

Lessons learned from NEAR for high-contrast imaging of exoplanets with ELT METIS

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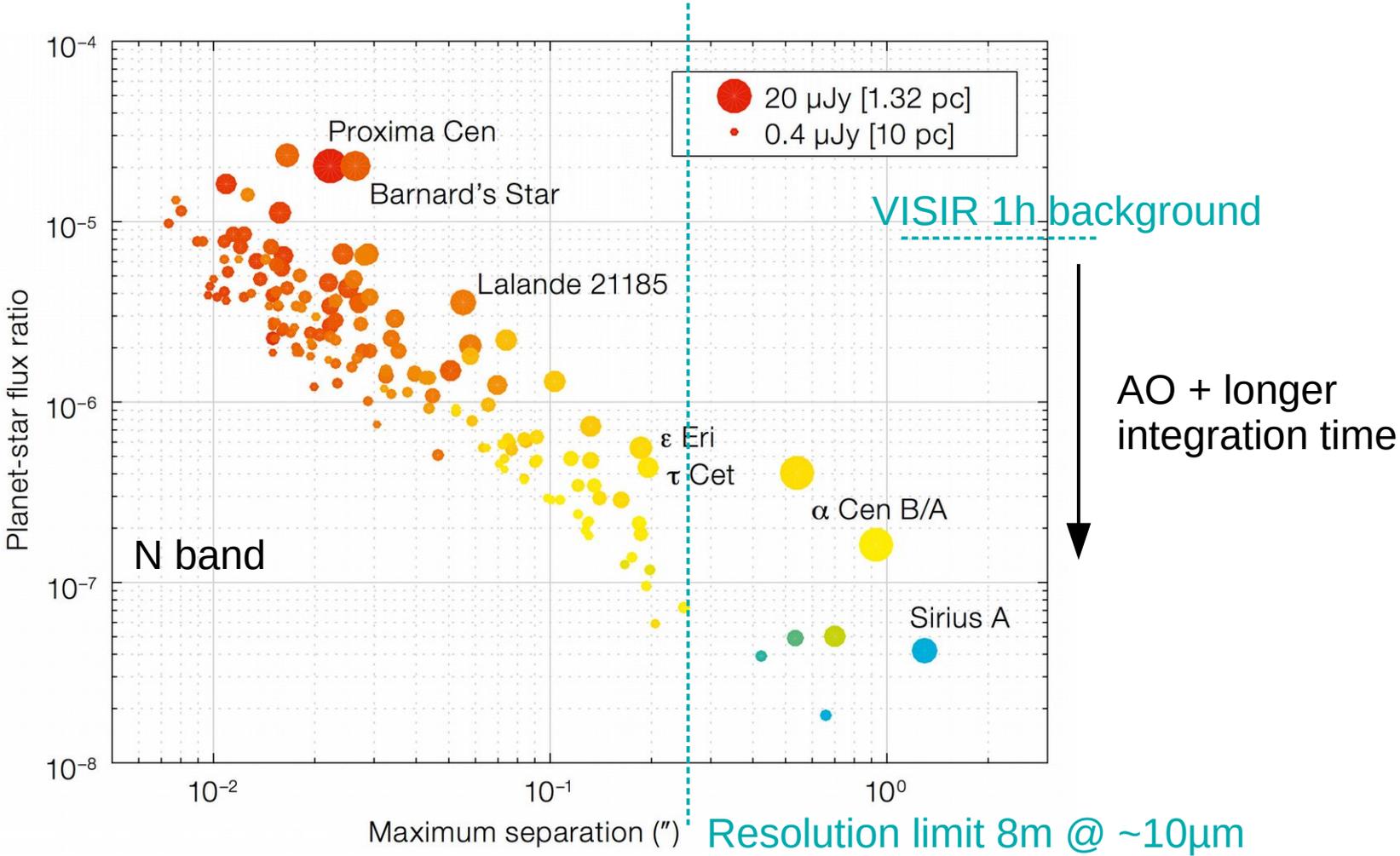
NEAR



- New Earths in the α Cen region
- **100-h MIR imaging search** rocky planets habitable zone α Cen
- Collaboration ESO - Breakthrough Initiatives
- **Upgraded VLT/VISIR coupled with Adaptive Optics Facility**
- Pathfinder ELT/METIS
- Commissioning 12 half nights April-May 2019
- Campaign **May-June 2019** ~75h data → talk M. Kasper
poster K. Wagner

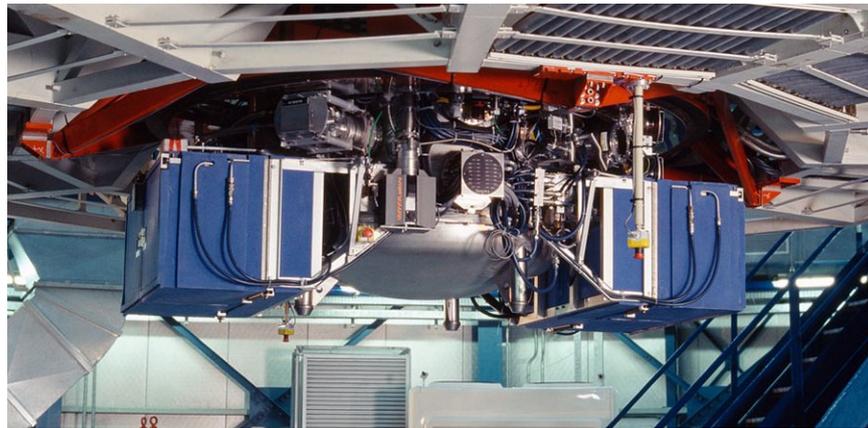
Kasper et al. 2017, 2019, Lagage et al. 2004, Arsenault et al. 2017

