Galactic Center Scattering, Pulsars, and Astrometry

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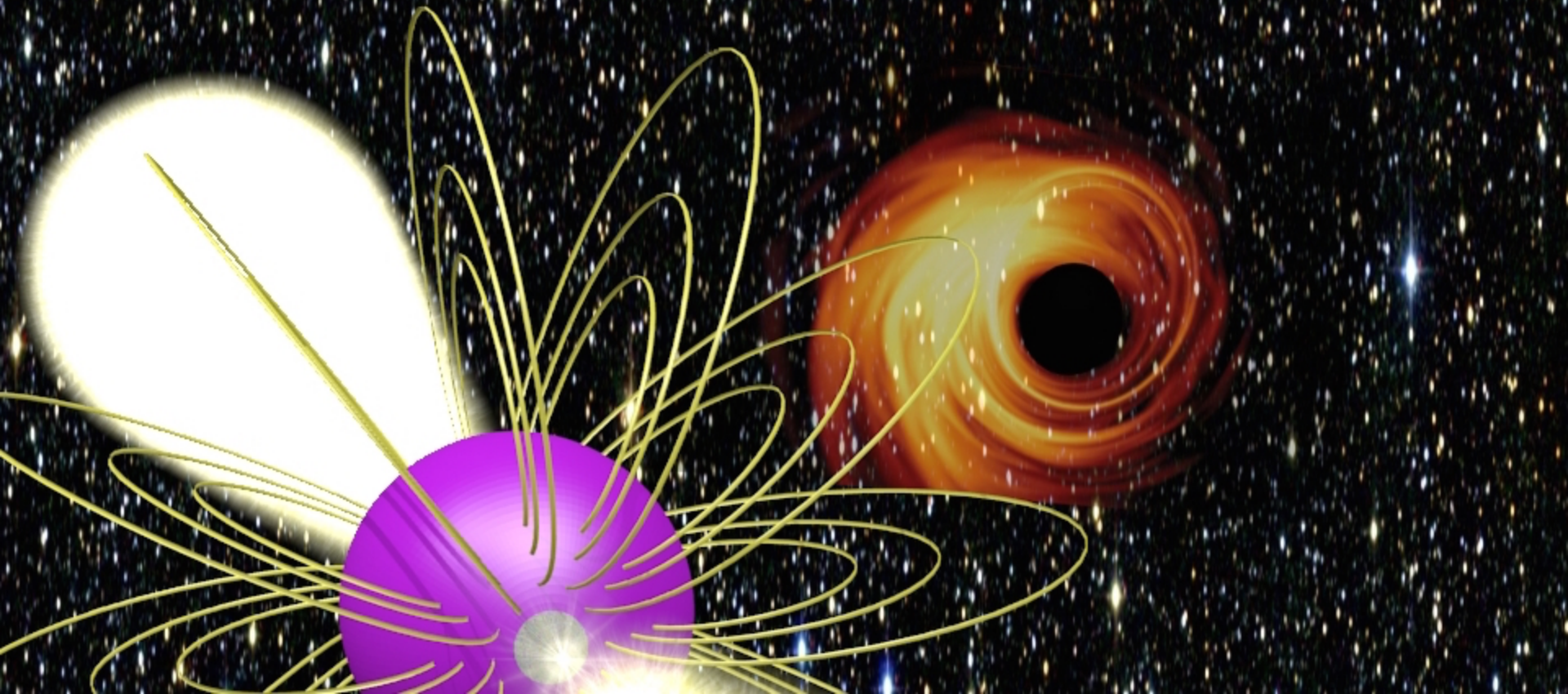
(ASIAA, Hilo)

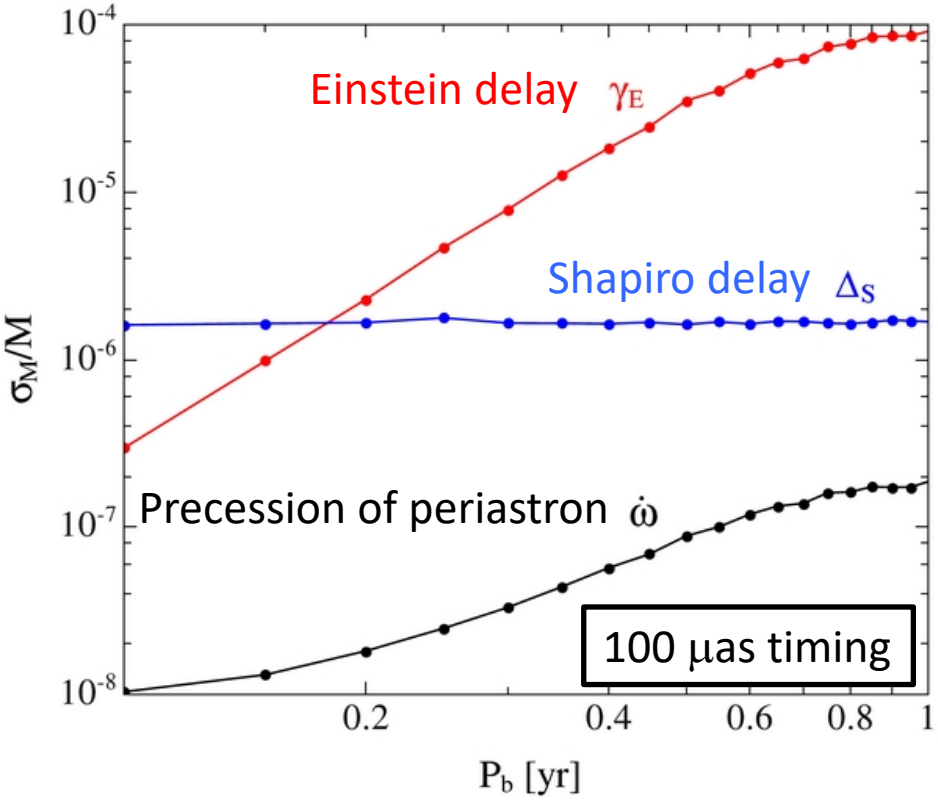


Galactic Center Pulsars

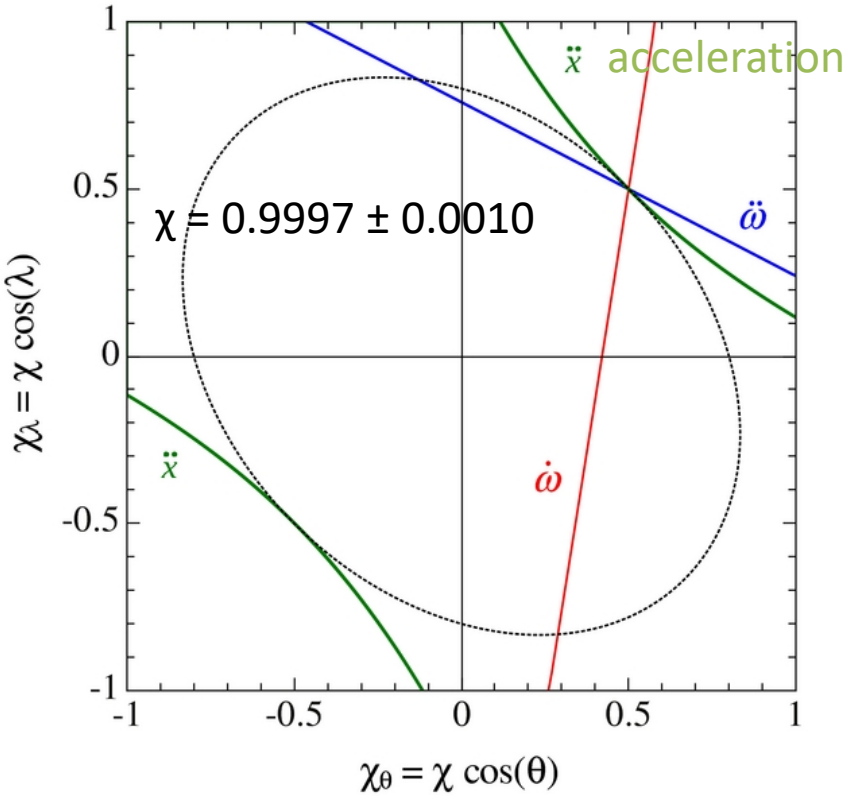
1. General Relativity and Black Hole Physics with Sgr A*-bound Pulsar
2. Star-formation, Stellar Death, Dynamical Evolution, Dark Matter within the Central Molecular Zone
3. Interstellar Medium, Turbulence, Magnetic Fields within the Central Molecular Zone

