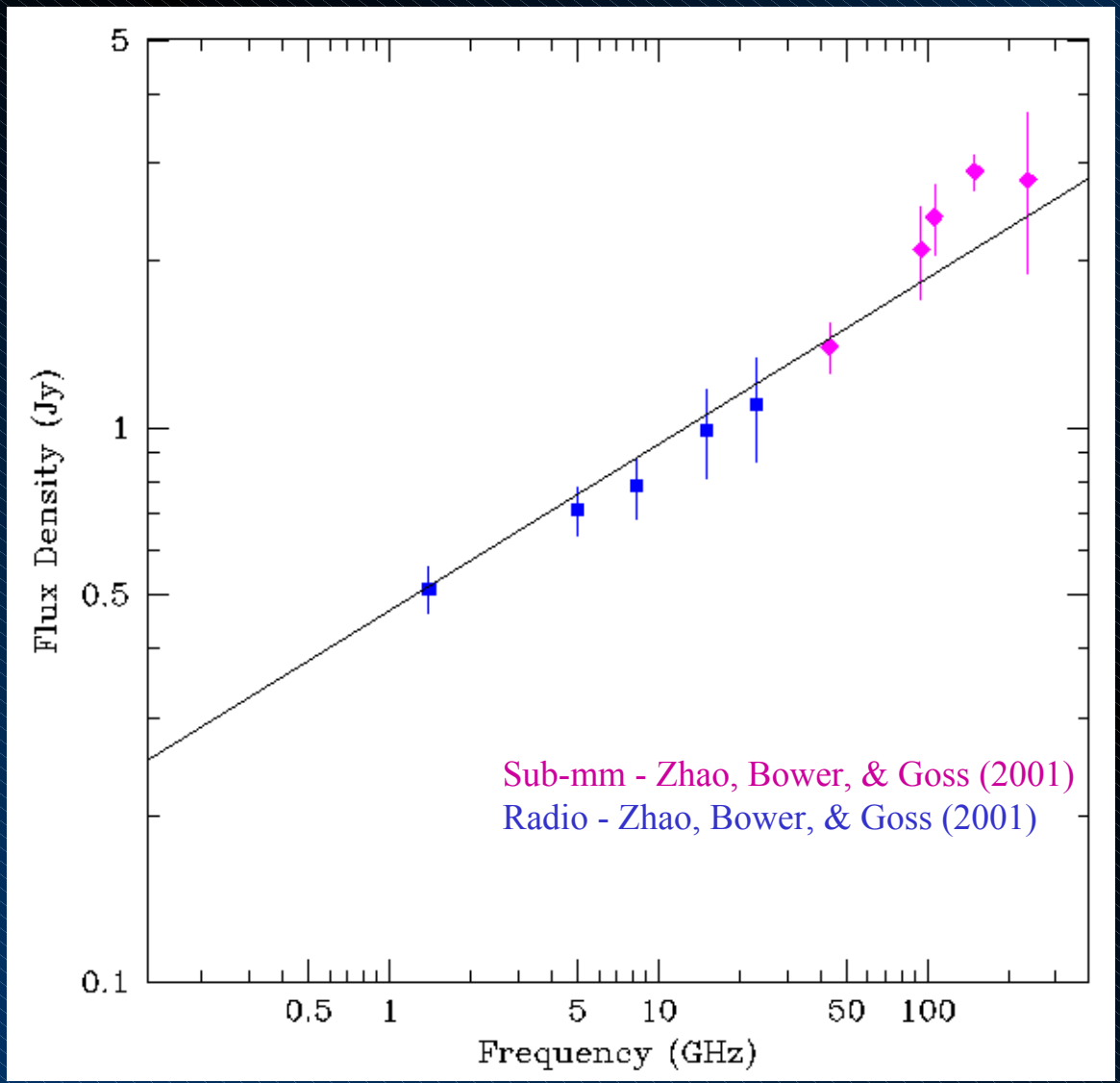
The Galactic Center at Low Radio Frequencies

Namir Kassim (NRL)
Crystal Brogan (IfA)

J. Lazio (NRL), Ted LaRosa (Kennesaw State), M. Nord (NRL/UNM), W. M. Goss (NRAO), S. Shore (U. Pisa), N. Duric (UNM), & K. Anantharamaiah (RRI)

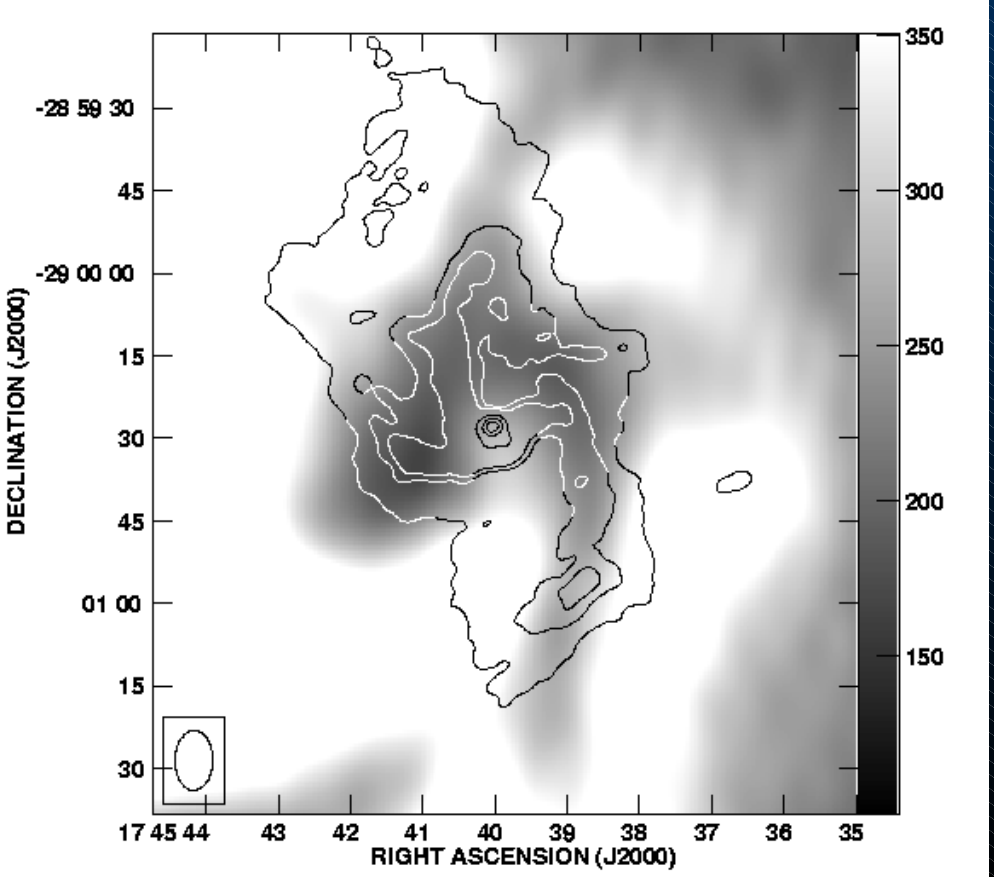
30th Anniversary of the Discovery of SgrA* March 26, 2004

The Radio/Sub-mm Spectrum of Sgr A*

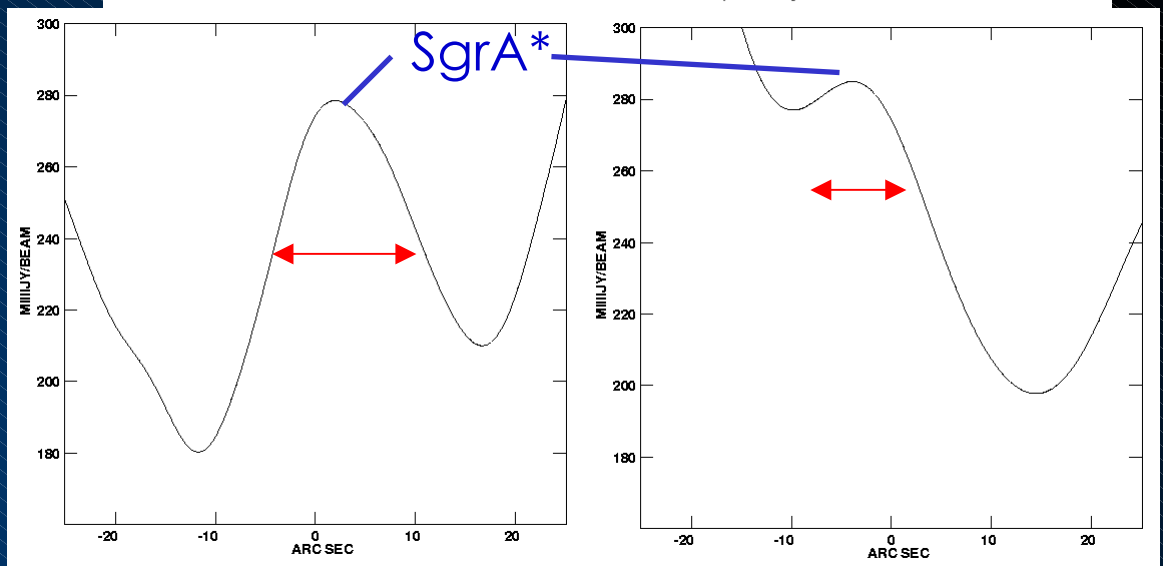


- Until recently, Sagittarius A* was undetected below 1.4 GHz.

