High-resolution polarimetric study of Sgr A* with the GMVA

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in collaboration with:

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and

I. van Bemmel, M. Kettenis, D. Small

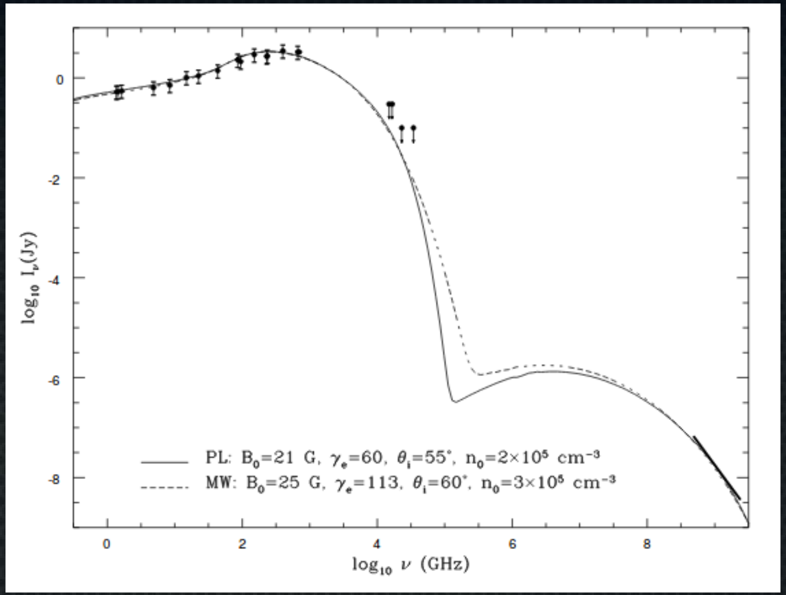
Outline

- Recent results of 3mm VLBI studies of Sgr A*:
  → Closure amplitude – source shape
  → Closure phase – source asymmetry

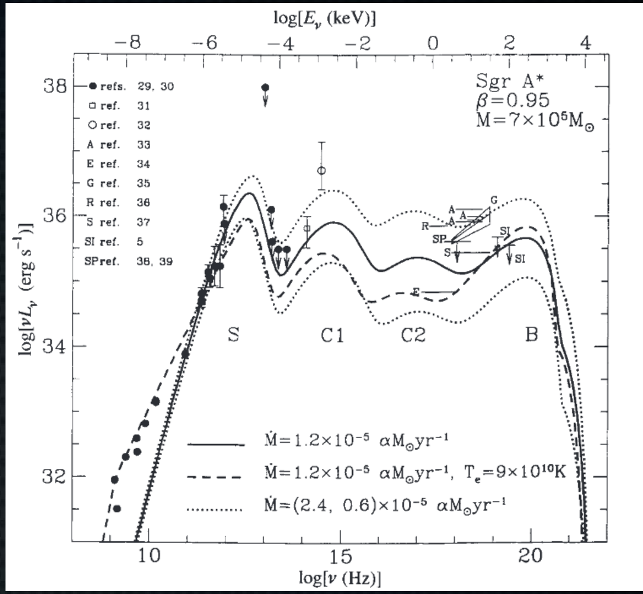
- Polarization properties of Sgr A* & upper limit for LP at 3mm on VLBI scales

- CASA as a VLBI data calibration tool:
  Recent developments & a future pipeline

