

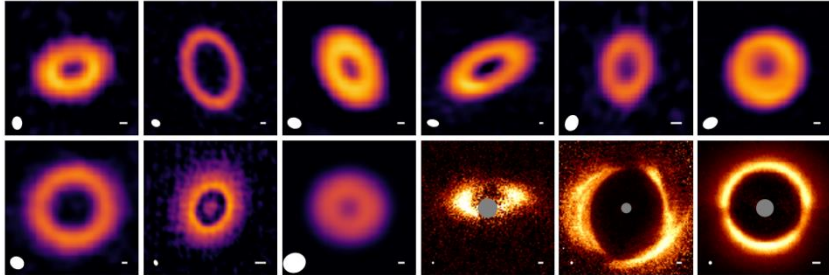
DETECTING SUBSTRUCTURES IN PROTOPLANETARY DISCS WITH MICADO/MORFEO



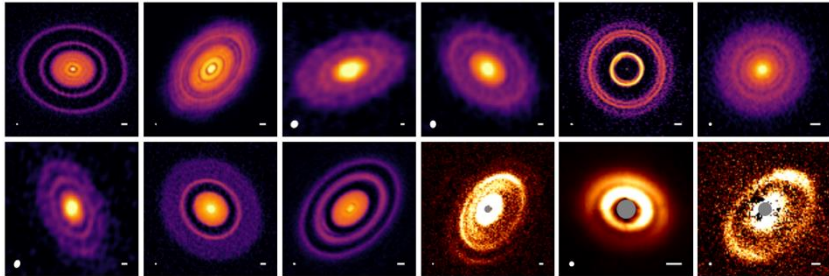
CLAUDIA TOCI & THE JEDIEX COLLABORATION
UNIVERSIDAD DE SEVILLA, ETSI / (EX) ESO FELLOW

SUBSTRUCTURES IN PROTOPLANETARY DISCS

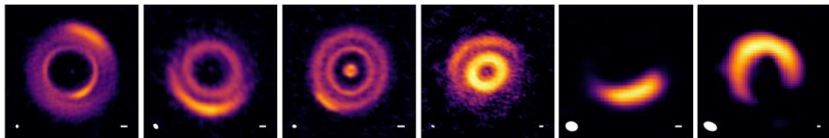
Ring/Cavity



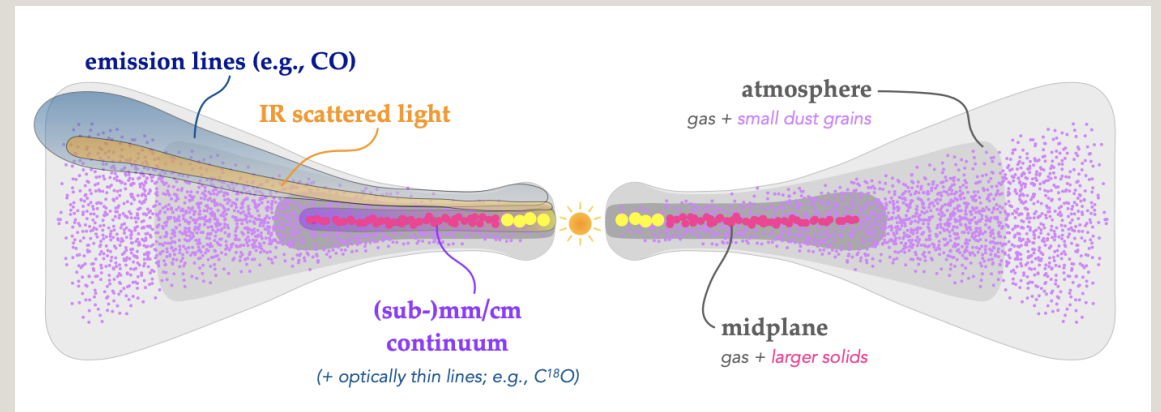
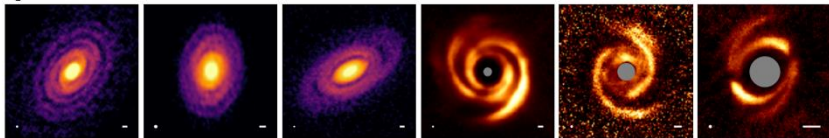
Rings/Gaps



