The Dynamic Inner Disk of HD 163296

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SUNRISE

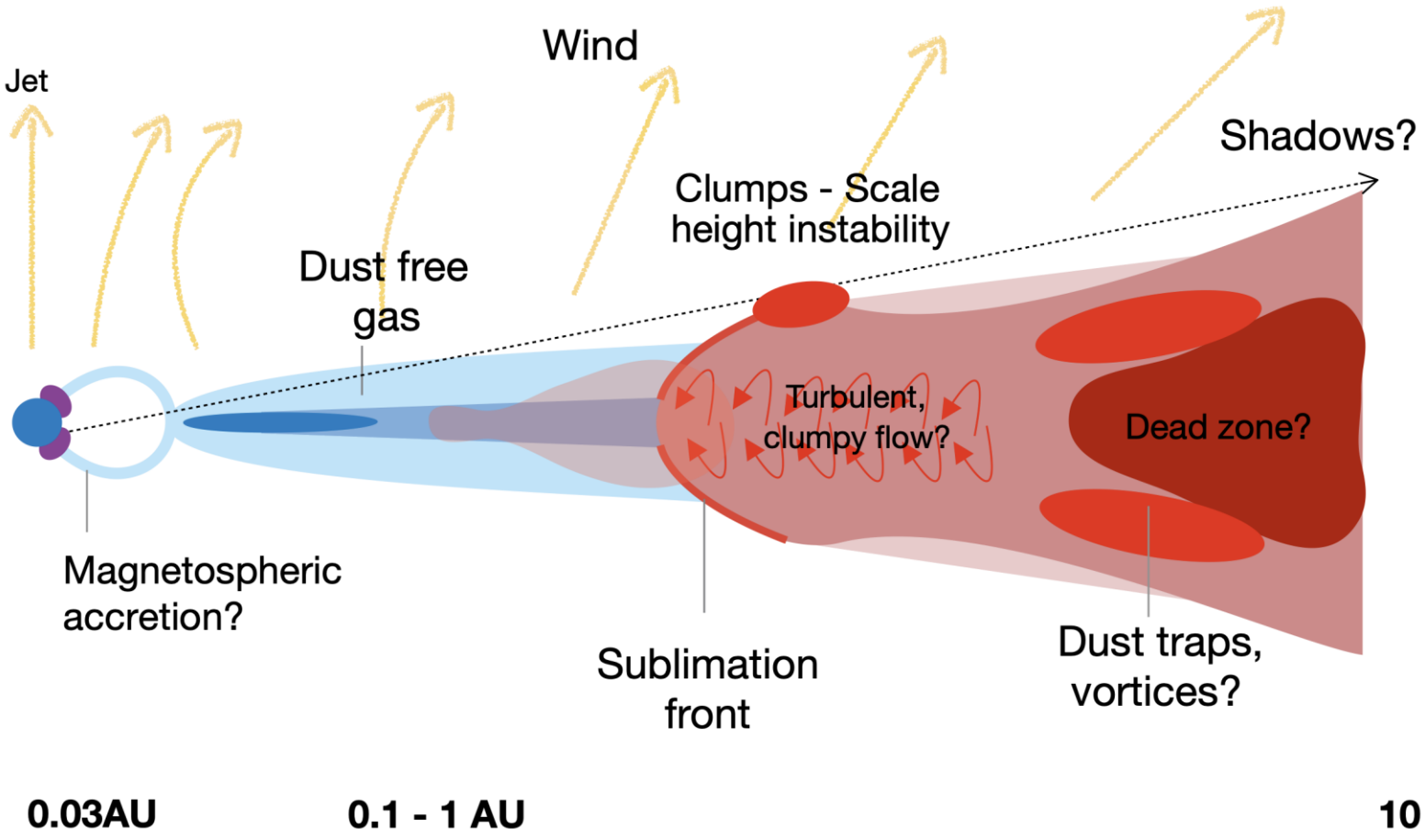
SUN RADIO INTERFEROMETER SPACE EXPERIMENT

HD 163296

YSO inner disks

- NIR interferometry studies of disks need high uv sampling to distinguish features
- Current facilities can only provide this by observing over time
- Imaging efforts have focused on using as much information to reconstruct a single image
- Studies often span several months or years
- *Key modeling assumption: Inner disk is static*

YSO inner disks



(Dullemond & Monnier 2010 / Berger 2018)

YSO inner disks

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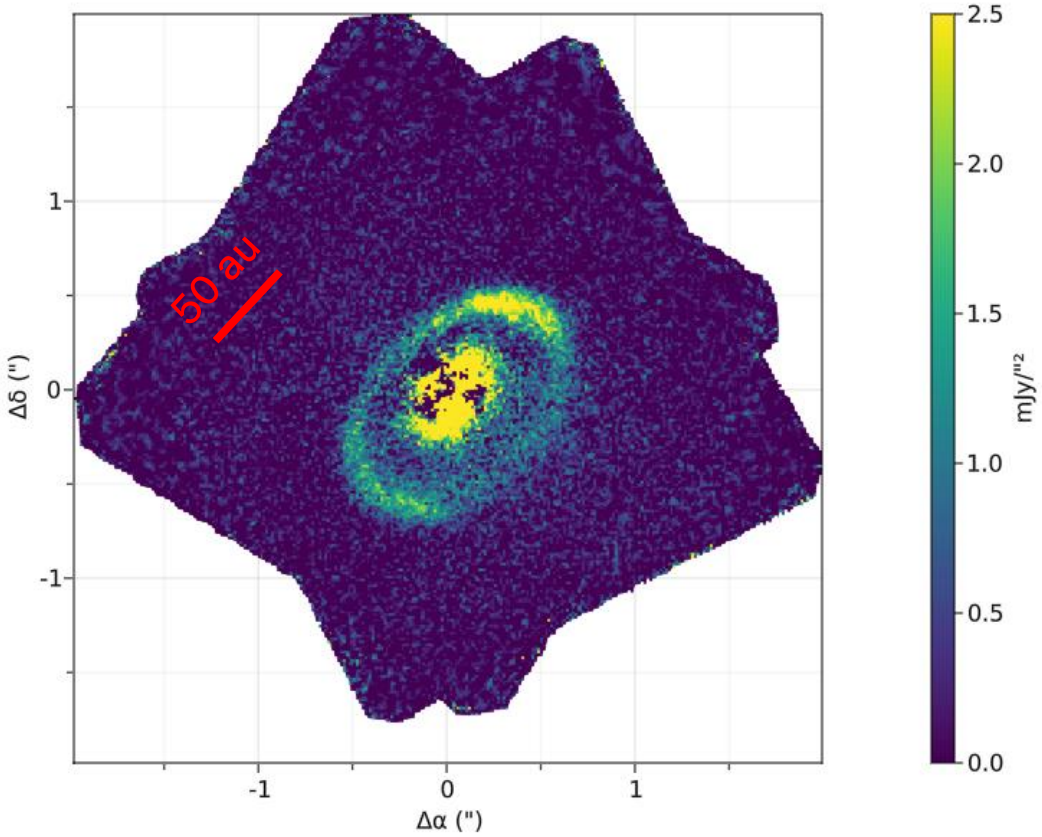
- *Key modeling assumption: Inner disk is static*
- We see brightness variations in YSO sources on day-month timescales
- Scattered light images show moving shadows in outer disk
- Typical orbital timescale on order of a month at sublimation radius for Herbig sources.

