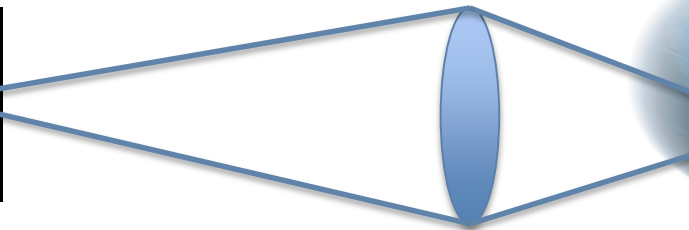
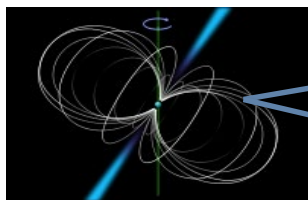
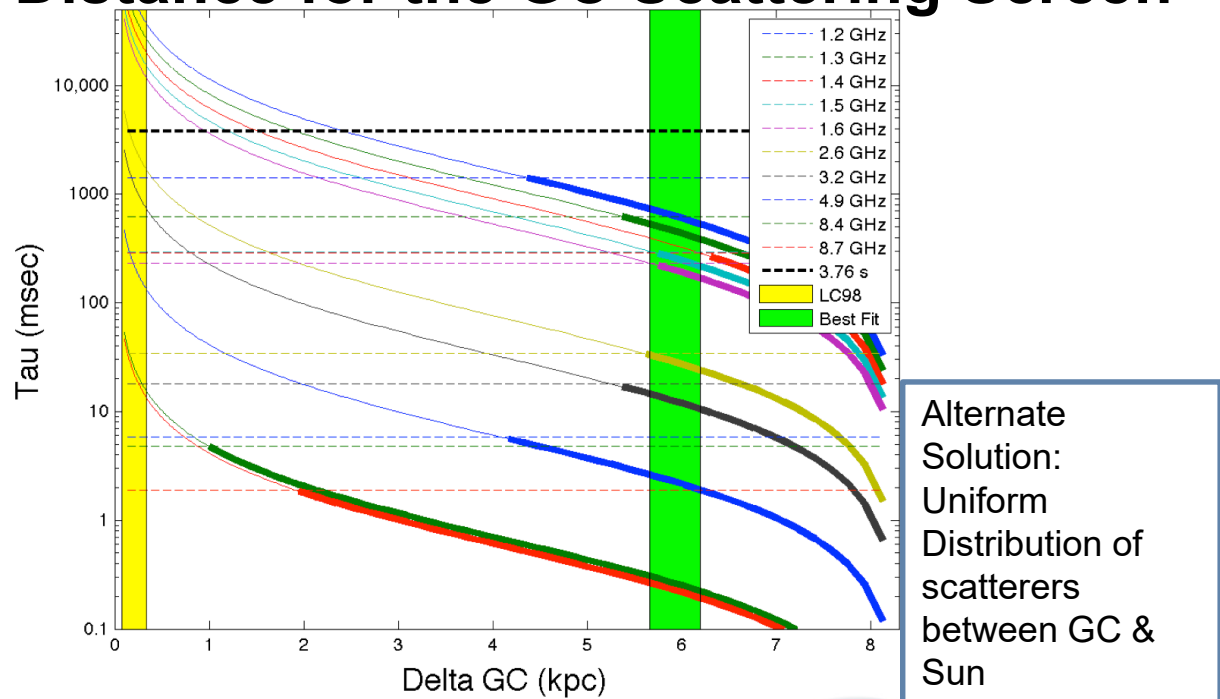


