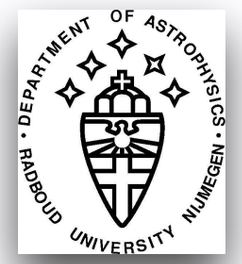
VLBA+LMT+GBT observations indicate asymmetry in 3mm emission of Sgr A*

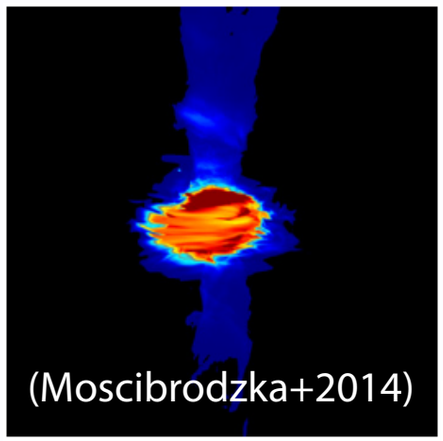
Cornelia Müller
Radboud University, Nijmegen

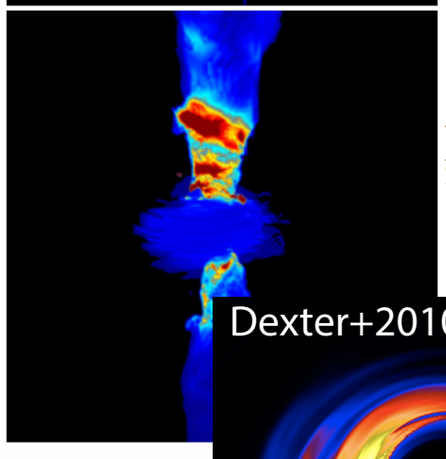
in collaboration with
C. D. Brinkerink, H. Falcke, T. P. Krichbaum, G. C. Bower, E. Castillo, A. Deller, S. Doeleman, R. Fraga-Encinas, C. Goddi, A. Hernández, D. Hughes, M. Kramer, J. Leon-Tavares, L. Loinard, A. Montana, M. Moscibrodzka, G. Ortiz-Leon, D. Sanchez-Arguelles, R. Tilanus, G. Wilson, J. A. Zensus

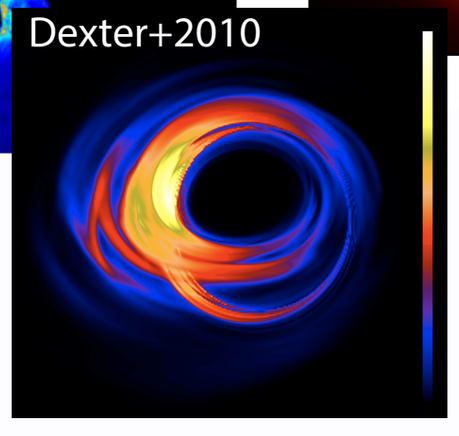


Jets 2016, Malaga

Sgr A* at mm-wavelengths


(Moscibrodzka+2014)

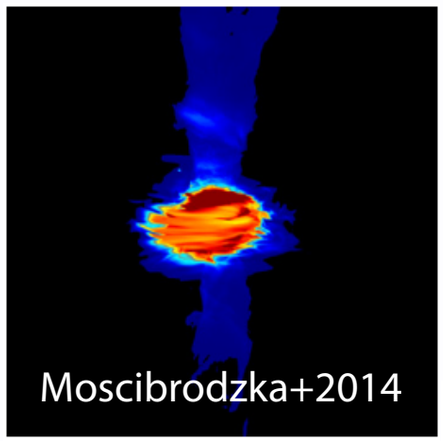


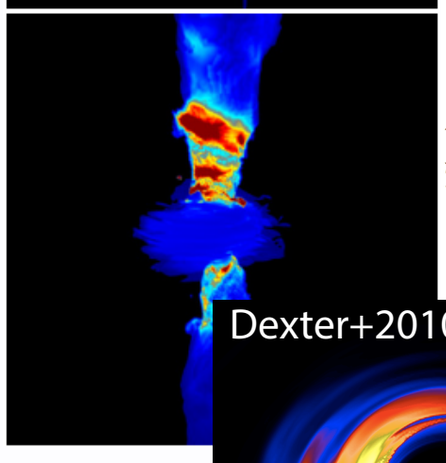

Dexter+2010

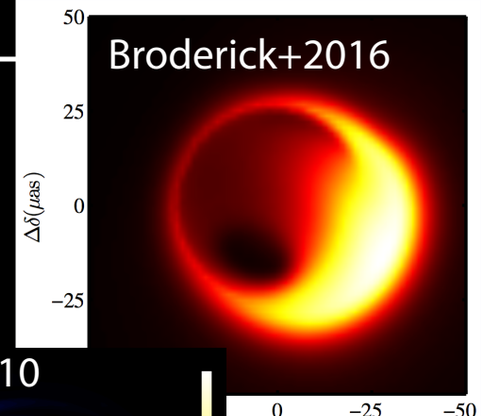
innermost emission structure of Sgr A* can be explained by radiatively inefficient flows and/or by a compact jet

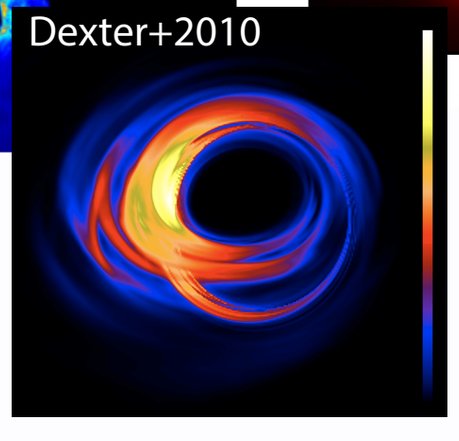
→ **mm-VLBI observations to uncover sub-structure**

Sgr A* at mm-wavelengths







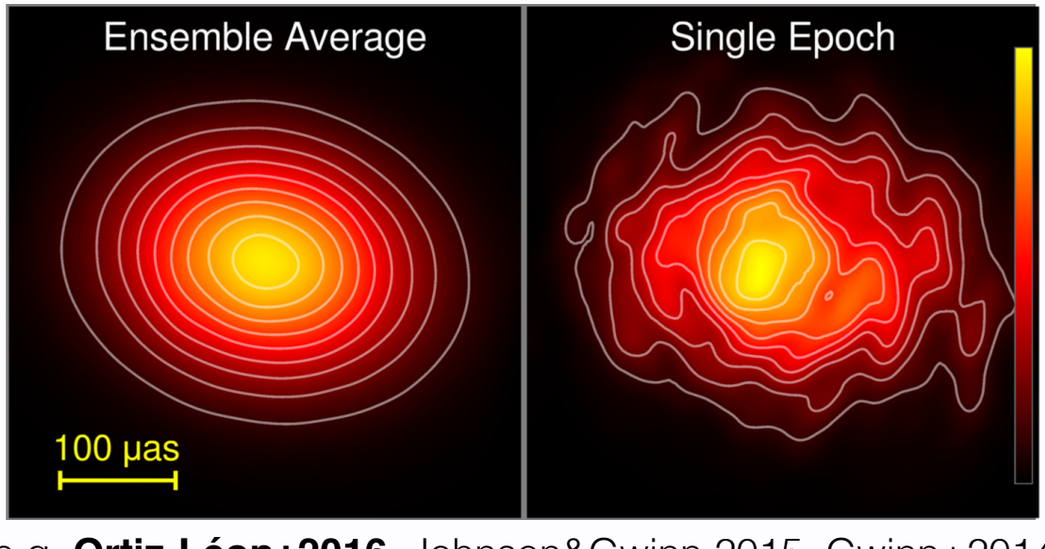


innermost emission structure of Sgr A* can be explained by radiatively inefficient flows and/or by a compact jet

