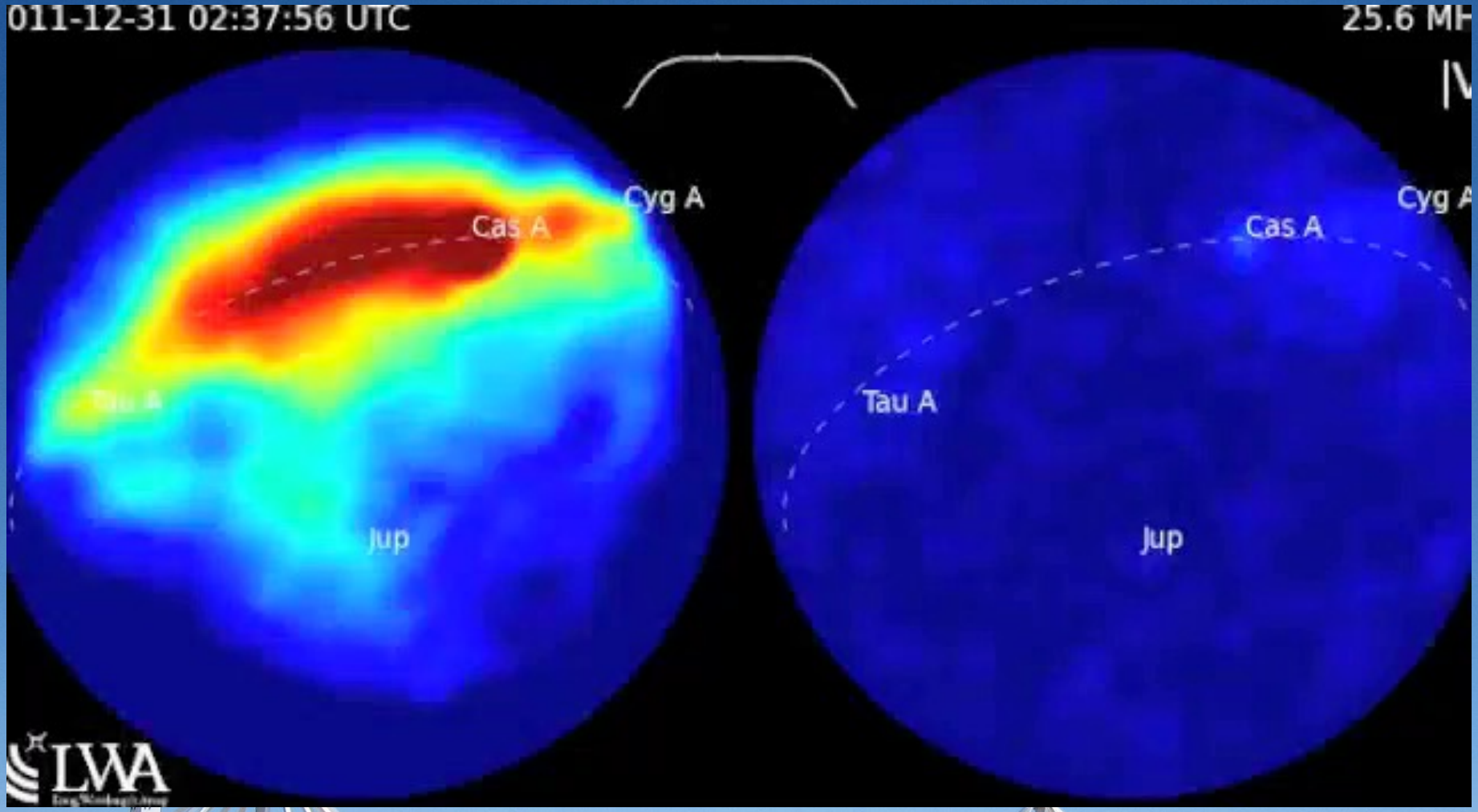
Name that object observed in the radio with the VLA



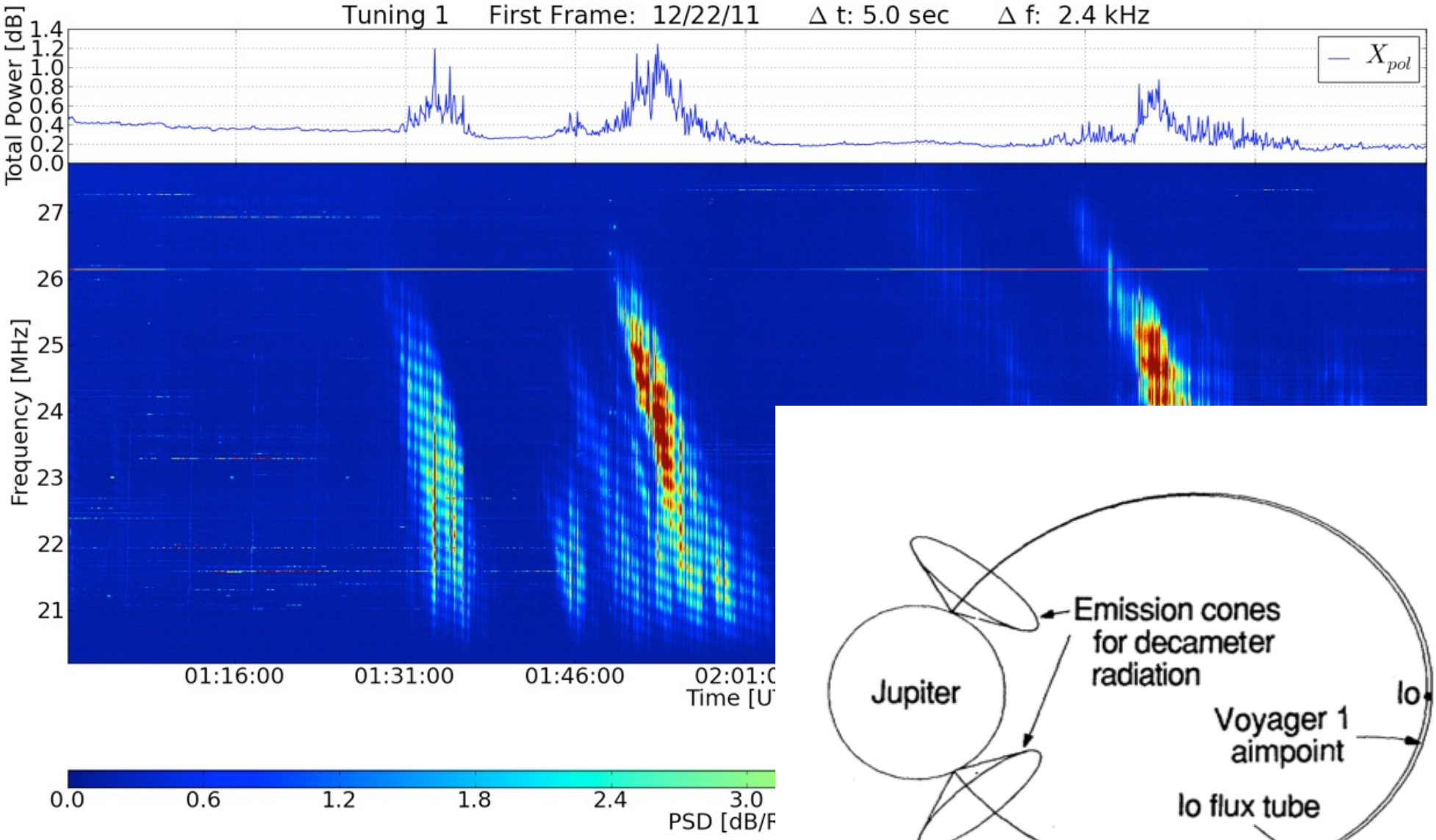
detection of the magnetic belts around Jupiter

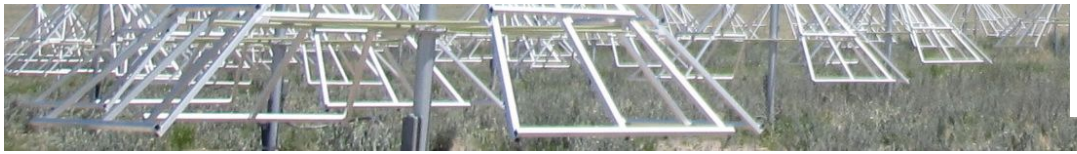
synchrotron emission from energetic particles in magnetic fields

LWA1 Observations of Jupiter



Decametric Jovian Emission



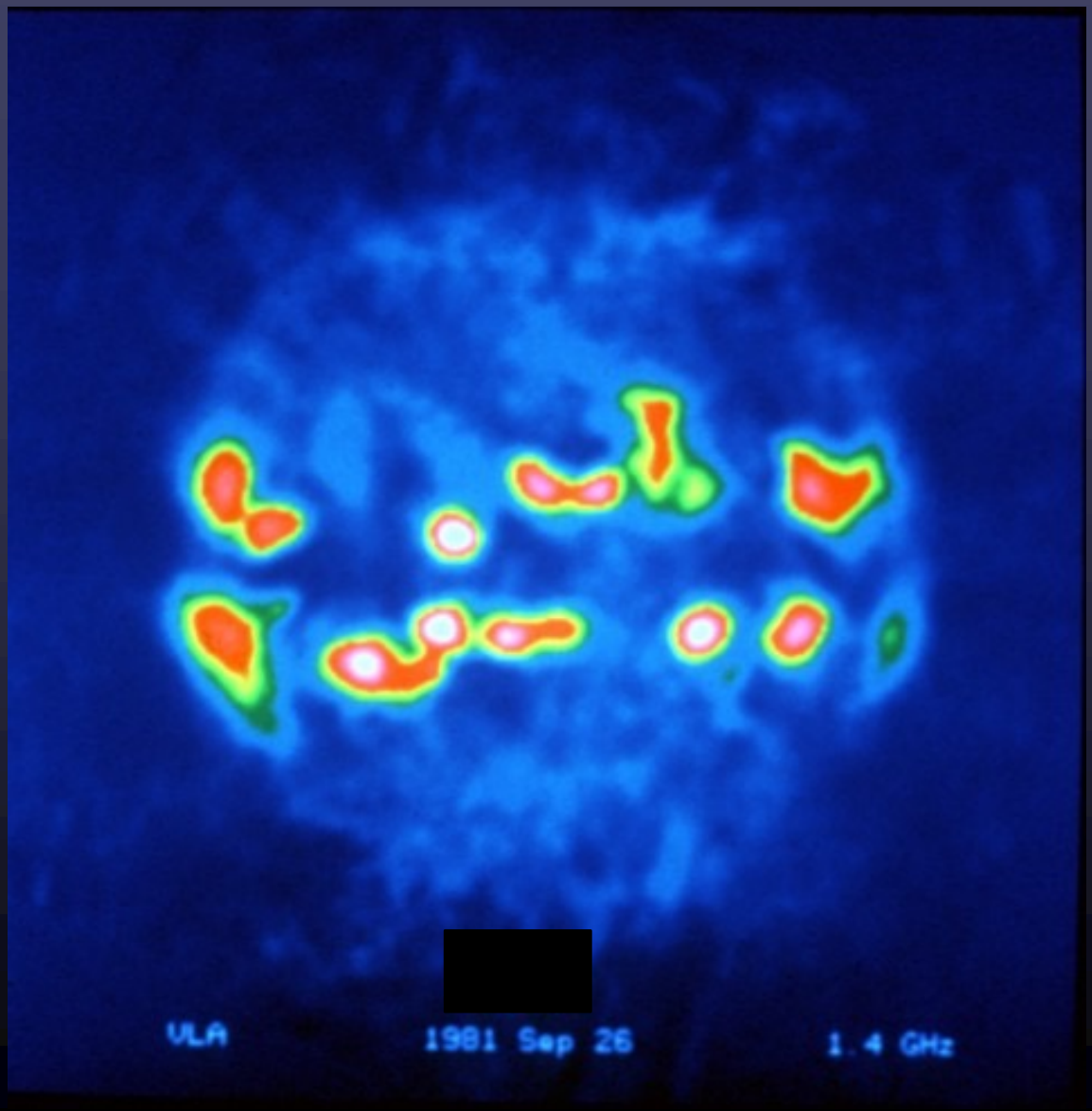


Possible LWA project #1

- Look for Jovian Bursts
  - Measure outbursts with a single LWA station
  - Estimate size of emission region
  - Consider physical conditions

Possible LWA project #2

- Use the LWA Swarm to localize the emission from Jupiter
  - Is RCP from the northern auroral region?
  - Is LCP from the southern auroral region?
  - Does any emission come from outside the poles?

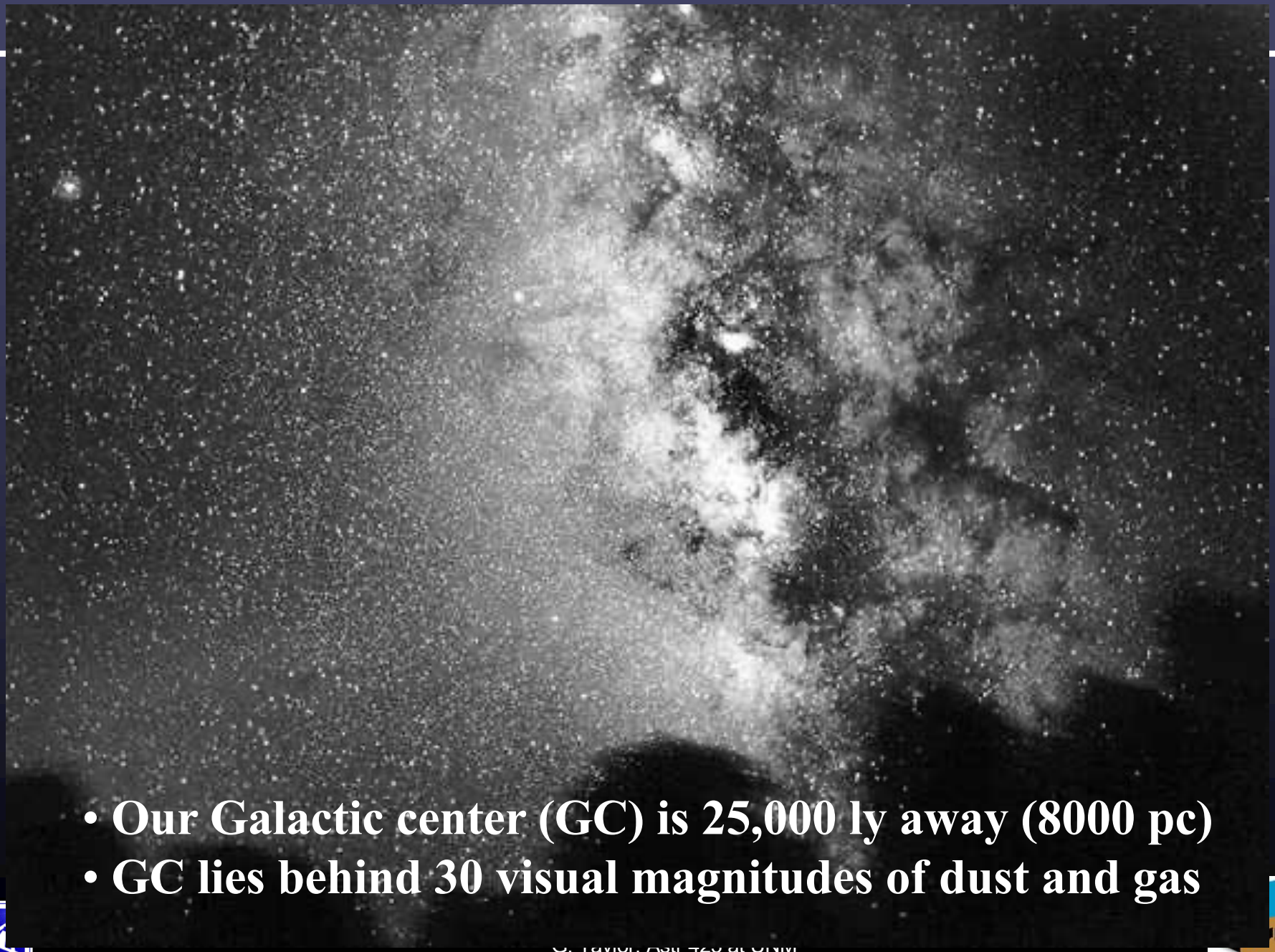


G. Taylor, Astr 423 at UNM

What are the benefits to doing radio astronomy?

