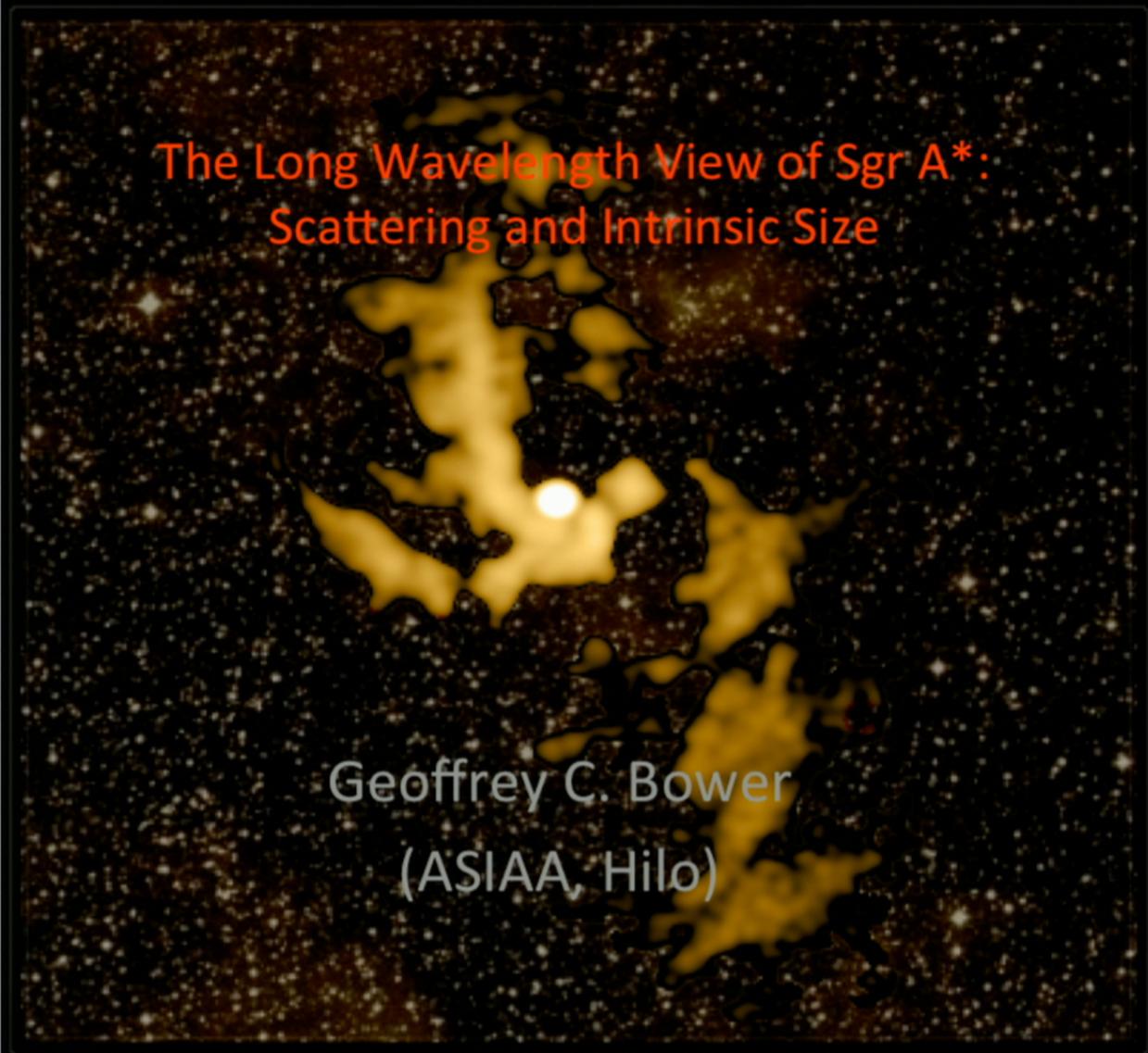


Title: The Size and Morphology of Sgr A* at 7mm

Date: Nov 10, 2014 11:35 AM

URL: <http://pirsa.org/14110067>

Abstract: Long wavelength measurements provide sensitive probes of the intrinsic structure of Sgr A* and of the scattering properties of the line-of-sight interstellar medium. At this wavelength, scattering dominates the apparent size of the source but careful closure amplitude techniques can provide highly accurate structural information. We present new results from the VLBA at 7mm wavelength that for the first time reveal two-dimensional intrinsic structure while also demonstrating the stability of the intrinsic size during periods of significant activity at NIR and X-ray wavelengths. These results also demonstrate the stability of the scattering medium over time. New observations of the Galactic Center pulsar PSR J1745-2900 show that the scattering properties of Sgr A* are spatially coherent over an angular scale of at least a few arc seconds. Analysis of the angular and temporal broadening data for the pulsar place the scattering medium at a distance of kiloparsecs away from the Galactic Center, resolving a significant mystery regarding the scattering medium.



The Long Wavelength View of Sgr A*:
Scattering and Intrinsic Size

Geoffrey C. Bower
(ASIAA, Hilo)

THE INTRINSIC TWO-DIMENSIONAL SIZE OF SAGITTARIUS A*

Geoffrey C. Bower^{1,2}, Sera Markoff³, Andreas Brunthaler⁴, Casey Law², Heino Falcke^{4,5,6}, Dipankar Maitra⁷, M. Clavel^{8,9}, A. Goldwurm^{8,9}, M. R. Morris¹⁰, Gunther Witzel¹⁰, Leo Meyer¹⁰, and A. M. Ghez¹⁰

A strong magnetic field around the supermassive black hole at the centre of the Galaxy

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

PULSE BROADENING MEASUREMENTS FROM THE GALACTIC CENTER PULSAR J1745-2900

L. G. Spitler¹, K. J. Lee¹, R. P. Eatough¹, M. Kramer^{1,2}, R. Karuppusamy¹, C. G. Bassa², I. Cognard³, G. Desvignes¹, A. G. Lyne², B. W. Stappers², G. C. Bower⁴, J. M. Cordes⁵, D. J. Champion¹, and H. Falcke^{1,6,7}