HD 163296

- Herbig Ae star
- 2 $M_{\odot}$ central source
- 100.5(4) pc distance from Earth
  - 10 mas = 1 au
- Outer disk is orbiting clockwise
- Outer disk shadowing variations seen on ~3 month timescales *(Rich+ 2020)*



GPI-LIGHTS *(Monnier+ 2017)*

HD 163296

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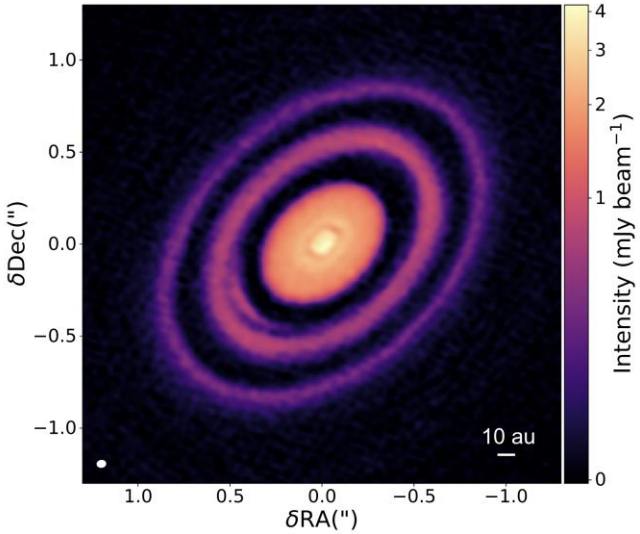
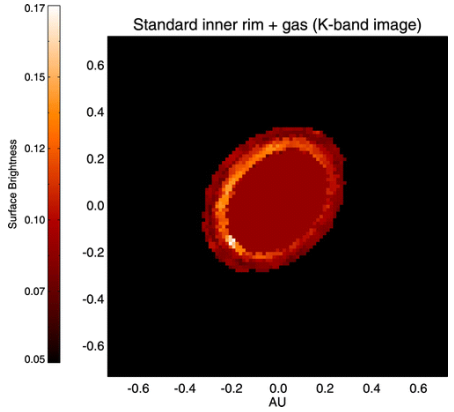