Using Pulsars to Measure Spacetime Around Sgr A*

Black Hole Mass

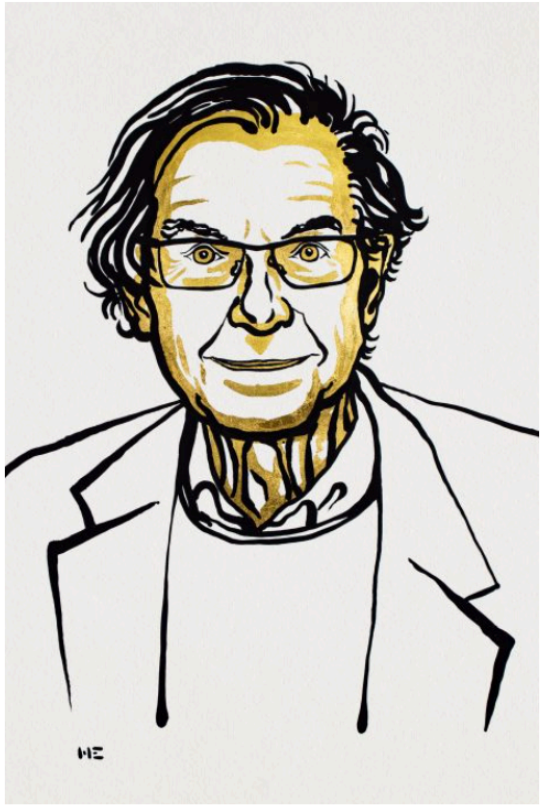


Black Hole Spin



Liu et al 2012

The Nobel Prize in Physics 2020



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Roger Penrose

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Reinhard Genzel

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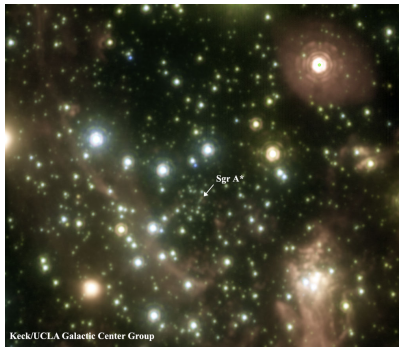
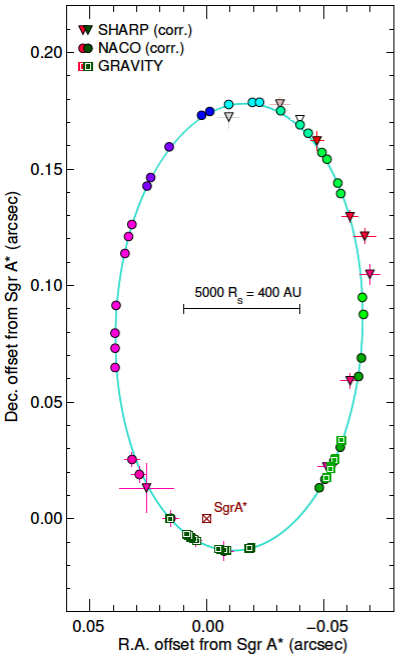
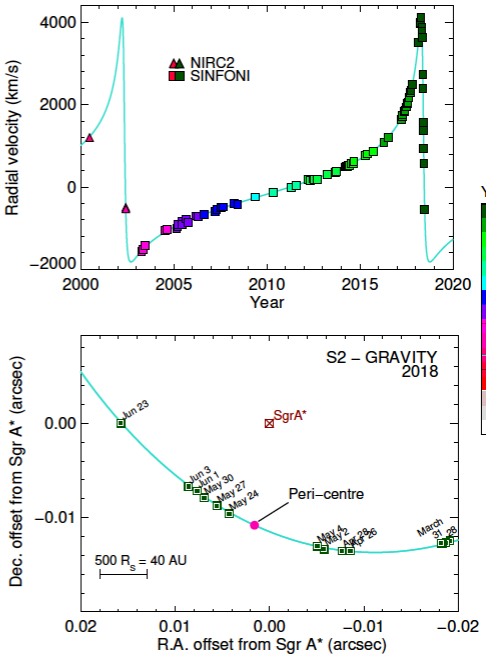
Andrea Ghez

