

**Frans Snik**

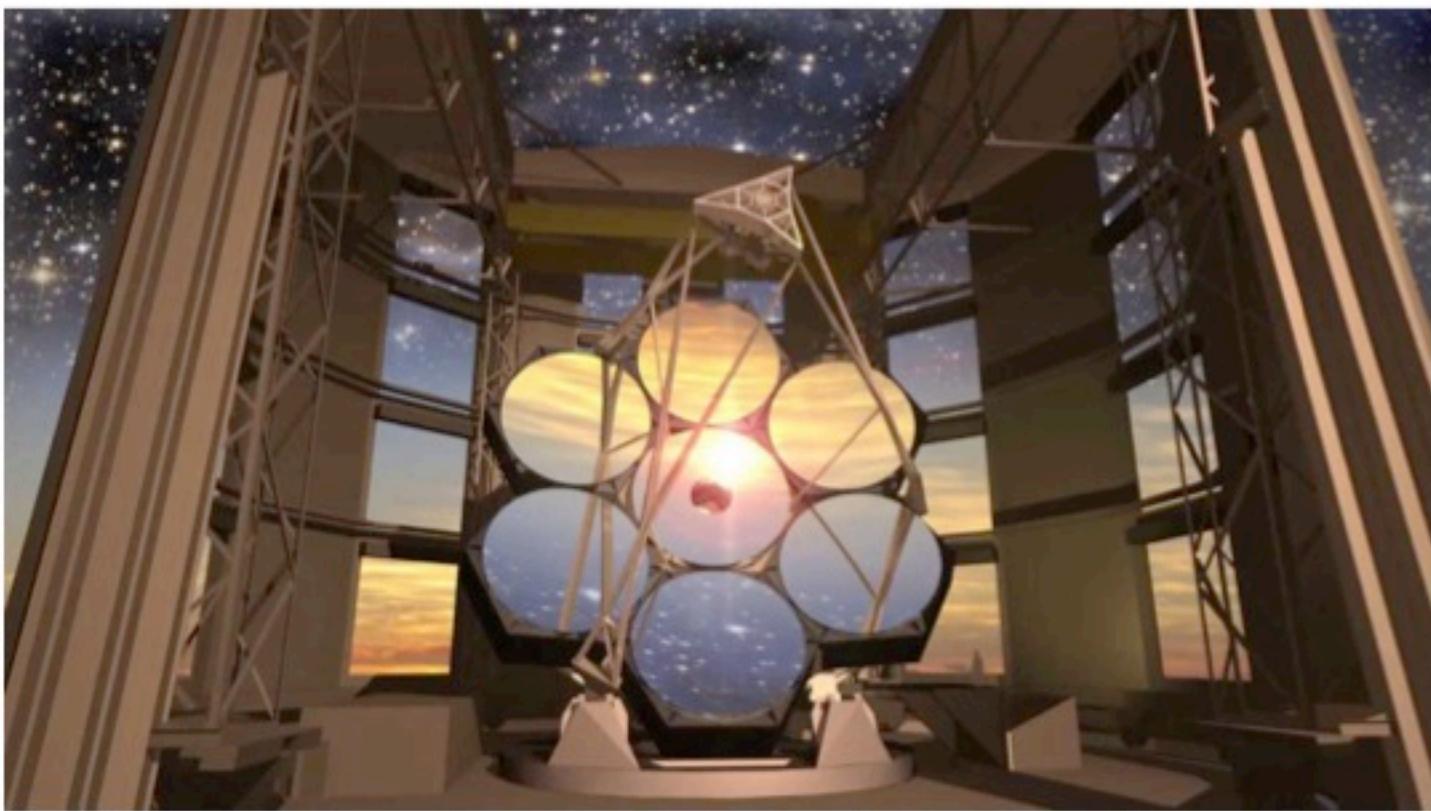
Stijn Debackere, Maria de Juan Ovelar  
Michiel Rodenhuis, Christoph Keller,  
Gilles Otten, Matthew Kenworthy

**Sterrewacht Leiden**

# the ELTs



E-ELT (39 m)



GMT ( $\sim 24.5$  m)



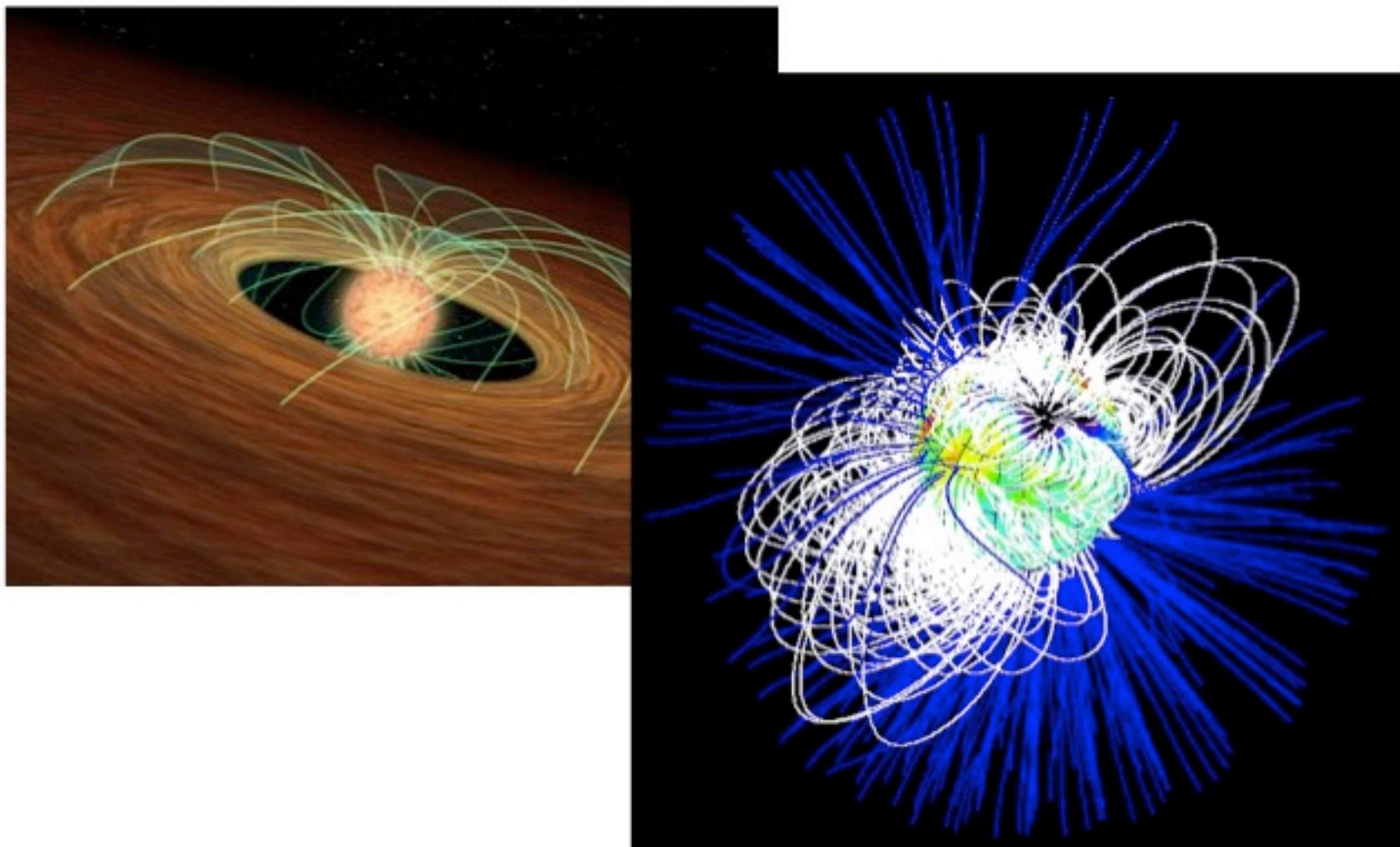
TMT

# killer polarimetric science with ELTs

**direct exoplanet imaging  
+ characterization**

high-contrast imaging

E-ELT/EPICS, TMT/PFI



**mapping protostellar  
magnetic fields**  
mid-IR imaging  
E-ELT/METIS, TMT/MICHI  
hi-res spectropolarimetry  
E-ELT/HIRES

# killer polarimetric science with ELTs

The image shows the front cover of a document titled "E-ELT Spectropolarimetry: The Science Case". The cover features a dark background with a central white rectangular area containing the title and subtitle. At the top left of the white area is a small logo consisting of a triangle with horizontal lines through it. Below the title and subtitle is a large, colorful illustration of a spiral galaxy with various emission regions and polarization vectors. The bottom half of the cover has a decorative border of wavy lines.

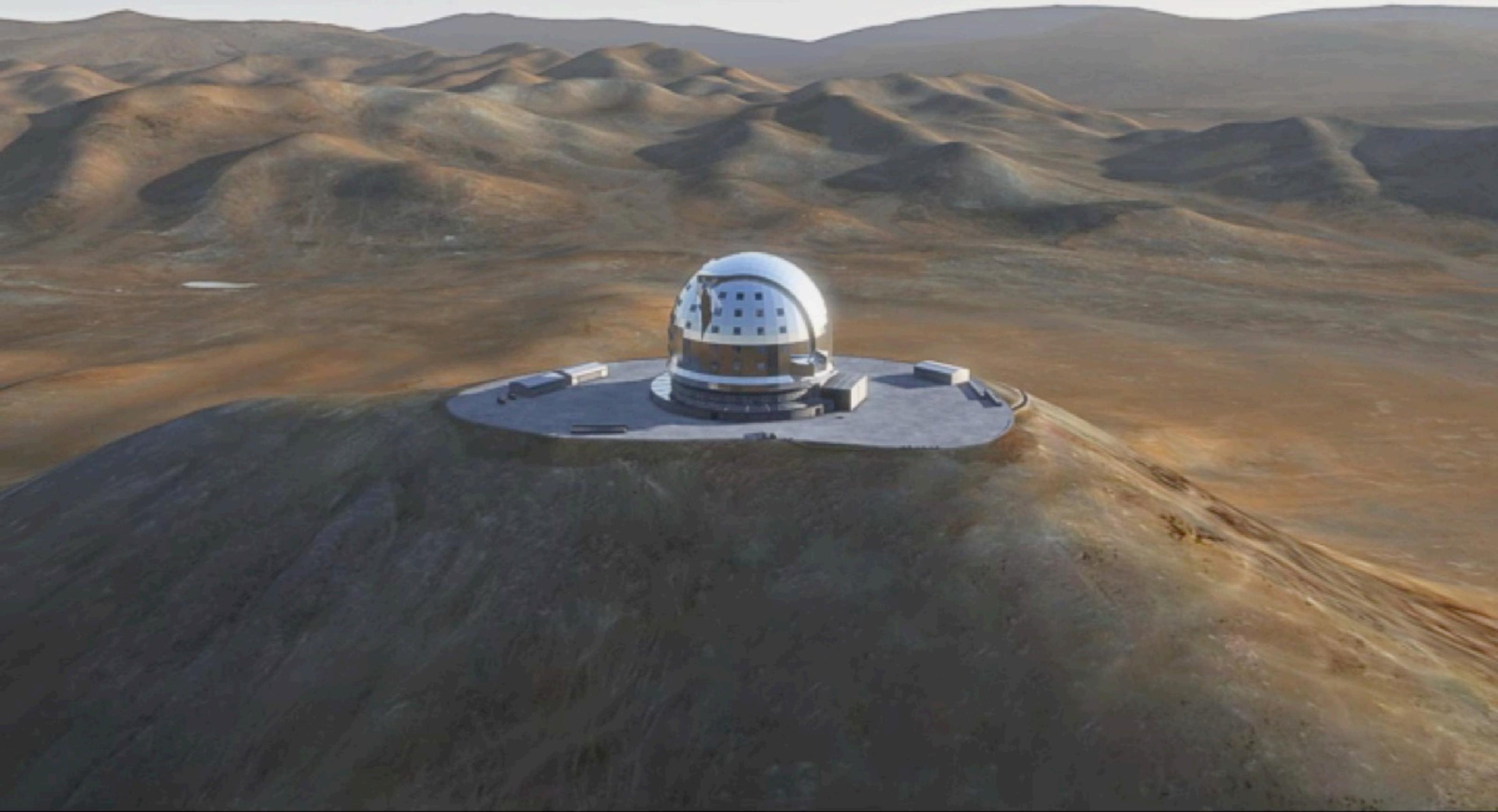
**E-ELT Spectropolarimetry: The Science Case**

A Community Proposal to ESO (July 2009)

A broad suite of astrophysical projects requiring spectropolarimetry and the E-ELT is presented. Spectropolarimetry not merely sorts photons by their wavelengths but unravels the physics of their history from the emission site all the way to the observer. Elaborating on Solar System bodies and extra-solar planets, the interstellar and intergalactic medium, young, old, and solar-like stars, supernovae, GRBs, galaxies, AGNs, weak cosmic lensing, and even the early universe, a synopsis of the unique benefits of this observing technique is developed. The aim is to stir and guide the discussion about polarimetric capabilities for the E-ELT.

