ASTRONOMICAL POLARIMETRY WITH EXTREMELY LARGE TELESCOPES

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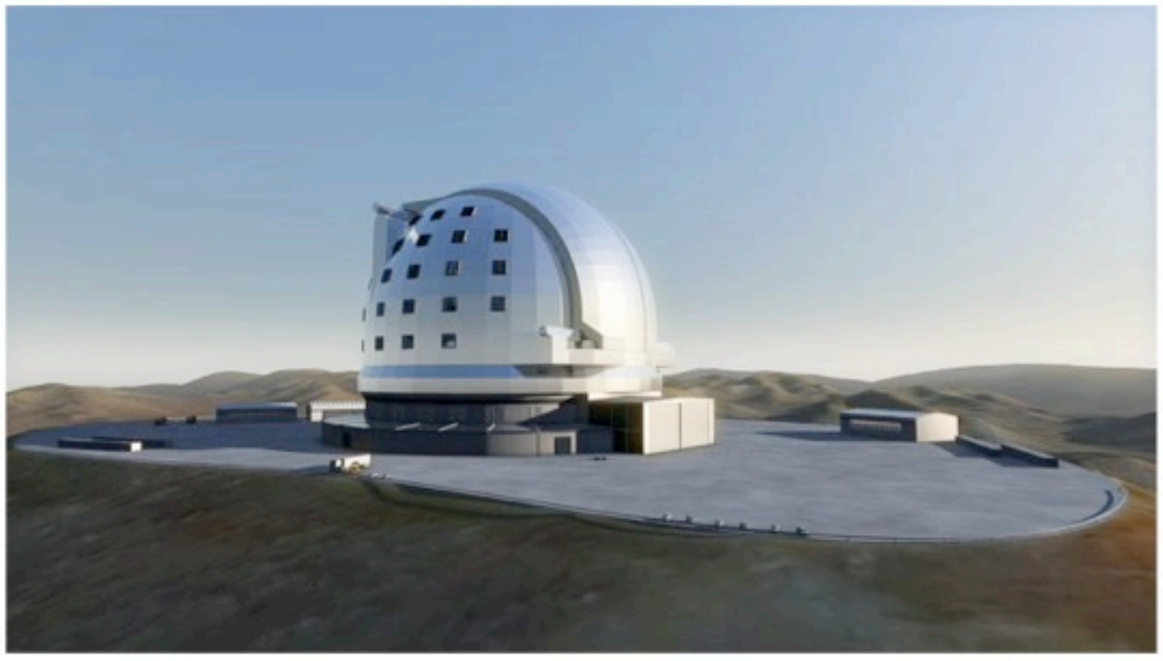
Michiel Rodenhuis, Christoph Keller,

Gilles Otten, Matthew Kenworthy

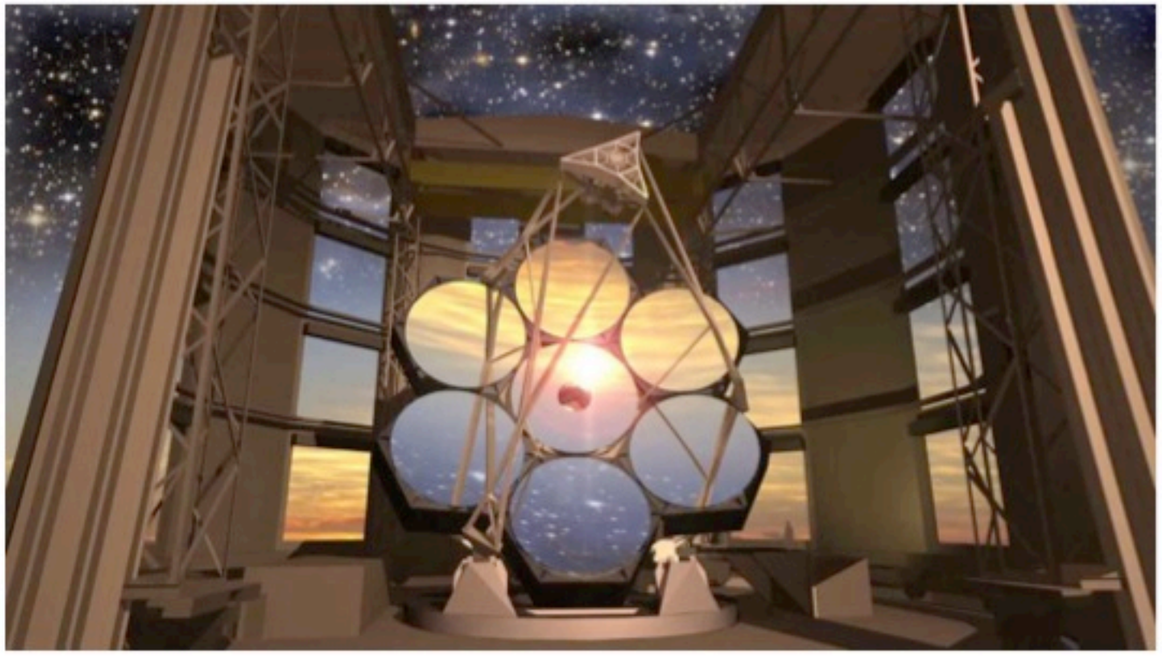
Sterrewacht Leiden

the ELTs



E-ELT (39 m)