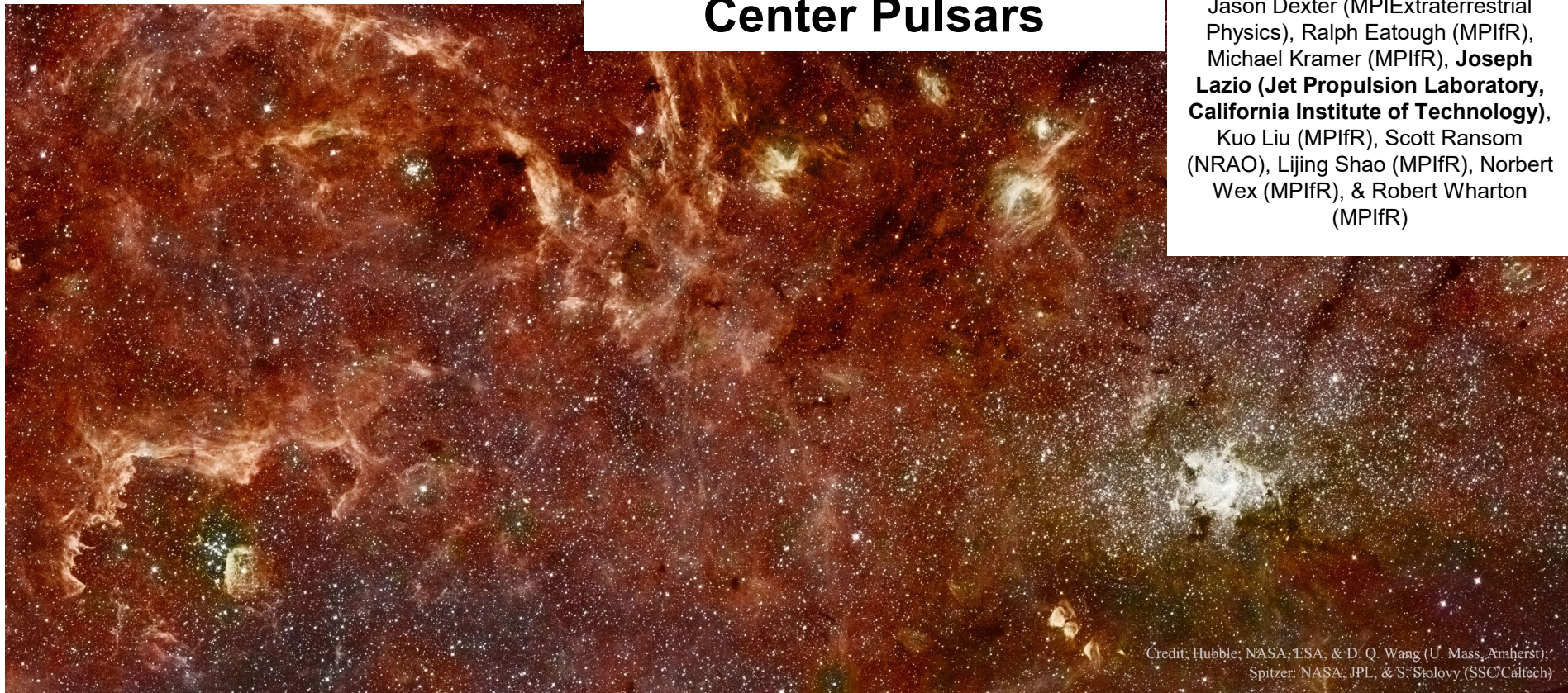
A New Distance for the GC Scattering Screen



Radio-Millimeter Astrophysical Frontiers
in the Next Decade

Testing Theories of Gravity with Galactic Center Pulsars

Geoffrey C. Bower (ASIAA), Shami Chatterjee (Cornell), James M. Cordes (Cornell), Paul Demorest (NRAO), Julia S. Deneva (George Mason-NRL), Jason Dexter (MPI Extraterrestrial Physics), Ralph Eatough (MPIfR), Michael Kramer (MPIfR), **Joseph Lazio (Jet Propulsion Laboratory, California Institute of Technology)**, Kuo Liu (MPIfR), Scott Ransom (NRAO), Lijing Shao (MPIfR), Norbert Wex (MPIfR), & Robert Wharton (MPIfR)



Credit: Hubble; NASA, ESA, & D. Q. Wang (U. Mass., Amherst);
Spitzer; NASA, JPL, & S. Stolovy (SSC/Caltech)

