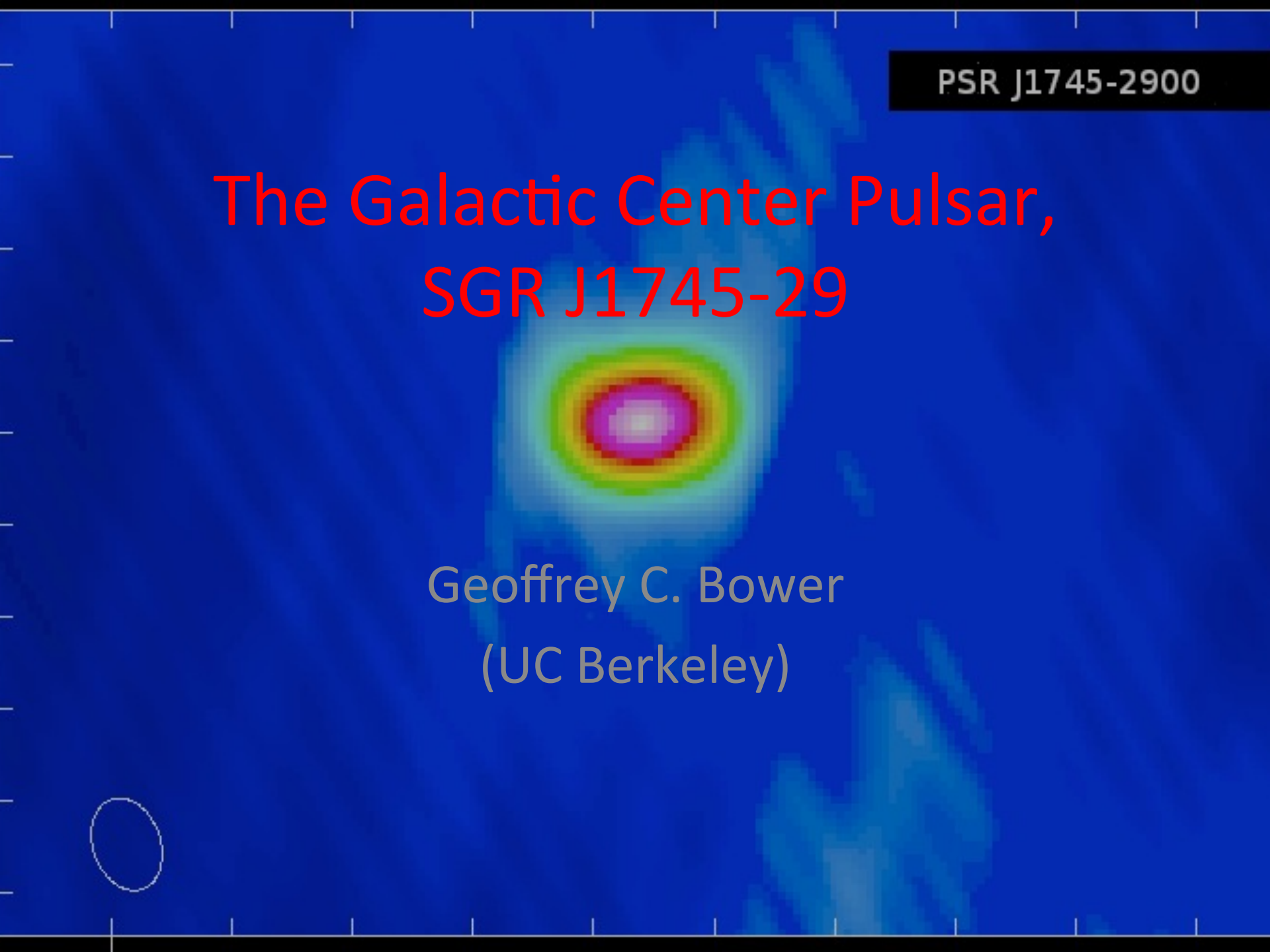


The Galactic Center Pulsar, SGR J1745-29

Geoffrey C. Bower

(UC Berkeley)

Revealing a high magnetic field around the supermassive black hole at the centre of the Galaxy

R. P. Eatough[1], H. Falcke[2,3,1], R. Karuppusamy[1], K. J. Lee[1], D. J. Champion[1], E. F. Keane[4], G. Desvignes[1], D. H. F. M. Schnitzeler[1], L. G. Spitler[1], M. Kramer[1,4], B. Klein[5,1], C. Bassa[4], G. C. Bower[6], A. Brunthaler[1], I. Cognard[7], A. T. Deller[3], P. B. Demorest[8], P. C. C. Freire[1], A. Kraus[1], A. G. Lyne[4], A. Noutsos[1], B. Stappers[4] & N. Wex[1]

The Angular Broadening of the Galactic Center Pulsar SGR 1745-29: A New Constraint on the Scattering Medium

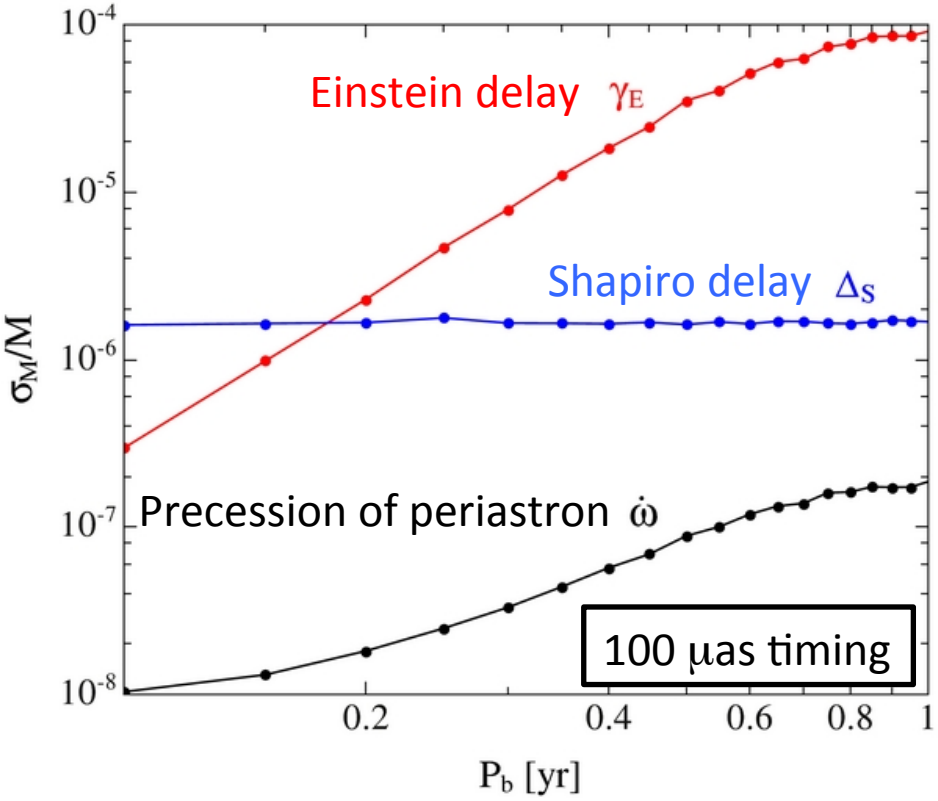
Geoffrey C. Bower[1], Adam Deller[2], Paul Demorest[3], Andreas Brunthaler[4], Ralph Eatough[4], Heino Falcke[5,2,4], Michael Kramer[4] K.J. Lee[4], Laura Spitler[4]