Sgr A* at mm wavelengths

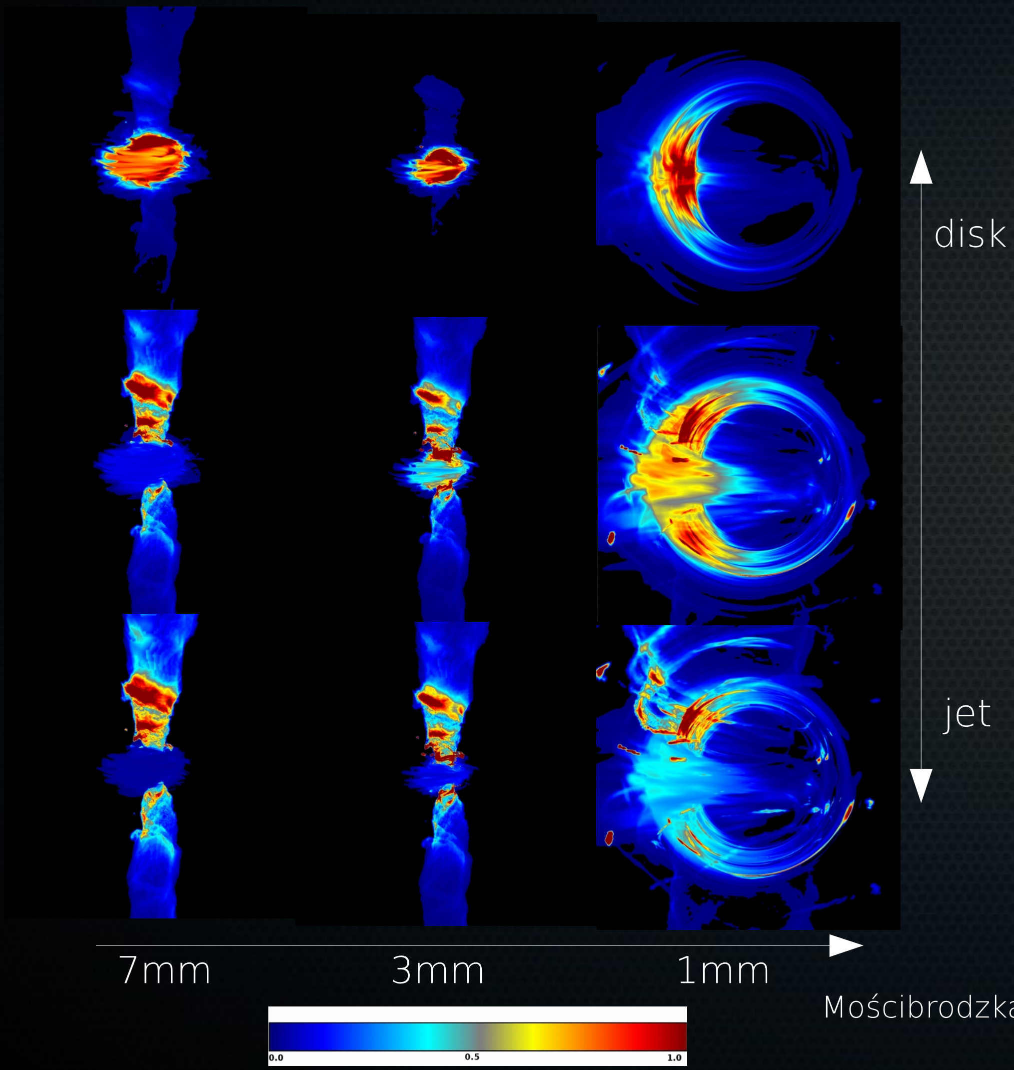


Falcke&Markoff 2000: Jet model

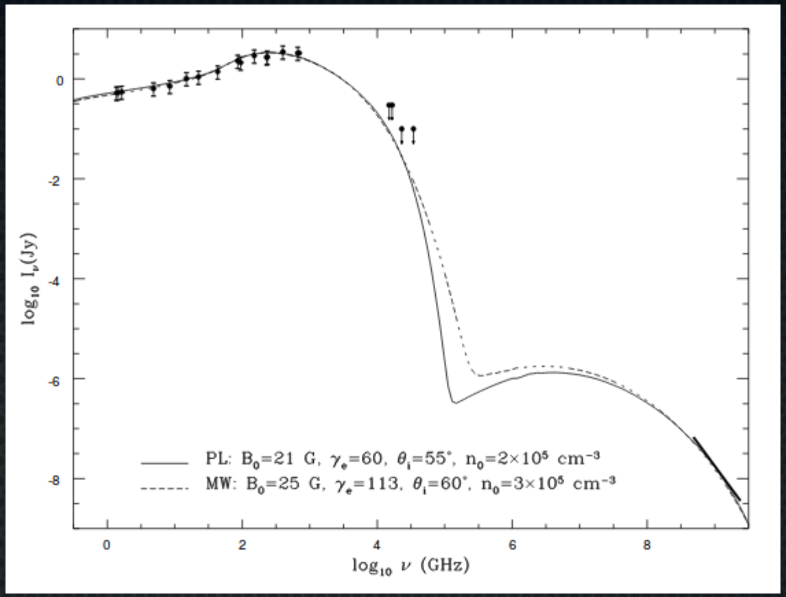


Narayan&Mahadevan 1995: disk model

Sgr A* at mm wavelengths