DSHARP *(Isella+ 2018)*

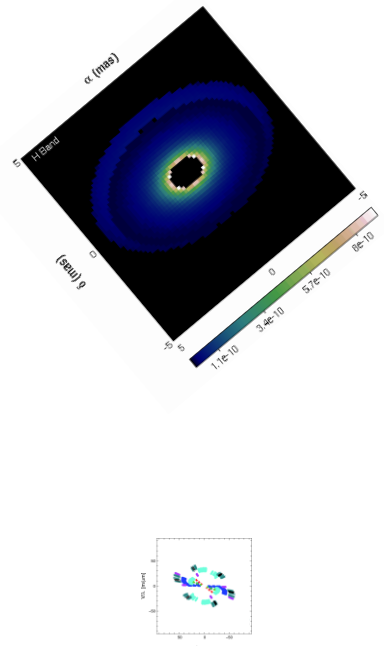
Earlier modeling efforts at H-band

Tannirkulam+ 2008b



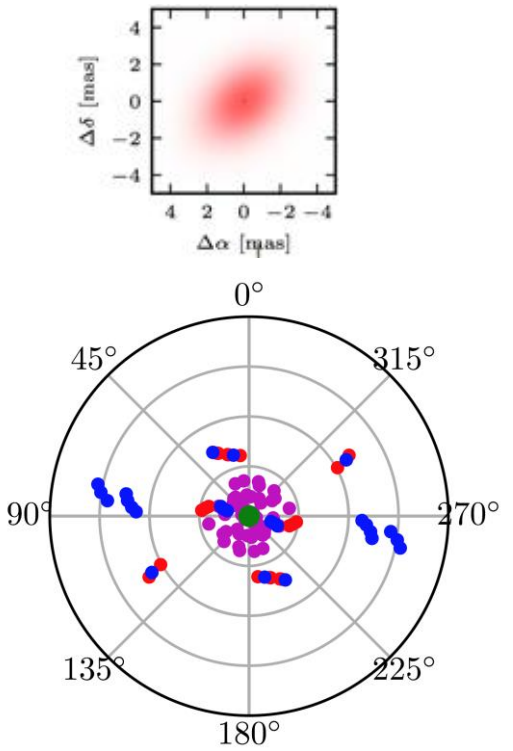
3 years

Benisty+ 2010a



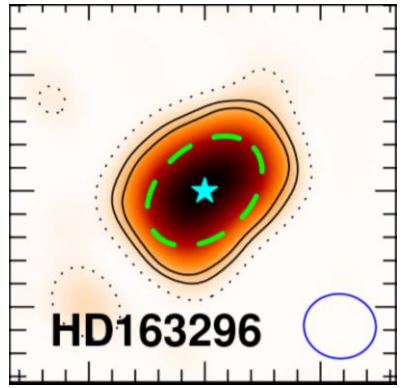
2 months

Setterholm+ 2018

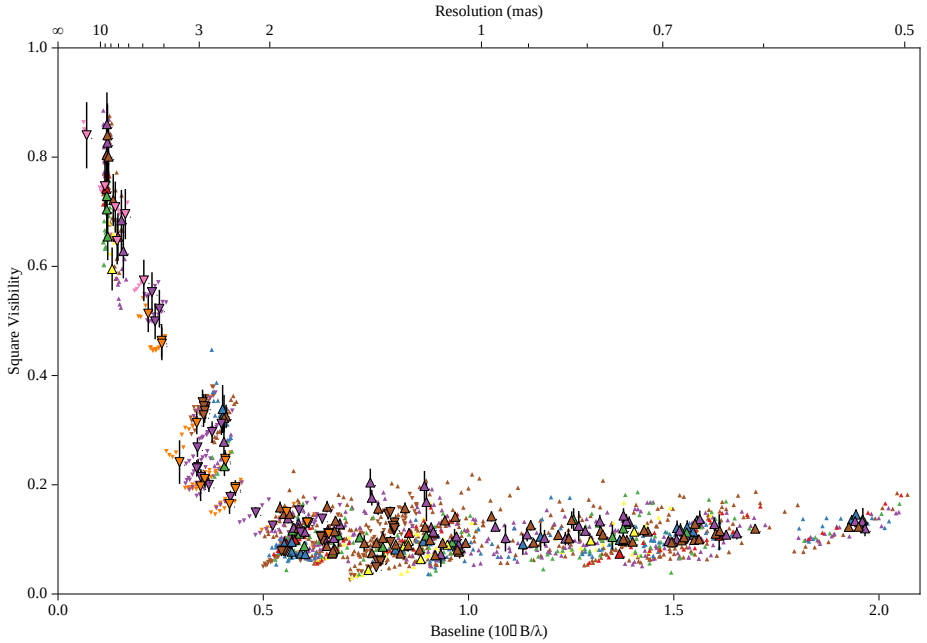


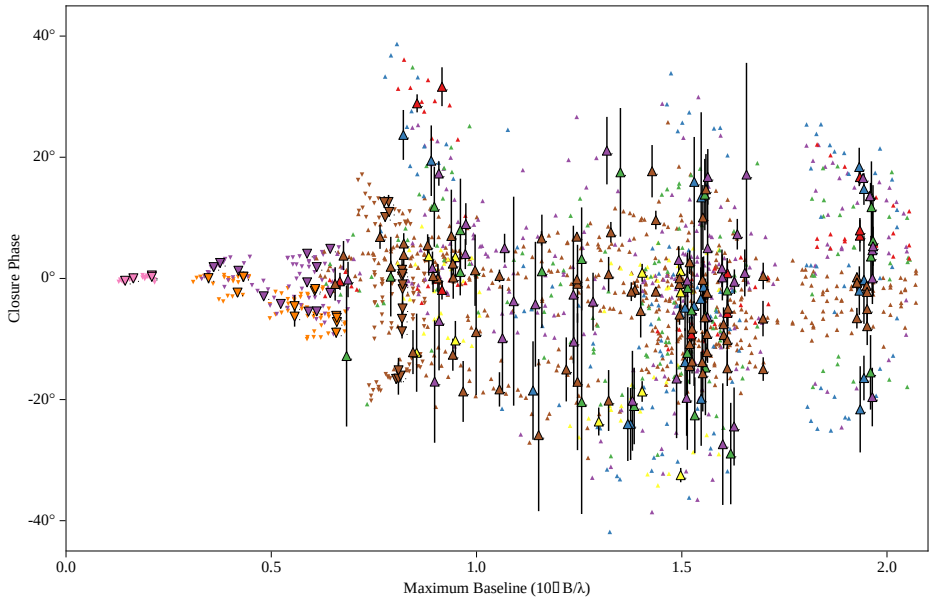
10 years

Lazareff+ 2017; Kluska+ 2020a



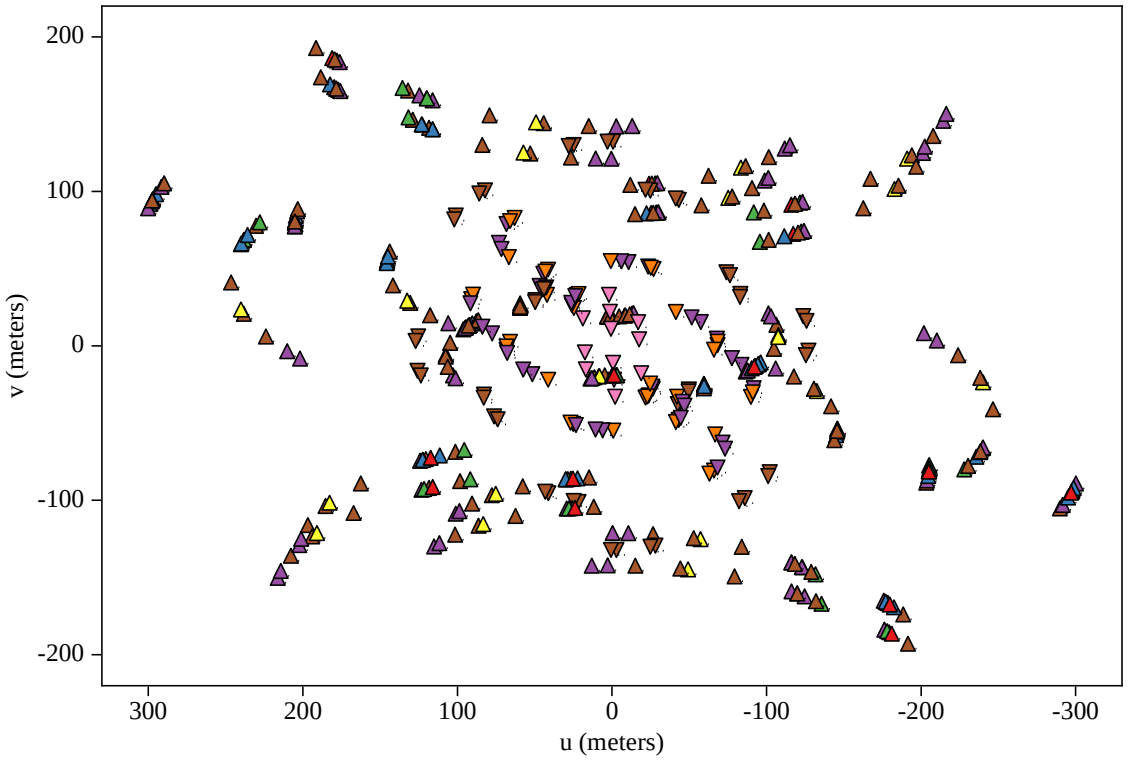
7 months





Date
- June 05, 2019
- June 06, 2019
- June 08, 2019
- June 09, 2019
- July 10, 2019
- July 13, 2019
- July 20, 2019
- July 29, 2019

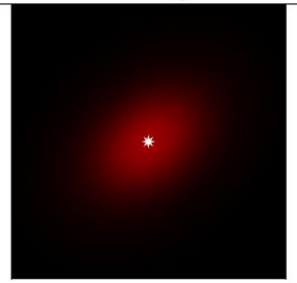
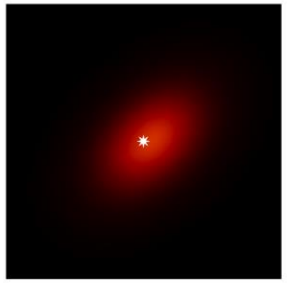
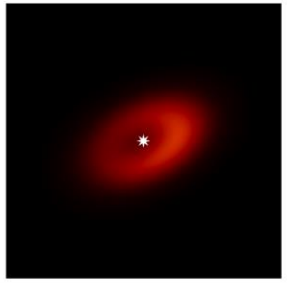
Instrument
- ▲ MIRC-X
- ▼ Pionier



HD 163296

(Setterholm+ 2023, in prep.)