TMT



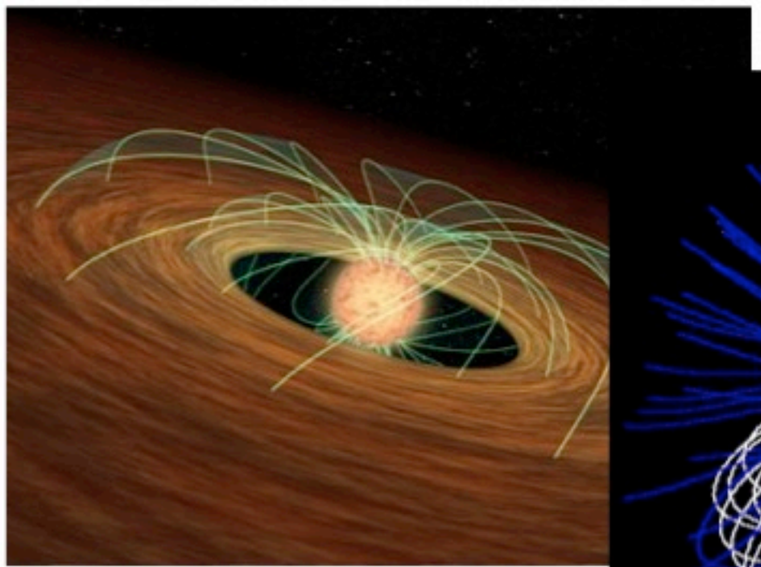
GMT (~24.5 m)