Arcs

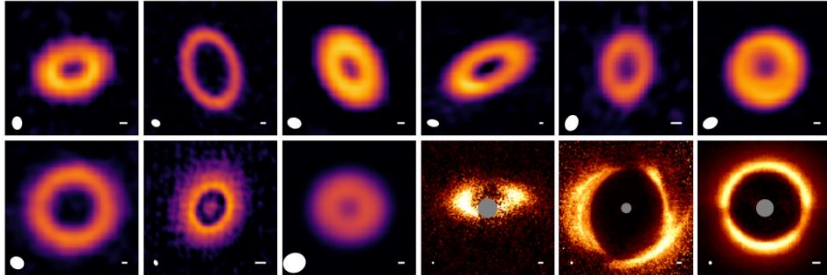


Spirals

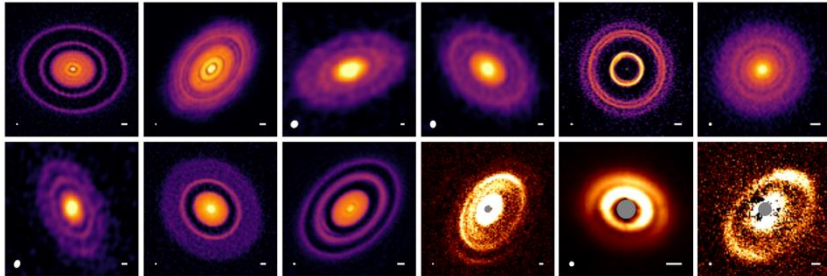


SUBSTRUCTURES IN PROTOPLANETARY DISCS

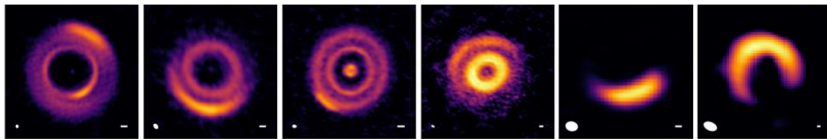
Ring/Cavity



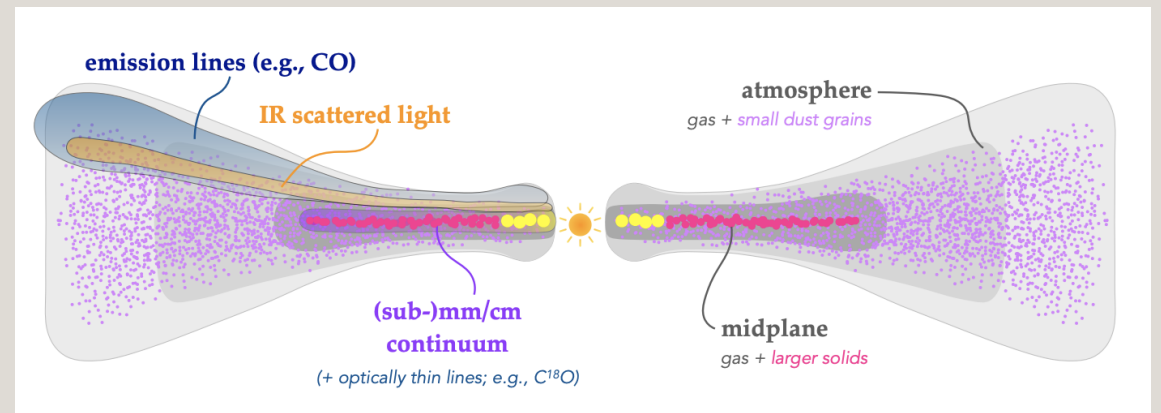
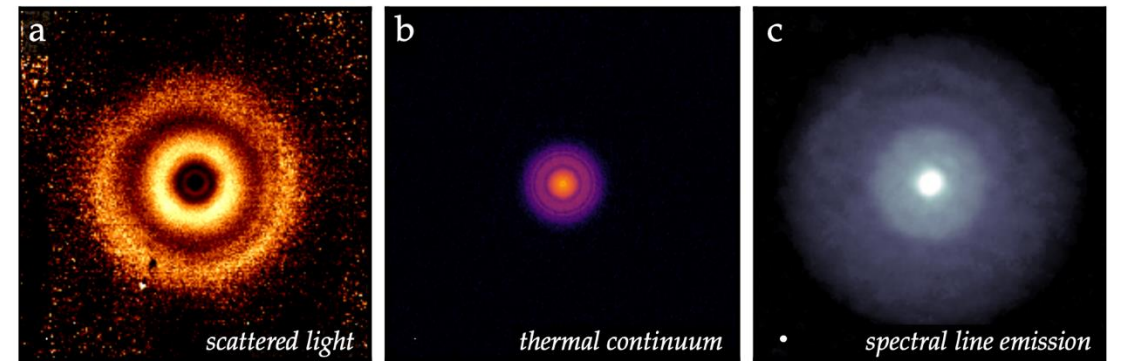
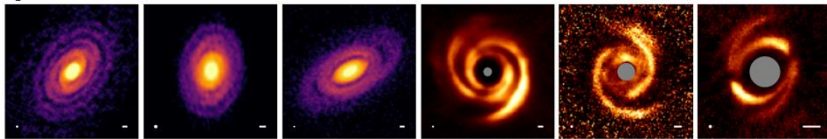
Rings/Gaps



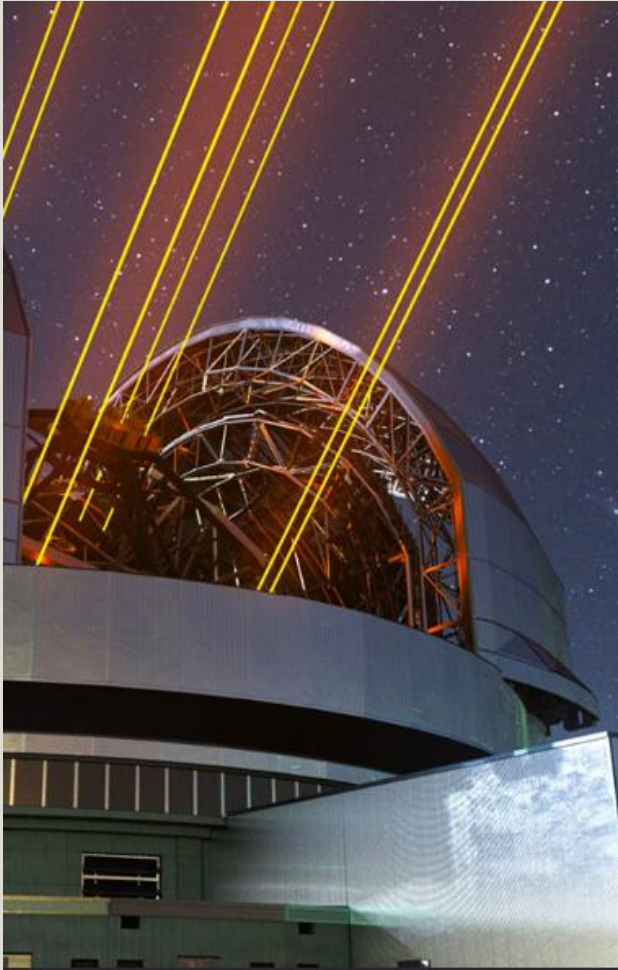
Arcs



Spirals



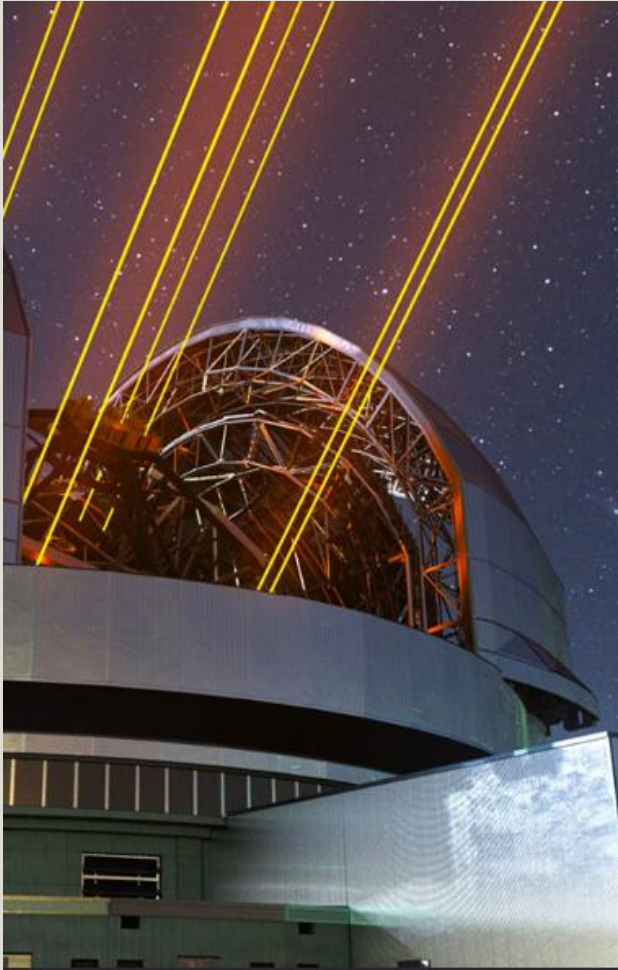
MICADO/MORFEO ON ELT



ESO

- ❑ Greater Collecting Area
(5xVLT)
→ Faint objects
- ❑ Angular resolution
with AO
→ Resolve 1 au @ 200 pc
- ❑ Higher Spectral
Resolution
→ Spectral character.
- ❑ Large field of view
(50"x50")
→ Observe complete
region