- The source was thought to be undetectable due to foreground thermal (free-free) absorption.

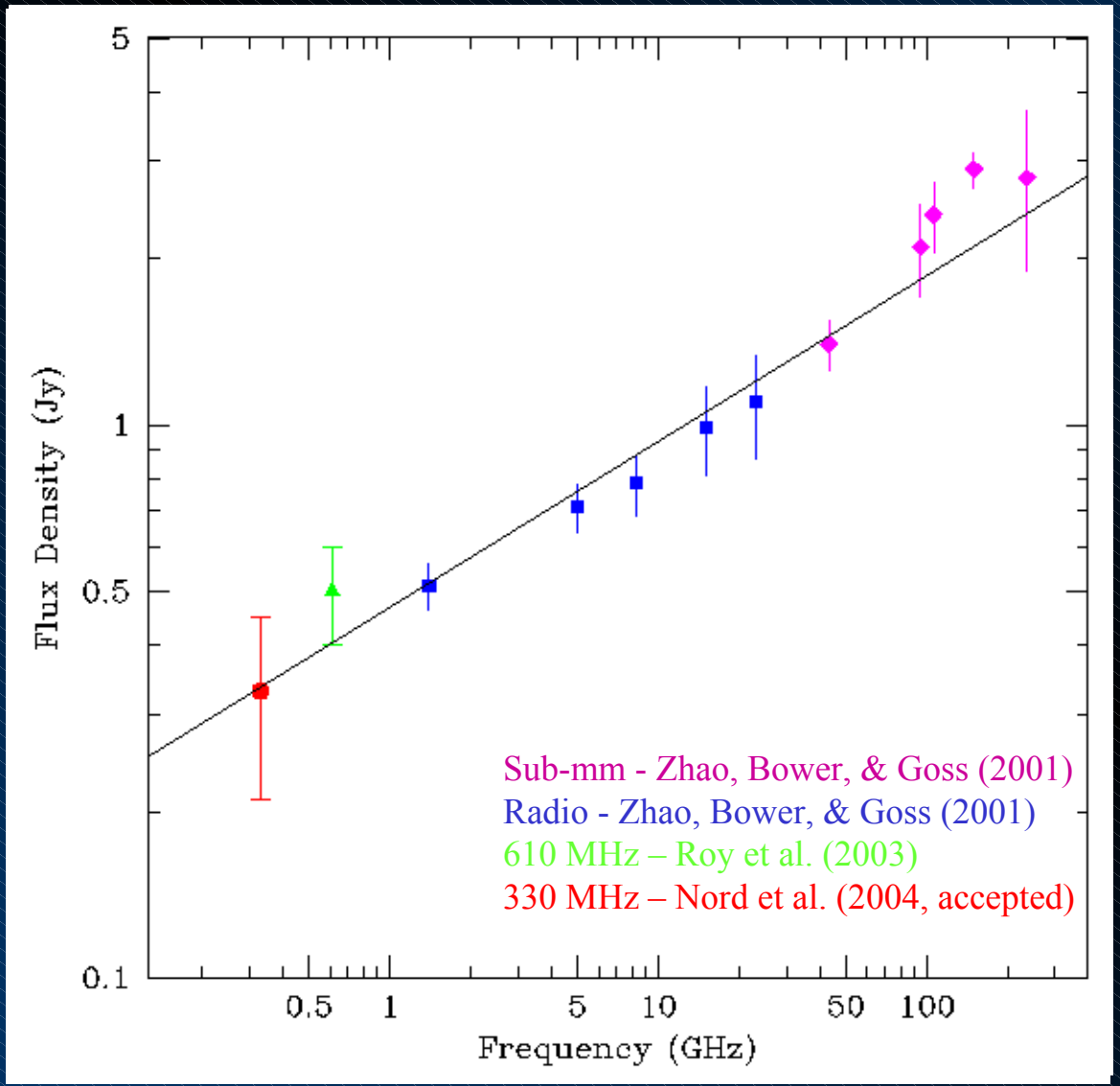


- Grey scale 330 MHz (non-thermal)
- Contours 5 GHz (thermal ionized gas)



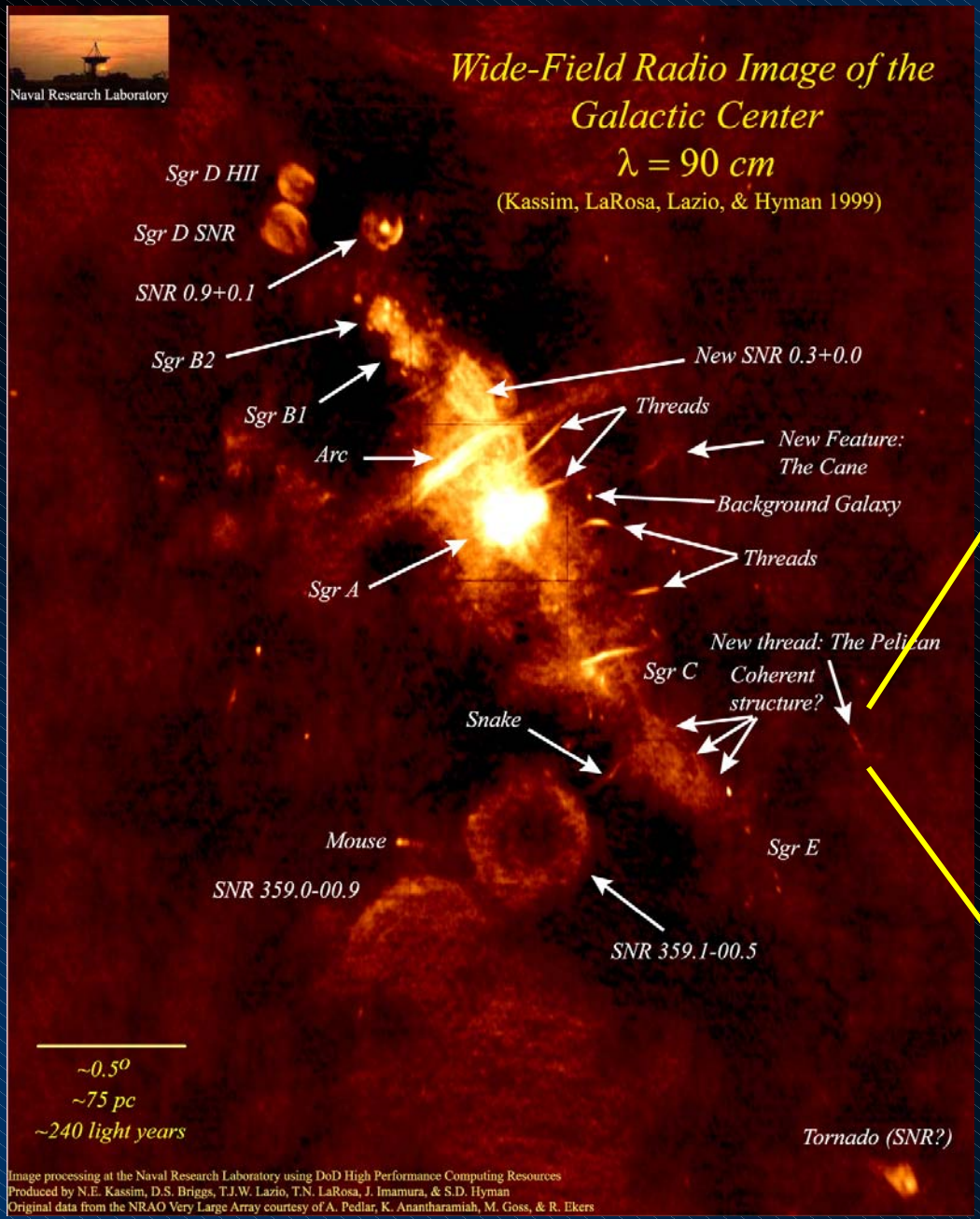
Slices through position of SgrA* at 330 MHz