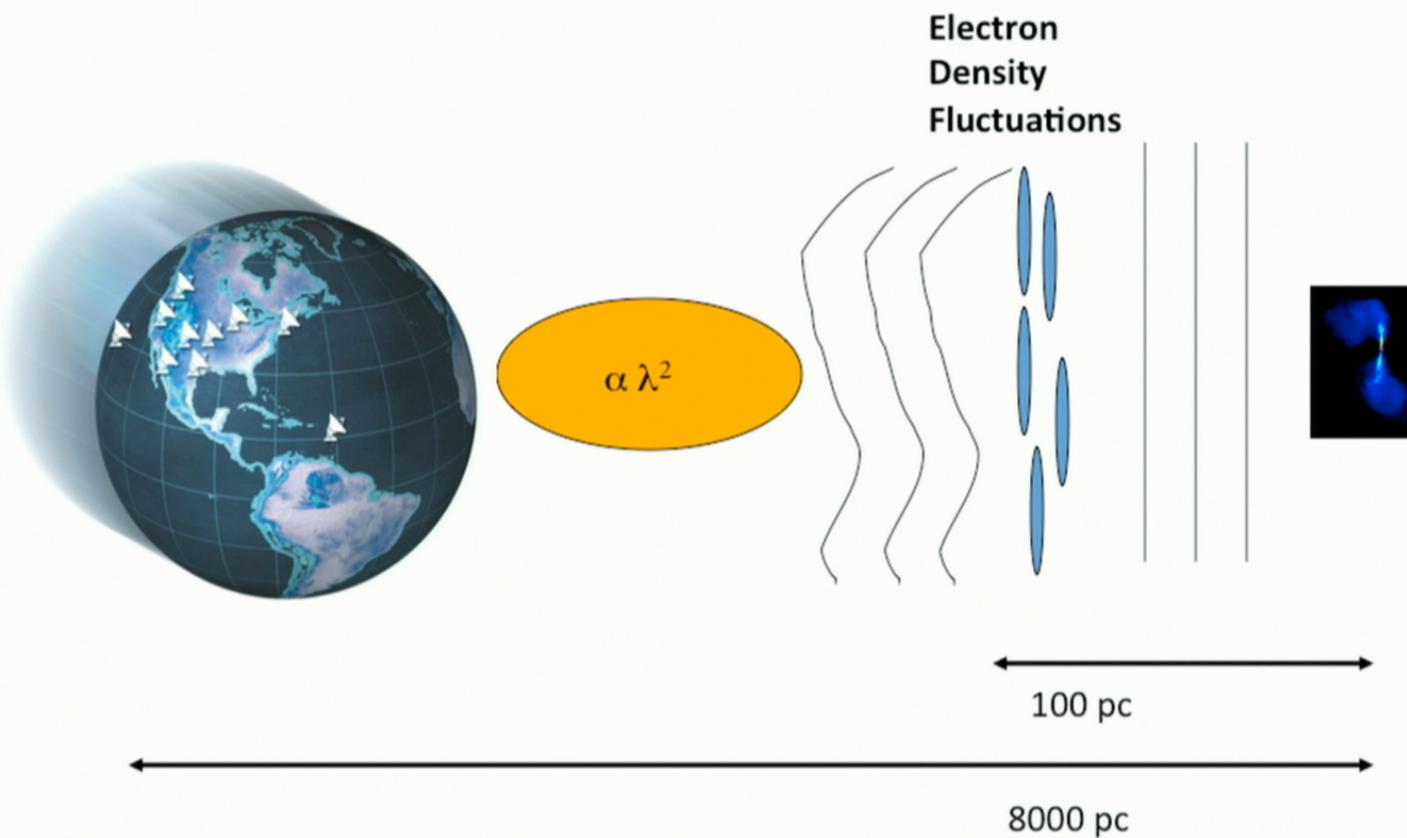
THE ANGULAR BROADENING OF THE GALACTIC CENTER PULSAR SGR J1745-29: A NEW CONSTRAINT ON THE SCATTERING MEDIUM

Geoffrey C. Bower¹, Adam Deller², Paul Demorest³, Andreas Brunthaler⁴, Ralph Eatough⁴, Heino Falcke^{2,4,5}, Michael Kramer⁴, K. J. Lee⁴, and Laura Spitler⁴

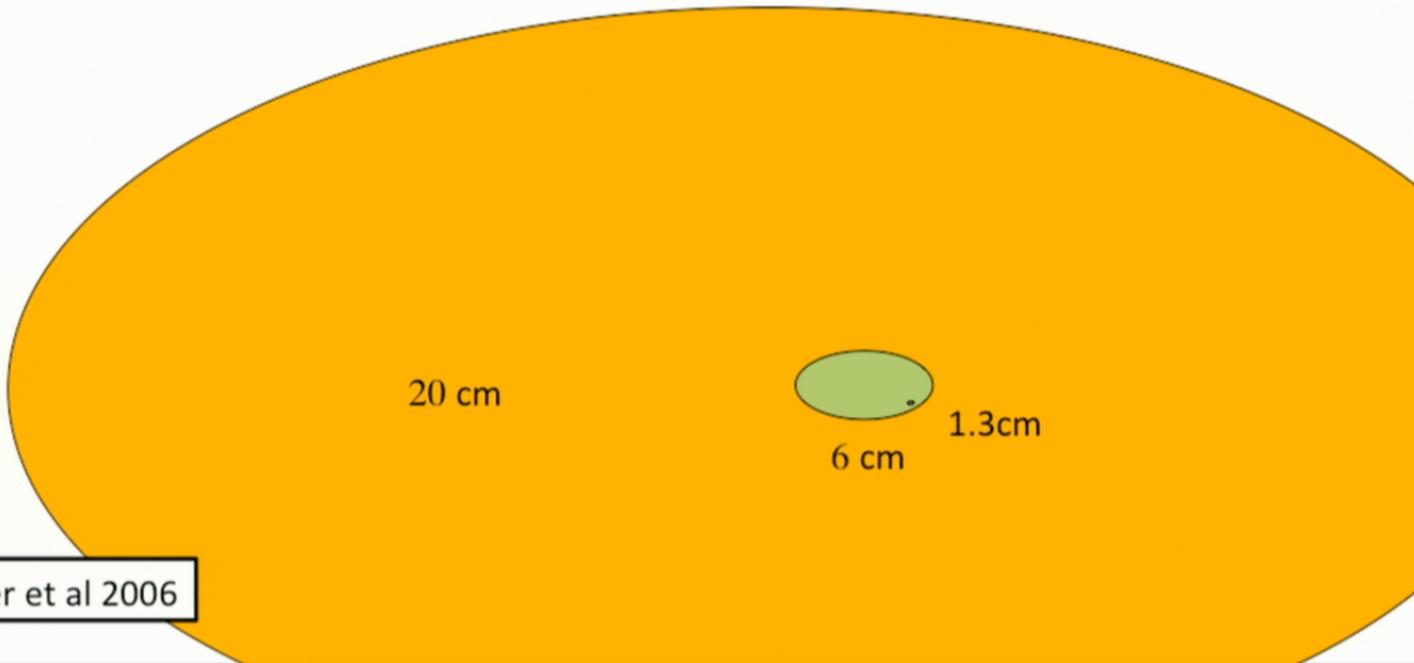
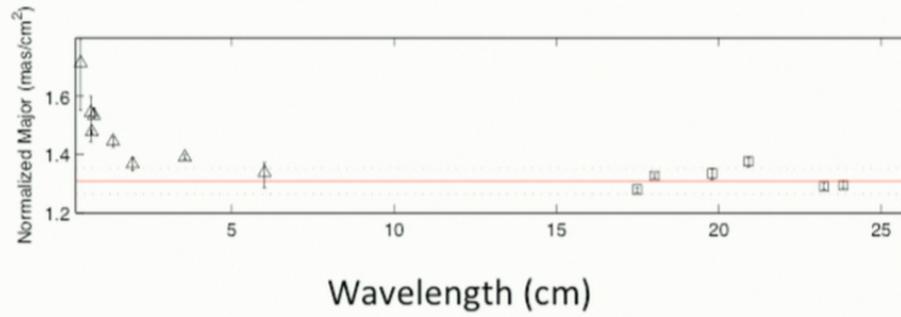
The Proper Motion of the Galactic Center Pulsar Relative to Sagittarius A*