Static disk fitting

Model Description	Fit Image	Fit Results
Centered Gaussian 6 fit parameters		Total $\chi^2_\nu = 18.7$ $\mathcal{V}^2$ $\chi^2_\nu = 7.9$ CP $\chi^2_\nu = 30.6$
Off-center Gaussian 8 fit parameters		Total $\chi^2_\nu = 14.9$ $\mathcal{V}^2$ $\chi^2_\nu = 8.6$ CP $\chi^2_\nu = 21.7$
Skew Ring 9 fit parameters		Total $\chi^2_\nu = 13.1$ $\mathcal{V}^2$ $\chi^2_\nu = 8.3$ CP $\chi^2_\nu = 18.4$

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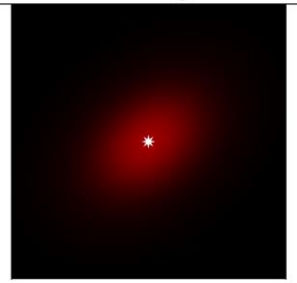
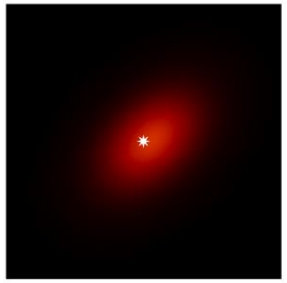
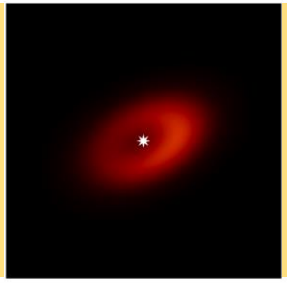
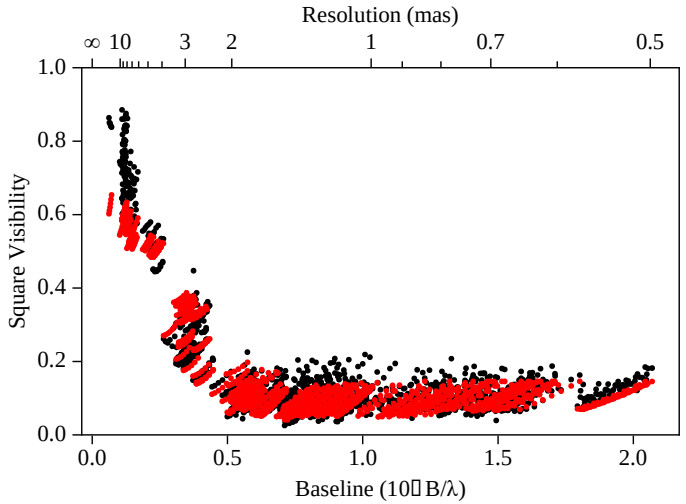
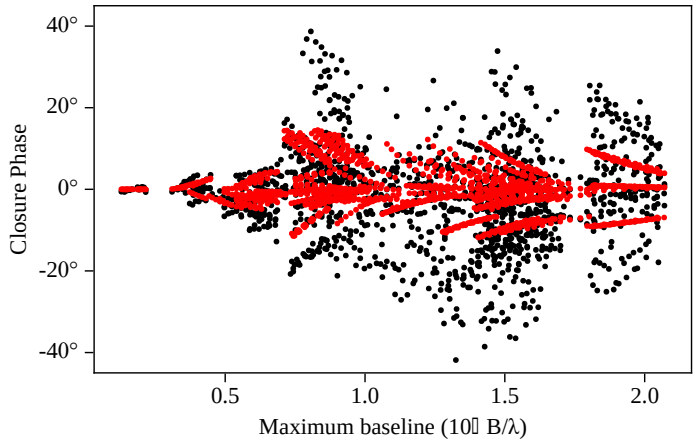
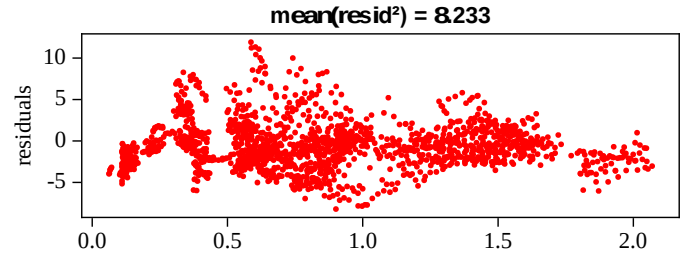
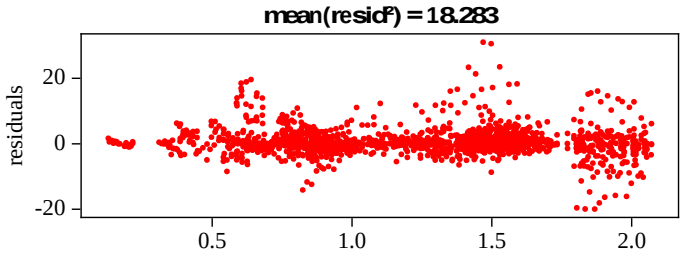
Centered Gaussian 6 fit parameters		Total $\chi^2_\nu = 18.7$ $\mathcal{V}^2$ $\chi^2_\nu = 7.9$ CP $\chi^2_\nu = 30.6$
Off-center Gaussian 8 fit parameters		Total $\chi^2_\nu = 14.9$ $\mathcal{V}^2$ $\chi^2_\nu = 8.6$ CP $\chi^2_\nu = 21.7$
Skew Ring 9 fit parameters		Total $\chi^2_\nu = 13.1$ $\mathcal{V}^2$ $\chi^2_\nu = 8.3$ CP $\chi^2_\nu = 18.4$