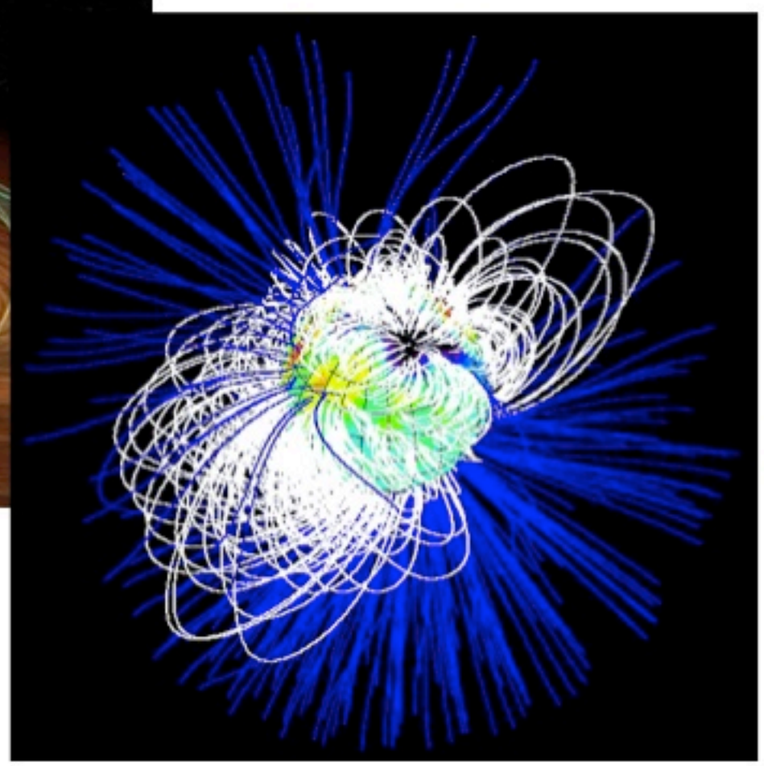
killer polarimetric science with ELTs

direct exoplanet imaging
+ characterization

high-contrast imaging

E-ELT/EPICS, TMT/PFI





mapping protostellar
magnetic fields

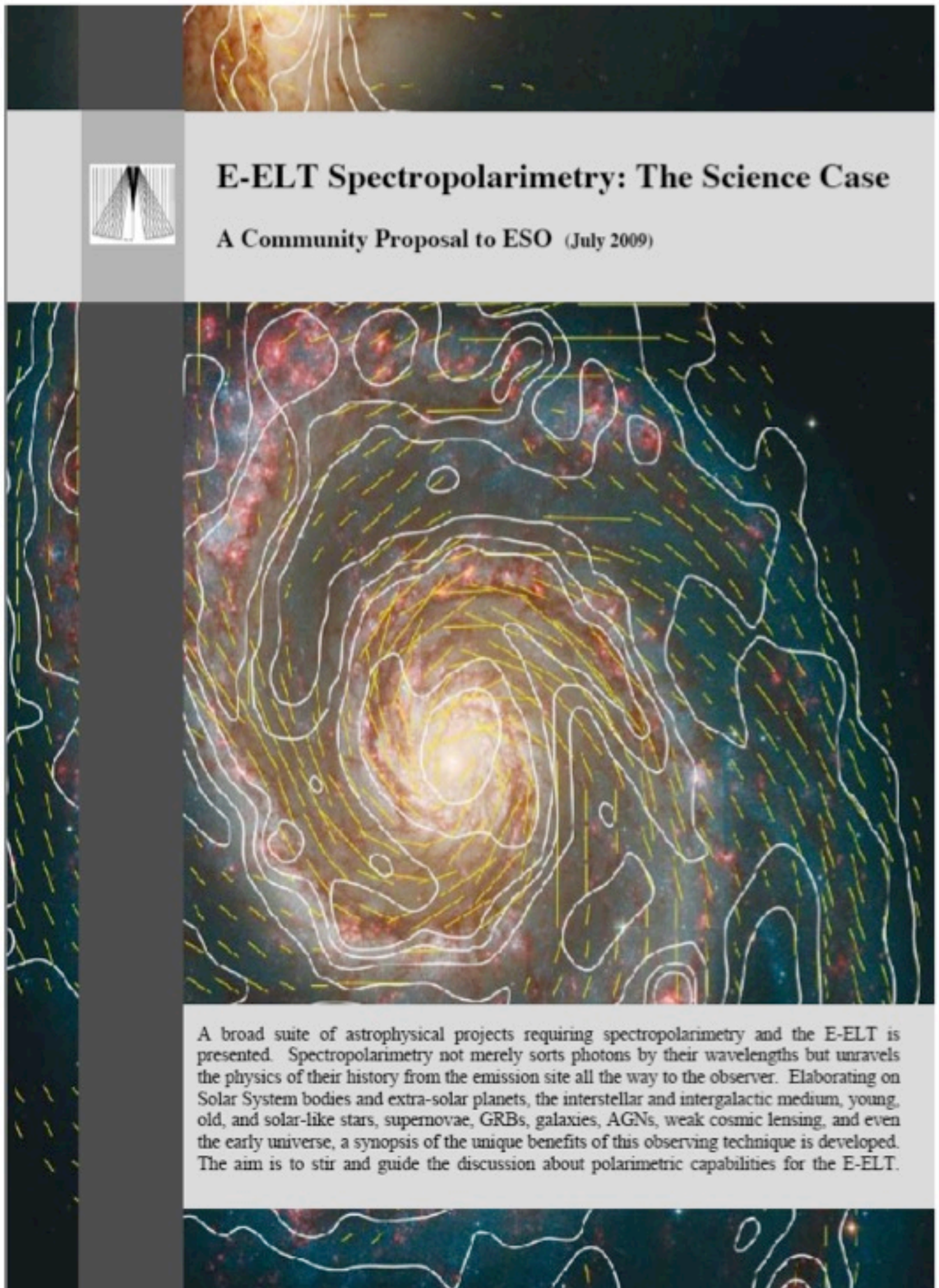