Mościbrodzka et al. 2014



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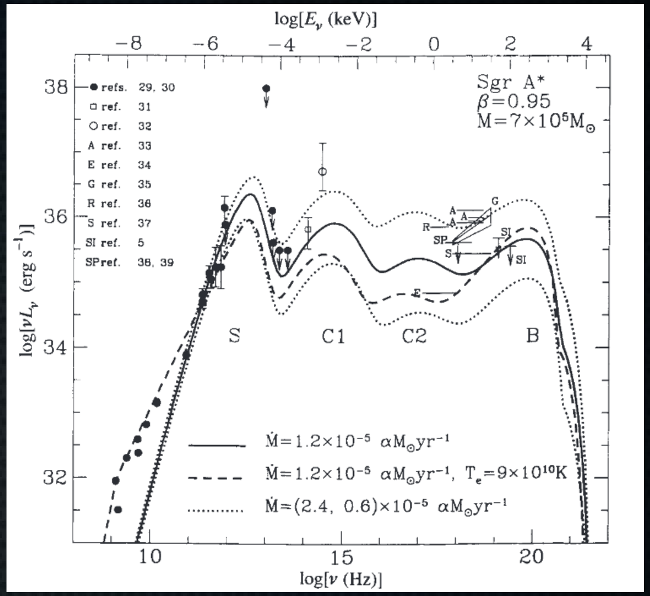

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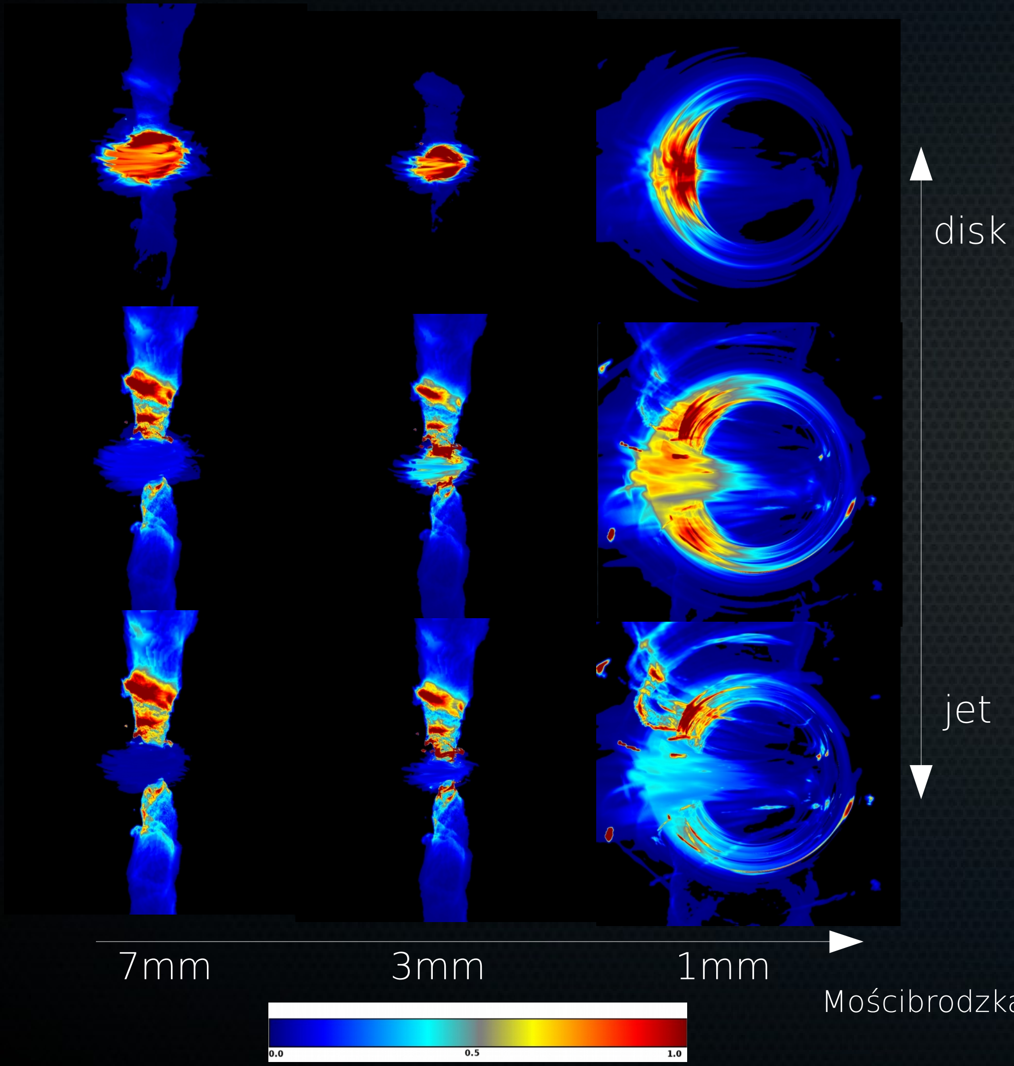