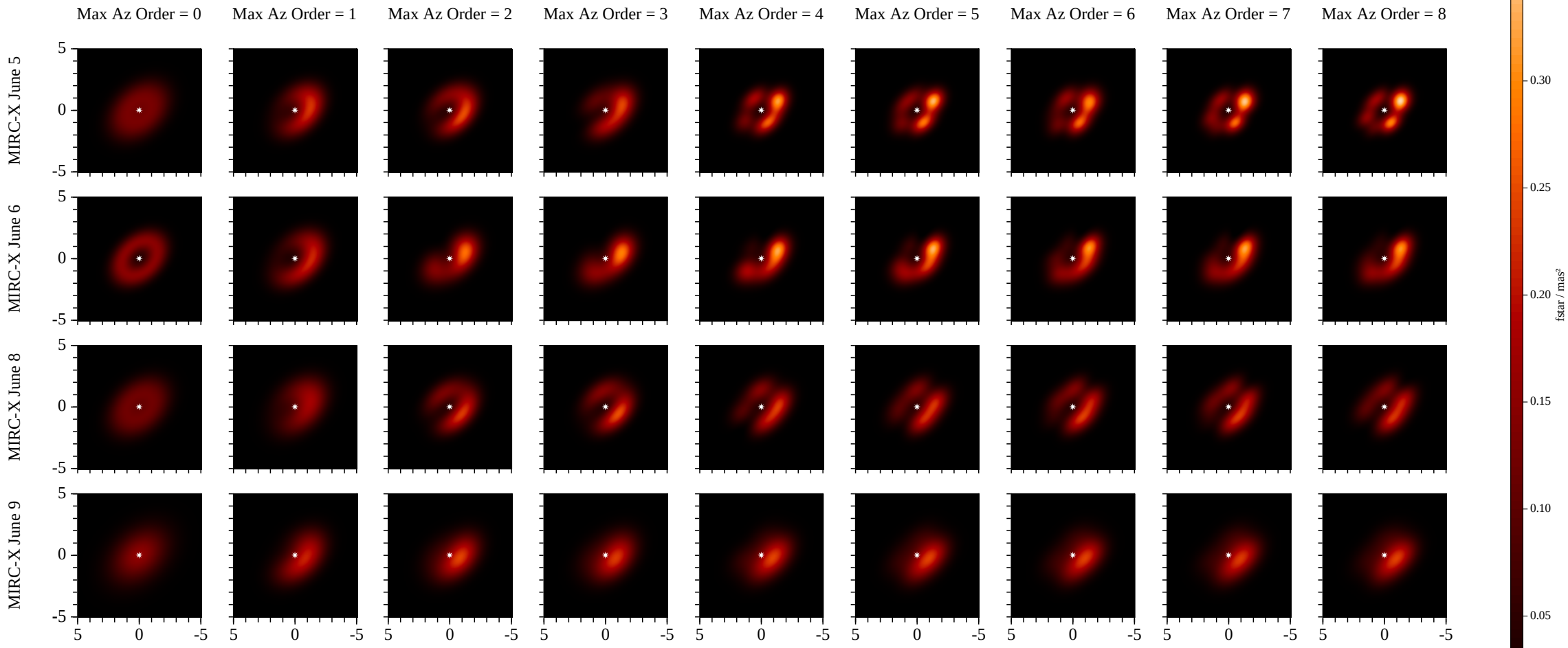






HD 163296

Dynamic disk fitting



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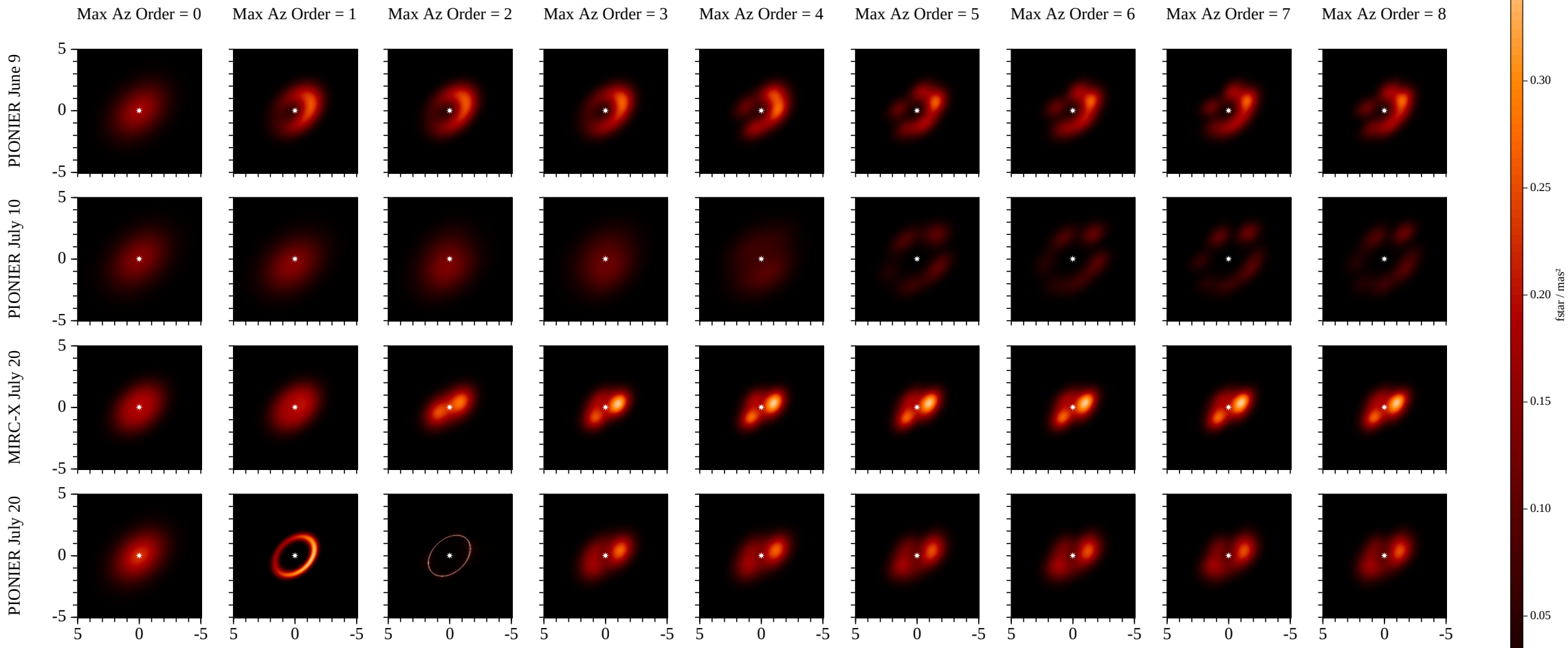