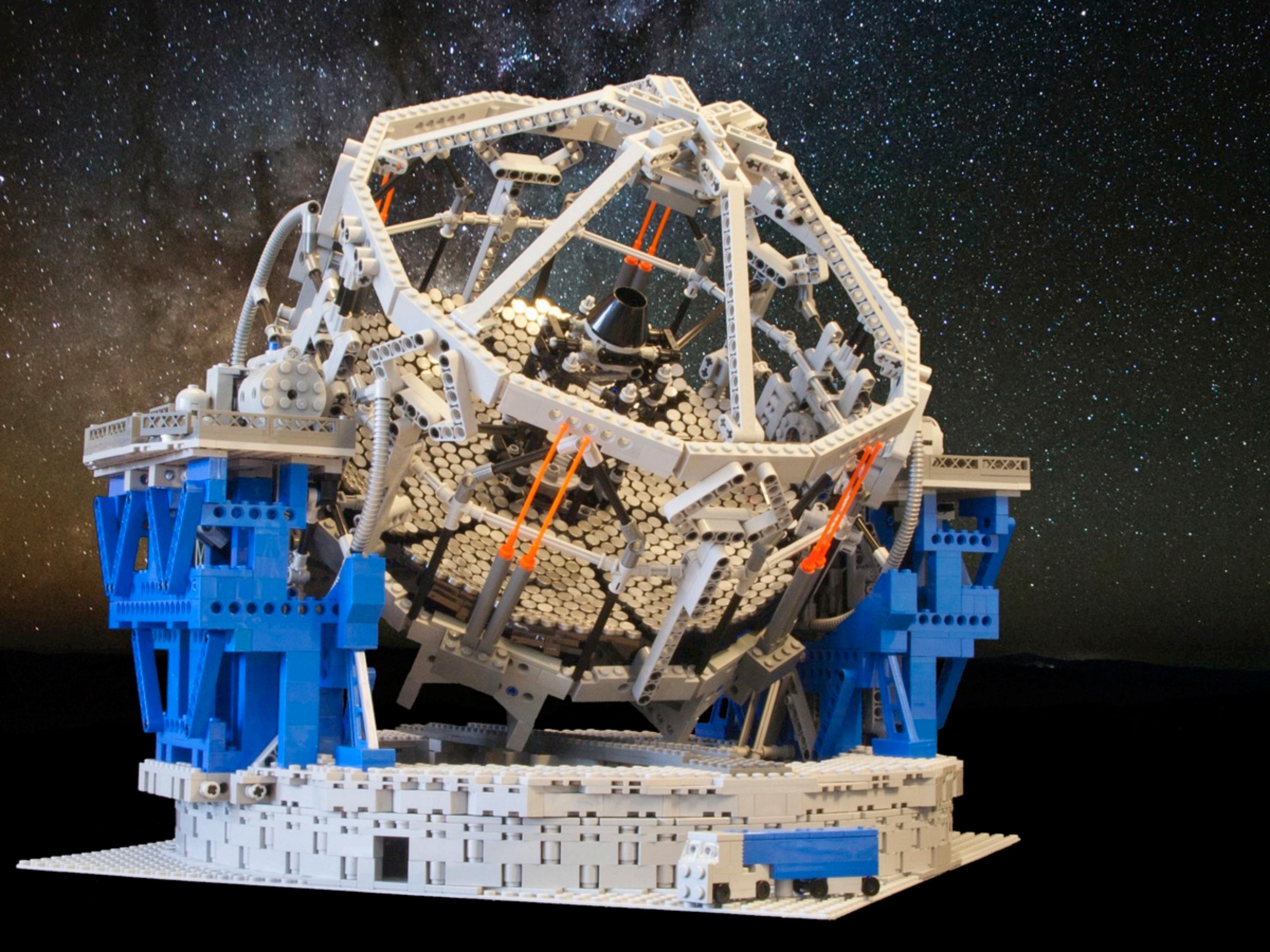
*Strassmeier et al. (2009)*

# the E-ELT

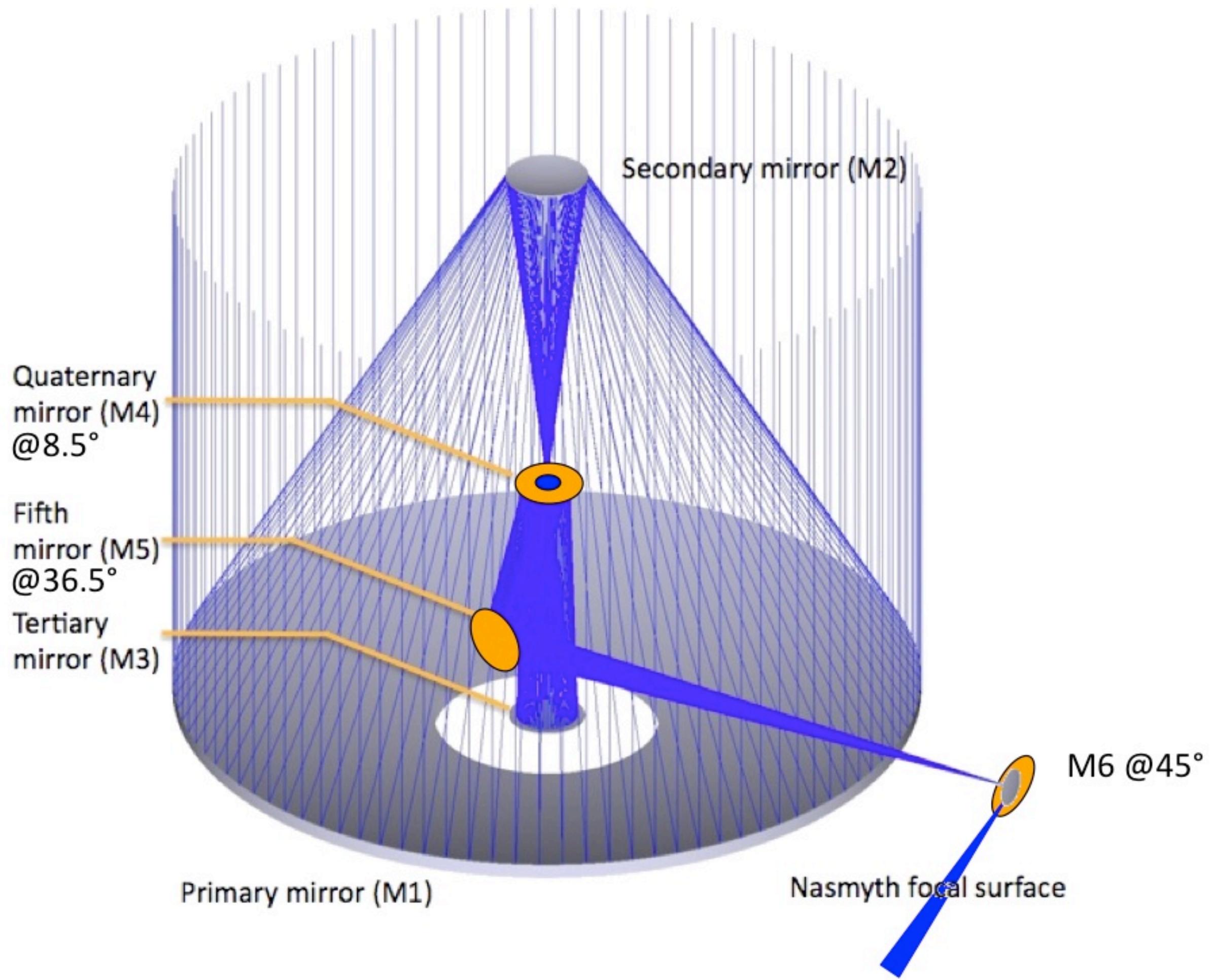


# E-ELT mountain top blasting: June 19, 2014

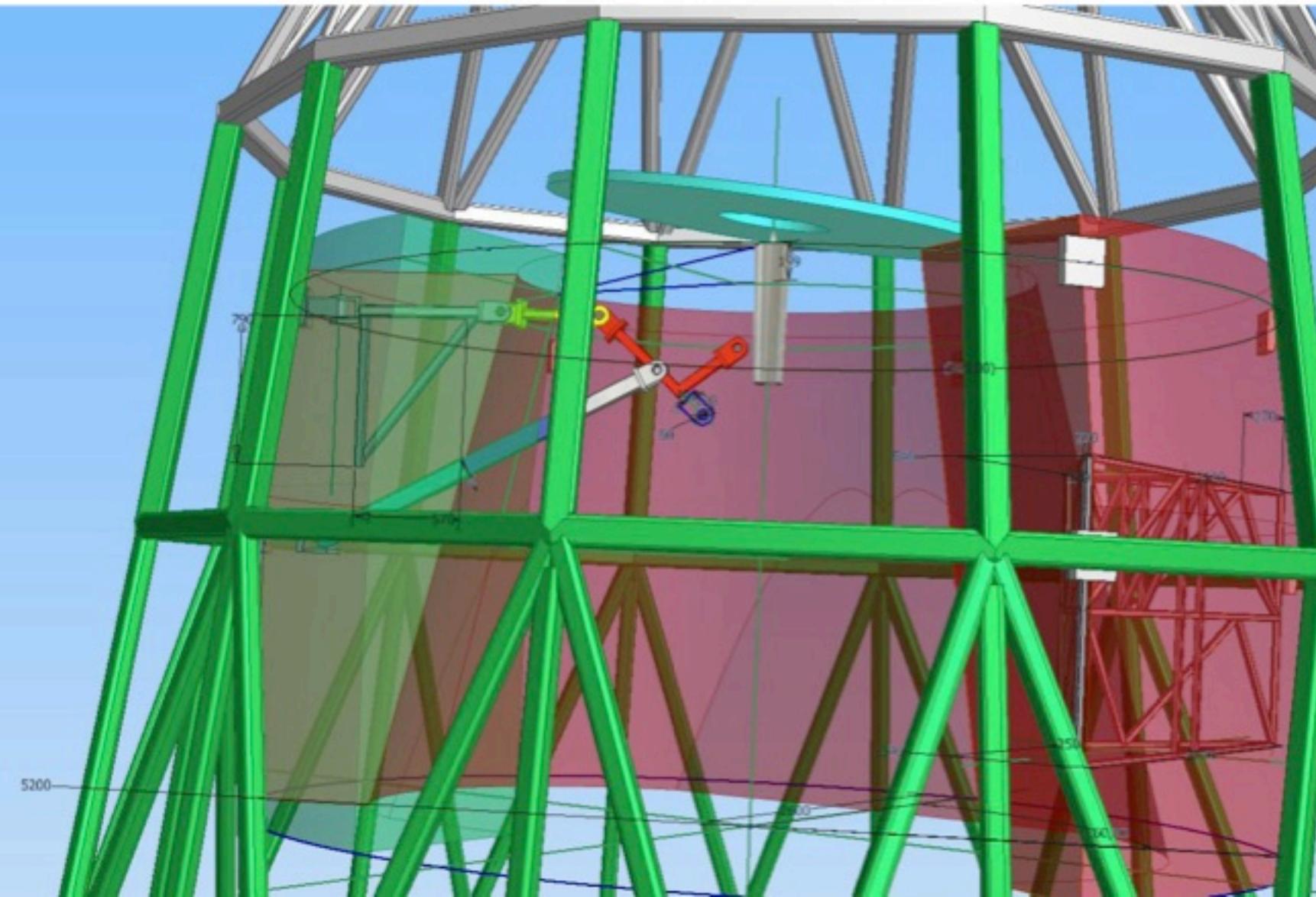
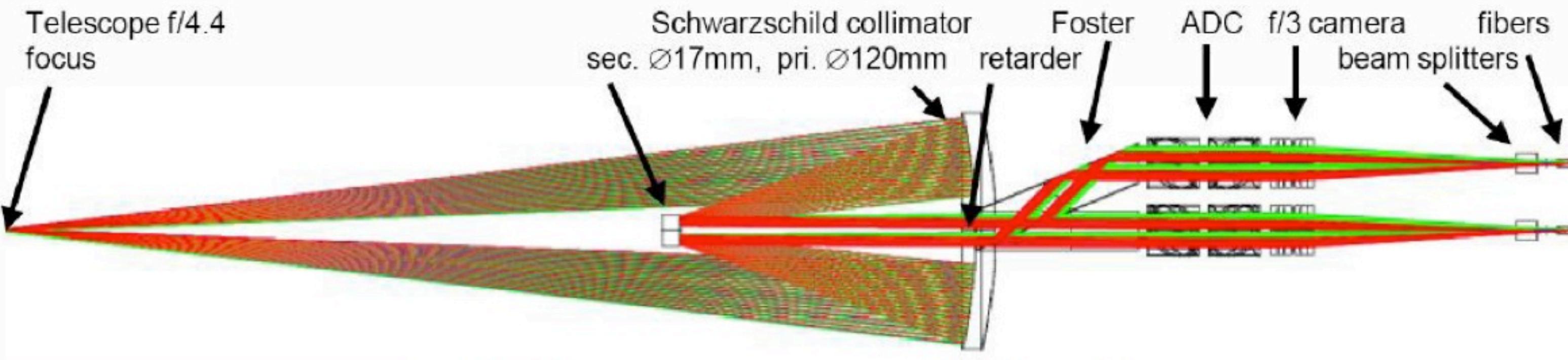




# E-ELT intermediate focus

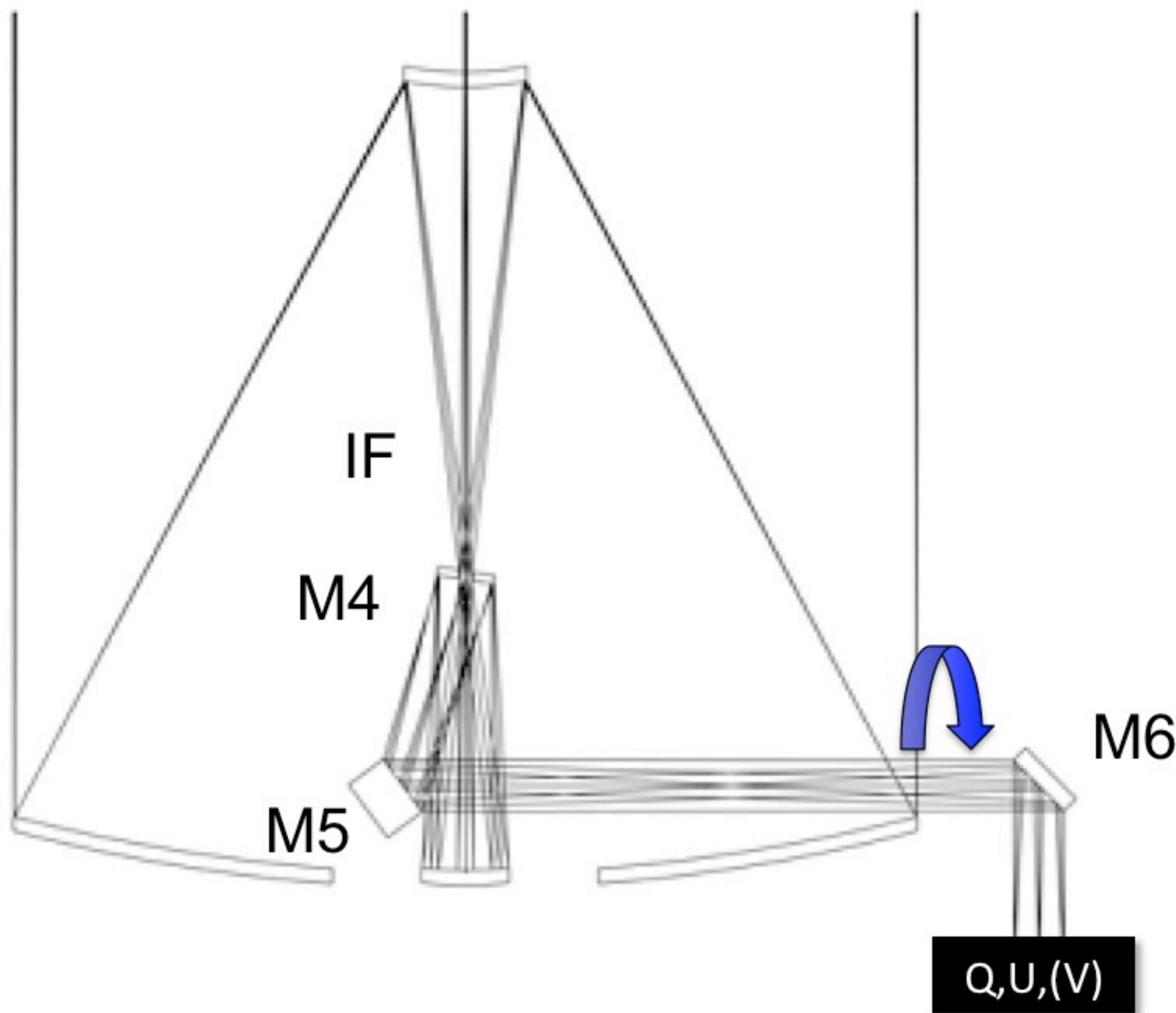


# E-ELT intermediate focus



Strassmeier et al. (2012)

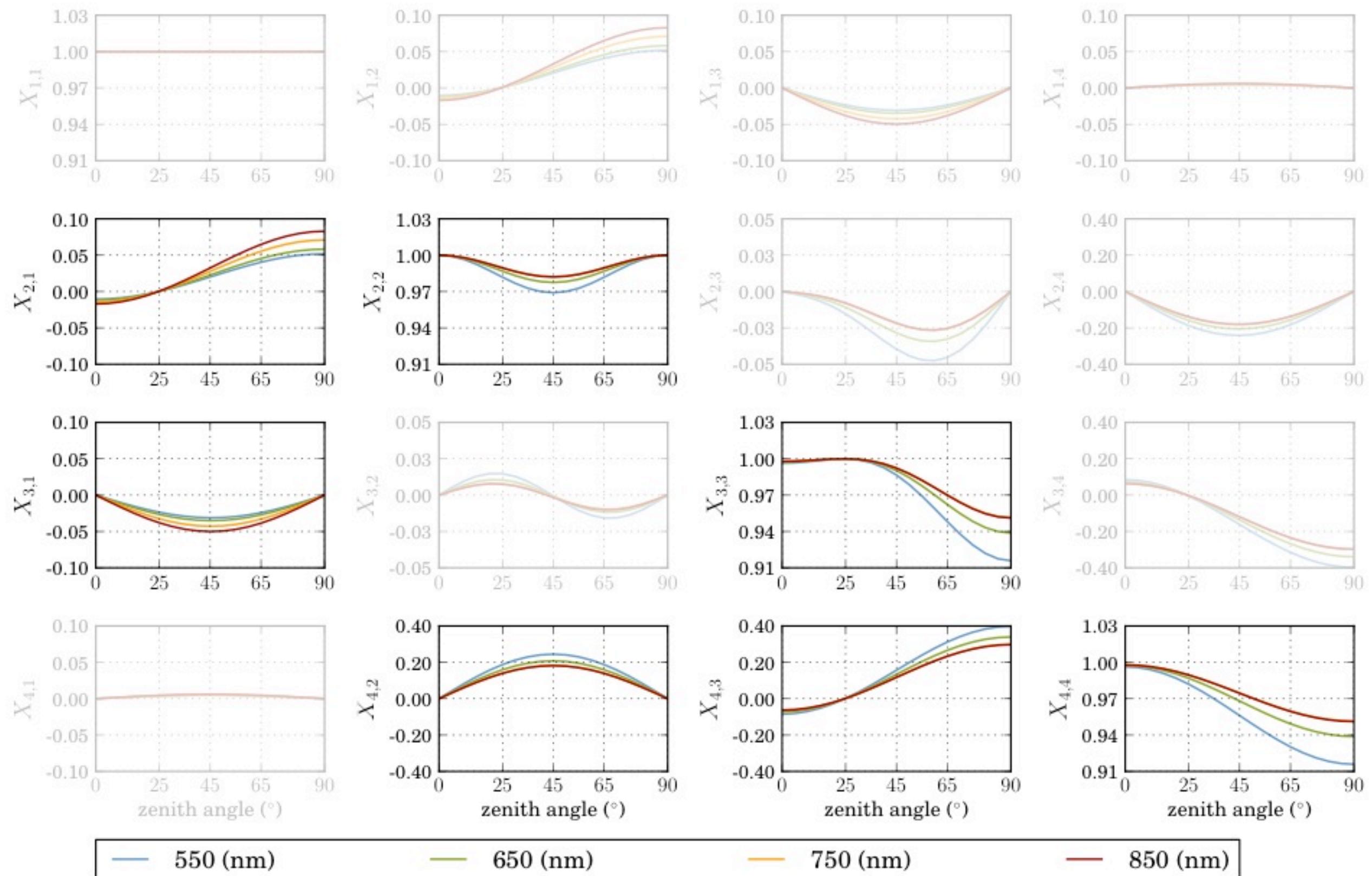
# E-ELT M4-6



*de Juan Ovelar, Snik et al. (2014a)*

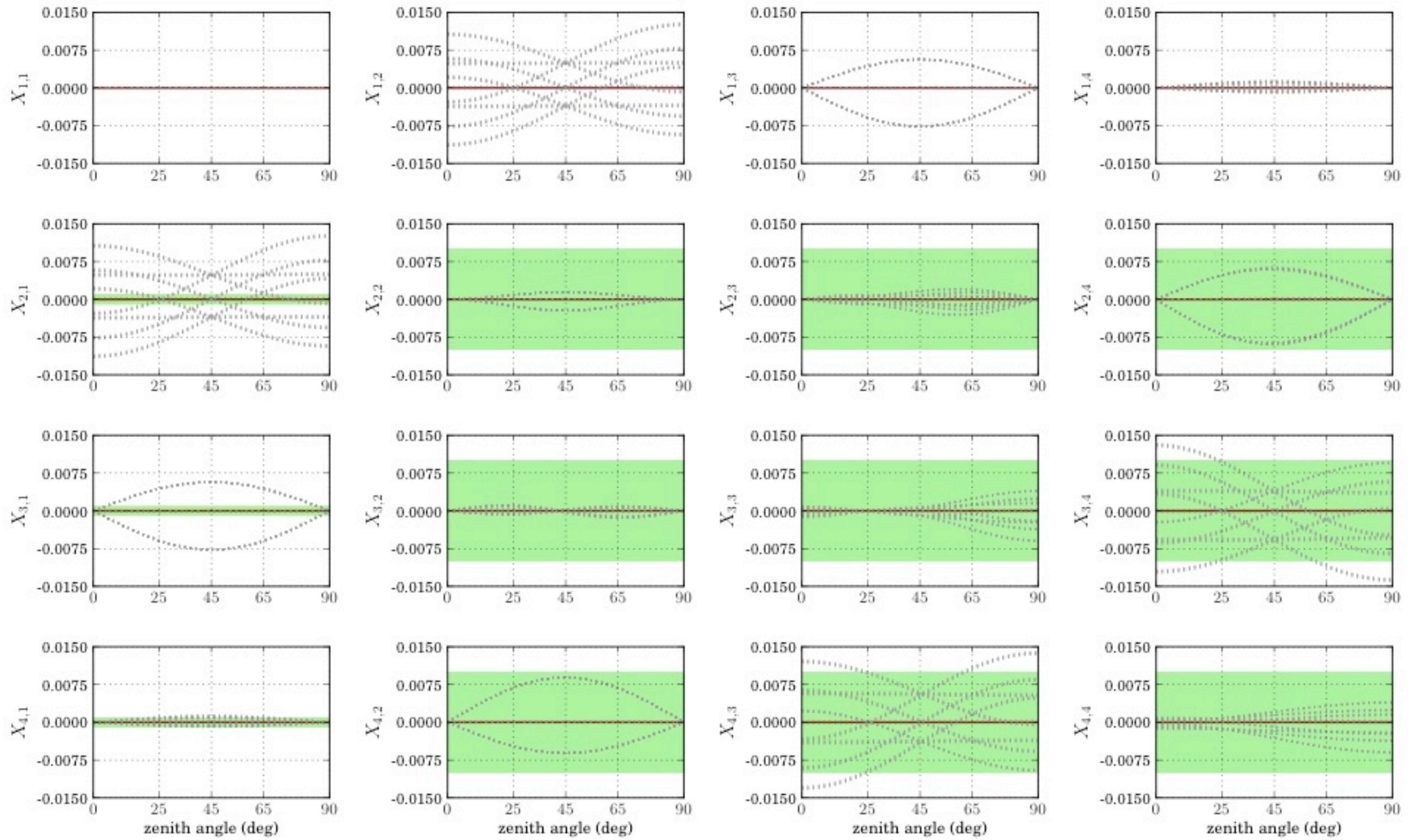
# E-ELT M4-6

E-ELT *full* Nasmyth configuration (M4-M5-M6-Nasmyth focus)

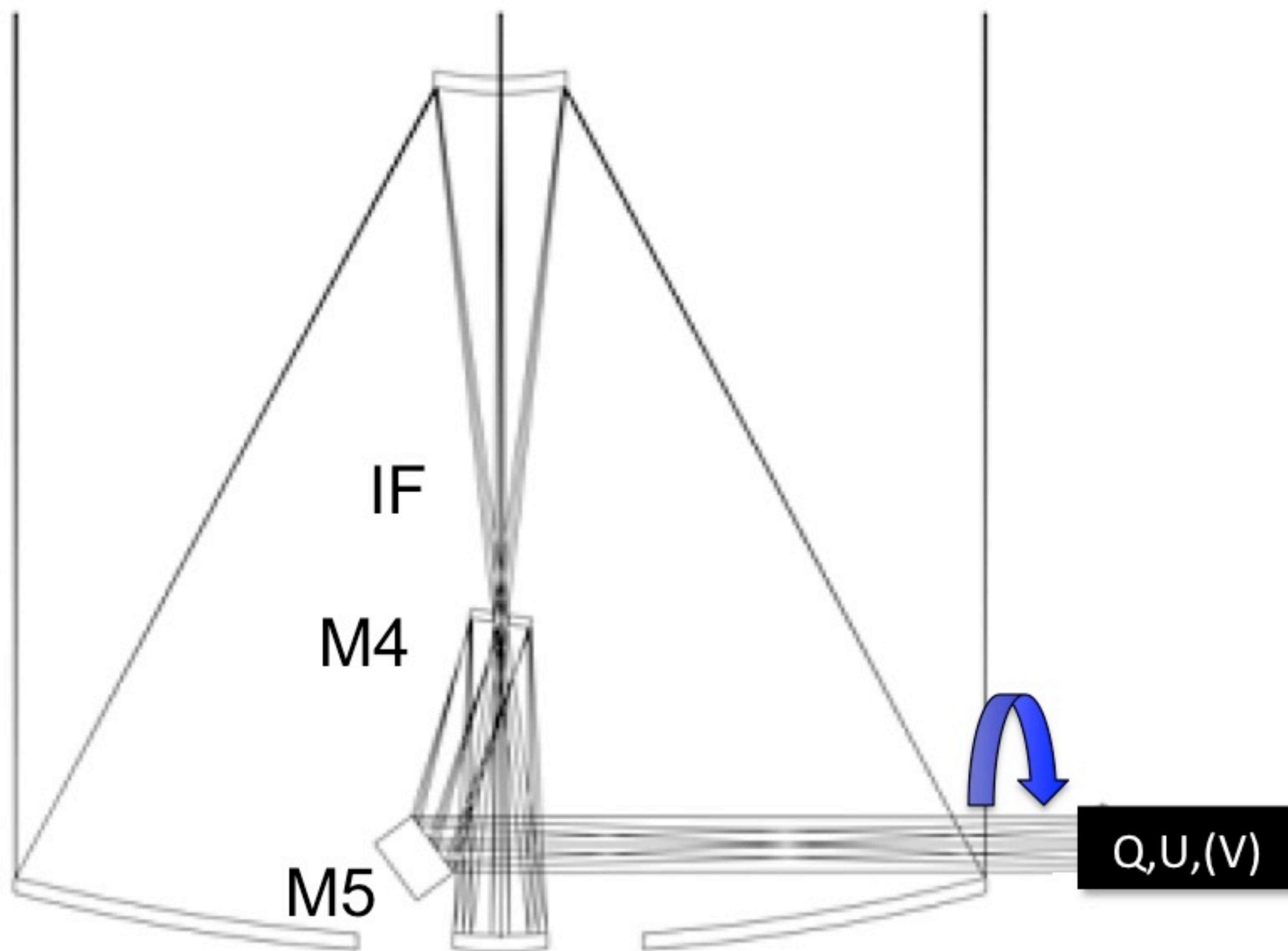


# E-ELT M4-6

is it calibrateable?