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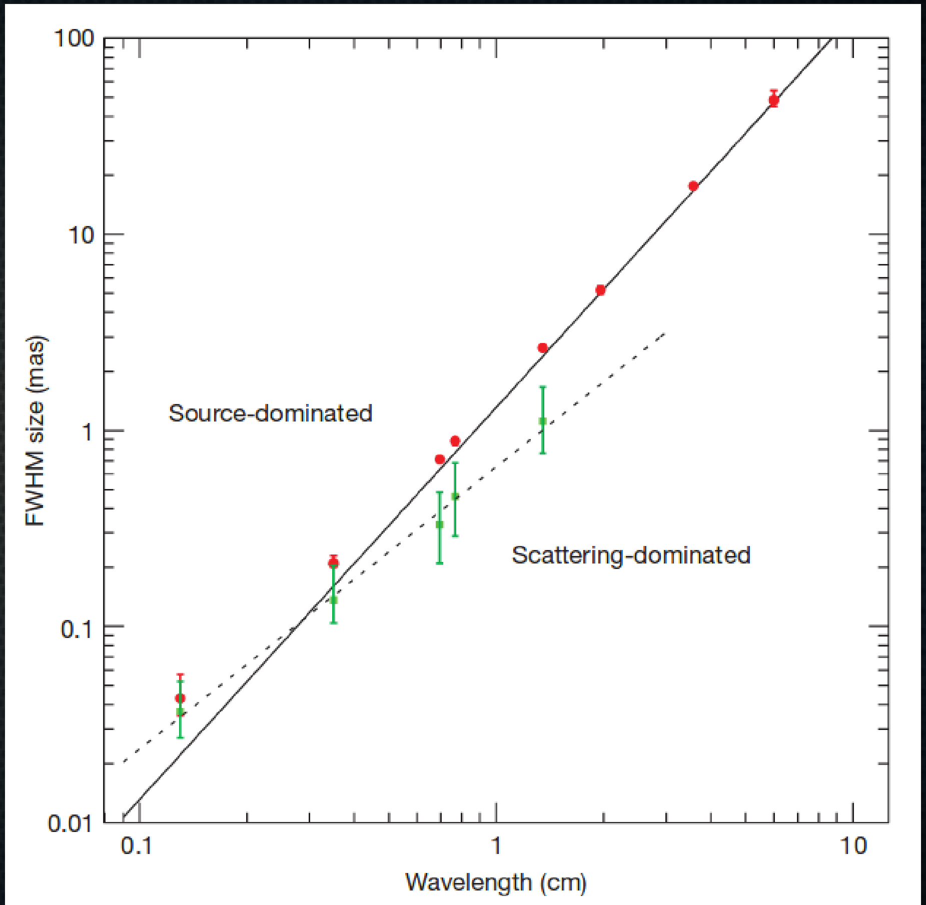
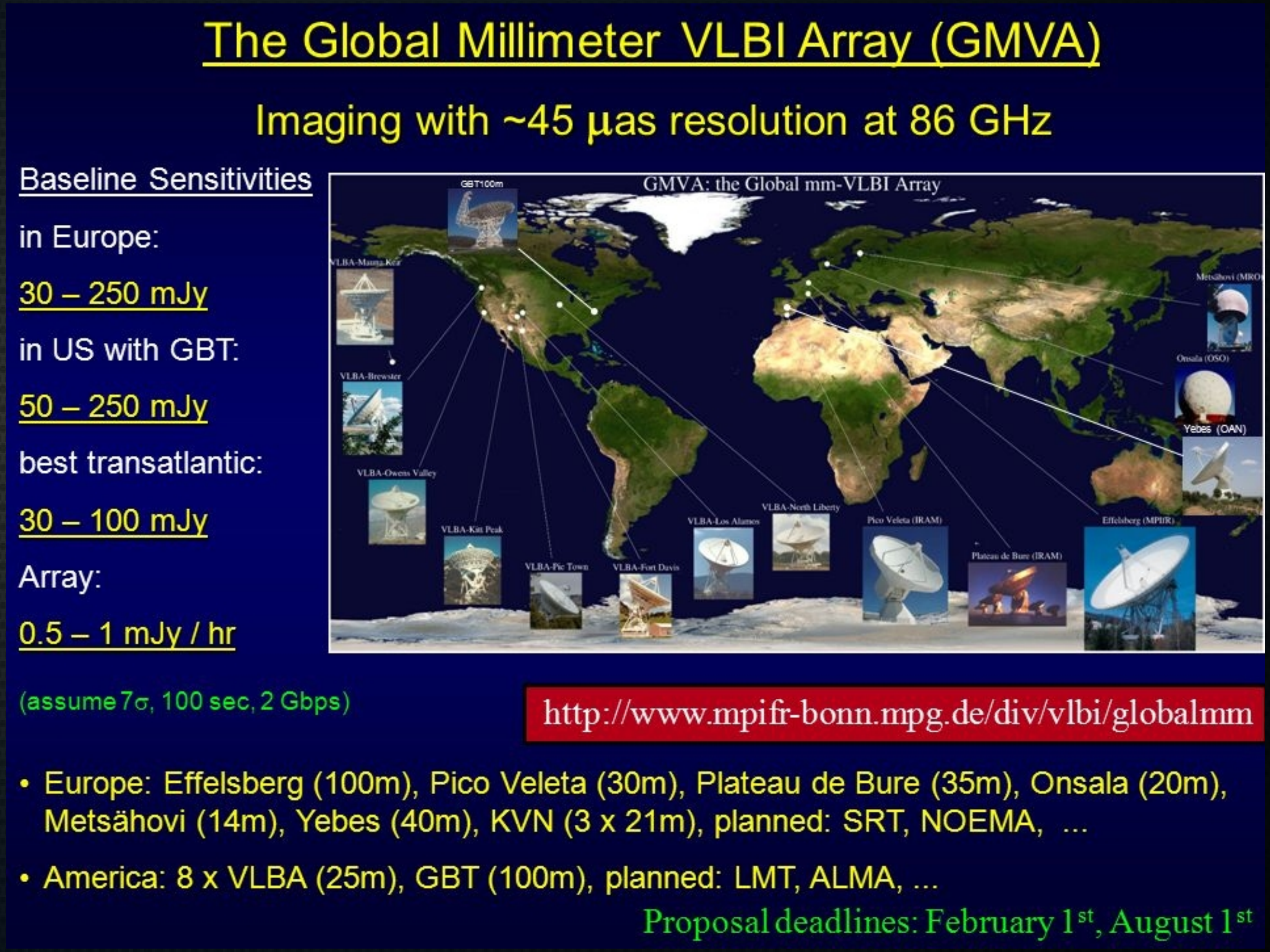