Contrast vs. separation



VISIR upgrade

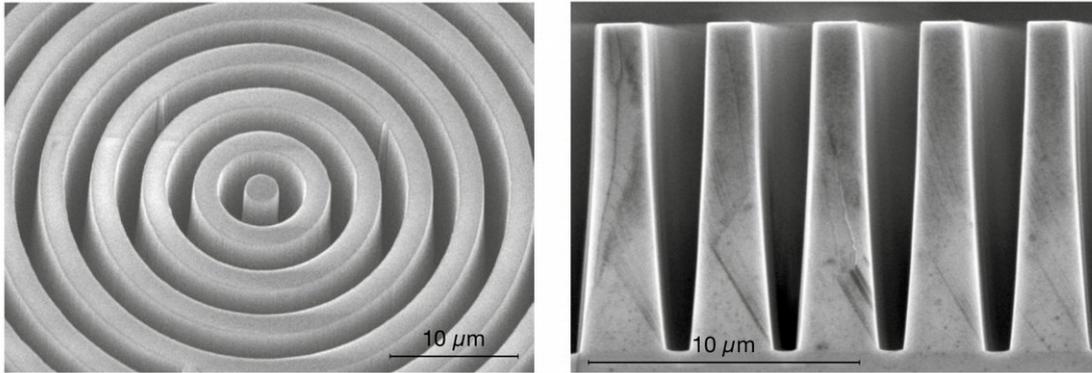
- Wavefront sensing I band → differential atmospheric refraction (no ADC) + non-common path aberrations
- Wavefront correction deformable M2 AOF → background
- Broad-band filter 10–12.5 μm → chromaticity coronagraph
- Vortex coronagraph + apodized Lyot stop



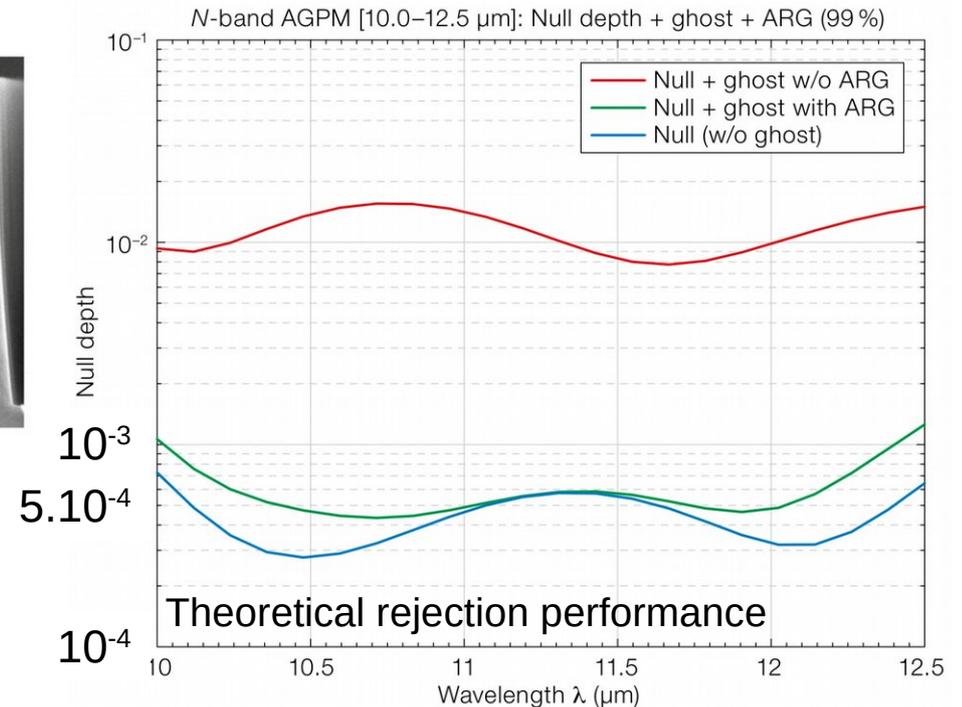
Talk M. Kasper

AGPM coronagraphy

Annular Groove Phase Mask



- Full discovery space down to $\sim 1 \lambda/D$
- High throughput ($> \sim 90\%$)
- Can work on large spectral bandwidths
- Sensitive to low-order aberrations (offsets), central obscuration telescope
- NEAR AGPMs designed and manufactured by team at ULiège, Uppsala, & Caltech
- Tests @ TIMMI2/ESO Garching