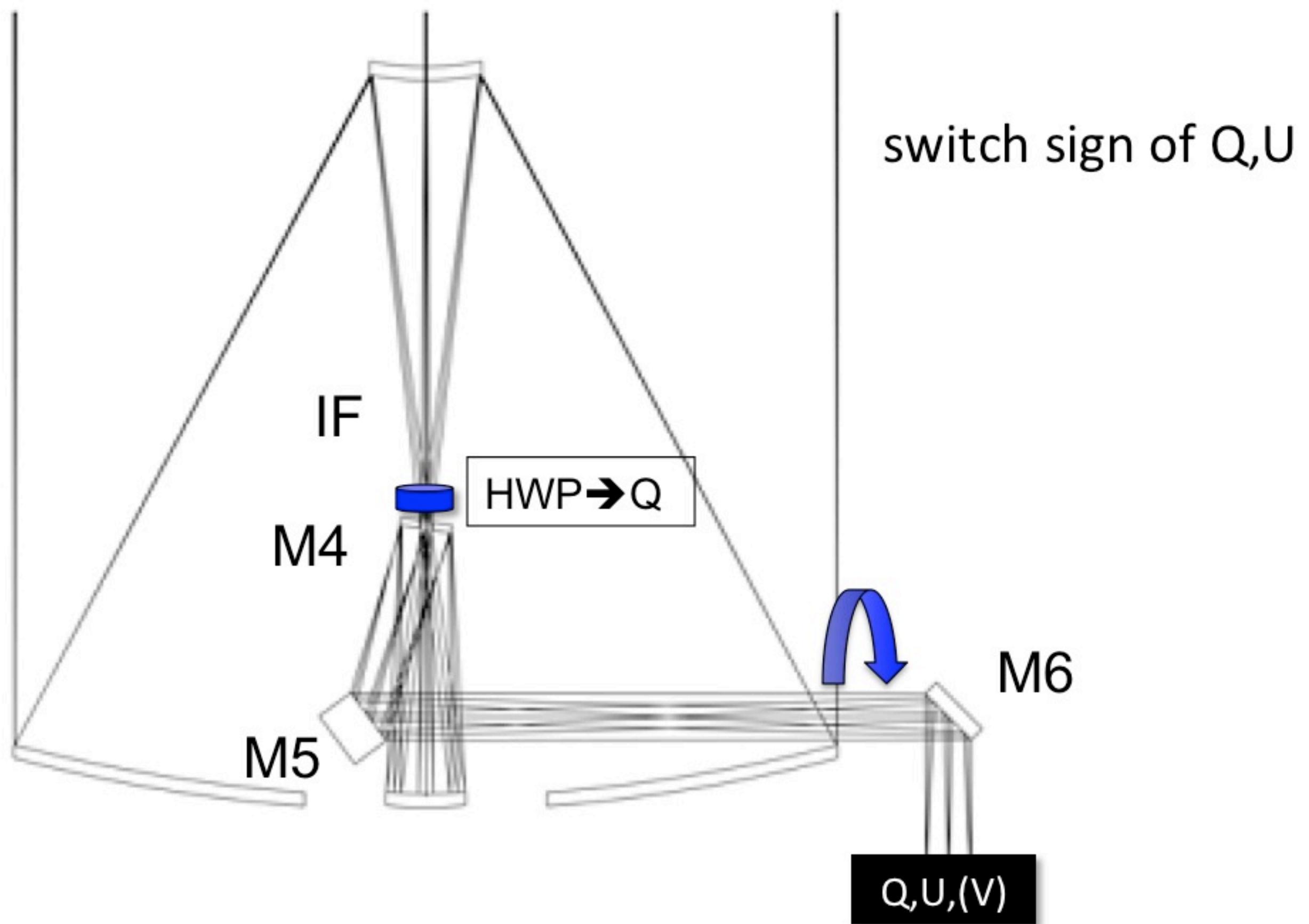


# E-ELT M4-6



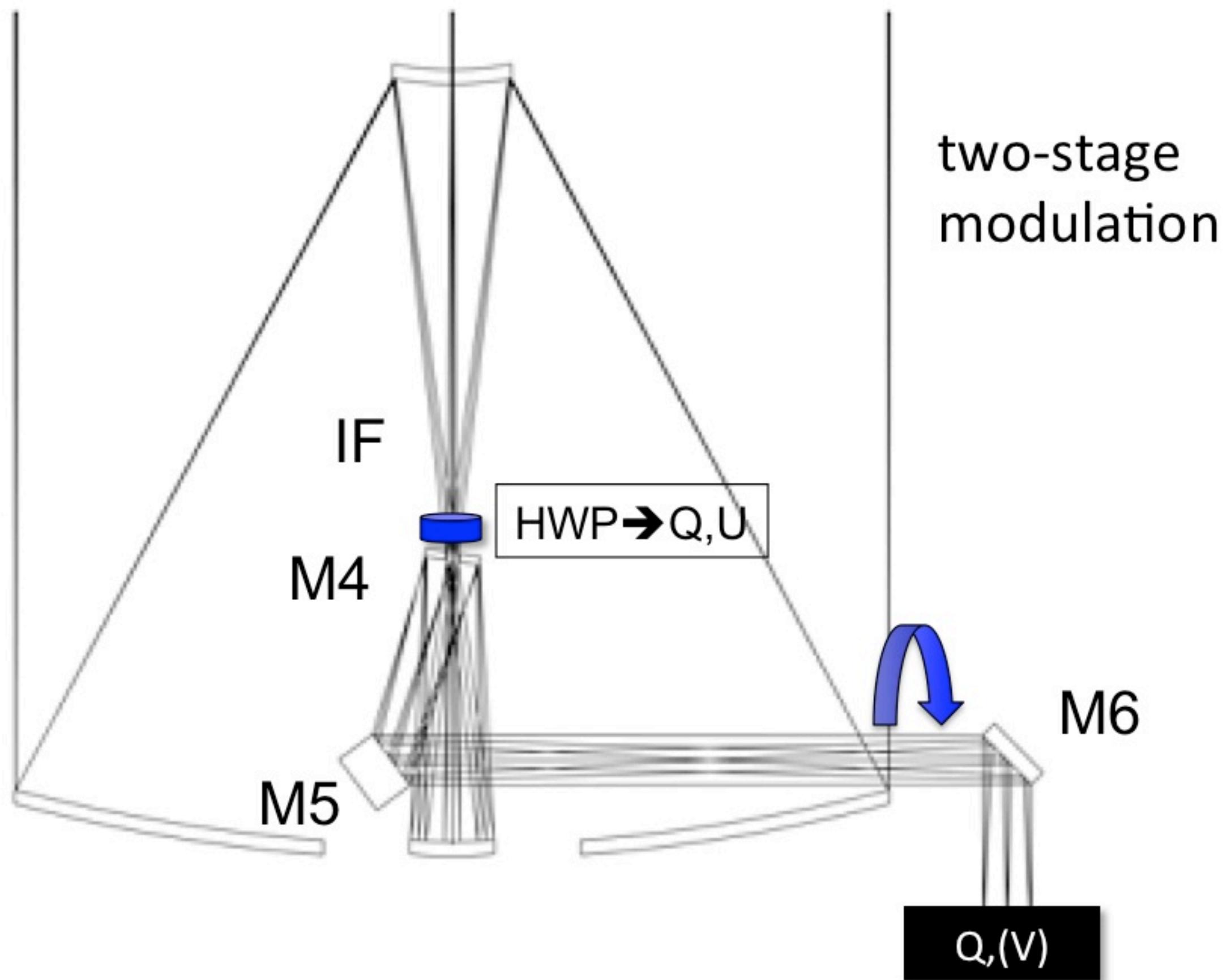
*de Juan Ovelar, Snik et al. (2014a)*

# E-ELT M4-6



*de Juan Ovelar, Snik et al. (2014a)*

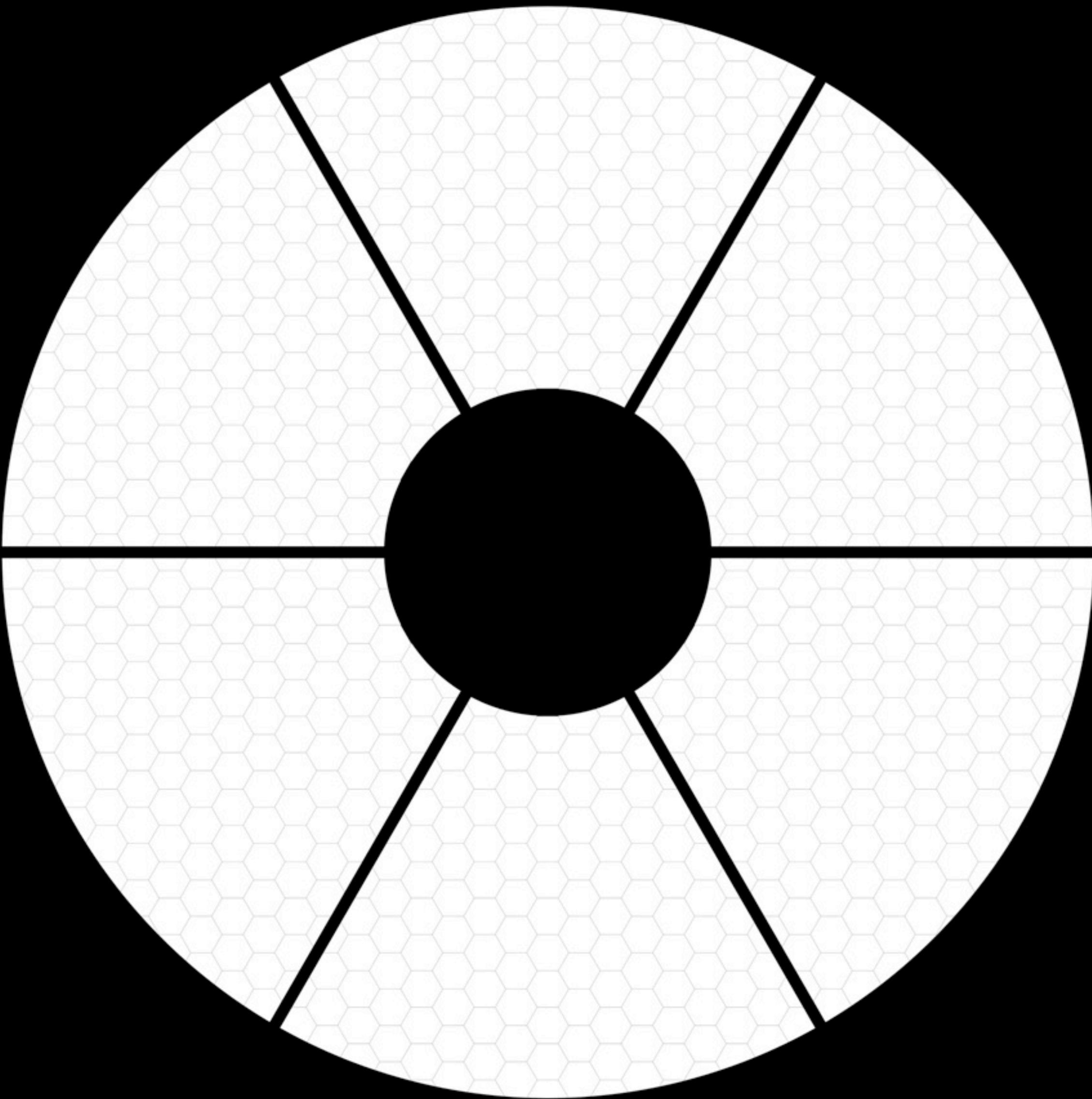
# E-ELT M4-6

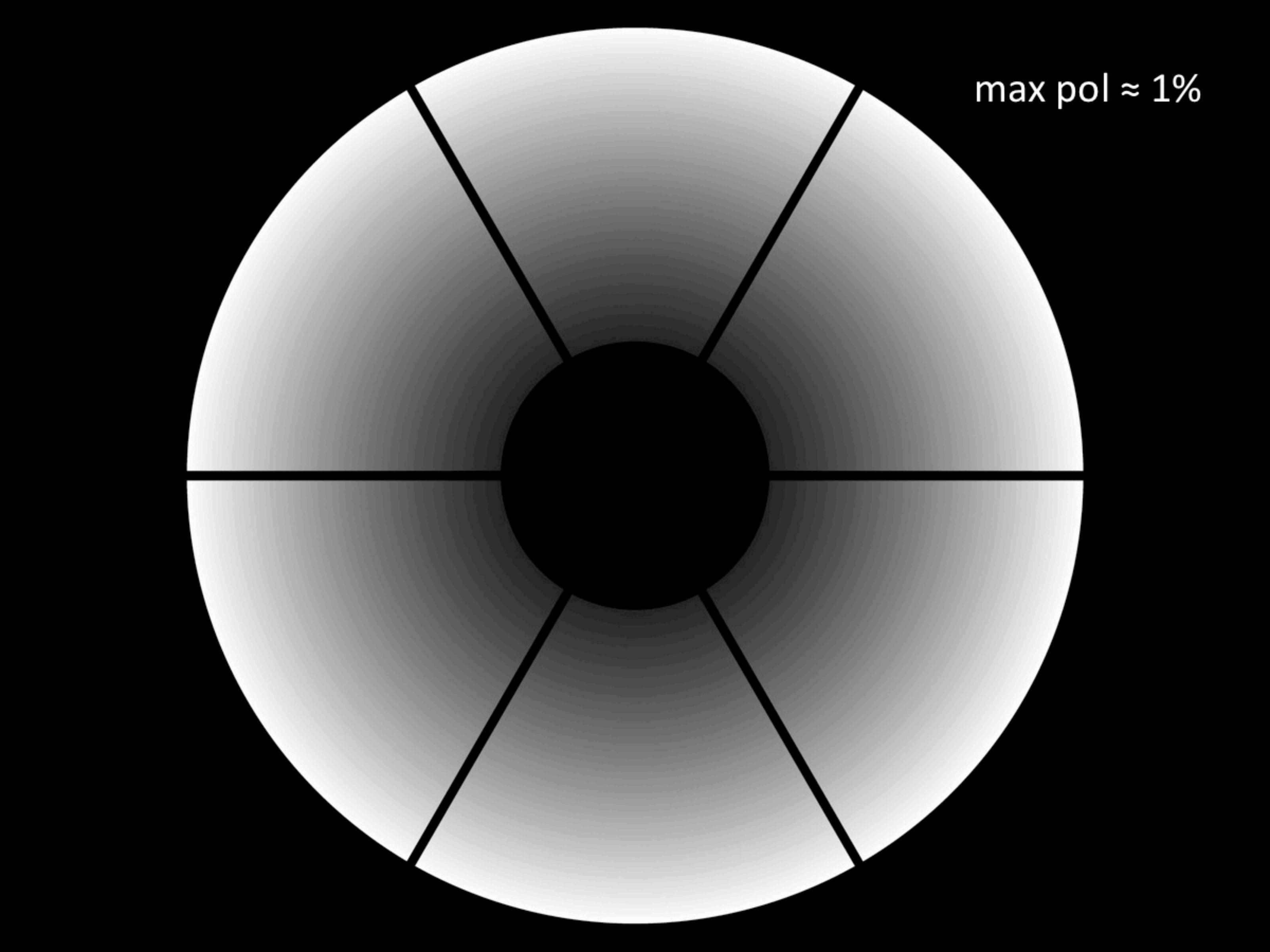


*de Juan Ovelar, Snik et al. (2014a)*

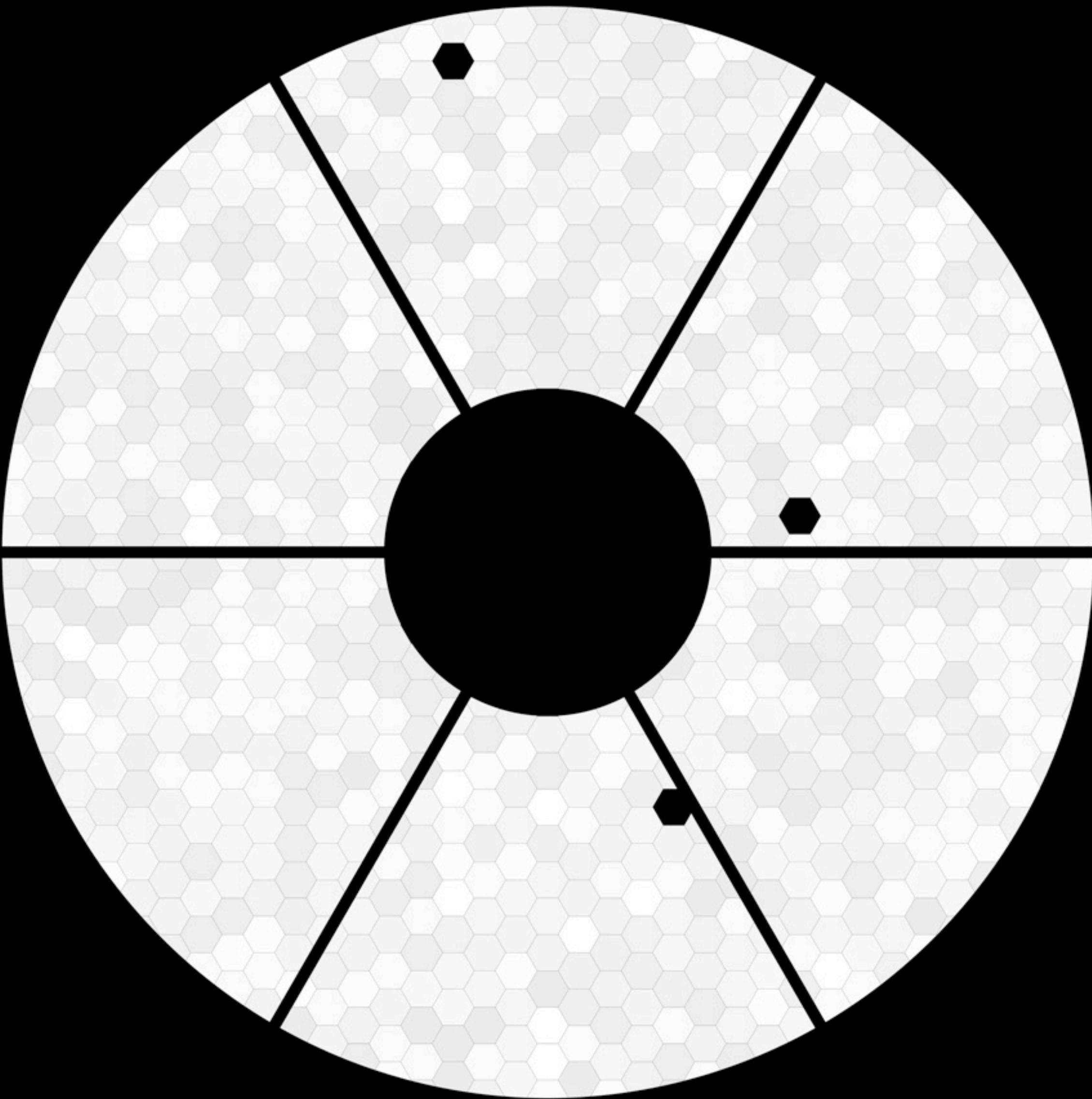
# E-ELT M1-3

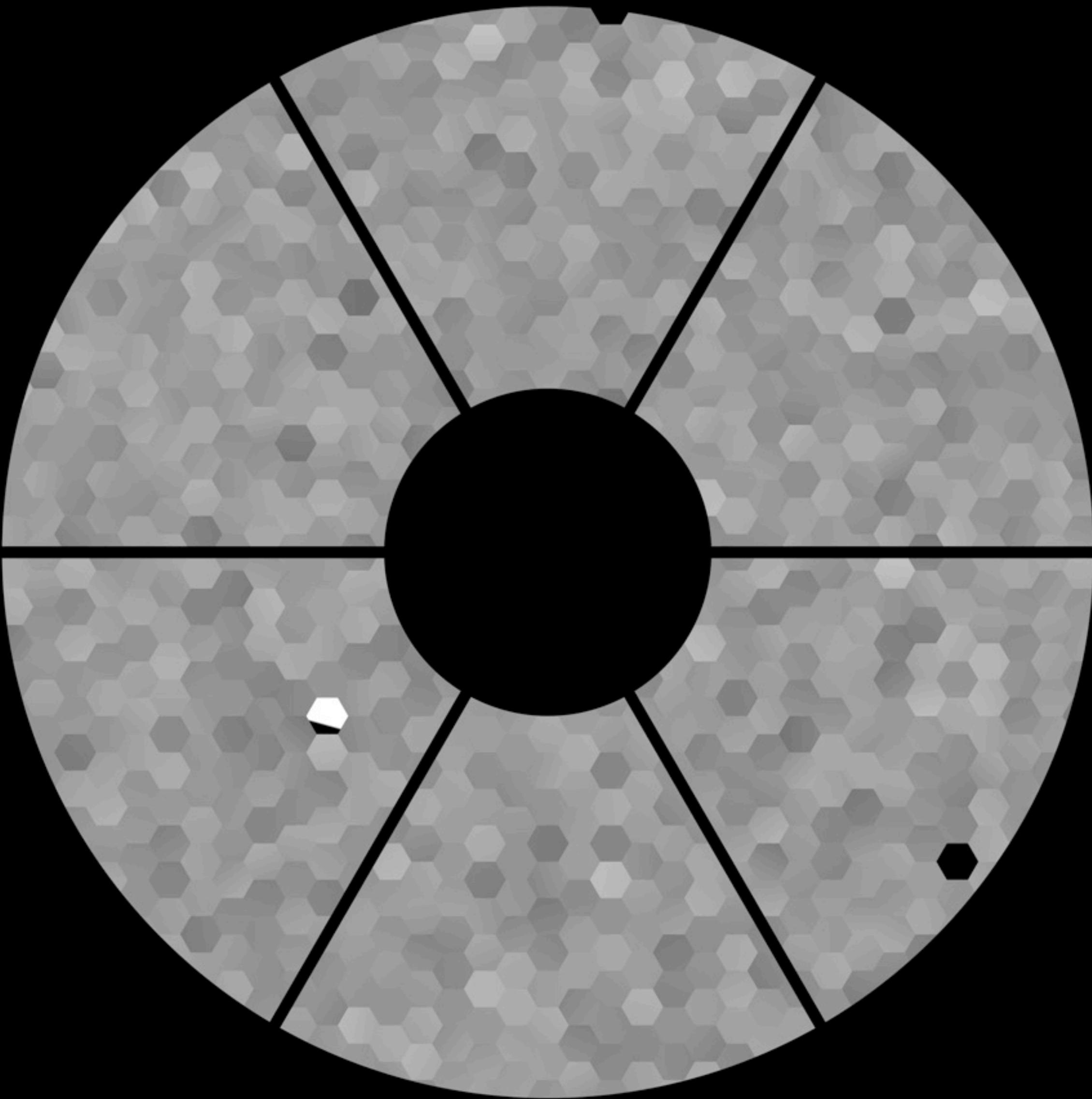
- Fraunhofer diffraction + Jones formalism  
*(Sanchez Almeida & Martinez Pillet, 1992)*
- amplitude & phase ->  
instrumental polarization & cross-talk
- rotationally symmetric ->  
average polarization is zero
- no vector-diffraction (3D) effects