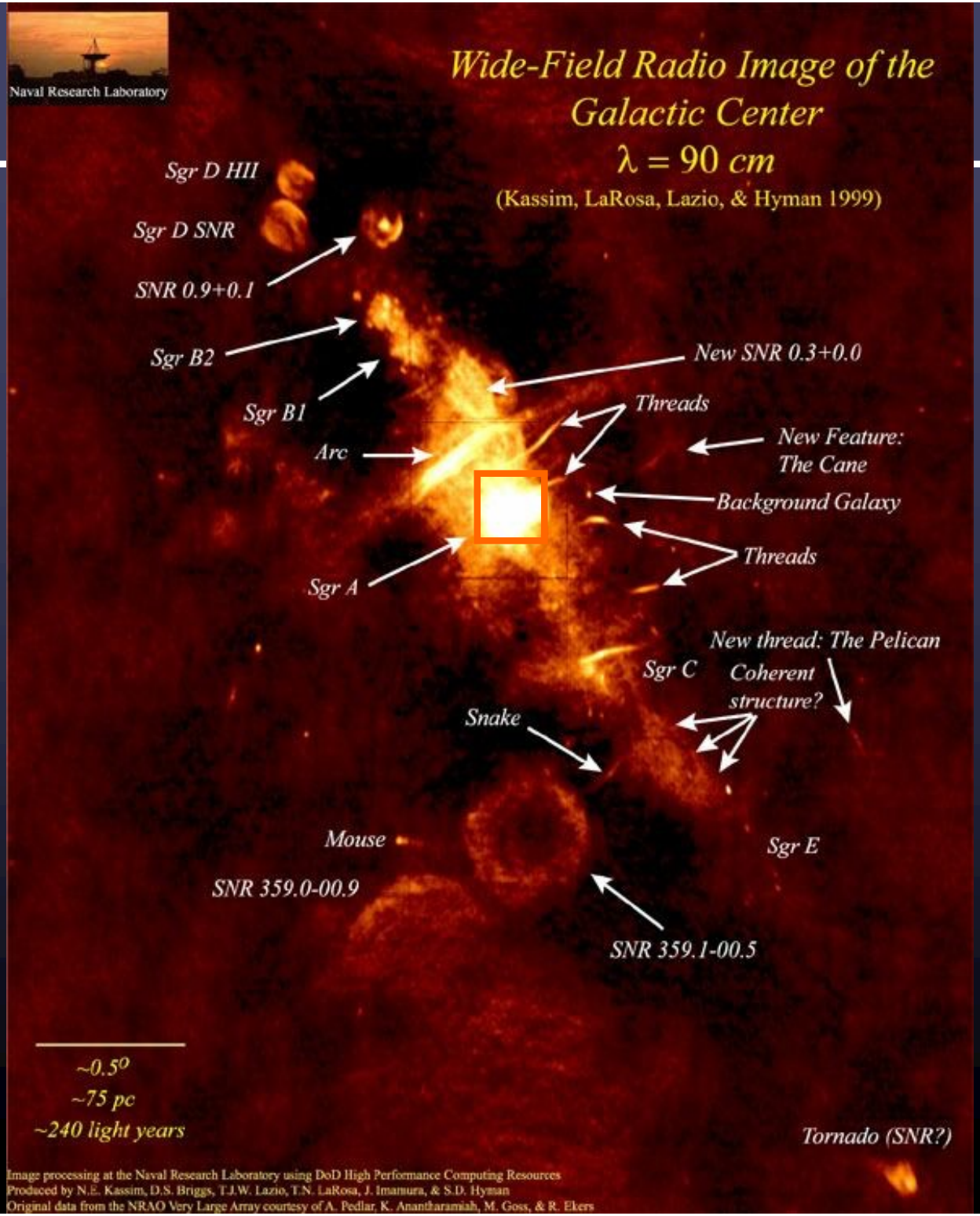
3. radio waves can propagate (fairly easily, sometimes affected) through the interstellar medium

unprecedented views of distant parts of our Galaxy
reveal details of visibly obscured regions – star formation

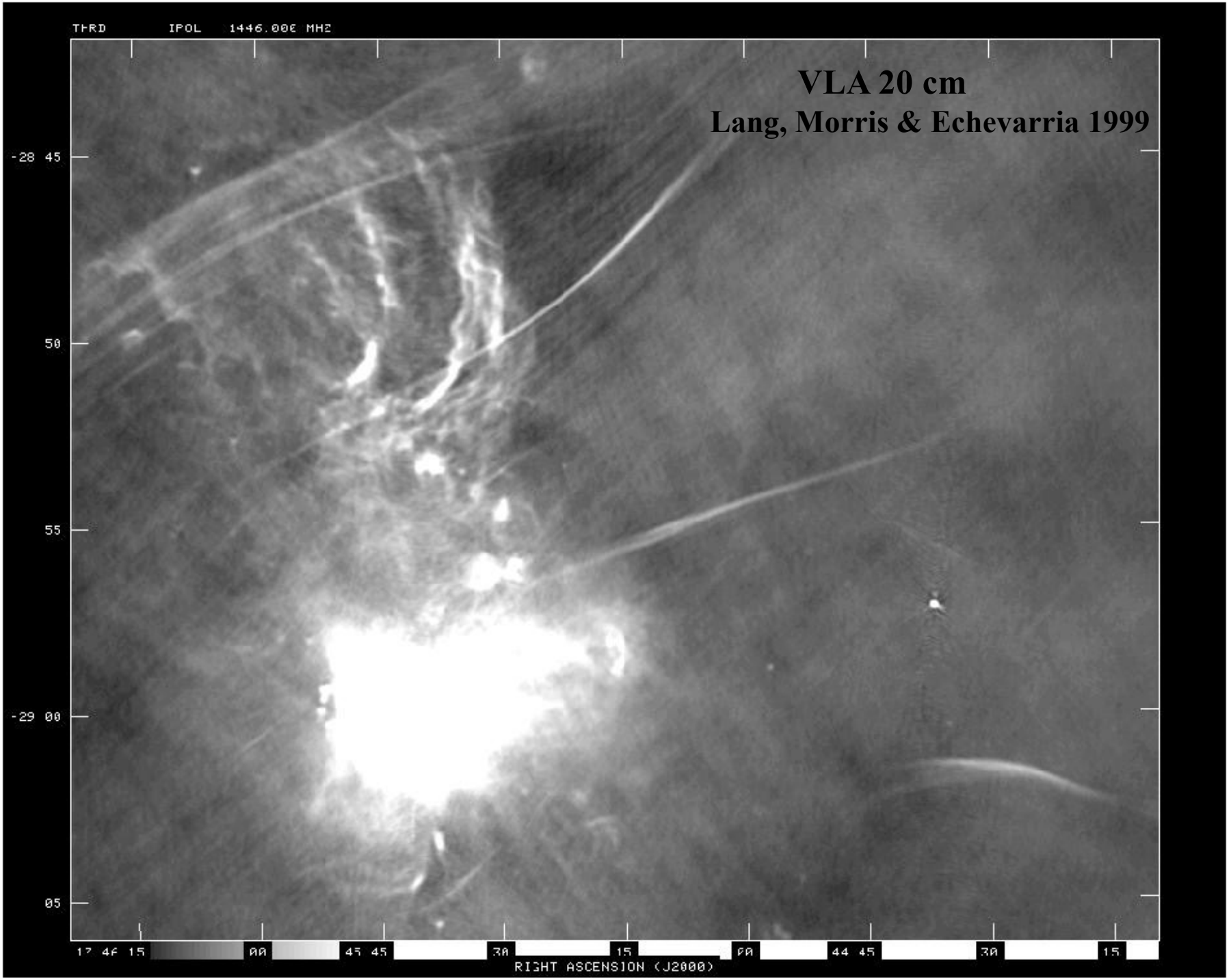


- **Our Galactic center (GC) is 25,000 ly away (8000 pc)**
- **GC lies behind 30 visual magnitudes of dust and gas**