Pulse Broadening Measurements from the Galactic Center Pulsar J1745–2900

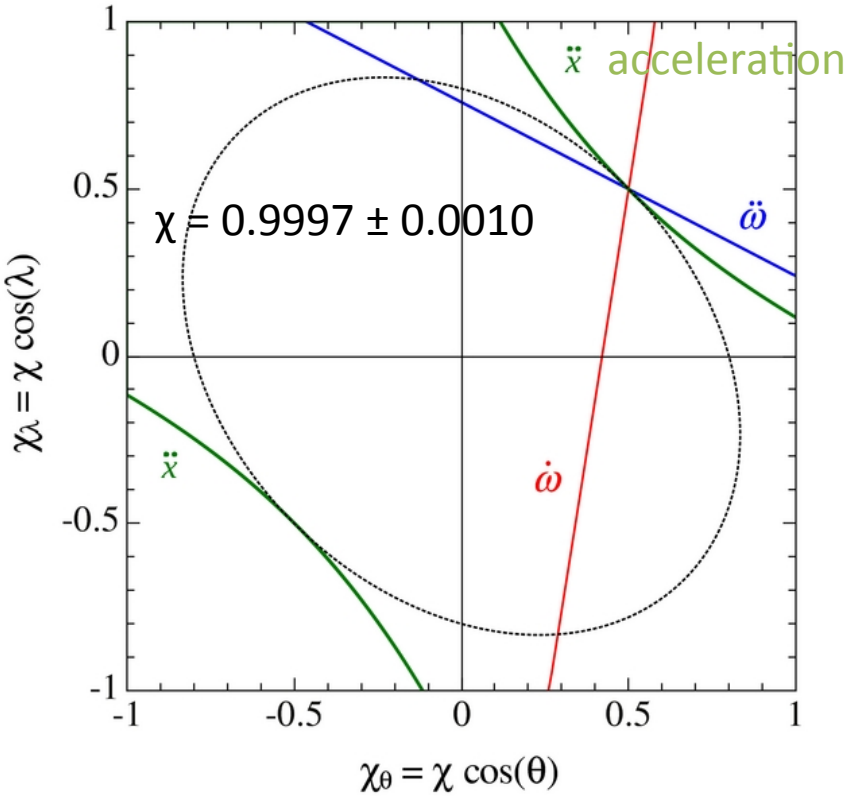
L. G. Spitler,[1] K. J. Lee,[1] R. P. Eatough,[1] M. Kramer,[1,2] R. Karuppusamy,[1] C. G. Bassa,[2] I. Cognard,[3] G. Desvignes,[1] A. G. Lyne,[2] B. W. Stappers,[2] G. C. Bower,[4] J. M. Cordes,[5] D. J. Champion,[1] & H. Falcke,[1,6,7]