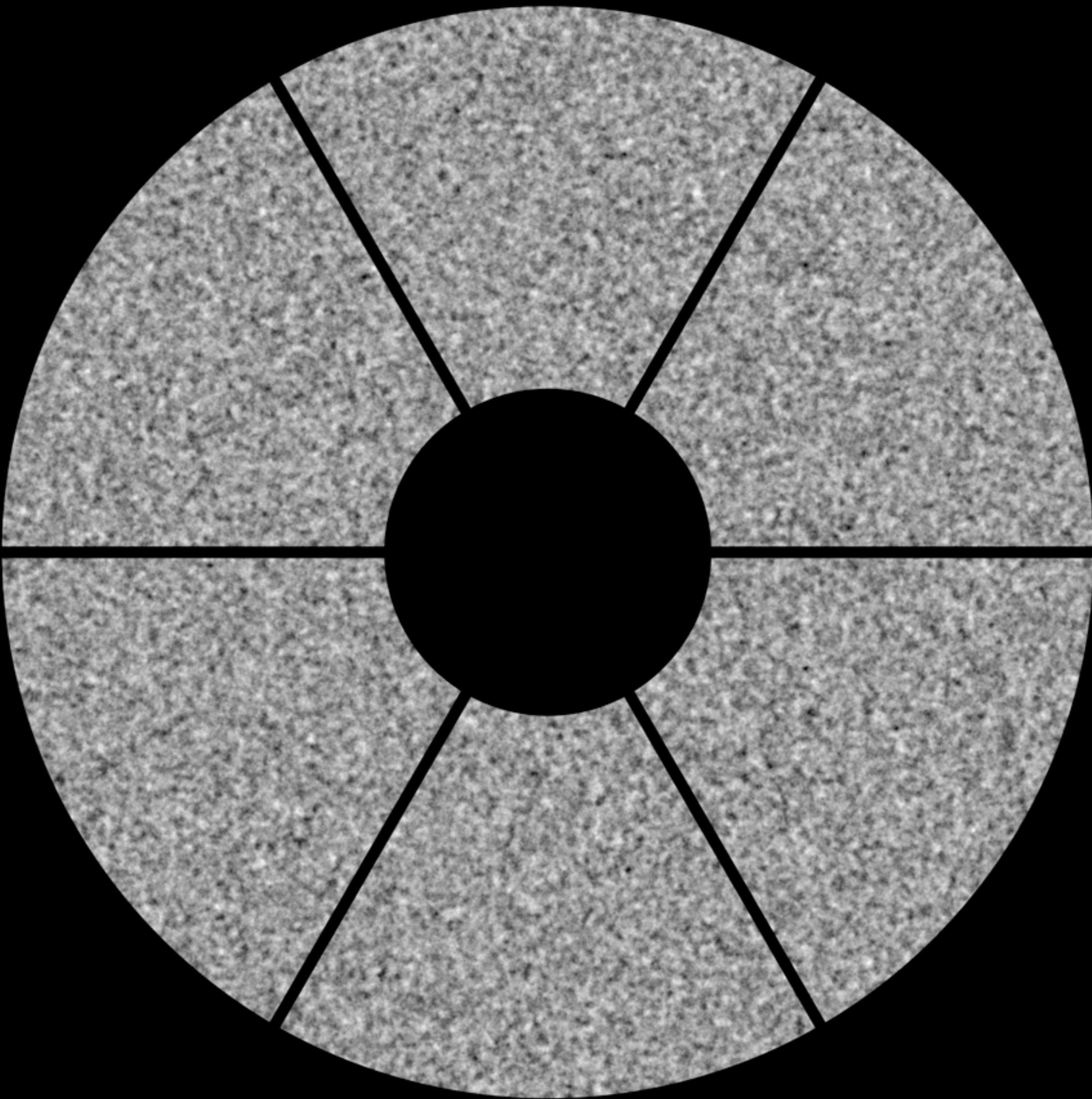




max pol ≈ 1%

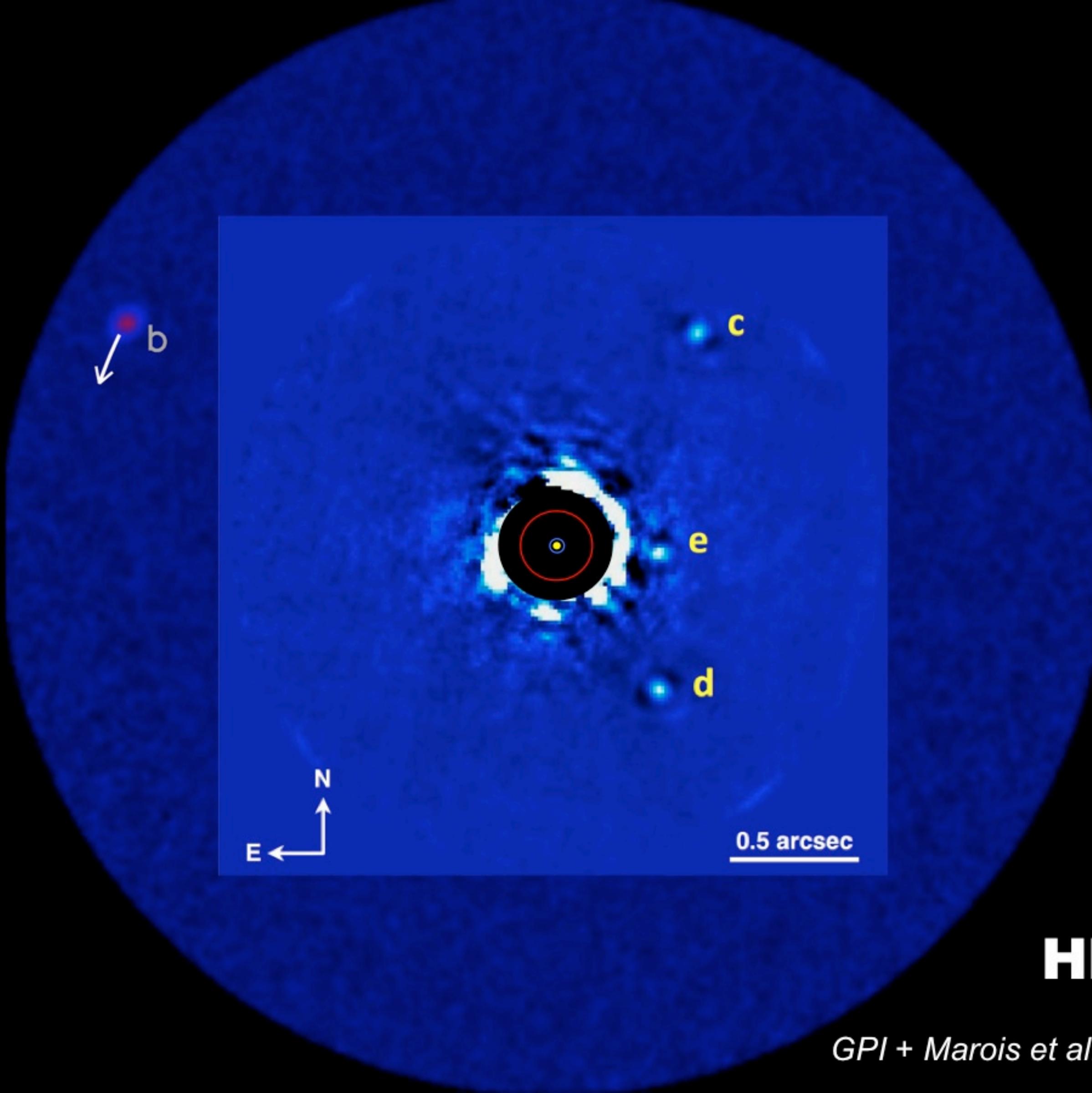








Sirius A&B

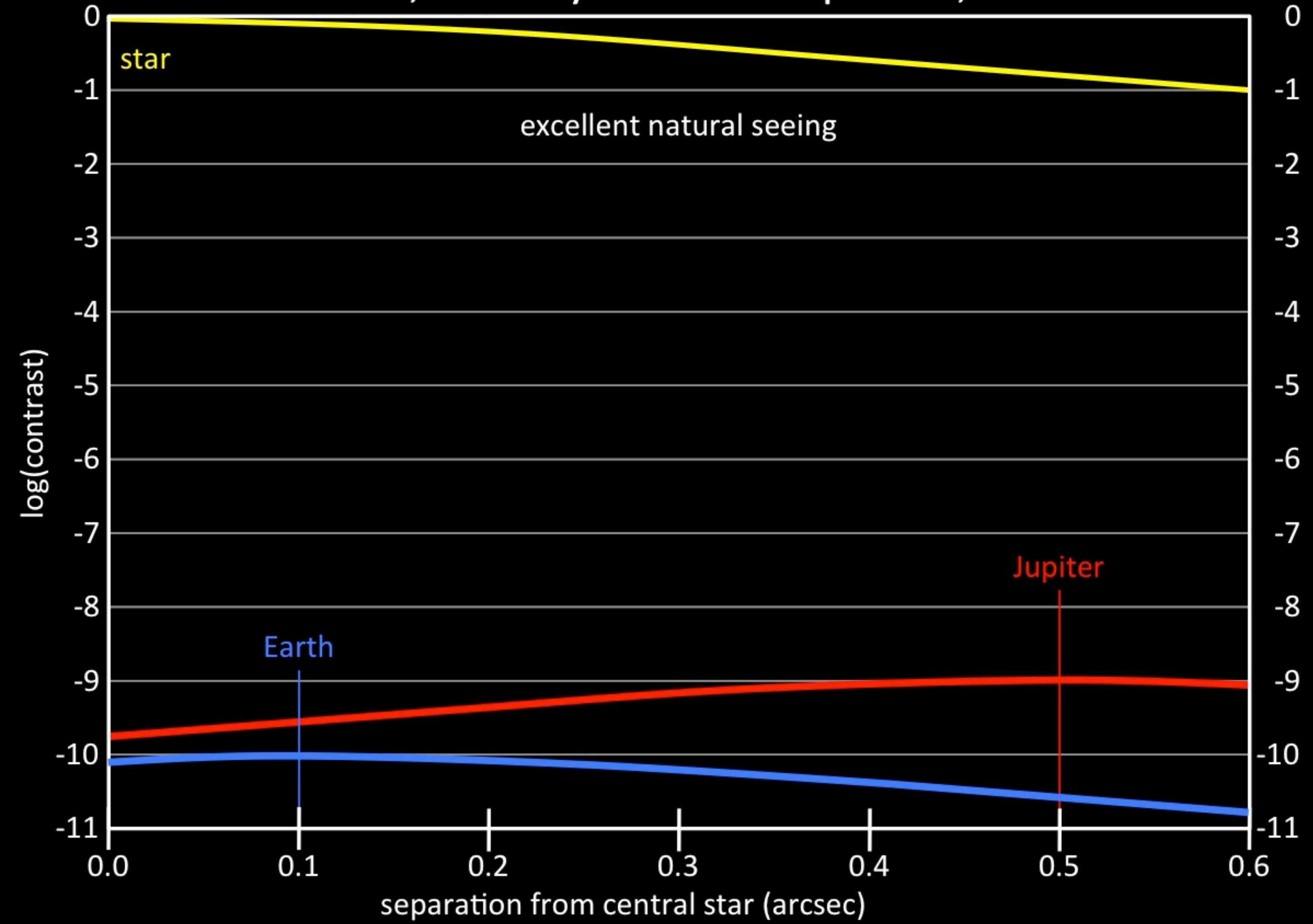


**HR8799**

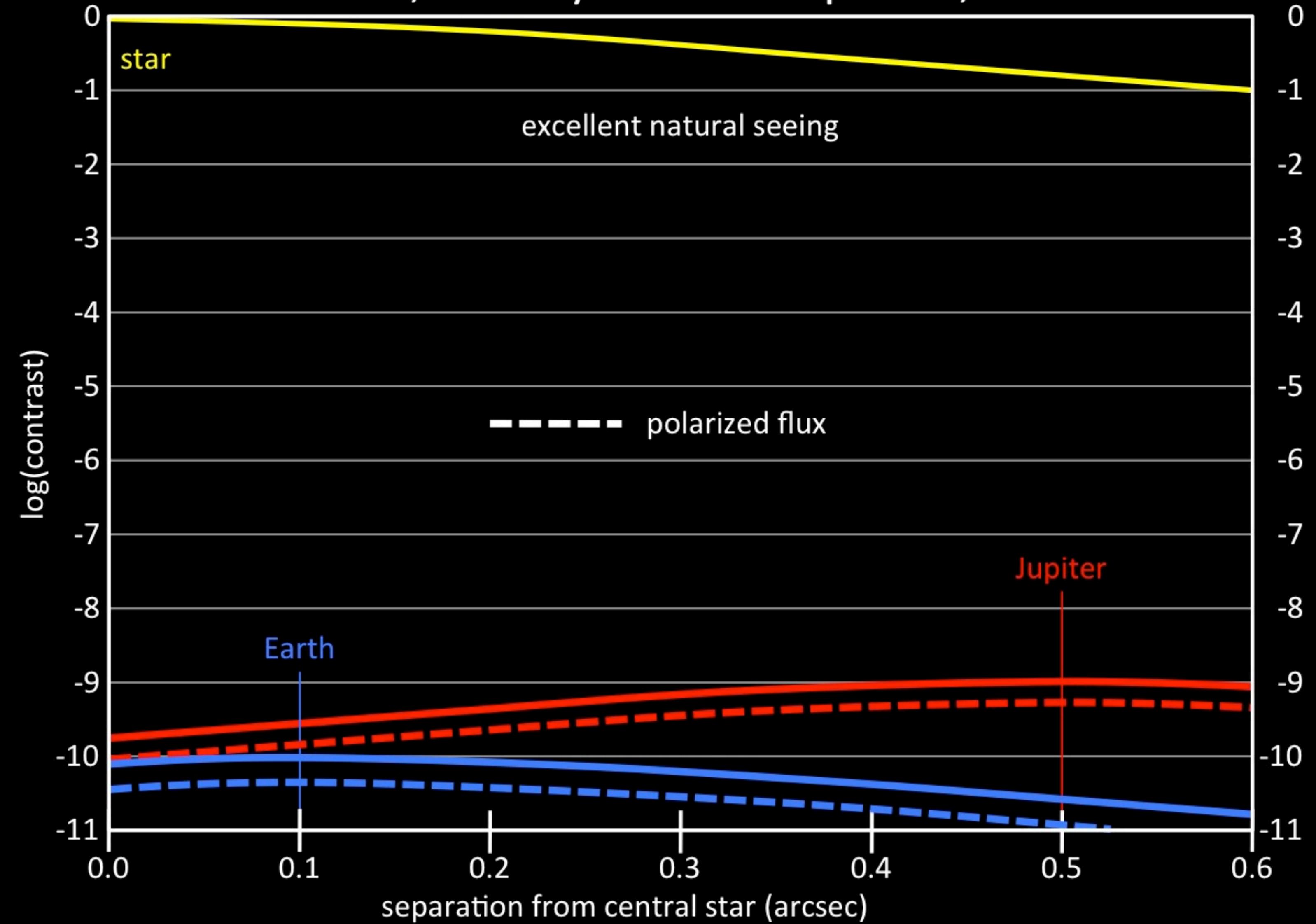
*GPI + Marois et al. (2008, 2010)*



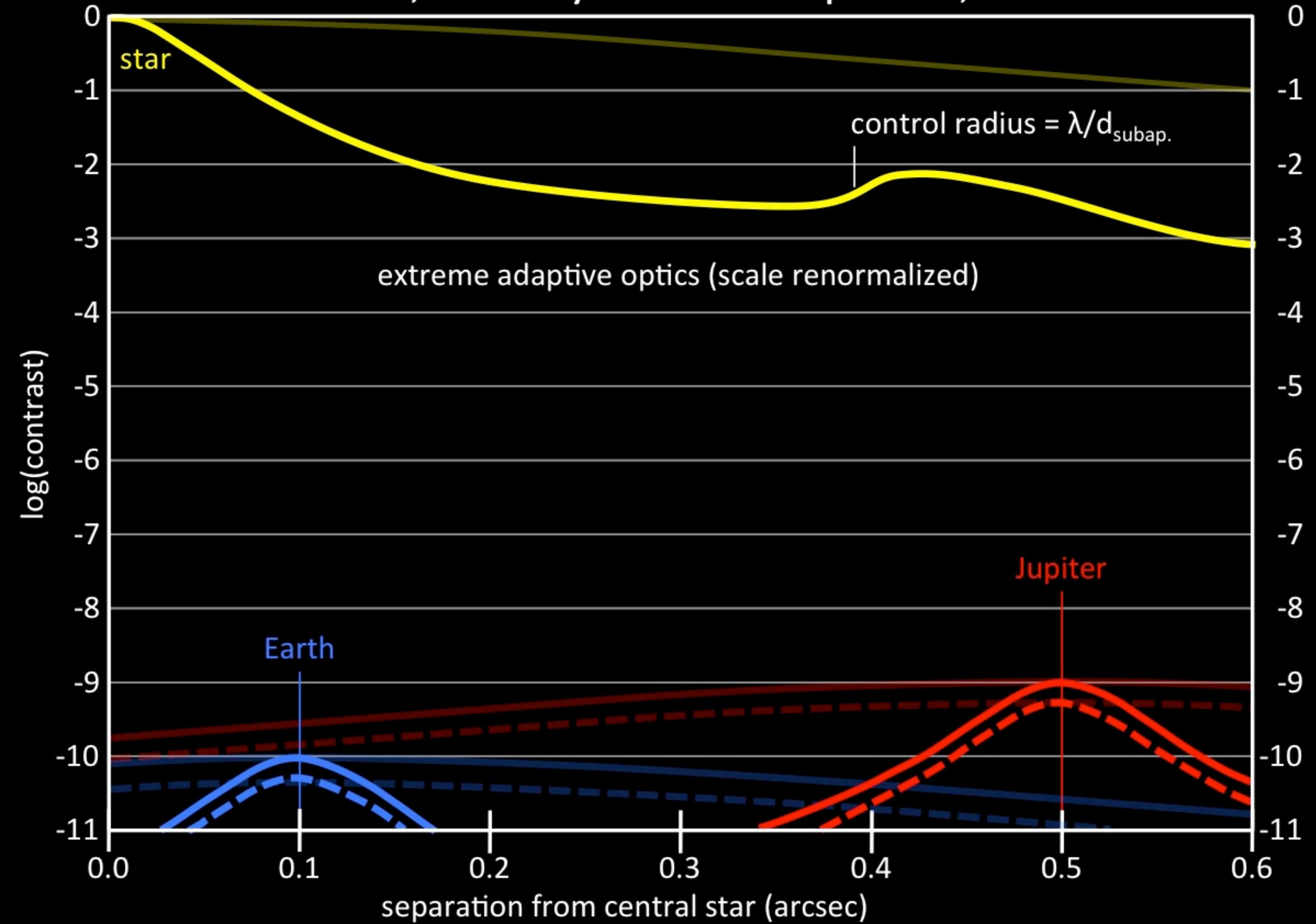
# 8-m VLT, solar system at 10 parsec, $\lambda=600$ nm



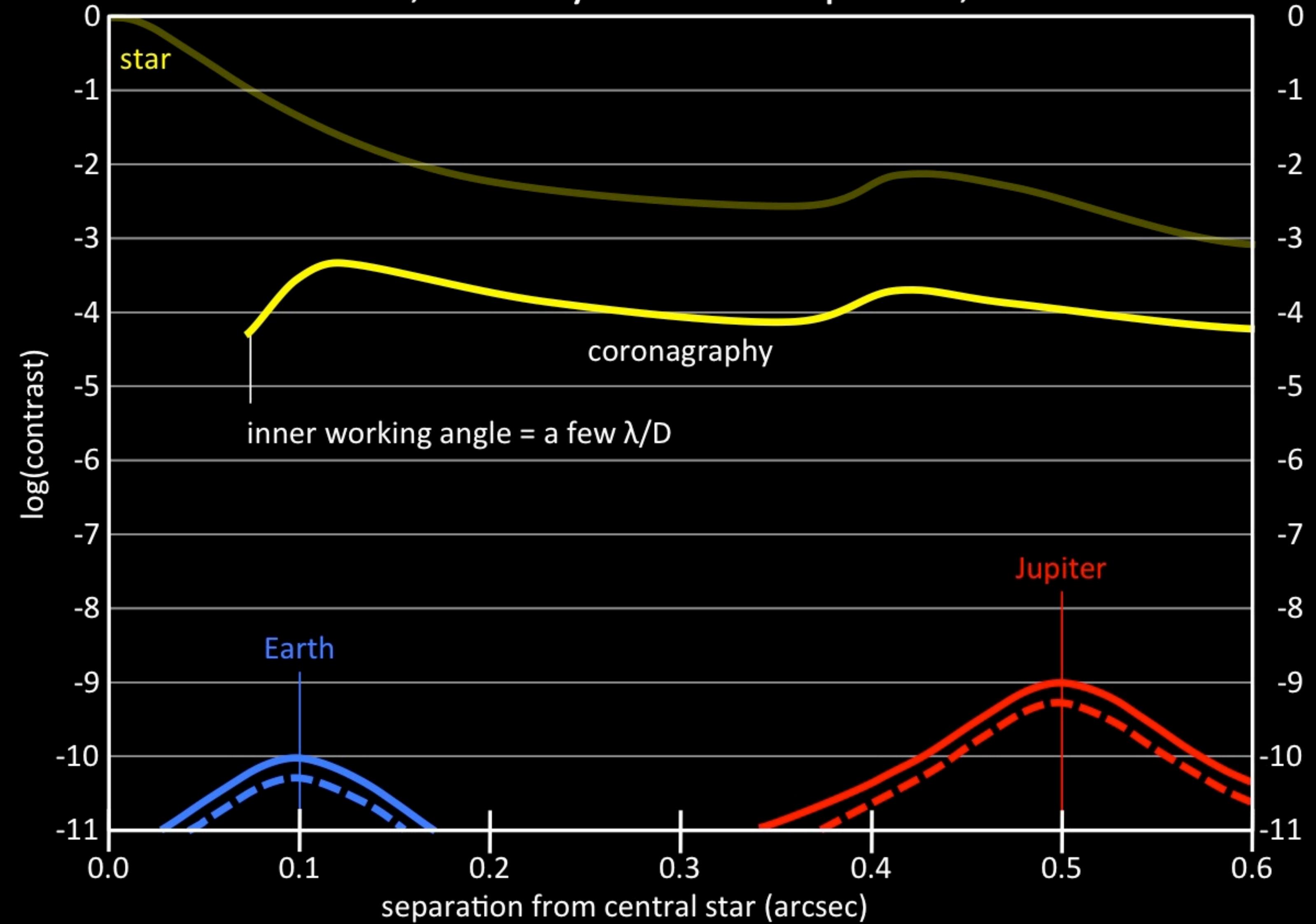
# 8-m VLT, solar system at 10 parsec, $\lambda=600$ nm



# 8-m VLT, solar system at 10 parsec, $\lambda=600$ nm

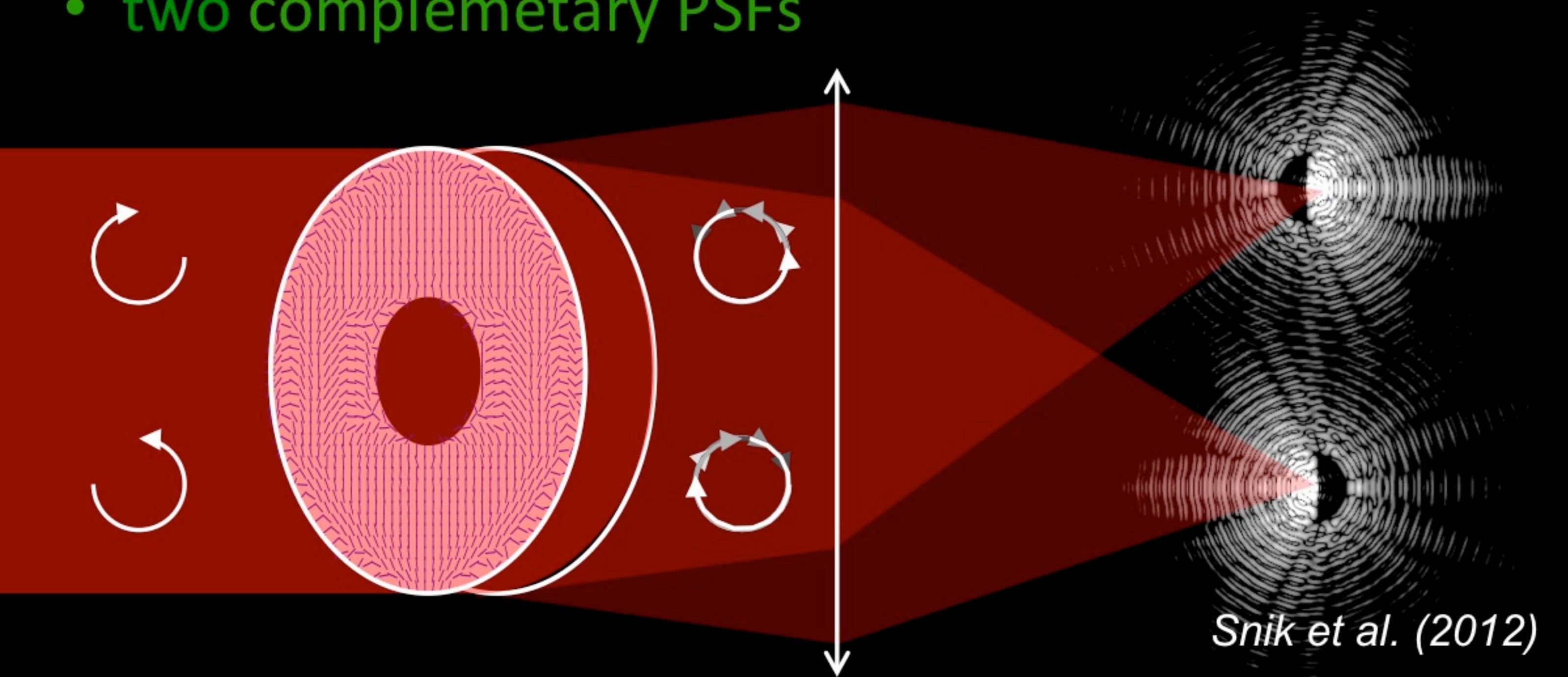