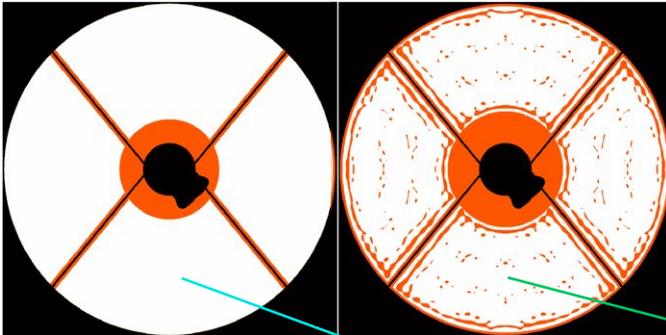


Mawet et al. 2005, Kasper et al. 2017, Maire et al. 2020

Apodized Lyot stop

Conventional Lyot stop

Apodized Lyot stop

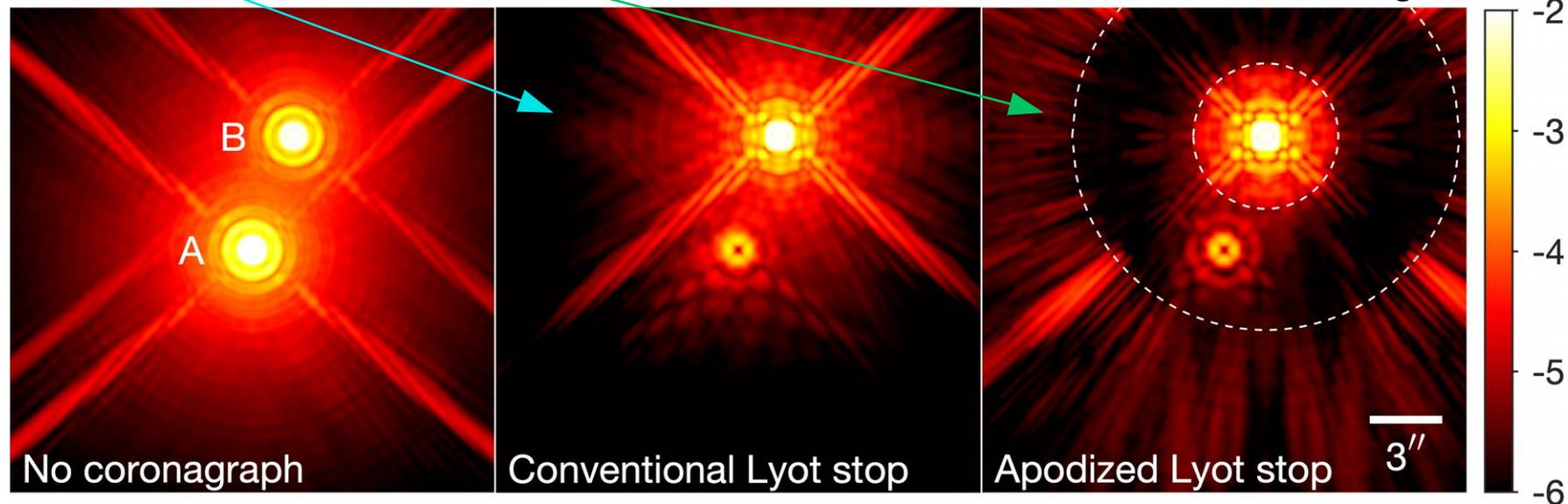


Central obscuration 35%

Throughput aperture $\sim 1 \lambda/D$ 50% throughput
VLT pupil

Raw contrasts $< 5e-6$ @ 11–29 λ/D

Simulated images

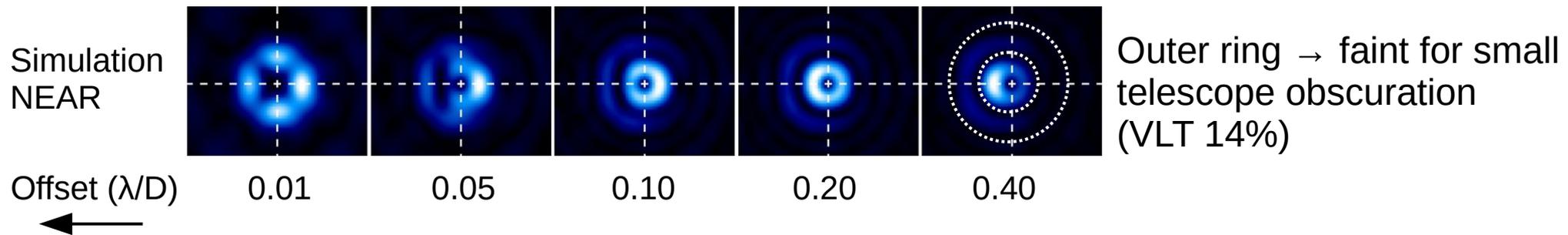


G. Ruane

Mawet et al. 2005, Kasper et al. 2017, Maire et al. 2020

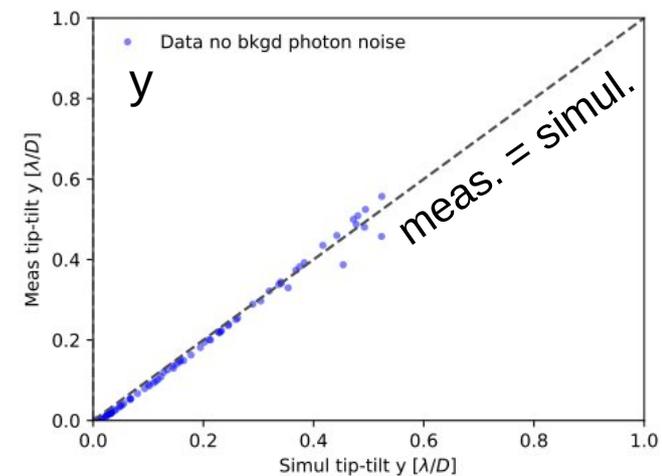
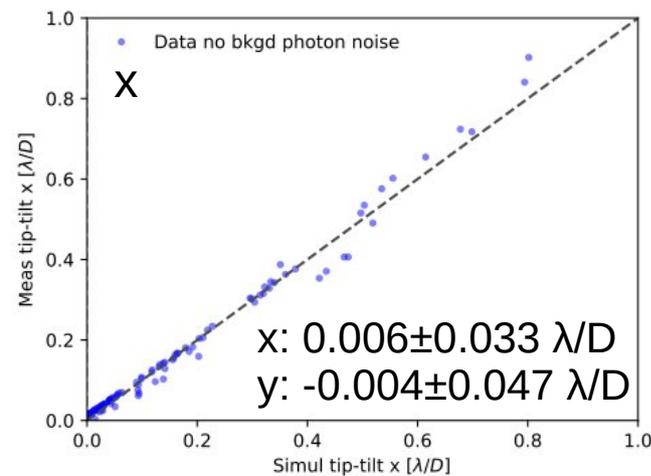
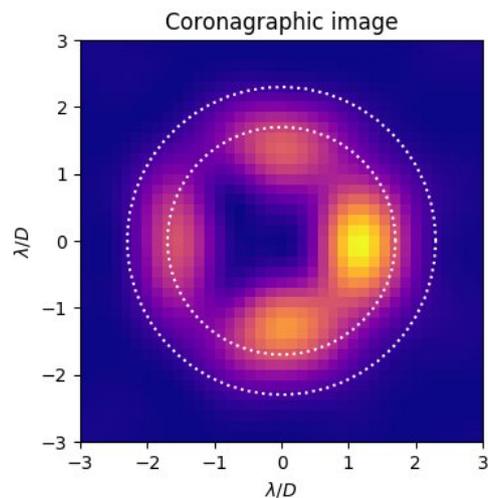
AGPM centering with QACITS

Quadrant Analysis of Coronagraphic Images for Tip-tilt Sensing



Tests model validation (no bkgd noise)

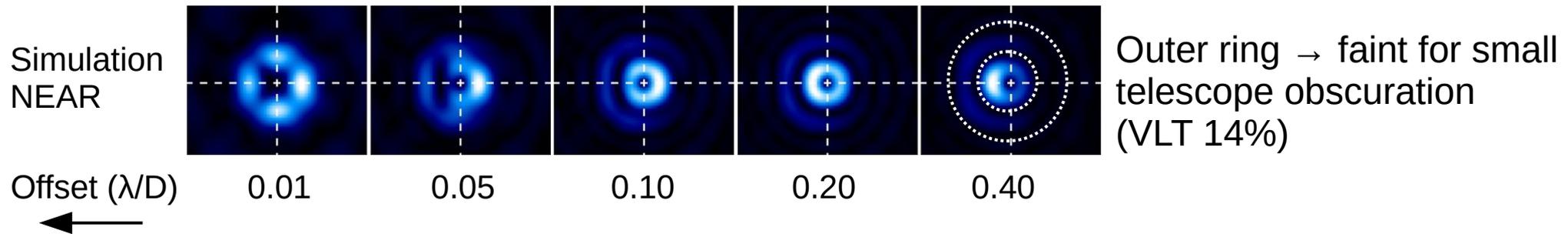
NEAR requirement $\sim 1/30 \lambda/D$ (~ 10 mas)



Huby et al. 2015 (concept), 2017 (on-sky validation+perf. Keck/L'), Maire et al. 2020 (on-sky perf. VISIR/N)