VLA image at
330 MHz
~45” resolution
inner few degrees
of the Galaxy



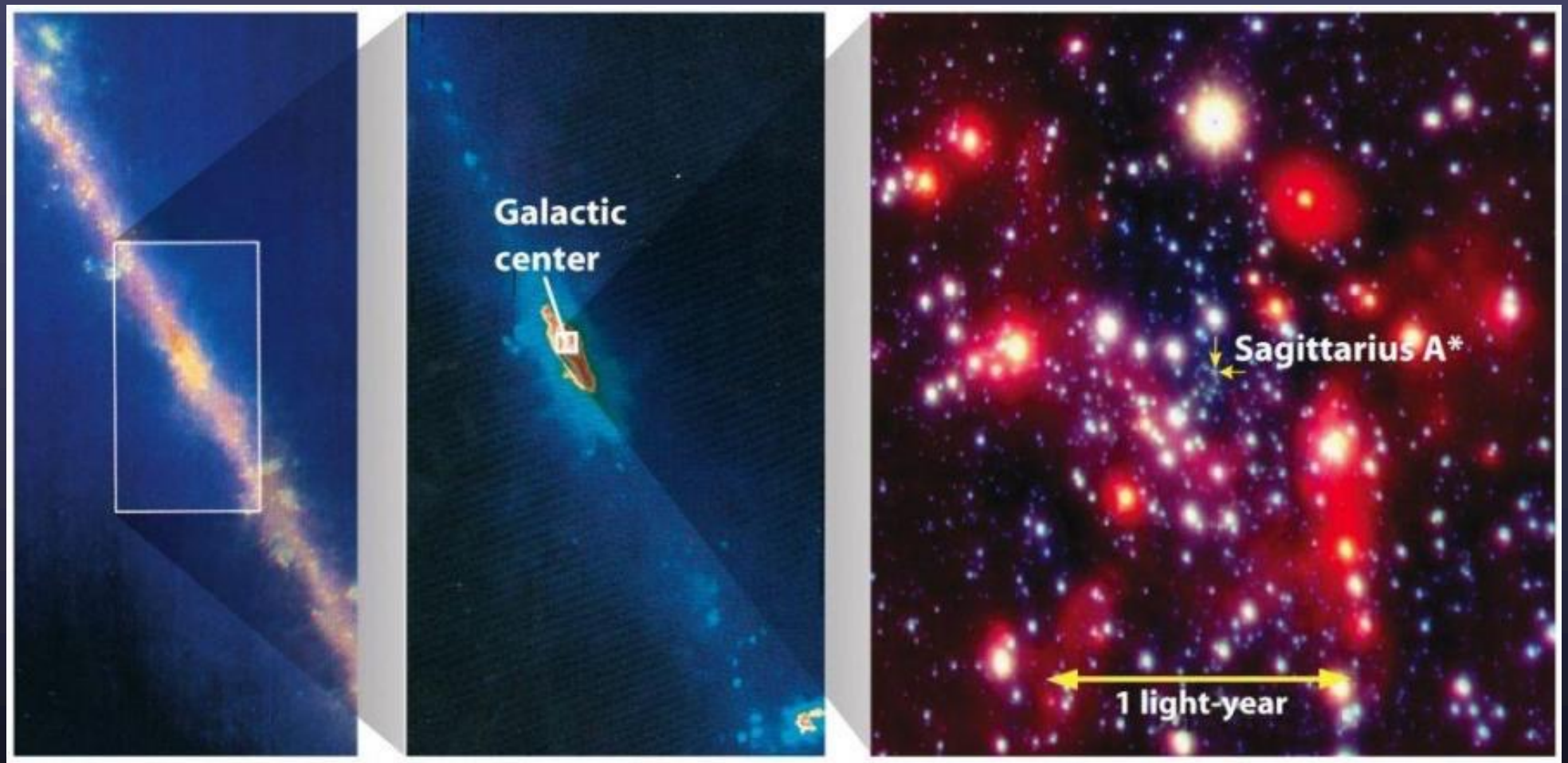
The University of New Mexico



VLA 20 cm

Lang, Morris & Echevarria 1999

IR views

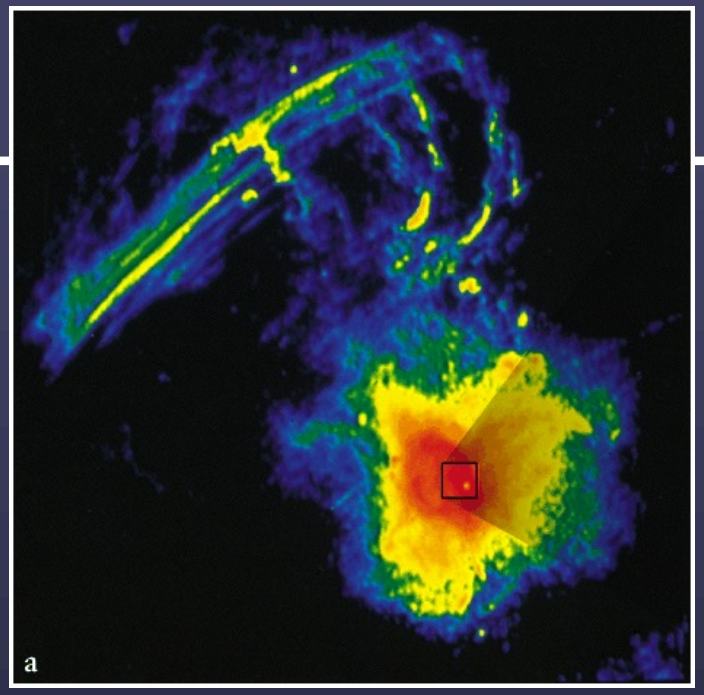


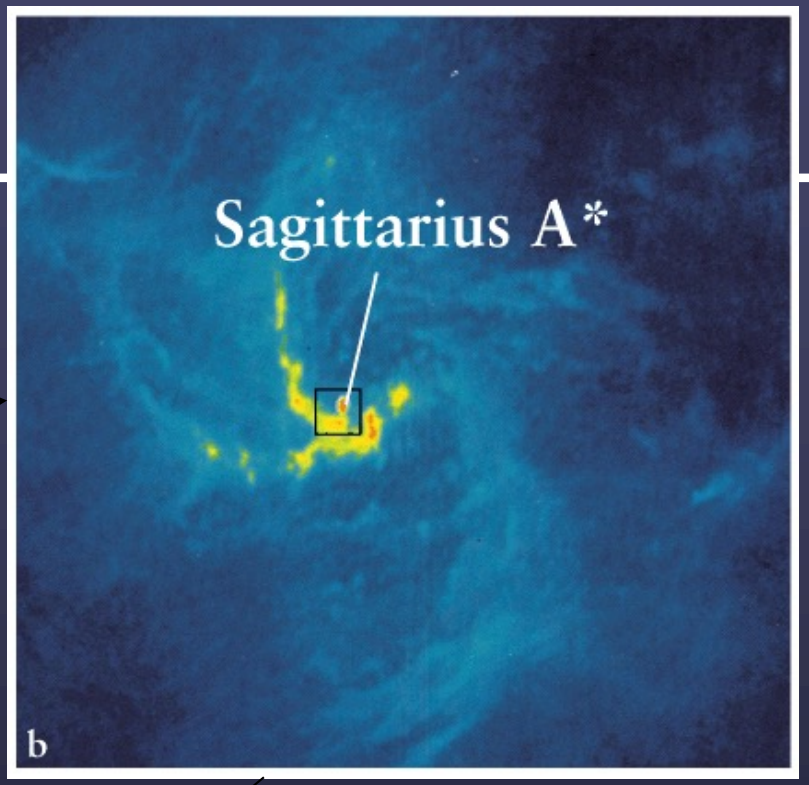
(a) A wide-angle (50°) infrared view

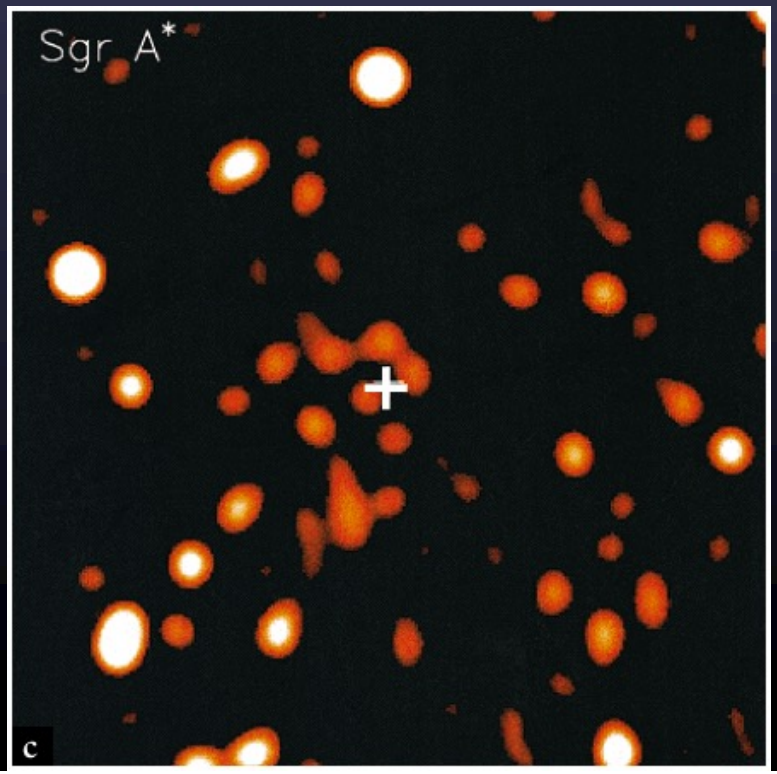
(b) A close-up view shows a more luminous region at the galactic center

(c) An extreme close-up view centered on Sagittarius A*, a radio source at the very center of the Milky Way Galaxy, shows hundreds of stars within 1 ly (0.3 pc)

Radio







Pinwheel of material is orbiting strong radio source Sgr A*

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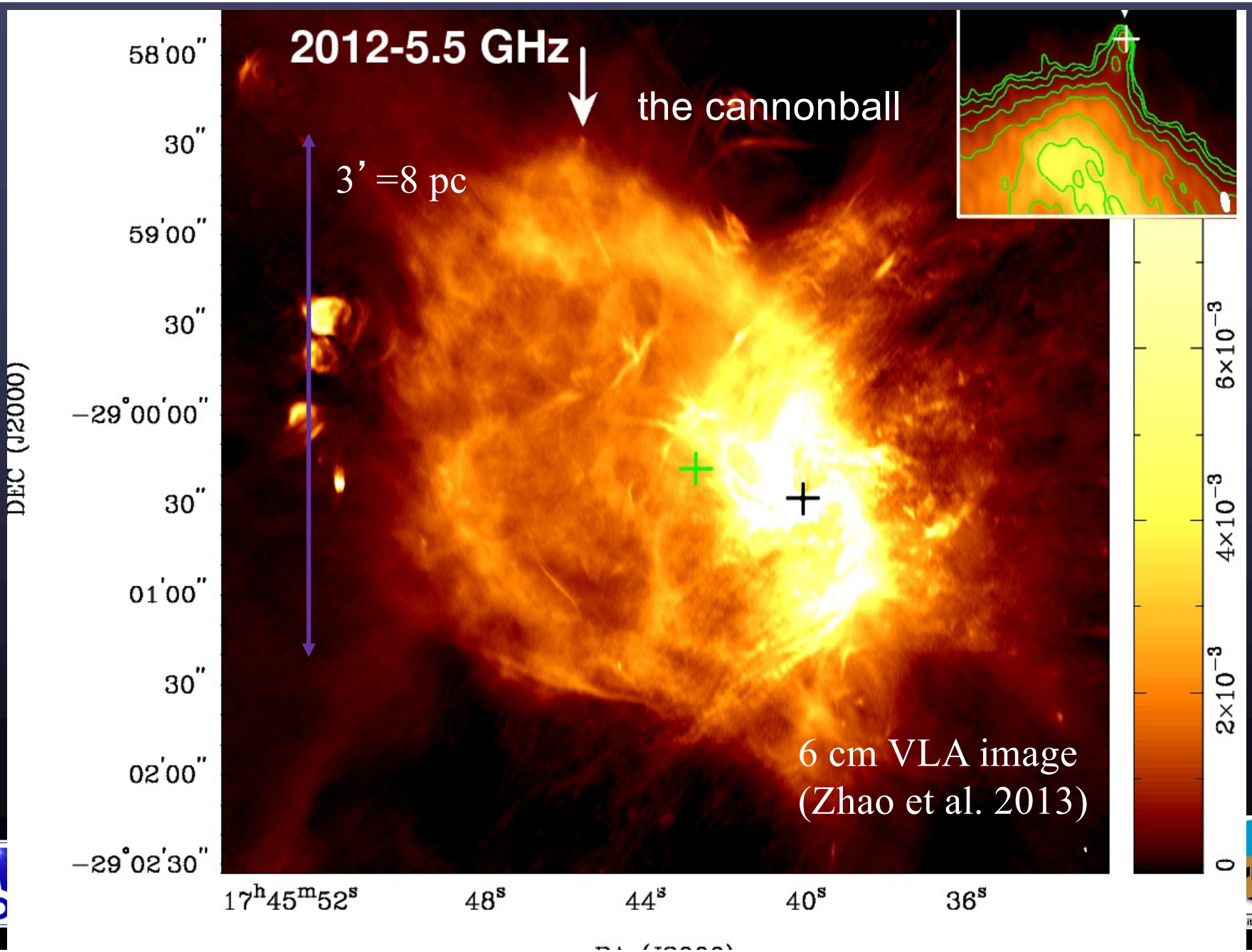
"Mini-spiral" of gas spiraling around (and onto) the central supermassive (~4 x 10^6 M_o black hole), SgrA*

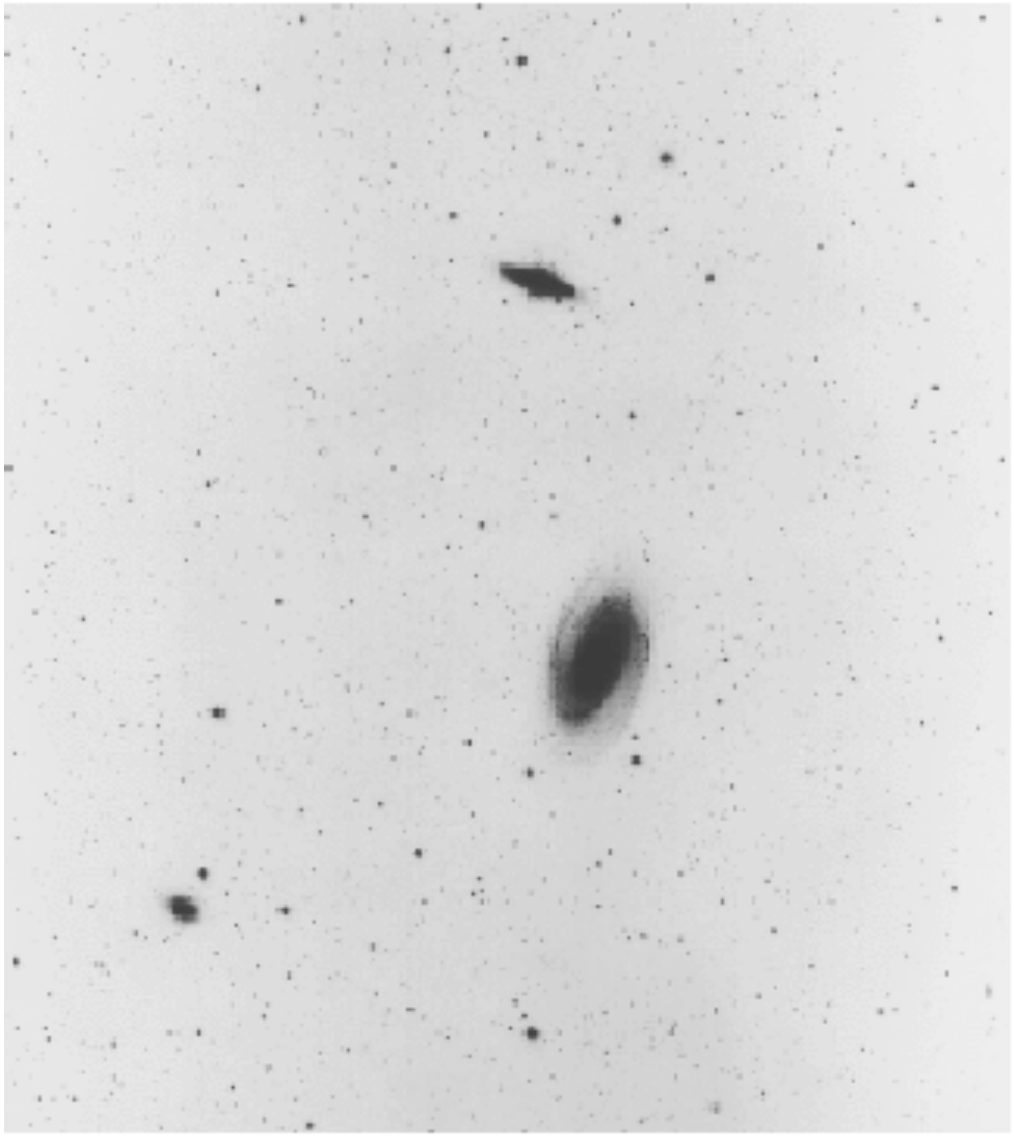


Possible LWA project #3

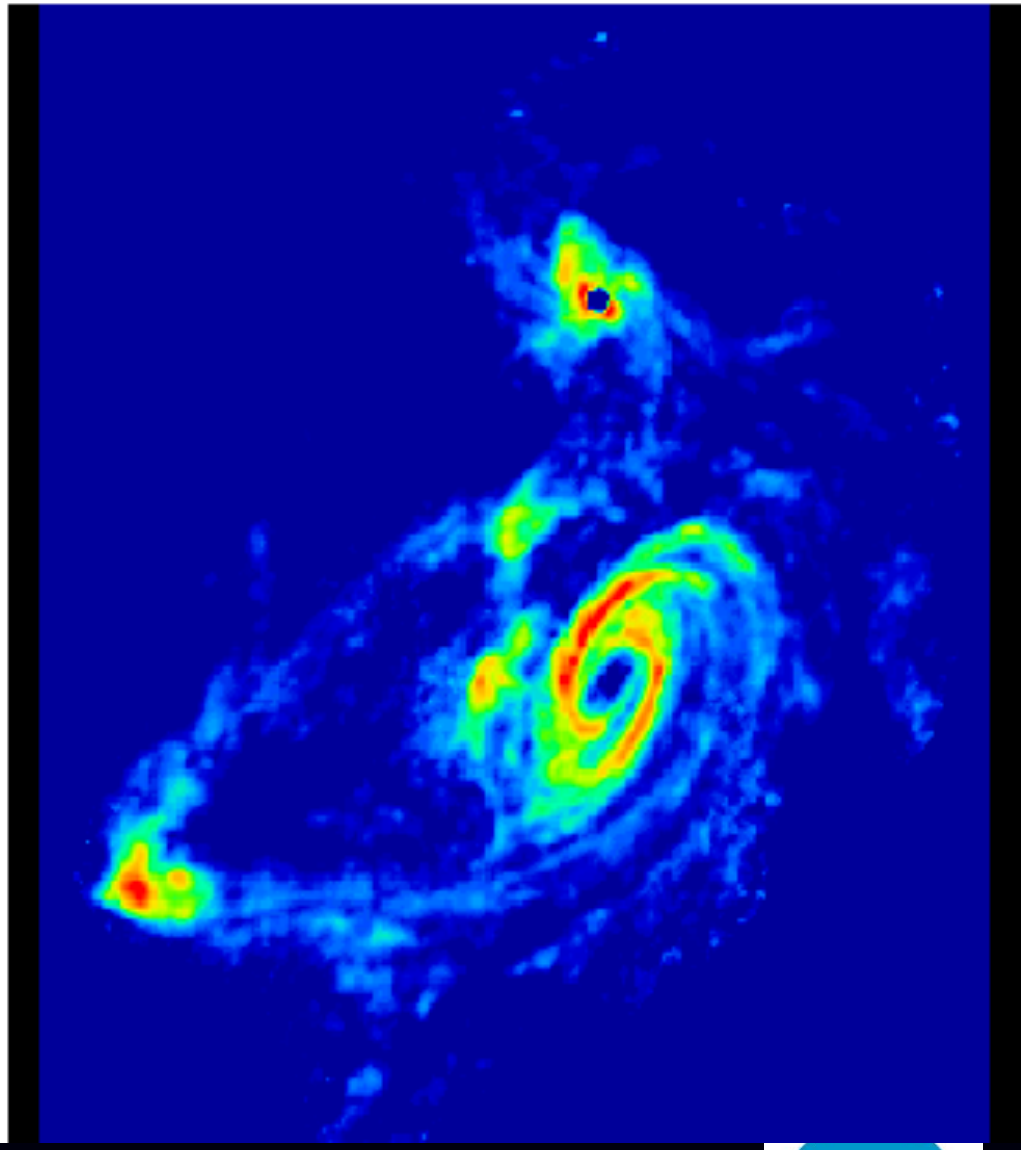
- Point at bright source near the Galactic Center with LWA Swarm
  - Any familiar structures?
  - What is the extent of the radio continuum?
  - Any sign of absorption?