# 8-m VLT, solar system at 10 parsec, $\lambda=600$ nm



# vector-APP coronagraph geometric phase

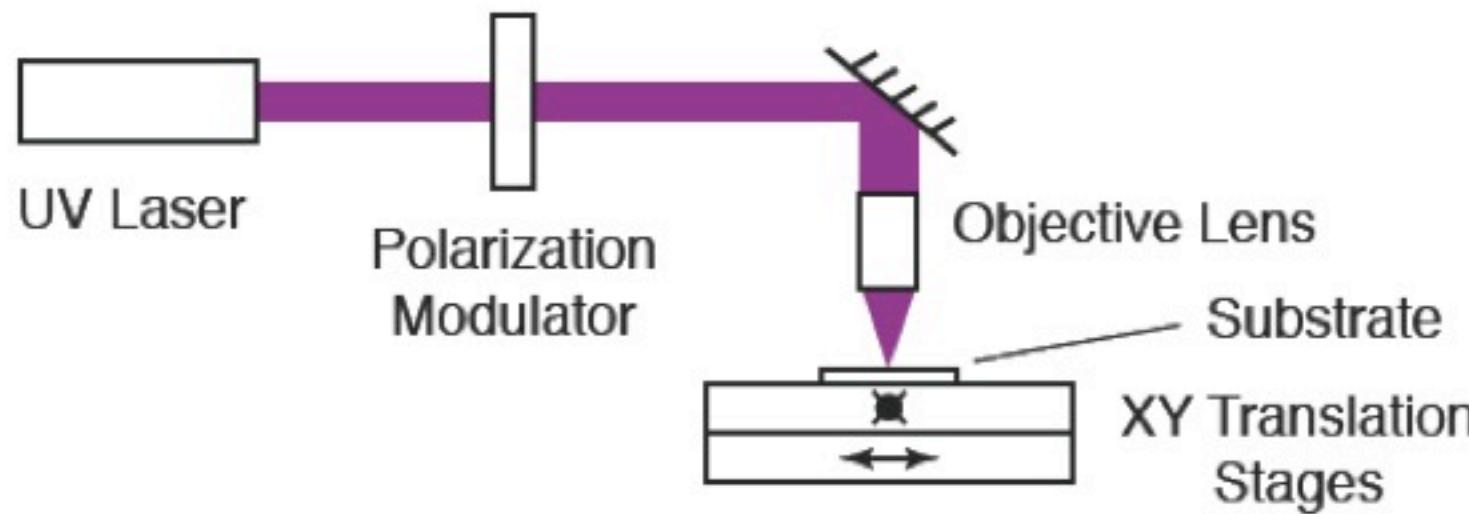
- inherently achromatic chromatic
- use liquid crystals for extreme patterns
- two complementary PSFs



Snik et al. (2012)

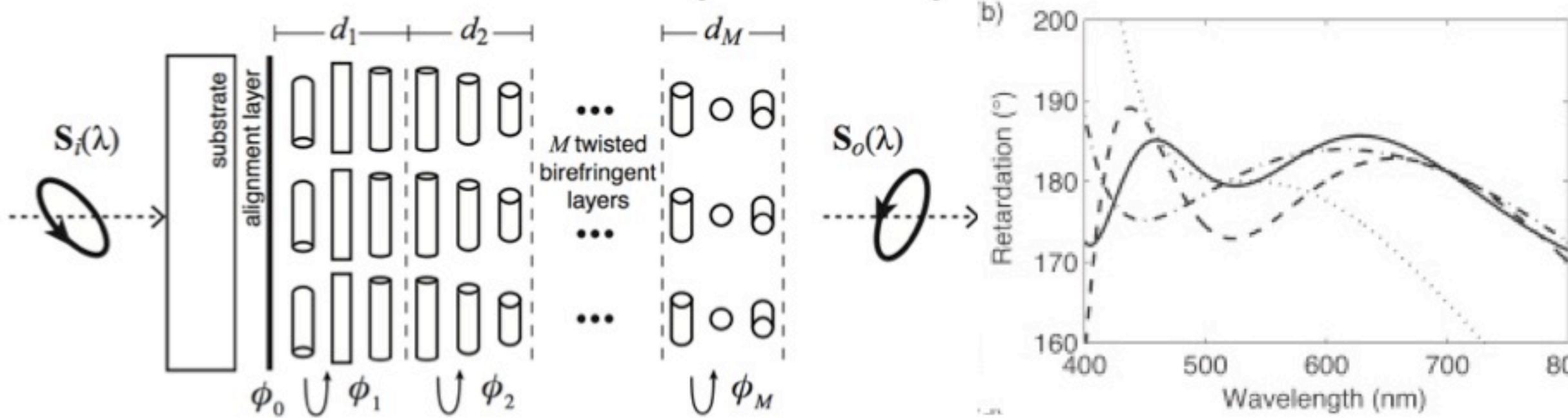
# the vector-APP

1. any phase pattern thanks to direct-write technique



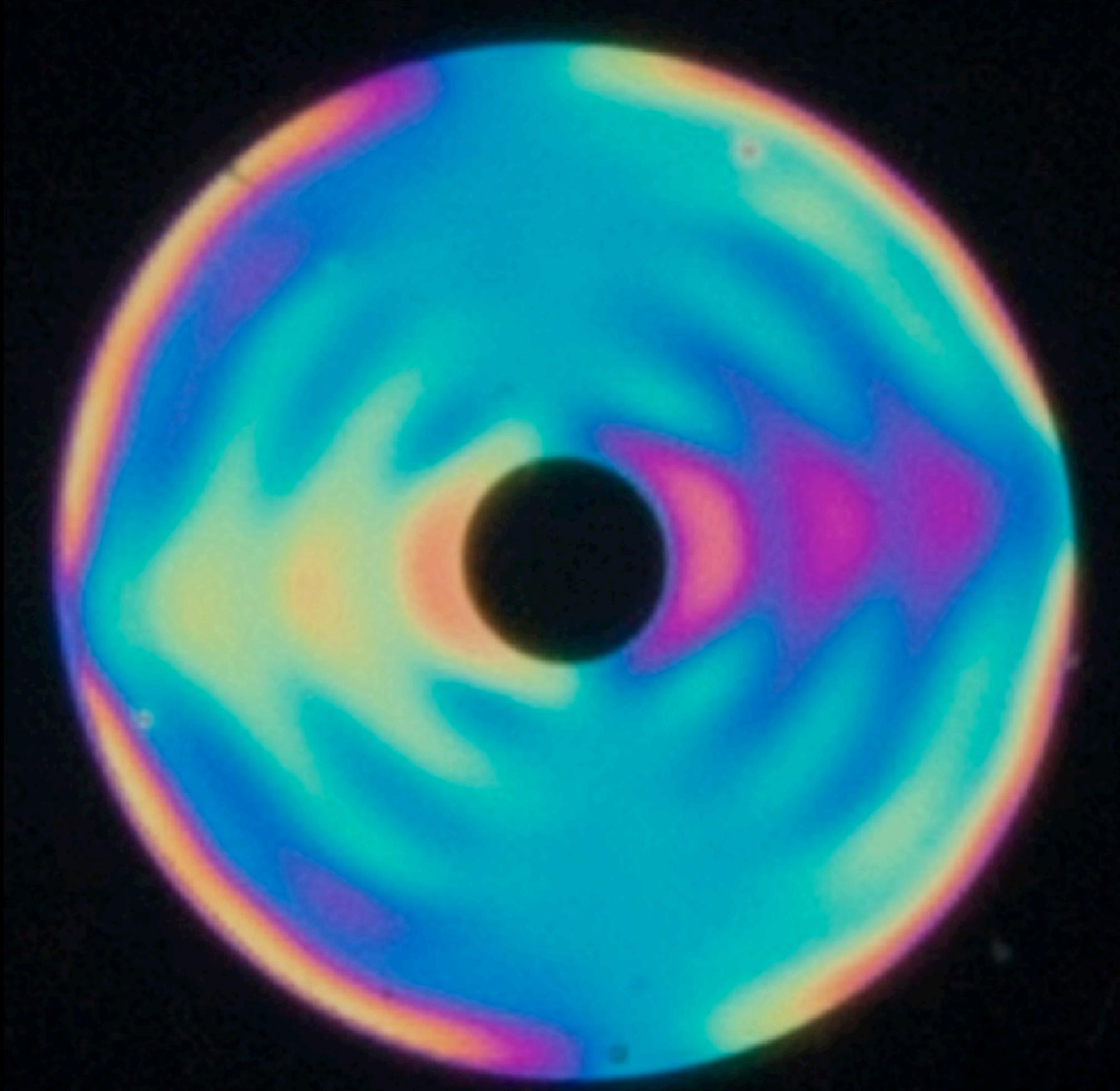
Miskiewicz  
& Escuti (2014)