→ mm-VLBI observations to uncover sub-structure

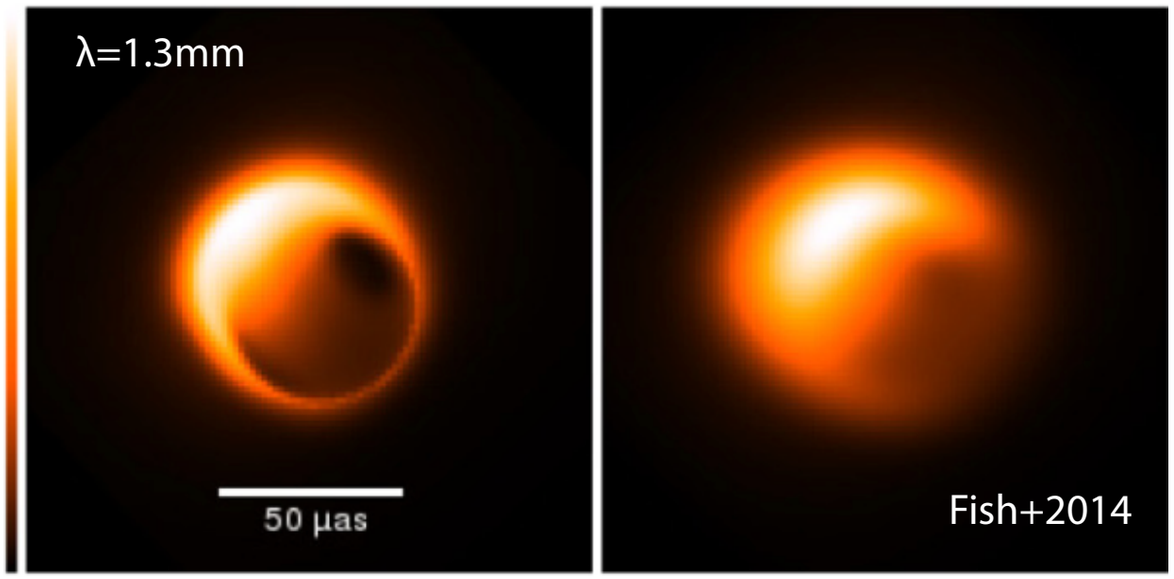
blurred emission at longer wavelengths due to **interstellar scattering**

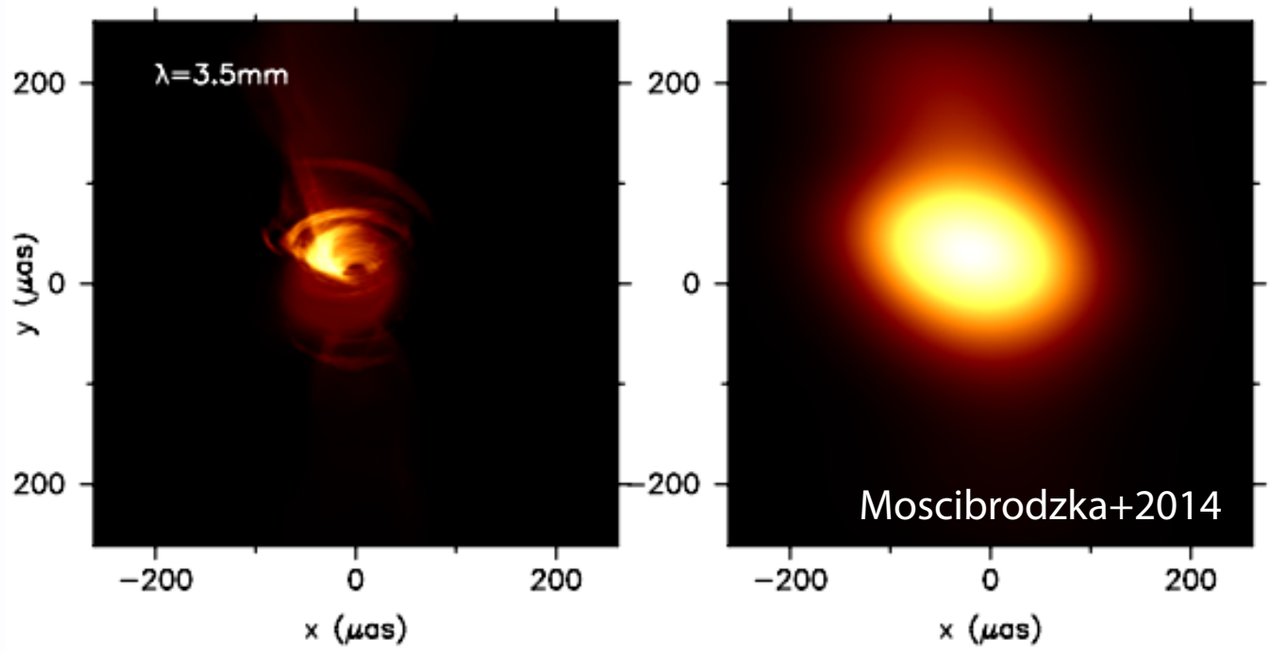
(→ λ^2-rule, e.g. Bower+2006)



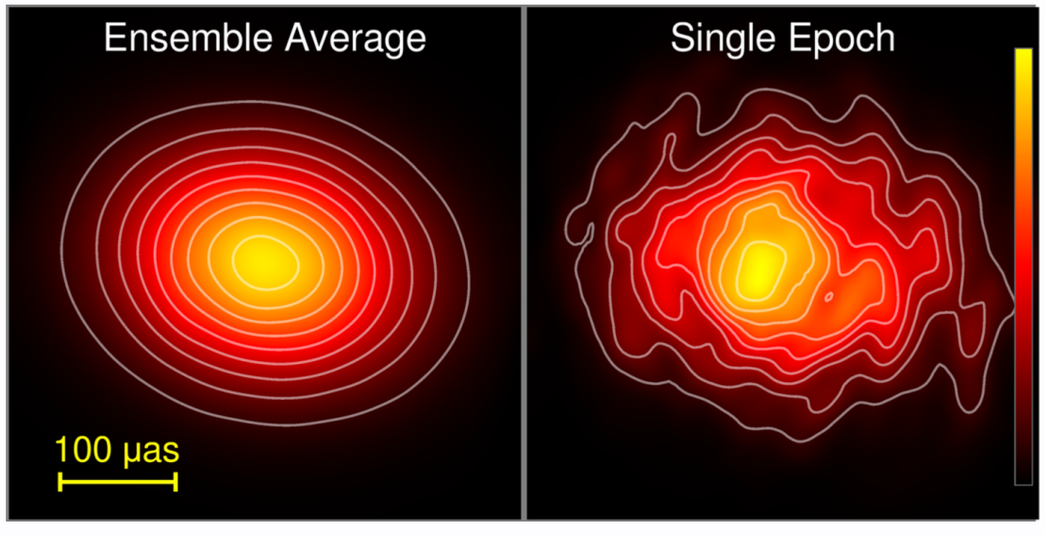
e.g.,**Ortiz-Léon+2016**, Johnson&Gwinn 2015, Gwinn+2014

Sgr A* at mm-wavelengths





blurred emission at longer wavelengths due to **interstellar scattering** (→ λ^2-rule, e.g. Bower+2006)