TIDAL INTERACTIONS IN M81 GROUP

Stellar Light Distribution



21cm HI Distribution



What are the benefits to doing radio astronomy?

4. radio emission provides a wide variety of quantitative physical information about the source

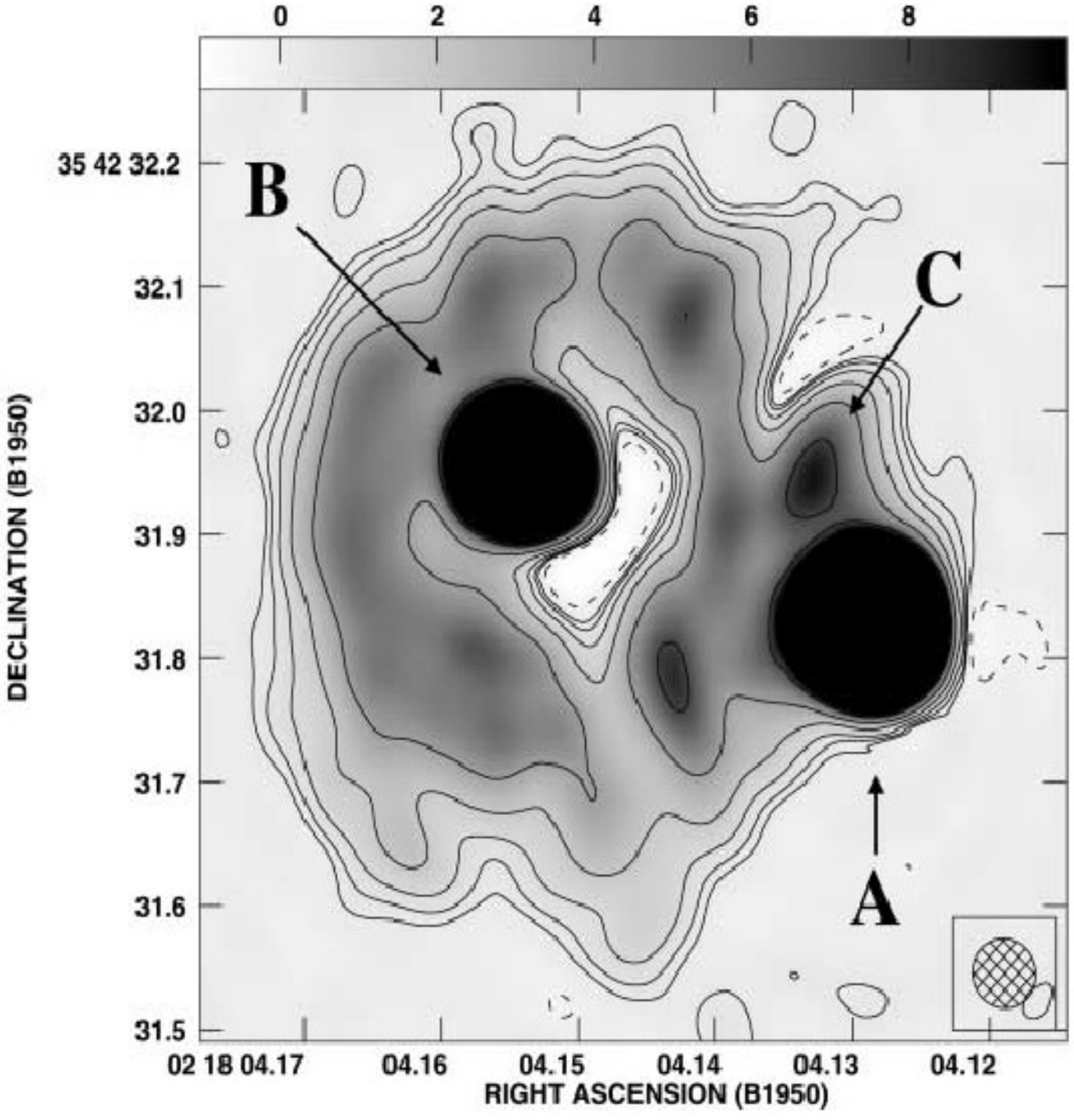
radio continuum emission

- spectral index (flux as a fxn. of frequency) = energetics
- brightness/flux = density, strength of magnetic field
  number of illuminating stars

radio spectral line emission

- width, amplitude of the line = temperature, density
- velocity = kinematic motions of gas, distance

0218+35


0
2
4
6
8
B
C
A
35 42 32.2
32.1
32.0
31.9
31.8
31.7
31.6
31.5
DECLINATION (B1950)
02 18 04.17
04.16
04.15
04.14
04.13
04.12
RIGHT ASCENSION (B1950)

Differences between optical and radio observing

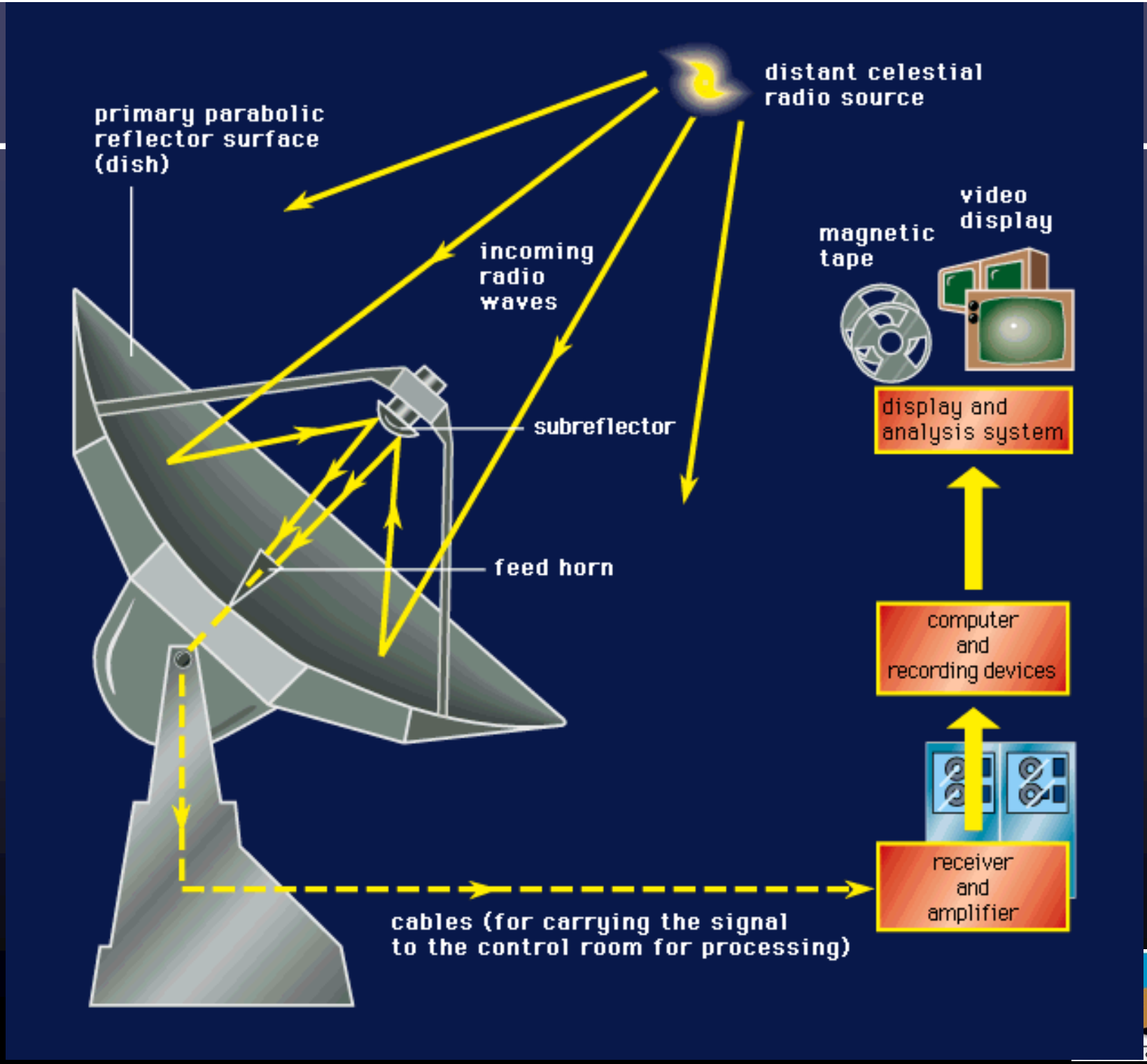
Optical

direct detection via CCD of the cosmic photon, strikes CCD → DETECTION

Radio

- radio wave (cosmic signal) is so weak that it needs to be amplified in order to be processed → *radio hardware*

- measure the wave properties of the radio wave, then reconstruct radio signal


distant celestial radio source
primary parabolic reflector surface (dish)
incoming radio waves
video display
magnetic tape
display and analysis system
subreflector
feed horn
computer and recording devices
receiver and amplifier
cables (for carrying the signal to the control room for processing)

Parkes 64-m in New South Wales, Australia

G. Taylor, Astr 423 at UNM

~~Arecibo Radio Telescope, Puerto Rico,~~ RIP

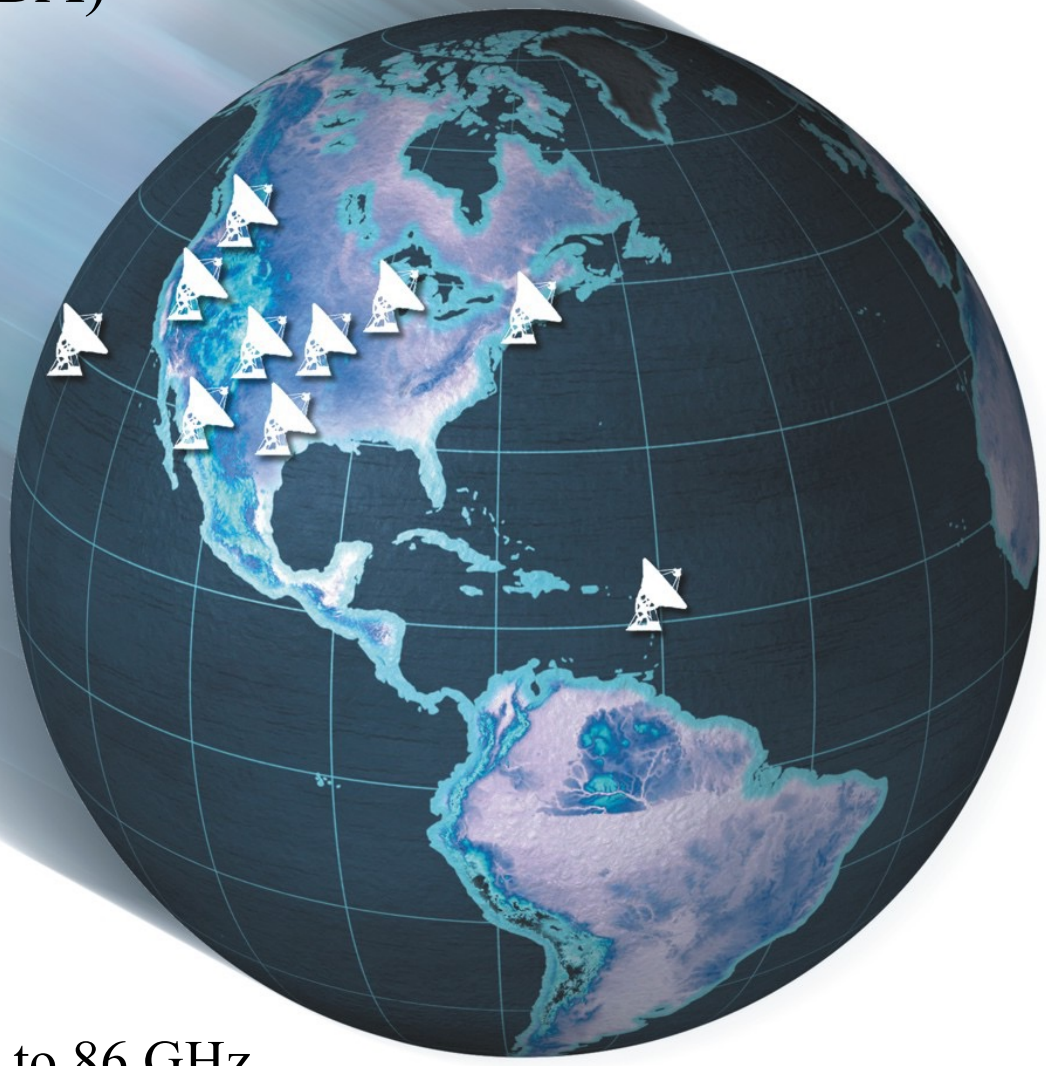
Very Long Baseline Array (VLBA)

Dedicated in 1993

10 antennas recording to tape

Correlator in Socorro, NM

Combinable with Global Arrays



- Frequencies ranging from 330 MHz to 86 GHz
- Angular resolution to 100 microarcseconds at highest frequency