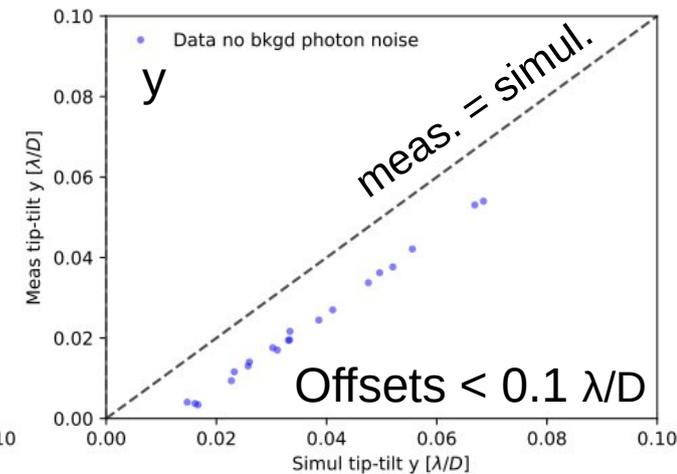
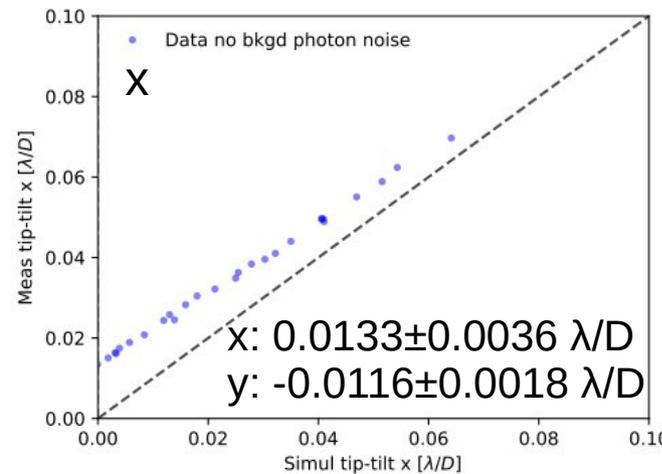
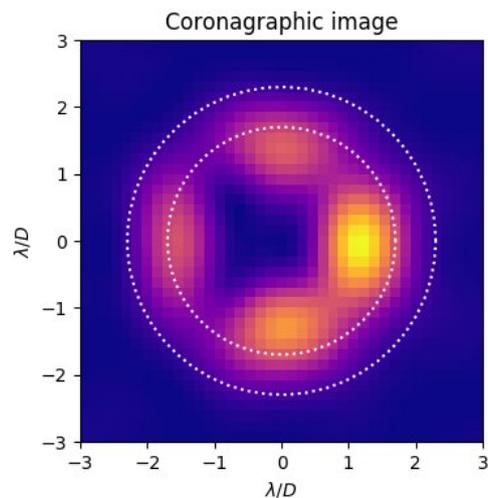
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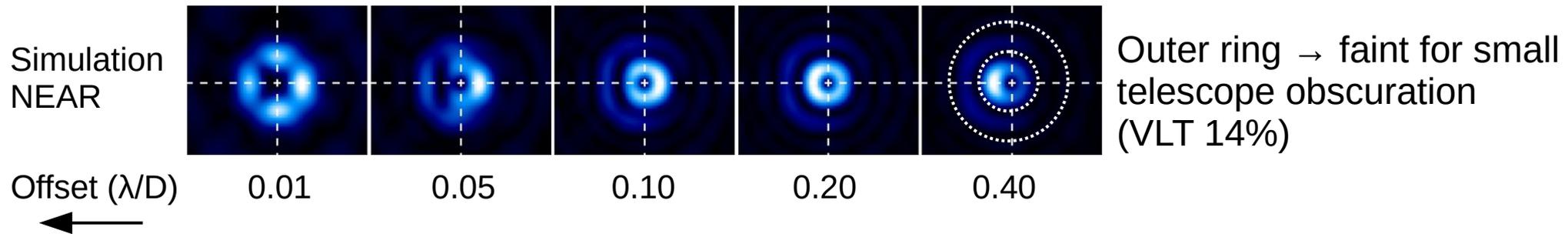
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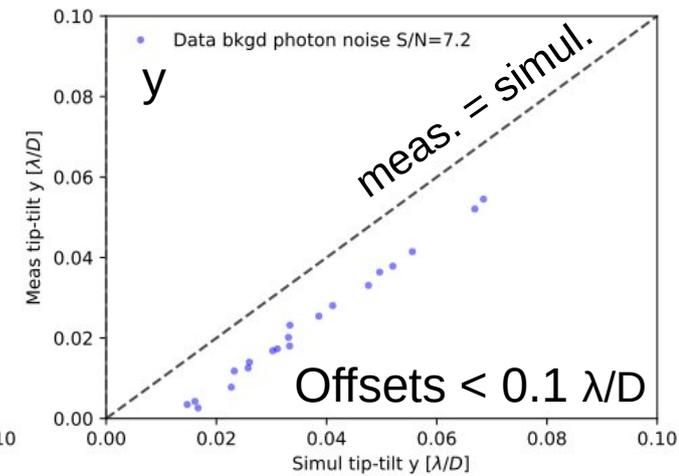
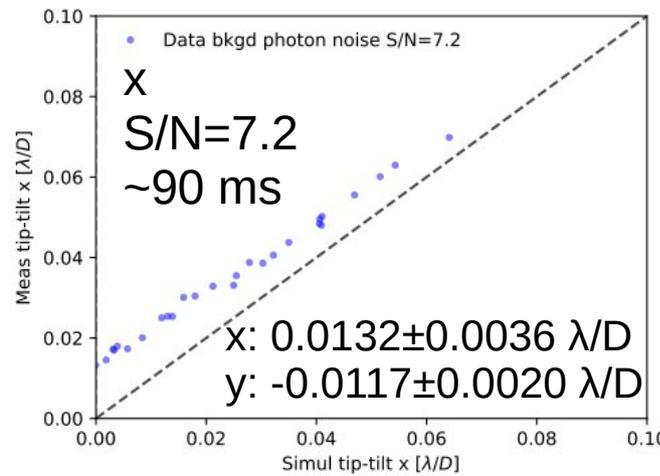
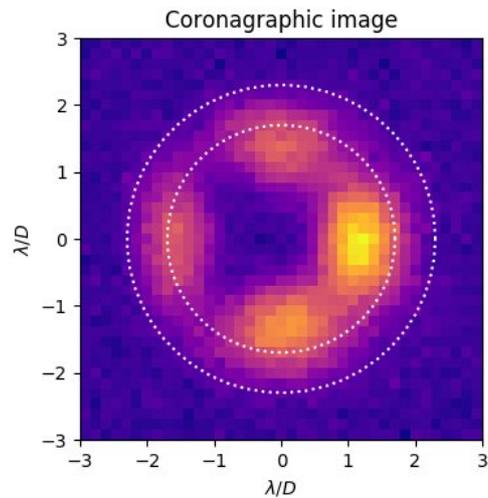
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Quadrant Analysis of Coronagraphic Images for Tip-tilt Sensing