Using Pulsars to Measure Spacetime Around Sgr A*

Black Hole Mass



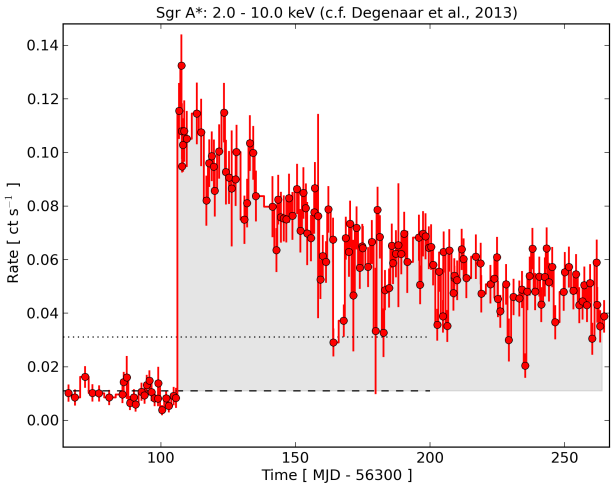
Black Hole Spin



Liu et al 2012

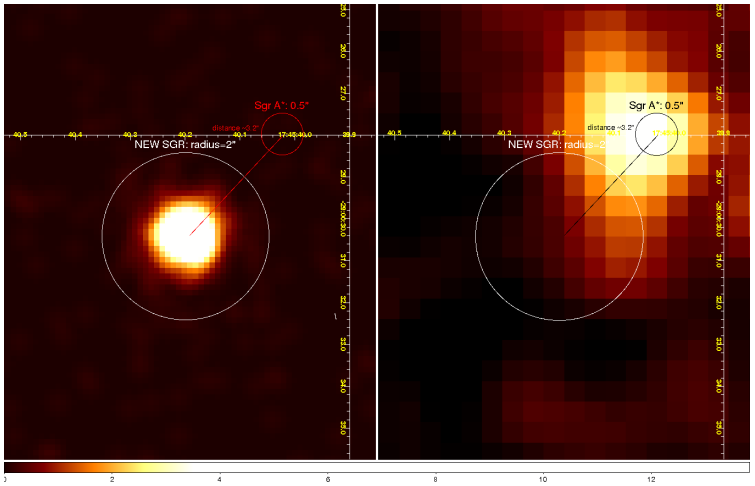
Galactic Center Magnetar Discovery

X-Ray Burst



Degenaar et al. 2013
Kennea et al. 2013

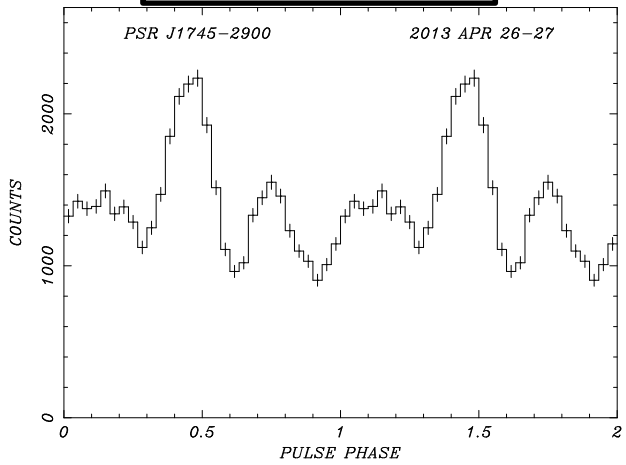
X-ray Localization: 3" to Sgr A*



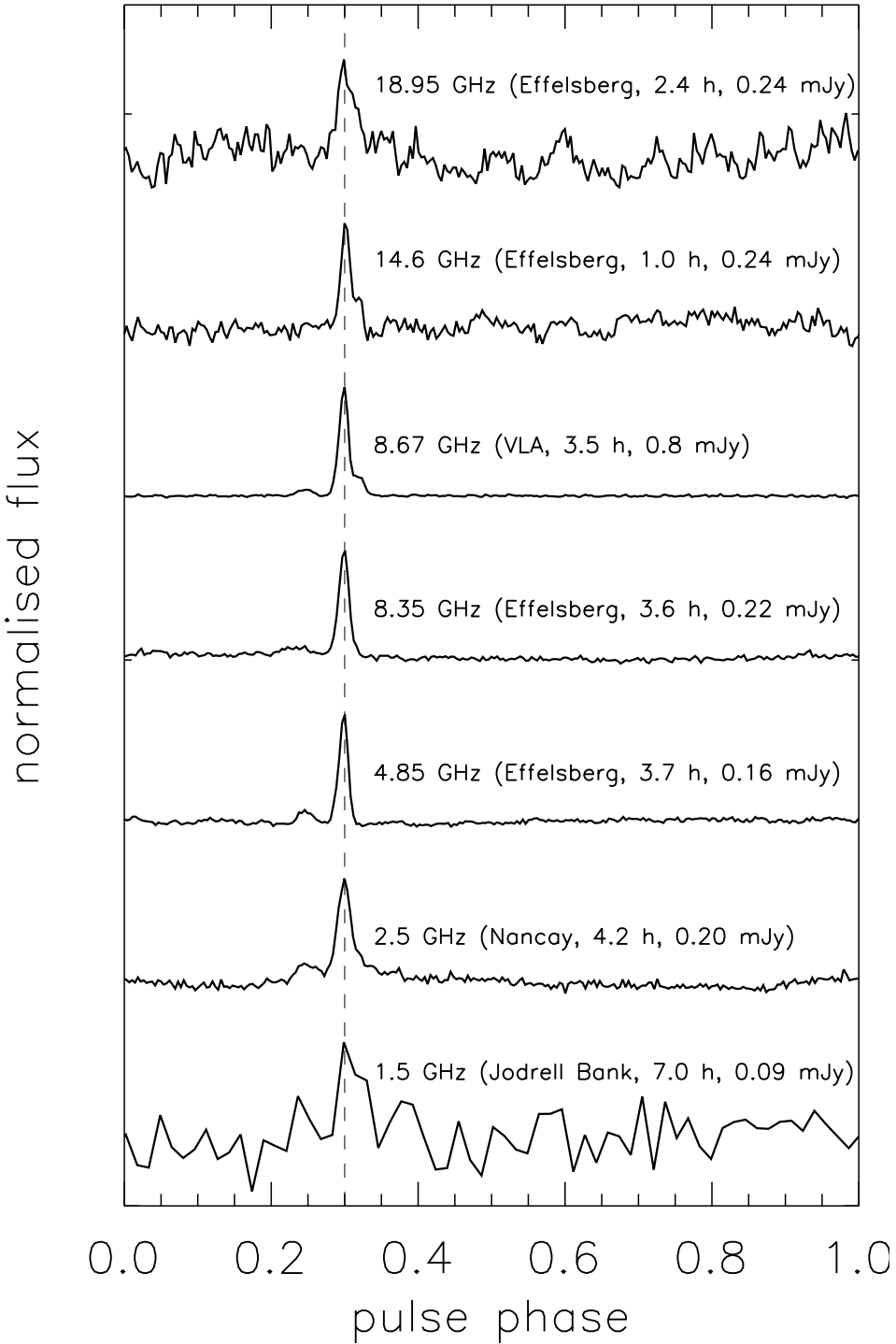
Rea et al. 2013

SGR J1745-29

X-ray Pulsations



Mori et al. 2013

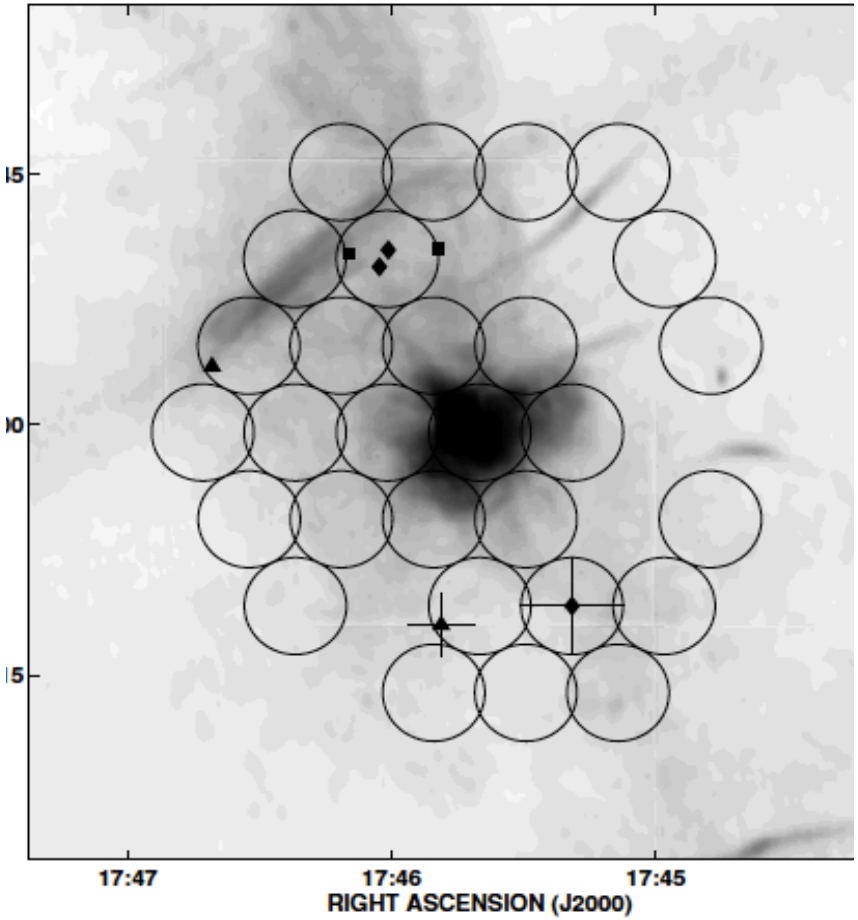


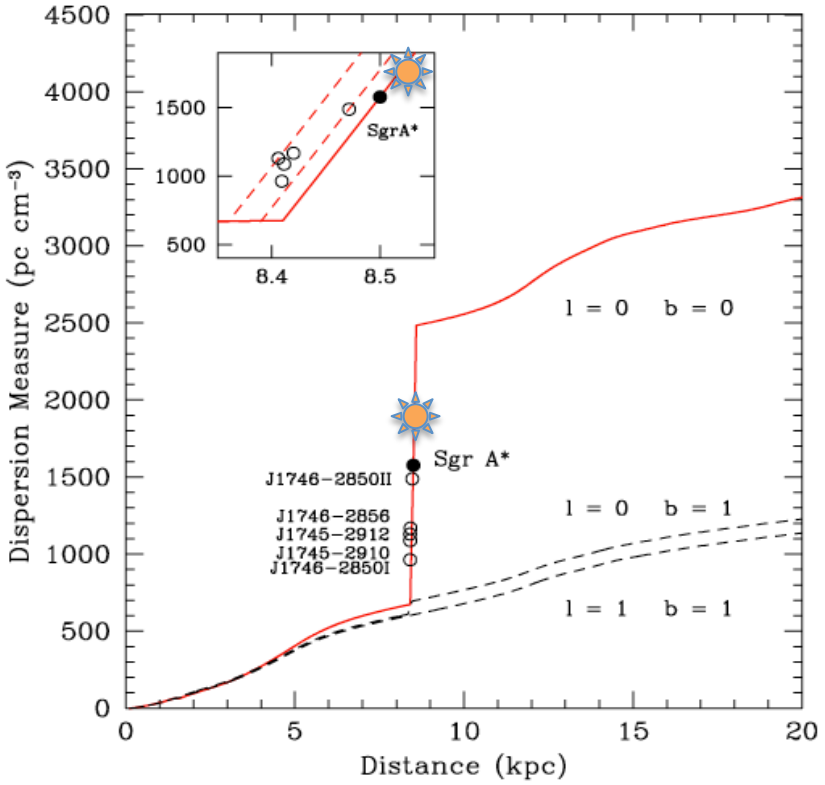
Radio Detection

- period
  P = 3.76354676(2) s
- period derivative (spindown) P/Pdot = 6.82(3) 10^{-12}
  B ~ 10^{14} G
- Spin-down age ~ 9000 yrs
- Dispersion
  DM = 1778 +/- 3 cm^{-3} pc
- Flux ~0.2 mJy
- spectrum ~flat
- Only 4 radio magnetars known – chance alignment is 10^{-8}