The New Radio/Sub-mm Spectrum of Sgr A*

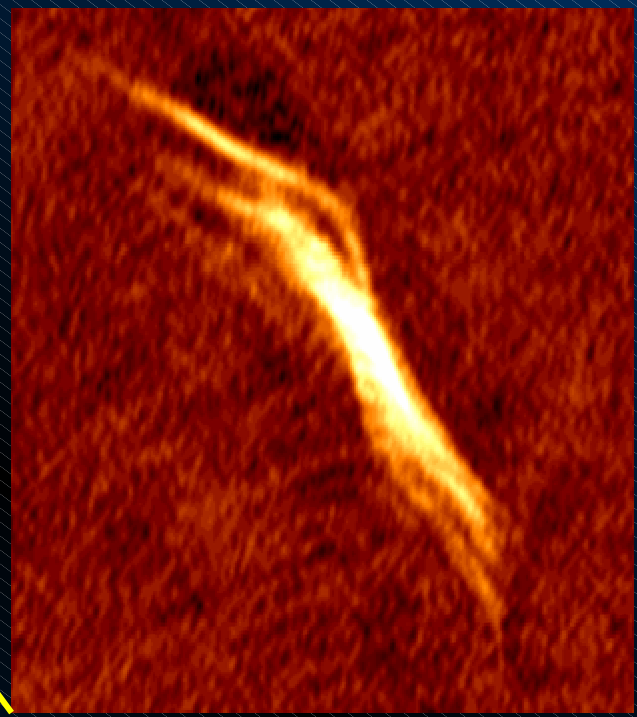


- We have detected SgrA* at the lowest frequency.
- The line of sight (free-free) optical depth to Sgr* is most likely low ($\tau_{330\ \mathrm{MHz}}<0.4$).
- Local clearing of the ambient gas, or clumpiness in the ionized ISM?
- Implications for emission mechanisms still being explored.

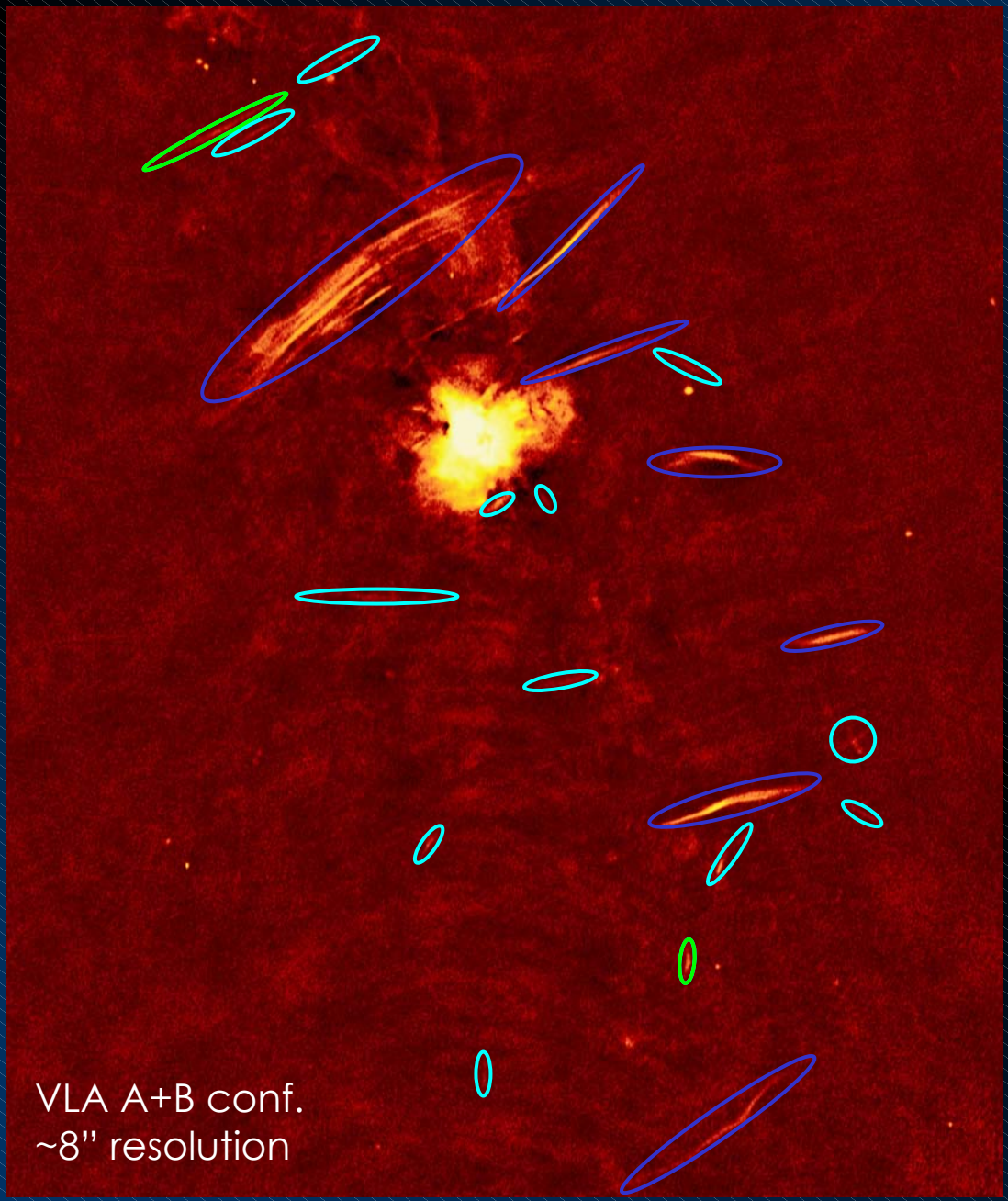
330 MHz Galactic Center



New GC non-thermal filament:
"The Pelican"



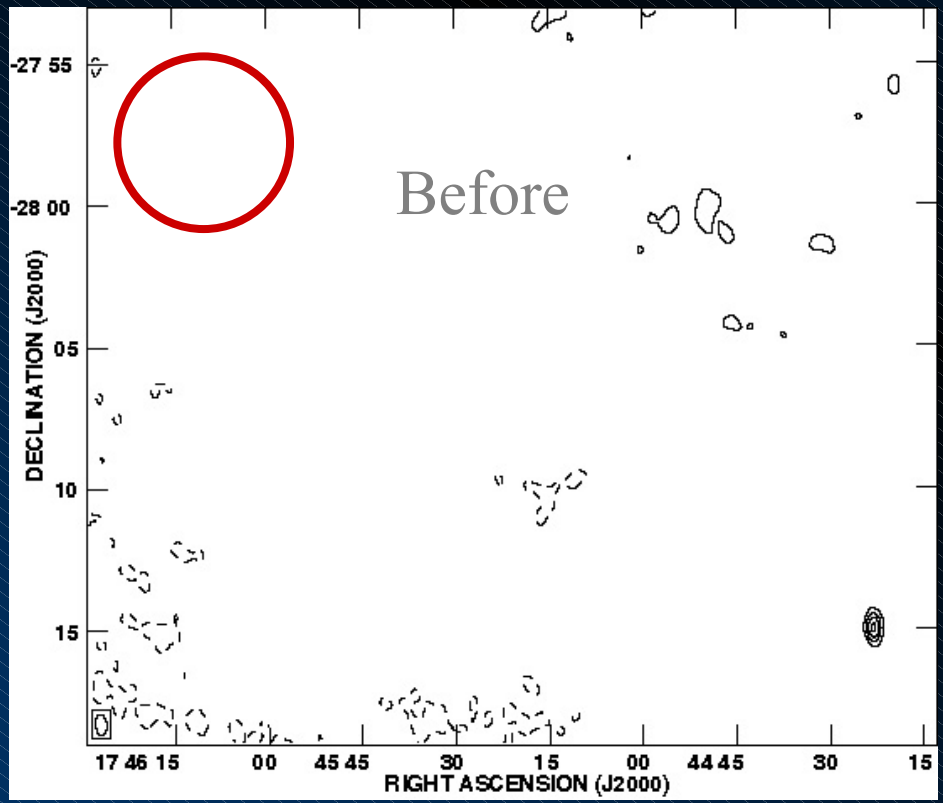
(Lang, Anantharamaiah, et al. 1999)