Testing Black Hole Physics with Pulsars

Solid: VLA; Dashed: ngVLA

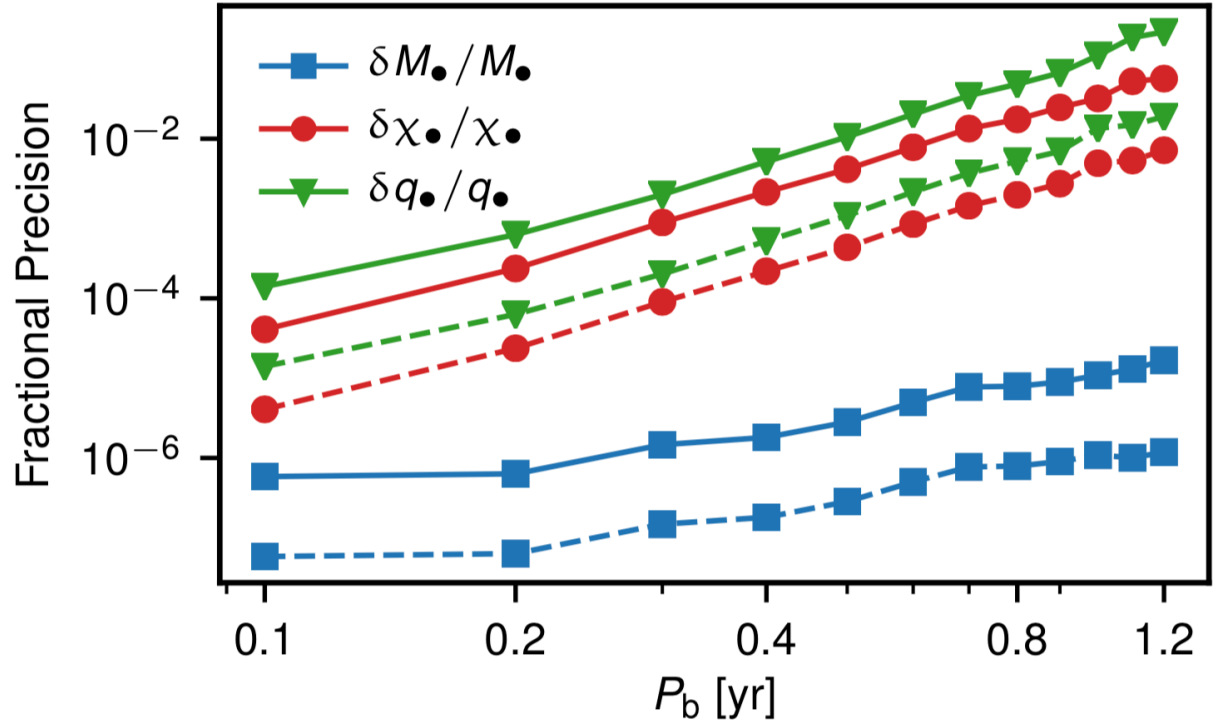
Time $P = 0.5$ s
pulsar around Sgr
A*

What constraints on
Sgr A* properties
derived?

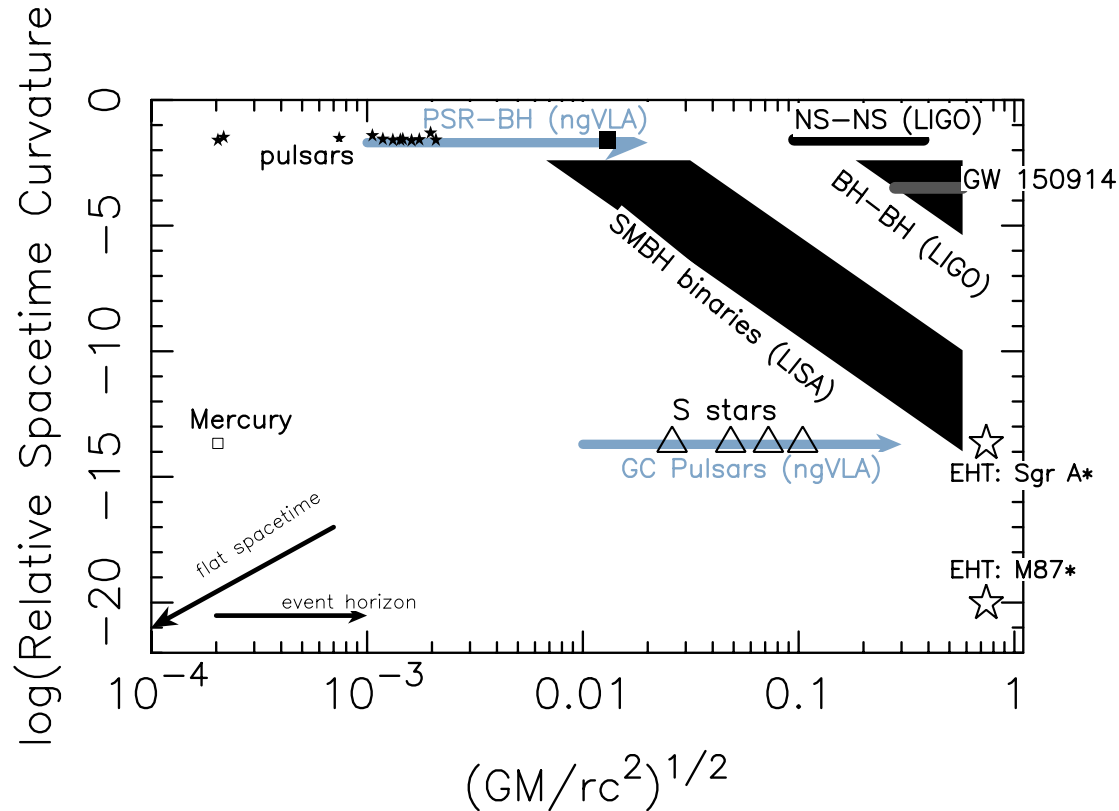
$\delta M_{\bullet}/M_{\bullet}$ = mass
measurement