Geoffrey C. Bower¹, Adam Deller², Paul Demorest³, Andreas Brunthaler⁴, Heino Falcke^{5,2,4}, Monika Moscibrodzka⁵, Ryan M. O'Leary⁶, Ralph P. Eatough⁴, Michael Kramer^{4,7}, K.J. Lee⁴, Laura Spitler⁴, Gregory Desvignes⁴, Anthony P. Rushton^{8,9}, Sheperd Doeleman^{10,11}, Mark J. Reid¹¹

Scattering Inhibits Imaging

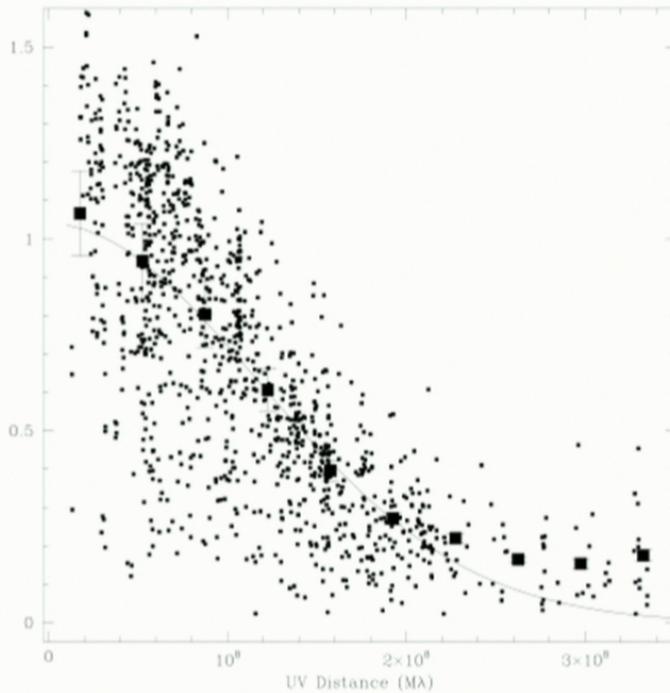


Observed Size of Sgr A*

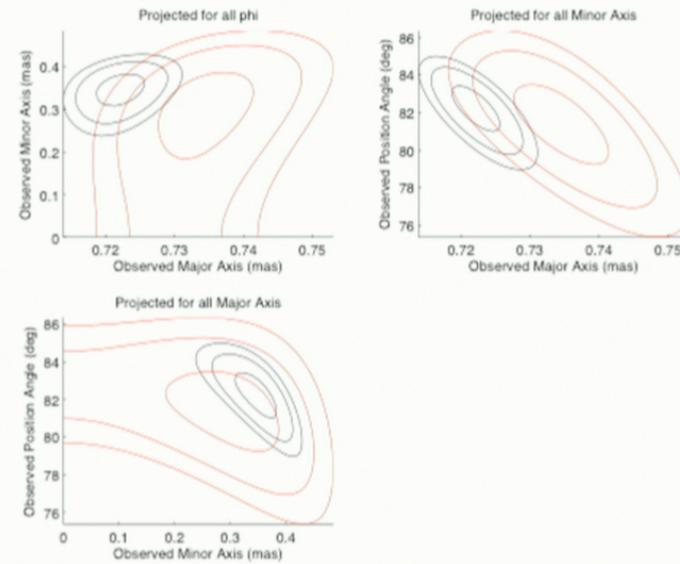


Bower et al 2006

How to Measure the Size of Sgr A*



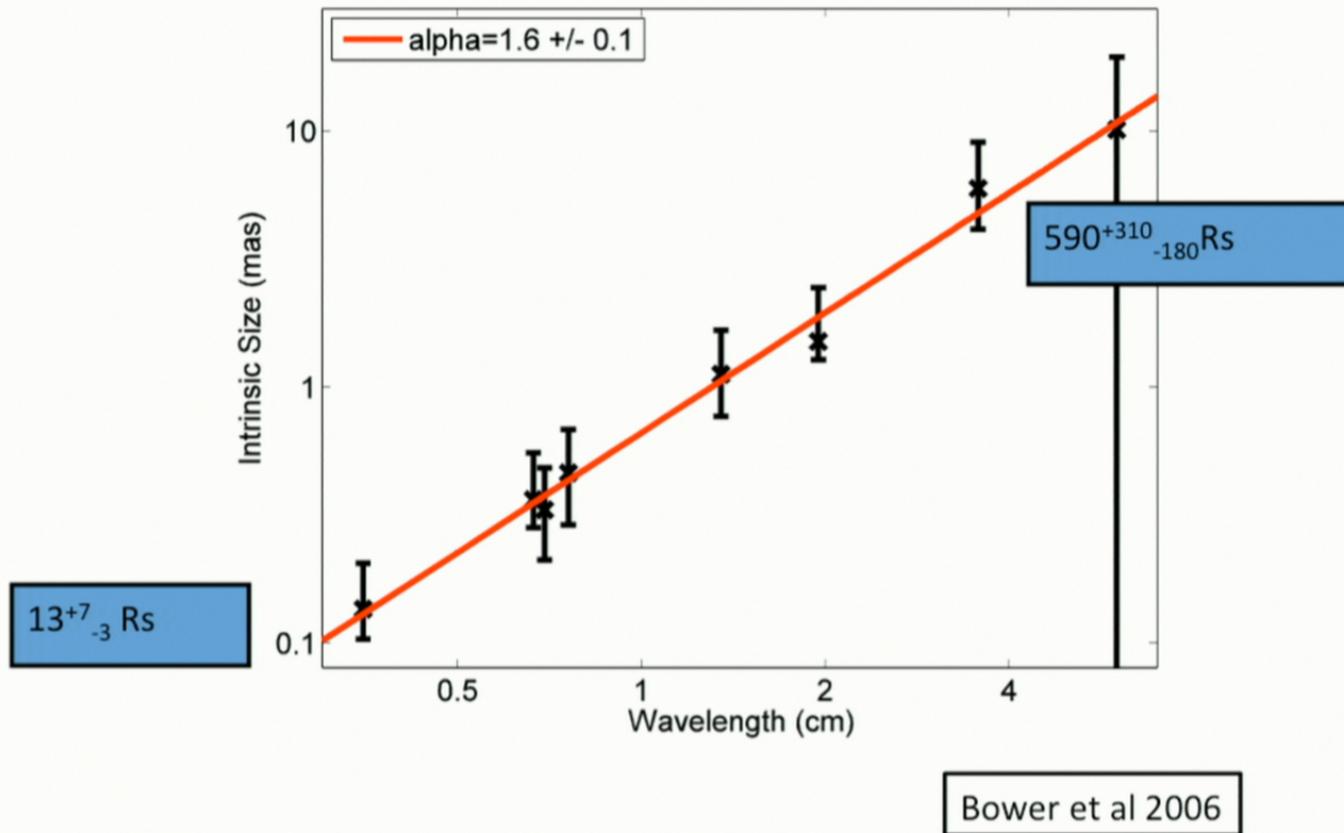
Bower & Backer 1998



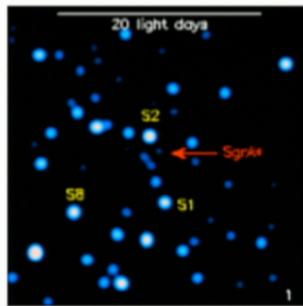
<~ 1% errors in major axis size
~3 μ as out of 700 μ as