Eatough et al. 2013
Shannon and Johnston 2013

Dispersion in the Galactic Center

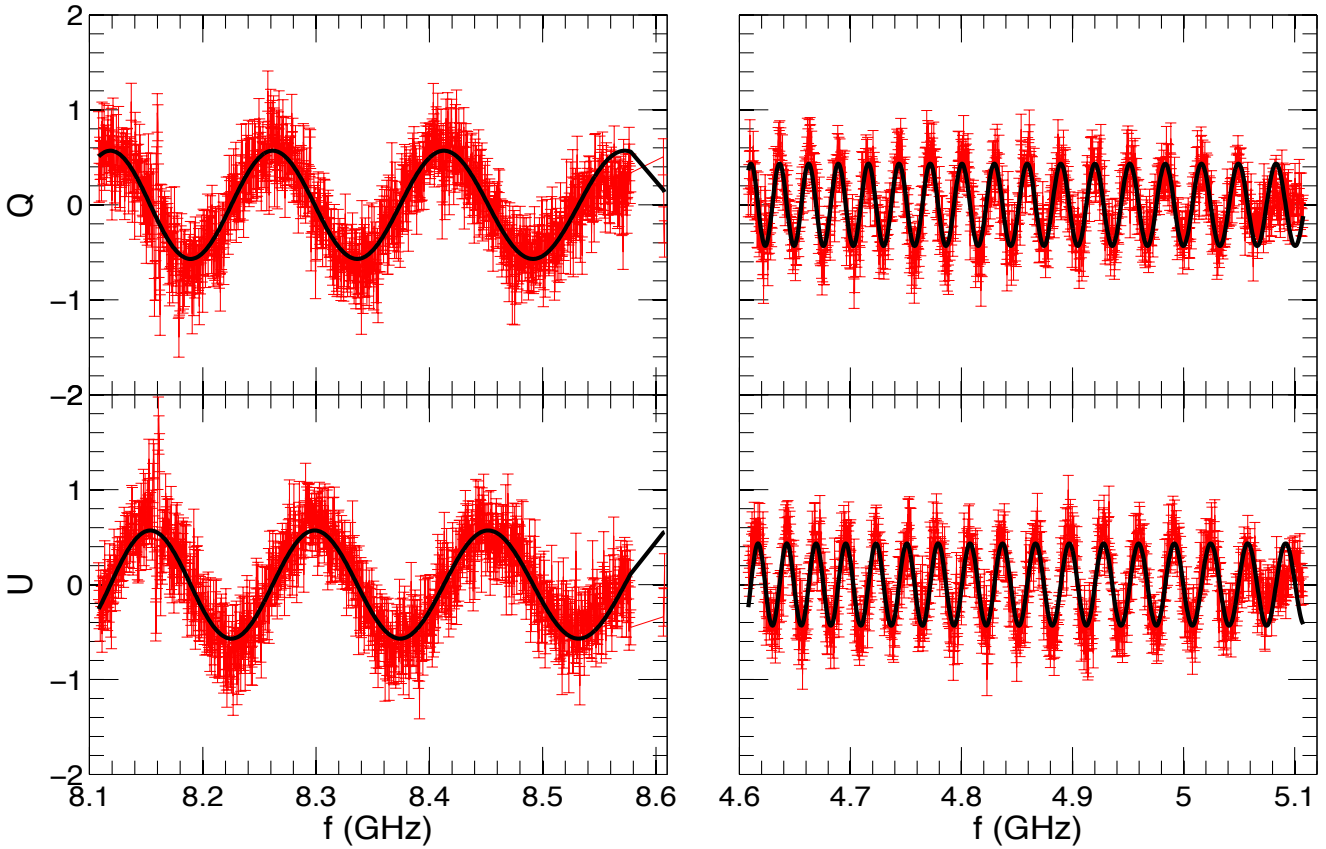




NE 2001 Model
Deneva et al. 2009

Rotation Measure

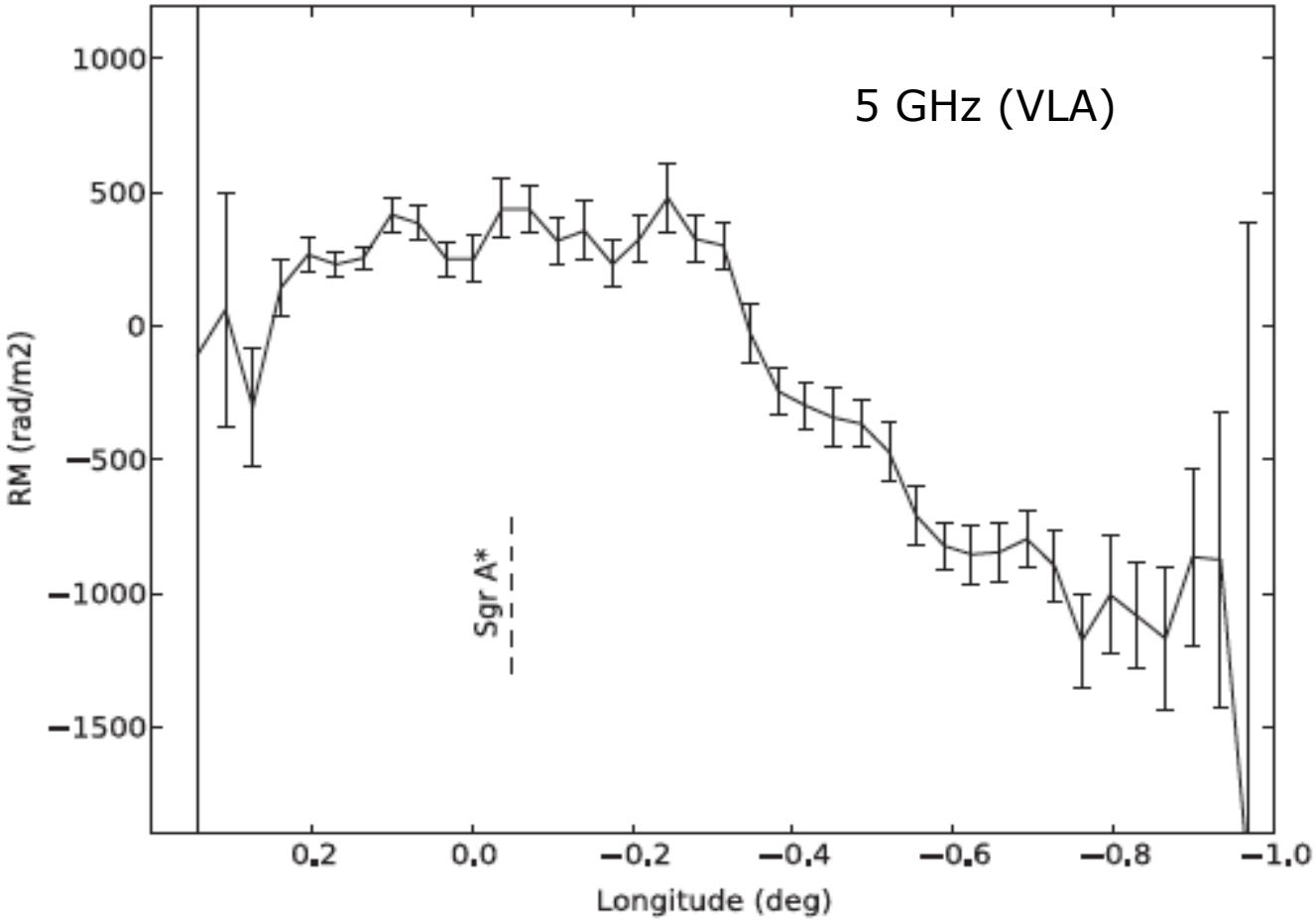
RM = - 66960 +/- 50 rad m^{-2}



$RM_{pulsar} \sim 0.1\ RM_{SgrA*}$

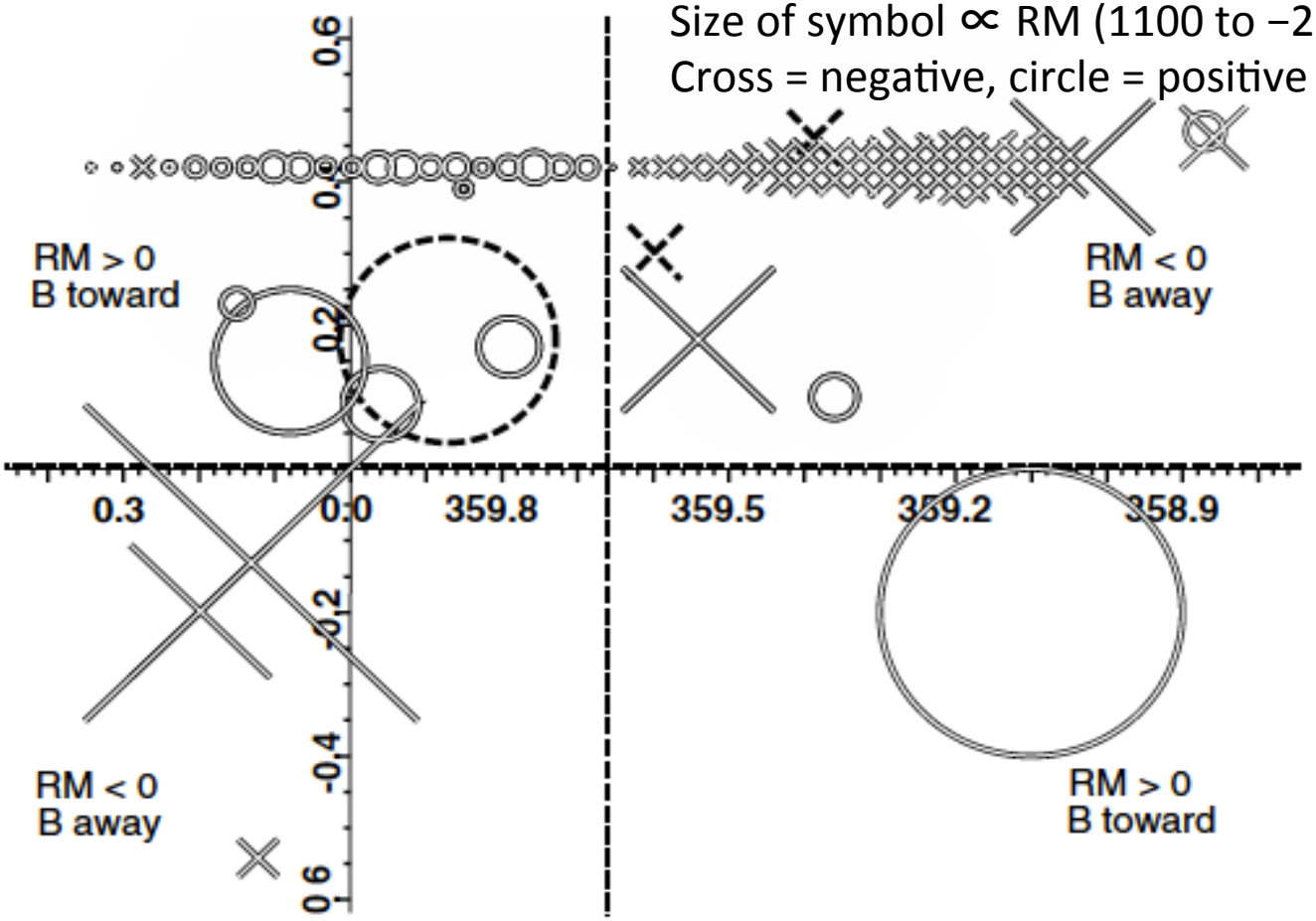
Eatough, HF, et al. (2013)

Galactic RM of diffuse gas



Law et al. (2011)