$\Delta\chi_{\bullet}/\chi_{\bullet} = \delta a_{\bullet}/a_{\bullet}$ = spin
parameter

$\delta q_{\bullet}/q_{\bullet}$ = quadrupole
moment
measurement

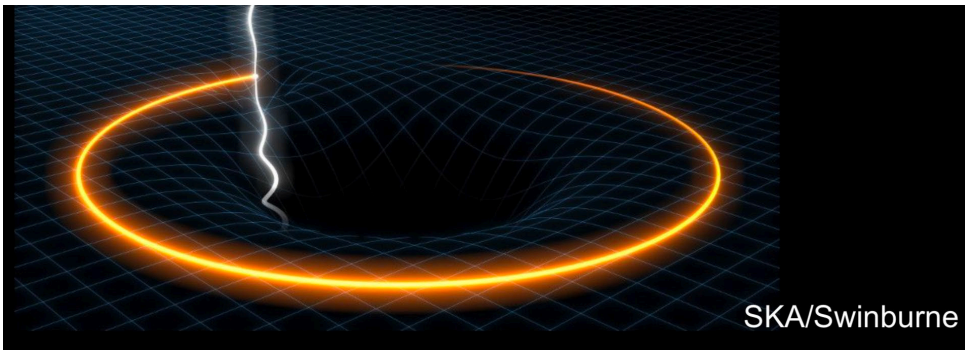


Testing Black Hole Physics with Pulsars



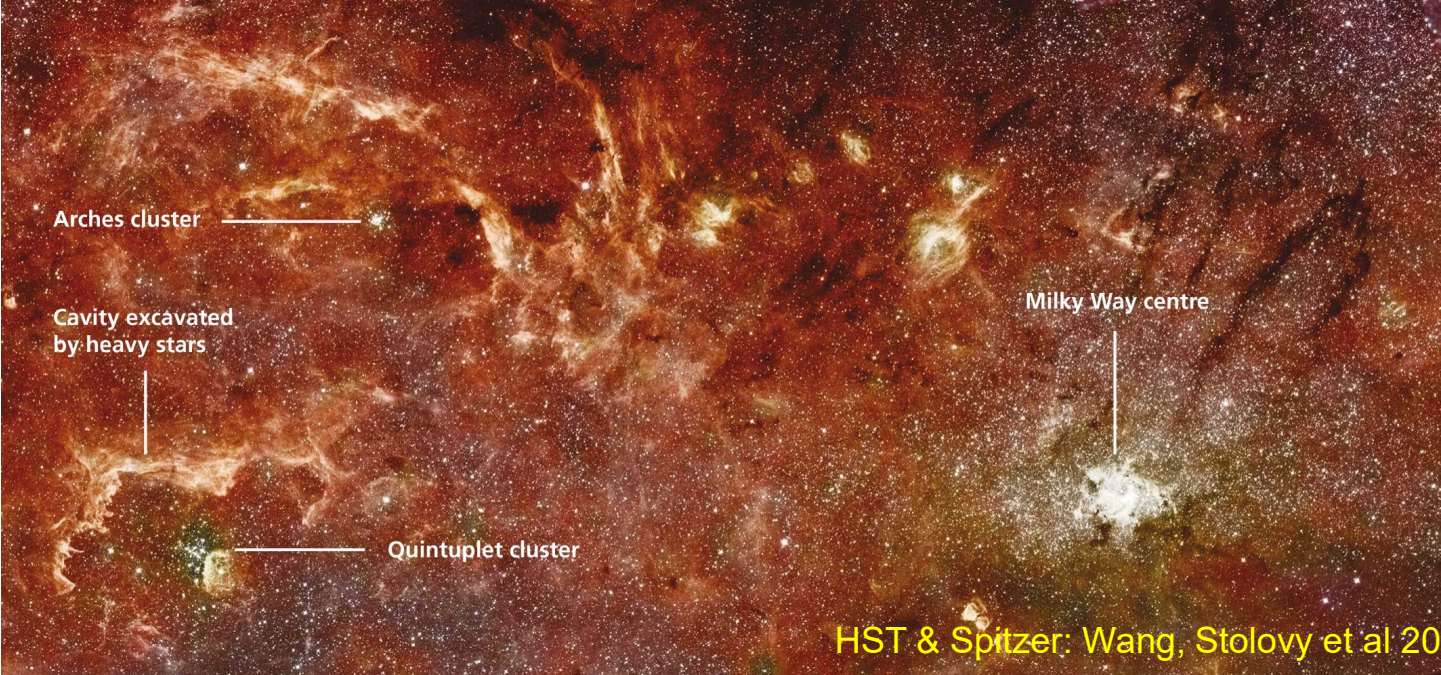
Pulsar-Black Hole Binaries

What To Do With Them ...



Exceptional GR tests (e.g., Seymour & Yagi 2019)

- **Testing No-Hair properties** (Psaltis et al. 2016; Liu et al. 2012, 2014)
- **Quadrupole moment** (Wex & Kopeikin 1999; Psaltis et al. 2016)
- **Scalar-Tensor theories** (Liu et al. 2014; Wex et al. 2012)
- **High-curvature theories** (Yagi et al. 2016)
- **Higher-dimensional gravity** (Simonetti et al. 2011)
- **Quantum gravity effects** (Estes et al. 2017)