Bower et al 2014

The Intrinsic Size of Sgr A*

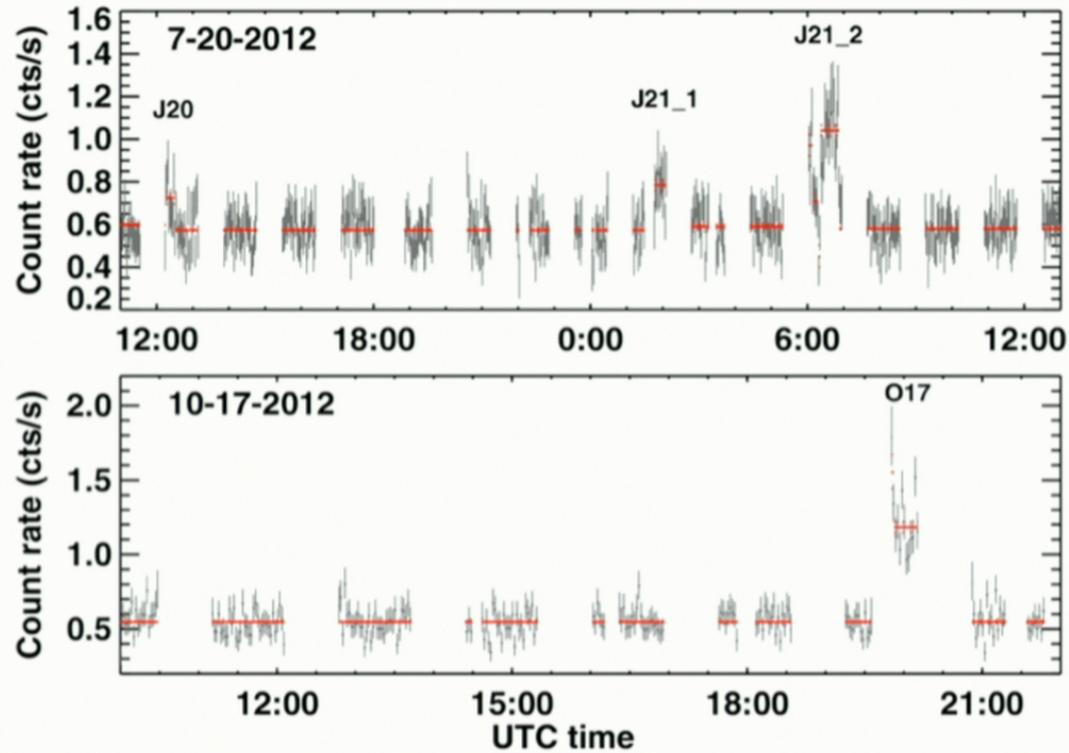


Time Variable Size for Sgr A*? NIR Triggered VLBA Observations



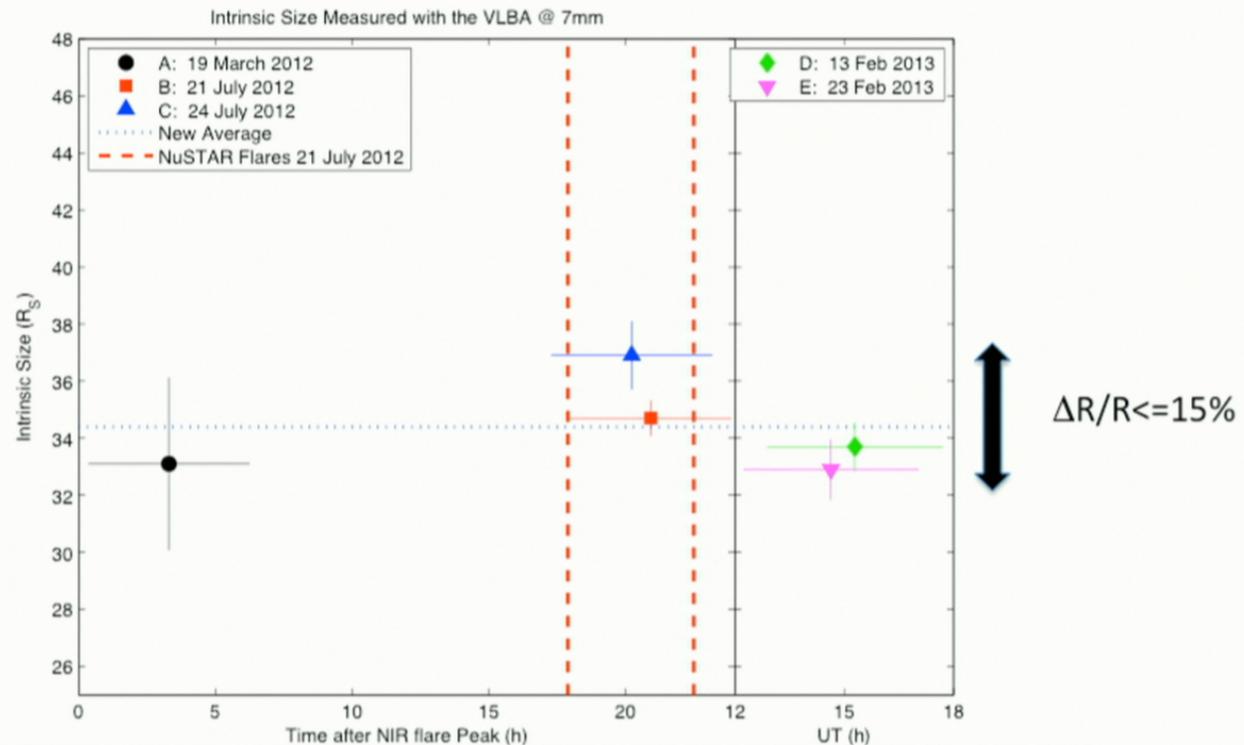
Epoch	UT Date	Trigger	NIR Observer
A	2012 MAR19 10:30 – 16:15	10 mJy flare VLT NIR	Dodds-Eden Clavel
B	2012 JUL 21 01:45 – 08:01	Keck NIR flare [prior day]	Morris
C	2012 JUL 24 01:33 – 08:03	Keck NIR flare $L' \sim 20$ mJy [prior day]	Morris