mid-IR imaging

E-ELT/METIS, TMT/MICHI

hi-res spectropolarimetry

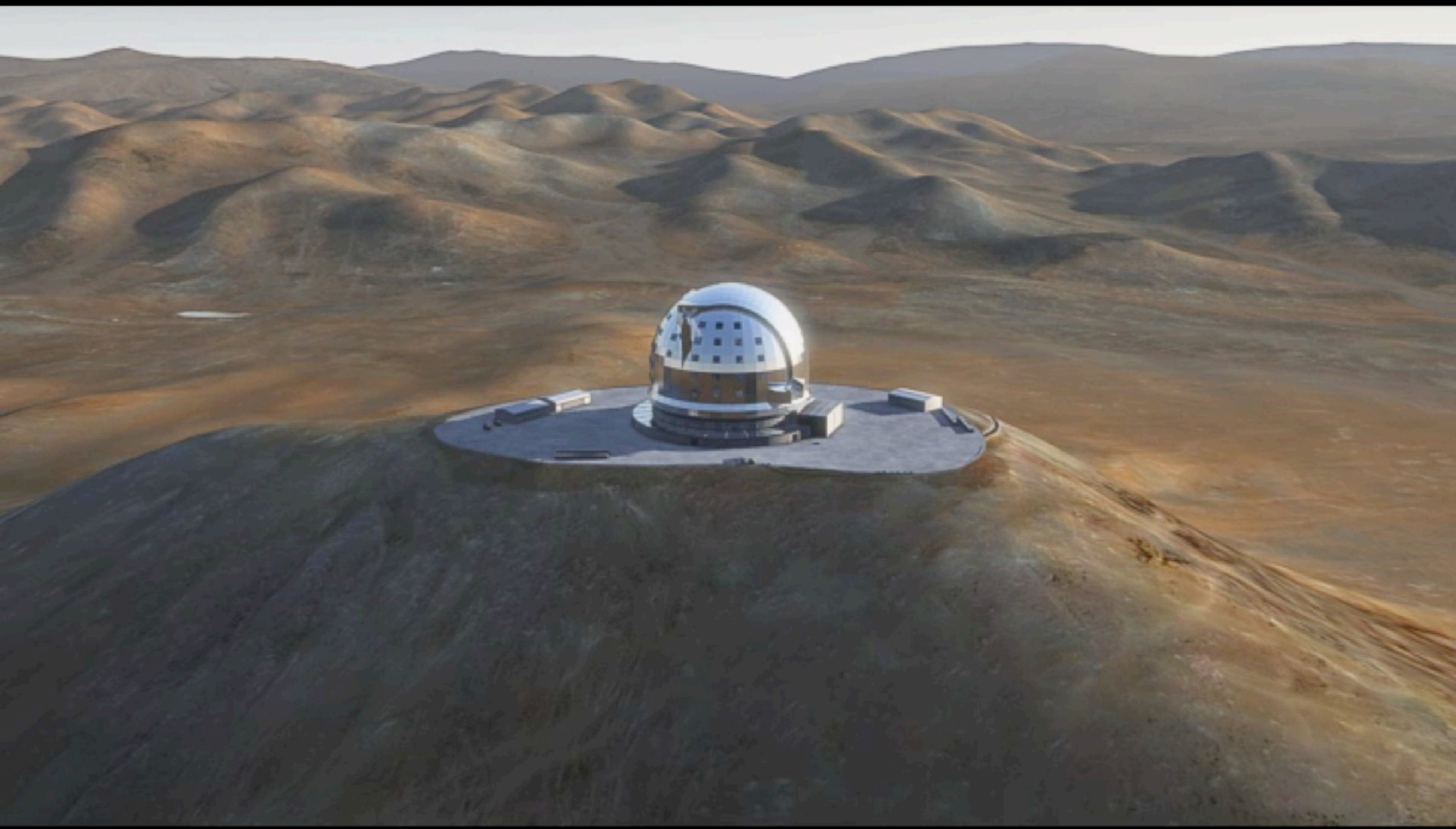
E-ELT/HIRES

killer polarimetric science with ELTs

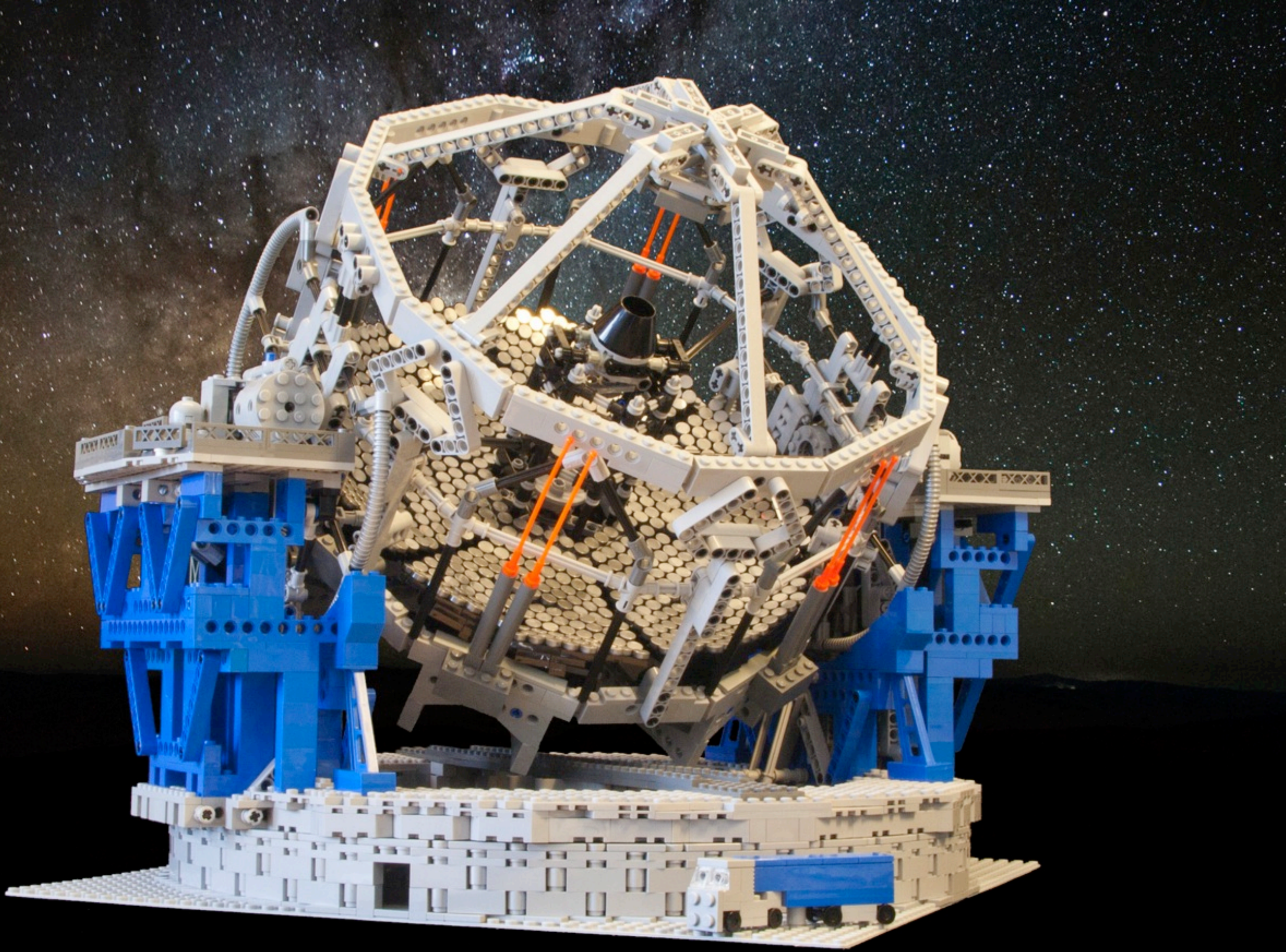


Strassmeier et al. (2009)