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High contrast imaging mode

SCAO and Coronagraph
Total intensity images in J, H, K filters
Contrast 10^{-4} @ 100 mas
 10^{-5} @ 500 mas

Post processes

ADI (angular)
RDI (reference)
differential Imaging

Multi-AO Imaging Camera for Deep Observations

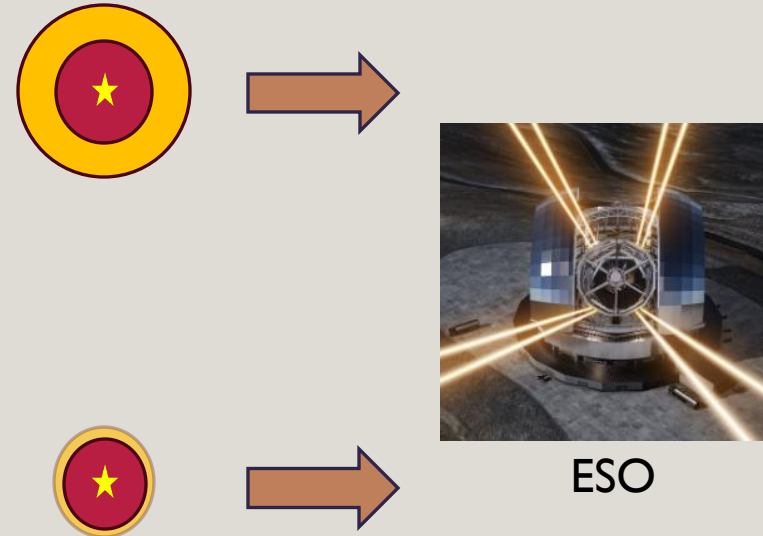
0.8–2.45 μm
SCAO or MCAO mode
6" FOV for 0.01" res

0.9–2.4 μm
Only SCAO mode
6" FOV for 0.01" res

ESO

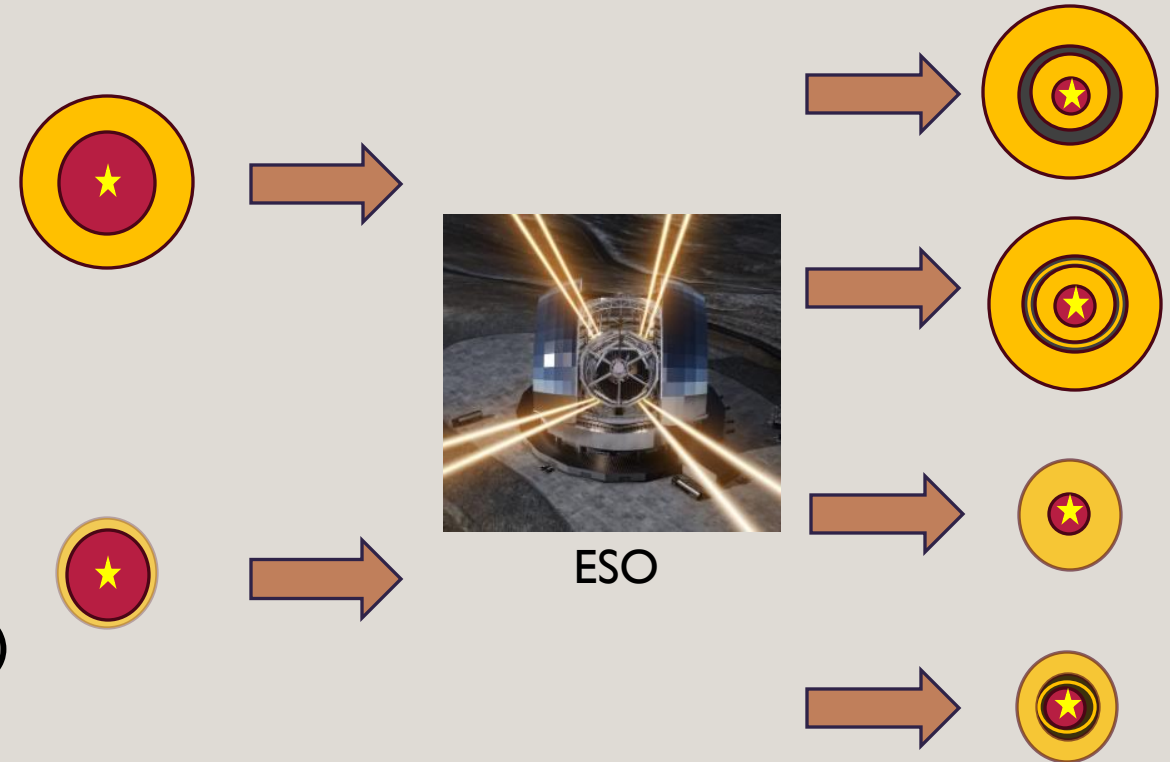
SUBSTRUCTURES SCIENCE CASE: SCIENTIFIC QUESTIONS

- ☐ Detect compact (0.1-1 au) substructures
- ☐ Sub-substructures
- ☐ Faint discs
- ☐ Compact discs
- ☐ Inner substructures (20-50 mas, < 10 au scales)



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METHODS: A TOY MODEL FOR GAPS IN DISCS

Synthetic 3D model of a disc

Pinte et al. 2006, 2009



- ❑ Classical T Tauri star

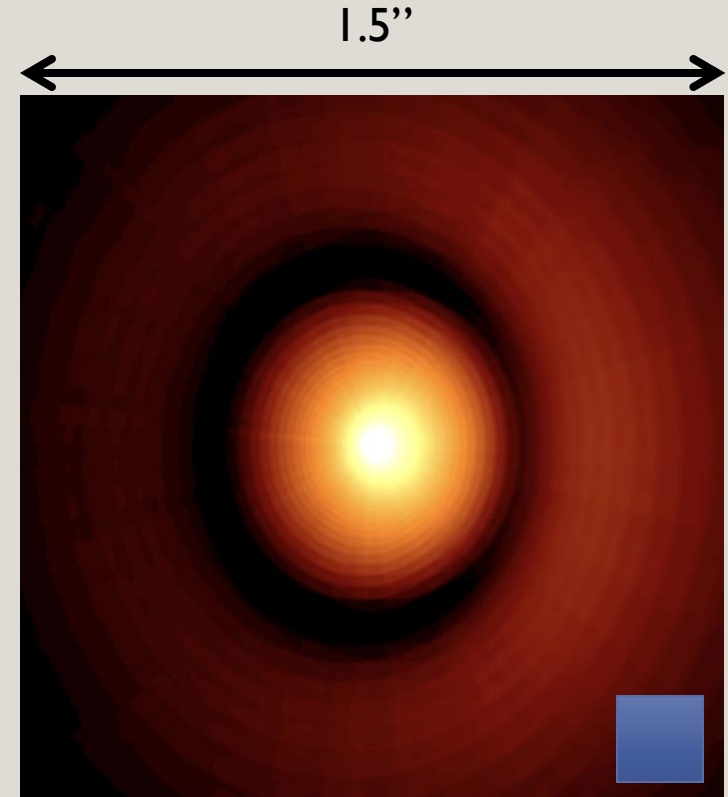
 - 4000K blackbody, $1 M_{\odot}$ $2 R_{\odot}$