Large X-ray Flare from NuSTAR



Barriere et al 2014

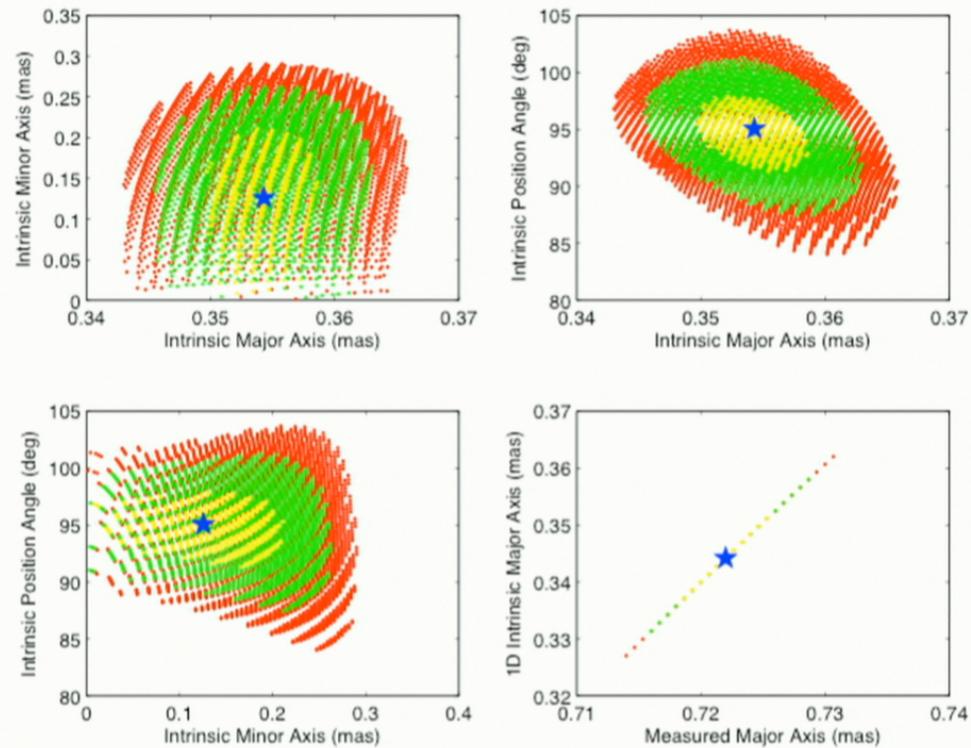
No Variations in Size Even with Large NIR/X-ray Variability



Next: VLBA triggered by millimeter flux density variations (ALMA, APEX, VLA, CARMA, SMA)

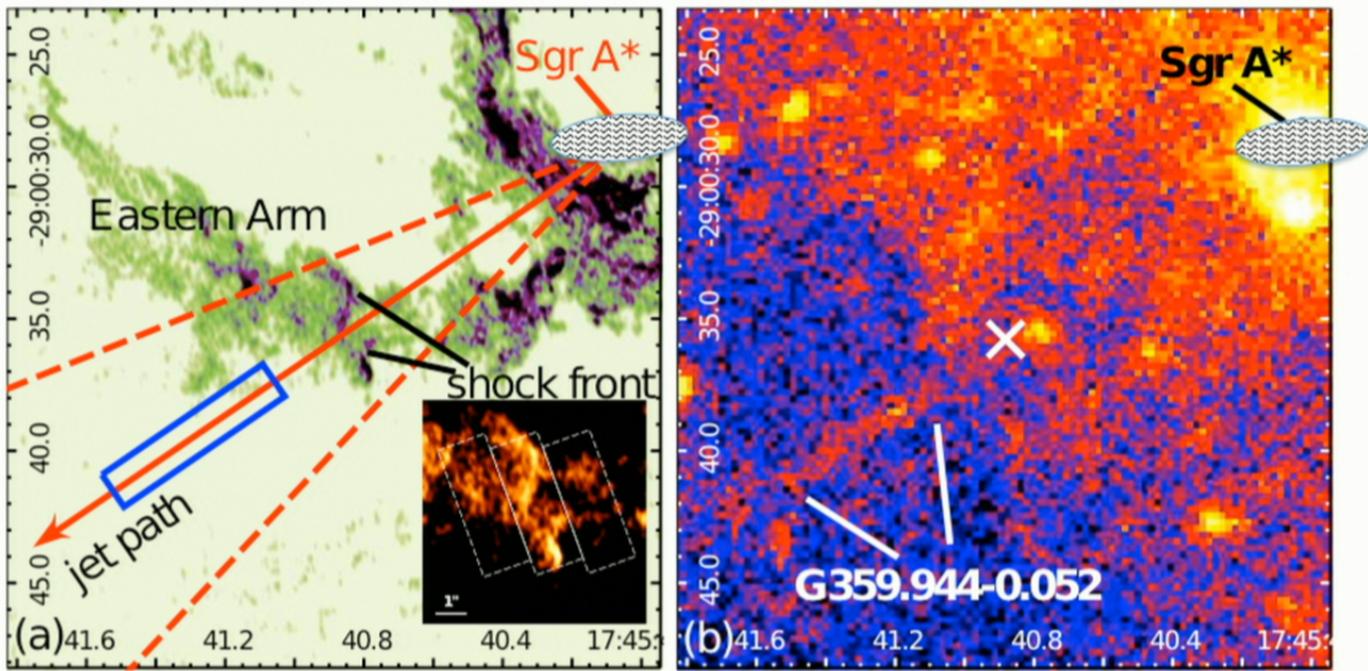
Bower, Markoff, Falcke, Brunthaler, Law 2013

With New VLBA Observations We Measure the 2D Intrinsic Size



Bower et al 2014

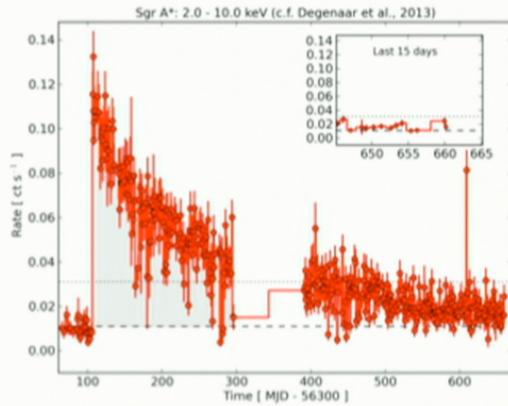
A Jet Axis?