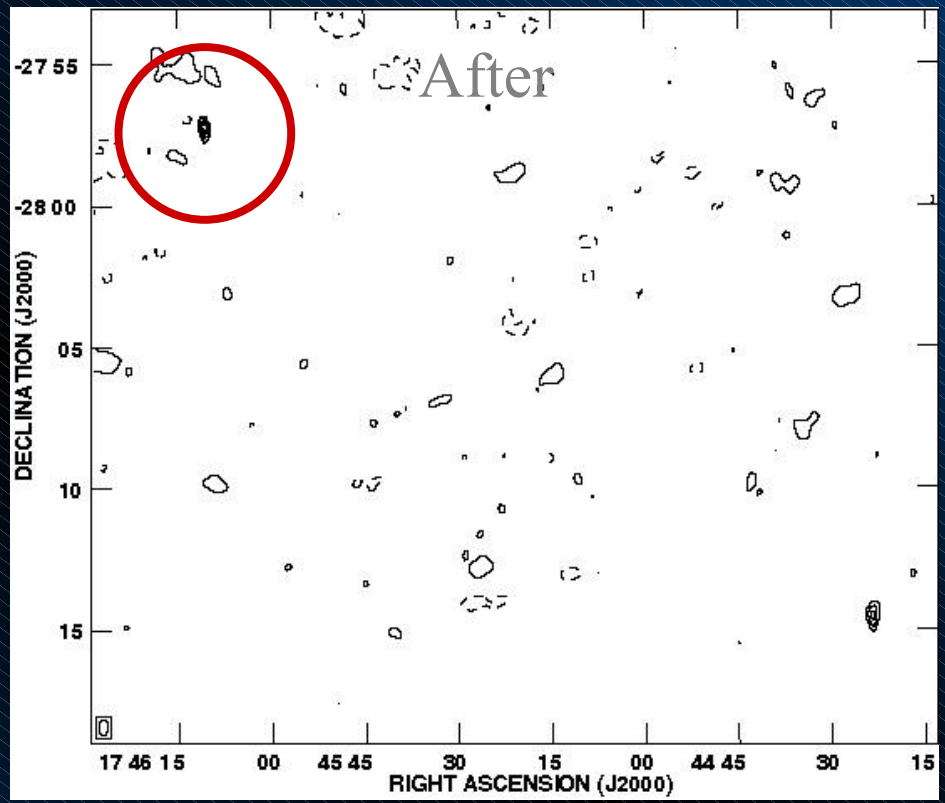


- Galactic Center: Many new NTFs
  - Orientation of newly discovered NTF's suggests a magnetic field structure more complicated than a simple dipole
  - Detecting only the peak of the NTF luminosity function?
  - A significant increase in sensitivity might detect hundreds of NTFs.