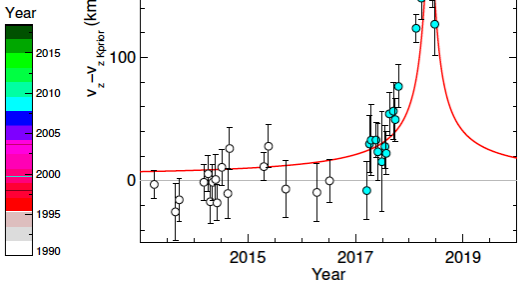
Event Horizon Telescope

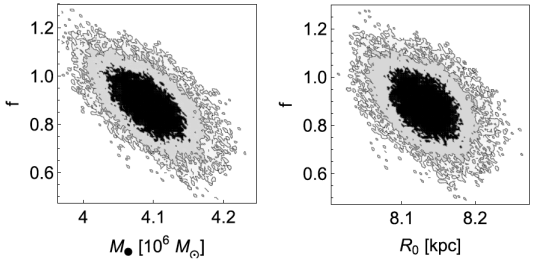
Strong Evidence for a Black Hole







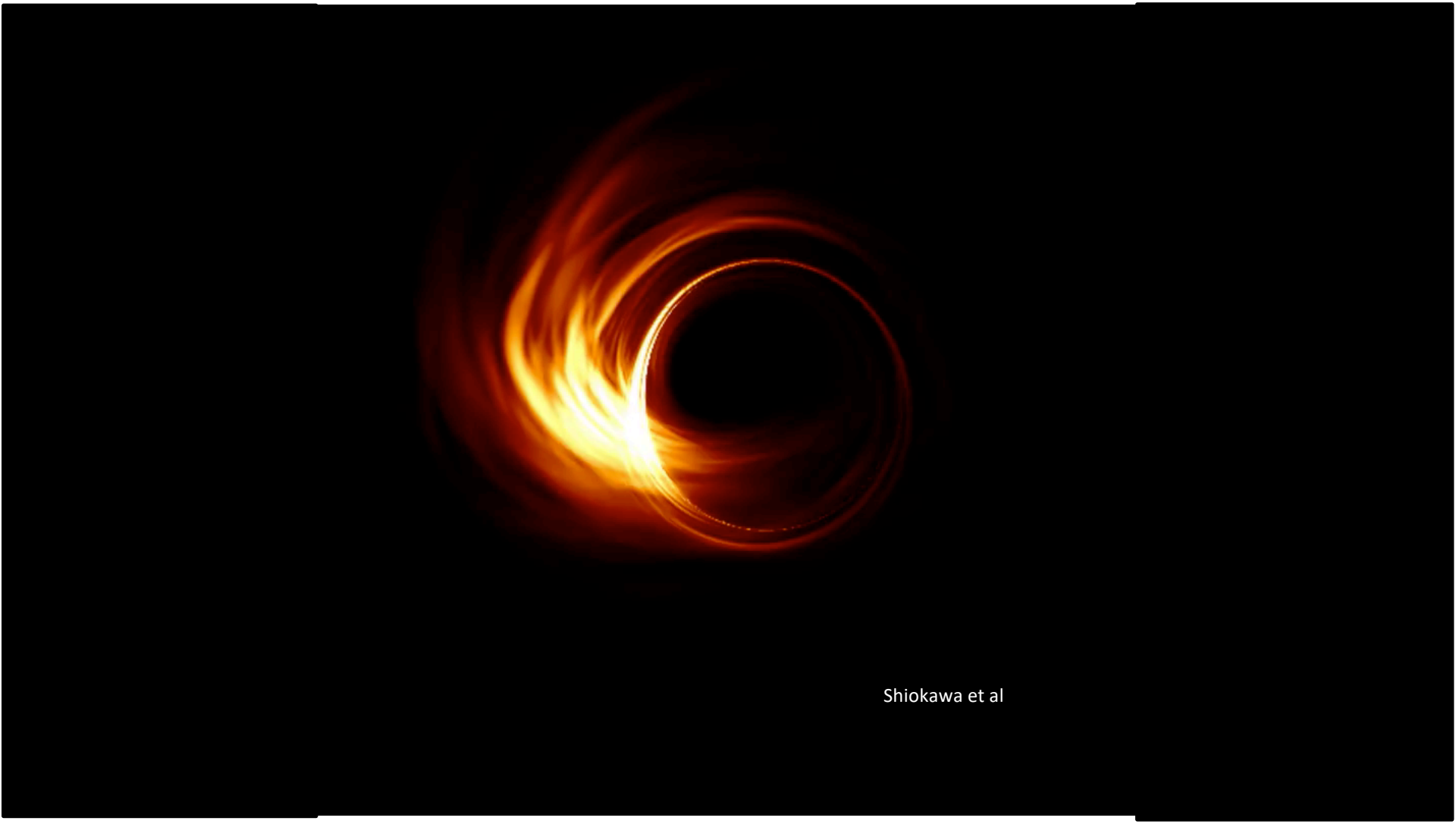




GRAVITY Collaboration 2018

Event Horizon Telescope

Event Horizon Telescope Imaging



Arches cluster

Cavity excavated by heavy stars

Quintuplet cluster

Milky Way centre

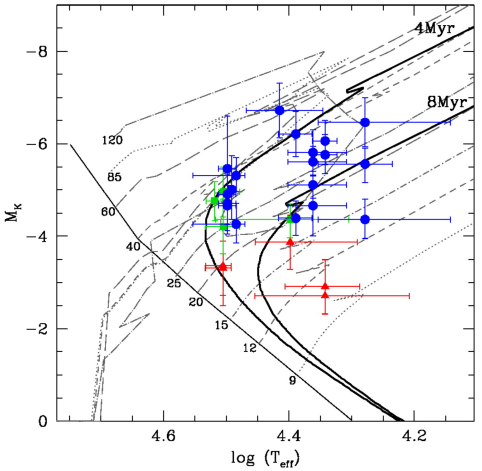
HST & Spitzer: Wang, Stolovy et al 2015

- WR+OB Stars
- T~2.5 – 5.8 Myr
- M~10^4 M_{sun}

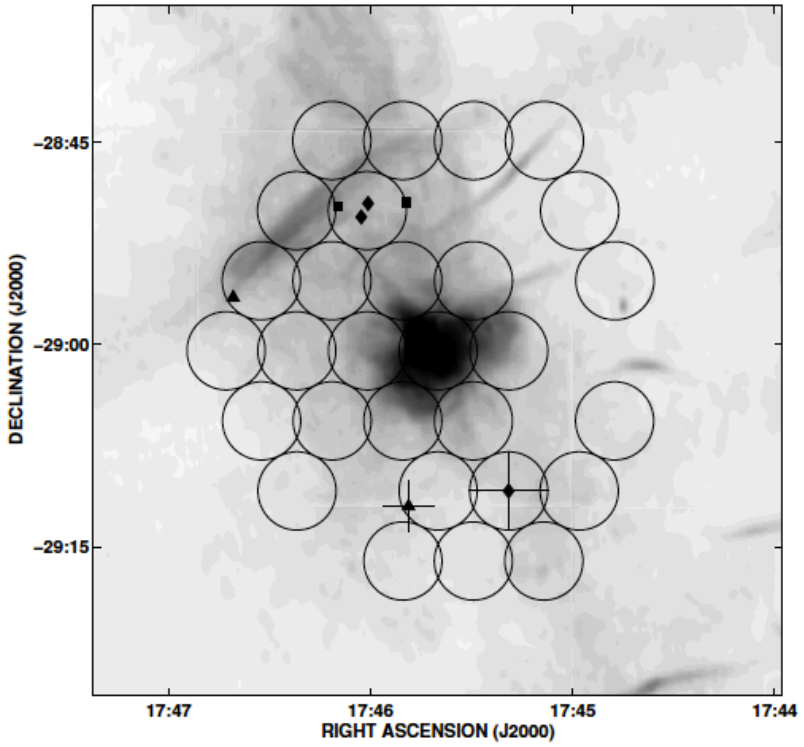