Li, Morris, Baganoff 2013

Galactic Center Magnetar Discovery

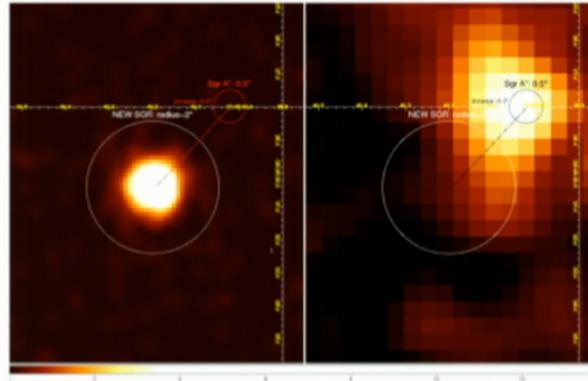
X-Ray Burst



Degenaar et al. 2013
Kennea et al. 2013

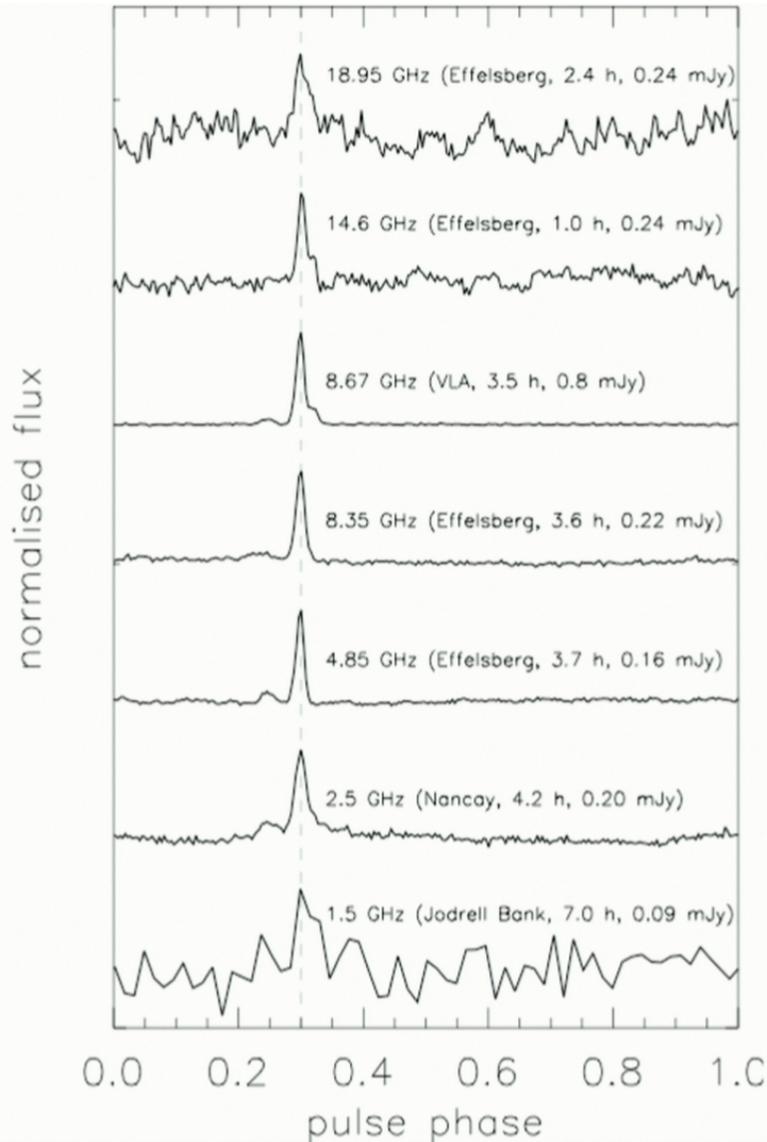
SGR J1745-29

X-ray Localization: ~3" to Sgr A*



Rea et al. 2013

3" ~ 0.1 pc



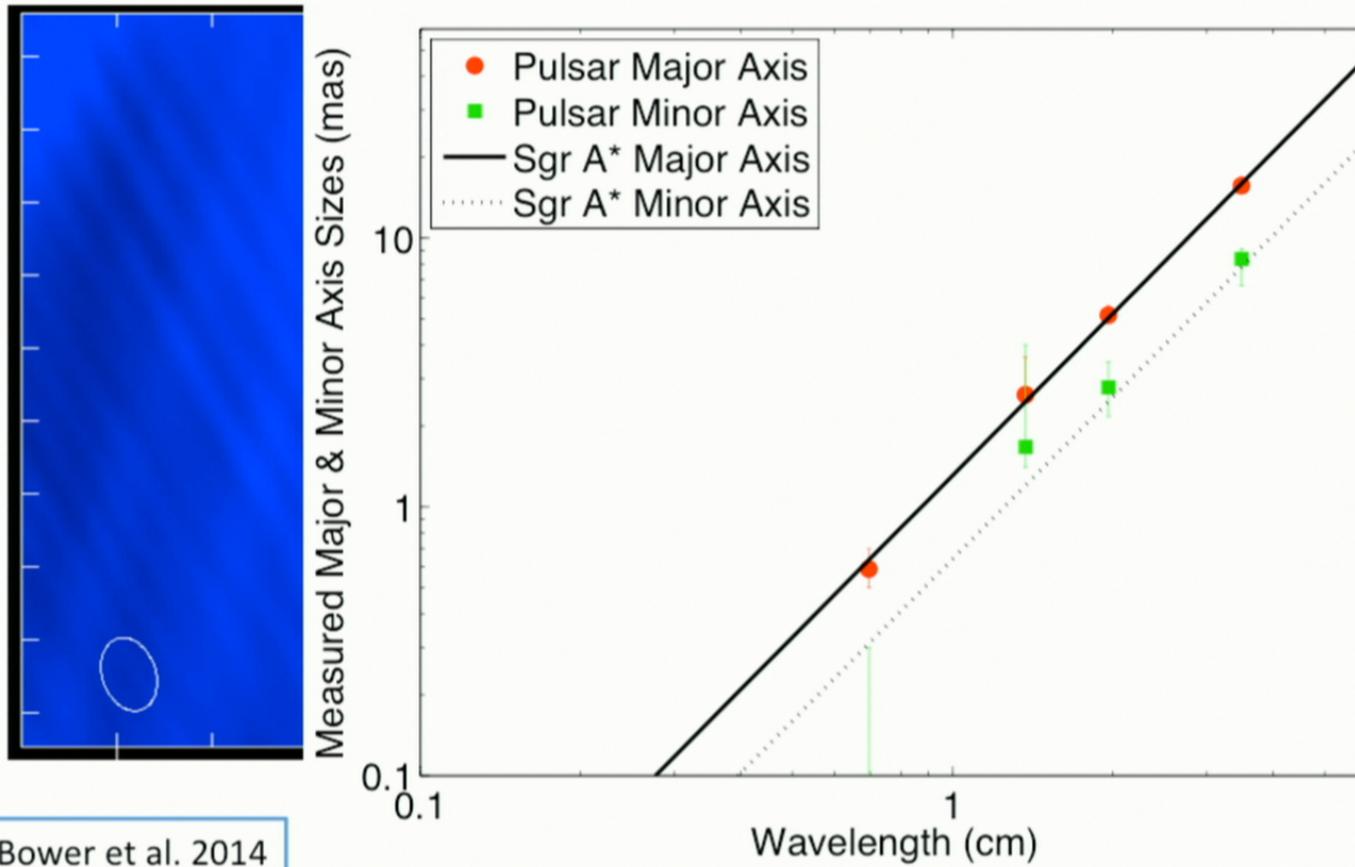
Radio Detection

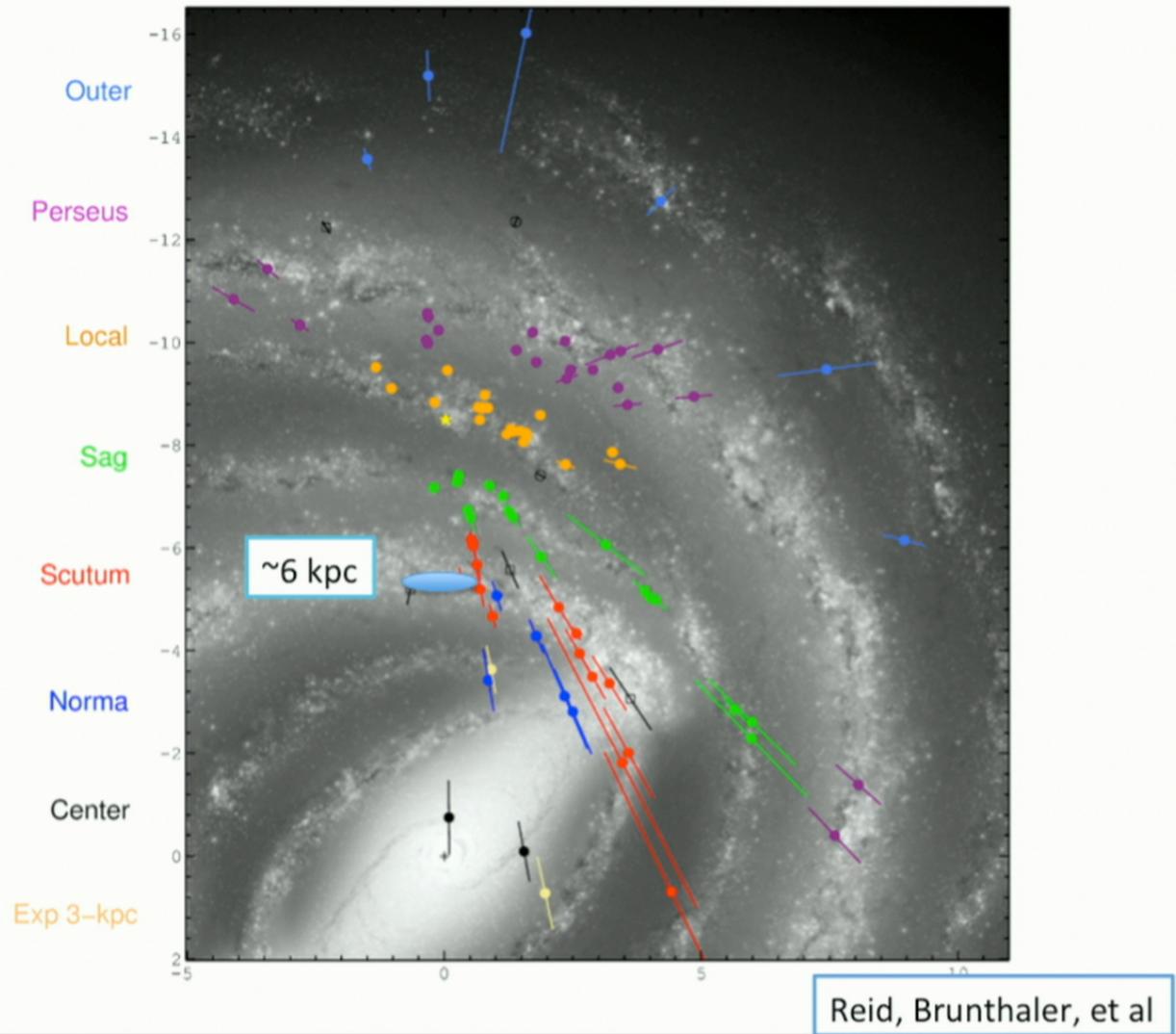
- $P = 3.76354676(2) \text{ s}$
- $P/\dot{P} \rightarrow B \sim 10^{14} \text{ G}$