RM of Galactic Center Sources

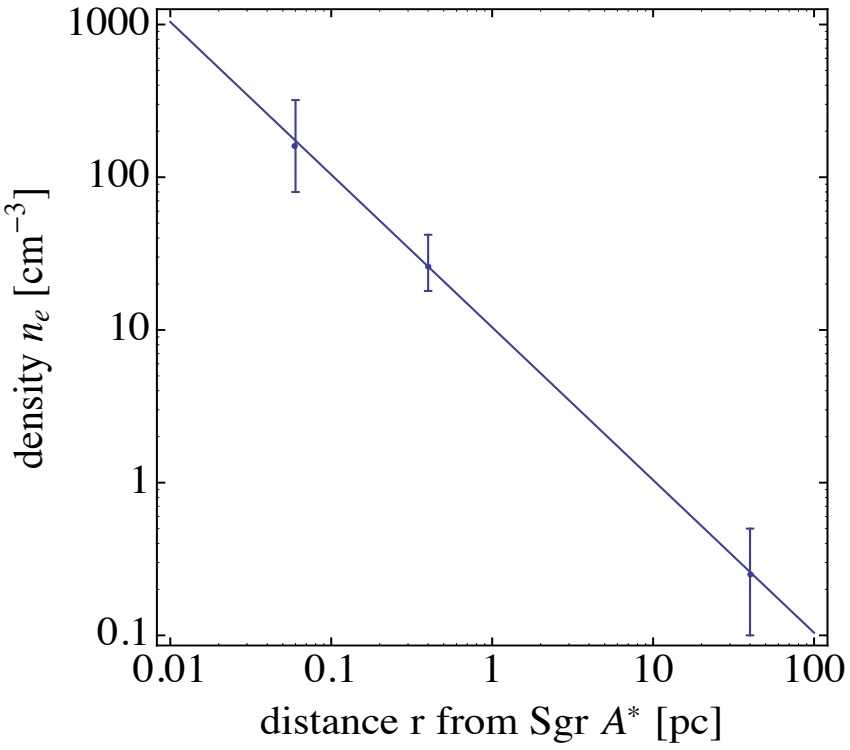


Law et al. (2011)

RM and DM from hot gas

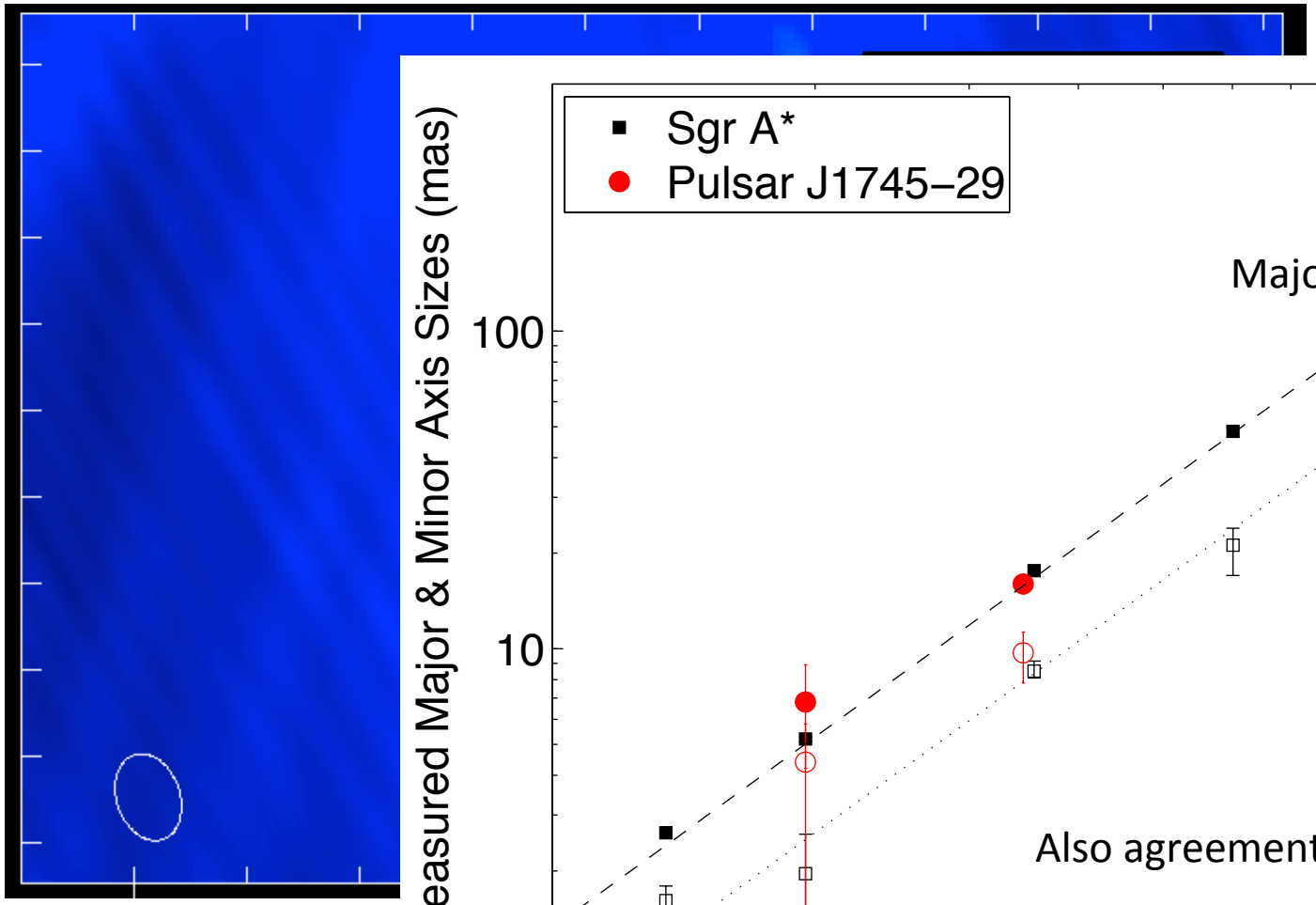
- Inferred densities at scales of 0.06, 0.15 and 40 pc roughly follow r^{-1} law.
- DM ~ n_e r ~ 10^2 cm^{-3} pc
- RM ~ B n_e r
  ⇒ B ∝ RM ~ 8 mG
- Equipartition: B ~ 2.5 mG

⇒ Sgr A* accretes from a highly magnetized hot gas



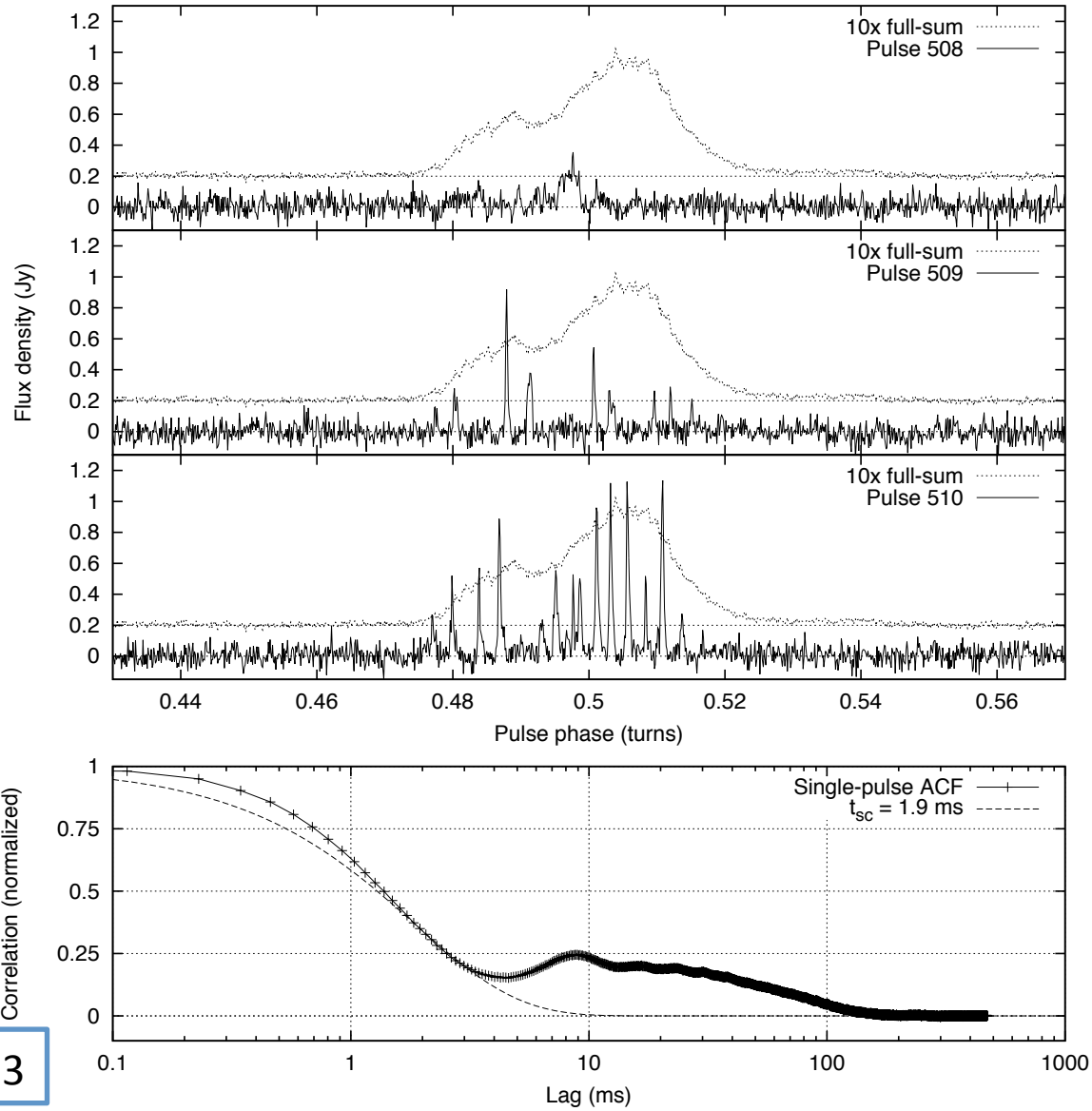
Based on Baganoff et al. (2003), Muno et al. (2004)