Tests int. time with bkgd photon noise

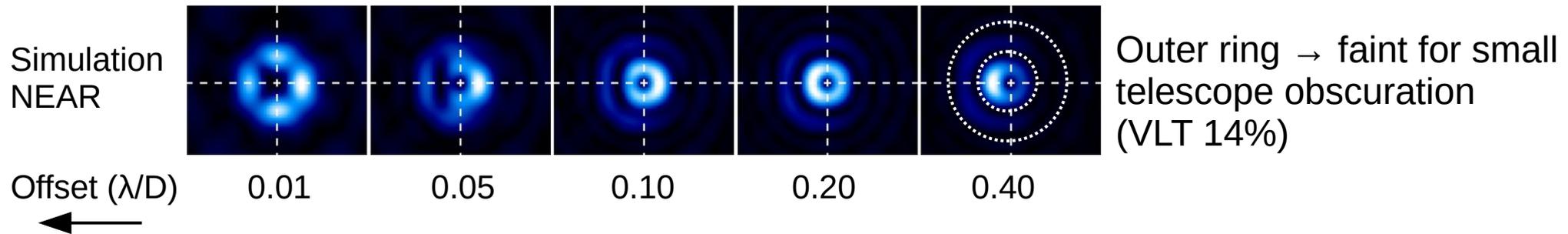
NEAR \rightarrow correction every 30s



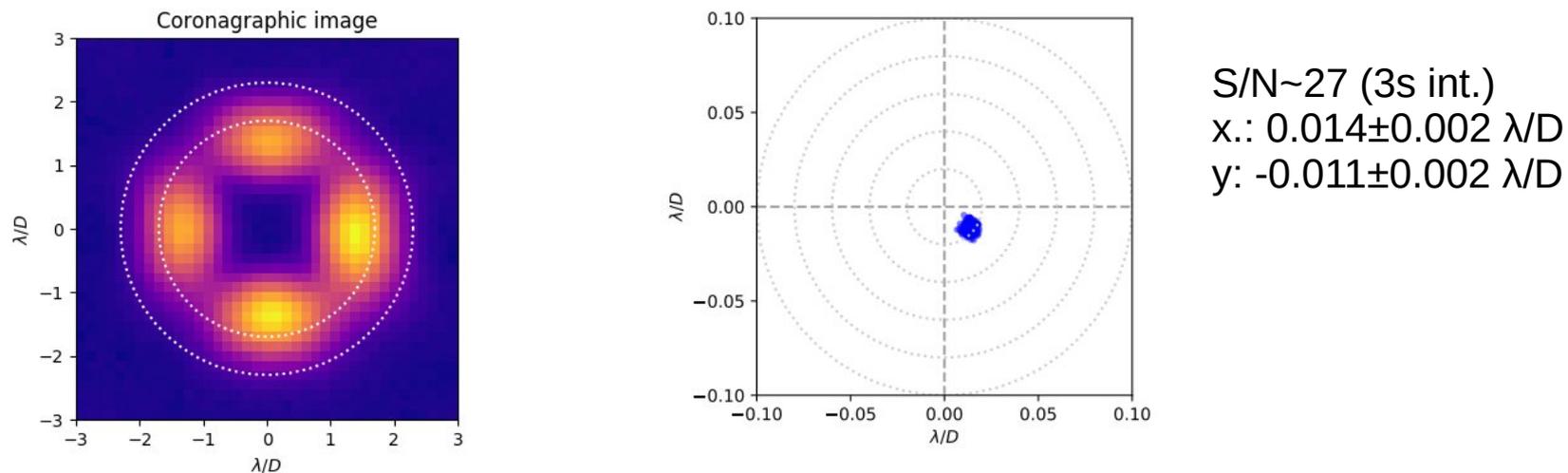
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AGPM centering with QACITS

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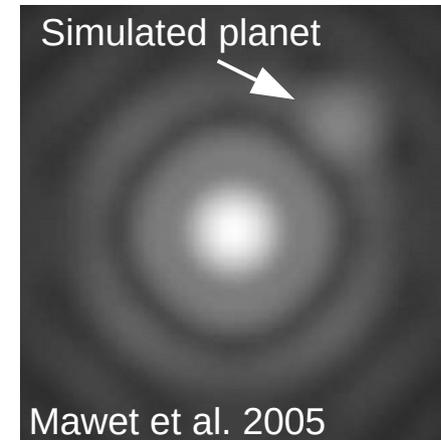
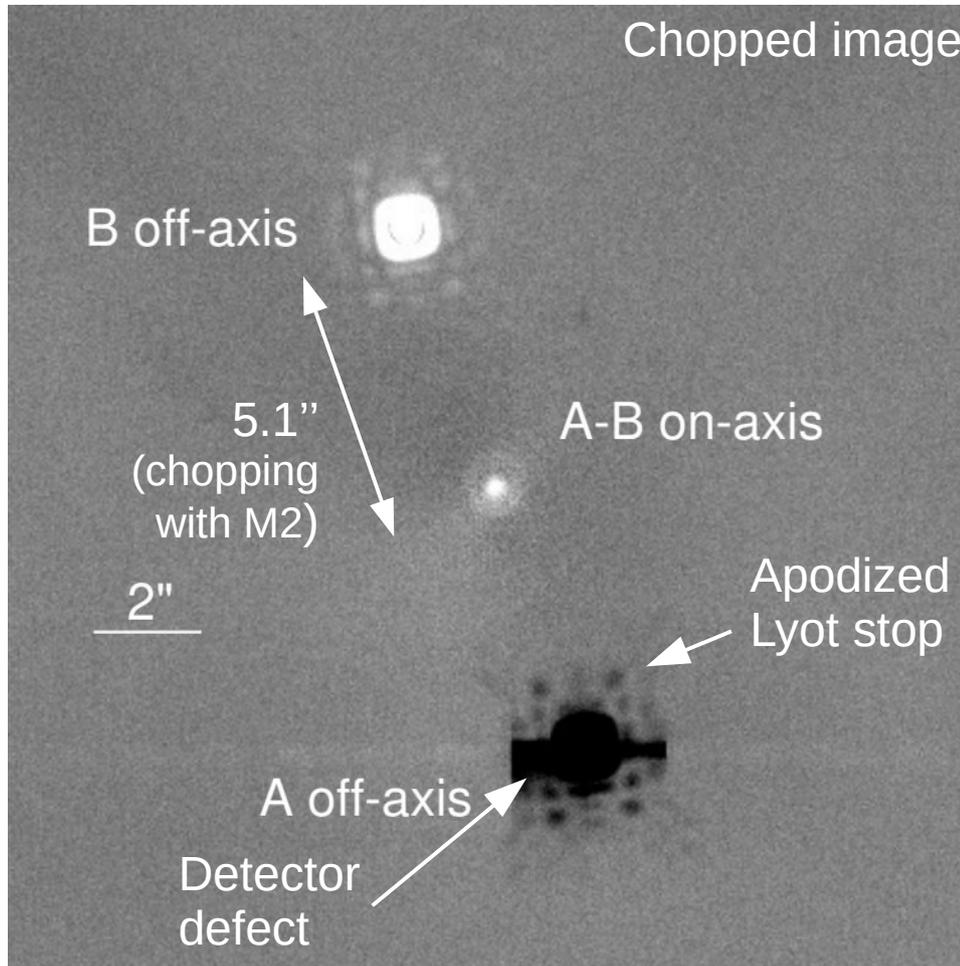