2. achromatization thanks to self-aligning multi-twist liquid crystal retarder



Komanduri et al.  
(2013)

# the vector-APP



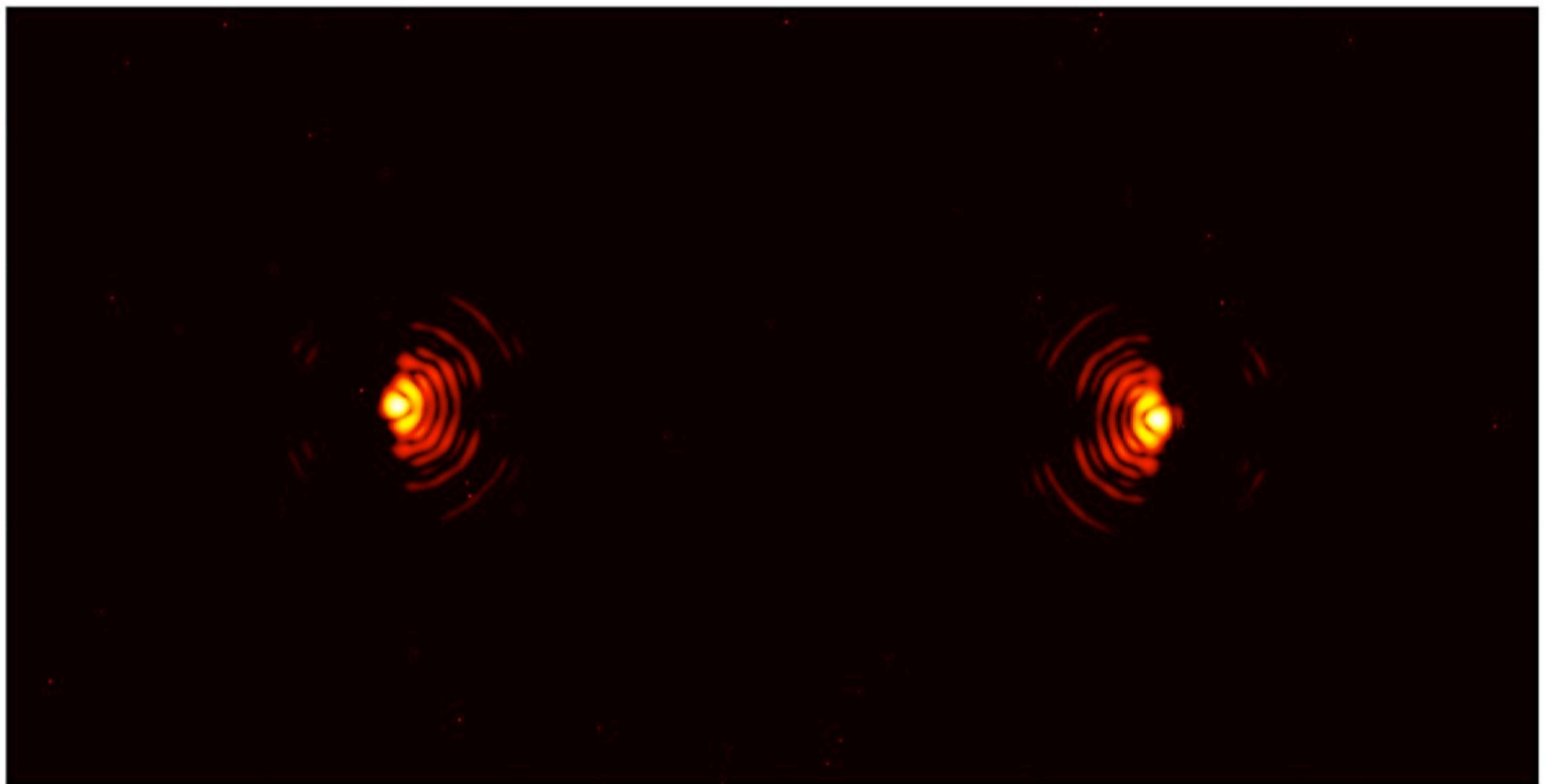
# the vector-APP



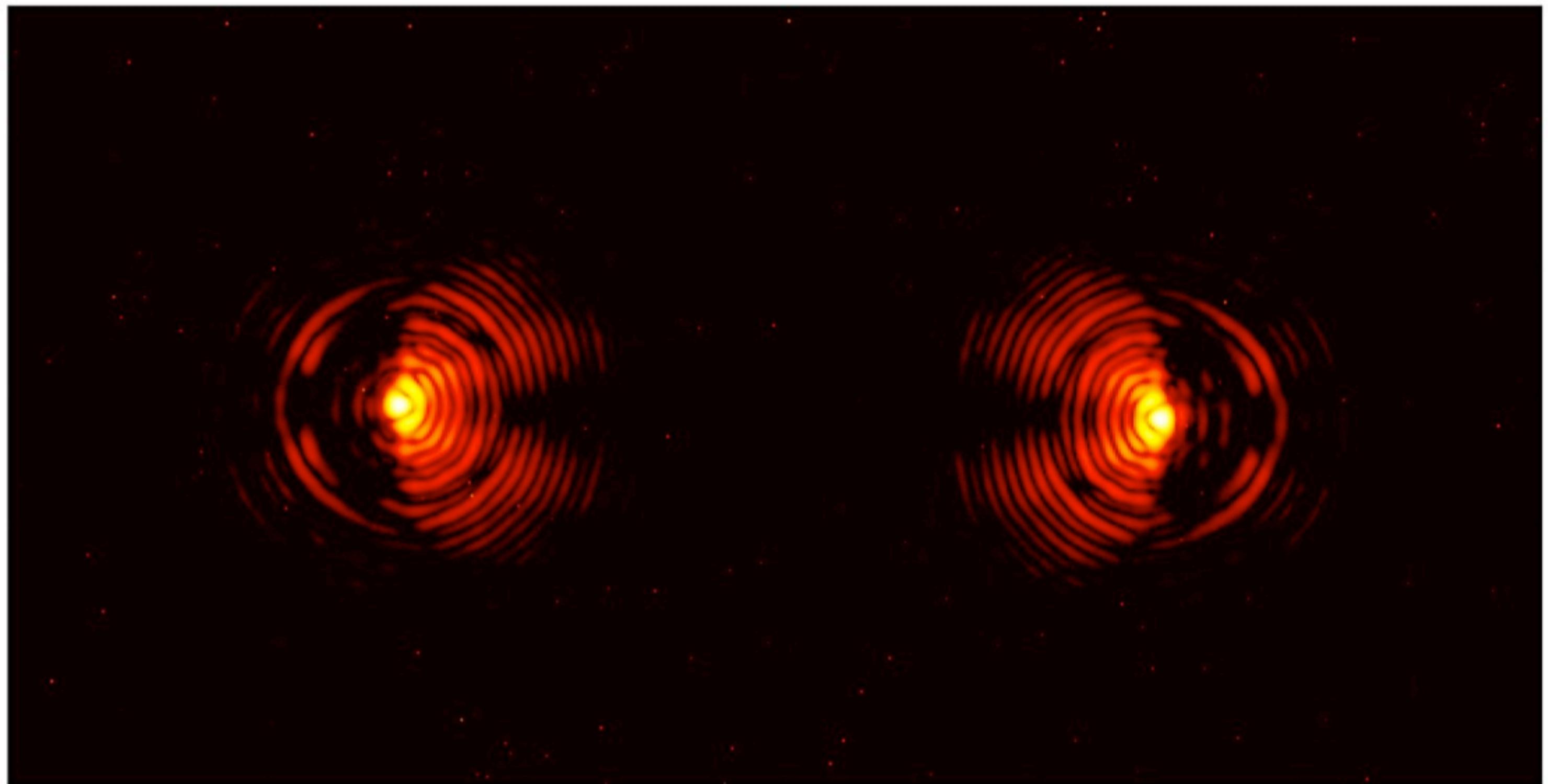
# the vector-APP



# the vector-APP

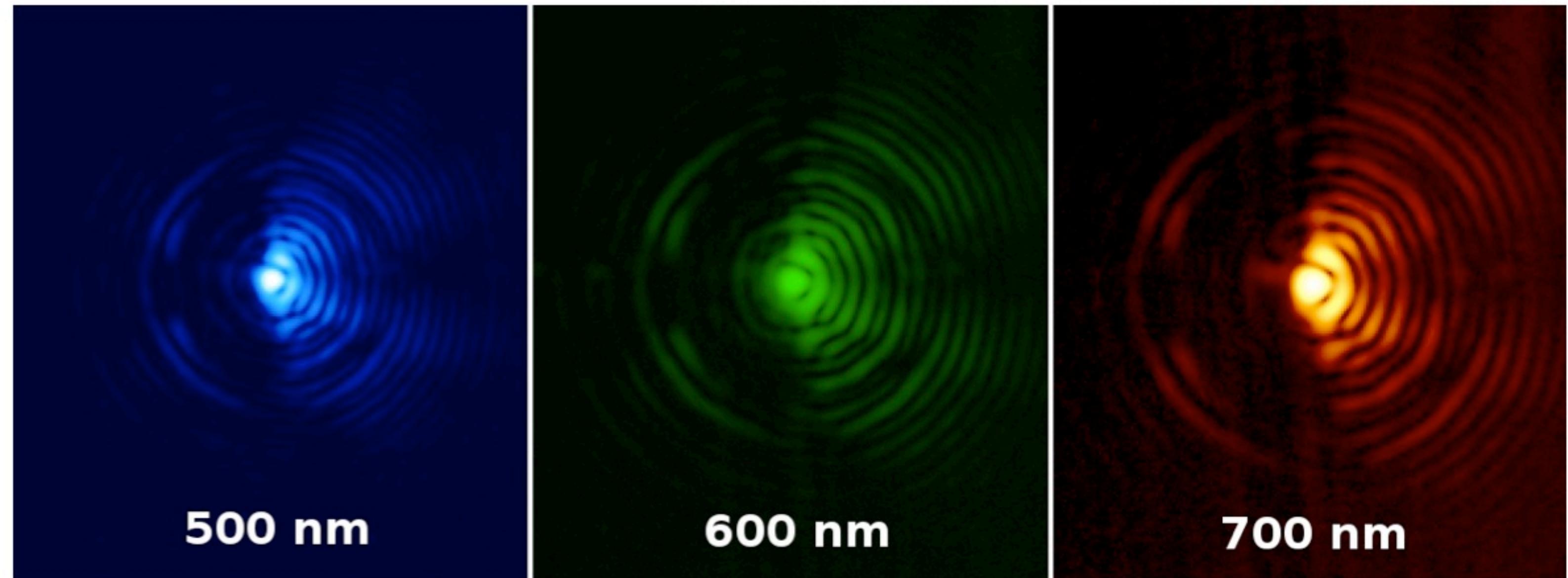


# the vector-APP

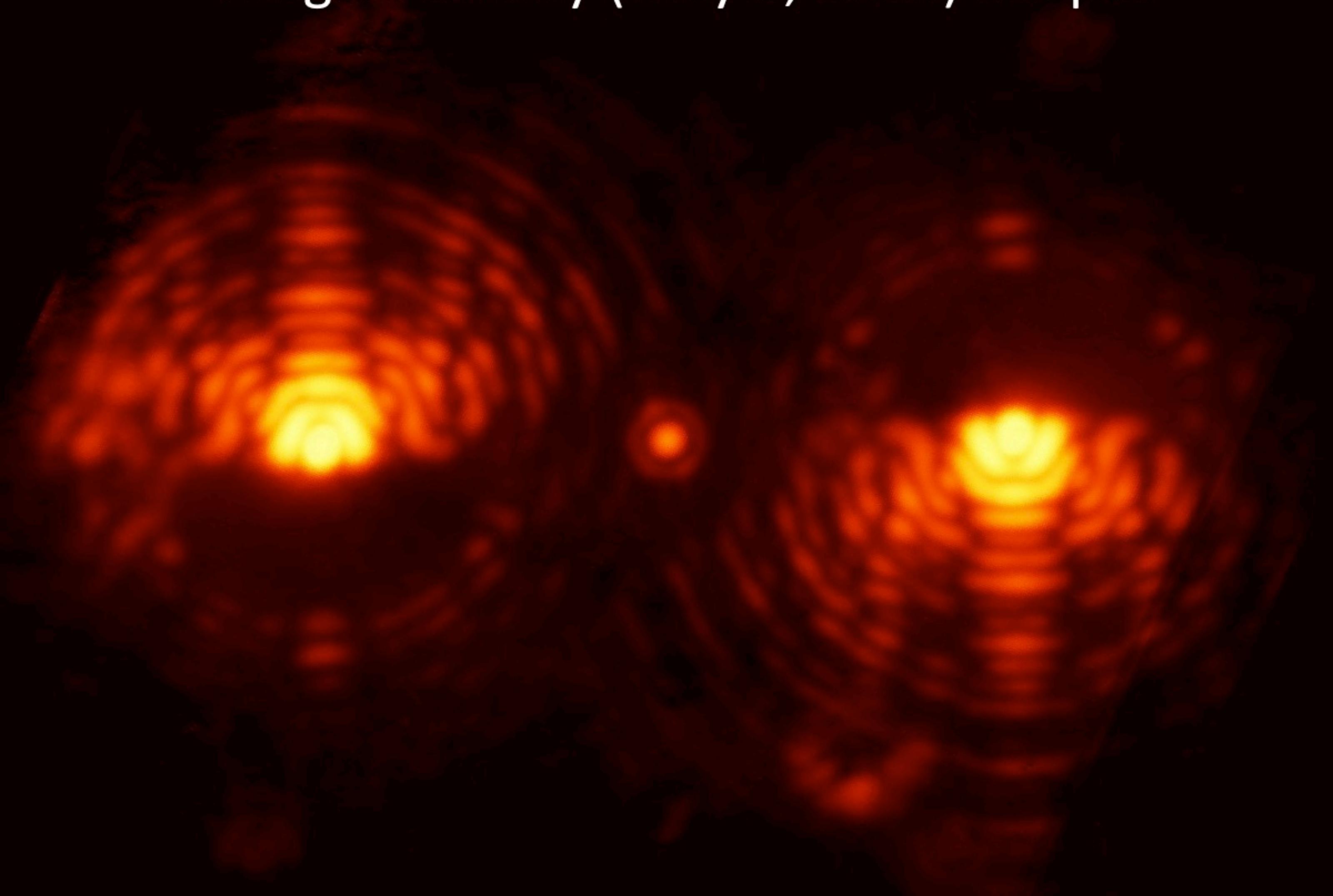


Otten, Snik, et al. (2014)