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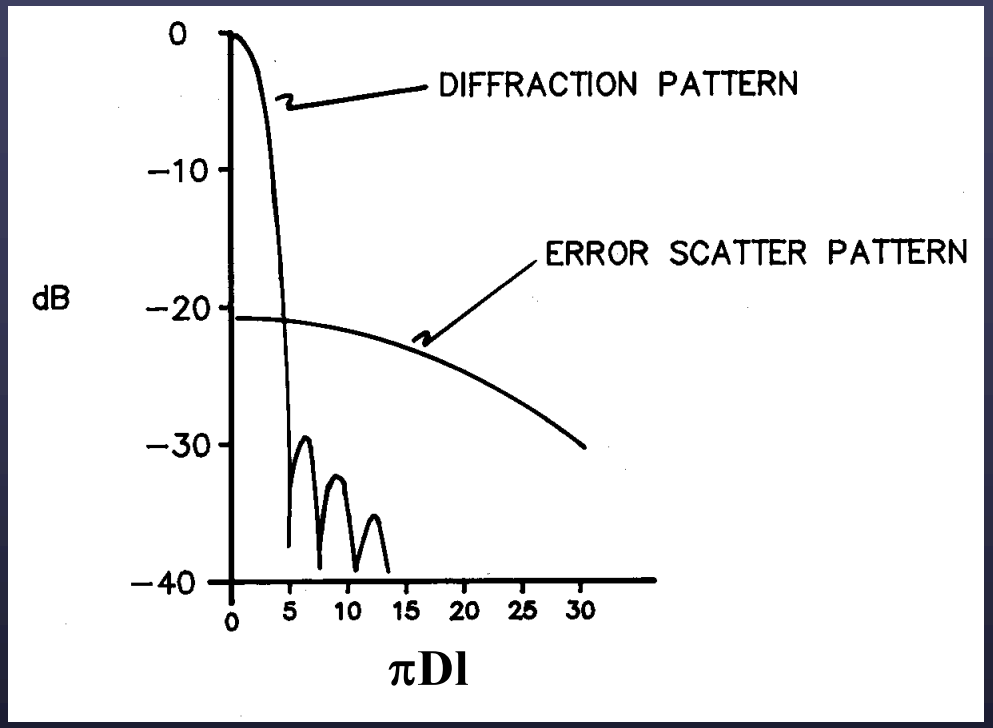
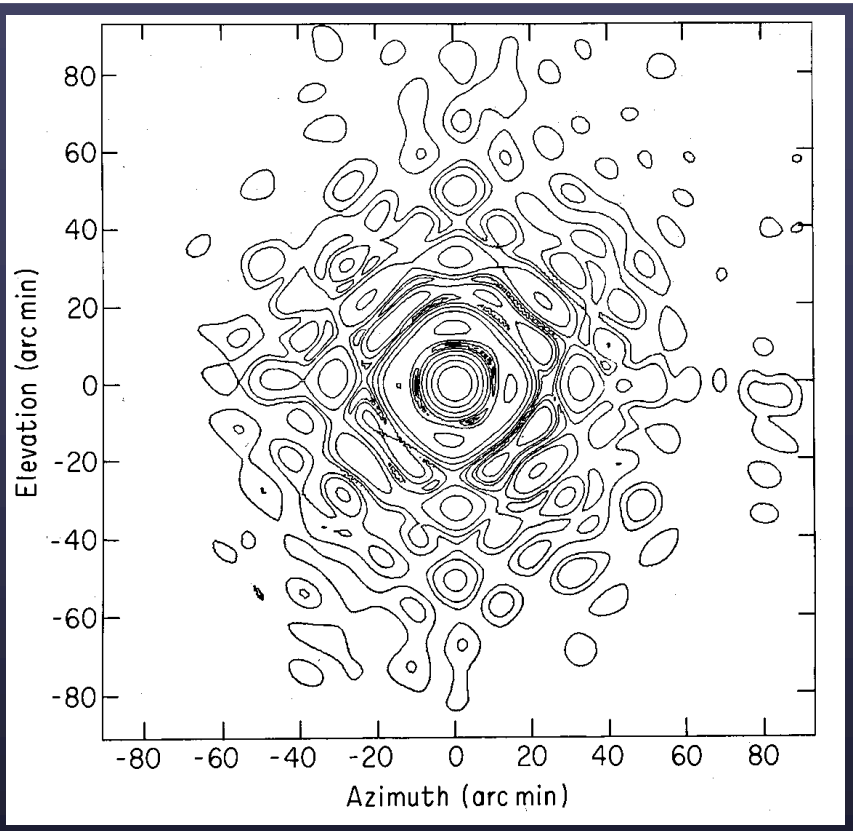
Antenna Performance Parameters

Primary Beam





l=sin(θ), D = antenna diameter in wavelengths

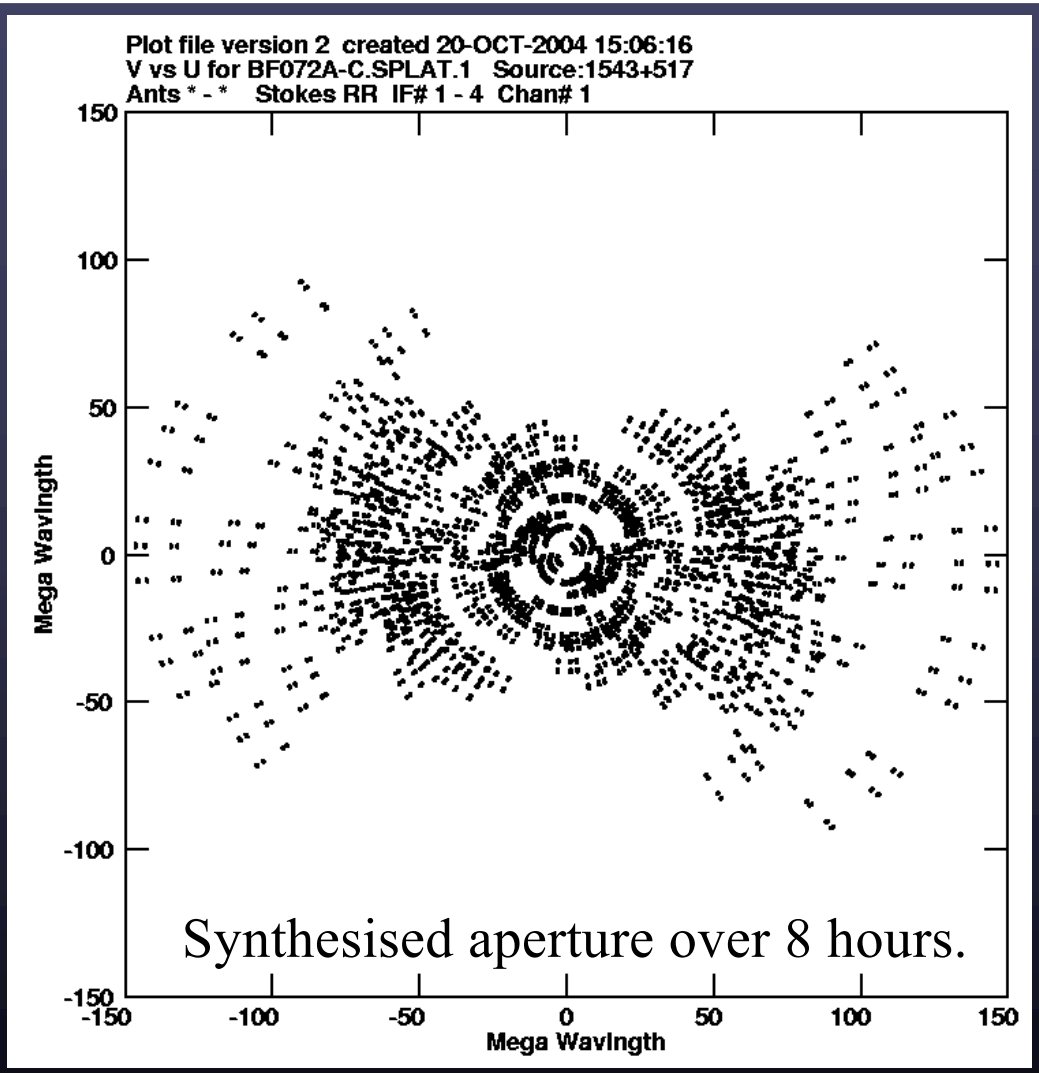
dB = 10log(power ratio)

For VLA: θ_{3dB} = 1.02/D, First null = 1.22/D

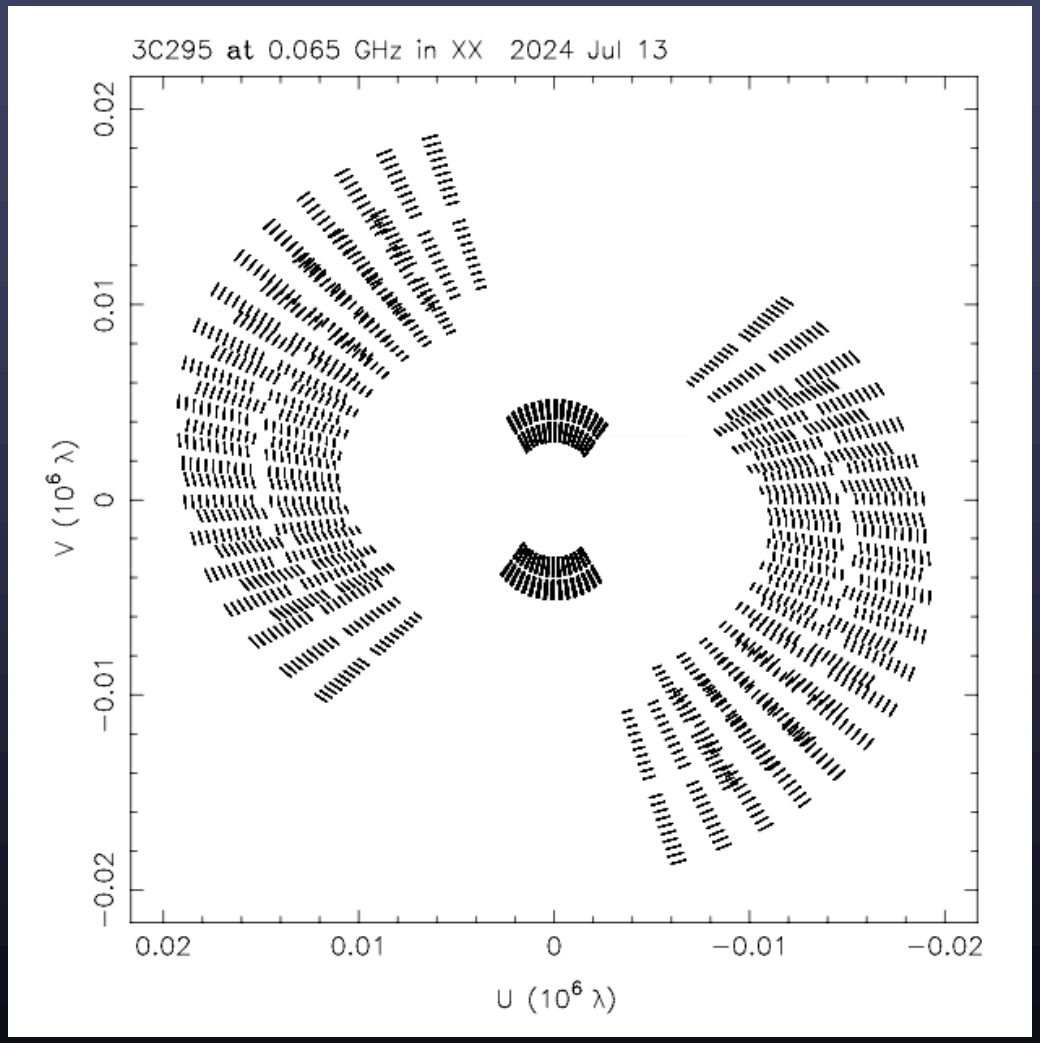
contours: at factors of 3 increments

VLBA Synthesised Aperture

The VLBA
10 antennas each 25 m in diameter



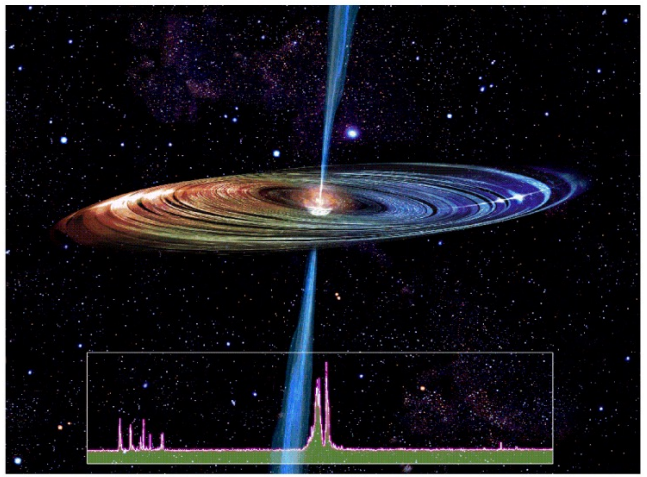
LWA Synthesized Aperture



The LWA Swarm – 3 stations

NGC 4258

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



NGC 4258

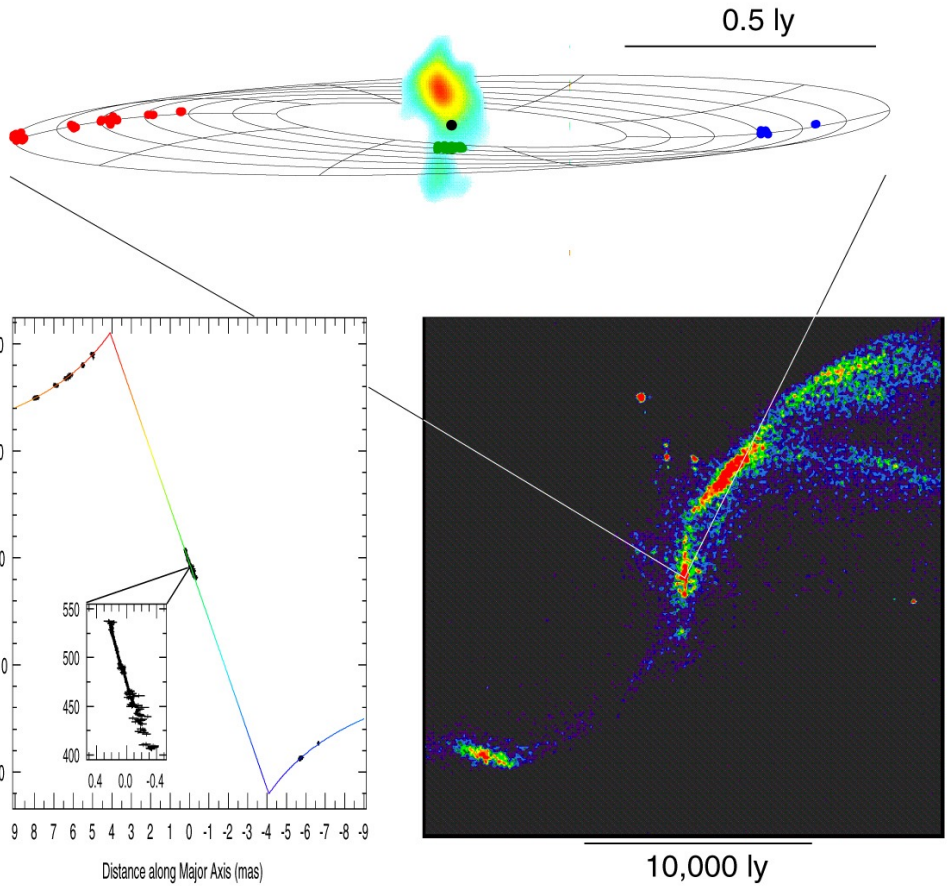


image courtesy Lincoln Greenhill
(see Miyoshi et al 1995
Herrnstein et al 1999)