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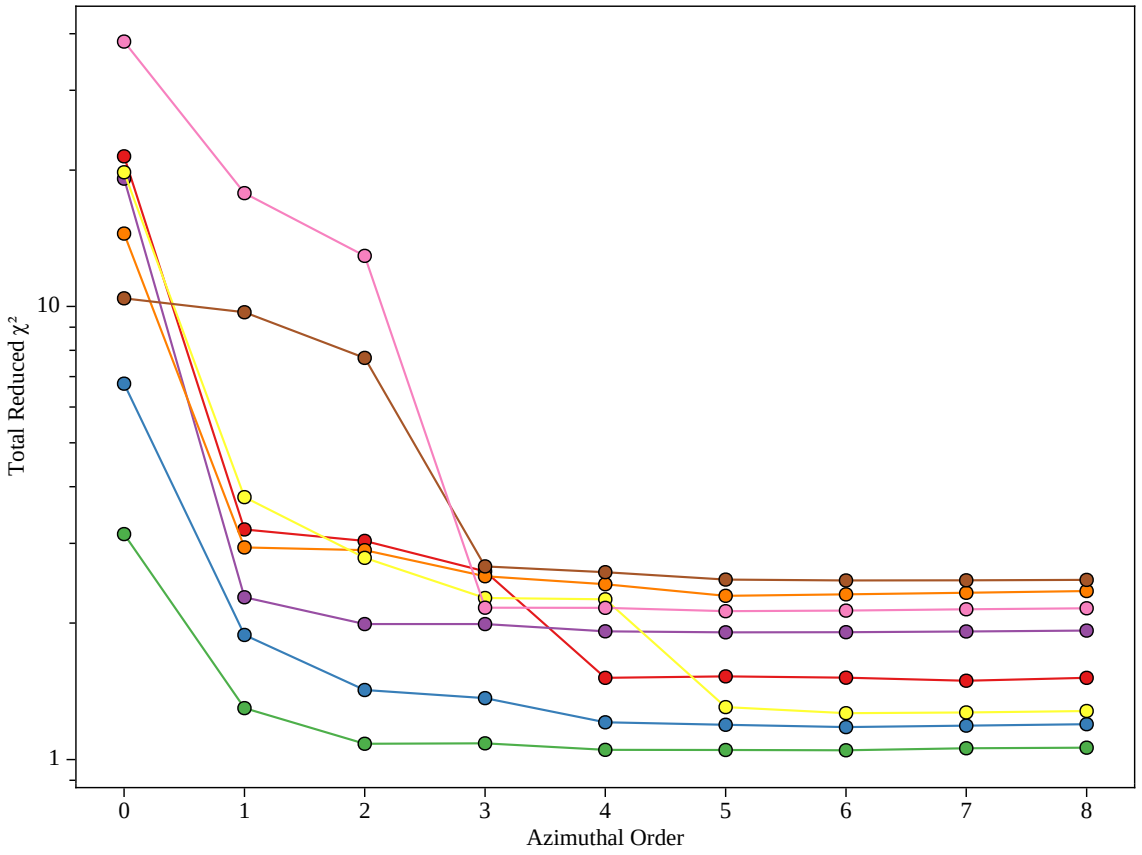