Tests impact residuals not corrected by AO + bkgd photon noise



Huby et al. 2015 (concept), 2017 (on-sky validation+perf. Keck/L'), Maire et al. 2020 (on-sky perf. VISIR/N)

NEAR data



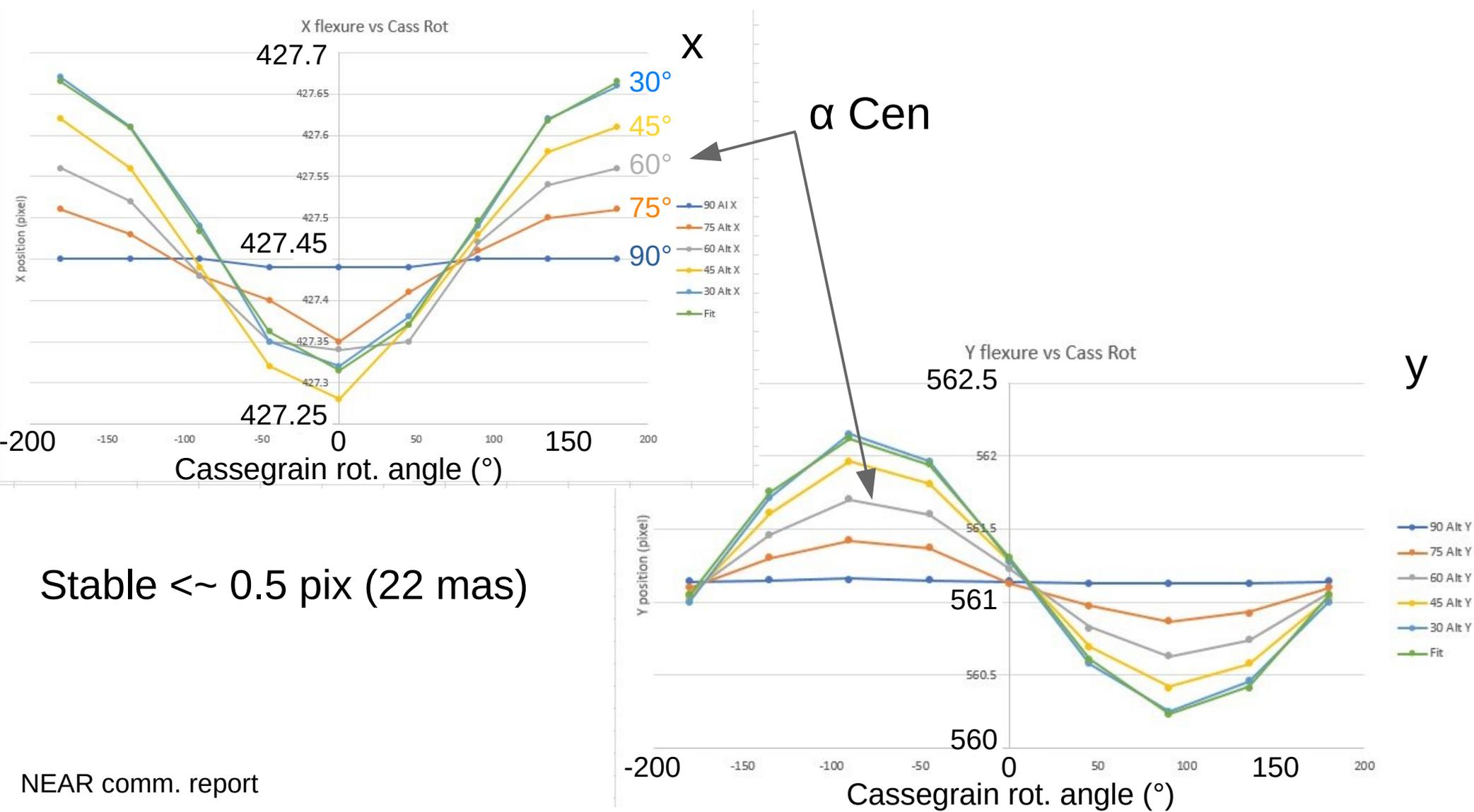
AGPM PSF ~ textbook scaled-down non-coro. PSF → almost perfect centering + corrected wavefront

QACITS workflow

- **AGPM position** → 2D Gaussian fit on glow (each night)
- **Bkgd images + chopping** → **calibration residuals** (every ~1h)
- ▶ • Science images + chopping + subtraction chopping residuals
- Aperture photometry α Cen A & B
- Differential intensity
- Correction offset for field selector

~1h

Stability AGPM position



Stable $\leq \sim 0.5$ pix (22 mas)