Angular Broadening of the Pulsar



Bower et al. 2013

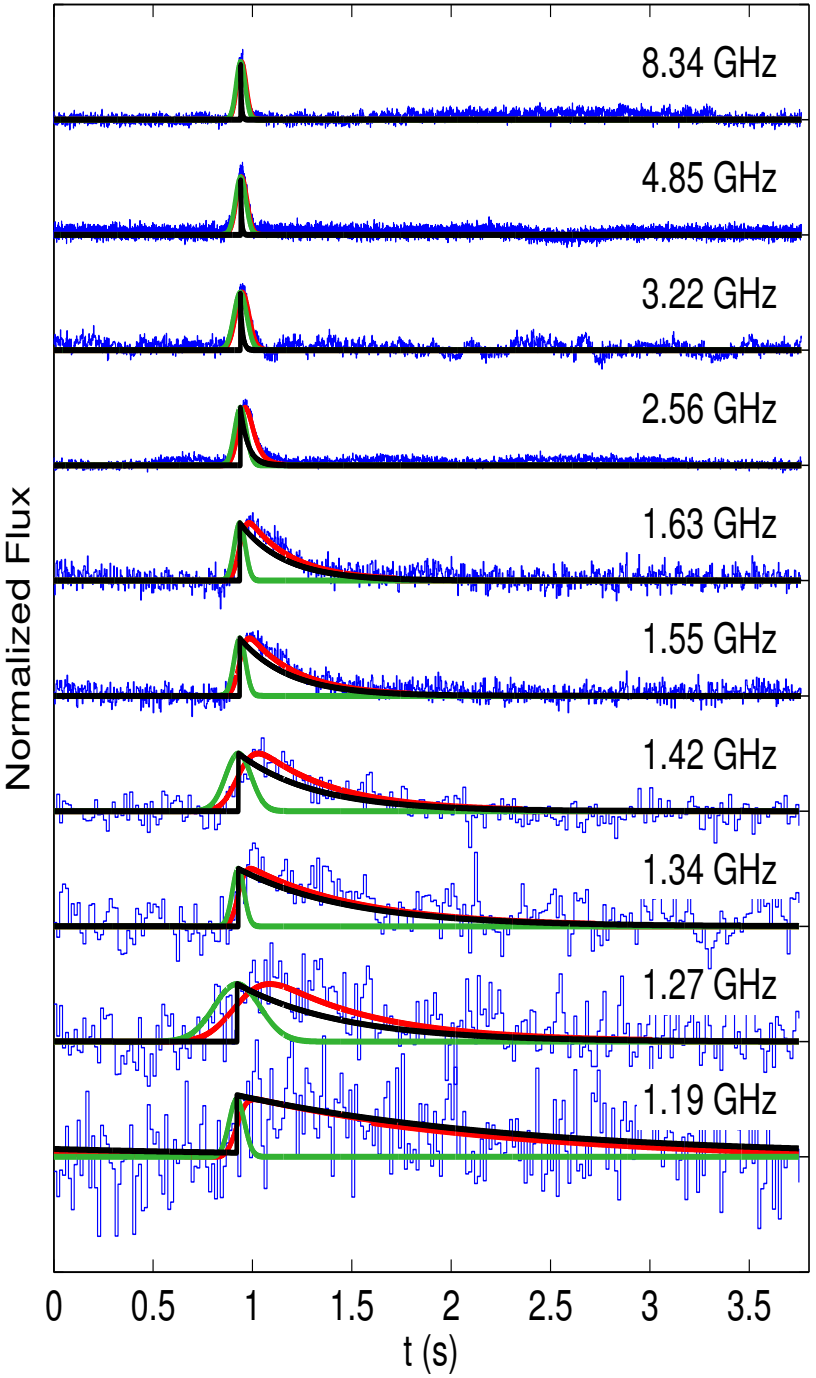
Individual Pulses are Highly Variable

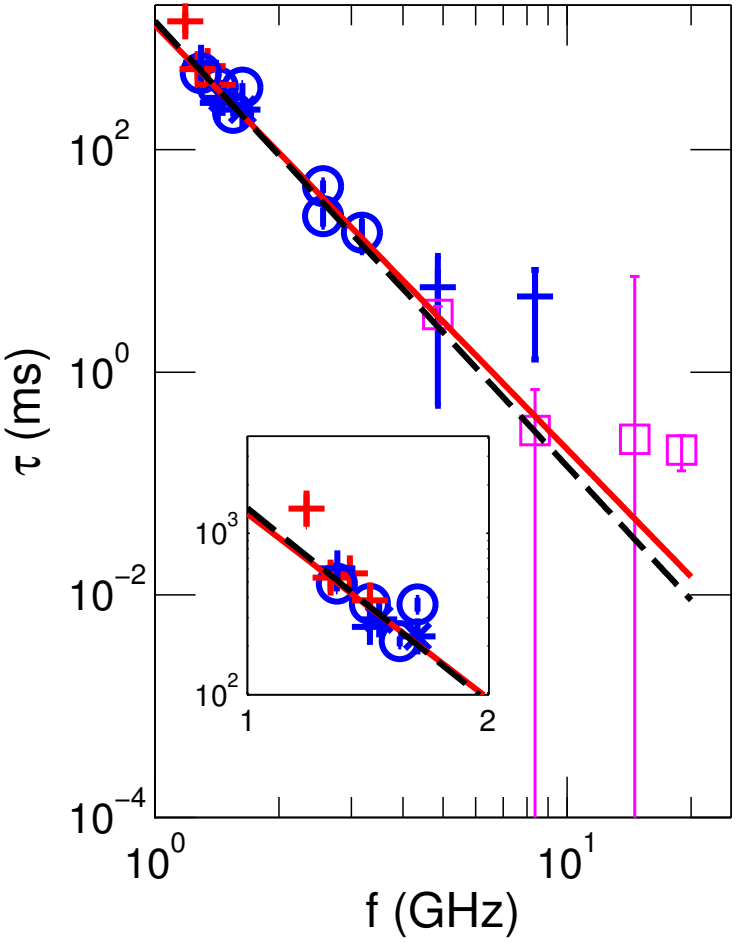


EVLA
8.7 GHz

Bower et al. 2013

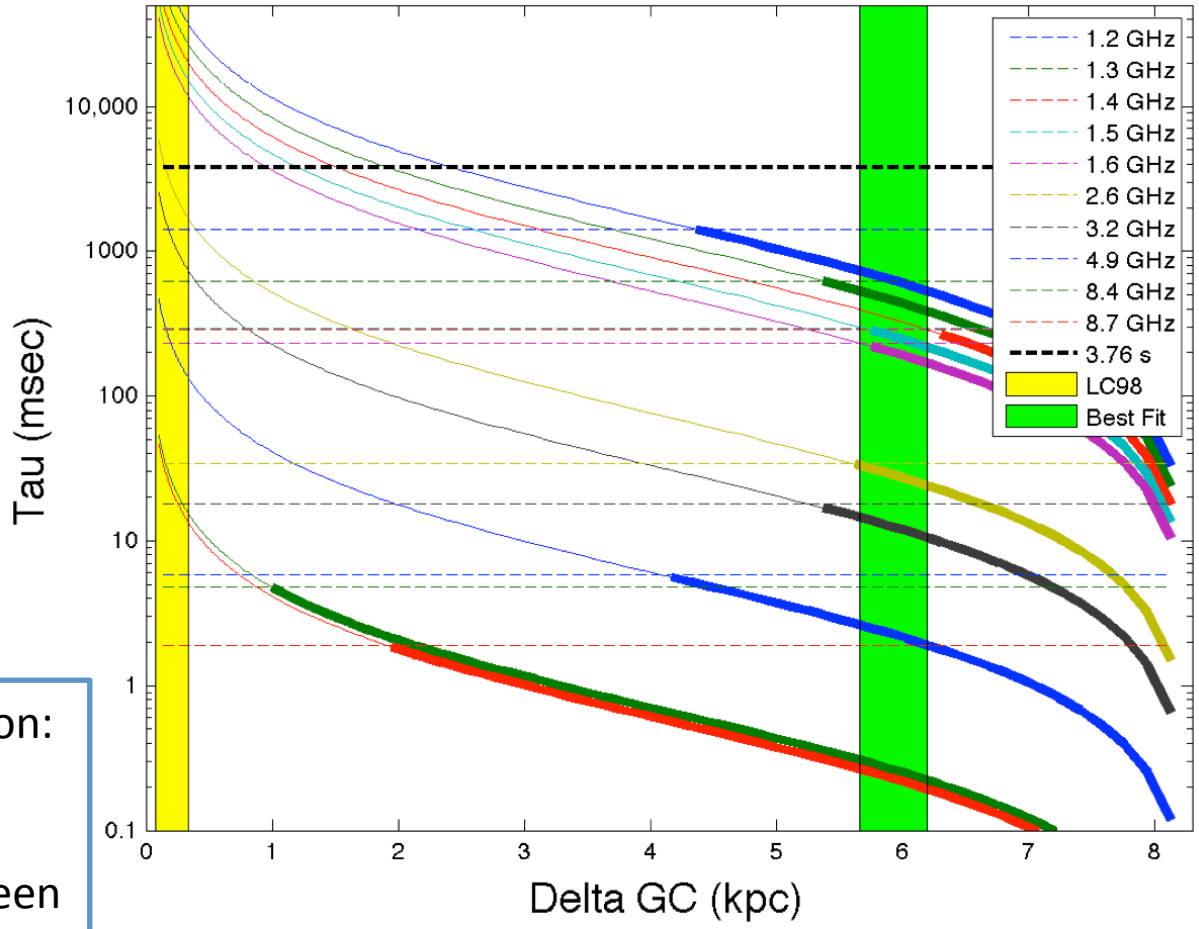
Temporal Scattering





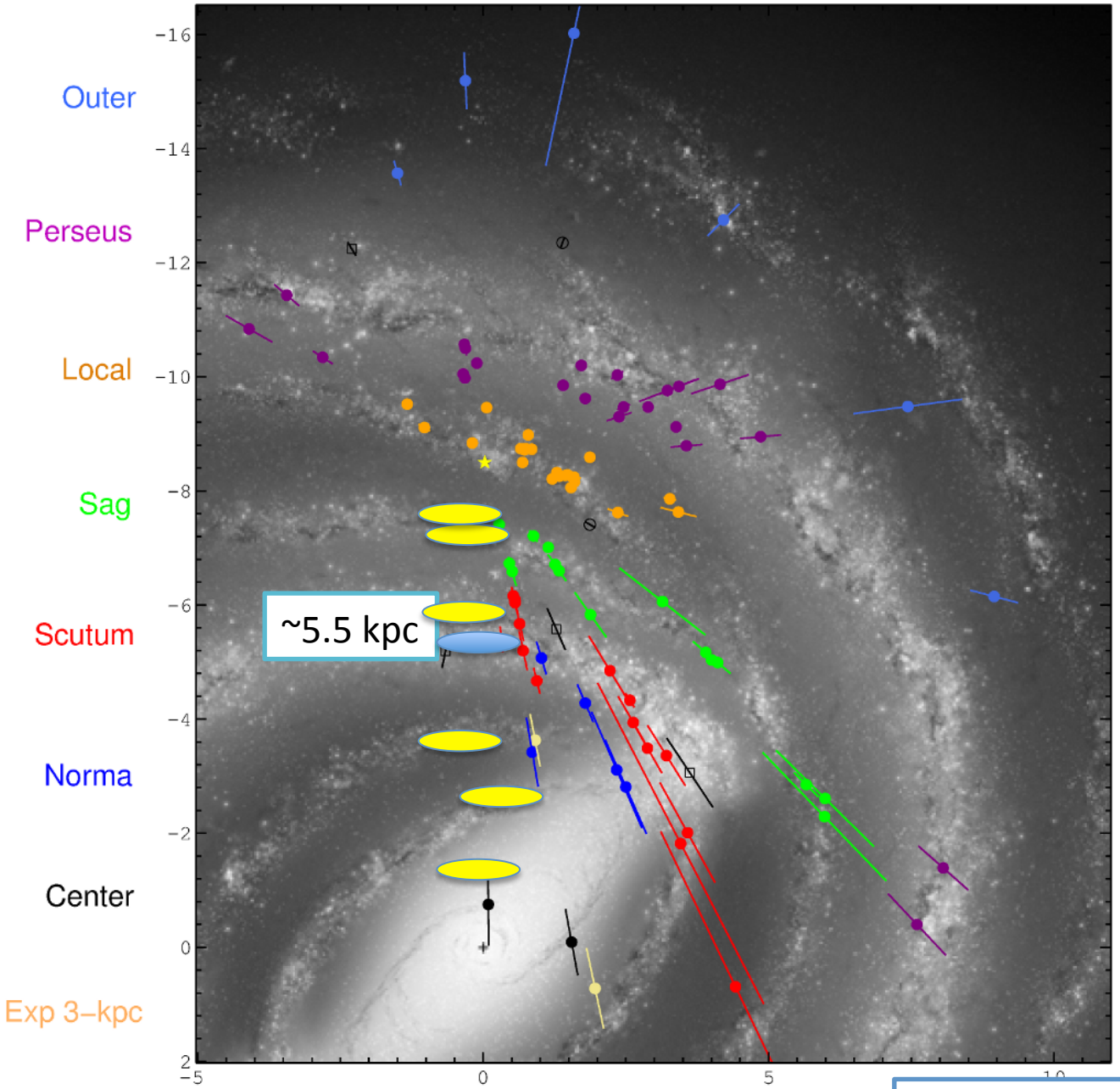