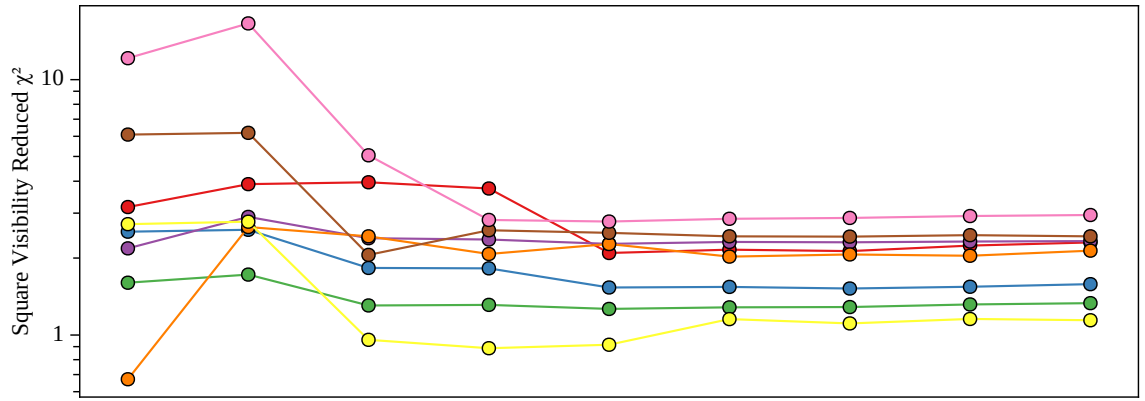

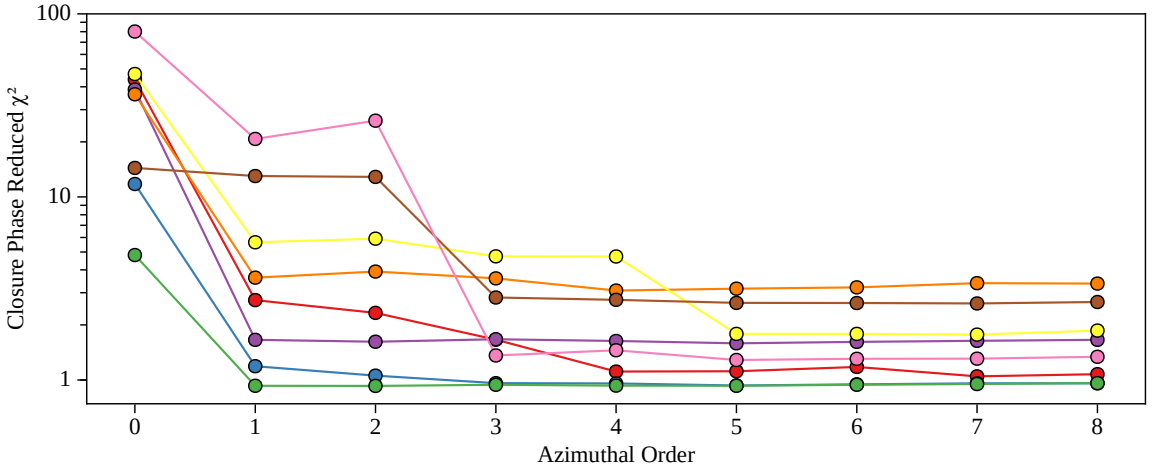

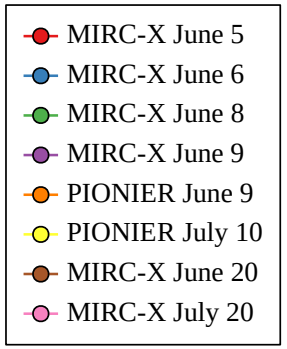

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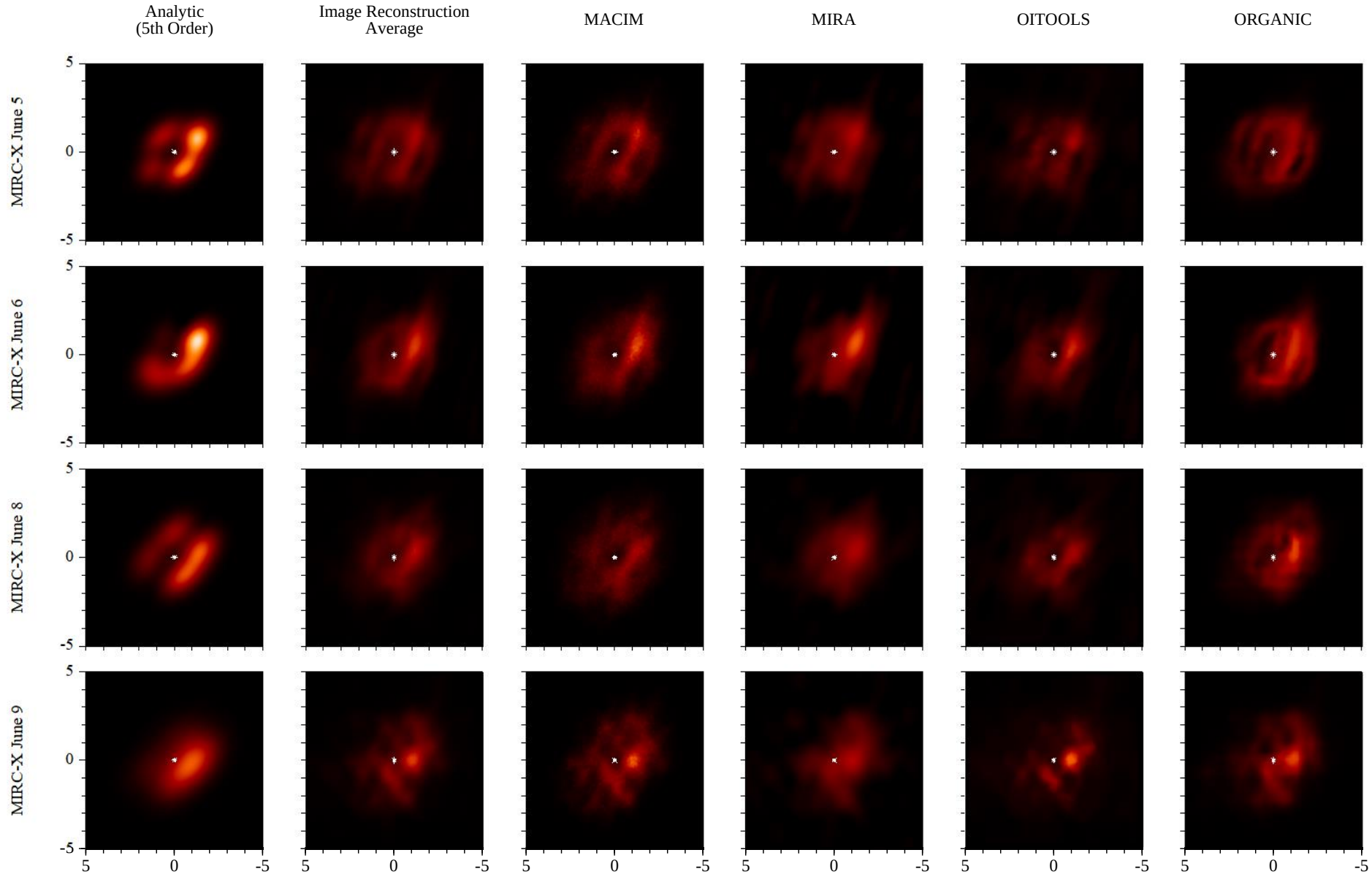
Analytic
(5th Order)
Image Reconstruction
Average
MACIM
MIRA
OITOOLS
ORGANIC
MIRC-X June 5
MIRC-X June 6
MIRC-X June 8
MIRC-X June 9
5
0
-5