- $T_{\text{spindown}} \sim 9000 \text{ yrs}$
- $DM = 1778 \pm 3 \text{ cm}^{-3} \text{ pc}$
- $RM = -7 \times 10^4 \text{ rad m}^{-2}$
- Flux $\sim 0.2 - 1 \text{ mJy}$
- spectrum \sim flat
- Only 4 radio magnetars known – chance alignment is 10^{-8}

Eatough et al. 2013

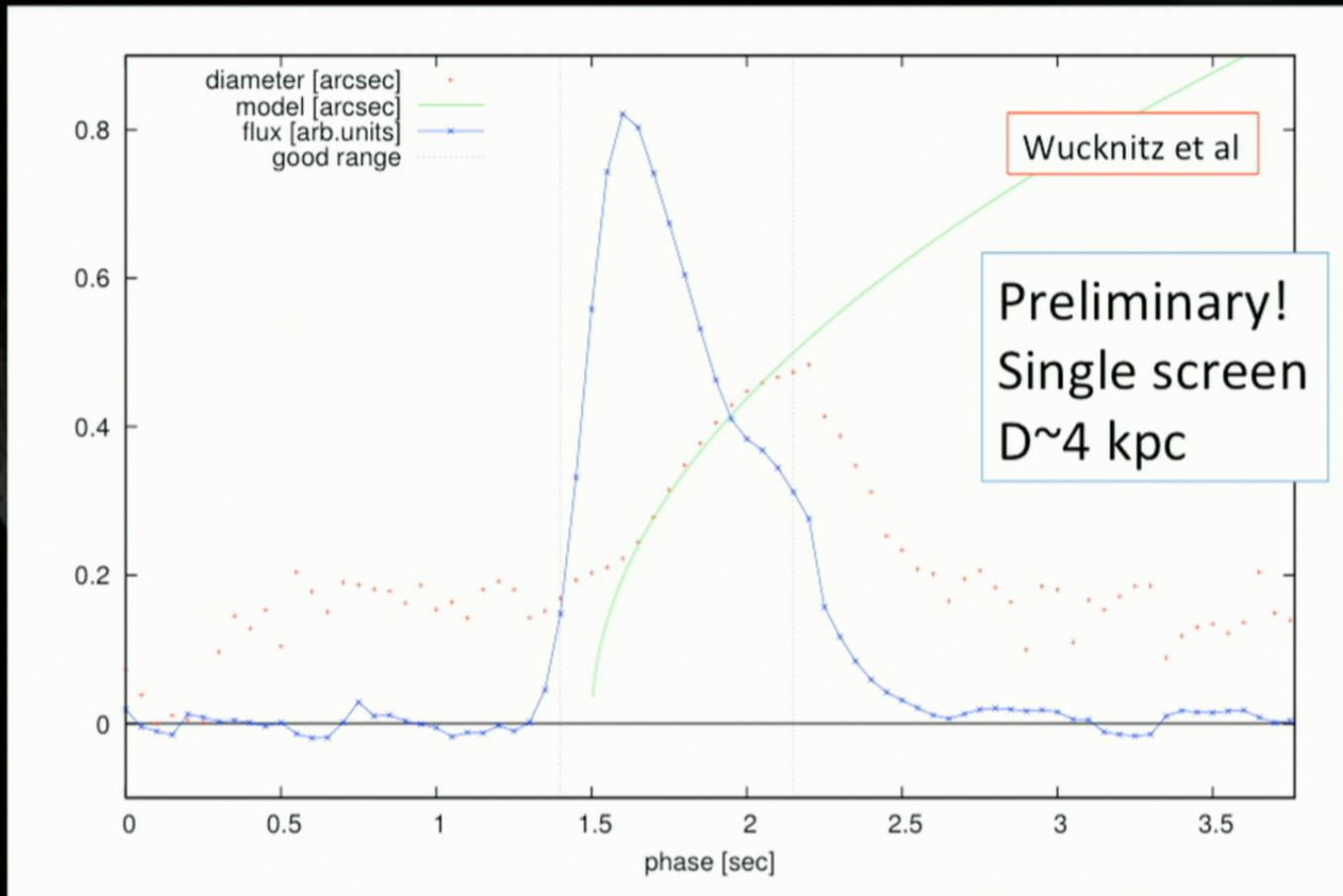
Shannon and Johnston 2013

Angular Broadening of the Pulsar



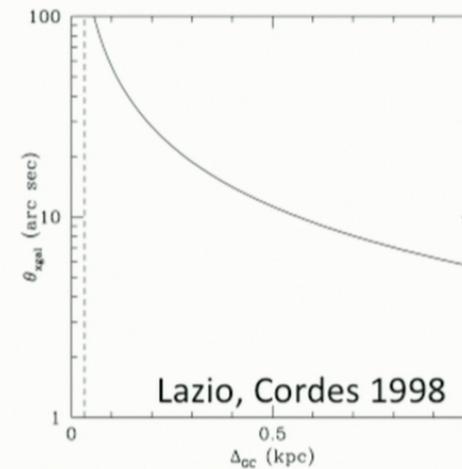


Size vs. time (binned)