Paumard et al 2006, Lu et al 2013

- 10^3 pulsars with P < 100 y

Pfahl & Loeb 2004

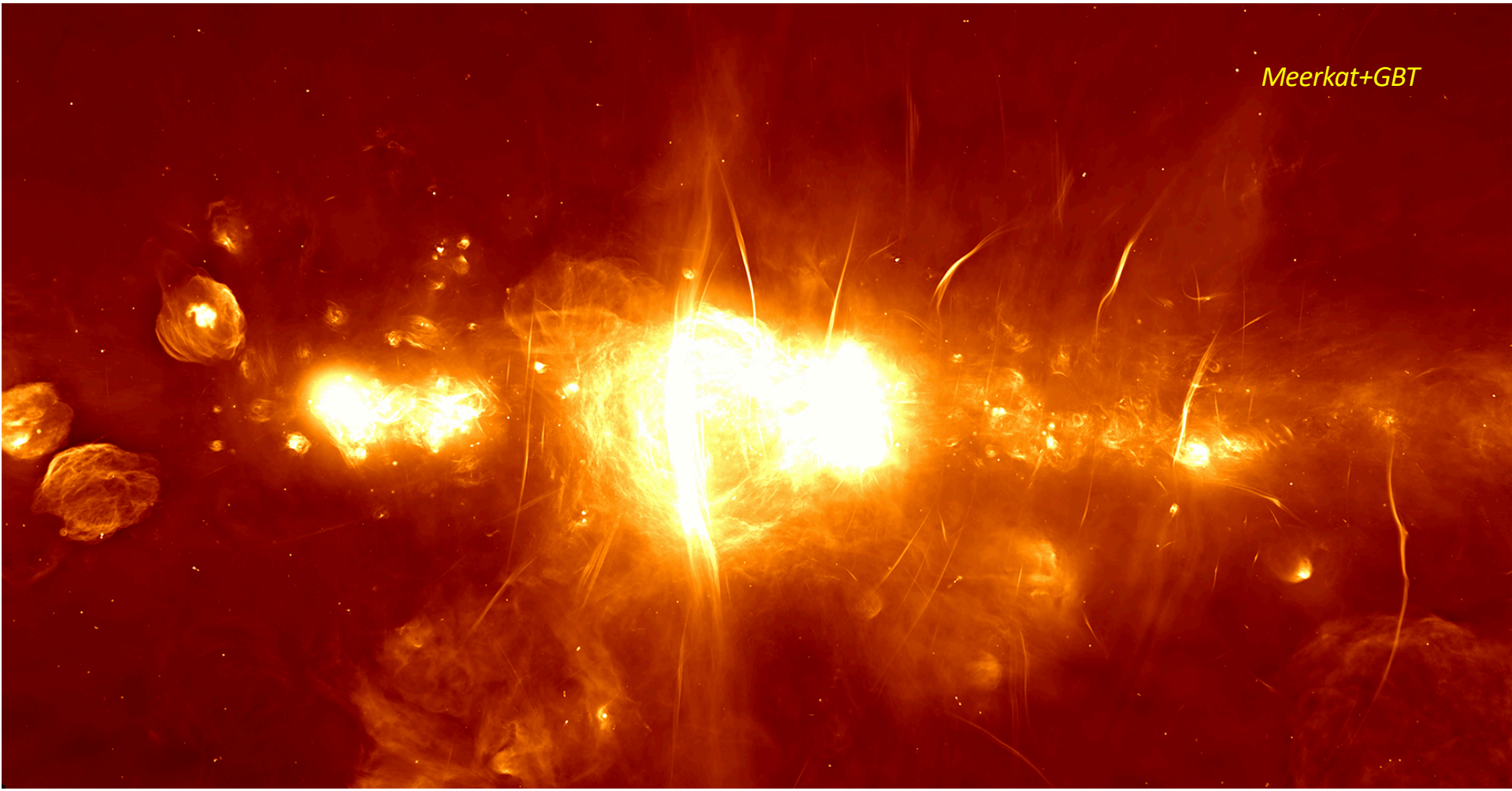


Known GC Pulsars

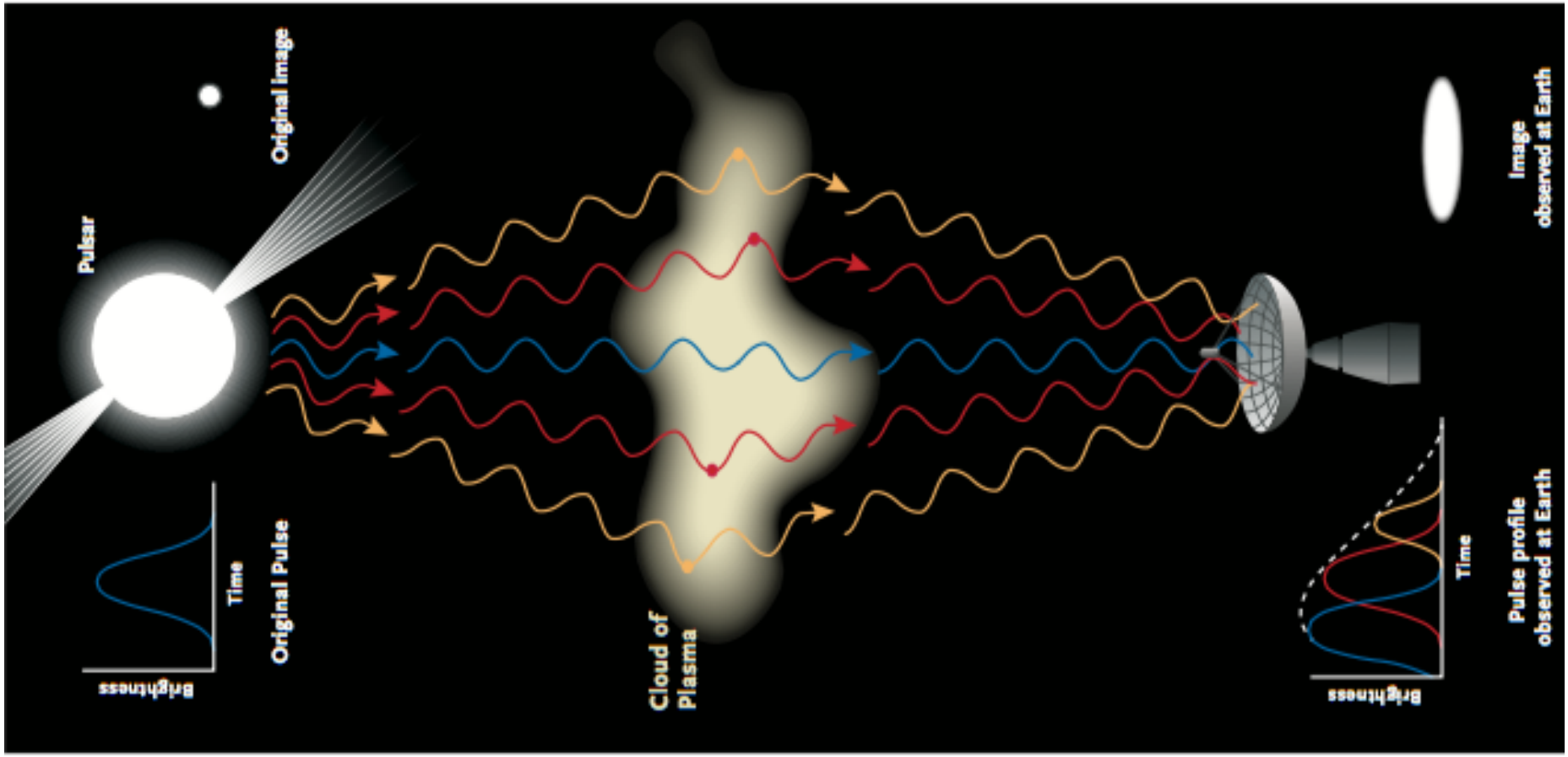


PSR	P (ms)	B (10^{12} G)	DM (pc cm^{-3})	τ_{sc} (2 GHz; ms)
1746-2850I	1077	38	962	100
1746-2850II	1478	3	1456	145
1745-2910	982	---	1088	---
1746−2856	945	4	1168	---
1745−2912	187	---	1130	144

Johnston et al. 2006
Deneva et al. 2009

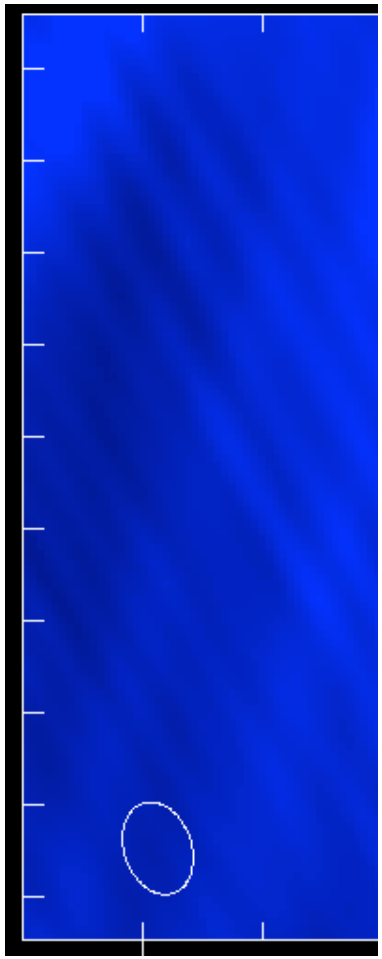

Meerkat+GBT

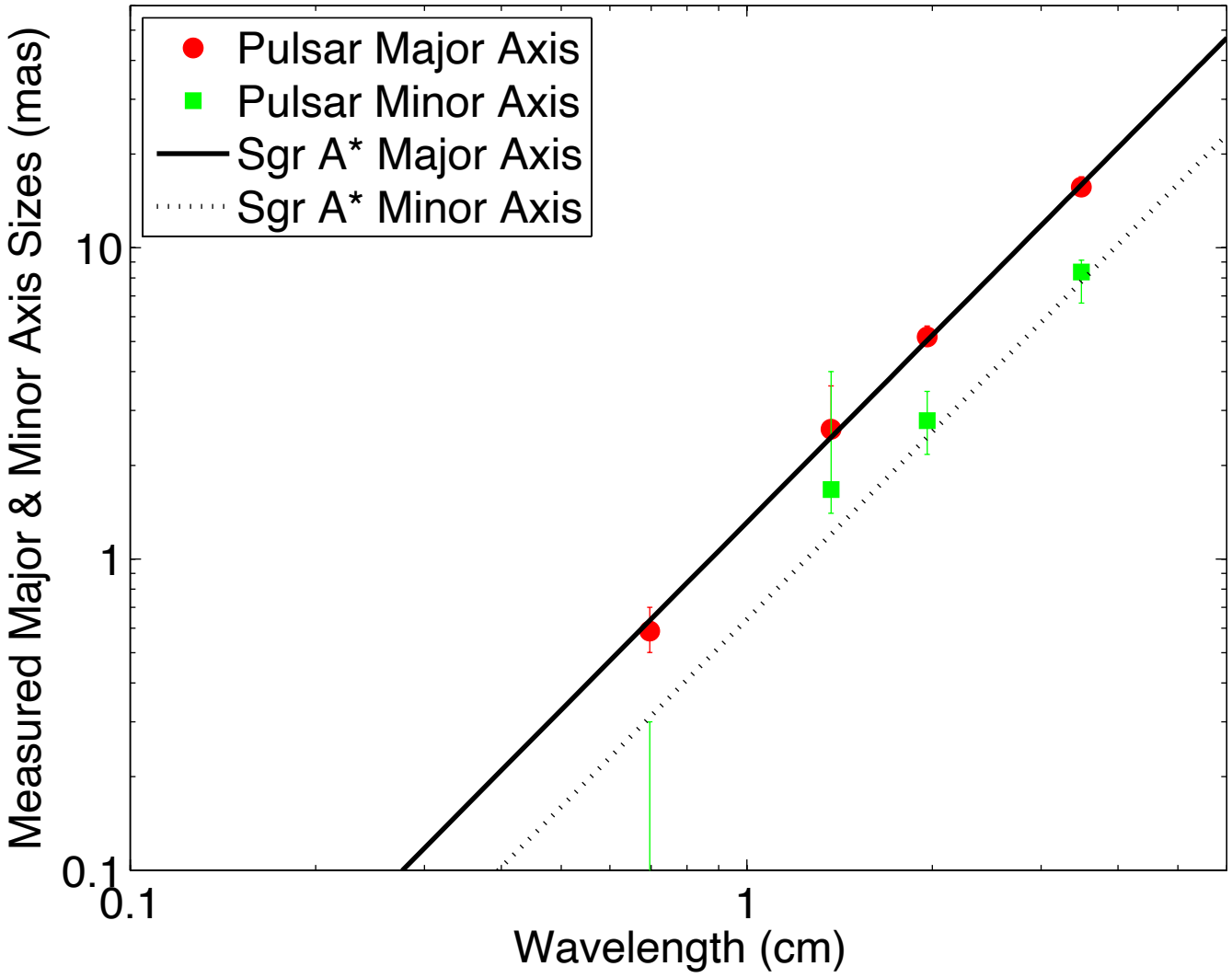
Scattering Inhibits Imaging & Pulsar Detection