Doeleman et al. 2008

VLBI observations of Sgr A* at 3mm

- Ortiz-León et al. 2016: VLBA+LMT from April 2015, single pol
- Brinkerink et al. 2016 and Müller et al. 2017 (in prep.): VLBA+GBT+LMT from May 2015, single pol
- Janssen et al. 2017 (in prep.): GMVA (this talk: only VLBA+GBT) from May 2016, <u>dual pol and full-Stokes correlation</u>



Taken from Thomas Krichbaum

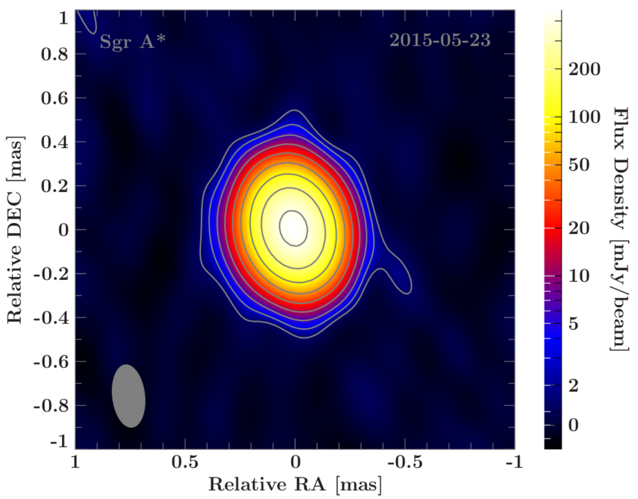
VLBI observations of Sgr A* at 3mm
Imaging & closure amplitudes