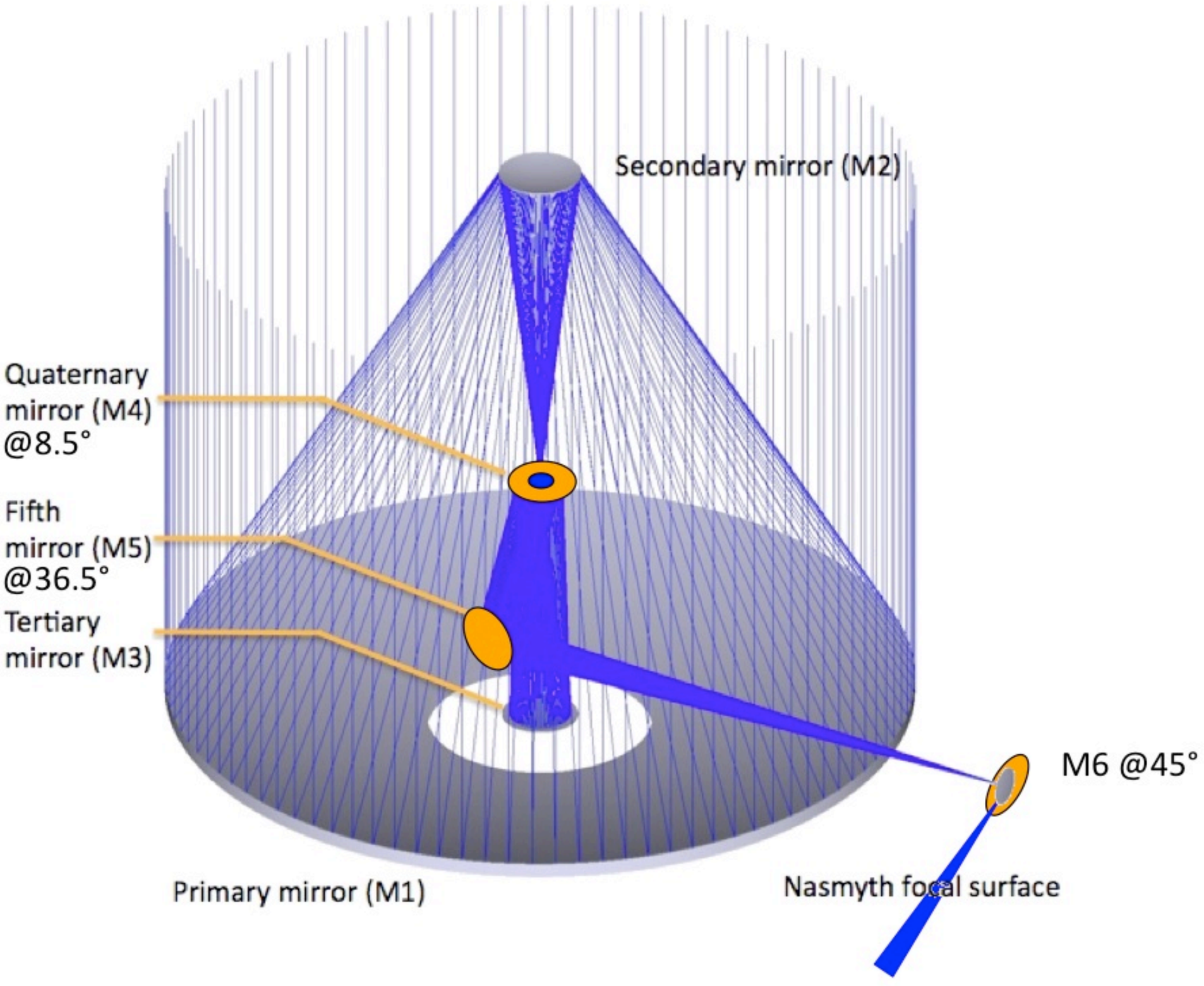
the E-ELT



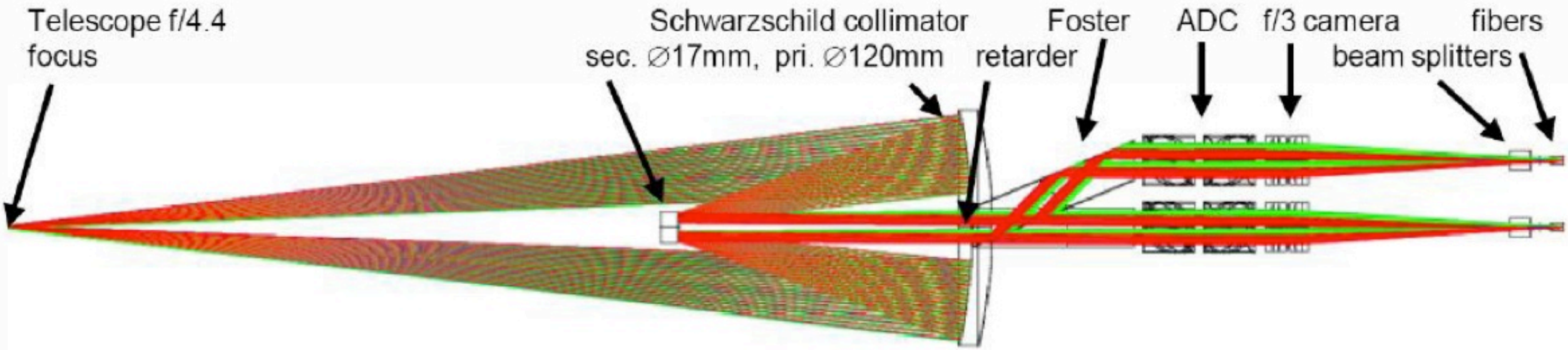
E-ELT mountain top blasting: June 19, 2014