Galactic Center Transients

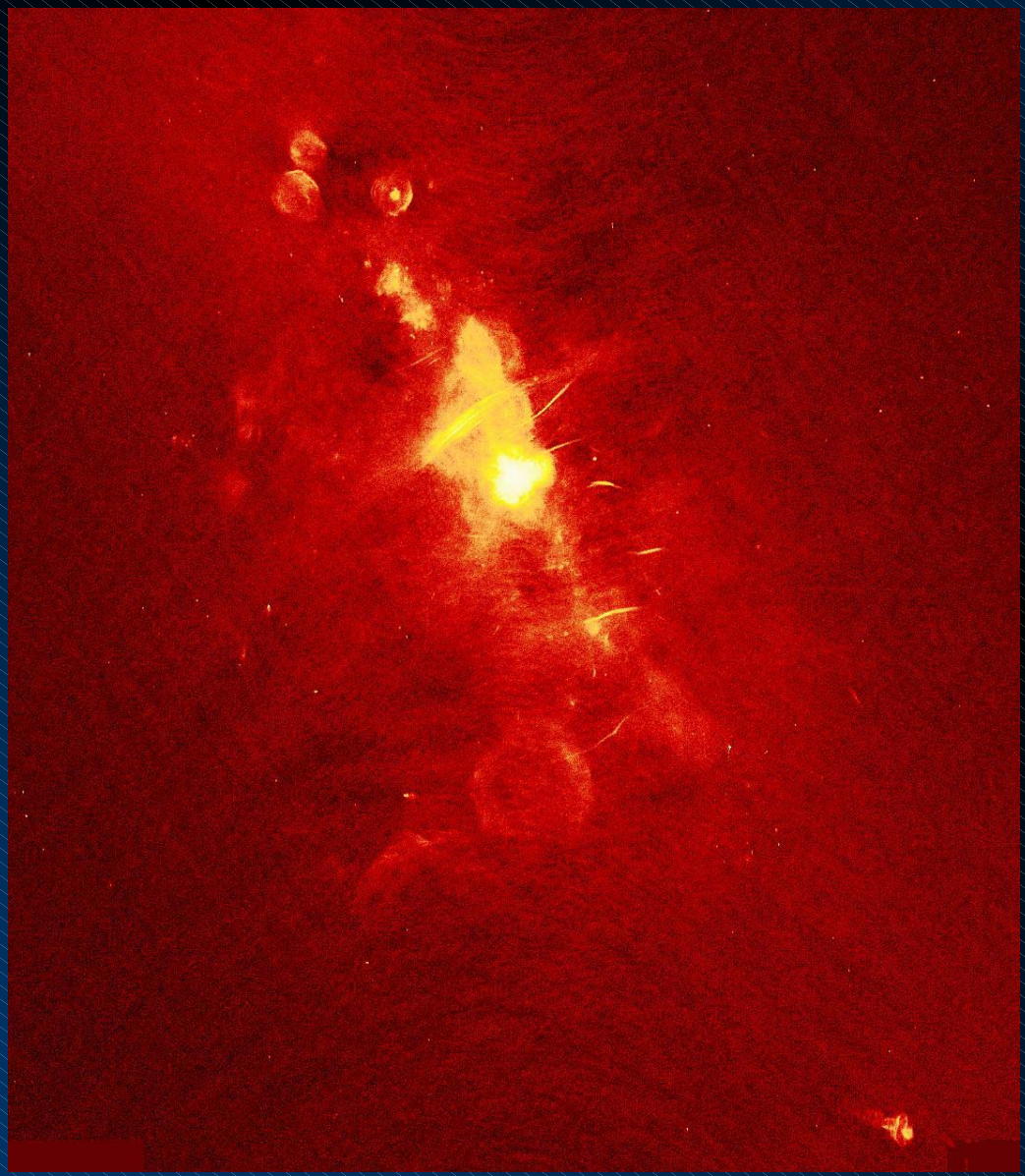
ν = 330 MHz





Hyman, Lazio, Nord, & Kassim 2002

Coming soon – new ABCD+GBT image

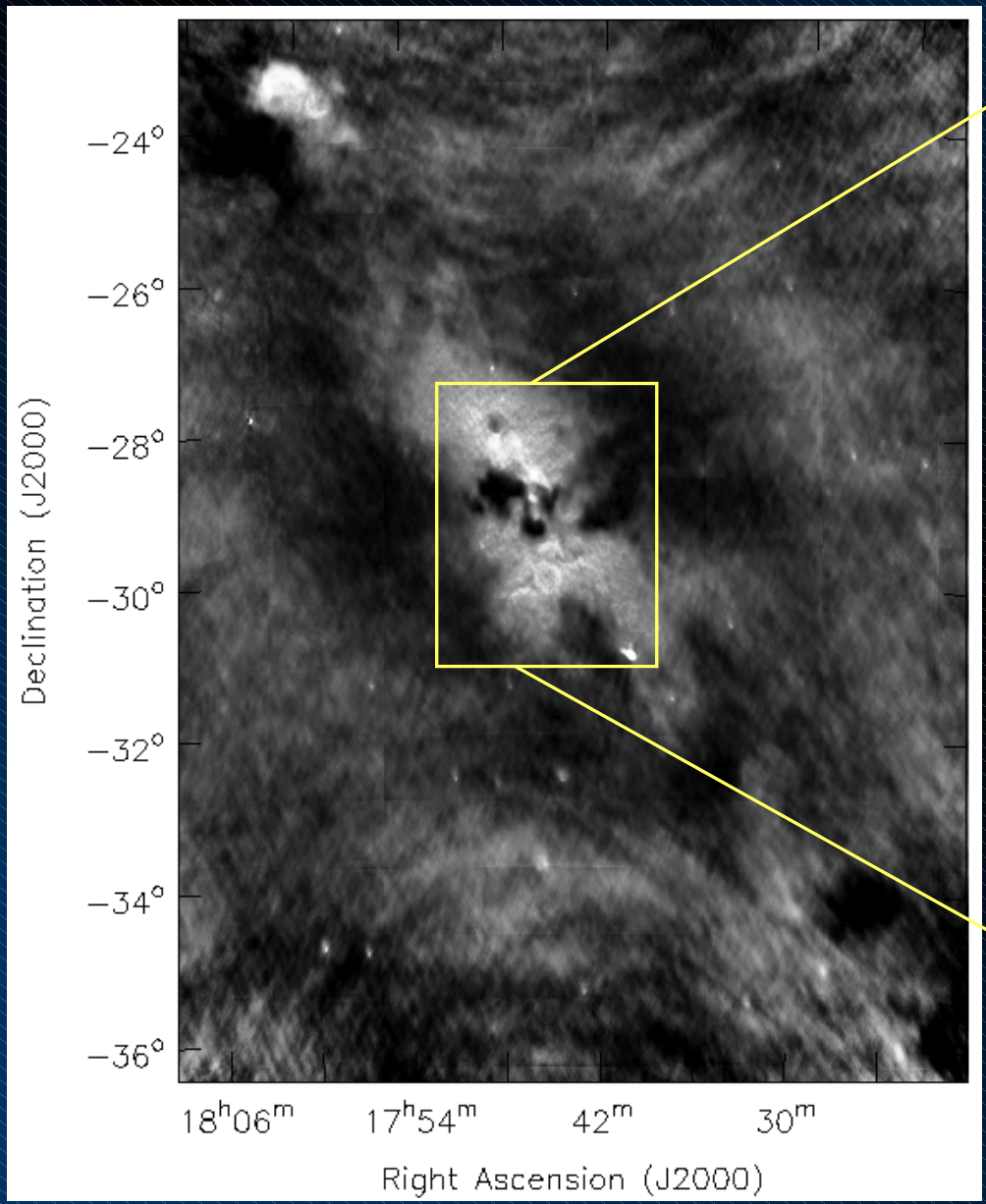


rms ~ 1 mJy (vs. 5)

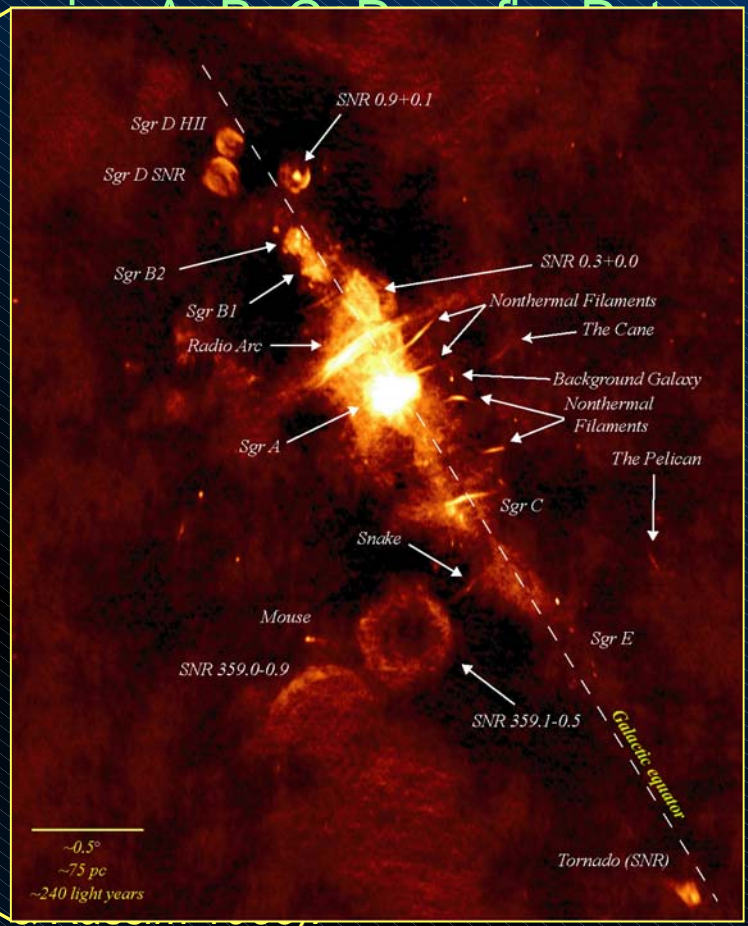
θ ~ 6” (vs. 45”)

Created using “Feathering” technique developed by Bill Cotton

VLA 74 MHz (4 m) Image

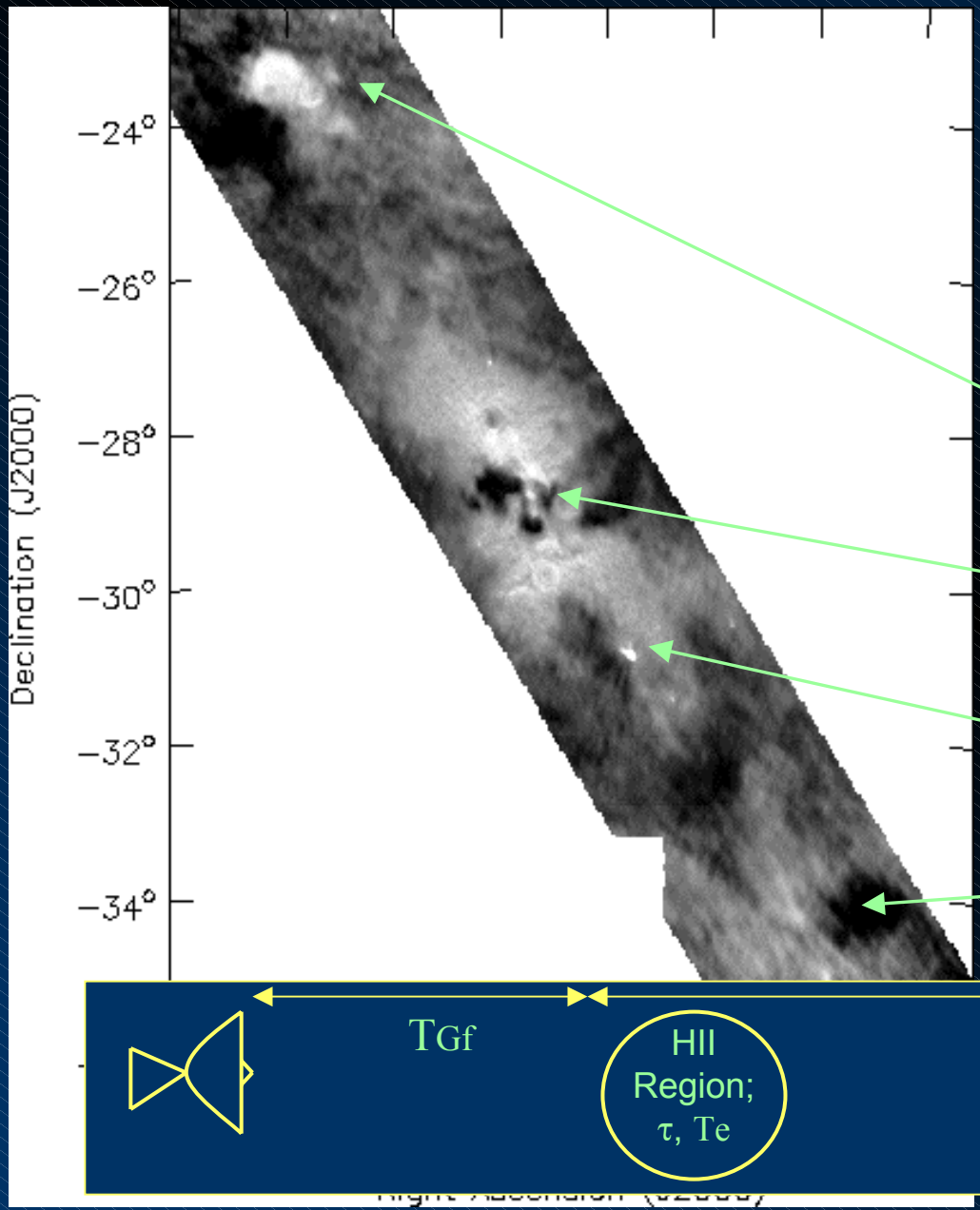


VLA 4m resolution 2.1’ x 1.2’