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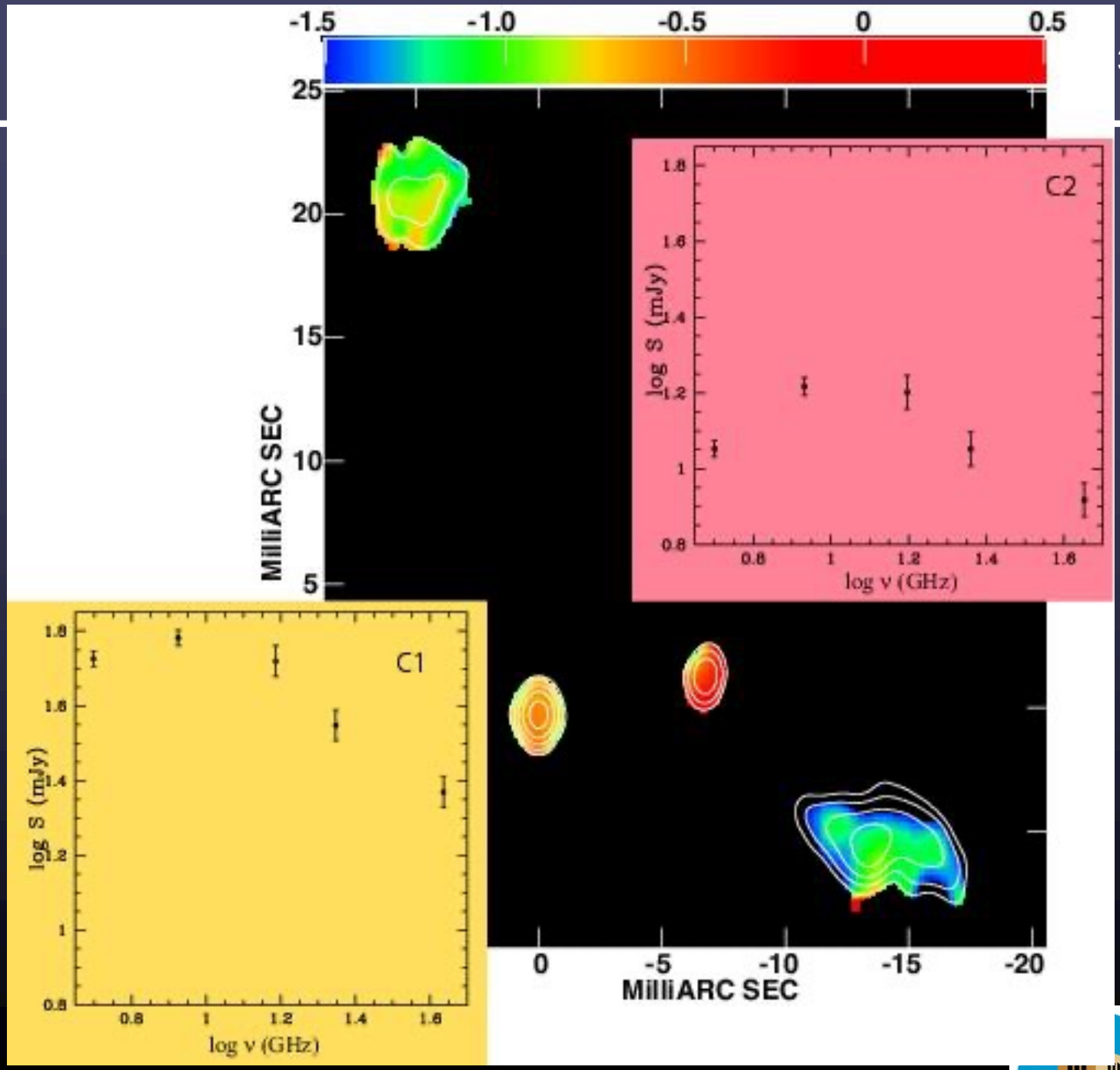
0402+379

Rodriguez et al. 2006



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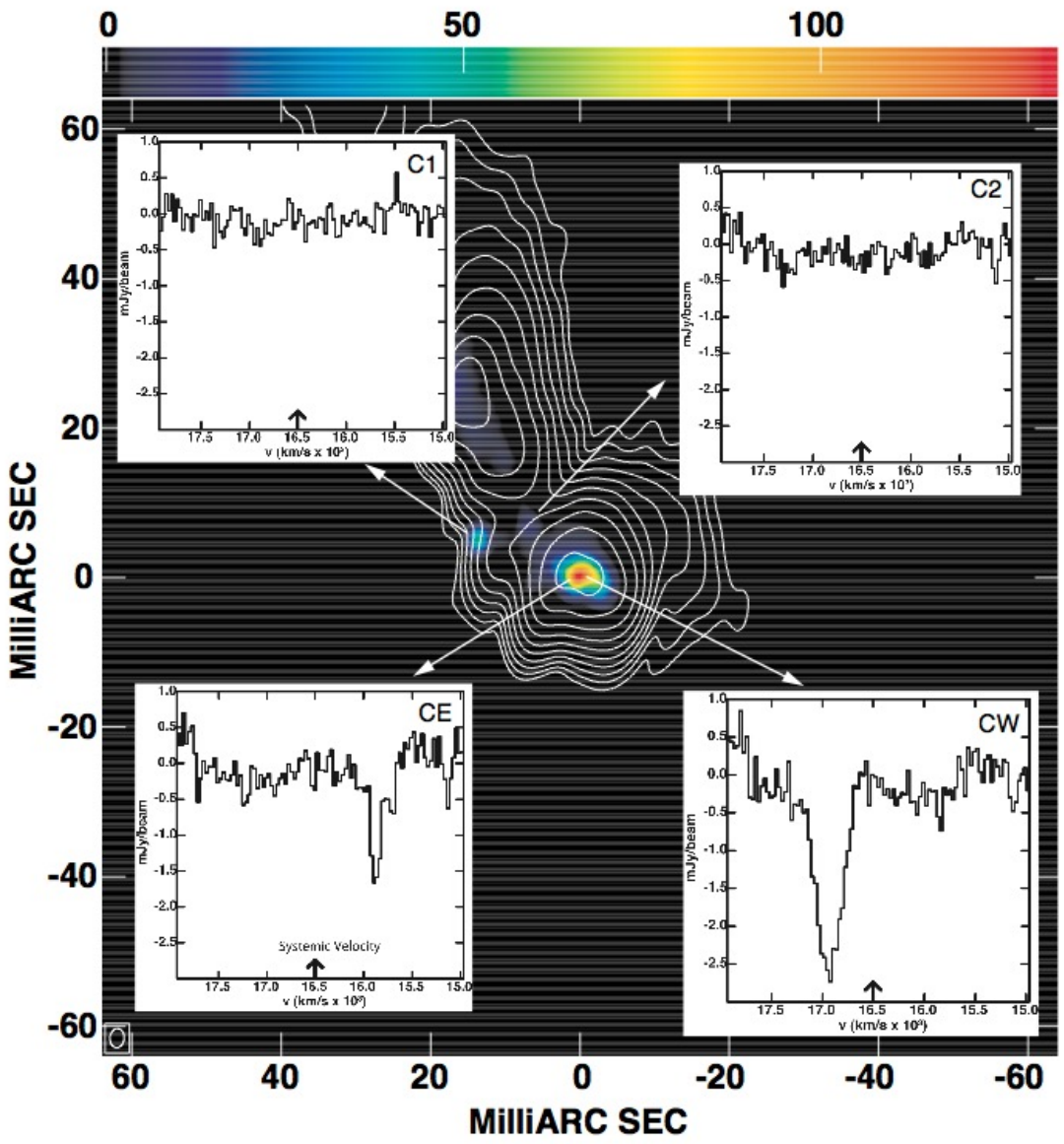
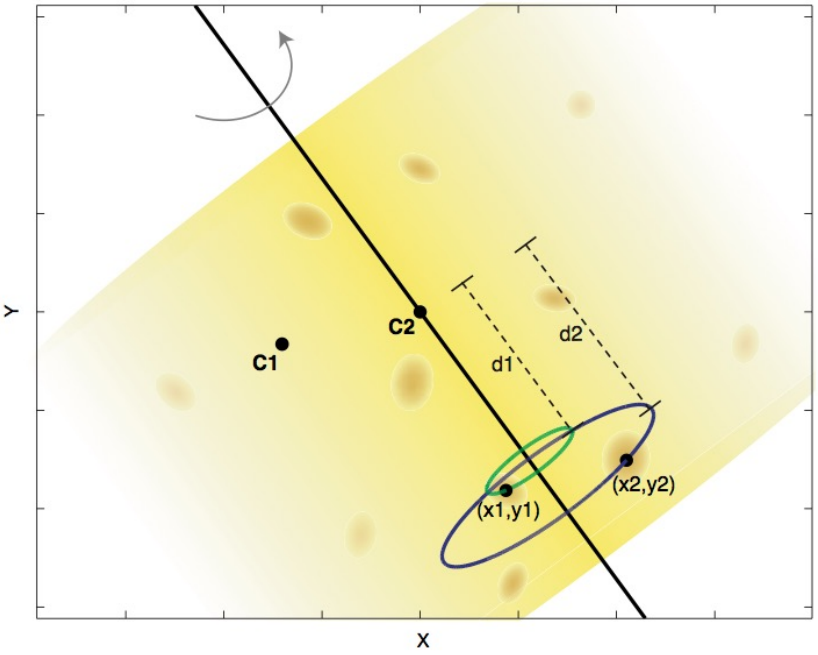