- ❑ Disc $0.01 M_{\odot}$, $i = 0^{\circ}, 30^{\circ}, 60^{\circ}$

Gap properties

- ❑ Gap width $\Delta \propto R_H$ Lodato et al. 2019, Kanagawa et al. 2016

- ❑ Gap depth $\propto M^2$ Kanagawa et al. 2015



Pixel scale: 1.5 mas

METHODS: OUR APPROXIMATED PSF

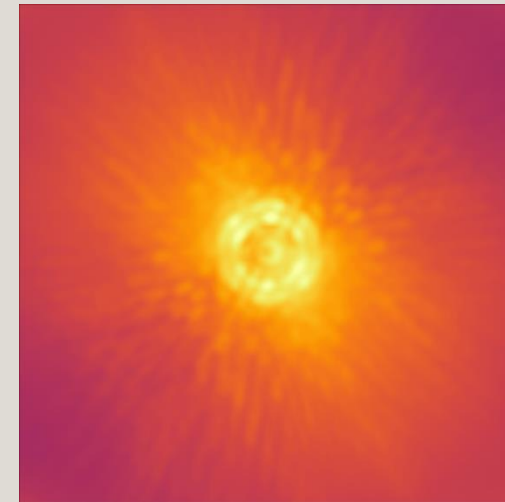
Ingredients

- ☐ Atmospheric background
(as a function of wavelength)
- ☐ Lyot coronagraph (CLC245)
- ☐ 15 min exposure
- ☐ PSF sequence
90 images, 10s each
- ☐ Detector noises
(shot noise, readout noise)

**Pierre's
talk!**

PSF

COMPASS/MYSTHIC software
Huby et al.2024

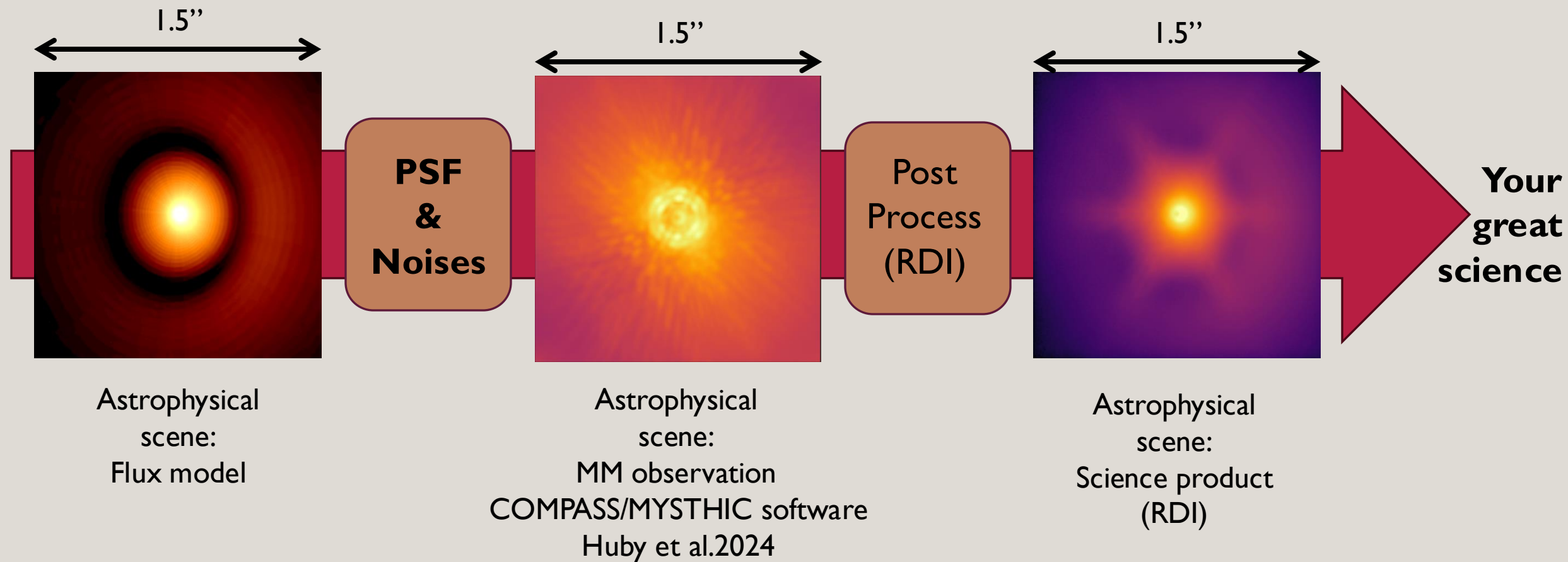


Off axis ($> 55\text{mas}$)
no spatial dependence

On axis ($< 20\text{mas}$)
no spatial dependence

Alaguero&JediEx 2026 in prep., Toci&JediEx 2026 in prep.

METHODS:THE PIPELINE



Alaguero&JediEx 2026 in prep.,Toci&JediEx 2026 in prep.