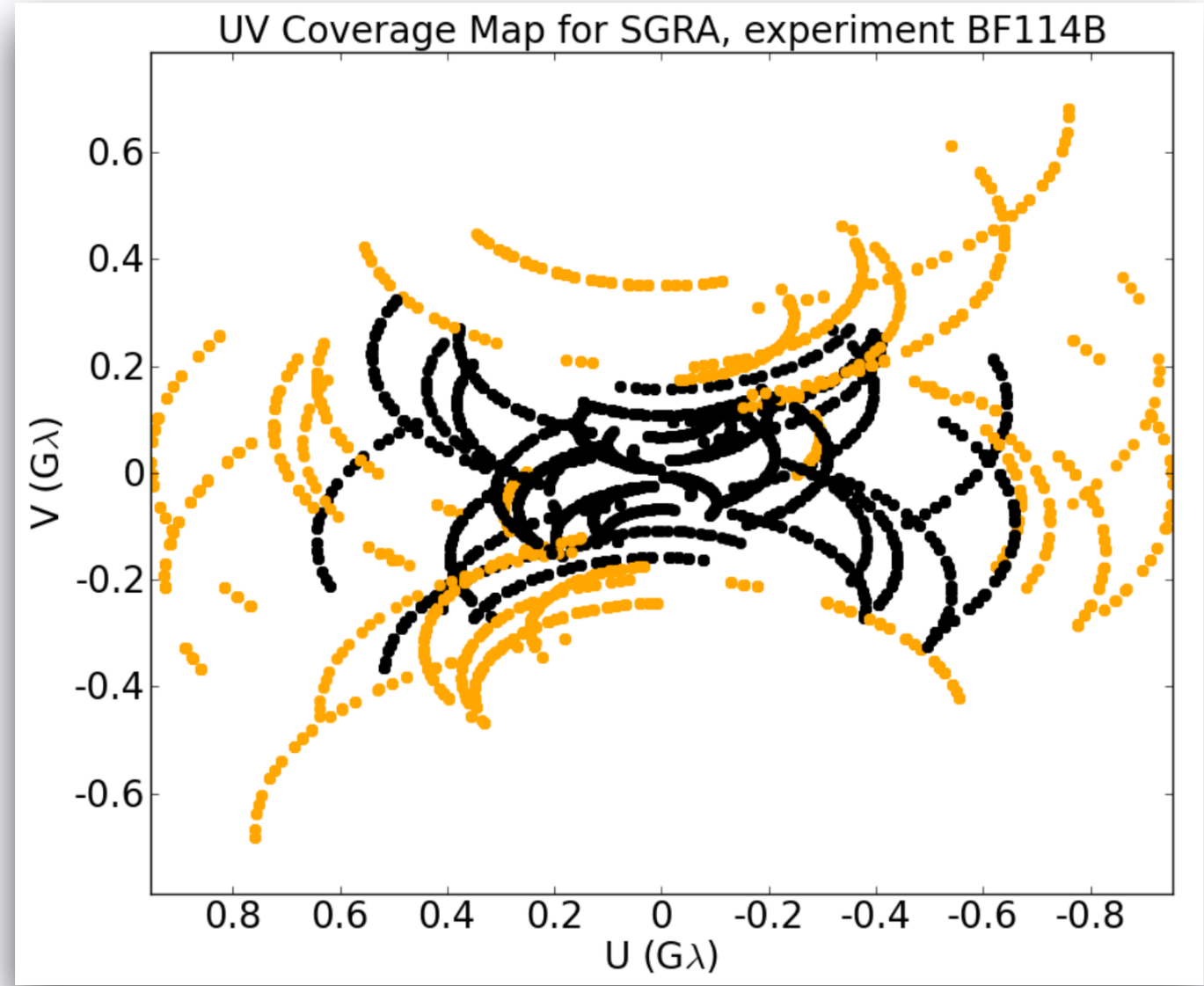


e.g.,**Ortiz-Léon+2016,** Johnson&Gwinn 2015, Gwinn+2014

VLBA+LMT+GBT observations at 86GHz

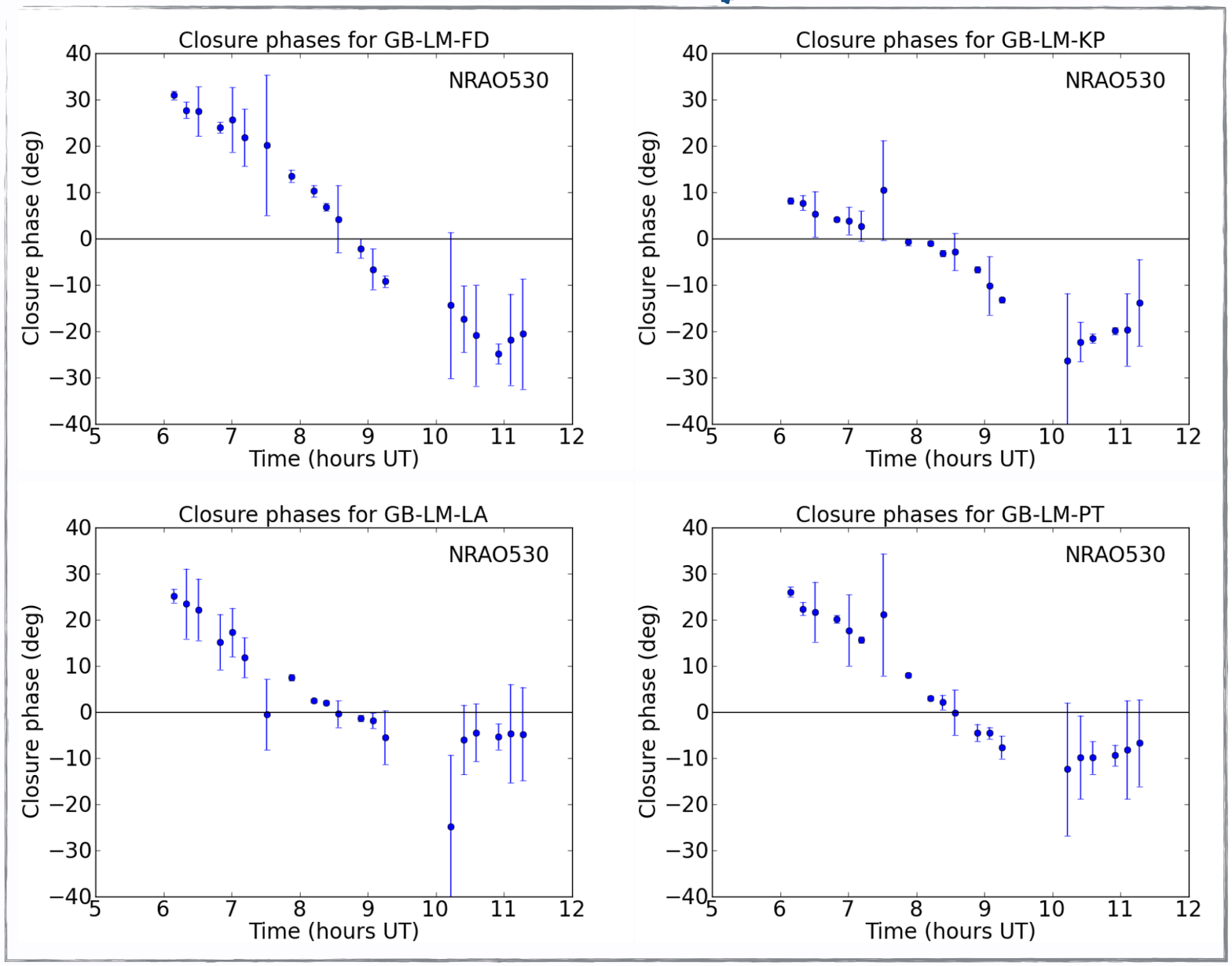
- May 2015
- LCP, 16IFs (32MHz each)
- check source: NRAO 530
- alternating scans every ~5min
- (~0.15x0.29)mas for Sgr A*

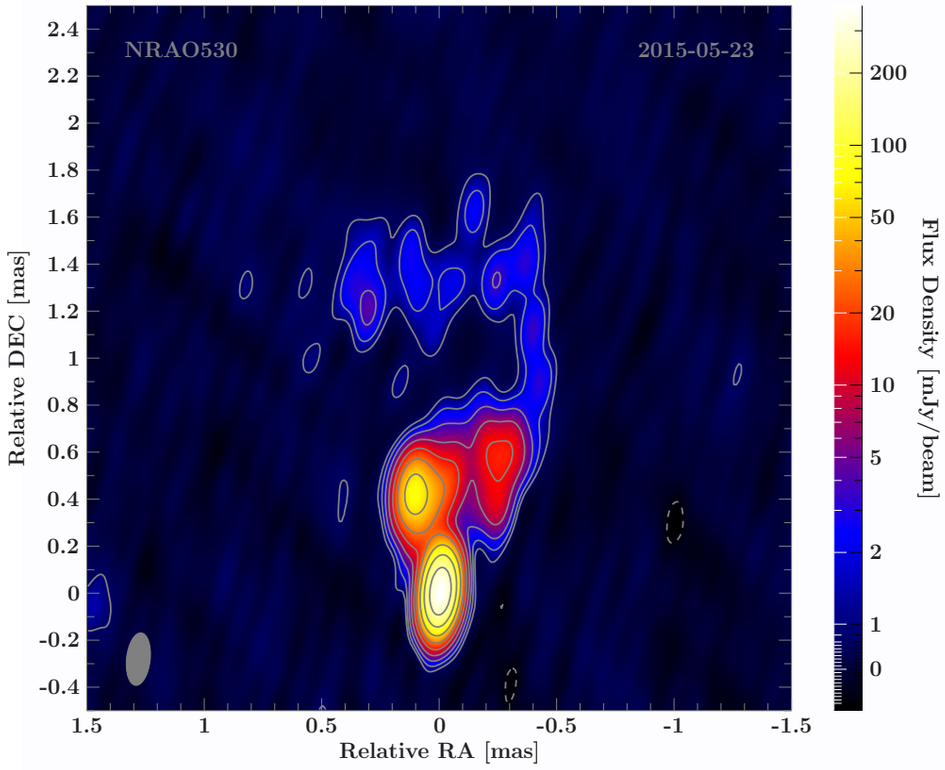
Brinkerink, Müller, Falcke, et al., MNRAS submitted