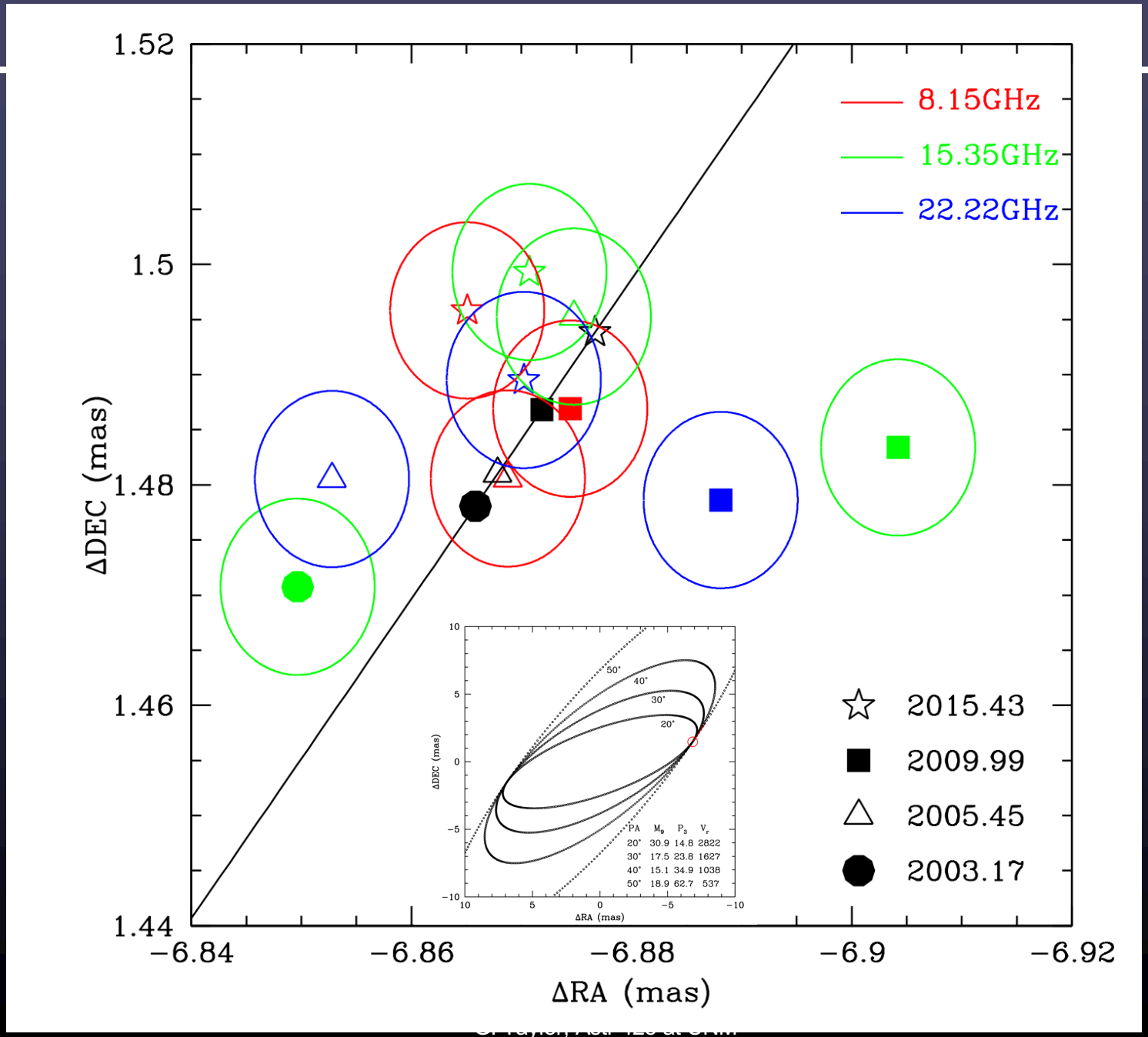
$v \sim 600$ km/s

$r \sim 7$ pc

$M(C2) \sim 7 \times 10^8 M_{sun}$

Rodriguez et al. 2009

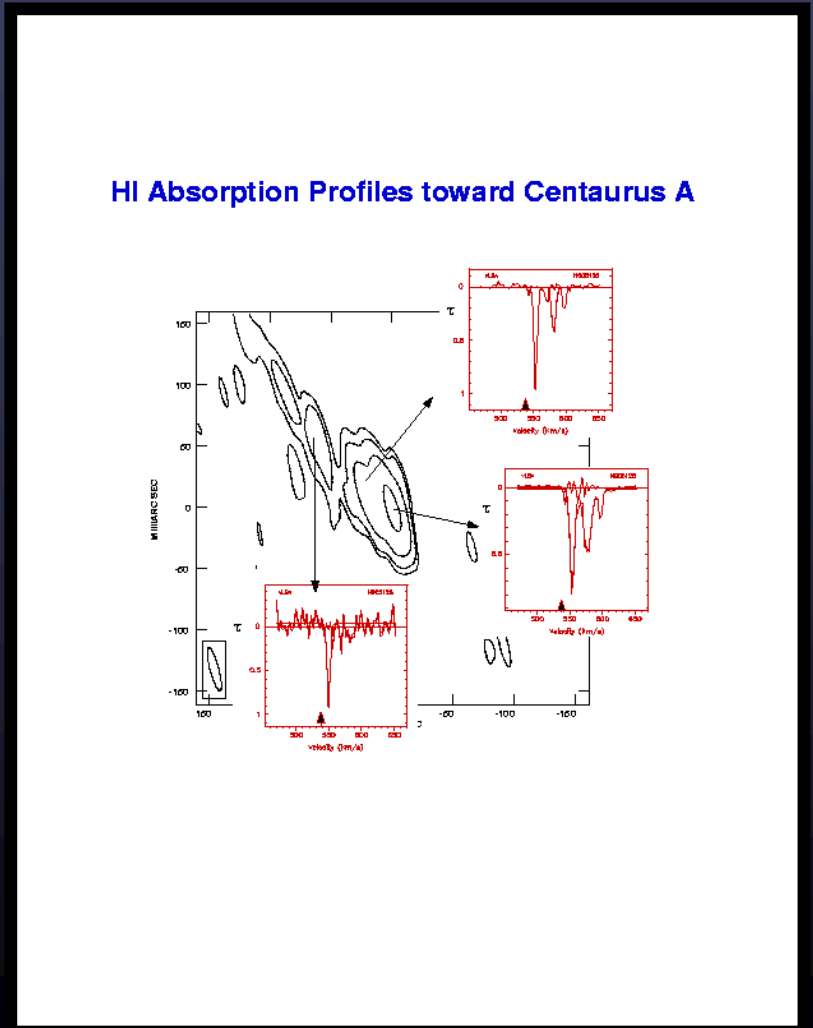
0402+379



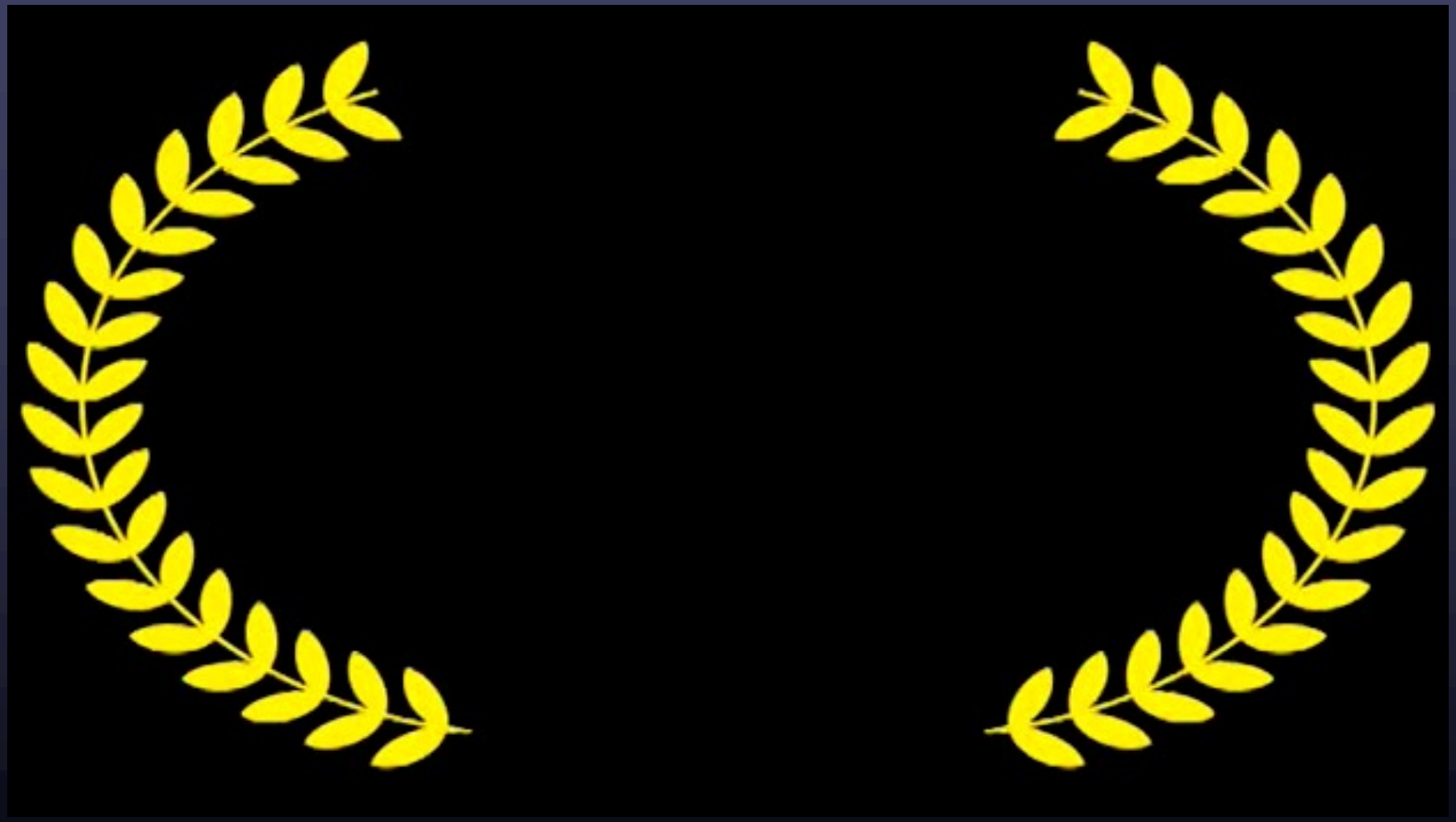
Bansal et al. 2017

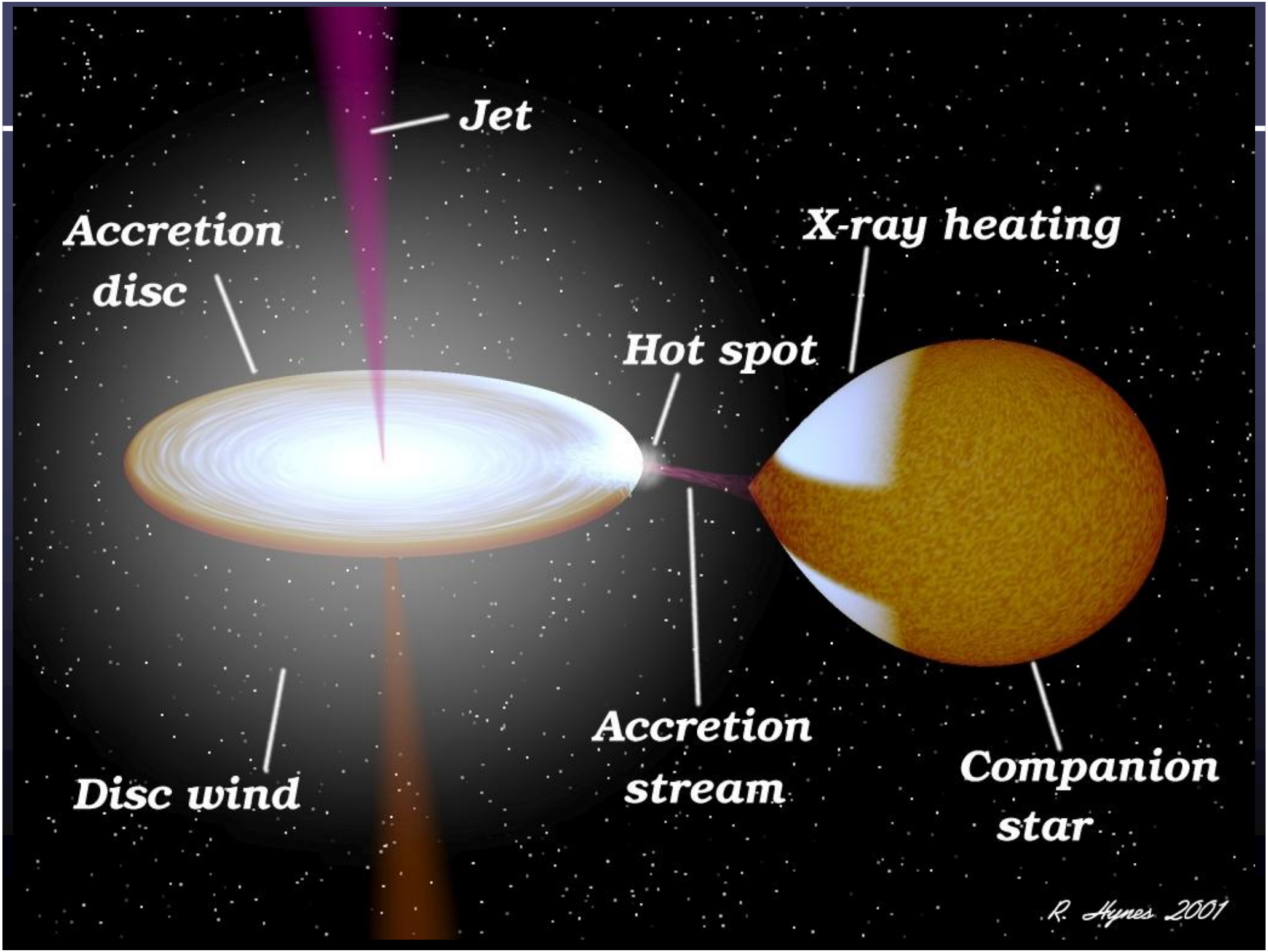
Centaurus A – a peculiar galaxy with extensive radio lobes

Not All Absorption is Associated with the AGN



(Peck 1999)

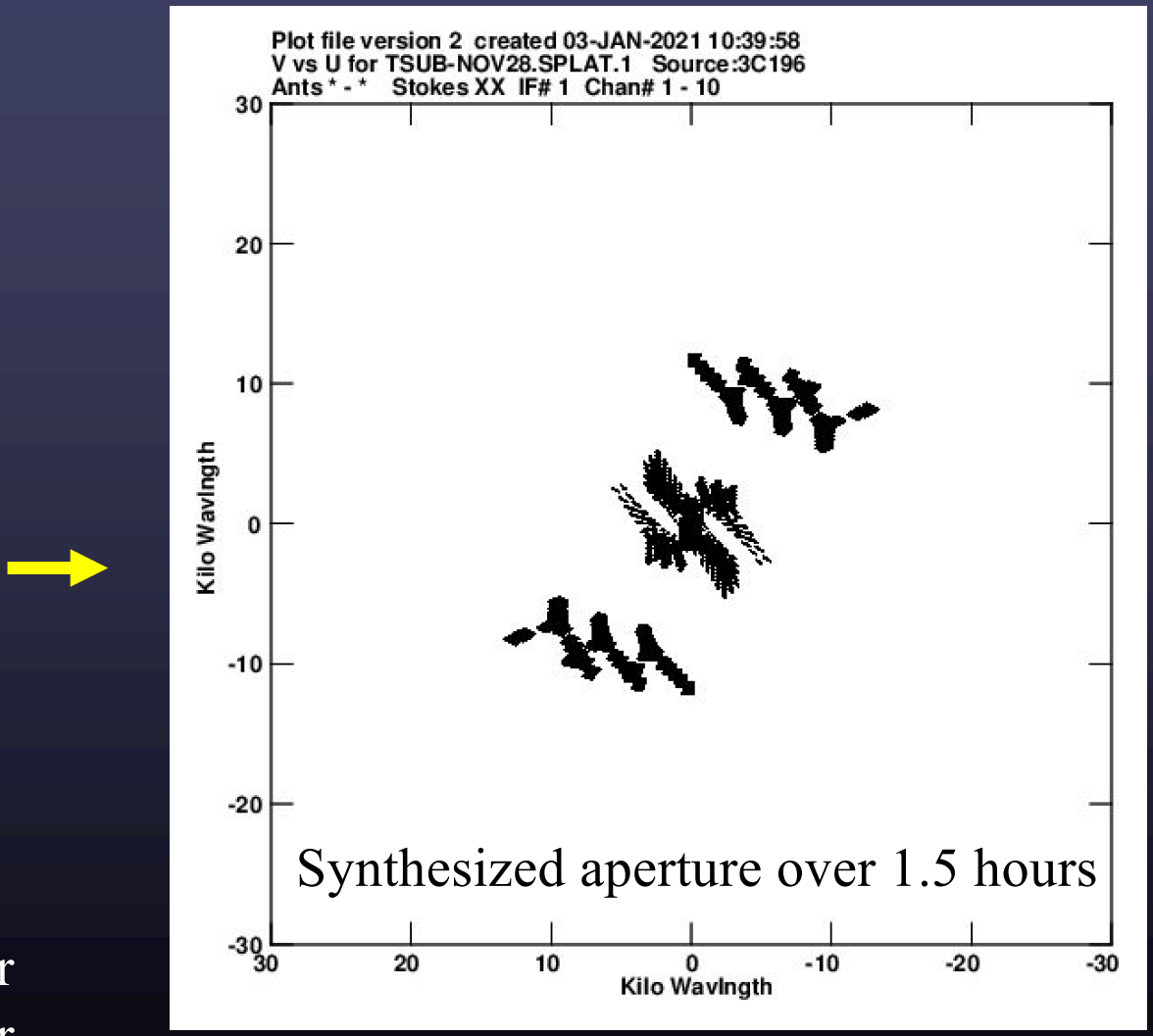



Jet
Accretion disc
X-ray heating
Hot spot
Disc wind
Accretion stream
Companion star
R. Hynes 2001