PARAMETER SPACE

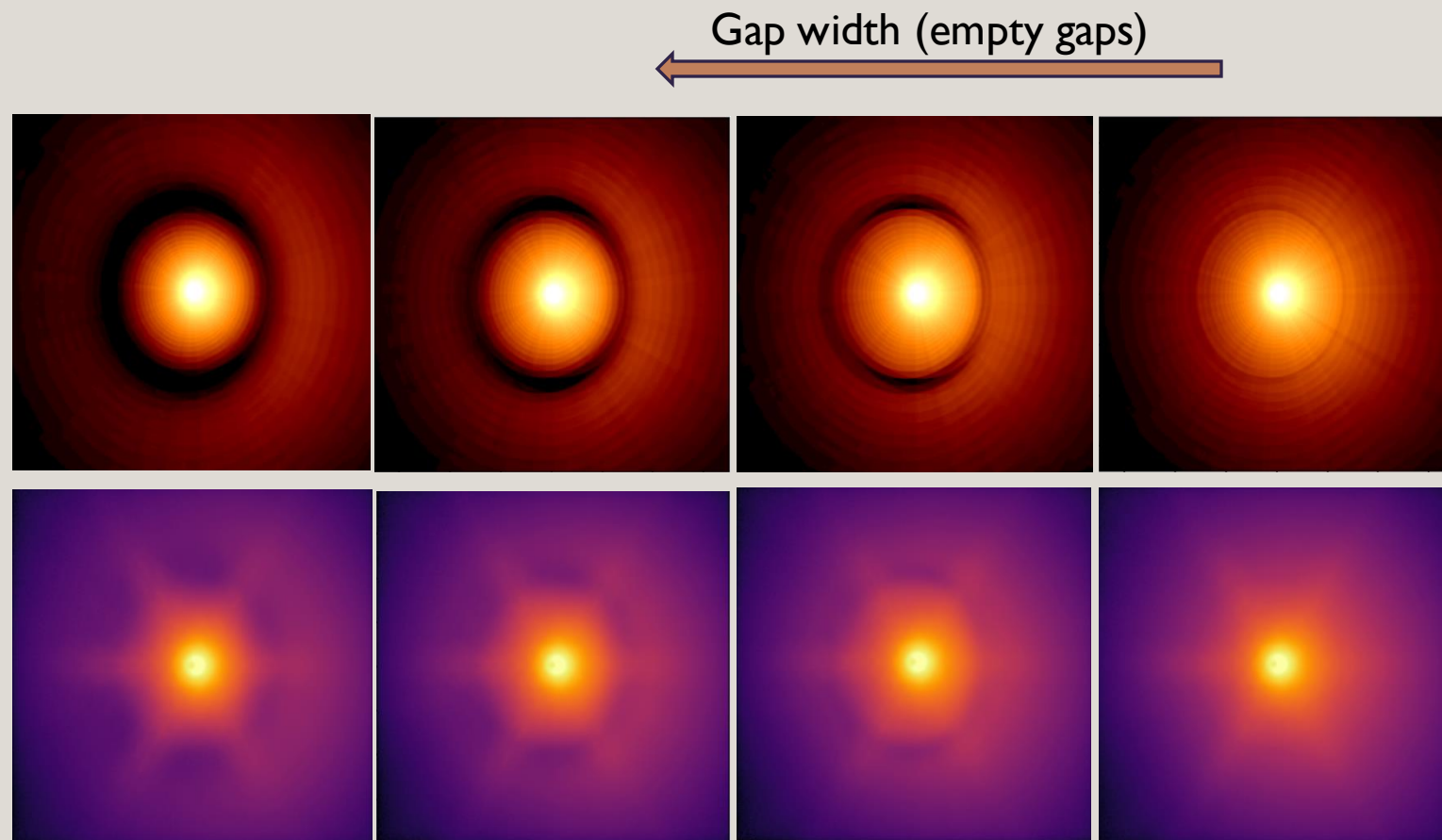
☐ Mass of the planet
0.06, 0.3, 1, 3, 10 M_J

☐ Distance
5, 15, 30, 50 au

➡ Gap depths: 0, 50, 100%
Gap widths: 1- 40 au

☐ Inclination, PA
0, 30, 60° -90, 0, 90°

☐ J,H,K wavelengths
1.25, 1.65, 2.15 μm

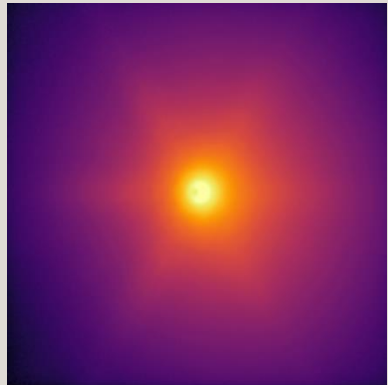
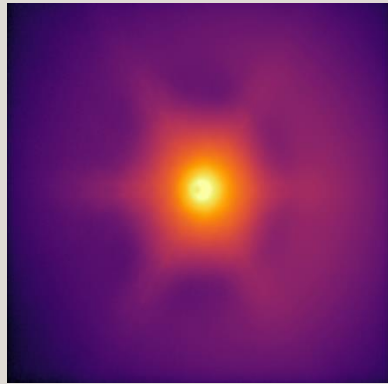


GAP DETECTION LEVEL

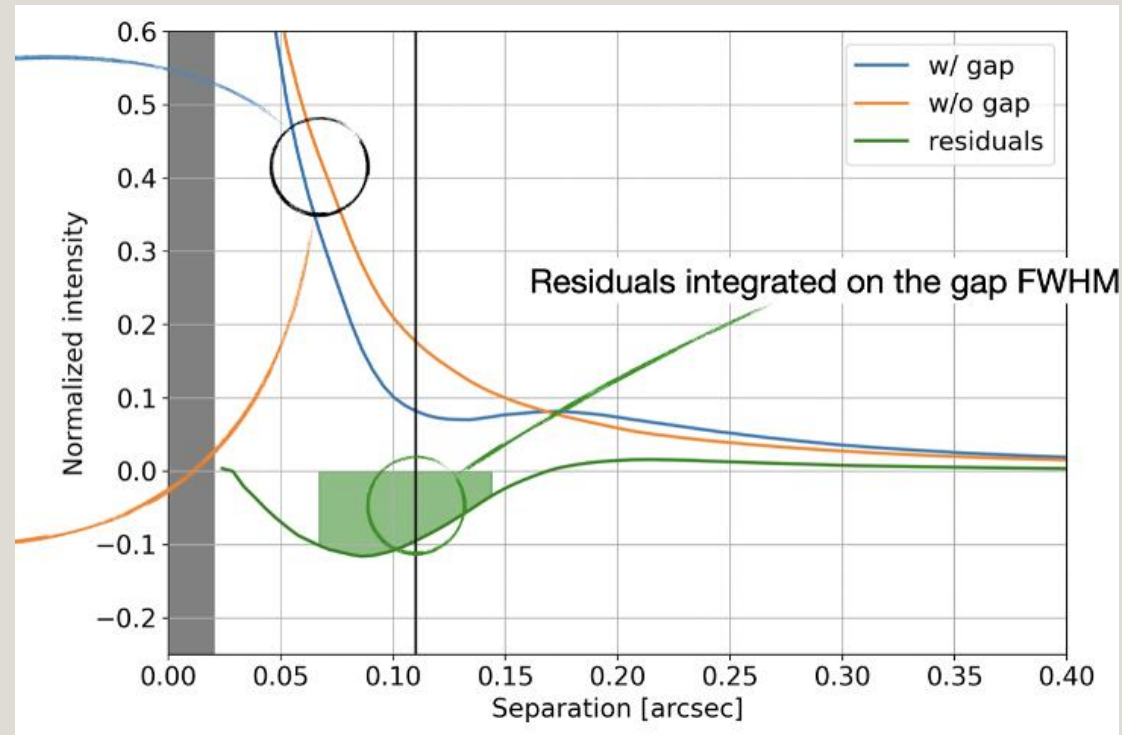


Alaguero&JediEx 2026 in prep.,Toci&JediEx 2026 in prep.