NRAO 530: Closure phases

$$\Phi ijk = \Phi ij + \Phi jk - \Phi ki$$

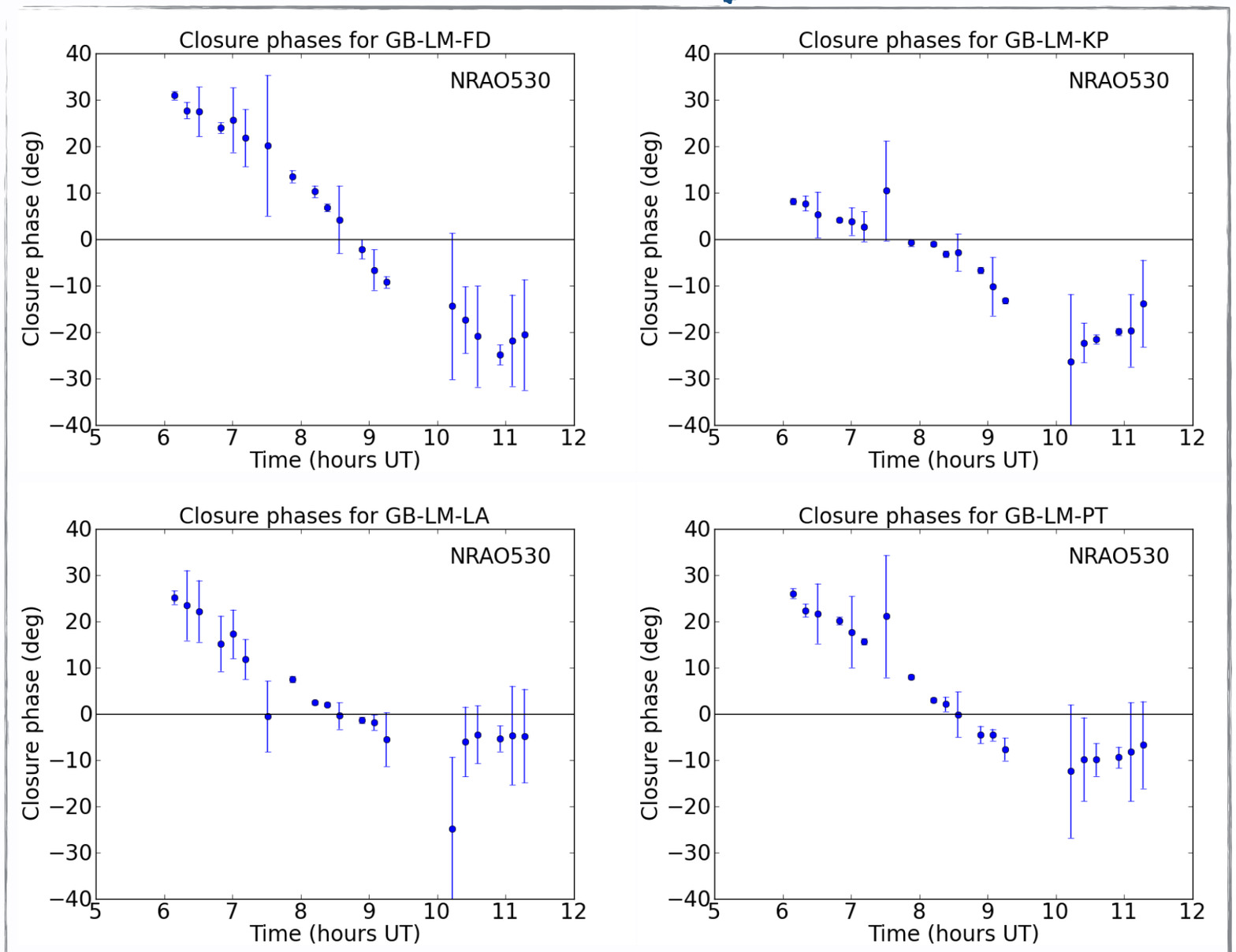


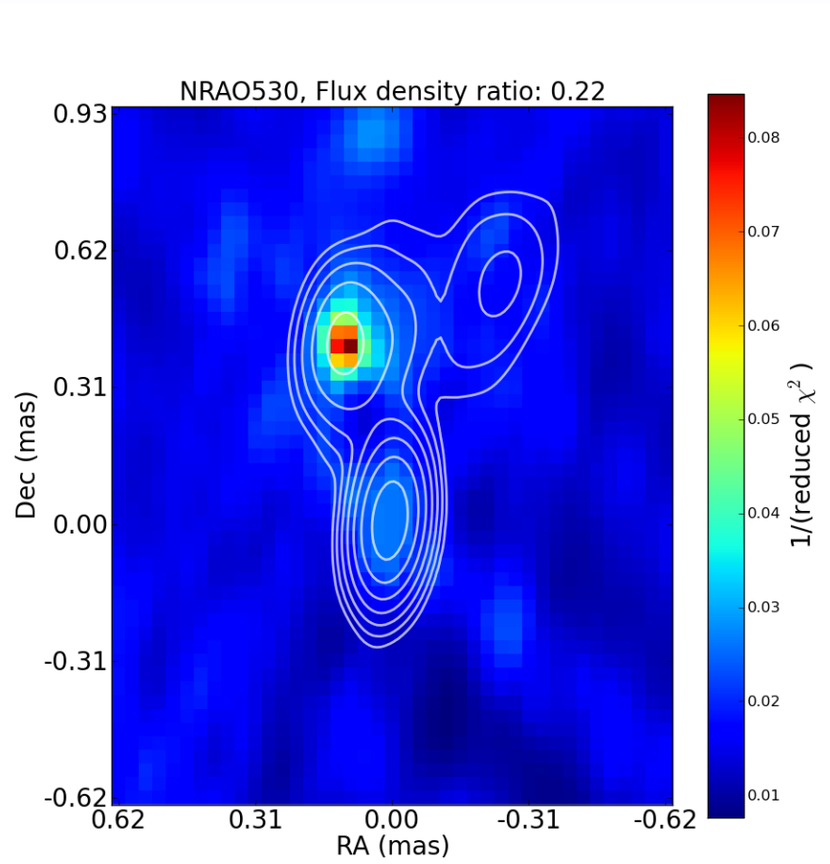


Brinkerink et al. (MNRAS submitted),
Müller et al. in prep.

NRAO 530: Closure phases

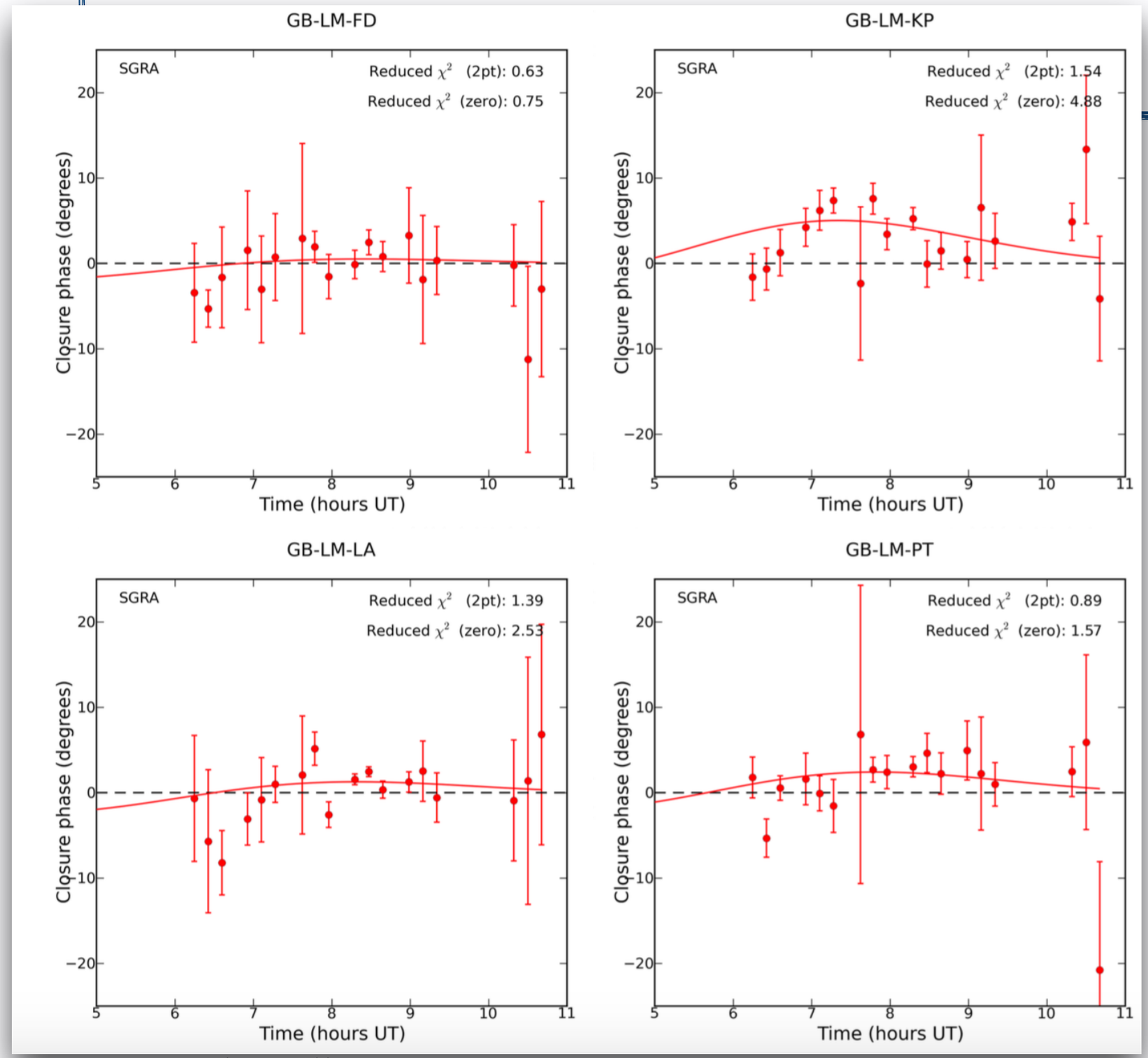
$$\Phi ijk = \Phi ij + \Phi jk - \Phi ki$$





Brinkerink et al. (MNRAS submitted),
Müller et al. in prep.