Spitler et al. 2013

A New Distance for the GC Scattering Screen



Alternate Solution: Uniform Distribution of scatterers between GC & Sun

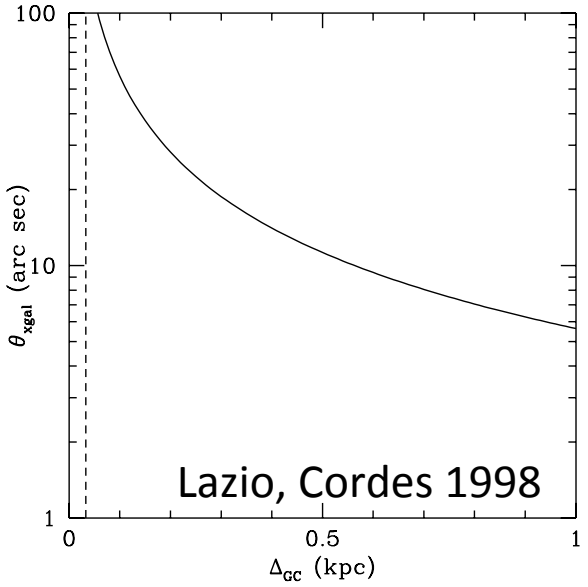
Bower et al. 2013

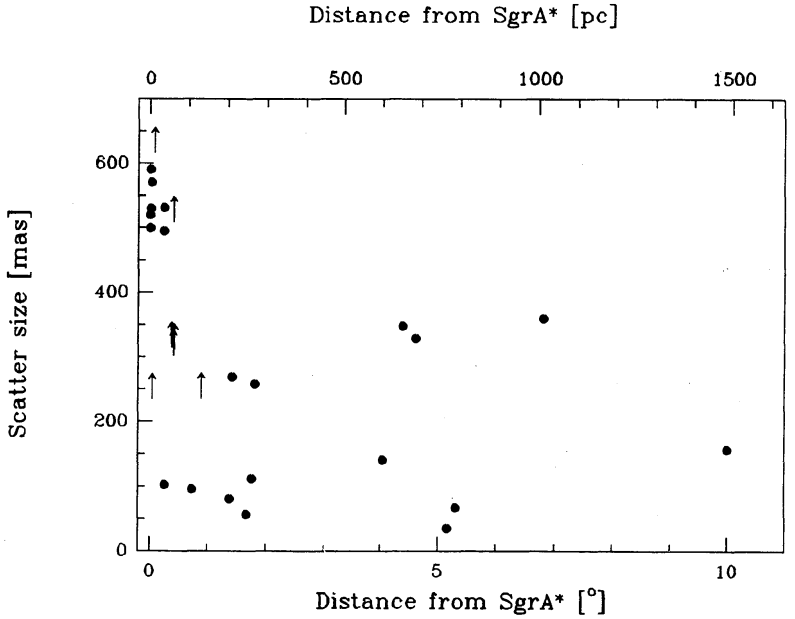


Reid, Brunthaler, et al

Does a Scattering Screen at Large Distances Make Sense?