- resolutions > 7’
- ~40x less sensitivity

Comparison of GC 4 m and 6 cm Images



VLA 4m resolution 2.1' x 1.2'
A+B+C+D config. data

Parkes 6 cm resolution 4':
Haynes et al. 1978, AuJPS, 45, 1

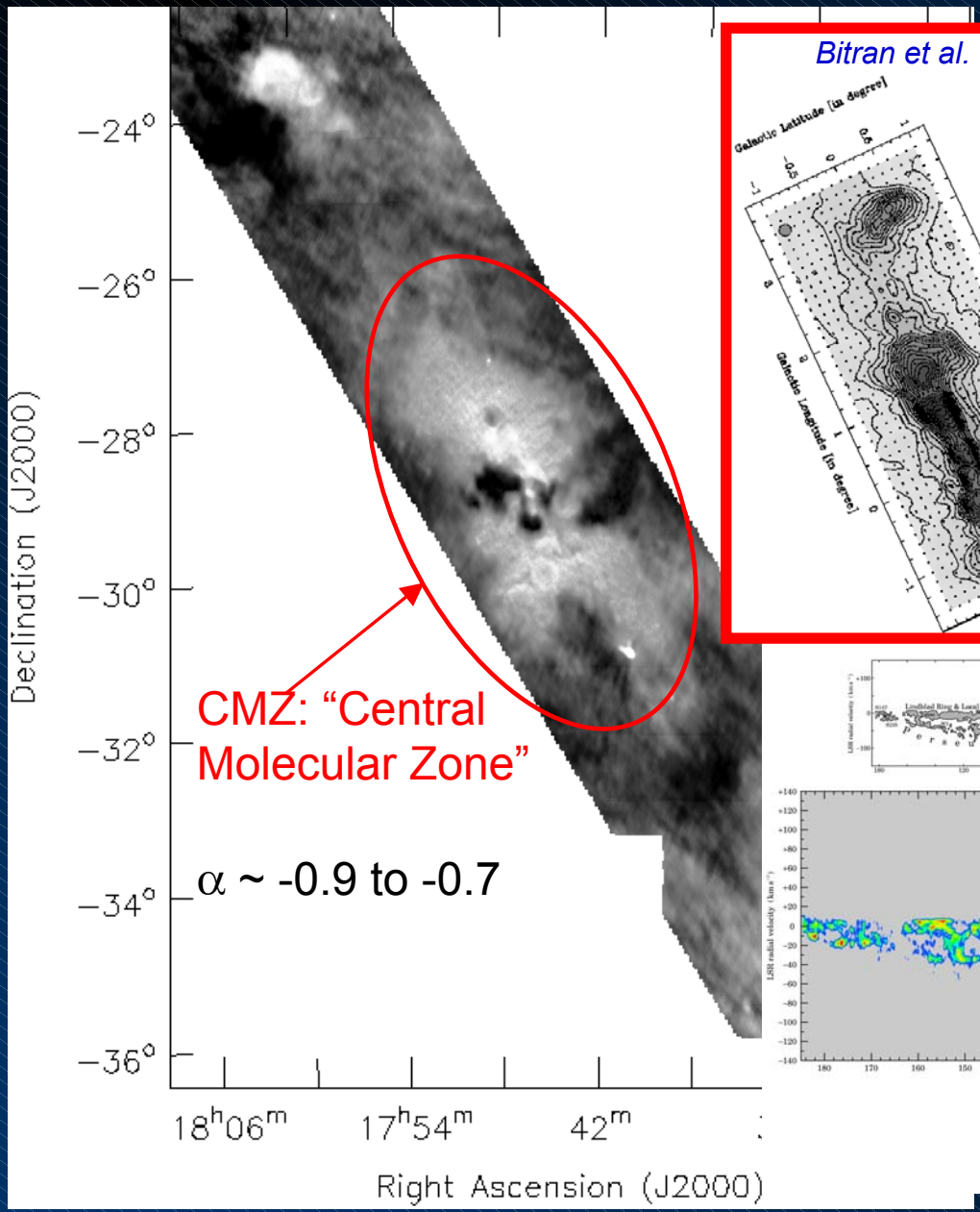
SNR: W28

Galactic Center

SNR: Tornado

HII Region: NGC 6357

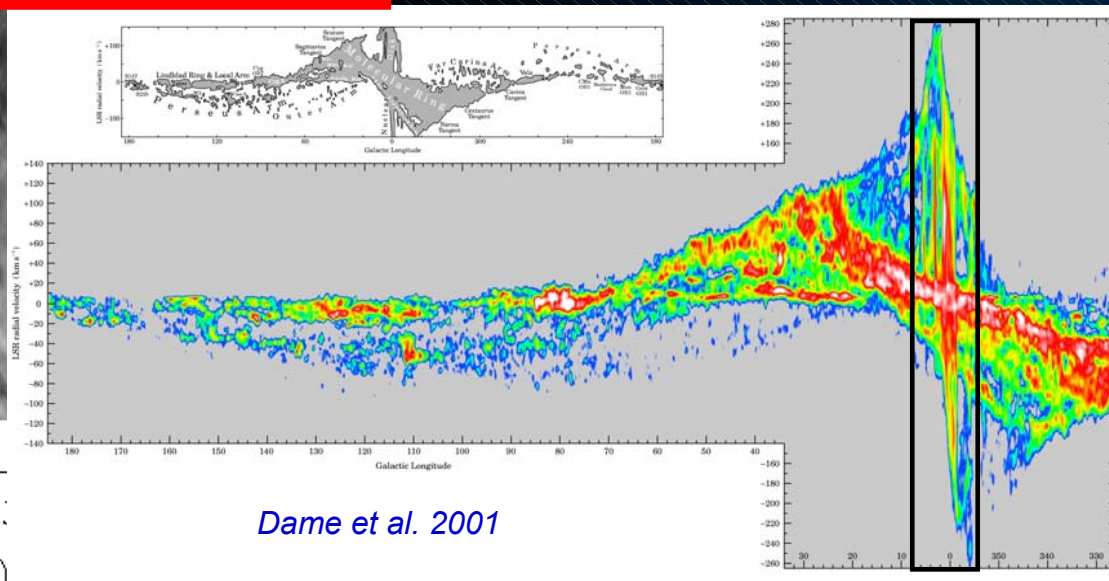
The Central Molecular Zone



Bitran et al. 1997

Enhanced synchrotron due to:

- Increased density
- Increased B
- Increased star formation rate/cosmic rays



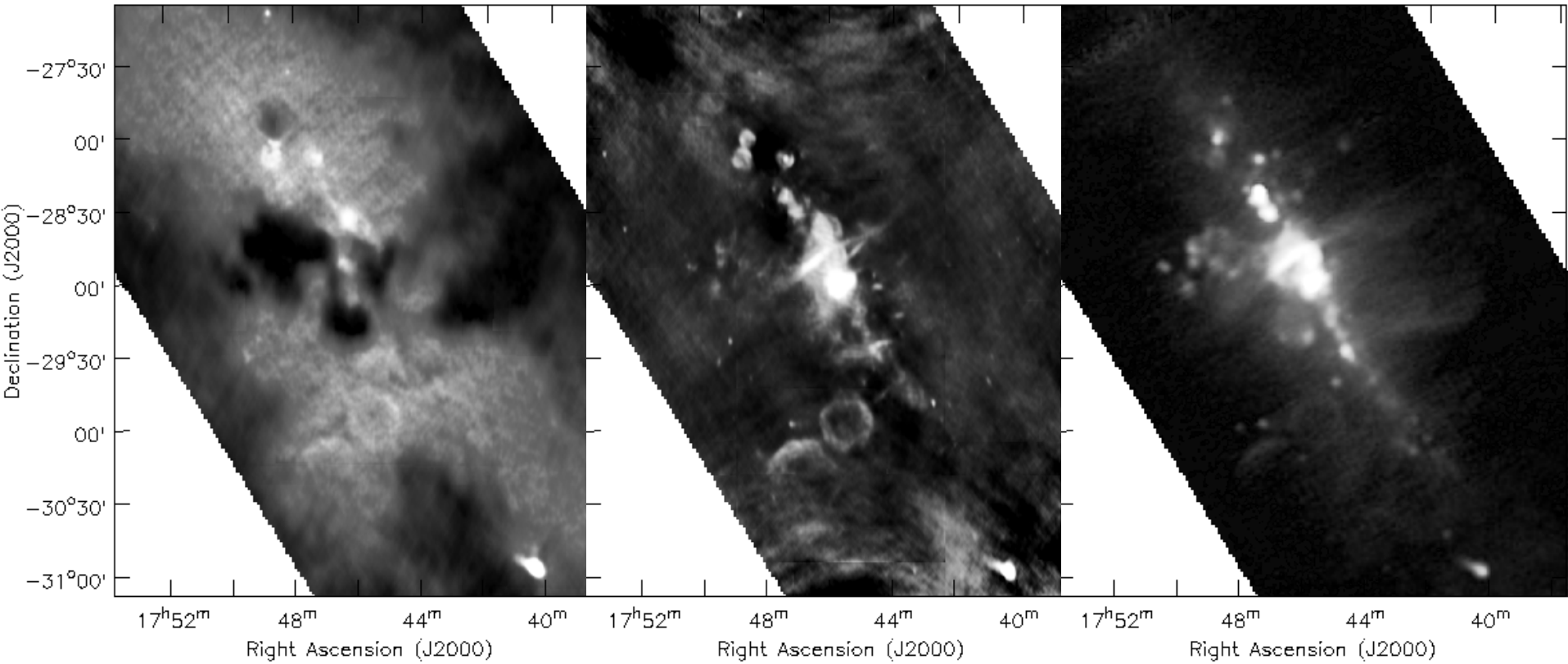
Dame et al. 2001

Close Up on the GC From 4m to 6cm

VLA 4m image
resolution 2.1' x 1.2'
using A+B+C+D config. data

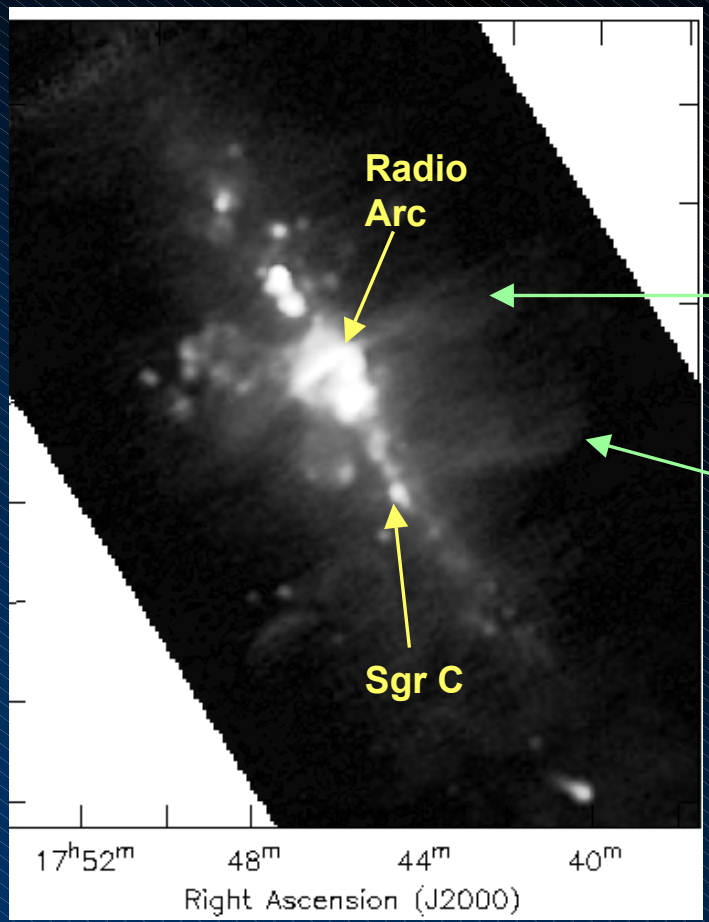
VLA 90 cm image
resolution 2.1' x 1.1'
using C+D config. data