Summary of Elliptical Gaussian Fits to 3 mm VLBI of Sgr A*

	BD183C		BD183D		Doeleman+('01)	Shen+('05)	Lu+('11)
	Closure Amp.	Self-Calibration	Closure Amp.	Self-Calibration	Self-Calibration	Closure Amp.	Self-Calibration
Major axis	$214.9 \pm 4.0\ \mu$as	$212.7 \pm 2.3\ \mu$as	$217.7 \pm 5.0\ \mu$as	$221.7 \pm 3.6\ \mu$as	$180 \pm 20\ \mu$as	$210^{+20}_{-10}\ \mu$as	$210 \pm 10\ \mu$as
Minor axis	$139.0 \pm 8.1\ \mu$as	$138.5 \pm 3.5\ \mu$as	$147.3 \pm 8.0\ \mu$as	$145.6 \pm 4.0\ \mu$as	...	$130^{+50}_{-130}\ \mu$as	$130 \pm 10\ \mu$as
P.A.	$80.8° \pm 3.2°$	$81.1° \pm 1.8°$	$80.2° \pm 4.8°$	$75.2° \pm 2.5°$	...	79^{+12}_{-33}°	$83.2° \pm 1.5°$
Axial ratio	1.55 ± 0.08	1.54 ± 0.04	1.48 ± 0.07	1.52 ± 0.05	...	$1.62^{+20}_{-0.6}$	1.62 ± 0.11

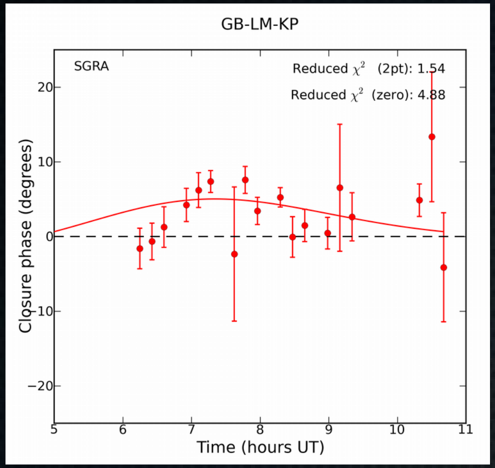
Ortiz-León et al. 2016

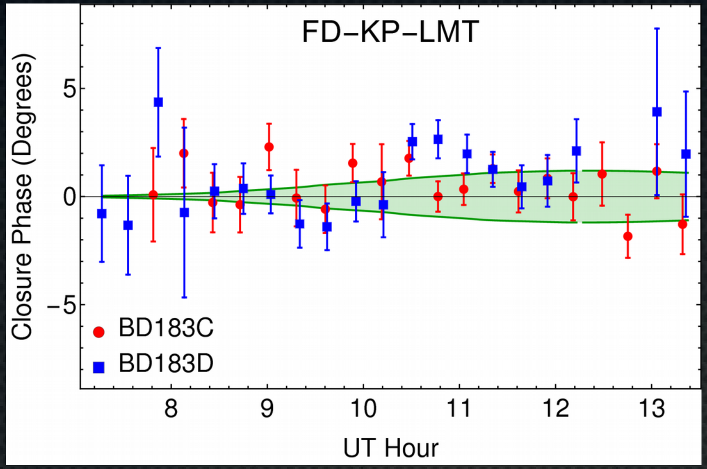
- Müller et al. 2017 (in prep.): 217x165 µas at 77°
- Janssen et al. 2017 (in prep.): 229 x 159 µas at 79°

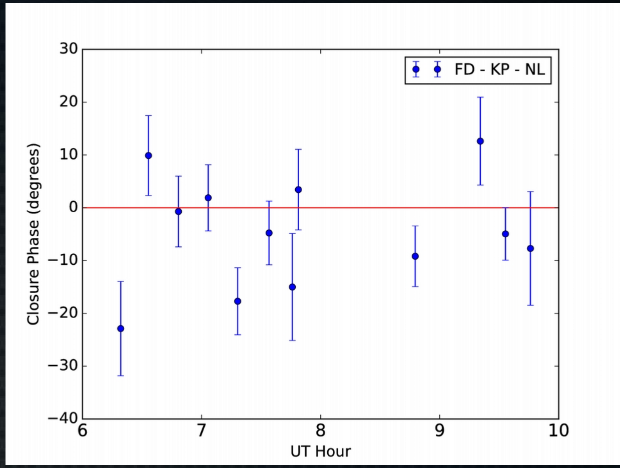


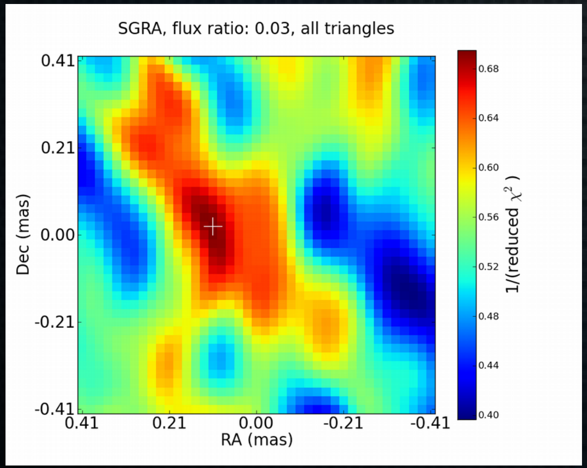
Müller et al. 2017 (in prep.): Modeling Sgr A* with a Gaussian