Haggard & Bower, Sky & Tel, 2016

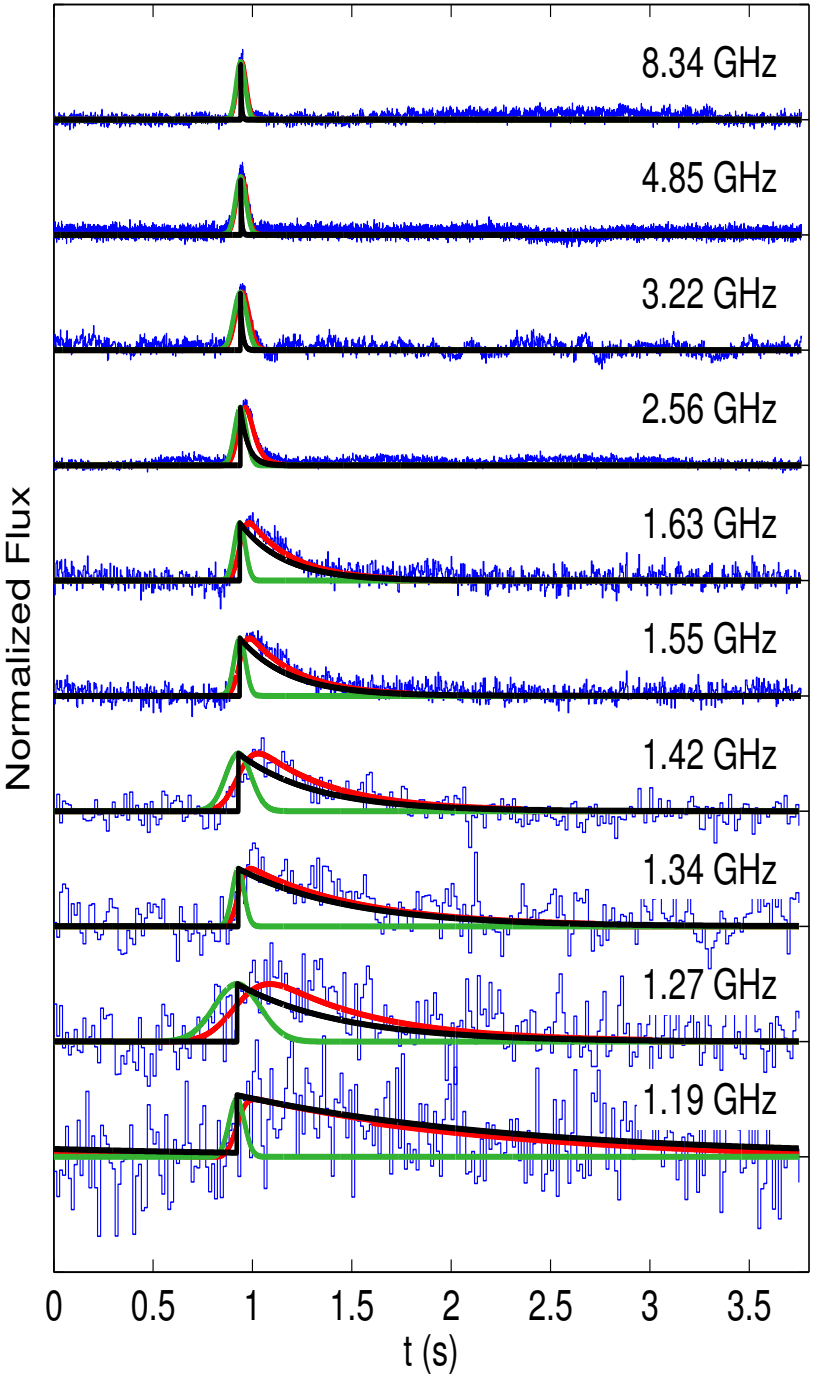
Angular Broadening of the Pulsar

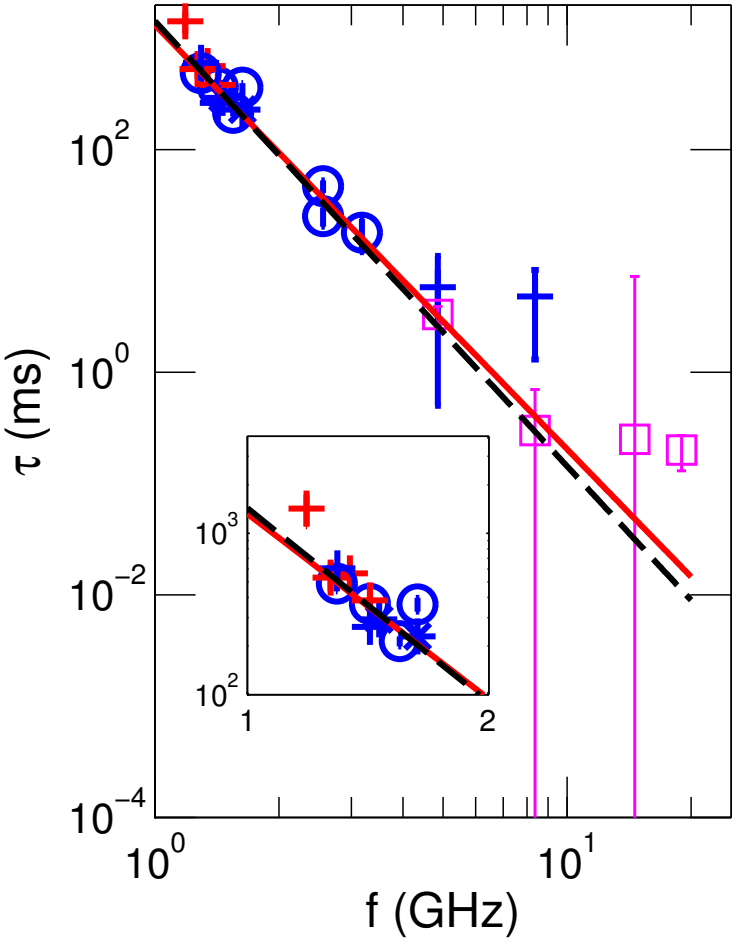




Bower et al. 2014

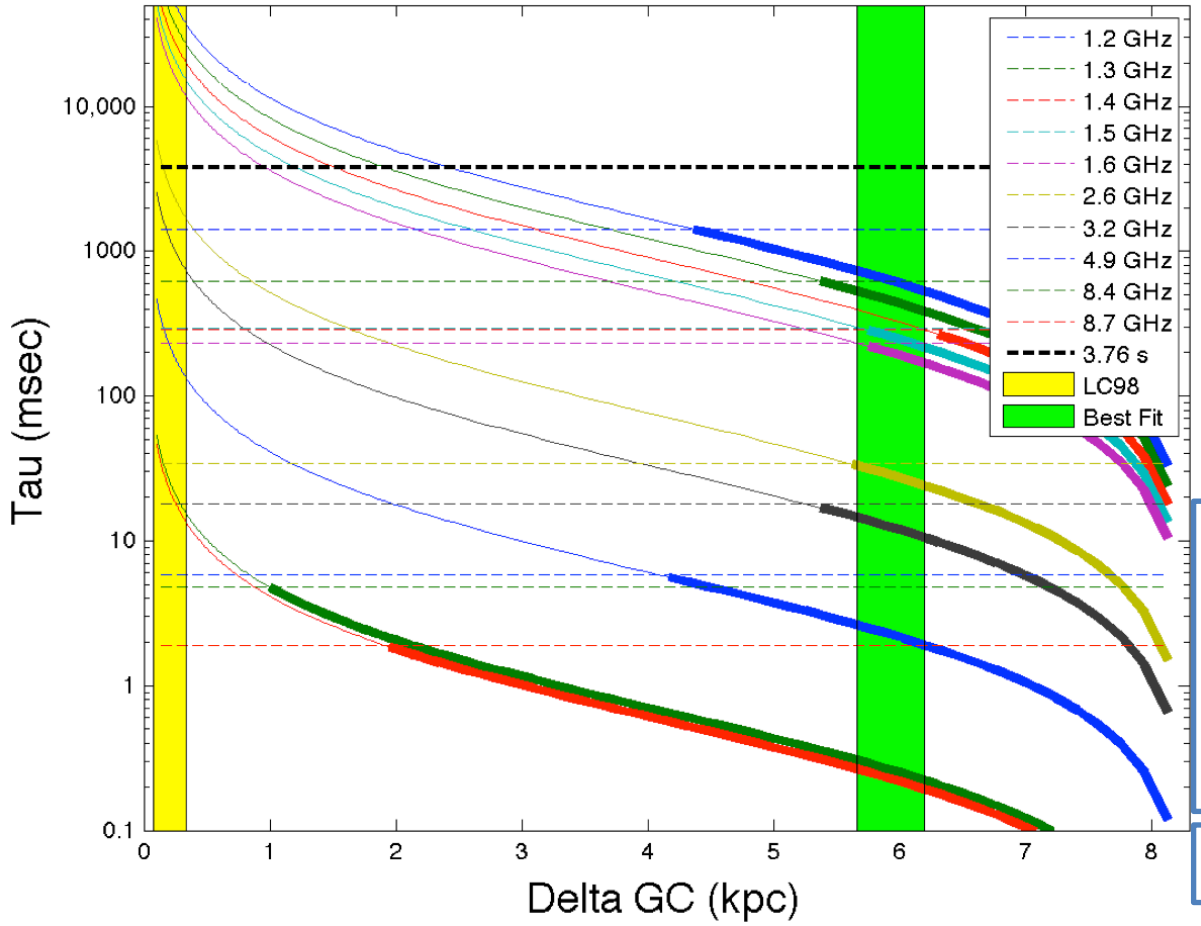
Temporal Scattering





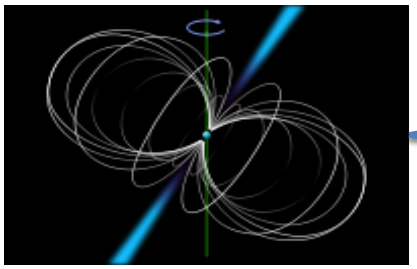
Spitler et al. 2014

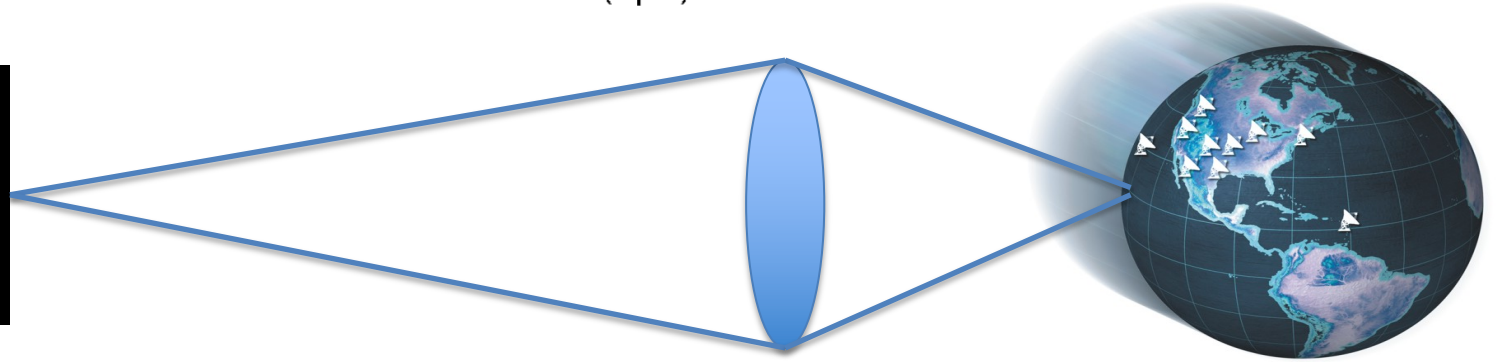
A New Distance for the GC Scattering Screen