Sgr A*: Closure phases



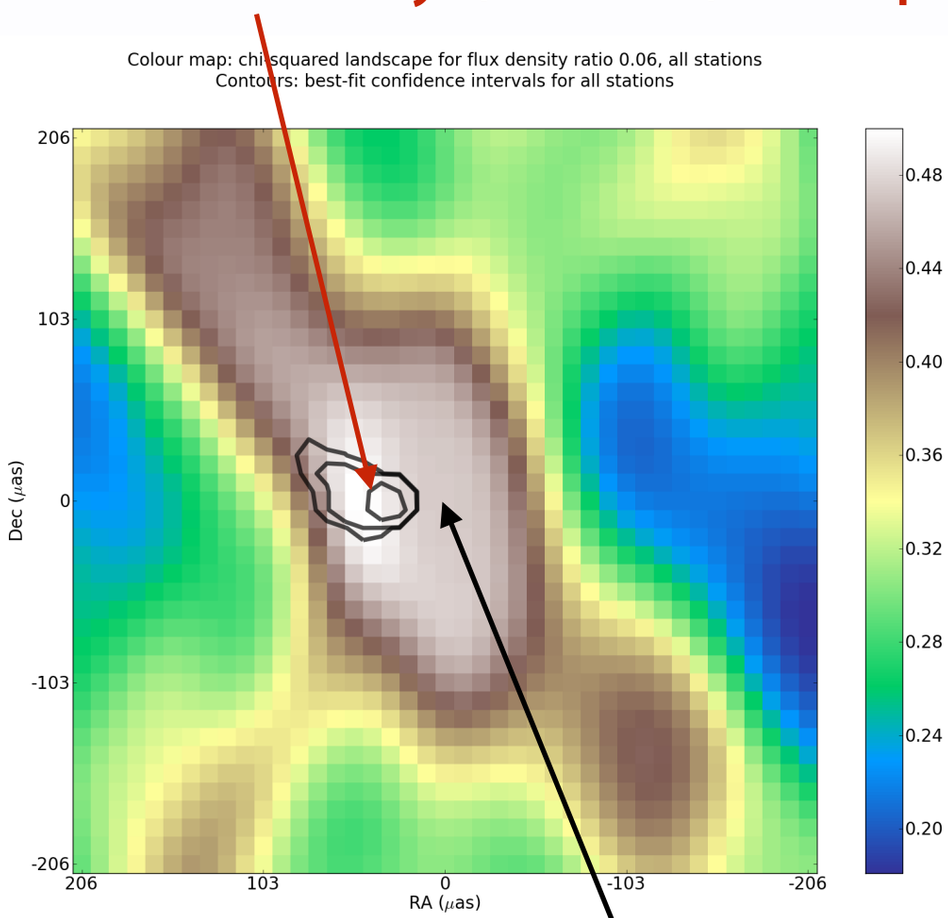
- scan averaged data
- **non-zero closure phases** for Sgr A* at 3mm

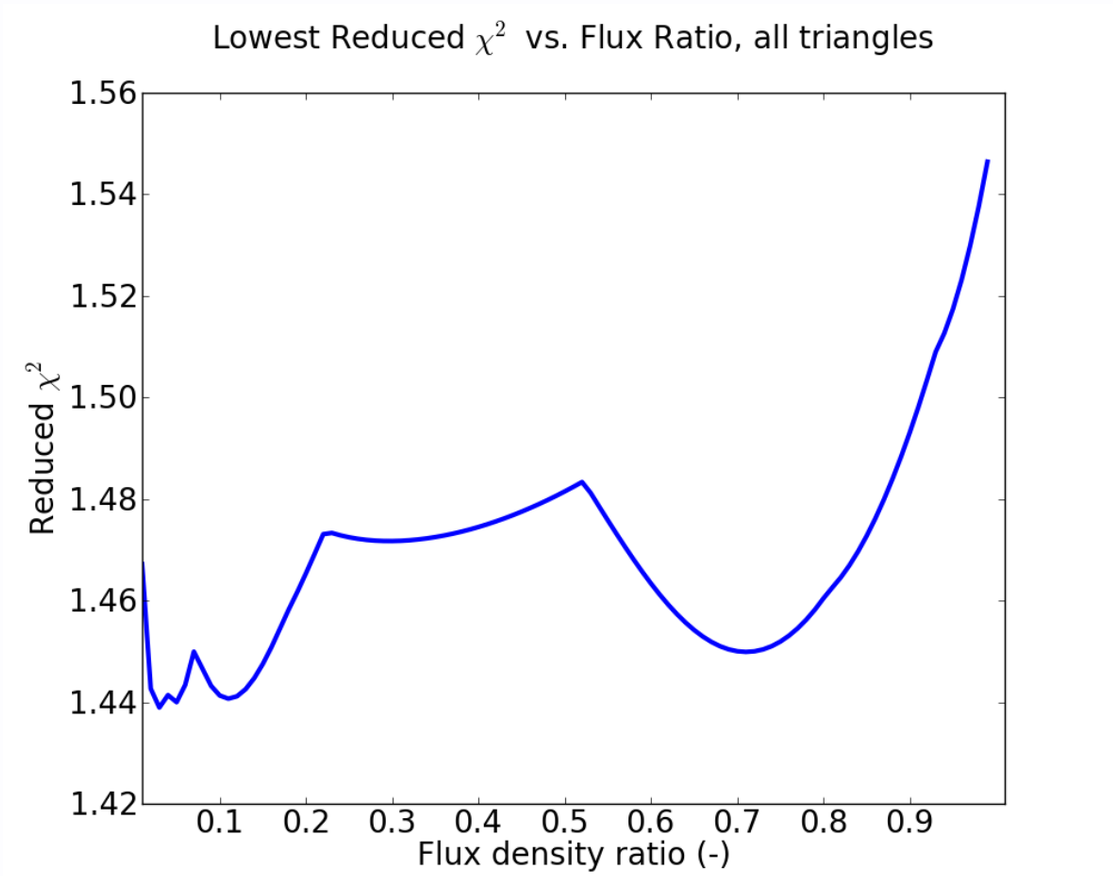
→ model with simple 2-point-source model