VLBI observations of Sgr A* at 3mm
Asymmetry & closure phases

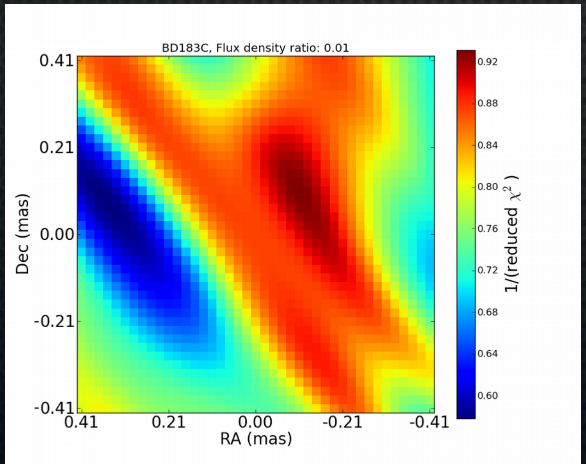




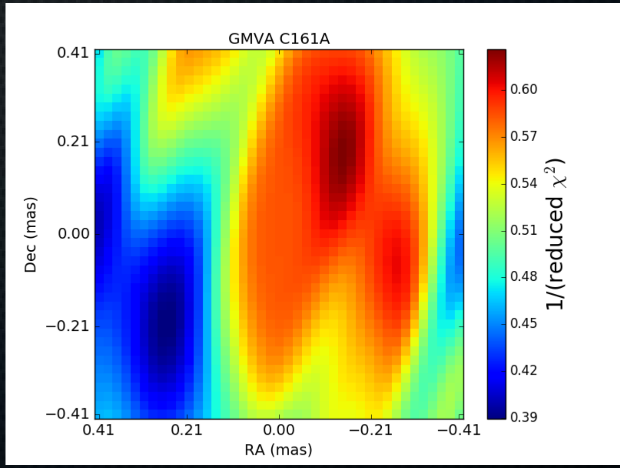




Brinkerink et al. 2016: 2. component towards south-east

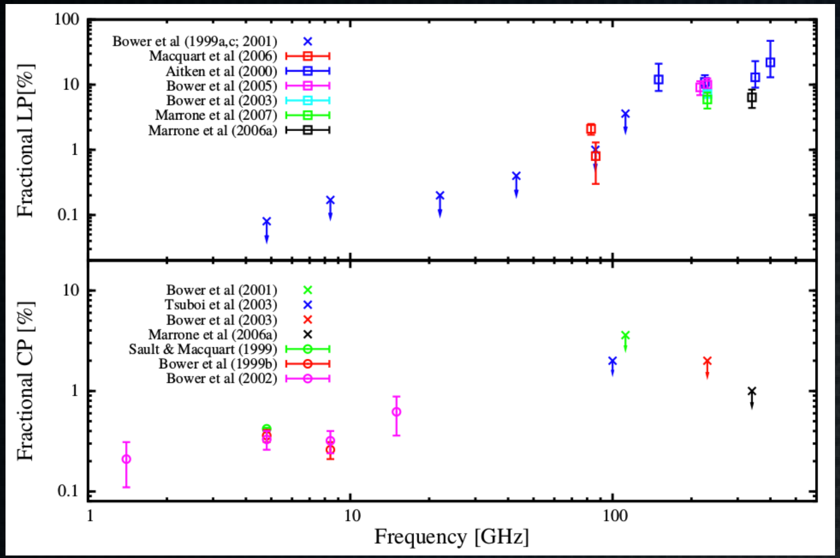


Based on data from Ortiz-León et al. 2016: 2. component towards north-west



Janssen et al. 2017 (in prep.): 2. component towards north-west

Polarization properties of Sgr A*



Muñoz et al. 2012

- Highly variable (e.g., Yusef-Zadeh et al. 2007)
- Bower et al. 1999: Observations in 1998 with BIMA array (as resolution) → LP < 1% at 3mm
- Macquart et al. 2006: 2004 with BIMA → LP ~ 2% at 3mm (unrepeated)
- Marrone et al. 2006:
  RM = - 6×10^5 rad/m²
  → 2×10^{-9} M_sun/yr < dM/dt < 2×10^{-7} M_sun/yr