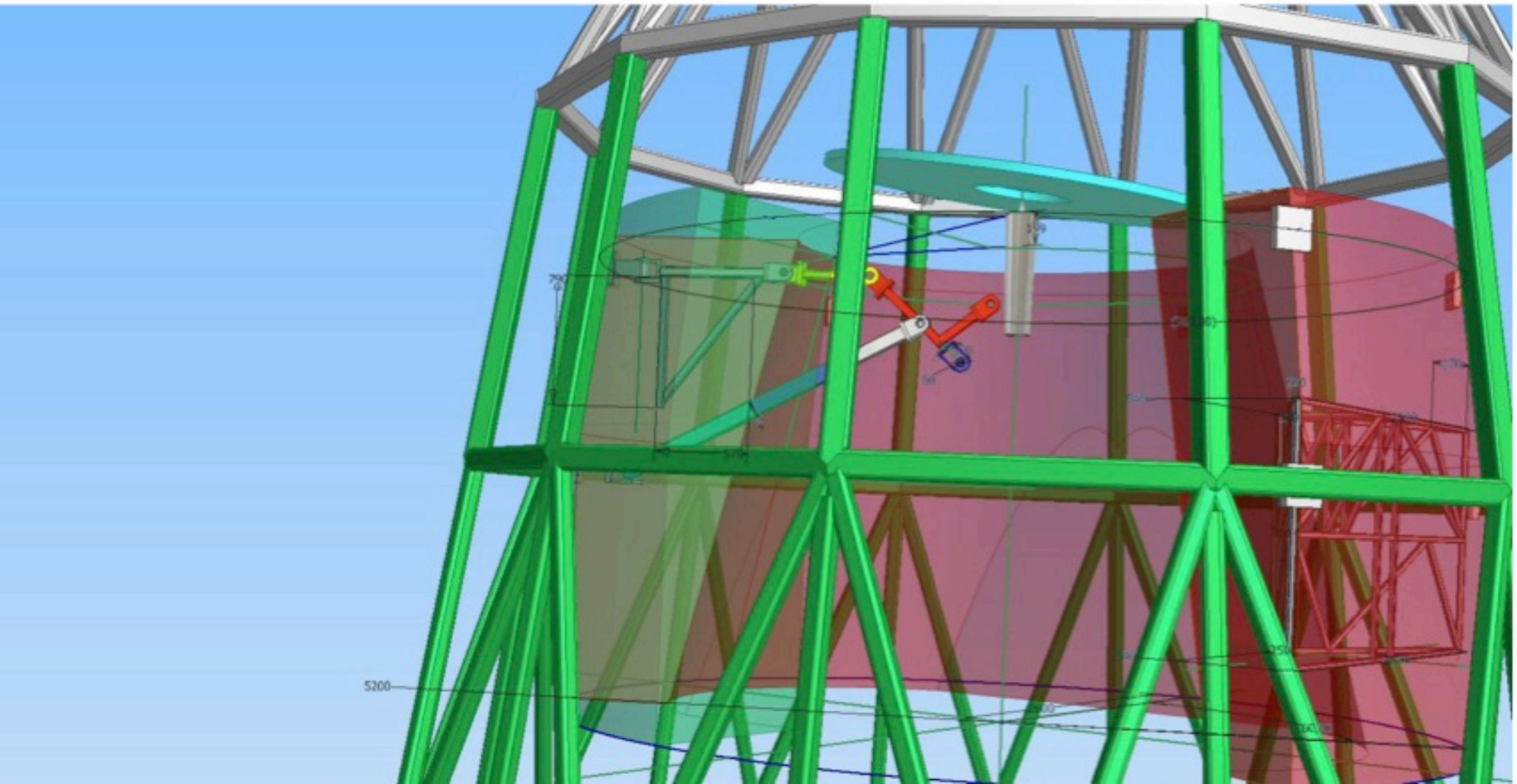


E-ELT intermediate focus



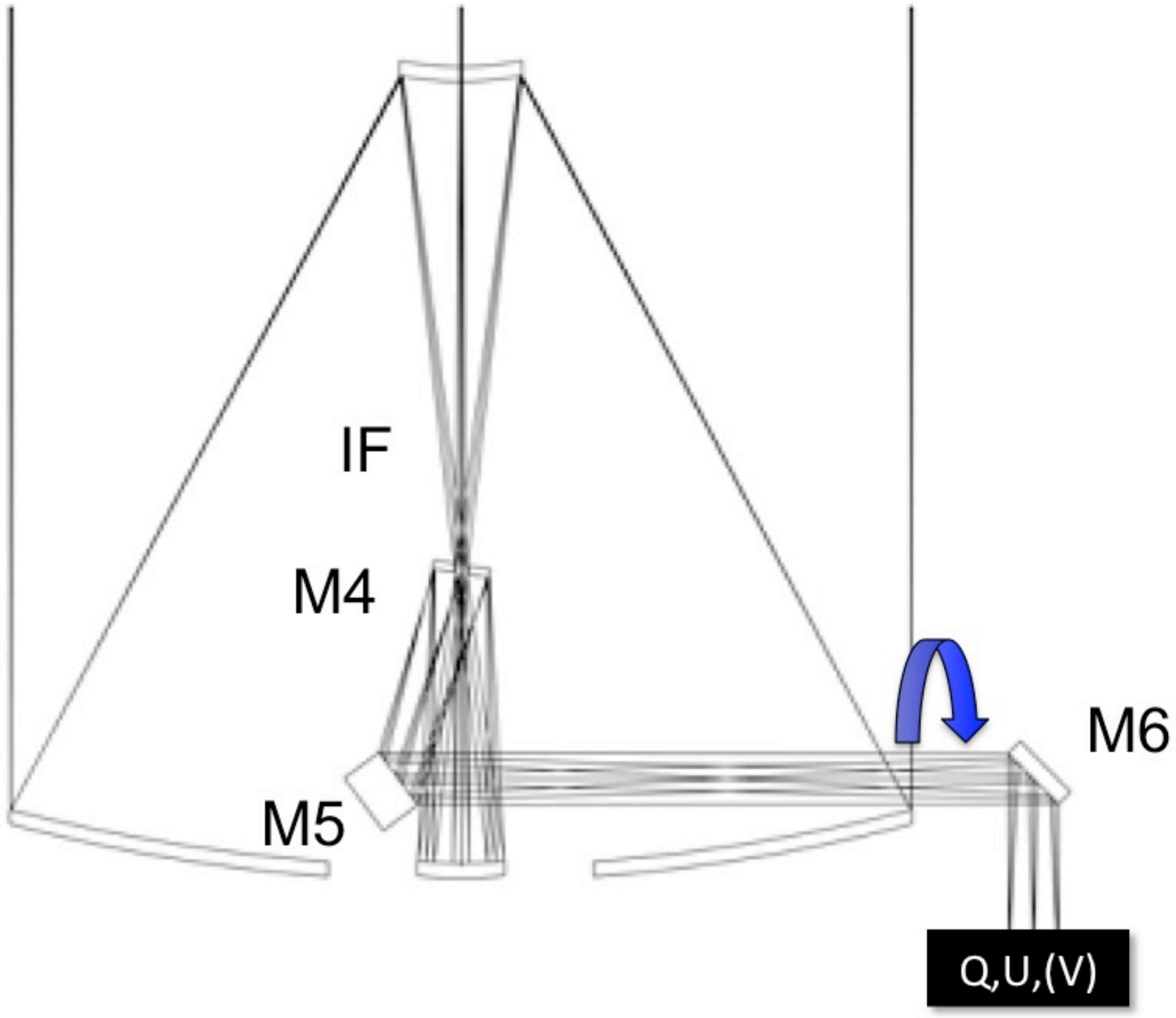