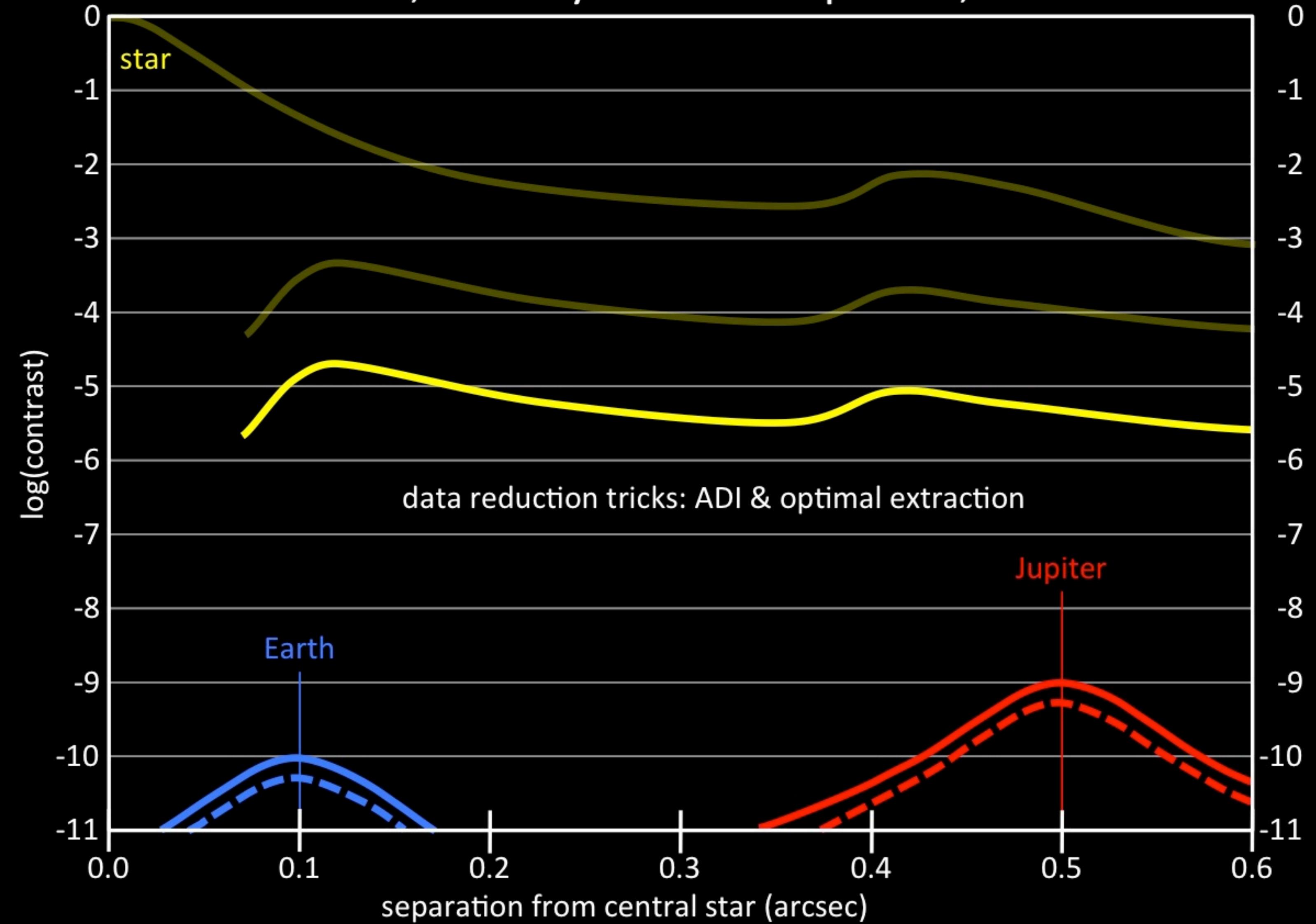
# the vector-APP



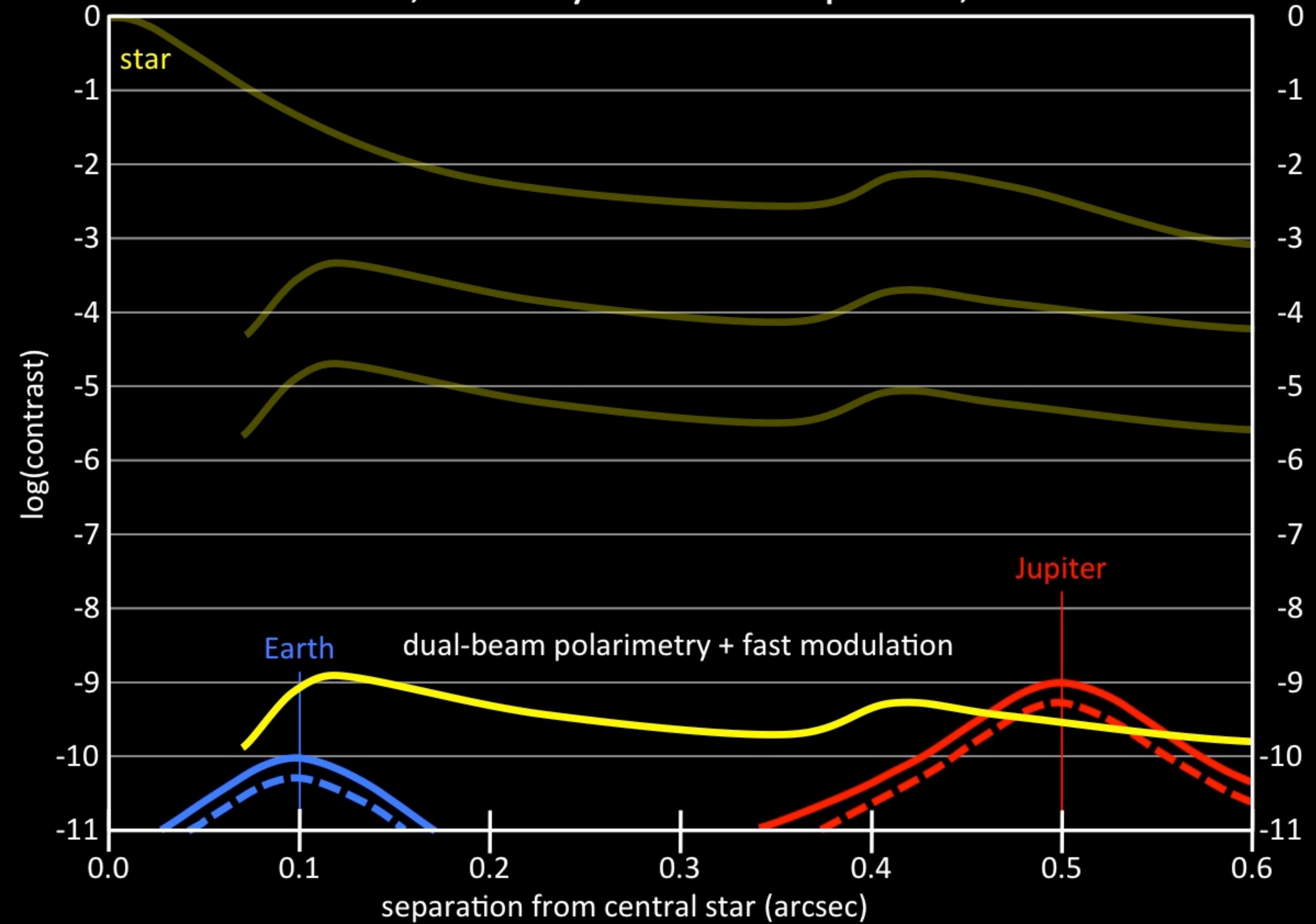
MagAO on-sky (May 6, 2015) 3.9  $\mu$ m

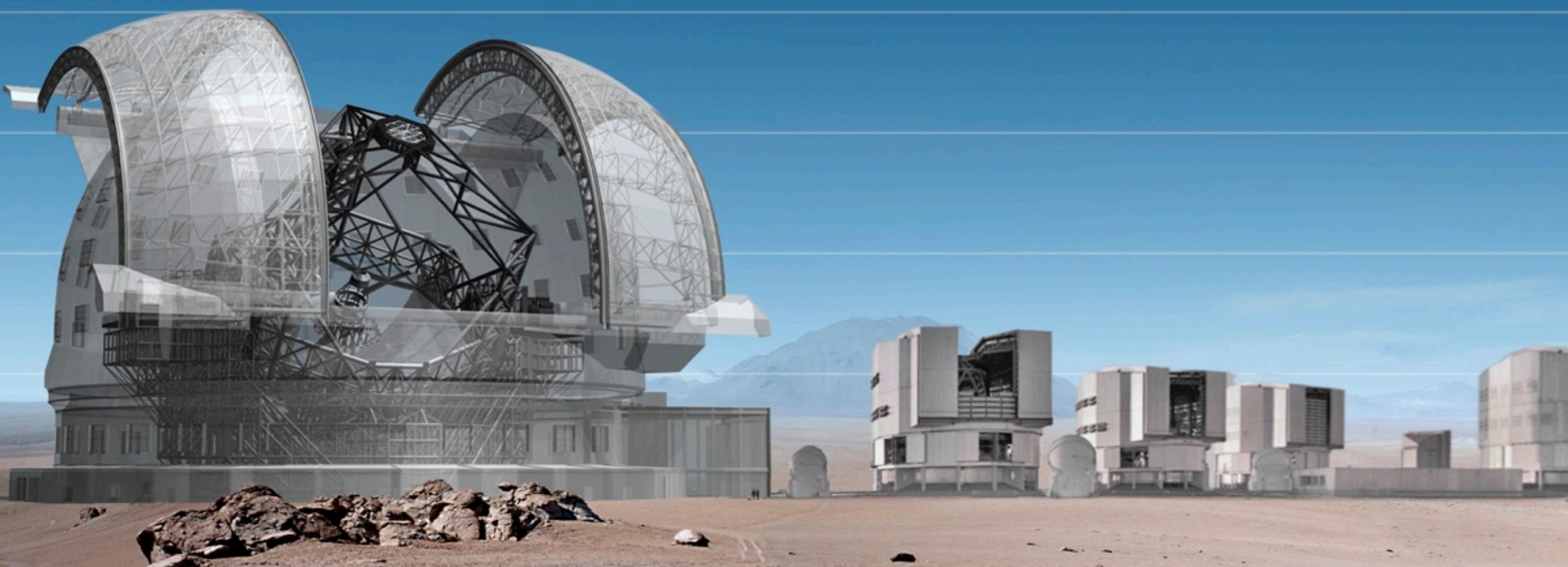


# 8-m VLT, solar system at 10 parsec, $\lambda=600$ nm

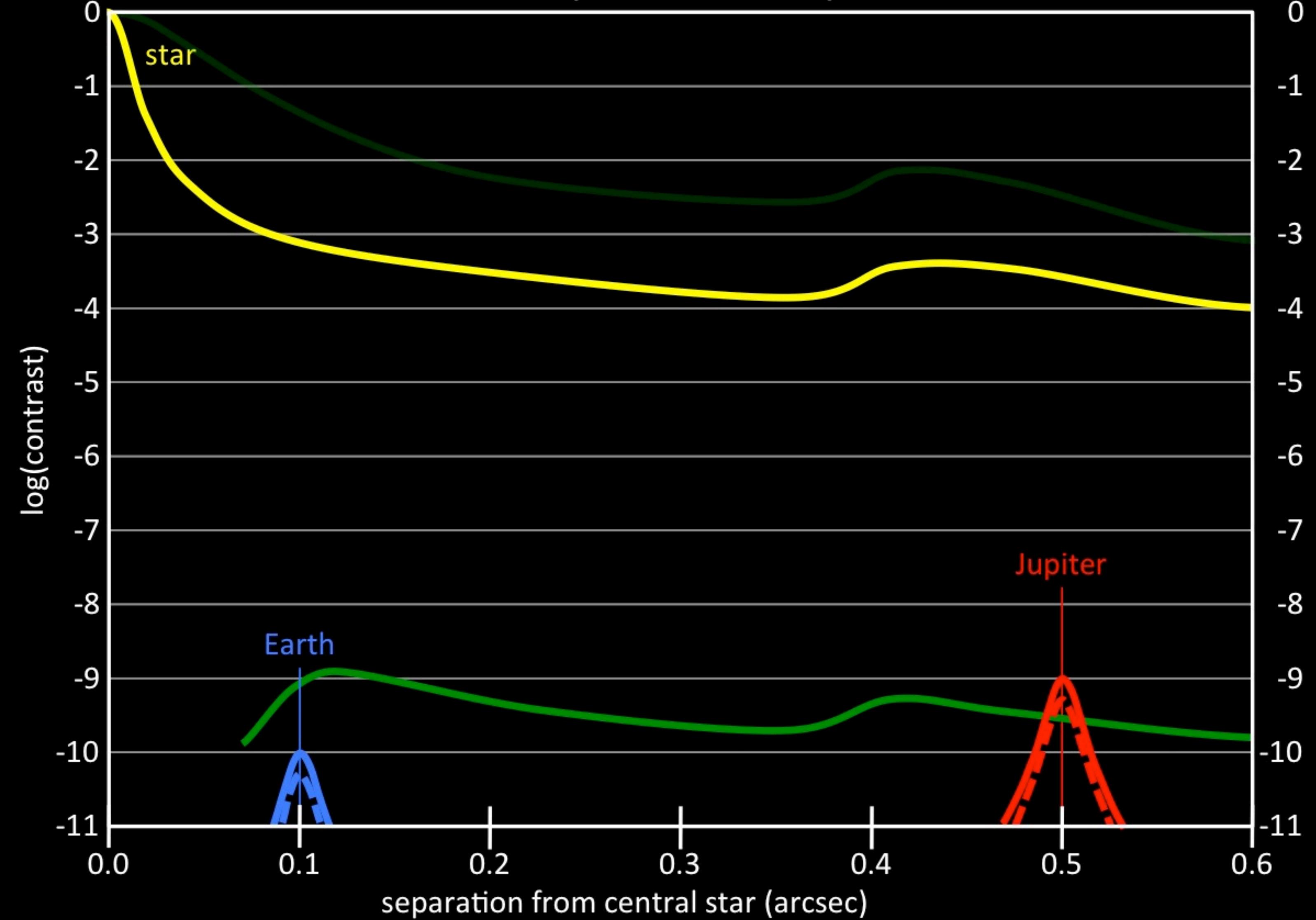


# 8-m VLT, solar system at 10 parsec, $\lambda=600$ nm

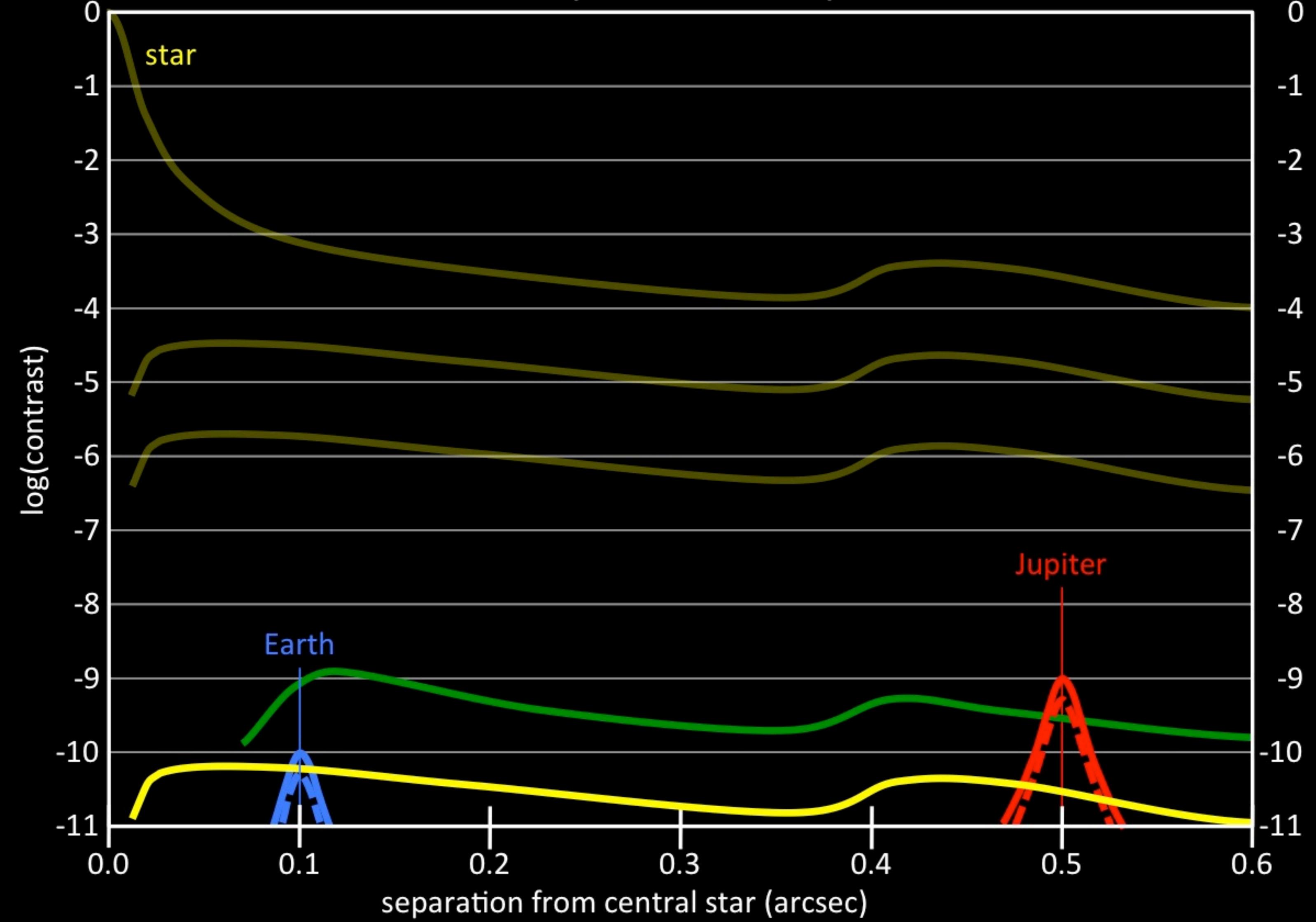


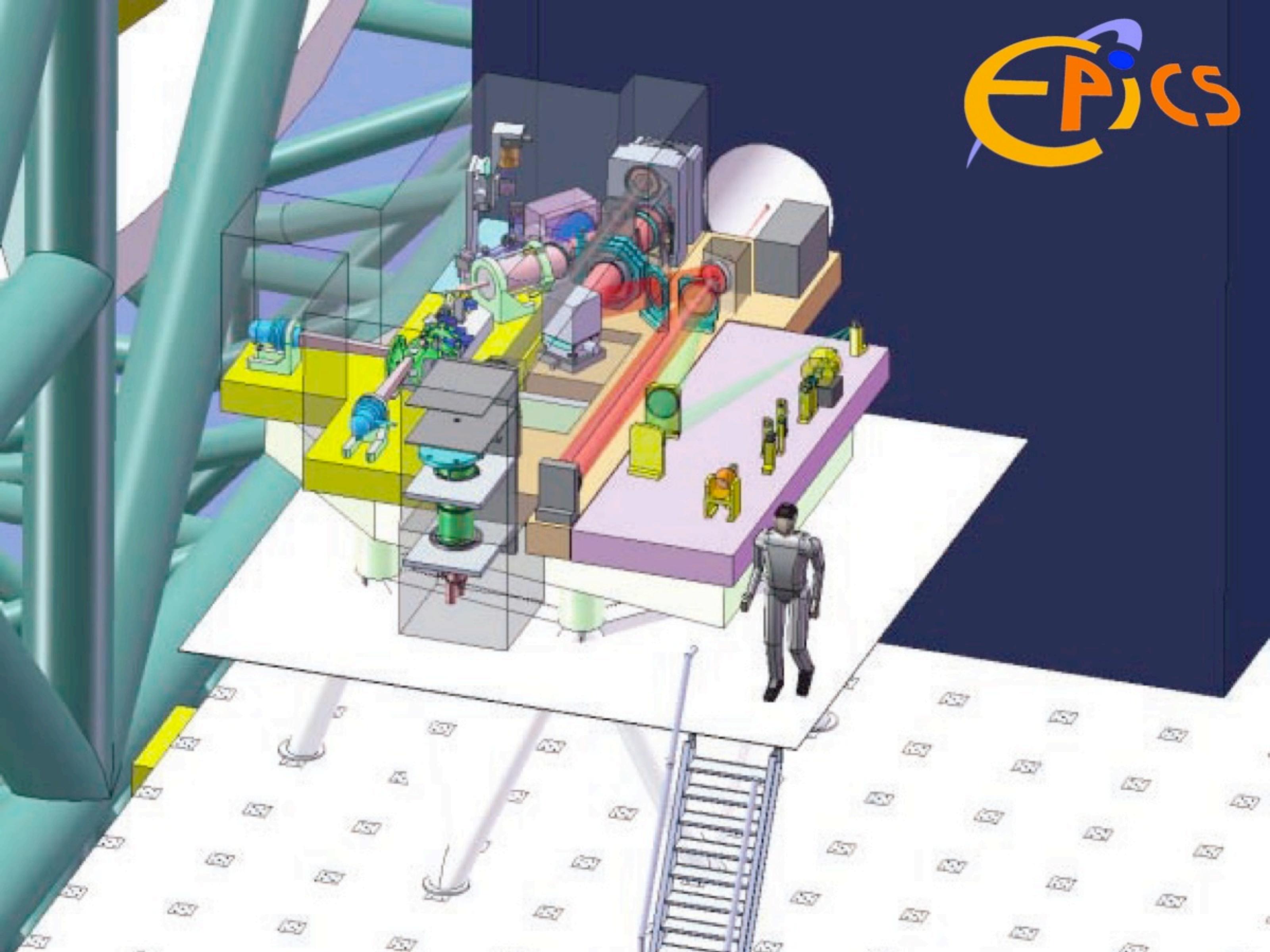


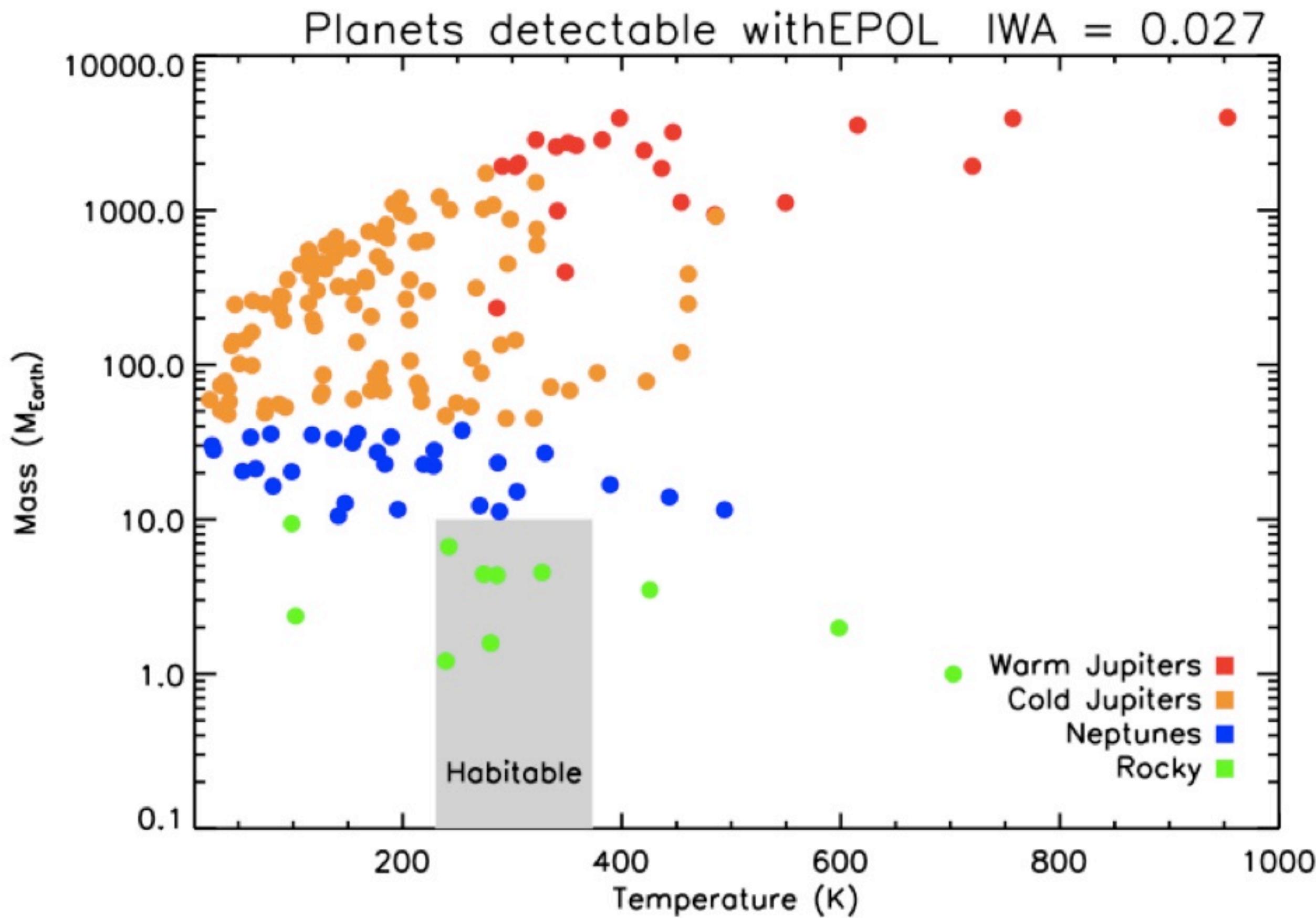
# 40-m ELT, solar system at 10 parsec, $\lambda=600$ nm



# 40-m ELT, solar system at 10 parsec, $\lambda=600$ nm



The EPICS logo is located in the top right corner. It features the word "EPICS" in a bold, orange, sans-serif font. A blue circular arrow is positioned above the letters "P" and "I", with a small blue dot at the top center.