GAP DETECTION LEVEL: SIGNAL & NOISE

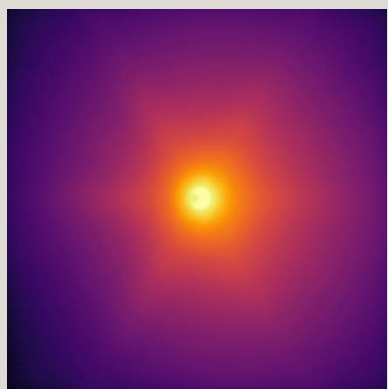
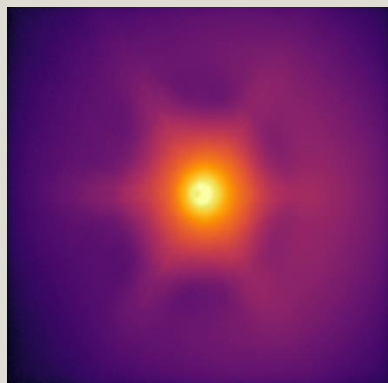


Science product (RDI)

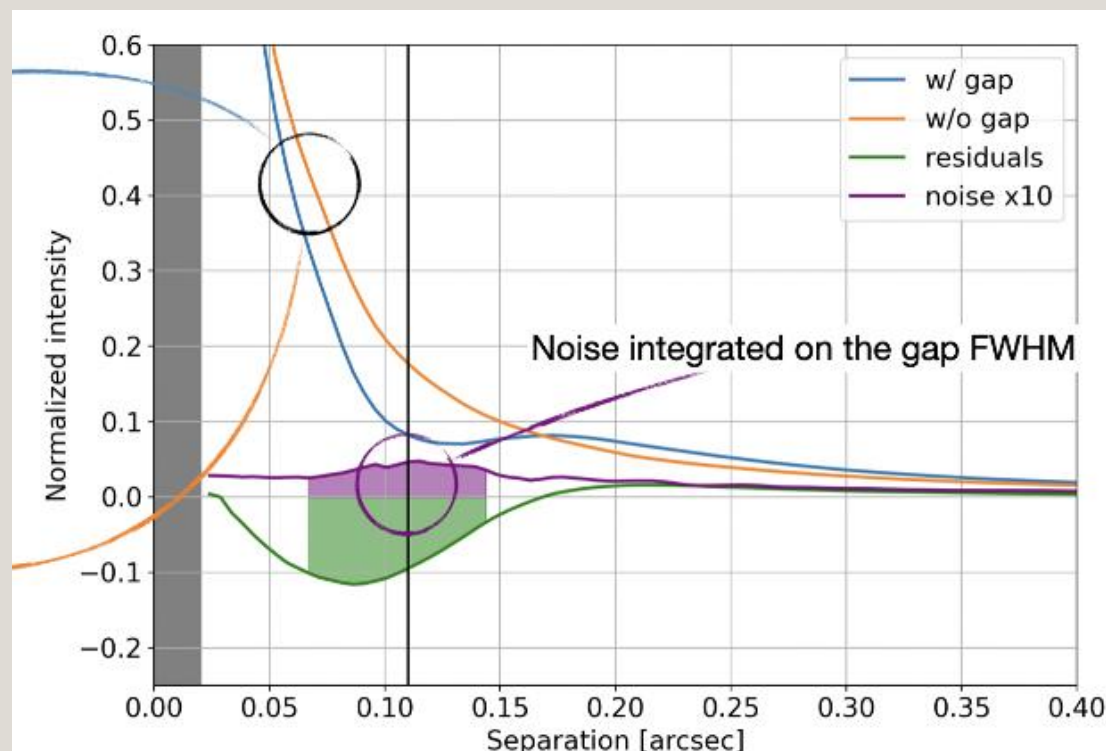


$$\chi = \int_{r_{gap}-\Delta}^{r_{gap}+\Delta} res(r) dr$$

GAP DETECTION LEVEL



Science product (RDI)