Brinkerink et al., MNRAS submitted

Sgr A*: Closure phases

→ secondary (fainter) component to East

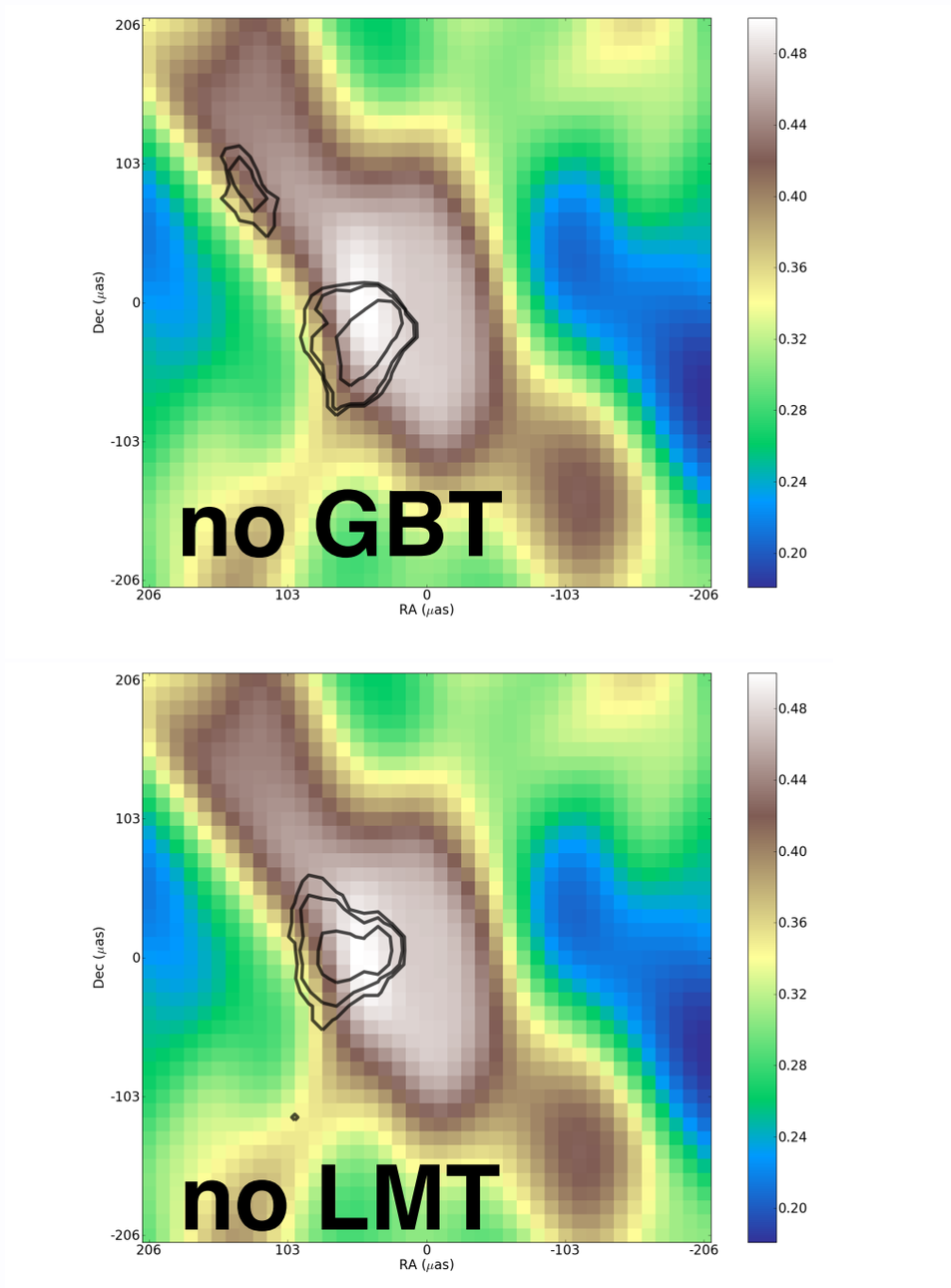




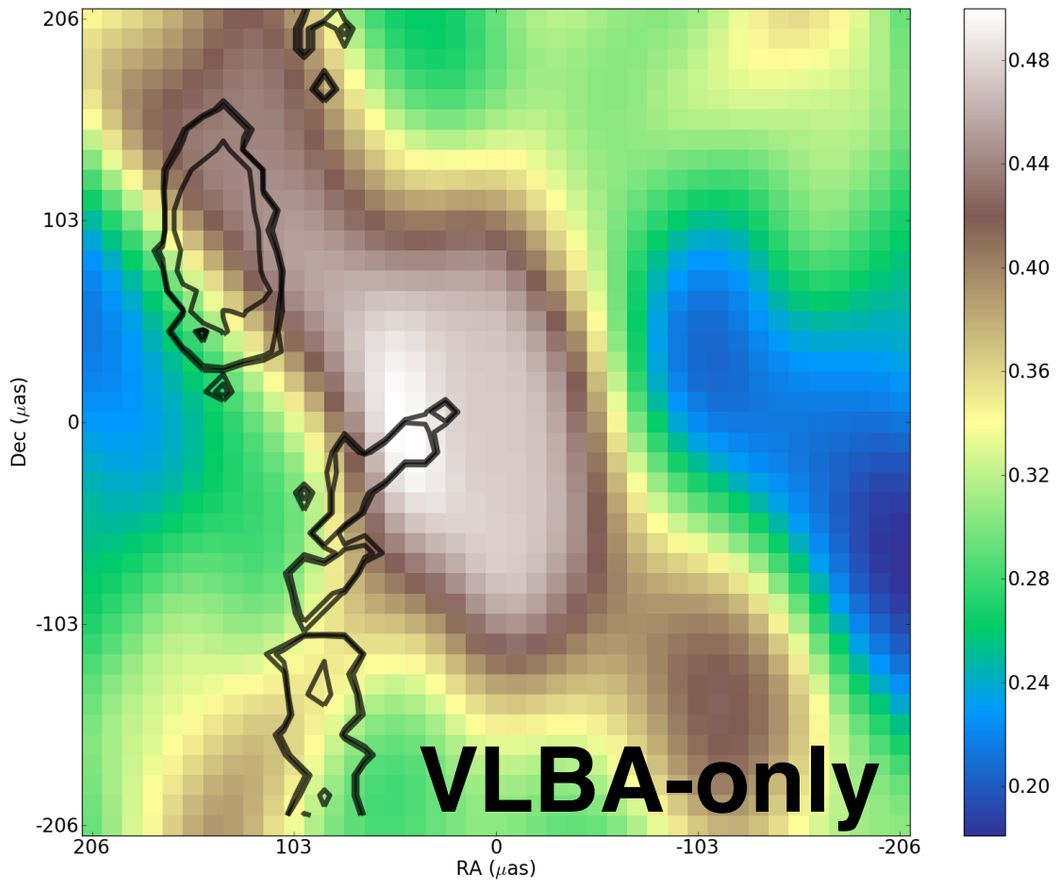
primary, brighter component at phase center