HST & Spitzer: Wang, Stolovy et al 2015

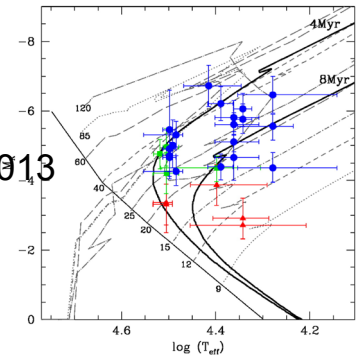


Arches
Stolte et al 2015

- WR+OB Stars
- $T \sim 2.5 - 5.8$ Myr
- $M \sim 10^4 M_{\text{sun}}$

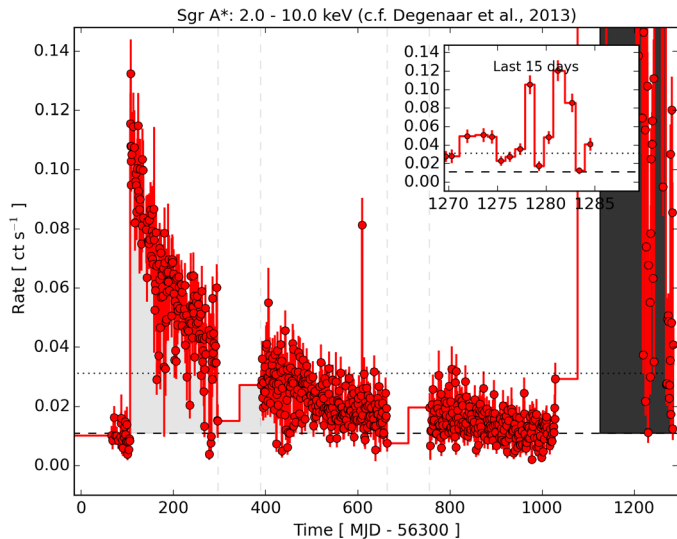
Paumard et al 2006, Lu et al 2013

- 10^3 pulsars with $P < 100$ y
- Pfahl & Loeb 2004



Galactic Center Magnetar Discovery

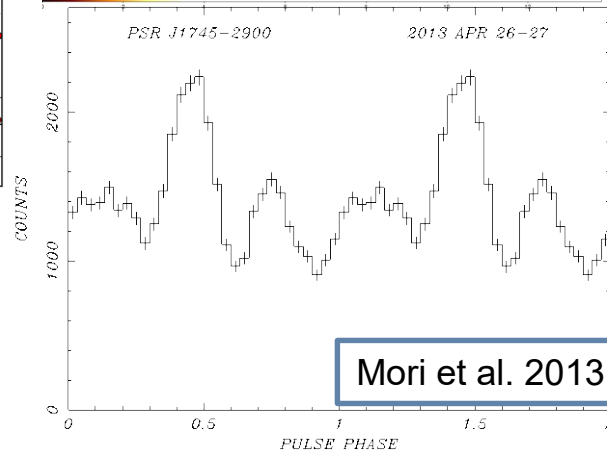
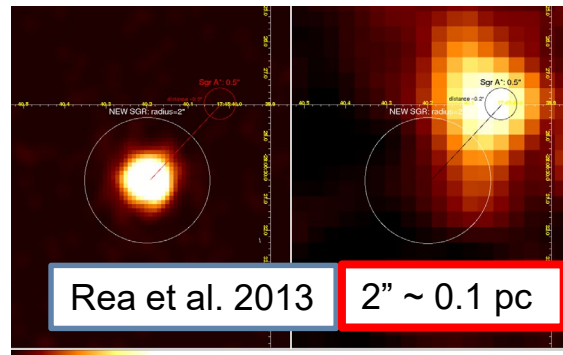
X-Ray Burst