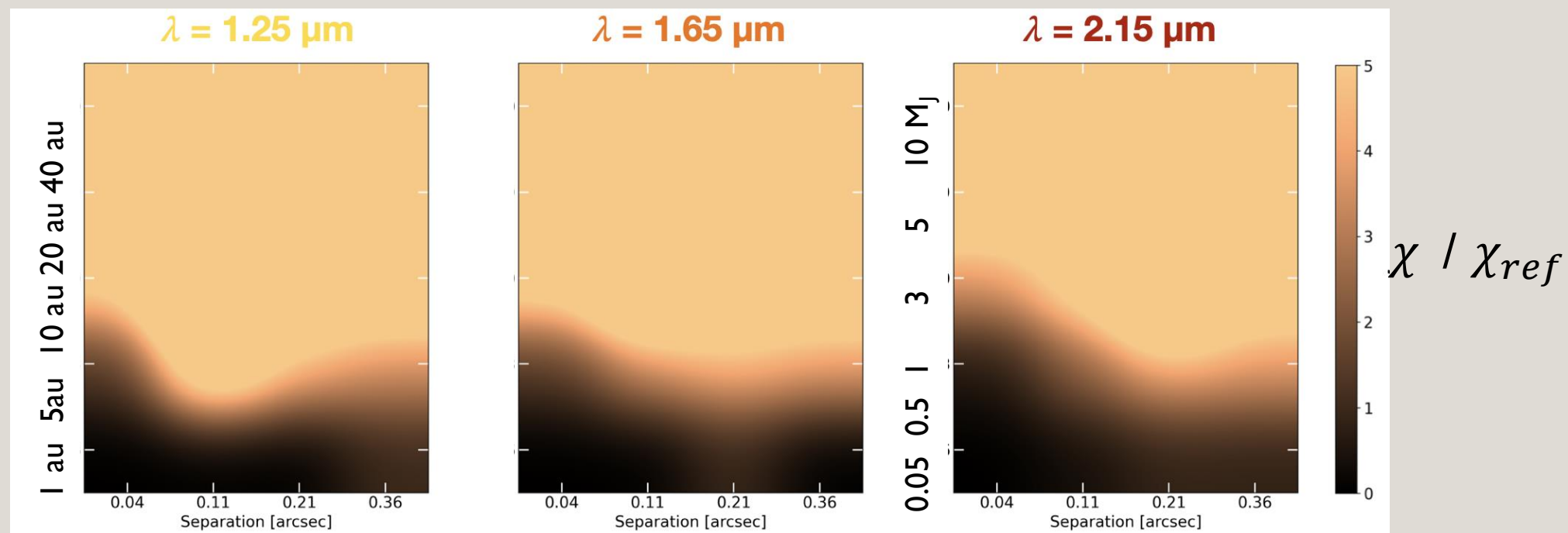


$$\chi = \int_{r_{gap}-\Delta}^{r_{gap}+\Delta} res(r) dr$$

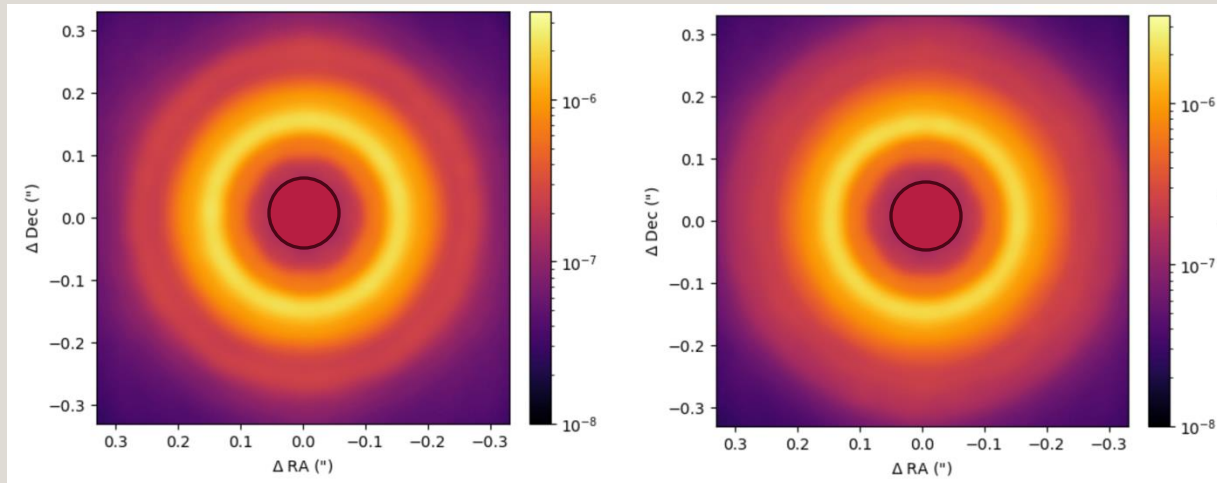
$$\chi_{ref} = \int_{r_{gap}-\Delta}^{r_{gap}+\Delta} N(r) dr$$

$$N(r) = \sigma_{rms} + \sigma_{ph}$$

RESULTS: GAP DETECTION LEVEL FOR A GRID OF MODELS



KNOWN SYSTEMS, NEW SCIENCE

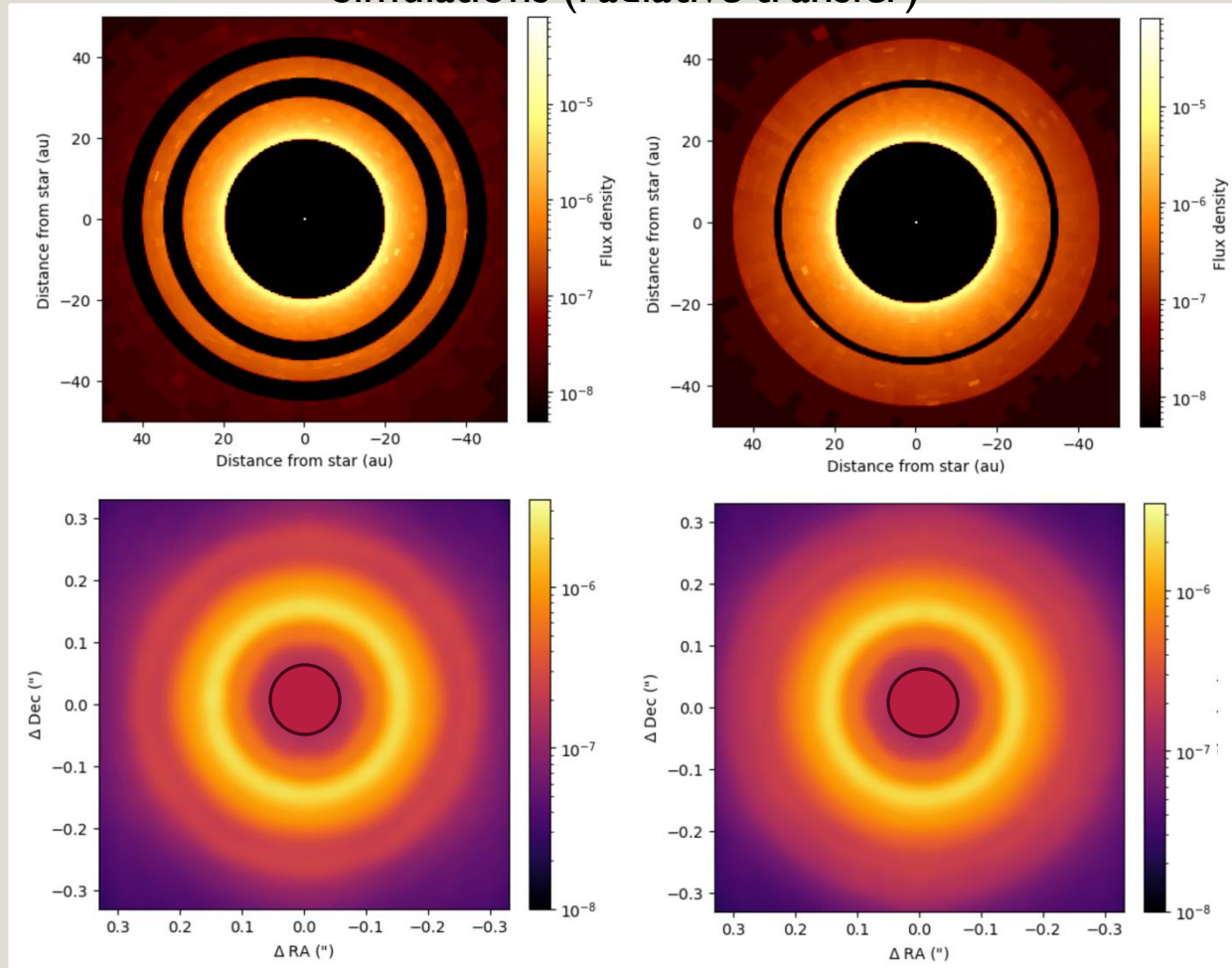


Science product (RDI)

Alaguero&JediEx 2026 in prep., Toci&JediEx 2026 in prep.

KNOWN SYSTEMS, NEW SCIENCE

Simulations (radiative transfer)