VLA 50-86 MHz

New 4 band feeds (MJP)
4 meter band: 50-86 MHz
All 28 installed

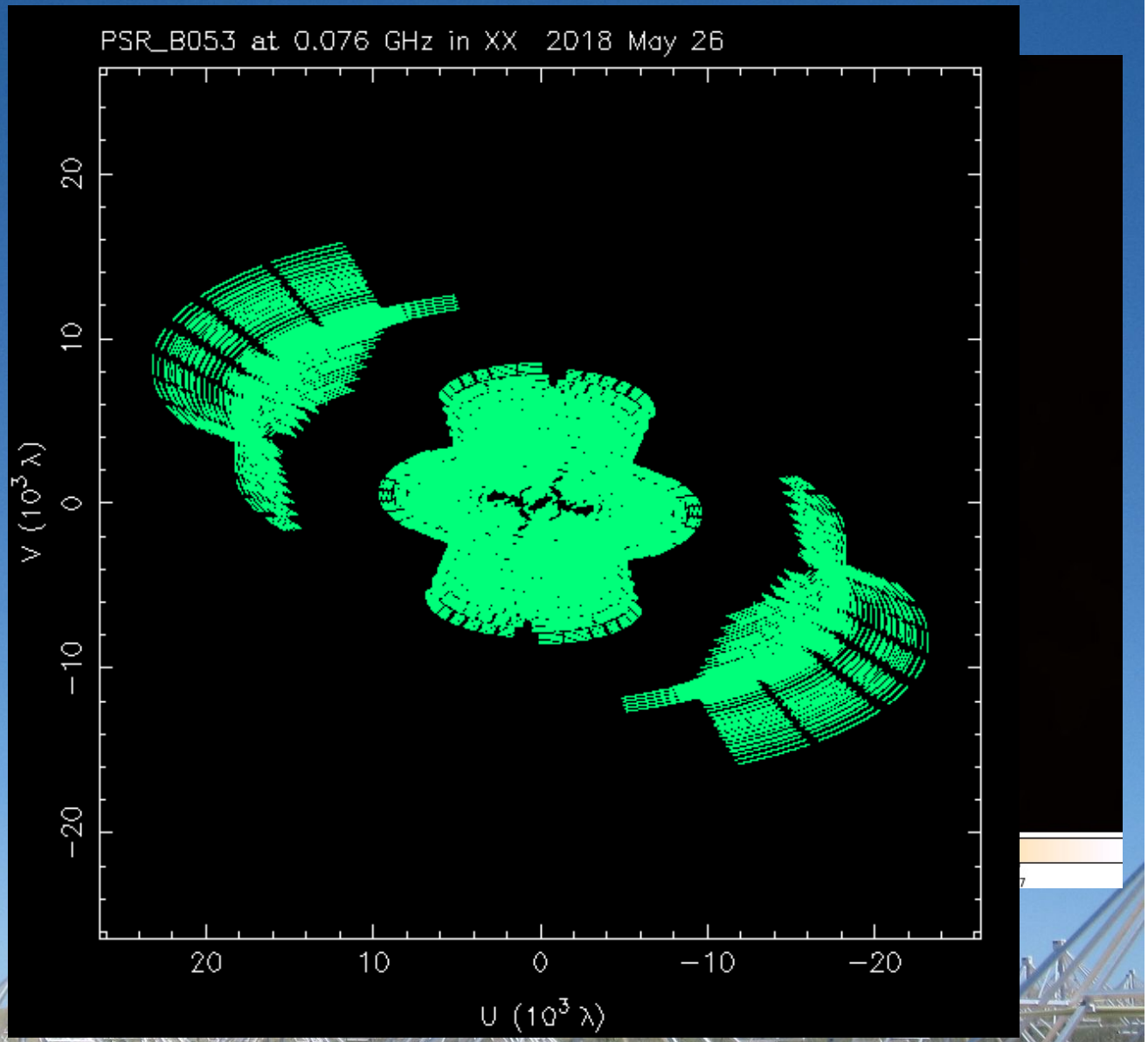
ELWA Synthesized Aperture



The ELWA
3 antennas each 100 m in diameter
27 antennas each 25 m in diameter

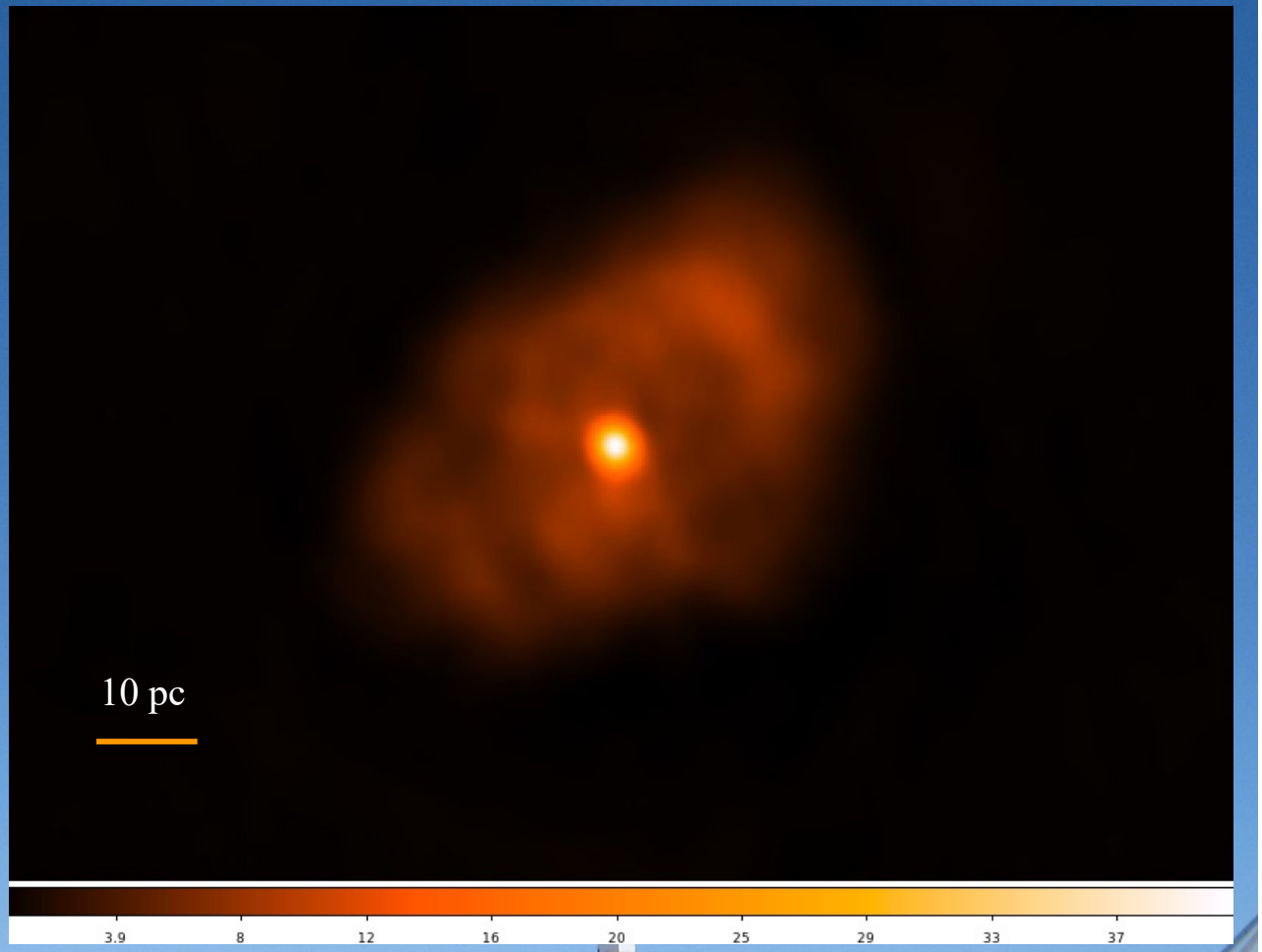
ELWA - Demonstration

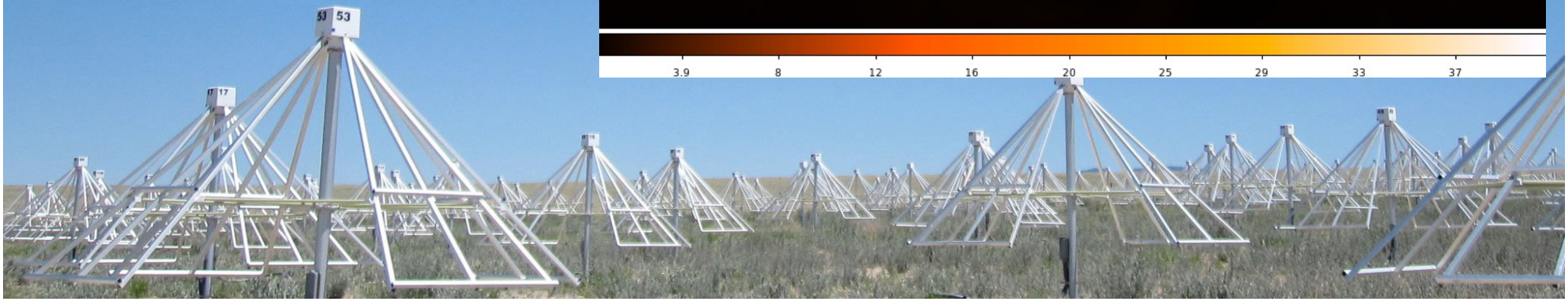
TauA (crab) at 72 MHz
May 26, 2018
2 LWA + 23 VLA
4 hours on source
38 Jy peak
RMS ~ 40 mJy/beam
Resolution ~ 15”



ELWA - Demonstration

TauA (crab) at 72 MHz
May 26, 2018
2 LWA + 23 VLA
4 hours on source
38 Jy peak
RMS ~ 40 mJy/beam
Resolution ~ 15”





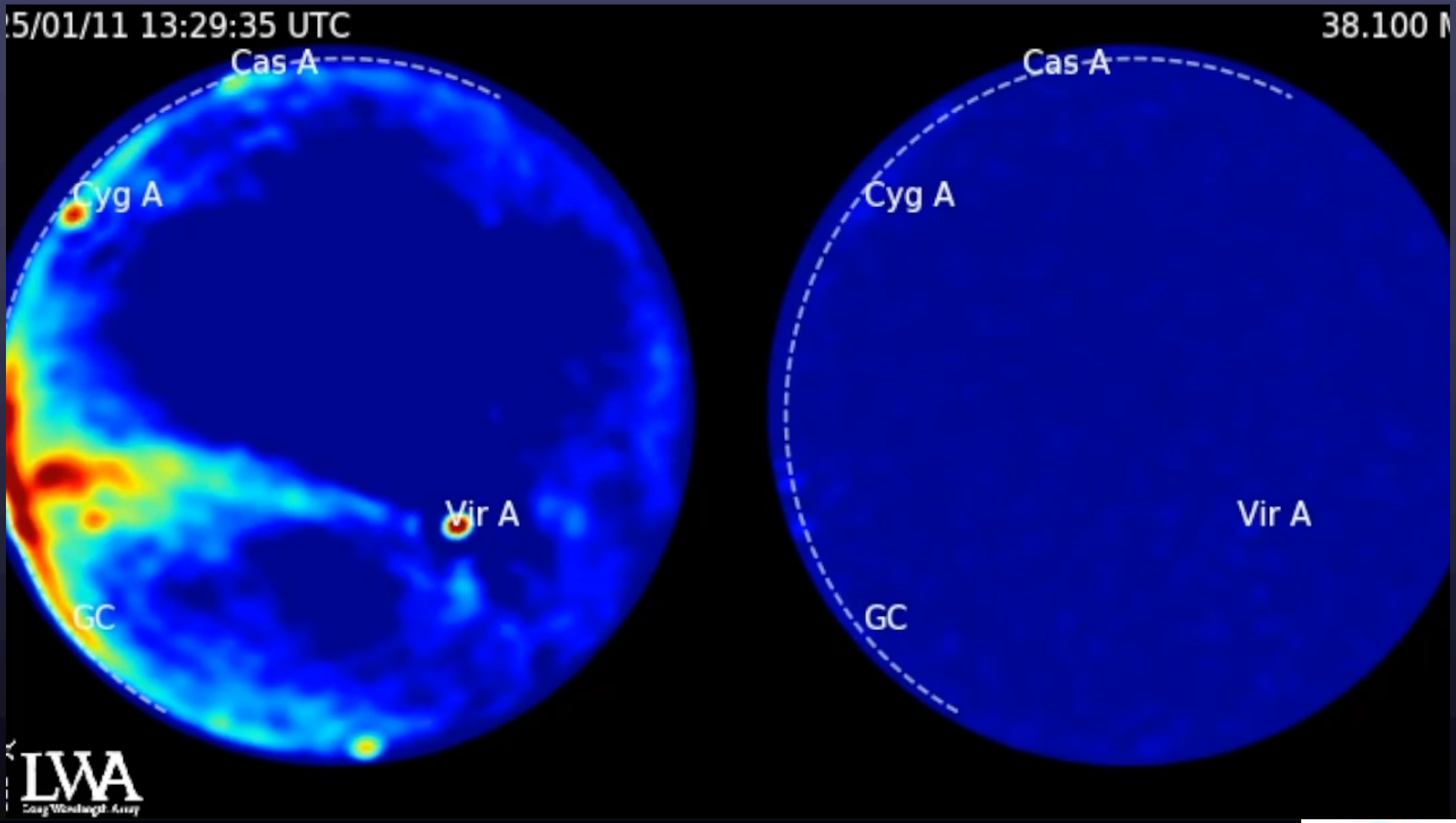
Possible LWA project #4

- Observe Crab Giant Pulses with LWA
  - Measure scattering time-scale
  - Compare with observations in the literature

Possible LWA project #5

- Look at a bright slow pulsar
  - Measure low frequency spectra of bright pulsars
  - Look at individual pulses and their variations in flux
  - Look for spectral turnovers
  - Look for scintillation

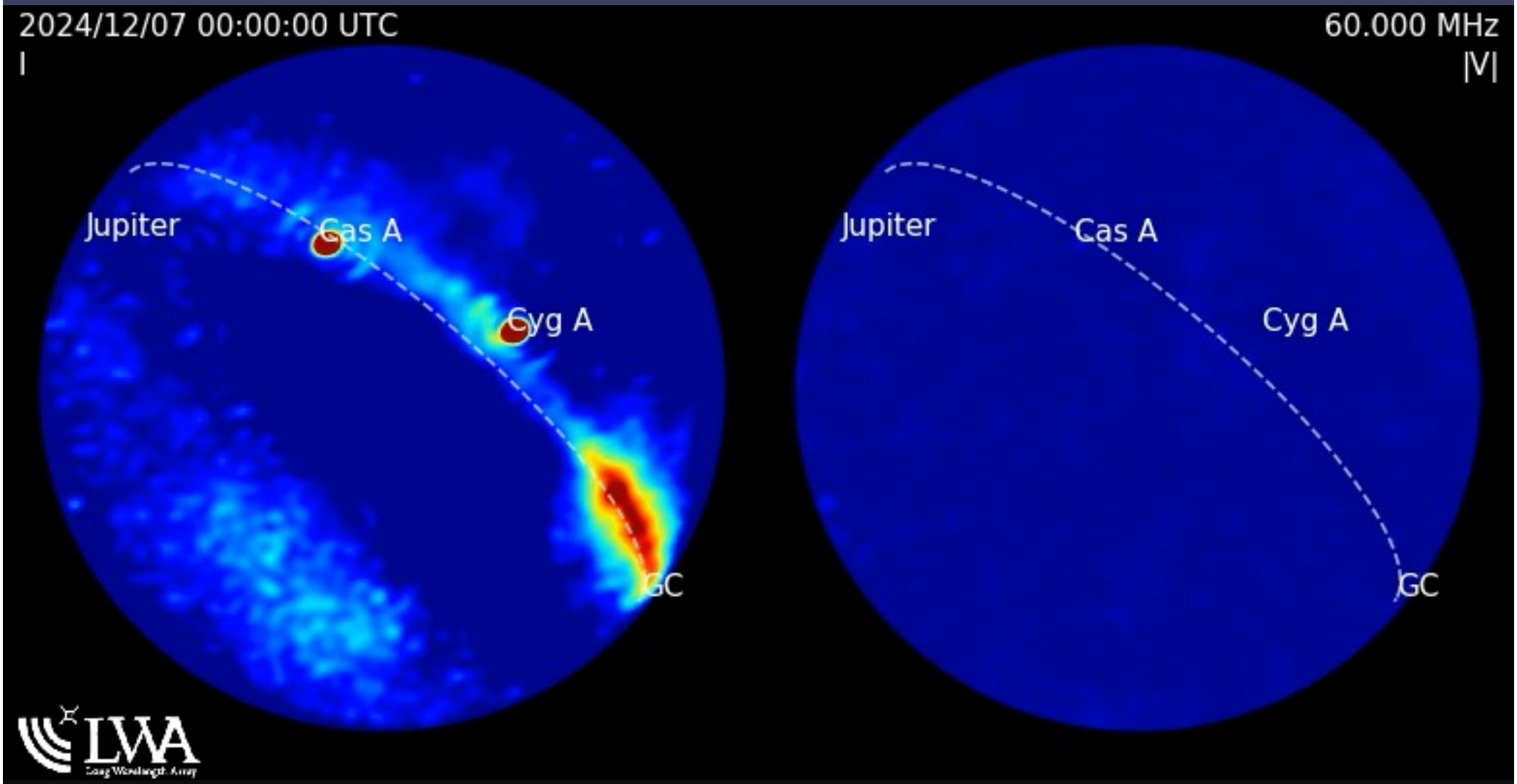
Example of Scintillation and Solar Variability



Possible LWA project #6

- Look at a bright AGN with the LWA Swarm
  - Measure low frequency spectra of bright AGN
  - Look for spectral turnovers
  - Look for scintillation

Starlink Satellites



Possible LWA project #7

- Measure Unintended emission from Satellites at 60 MHz
  - Estimate number of emitters
  - Extrapolate to the future

Further Reading

http://www.vla.nrao.edu/astro/

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