NEAR comm. report

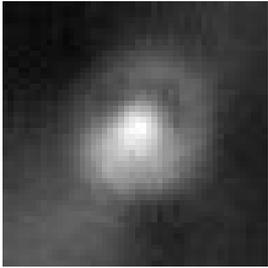
13/10/2020

IR2020

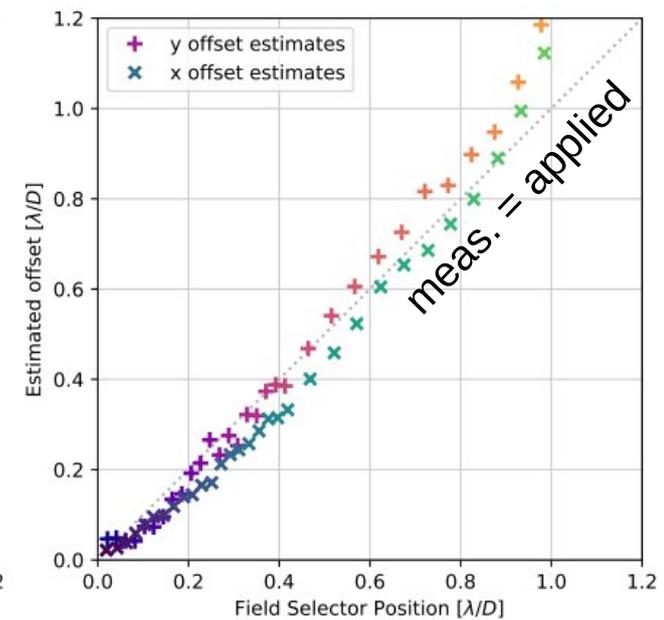
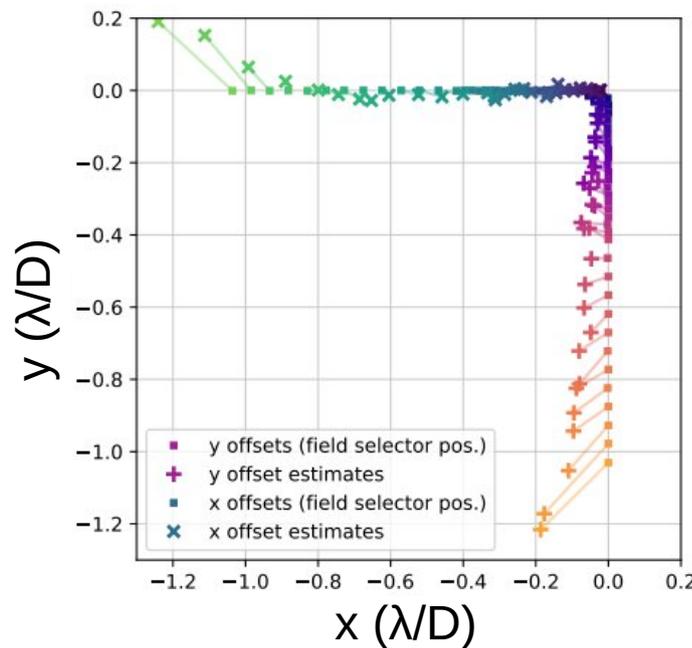
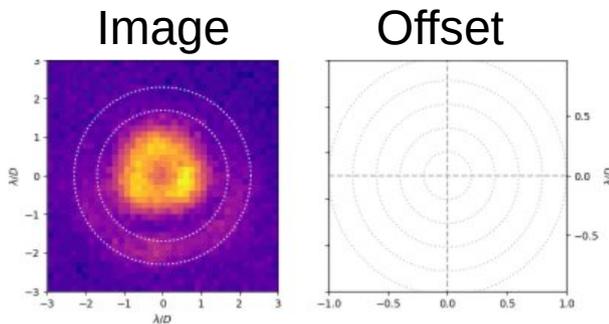
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QACITS on-sky tests

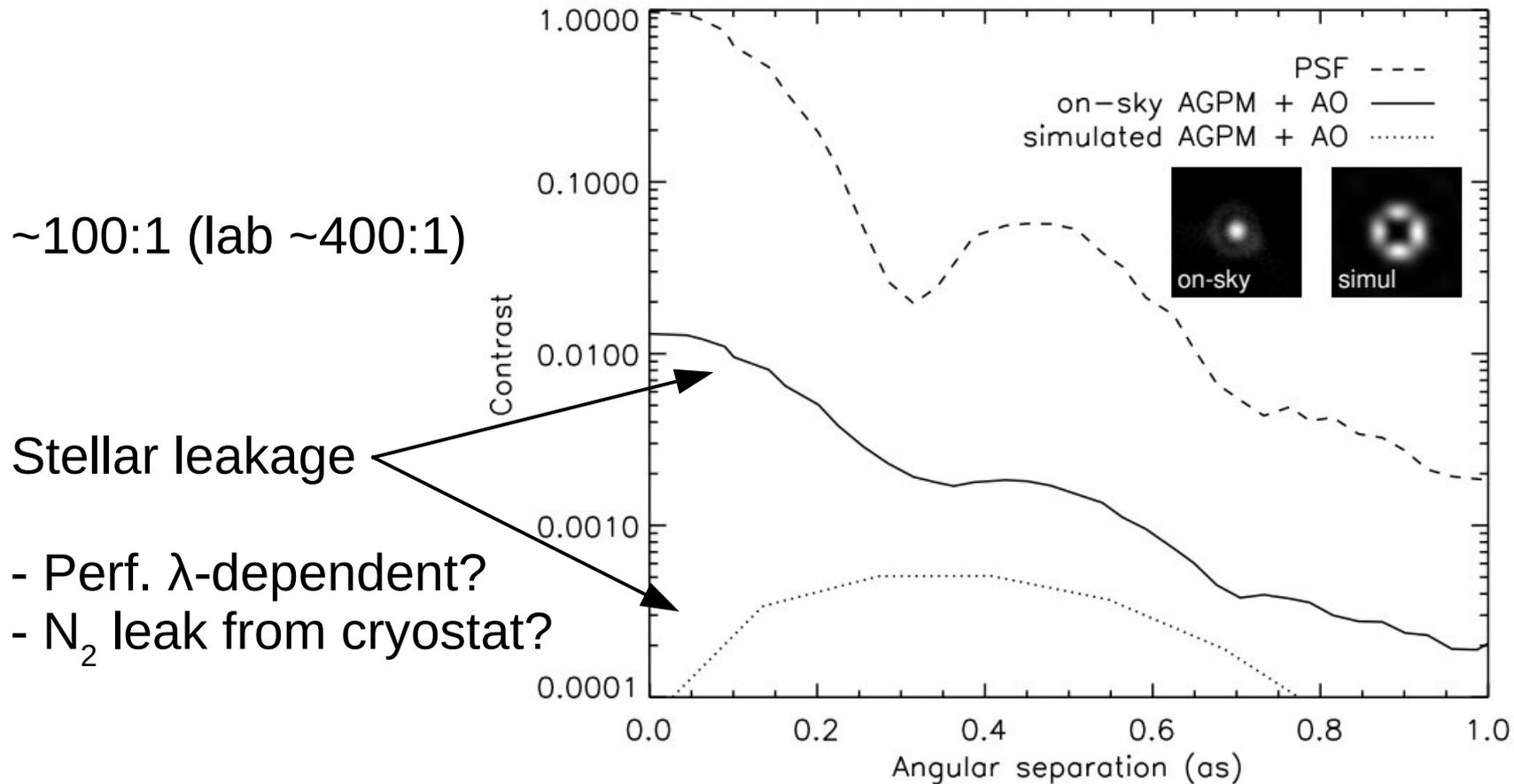
Chopping residuals bias $\sim 0.2 \lambda/D$ + time-dependent \rightarrow regular calib. (~ 1 h)