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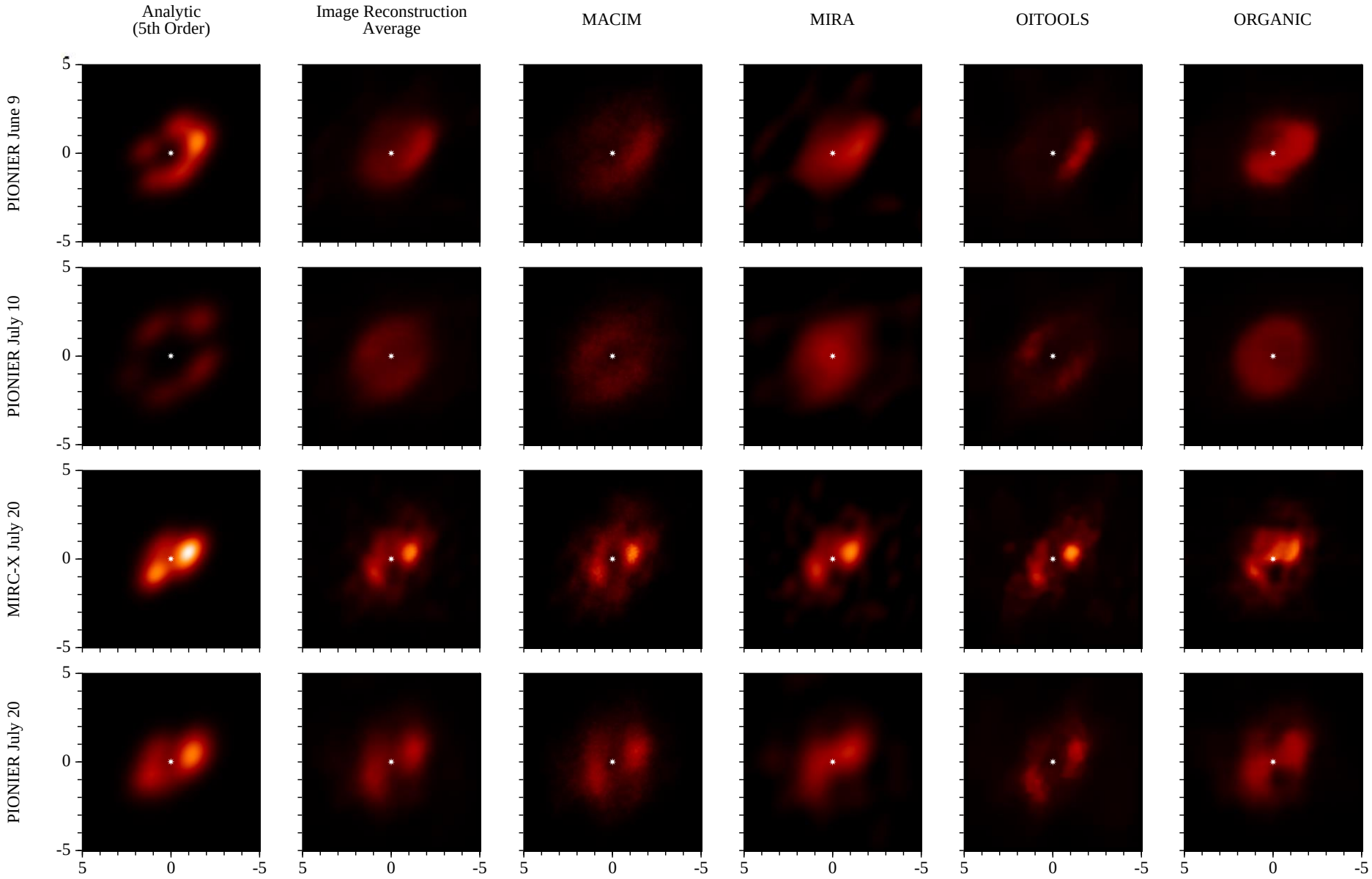
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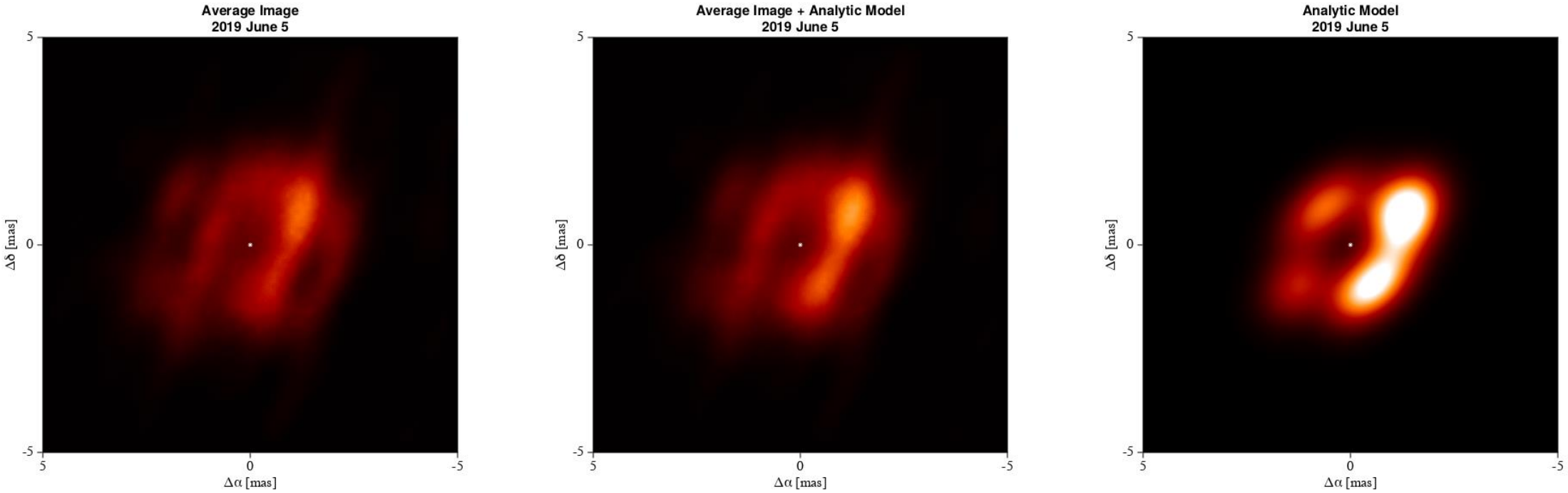
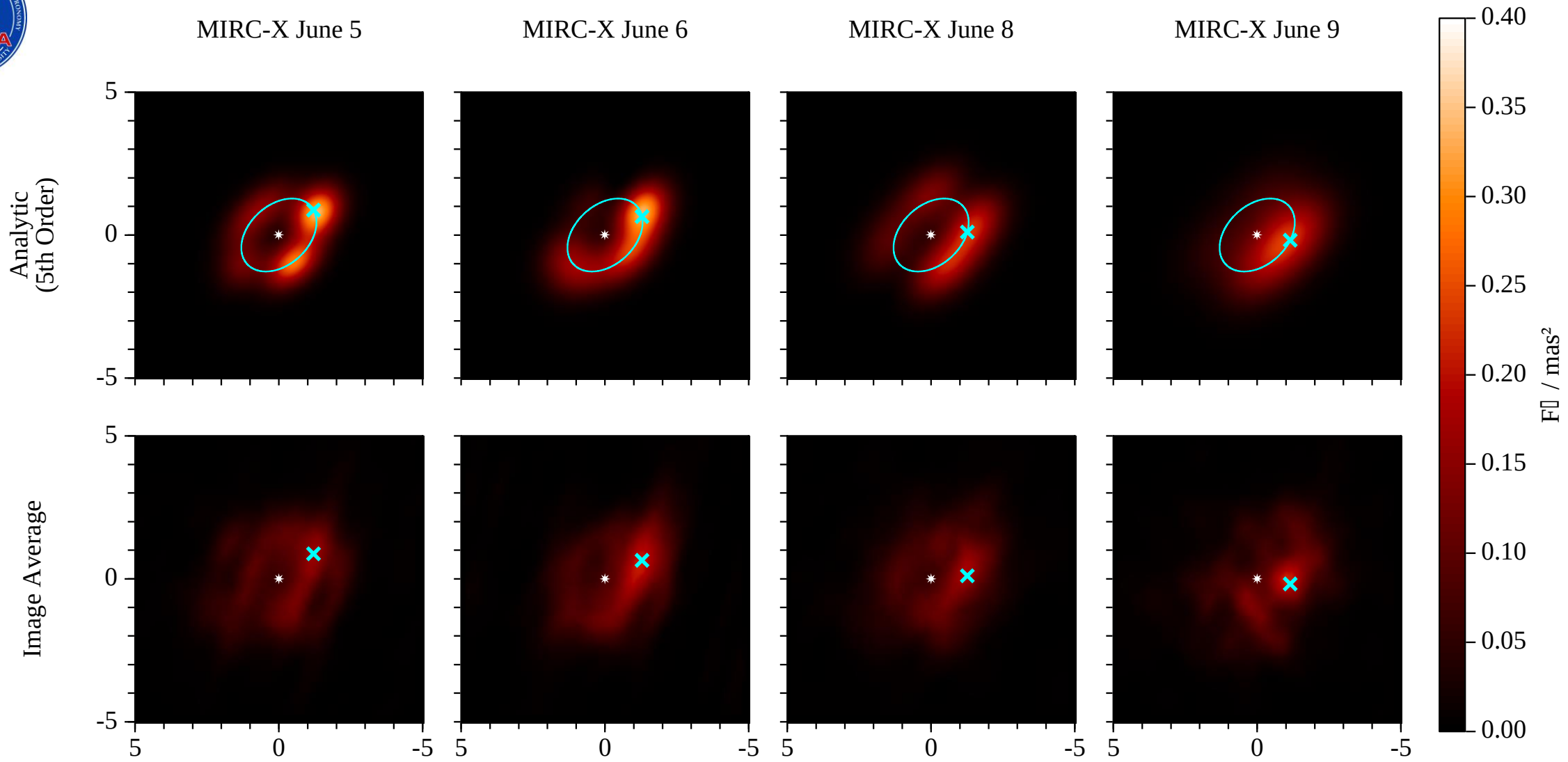


First convincing detection of orbital motion in the inner au of a protoplanetary disk!



Orbital motion for a spot with a ~35.5 day period

HD 163296

Interpretation (ongoing)

- Keplarian orbit at 0.16 au radius should be ~16 days
  - Feature we see over 4 days moving about half-Keplarian speed
- Rotation is CW, like the outer disk

- Rossby wave instability in dead-zone => vortex? *(Flock+ 2017, 19)*
- Planetary wake? *(Bae+ 2019)*
- Gas in elliptical orbits near the sublimation radius => stable spiral wake? *(Li+ 2021)*

- July data even more weird; multiple sources?
  - Not enough temporal coverage to make definitive statements
- Fantastic demonstration of MIRC-X capability, shows need for contemporary VLTI observations