E-ELT intermediate focus





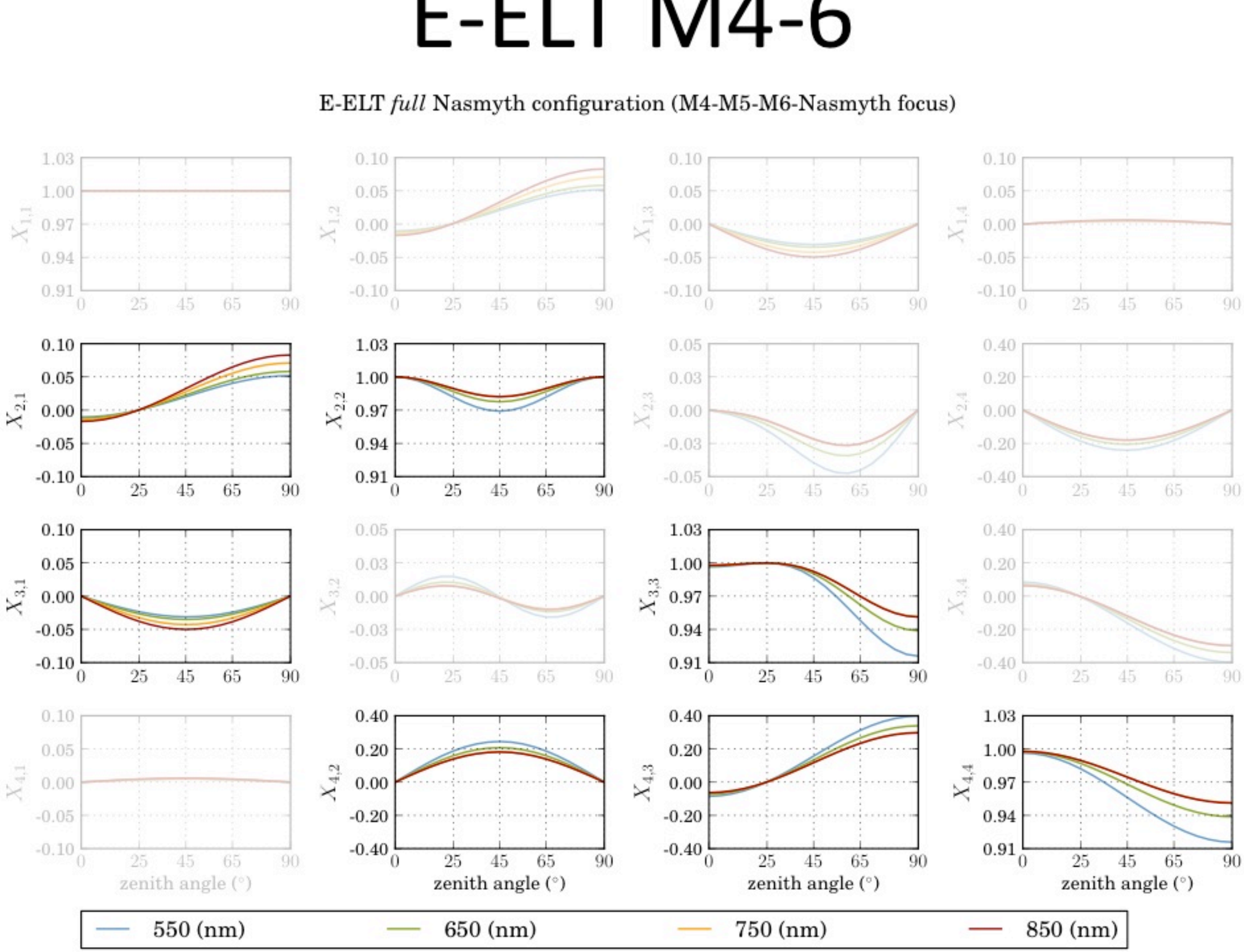
Strassmeier et al. (2012)