- NGC 6334B & Cyg X-3 have similar scattering sizes and non-local scattering screens
- 50 pc diameter screen associated with HII regions or GMC surfaces can provide the scattering
- Missing extragalactic background sources?
- Apparent peak of OH/IR masers around Sgr A*?
- Patchiness?
  - Scale ~5' from G359.87+0.18

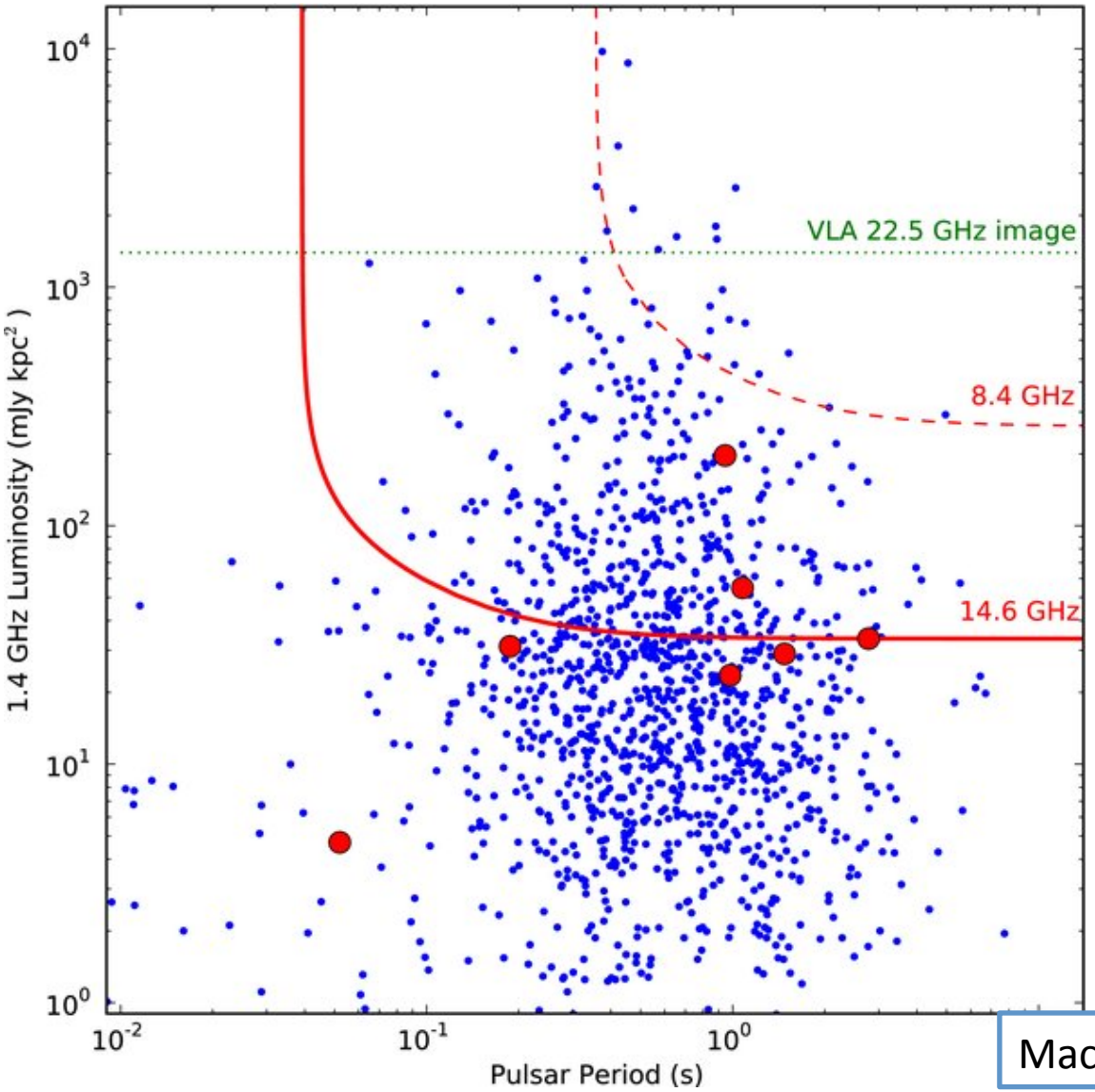




van Langevelde 1992

Where are the GC pulsars?

GC Pulsar search does not require high frequencies!

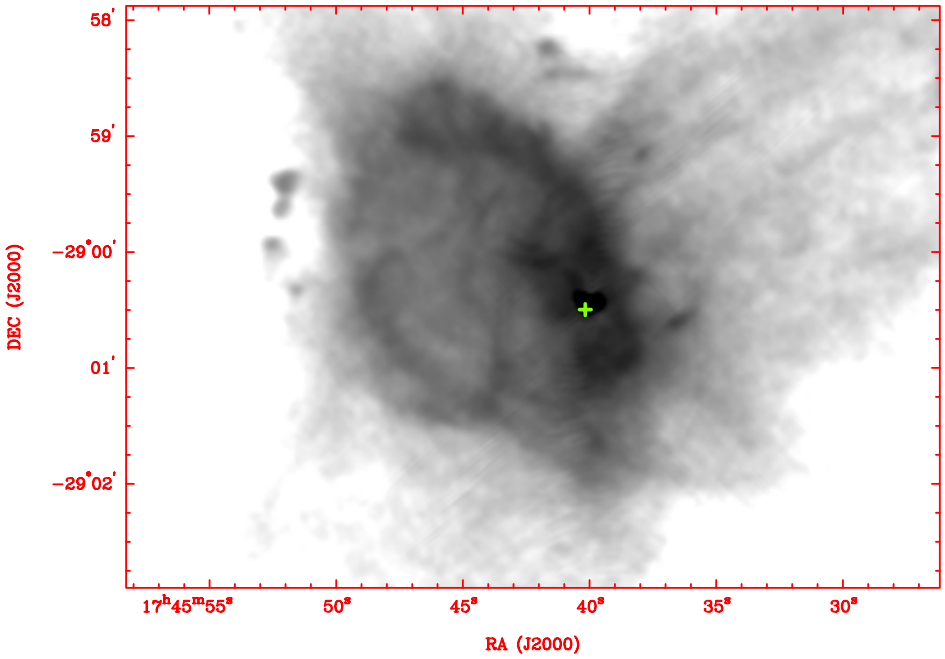


~1000 pulsars with periods <100y expected (Liu et al 2012)

Macquart et al 2012

Astrometry

- 4 astrometric detections
- Accuracy ~0.3 mas/epoch
- Velocity accuracy @ GC ~100 km/s [2 months data]
  - → ~10 km/s in 1 year
- Where is it going? Where did it come from?
  - Characteristic velocity ~390 km/s
  - Escape velocity ~600 km/s
  - T_SgrA* < 1000y
  - Acceleration ~ 1 km/s/y



Conclusions

- First true GC pulsar discovered
  - Highest DM, RM, SM of any known pulsar
  - X-ray absorption consistent with GC location
  - Too unstable for precision timing tests
- Important probe of the Sgr A* environment
  - Sgr A* accretes from hot gas with high and ordered B-fields
  - Motion of the pulsar could provide length scales for ISM structures
- Scattering must originate at large distances
  - Resolves long-standing mystery --- but creates new ones
- Proper motion to come … (tracing back to origin?)
  - Sgr A* orbit ~10^3 yrs – likely too long for precision GR tests
- Where are the other GC pulsars?
  - Can easily detect ordinary pulsars at few GHz
  - Can detect MSPs at >10 GHz