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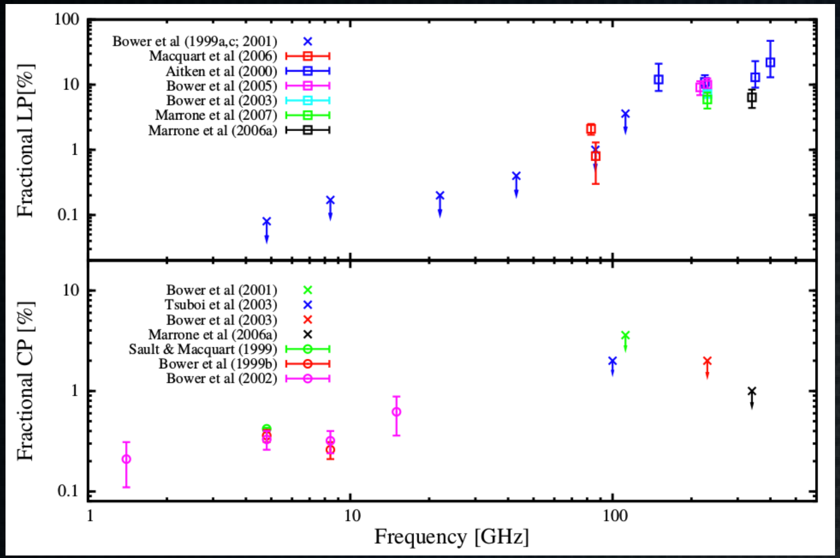

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- Janssen et al. 2017 (in prep.): LP < 1% at 3mm at 0.2mas resolution

CASA as VLBI calibration tool

Advantages of CASA:

- Easily scriptable → pipeline
- Supports MPI parallelization
- Widely used and secure future

Recent developments:

- JIVE developers: Ilse van Bemmel, Mark Kettenis and Des Small
- At Radboud: Code testing and verification with EHT, GMVA and VLBA data
- mm VLBI expertise: MPIfR and Radboud
- CfA and Haystack involvement soon

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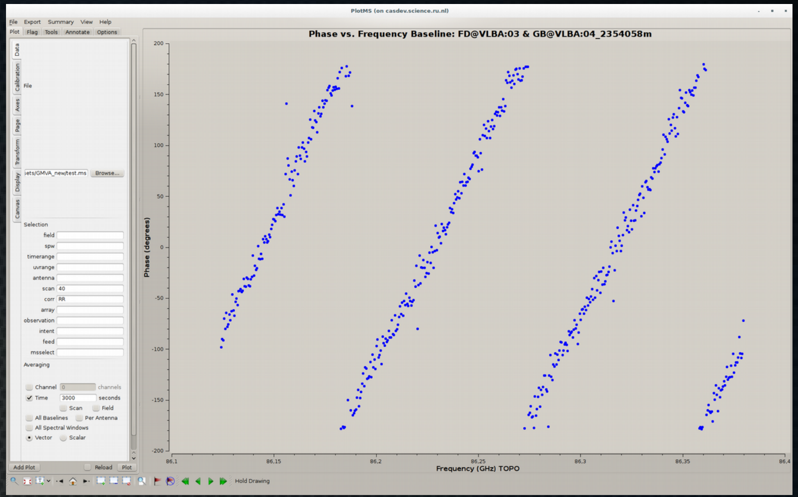
Status:

- Python version of Cotton-Schwab fringe-fitter is working (sbd&mbd) → being ported to CASA c++ code
- Amplitude calibration based on telescope metadata (ANTAB) works
- Bandpass calibration works
- Polarization calibration works (delay+phase)
- DiFX fits-idi format supported
- Will go into CASA 5.1 release
- For now: Binary tarball with dynamically linked libraries is working under Linux
- Cross-comparison of results is ongoing

Summary & Outlook

- CASA is now VLBI ready
- Work towards a fully automated pipeline
- 2.10 – 6.10 CASA VLBI workshop @JIVE: contact Ilse van Bemmel

  http://www.jive.eu/casa-vlbi2017/



- LP < 1% at 3mm on sub-mas scales in Sgr A*
- Clear asymmetry at 3mm in Sgr A* detected – unclear if intrinsic or due to scattering
- Next steps: Analyze data from European stations & check consistency with self-calibration