Brinkerink et al., MNRAS submitted

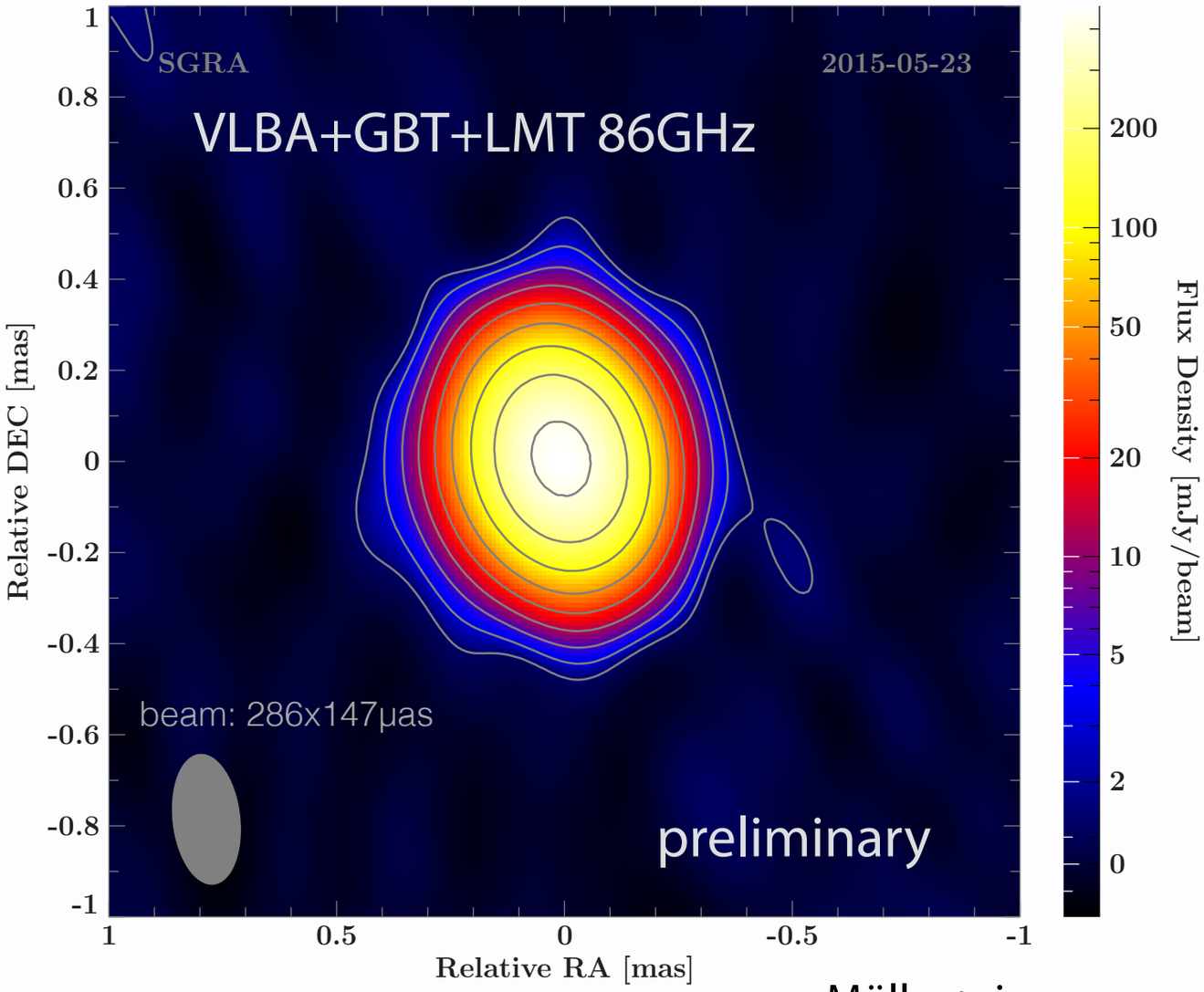
Sgr A*: Closure phases



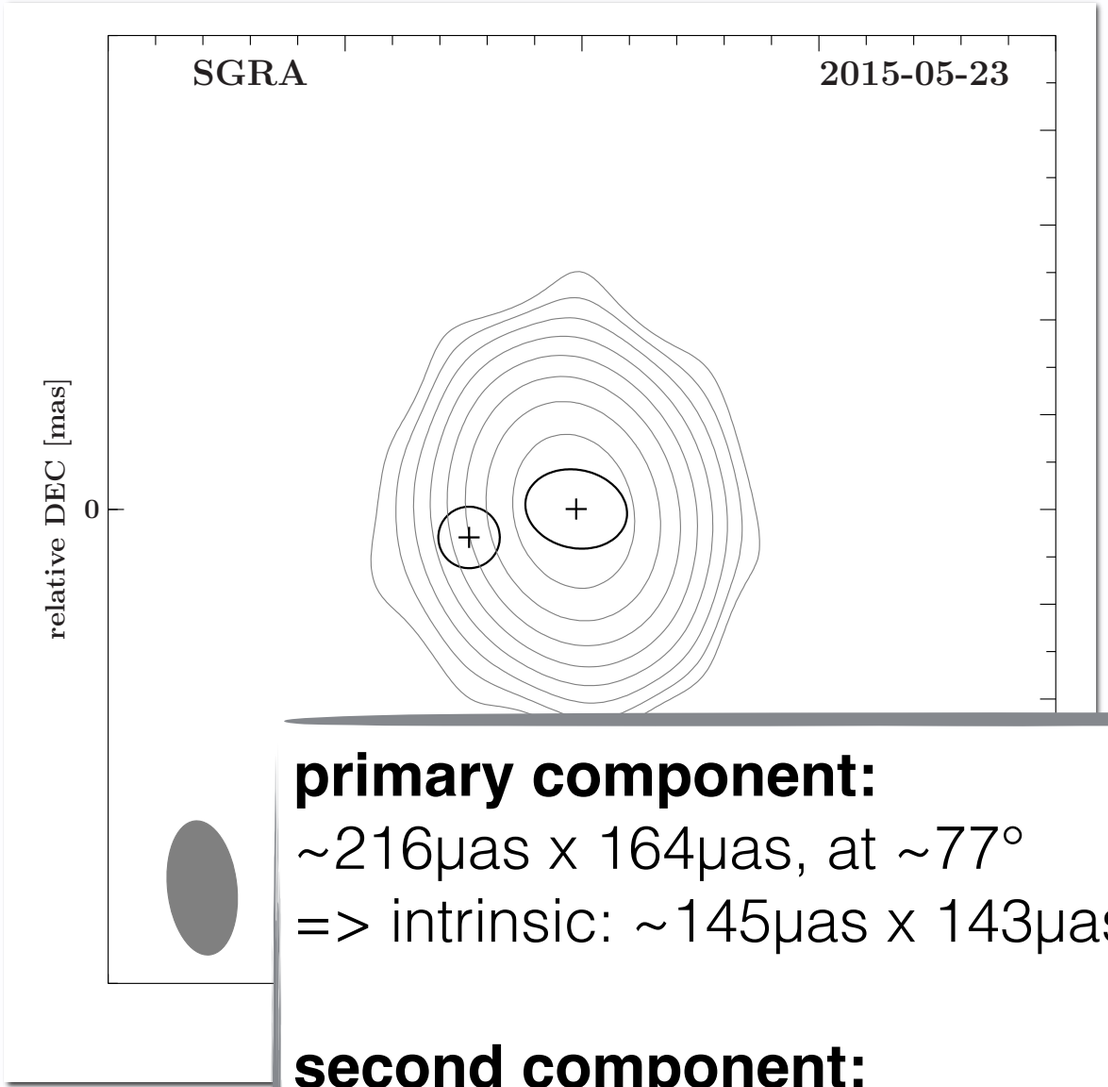
Colour map: chi-squared landscape for flux density ratio 0.06, all stations
Contours: best-fit confidence intervals for VLBA only



Imaging of Sgr A*



Müller+, in prep.



primary component:
~216μas x 164μas, at ~77°
=> intrinsic: ~145μas x 143μas

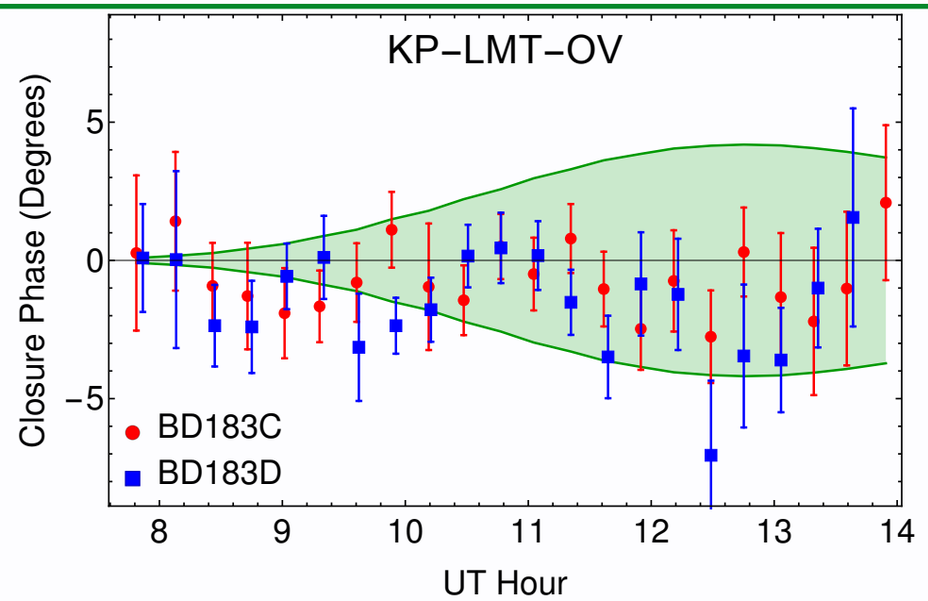
second component:
separation ~230μas
flux ratio ~0.01 (~22 σ)

Sgr A*: Closure phases

Recent results

Ortiz-Léon et al. 2016

- VLBA+LMT 86GHz observations (2015)
- non-zero closure phases
- consistent with scattering substructure
- intrinsic size: (147±7)μas x (120±2)μas