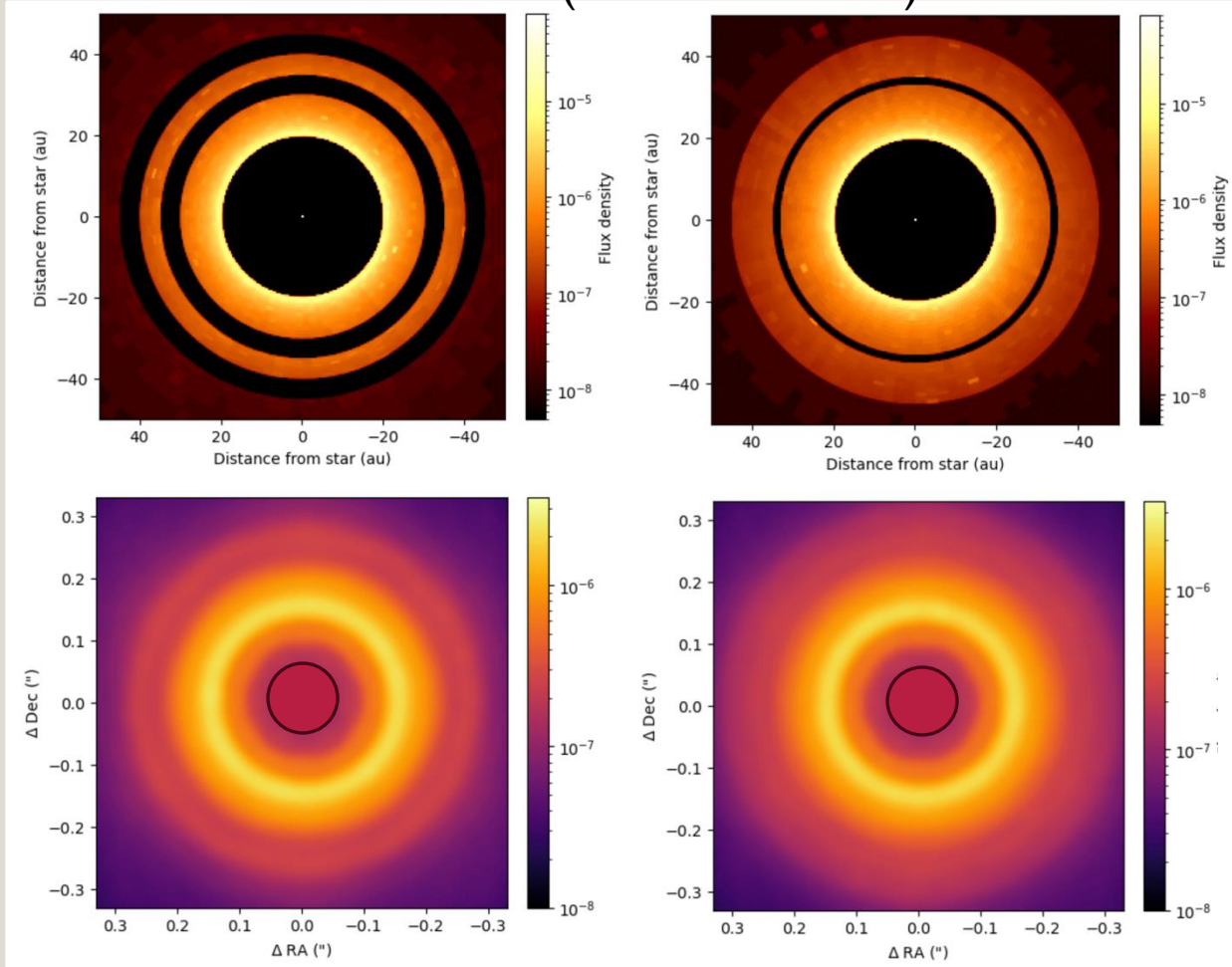


Science product (RDI)

Alaguero&JediEx 2026 in prep., Toci&JediEx 2026 in prep.

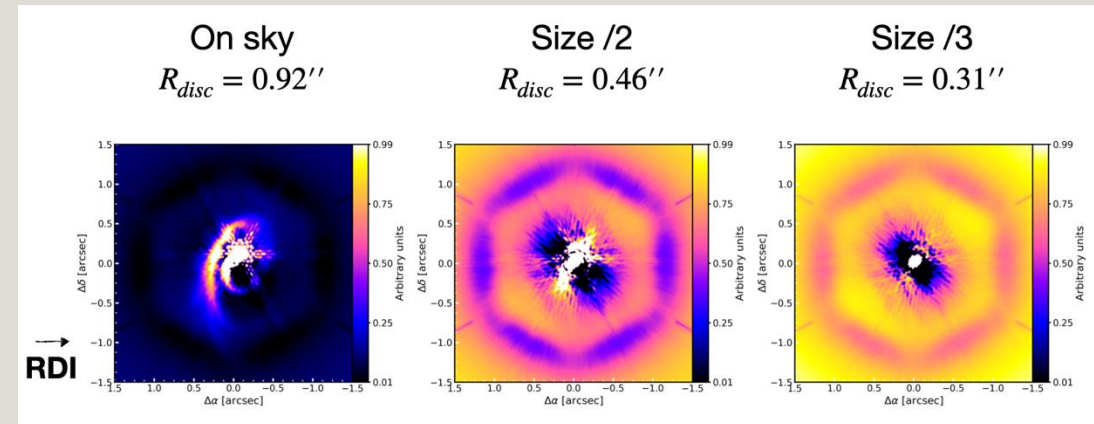
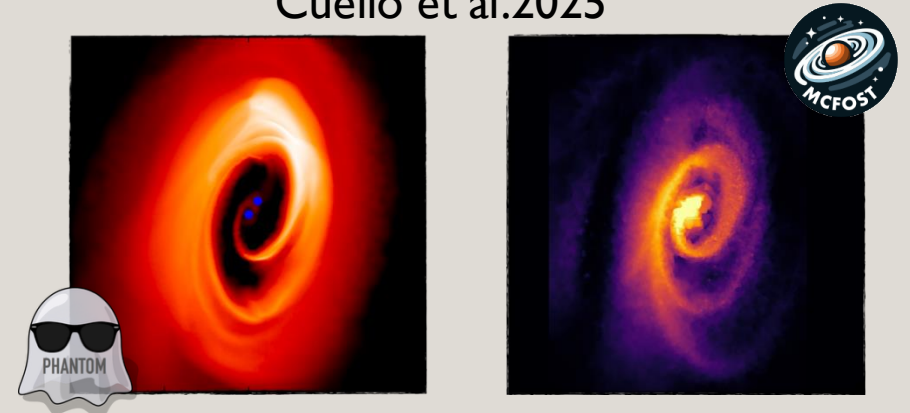
KNOWN SYSTEMS, NEW SCIENCE

Simulations (radiative transfer)



Science product (RDI)

Cuello et al.2025



Alaguero&JediEx 2026 in prep., Toci&JediEx 2026 in prep.

CONCLUSIONS

- ❑ Team effort to deliver a pipeline for simulations for ELT-MICADO/MORFEO in High Contrast mode (mostly A. Alaguero+MYSTHIC team)
- ❑ Characterization of Gap detectability at 'low' separation
Best at 0.1' from the star, sizes $> 1-2$ au, 50% empty, corresponding to Jupiter mass planets
- ❑ Band J and K optimal for high sensitivity and resolution, H for S/N
- ❑ Relevant targets explored

CONCLUSIONS & FUTURE

- ❑ Team effort to deliver a pipeline for simulations for ELT-MICADO/MORFEO in High Contrast mode (mostly A. Alaguero+MYSTHIC team)
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- ❑ Band J and K optimal for high sensitivity and resolution, H for S/N
- ❑ Relevant targets explored

... Explore inner 50 mas & better sampling



THAT'S ALL FOR NOW

CONTACT US AT:
CTOCI@US.ES