Alternate Solution: Uniform Distribution of scatterers between GC & Sun

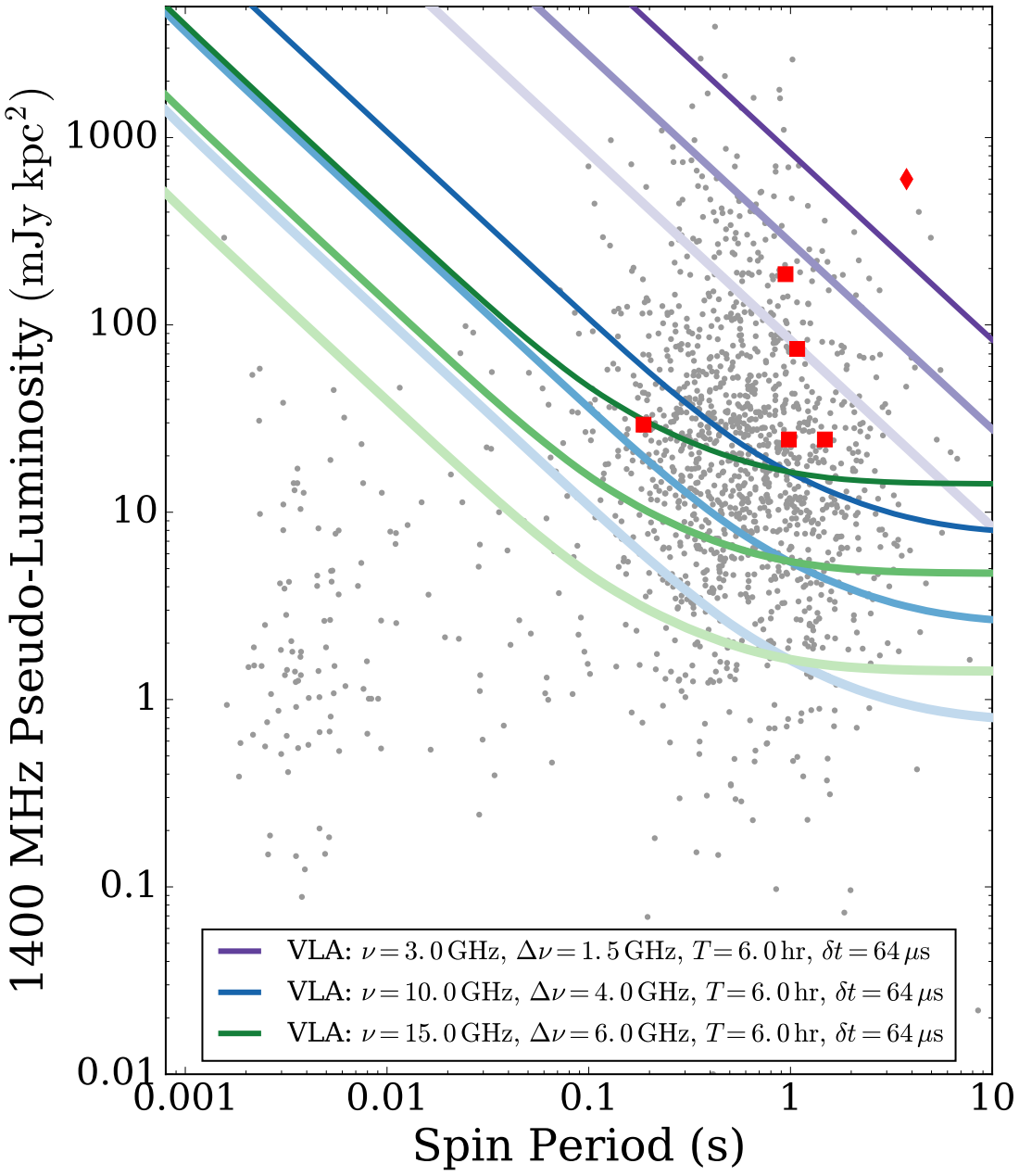
Bower et al. 2014



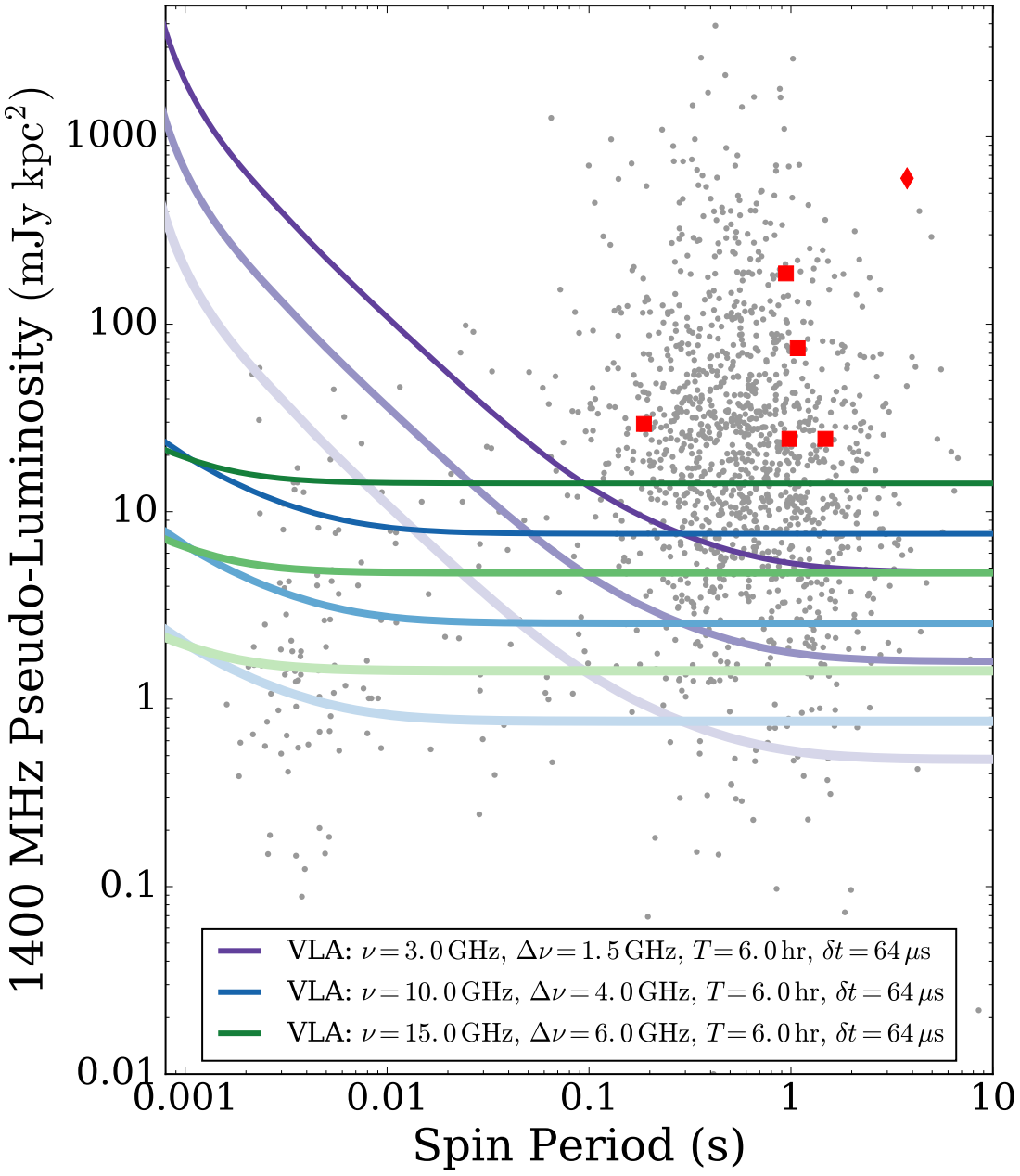


Hyperstrong Scattering

MSPs not detectable