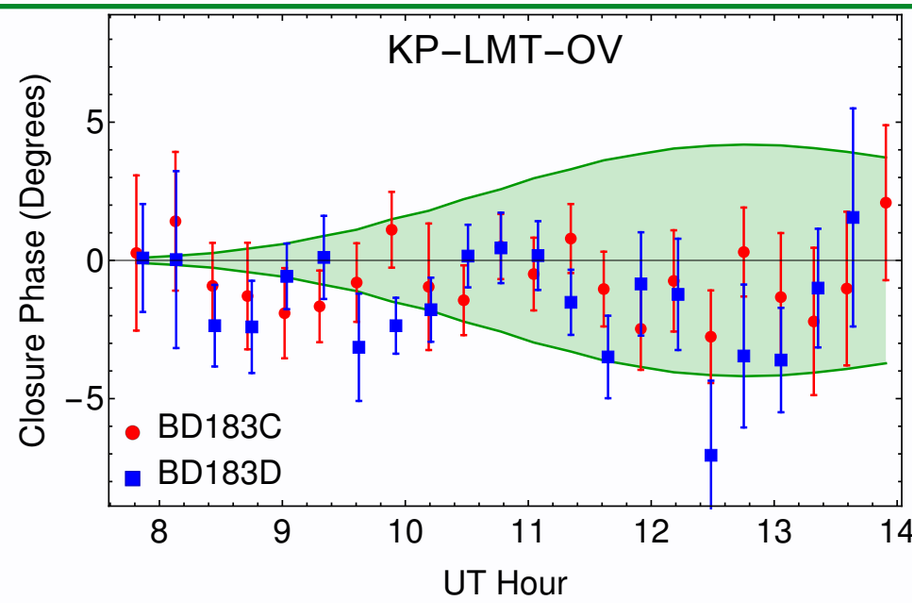


Sgr A*: Closure phases

Recent results

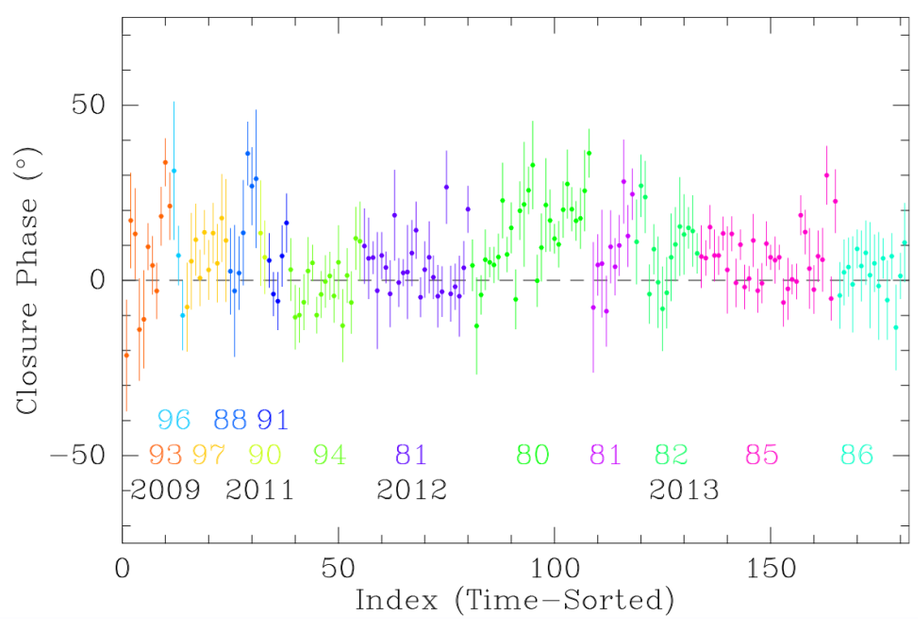
Ortiz-León et al. 2016

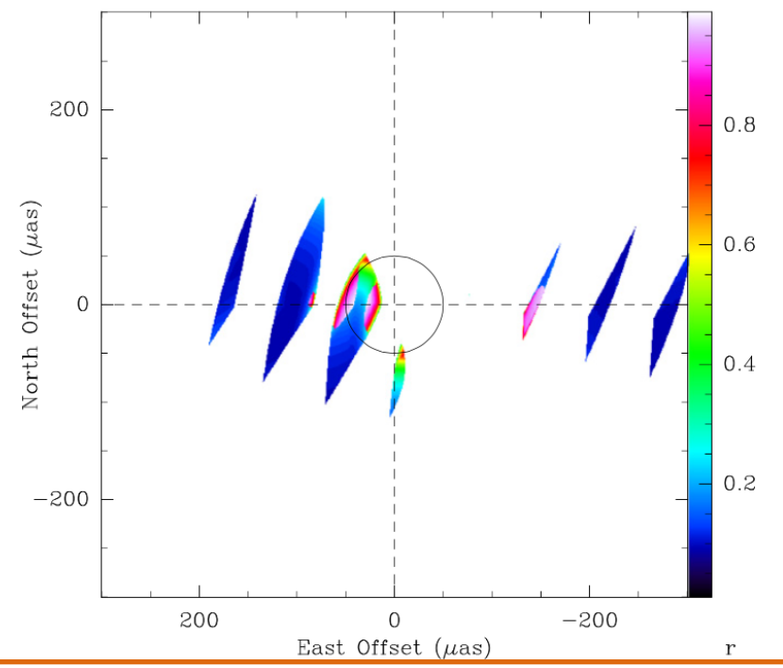
- VLBA+LMT 86GHz observations (2015)
- non-zero closure phases
- consistent with scattering substructure
- intrinsic size: (147±7)μas x (120±2)μas



Fish et al. 2016

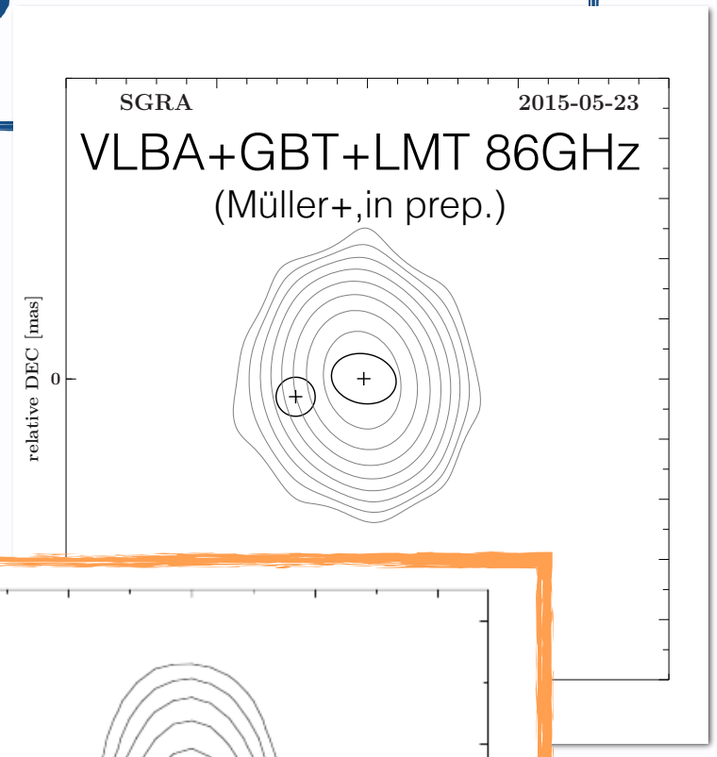
- EHT 1mm, 2009-2013
- persistent non-zero closure phases
- asymmetry on scales of few R_S

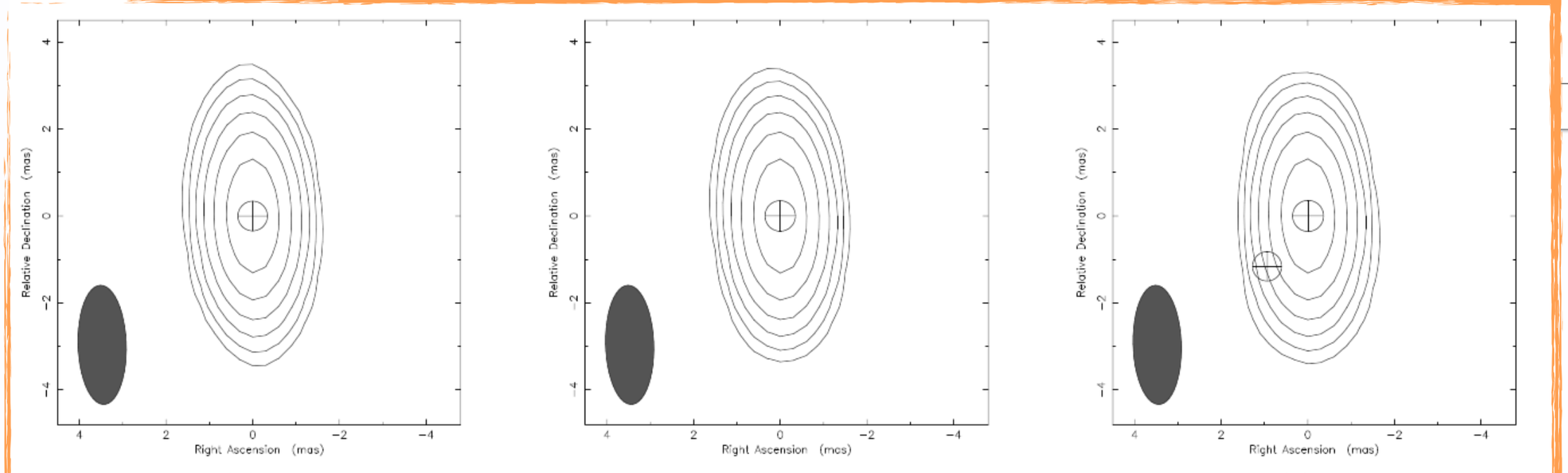




Imaging of Sgr A*

Rauch et al. 2016 (VLBA 43GHz):
secondary component (0.02Jy, flux ratio 0.01) at ~1.5mas towards south-east, close in time with radio flare





Summary & Conclusions

- 3mm VLBI observations of Sgr A* using VLBA+LMT+GBT
- closure phase analysis and imaging indicate asymmetry to East
- no distinction between intrinsic substructure or scattering possible
- compare to: VLBI at 1mm (Fish+2016), at 3mm (Ortiz-Léon+2016), at 7mm (Rauch+2016)

- further (multi-frequency) observations needed → constraints on theoretical models
- May 2016: dual-pol. GMVA observation of Sgr A*