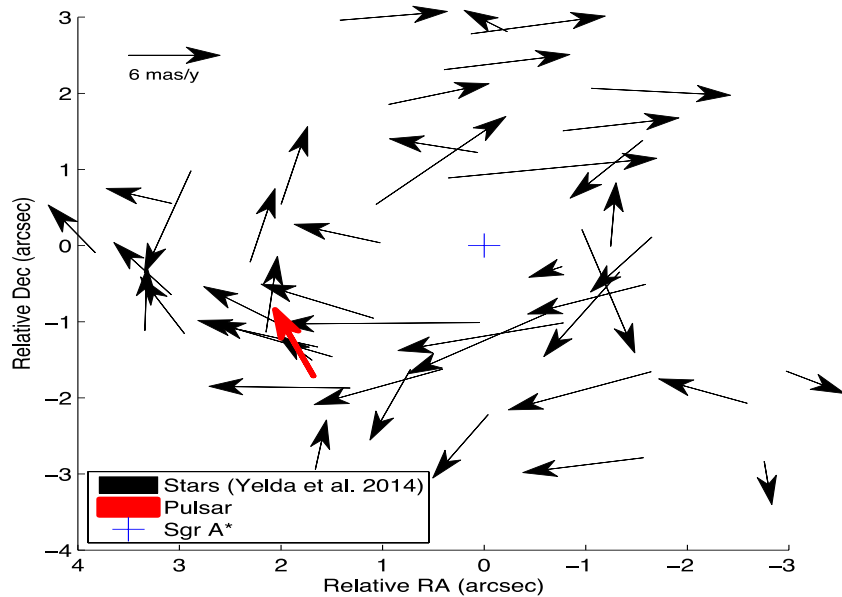
Degenaar et al. 2013
Kennea et al. 2013

SGR J1745-29

X-ray Localization: $\sim 2''$ to Sgr A*

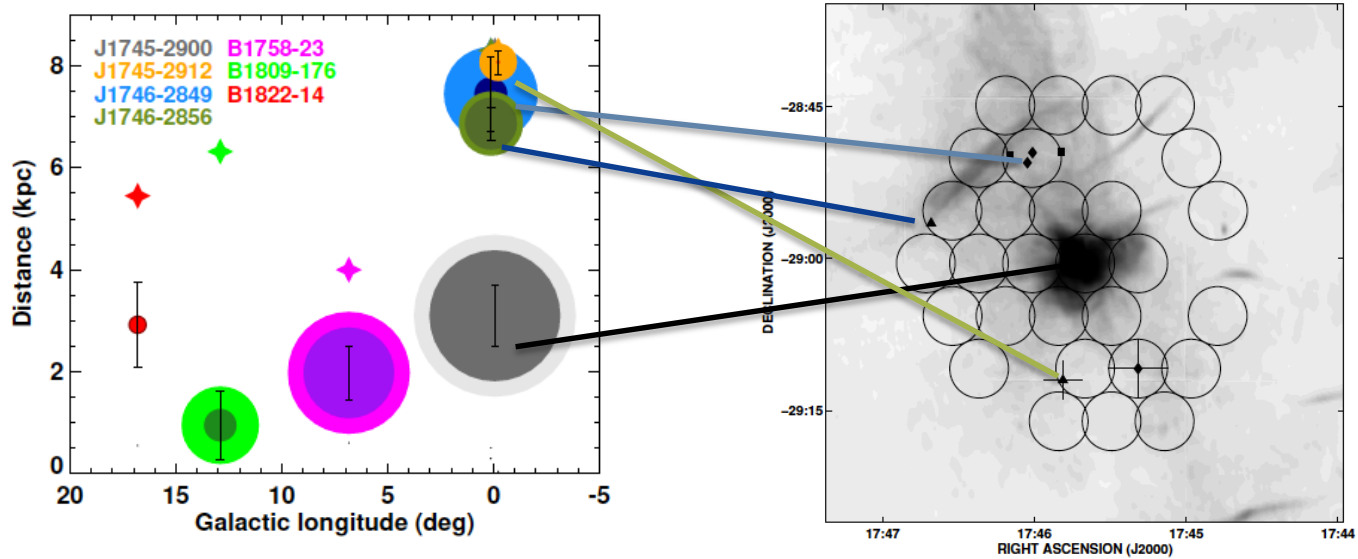


The GC Pulsar Likely Originates in the Clockwise Stellar Disk



- $V_{\text{proj}} = 240 \pm 3 \text{ km s}^{-1}$
- $R_{\text{proj}} = 0.097 \text{ pc}$