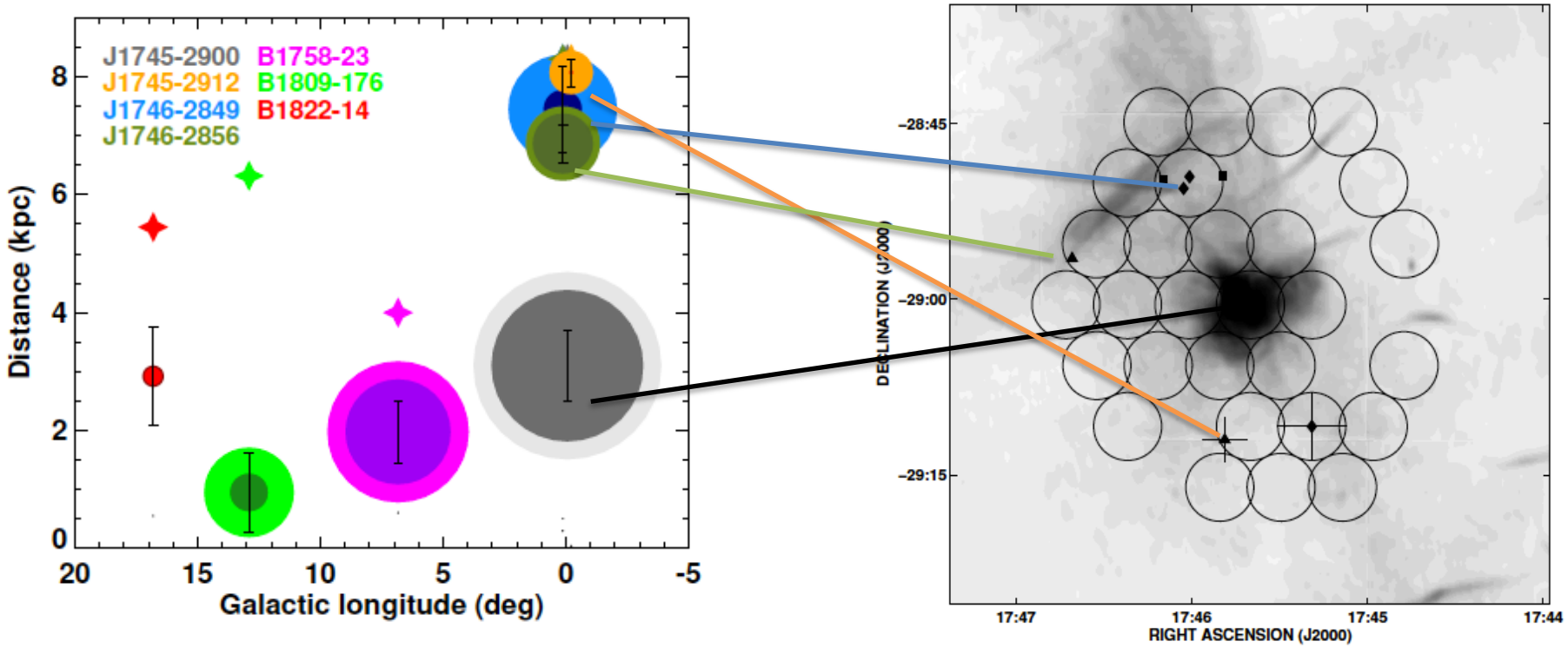
Galactic Plane Scattering



Key Probes of the GC Scattering

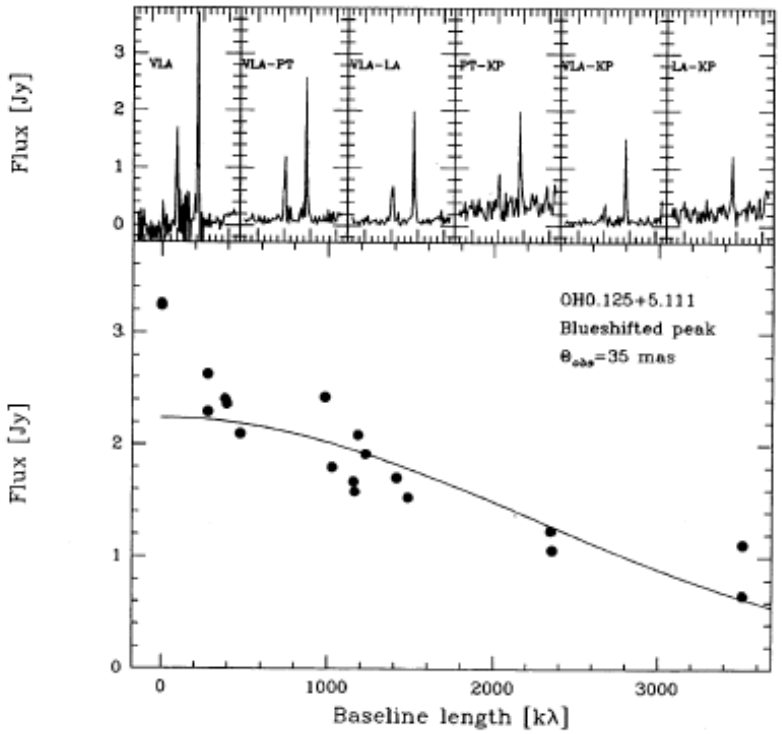
- Pulsar scattering
- OH/IR Stellar Masers
- Extragalactic background sources