On-sky validation tests



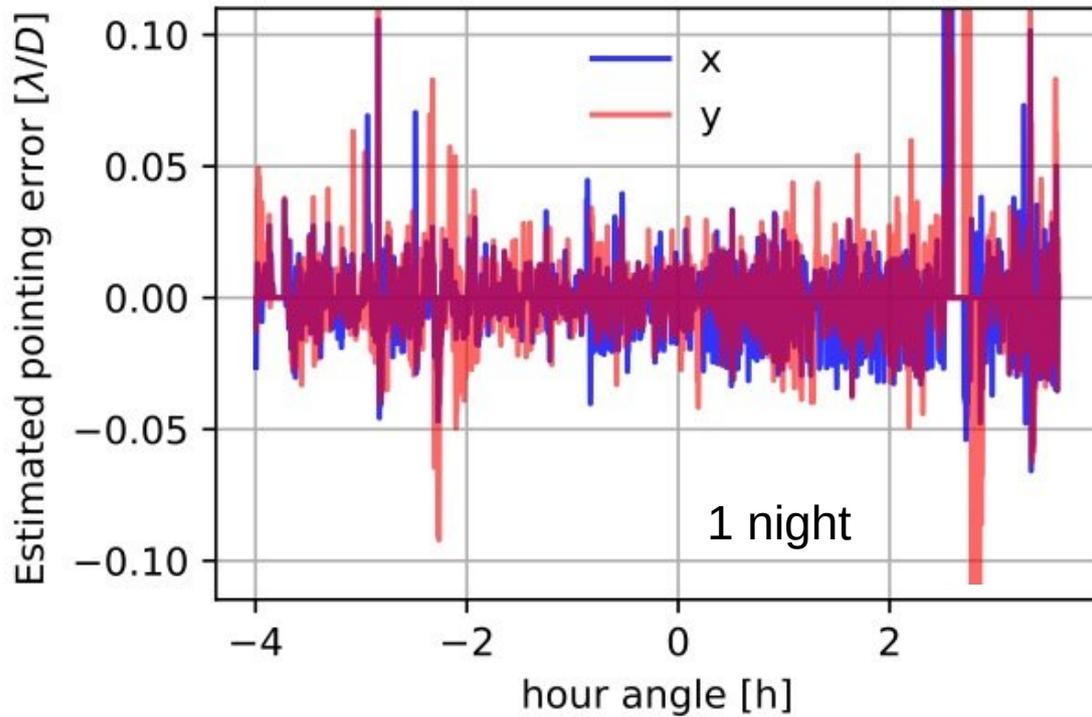
On-sky AGPM rejection



Maire et al. 2020, Kasper et al. 2019

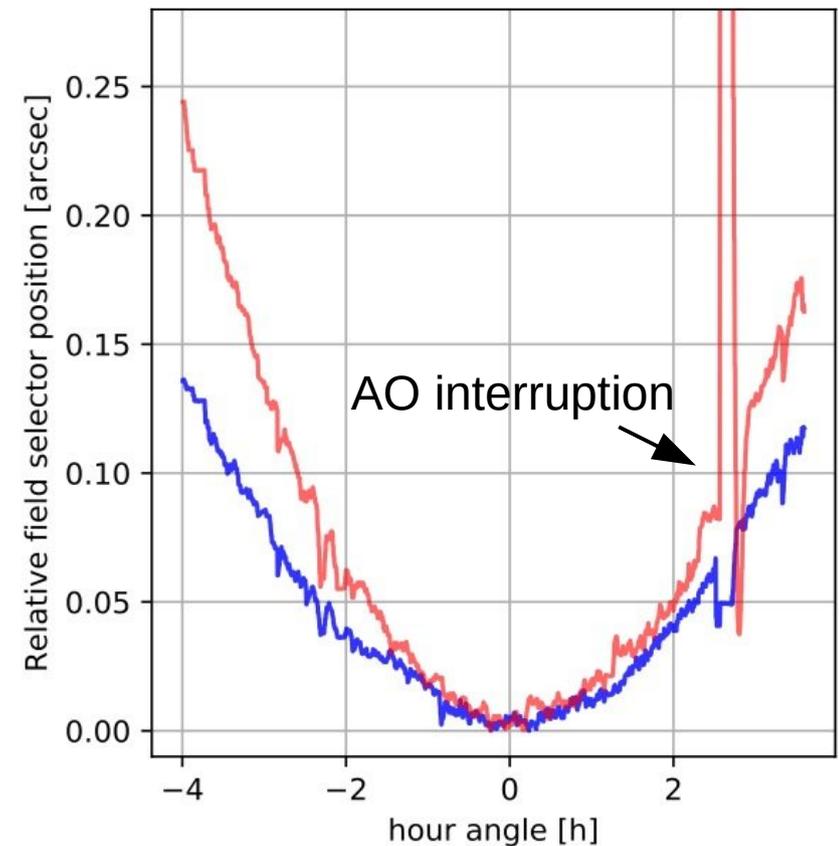
QACITS closed-loop performance

Meridian passage



0.015 λ/D rms over 4h near meridian passage

Field selector position



Lessons learned for METIS

- VLT/NEAR campaign valuable pathfinder exoplanet imaging ELT/METIS
- **Precise pointing control** AGPM coronagraph critical → QACITS
 - **Stability star image** behind AGPM → **Good AO correction**
 - **Stability AGPM position** → **Subpixel** accuracy
 - **S/N issues** high & variable mid-IR bkgd, small VLT obscuration → **No**
 - **Bias issues** mid-IR bkgd → Adapted observing strategy for **regular measurement chopping residuals** (pupil tracking)
 - **Stability photometric normalization** → “simultaneous” with **chopping**
- Control **0.015 λ/D rms** → QACITS robust approach
- **Mid-IR lab bench wide bandwidth** for AGPM testing → on-going CEA Saclay