*Simulations by: Mariangela Bonavita*

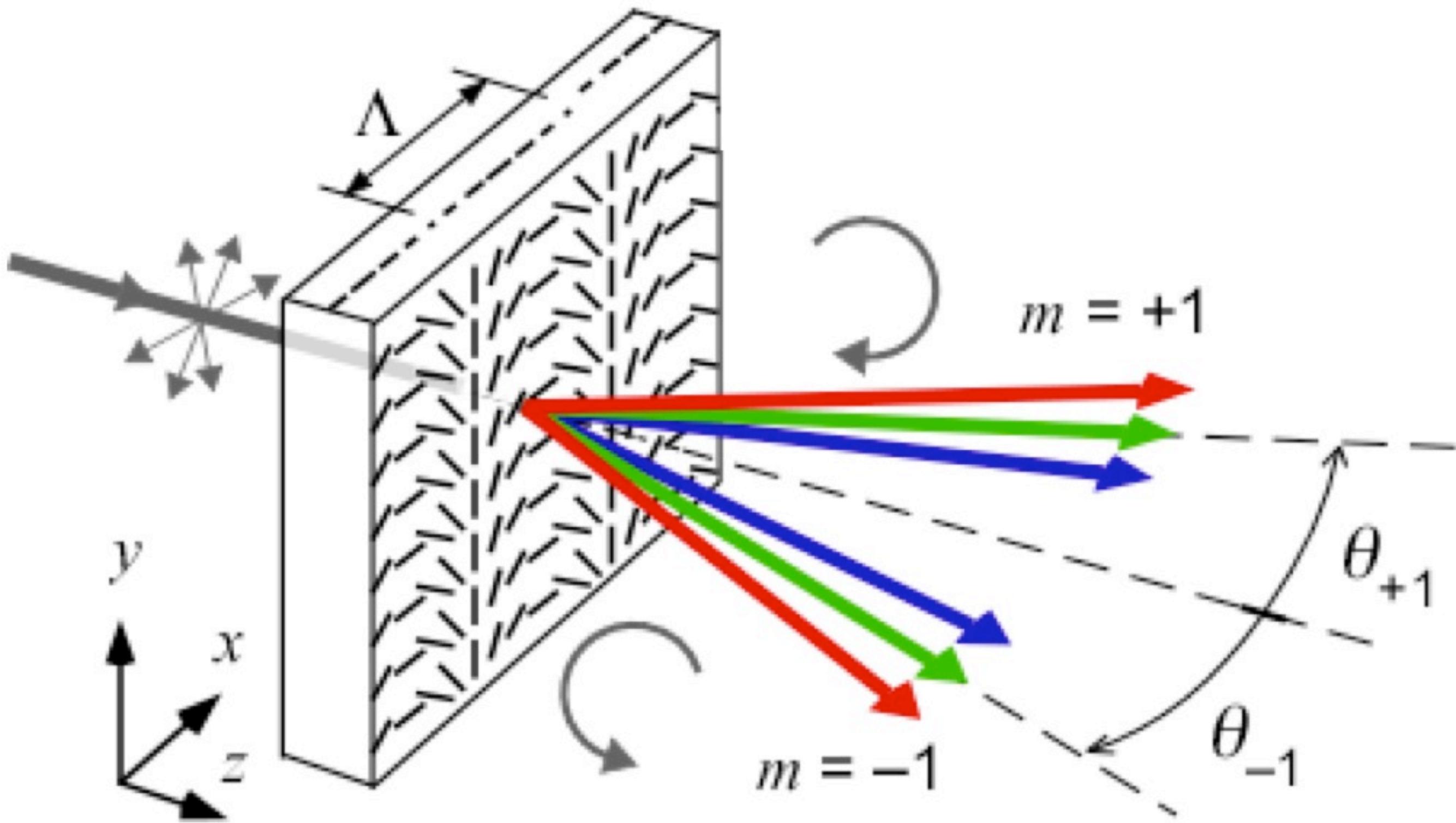
# why we need polarimetry

- Cold (rocky) planets are not very bright in the infrared.
- Other differential techniques fail at small angular separations.
  - Angular Differential Imaging
  - Spectral Differential Imaging
- Immediate confirmation of companionship.
- Spectropolarimetric characterization!



ExPo pIFU

# the polarization grating



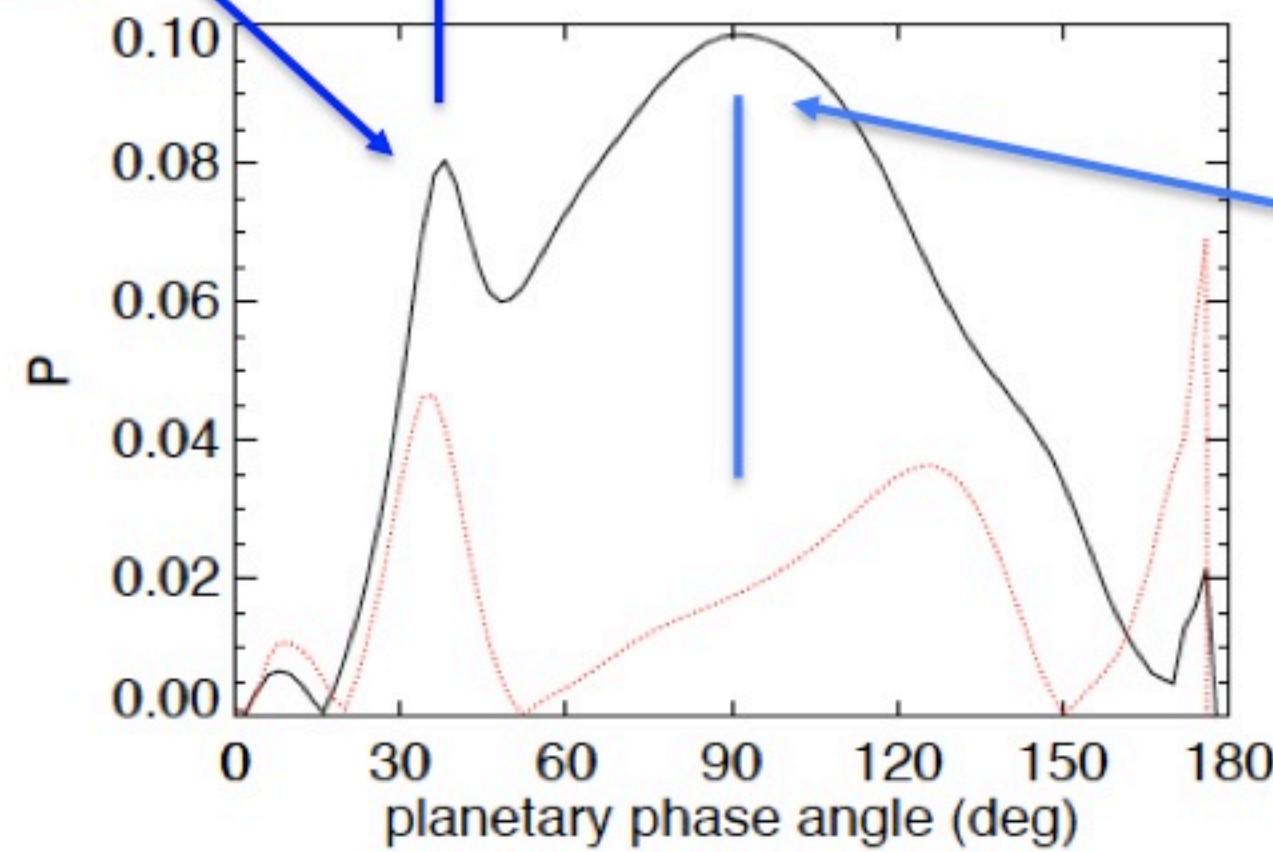
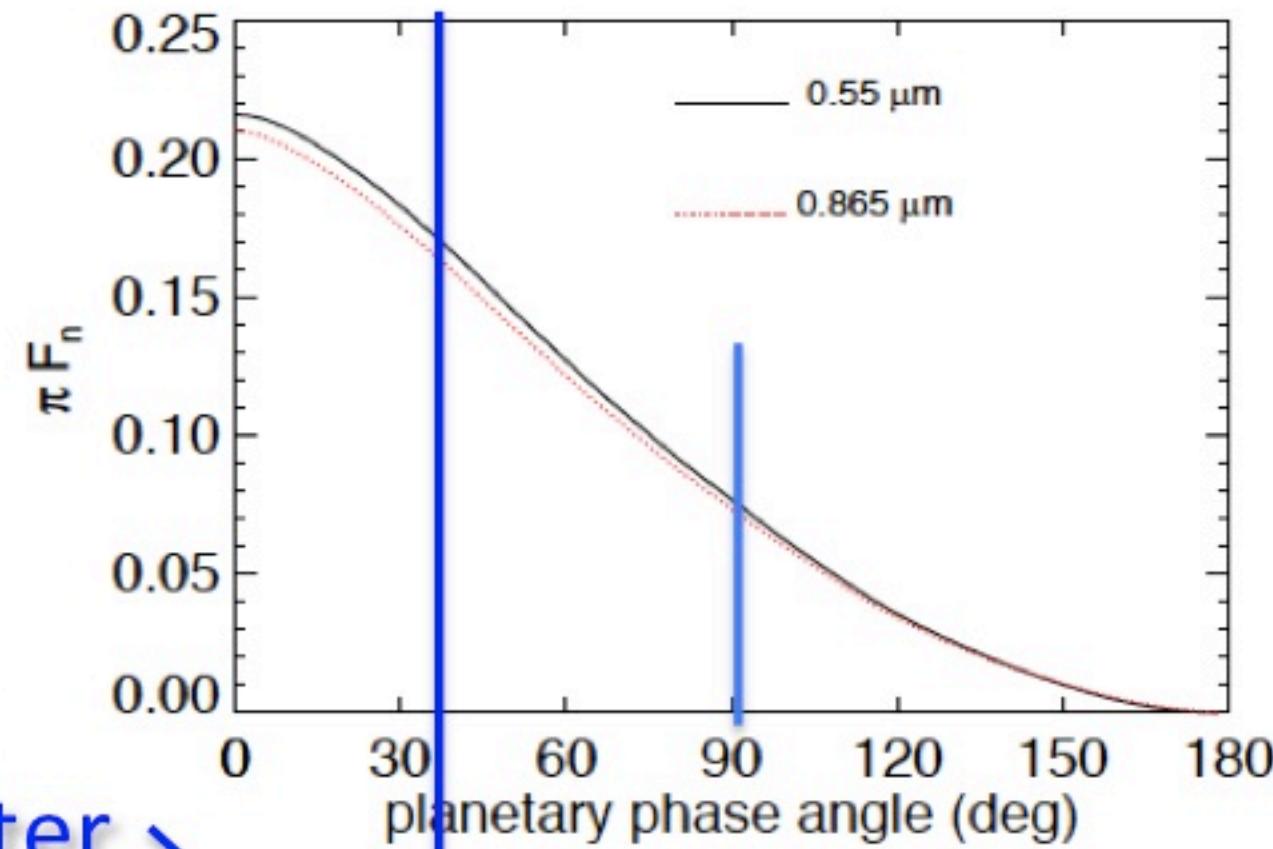
courtesy:  
Michael Escuti (NCSU)



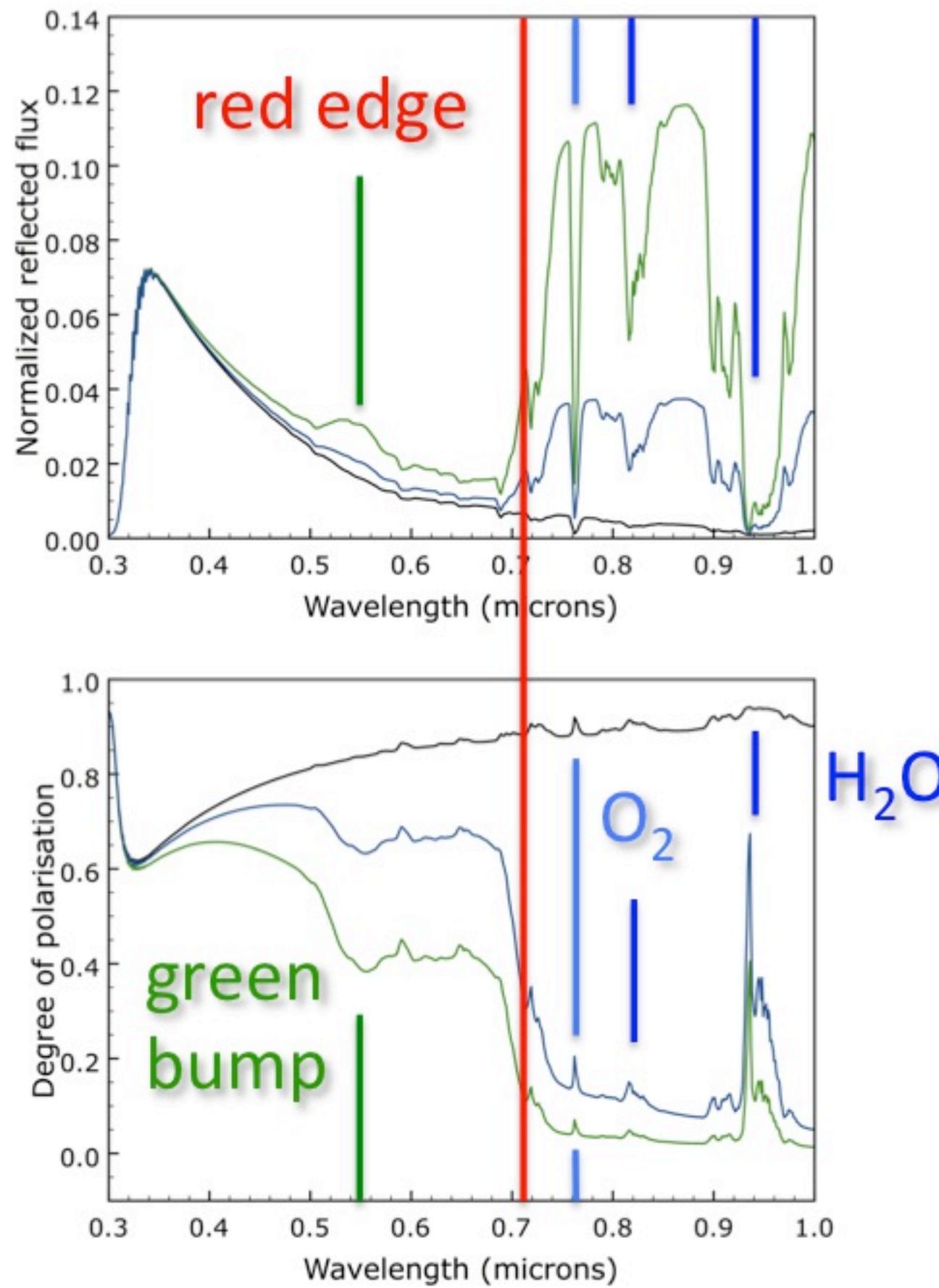
*credit: Studio Roosegaarde, Frans Snik, Michiel Rodenhuis*

# finding extraterrestrial life

rainbow:  
liquid water  
droplets



# finding extraterrestrial life



Looking for  
extraterrestrial life?

Put on polarized  
glasses!