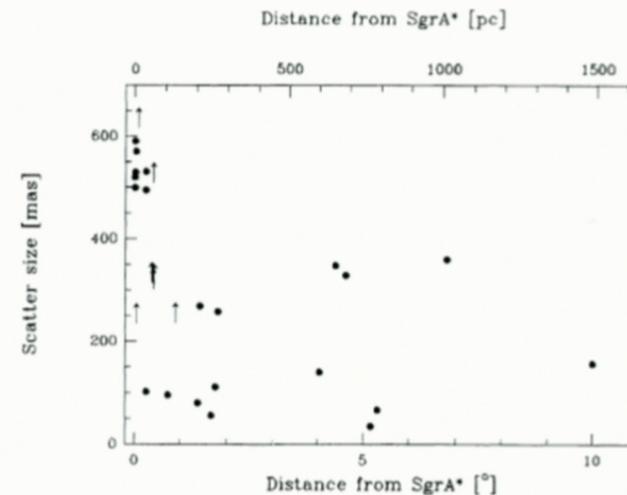


Does a Scattering Screen at Large Distances Make Sense?

- 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 $\sim 5'$ from G359.87+0.18

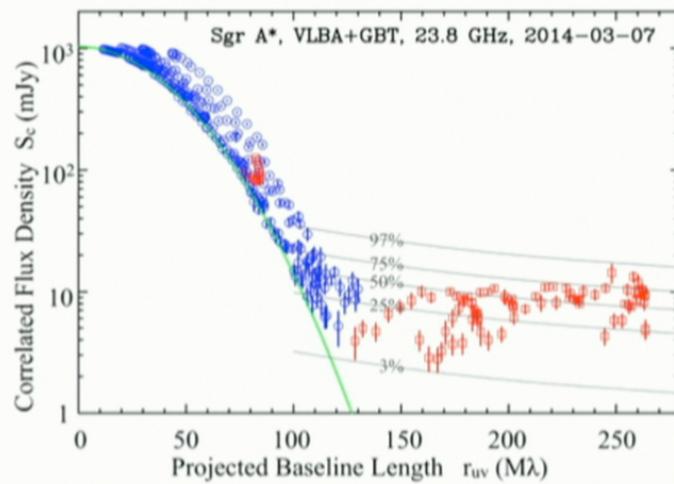


Lazio, Cordes 1998

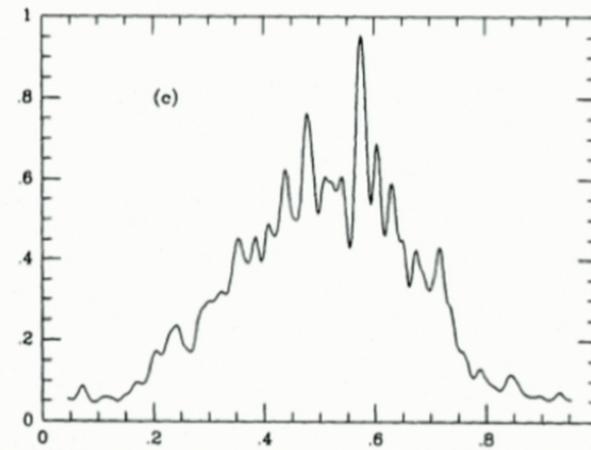


van Langevelde 1992

Average Image

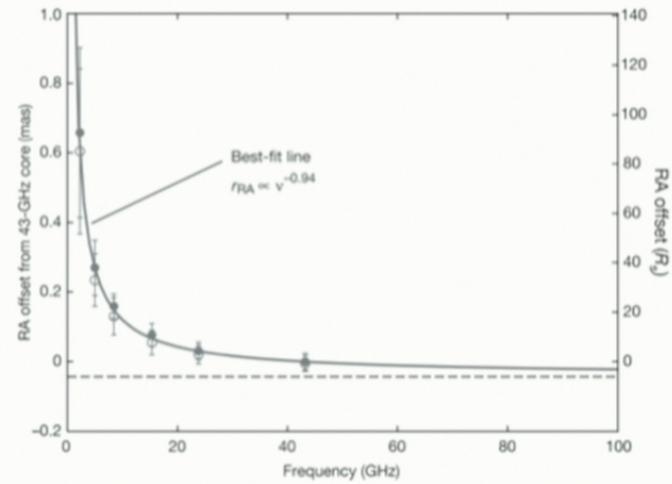
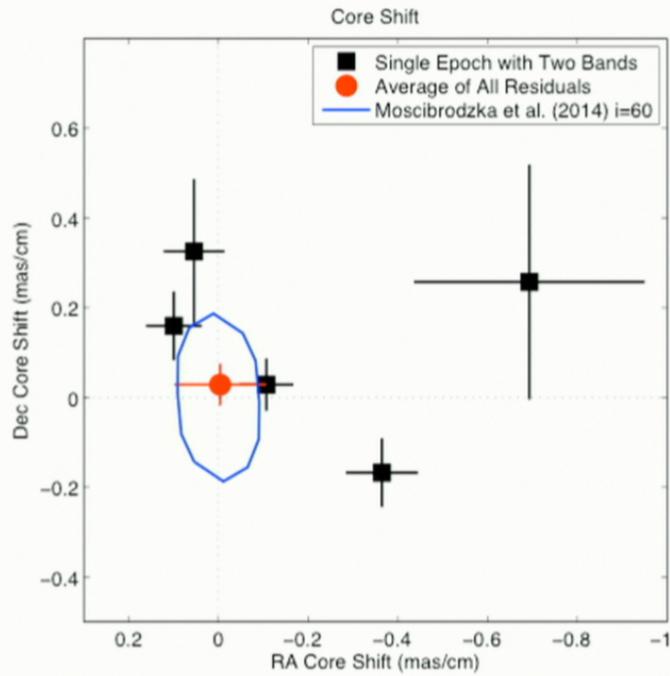
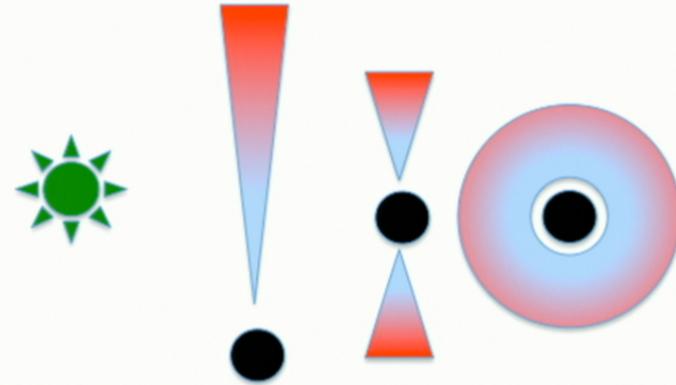


Gwinn et al 2014



Narayan and Goodman 1989

Core Shift



Hada et al 2013

Summary

PSR J1745-2900

Scattering Properties

- Very stable ~ 500 years?
- Pulsar observations resolve distance to scattering screen
- “Average image” provides a new tool for characterizing refractive effects & measuring intrinsic source effects

Intrinsic Properties

- Resolved 2D intrinsic size
- Pulsar phase referencing provides opportunity for core shift

No Activity from G2