Nobeyama 3 cm image
resolution 3'
Handa et al. 1989, PASJ, 39, 709

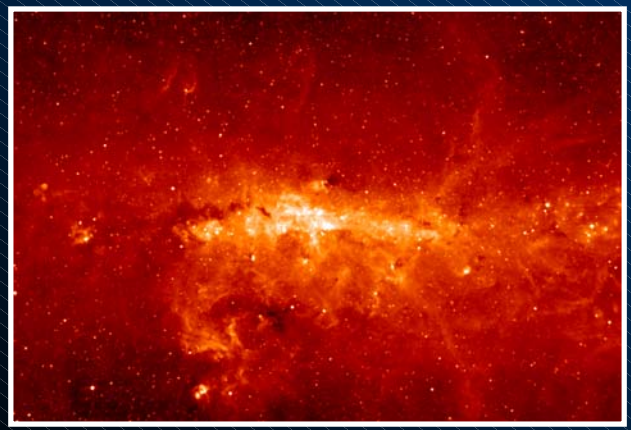


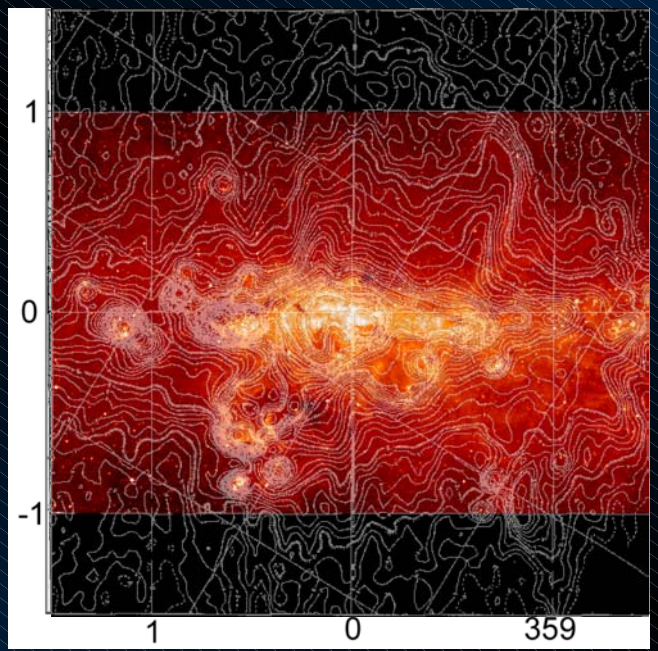
Large Scale Outflows from the GC

First identified by *Sofue & Handa (1984)*
from Nobeyama 3 cm survey

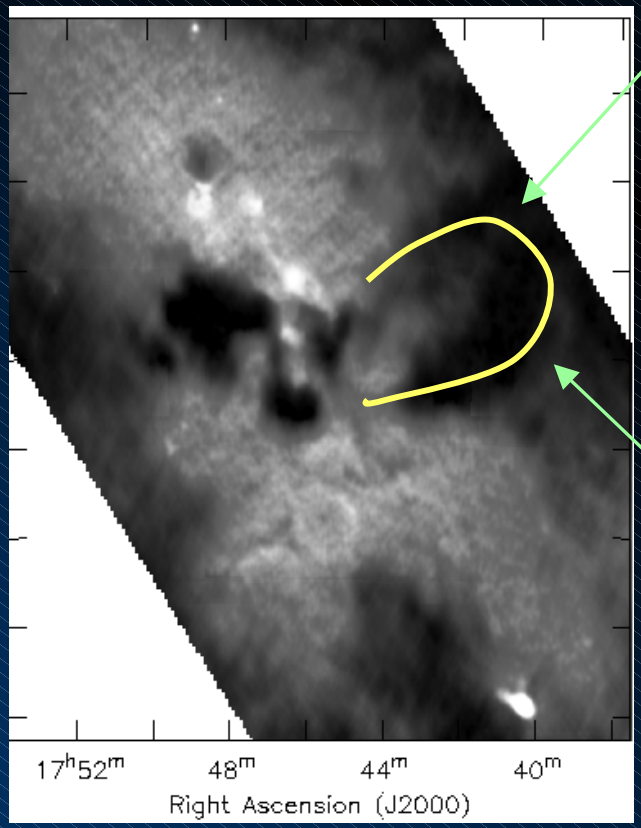


Bland-Hawthorn & Cohen (2003)
MSX at 8.3 μm





Large Scale Outflows from the GC



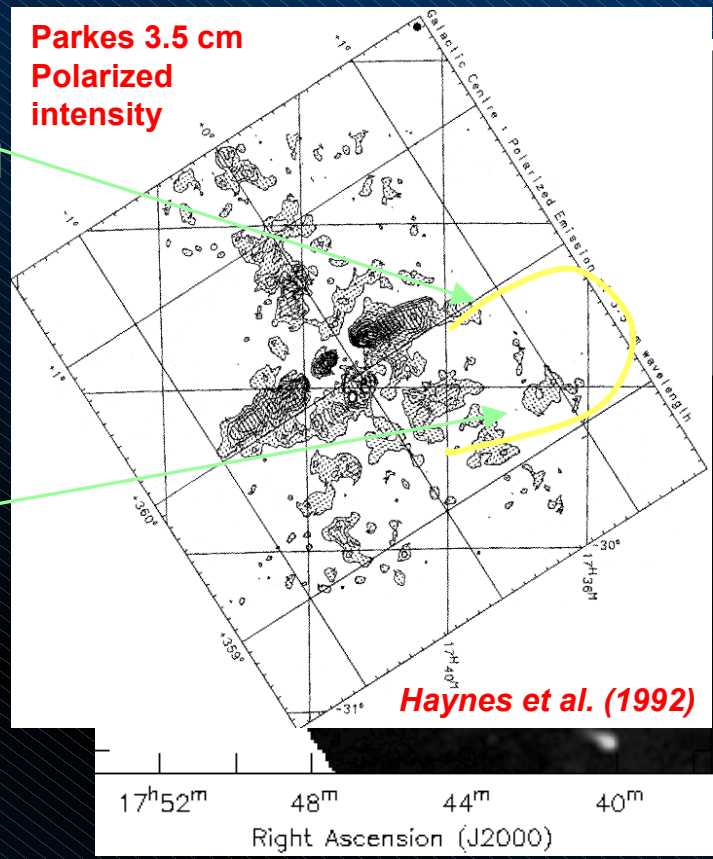
VLA 4 m Image

East Lobe

⇒ Partially non-thermal based on polarization *(Haynes et al. 1992; Tsuboi et al. 1986)*

West Lobe

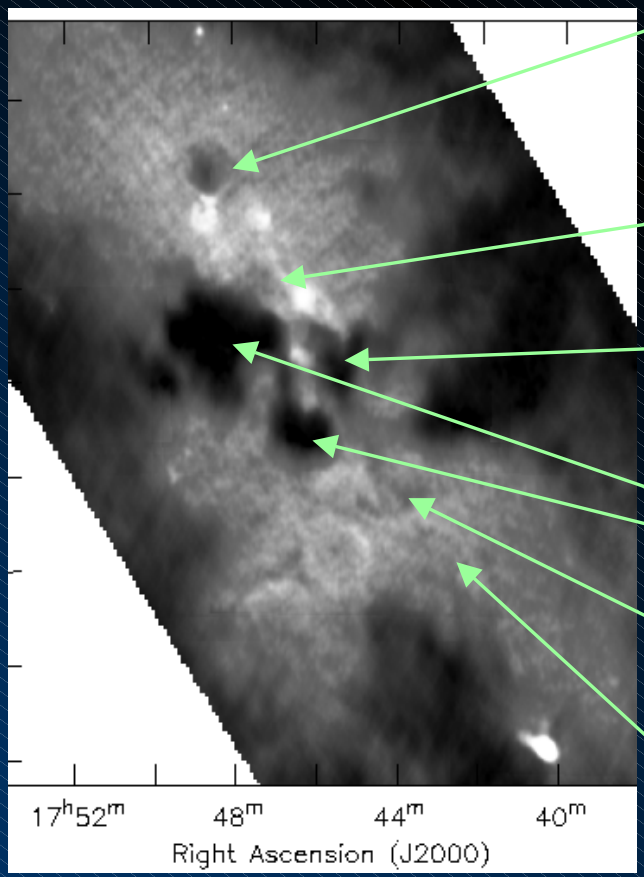
⇒ Thermal based on deep 4m absorption



Nobeyama 3 cm Image

Absorption Near the GC (4m vs. 6cm)

VLA 4 m Image



HII: Sgr D

HII: Sgr B1 & B2

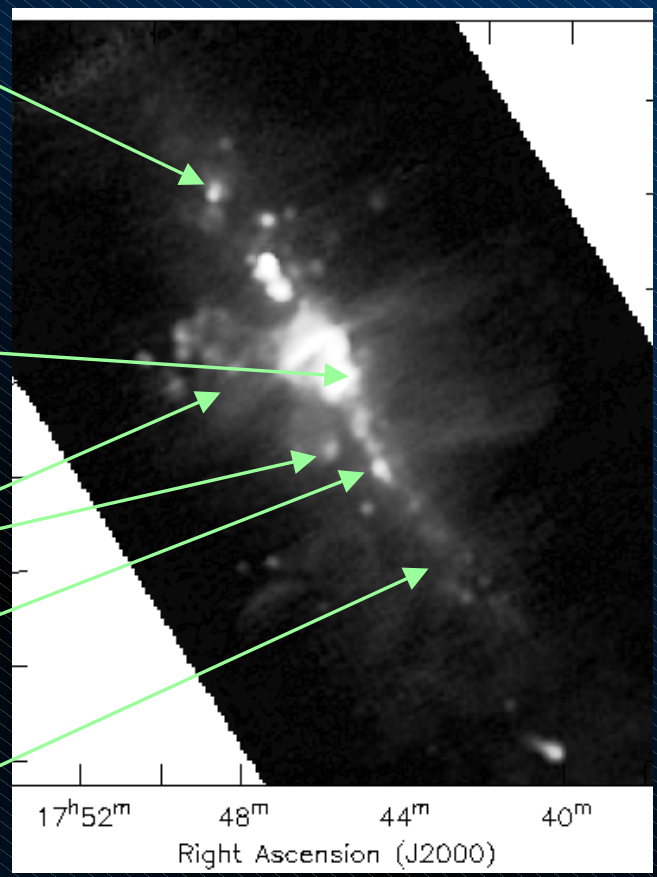
Sgr A West

Diffuse HII Regions

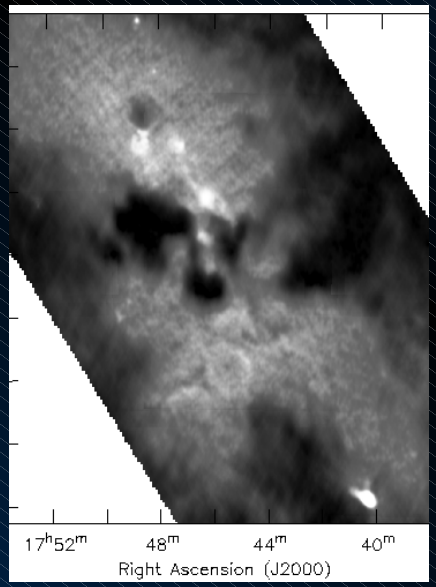
Sgr C

HII: Sgr E

Nobeyama 3 cm Image



A 3-D Cartoon of the GC Region



Diffuse HII Regions

Sgr D HII

+200 km/s

Central Molecular Zone

Sgr B2 HII

Sgr B1 HII

Sgr A*

Sgr C

Sgr E

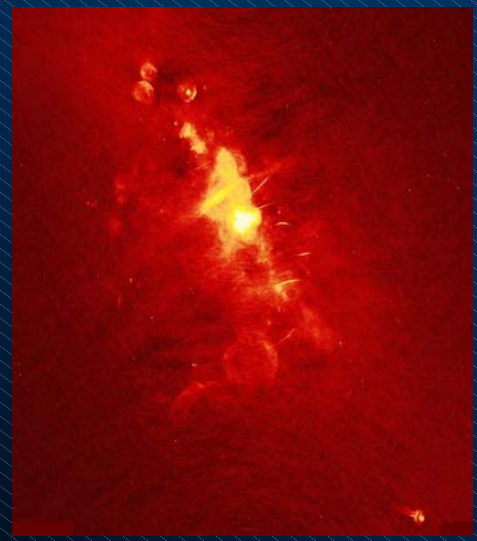
3 kpc Arm

-200 km/s

Relative distance along line of sight

Summary of GC at Low Frequency

- Lowest frequency detection of SgrA*
- New nonthermal filaments imply complex B morphology
- Ongoing wide field search for transient sources



- True extent of low density GC synchrotron emission
  - Encompasses CMZ “Central Molecular Zone”
  - Confinement? Particle spectrum? B-field?
- Identifying thermal gas near the GC from absorption
  - Large scale outflow
  - Sgr A West, Arched filaments, Sgr C
- Resolving distance ambiguity for HII regions in absorption