- $P > 700 \text{ y}$
- Acceleration measures $|z|$ and would conclusively demonstrate that the PSR is bound to Sgr A*

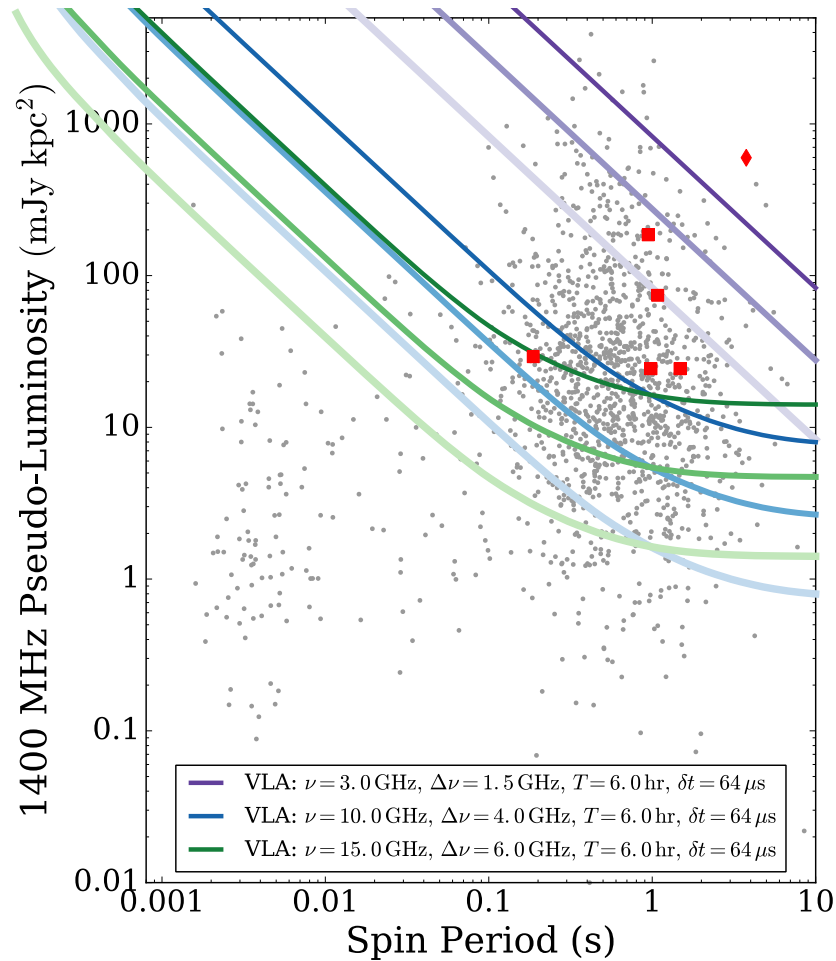
Other GC Pulsar Scattering Indicates Complex, Patchy Scattering



Dexter et al 2017

Hyperstrong Scattering

MSPs not detectable



Galactic Plane Scattering