Other GC Pulsar Scattering Indicates Complex, Patchy Scattering



Dexter et al 2017

OH/IR Stars



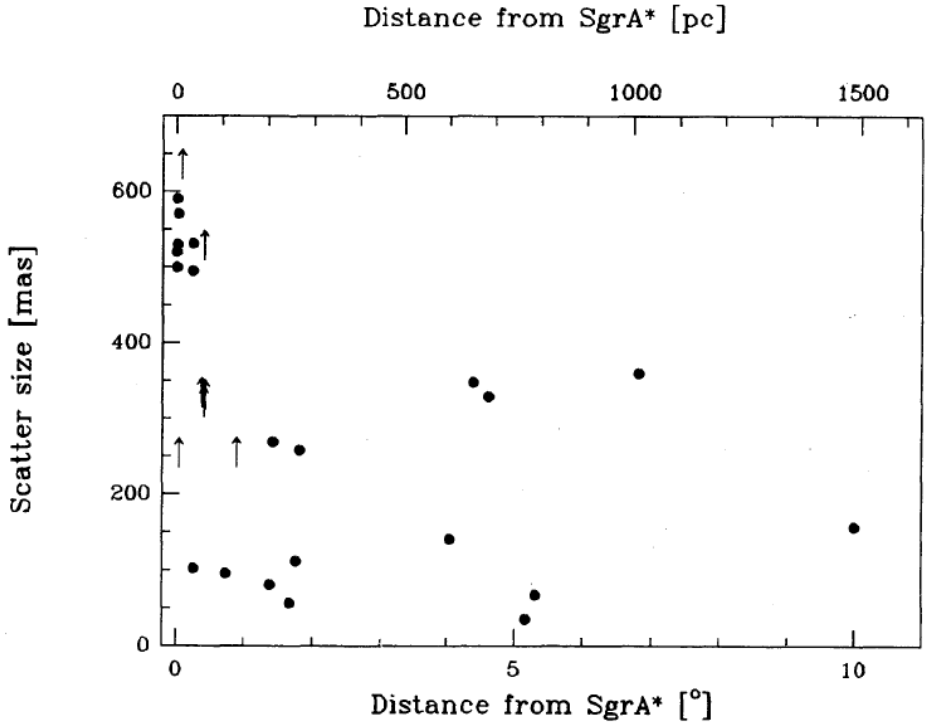
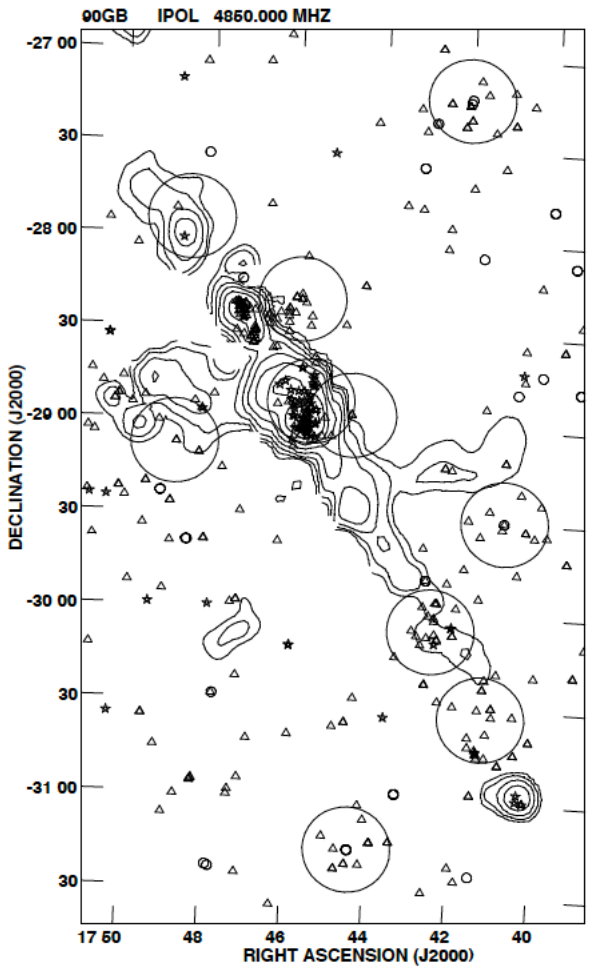
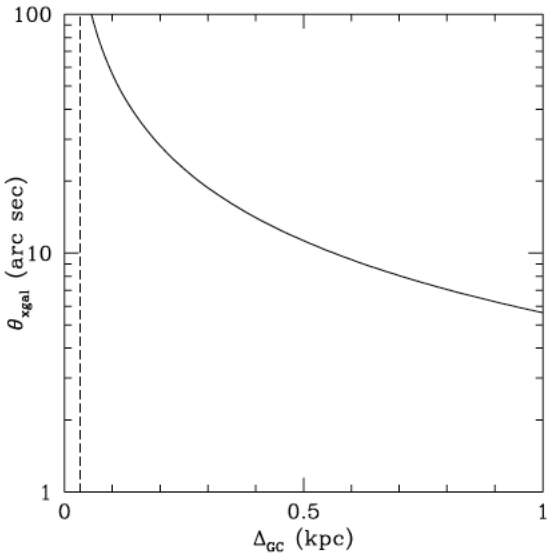


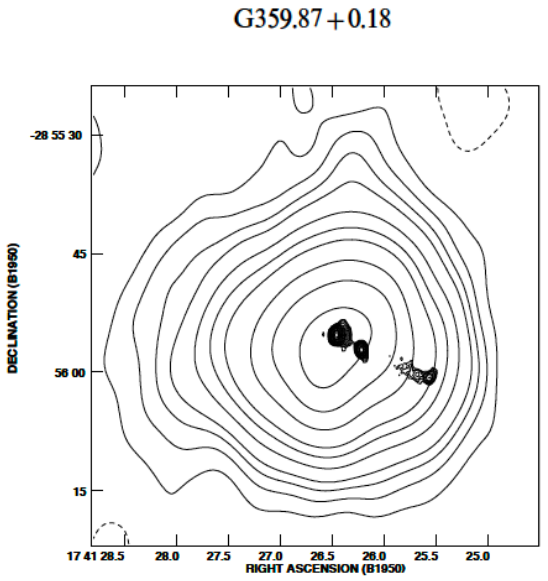
FIG. 3.—Plot of scatter sizes with distance from Sgr A*

Van Langevelde+ 1992

Extragalactic Background Sources

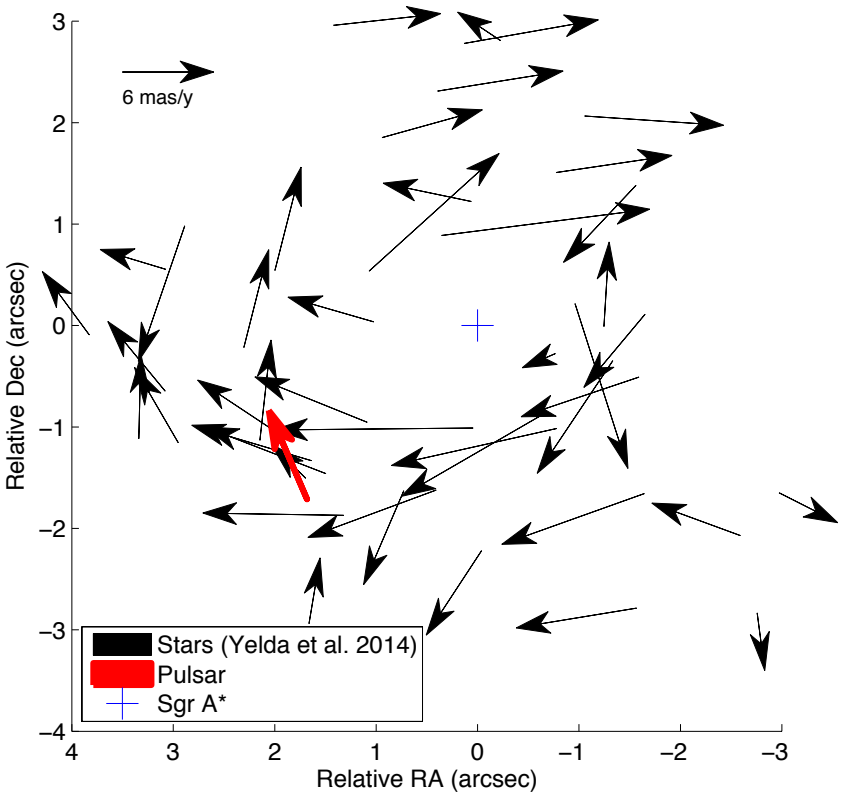






Lazio & Cordes 1998, Lazio et al 1999

The GC Pulsar Likely Originates in the Clockwise Stellar Disk



- V_{proj}=240 +/- 3 km s^{-1}
- R_{proj}=0.097 pc
- P>700 y

VLBA+Y1 Astrometry

Summary

- Missing Galactic Center pulsars is an ongoing and significant Problem
  - Gravity
  - Star-formation, stellar death
  - ISM
- Characterization of the large-scale GC scattering medium and pulsar problem is key to understanding and may be key for discovery of a Sgr A*-bound pulsar
- How unique is the GC scattering?
- High-sensitivity at long wavelengths will be powerful