E-ELT M4-6



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

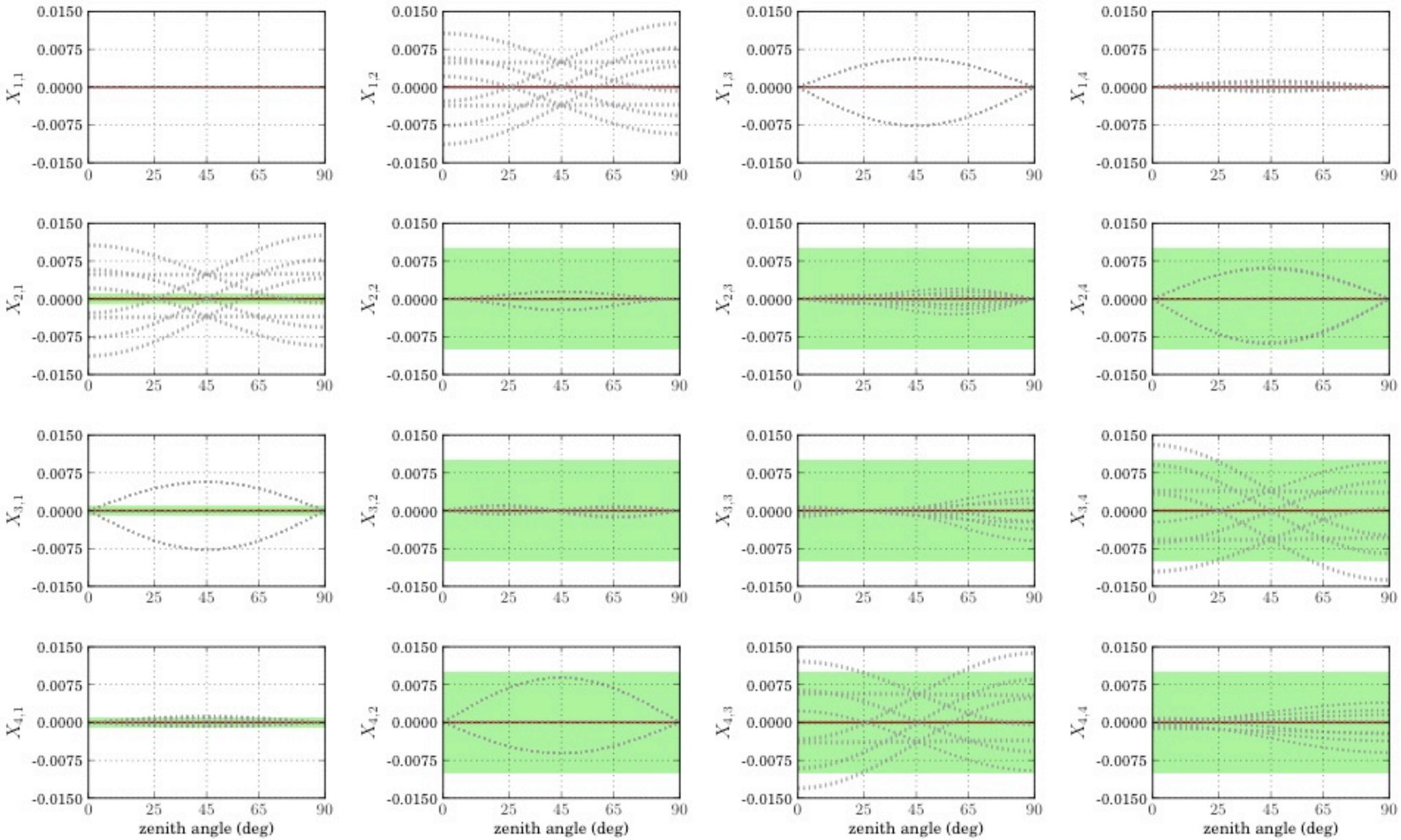
E-ELT M4-6



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

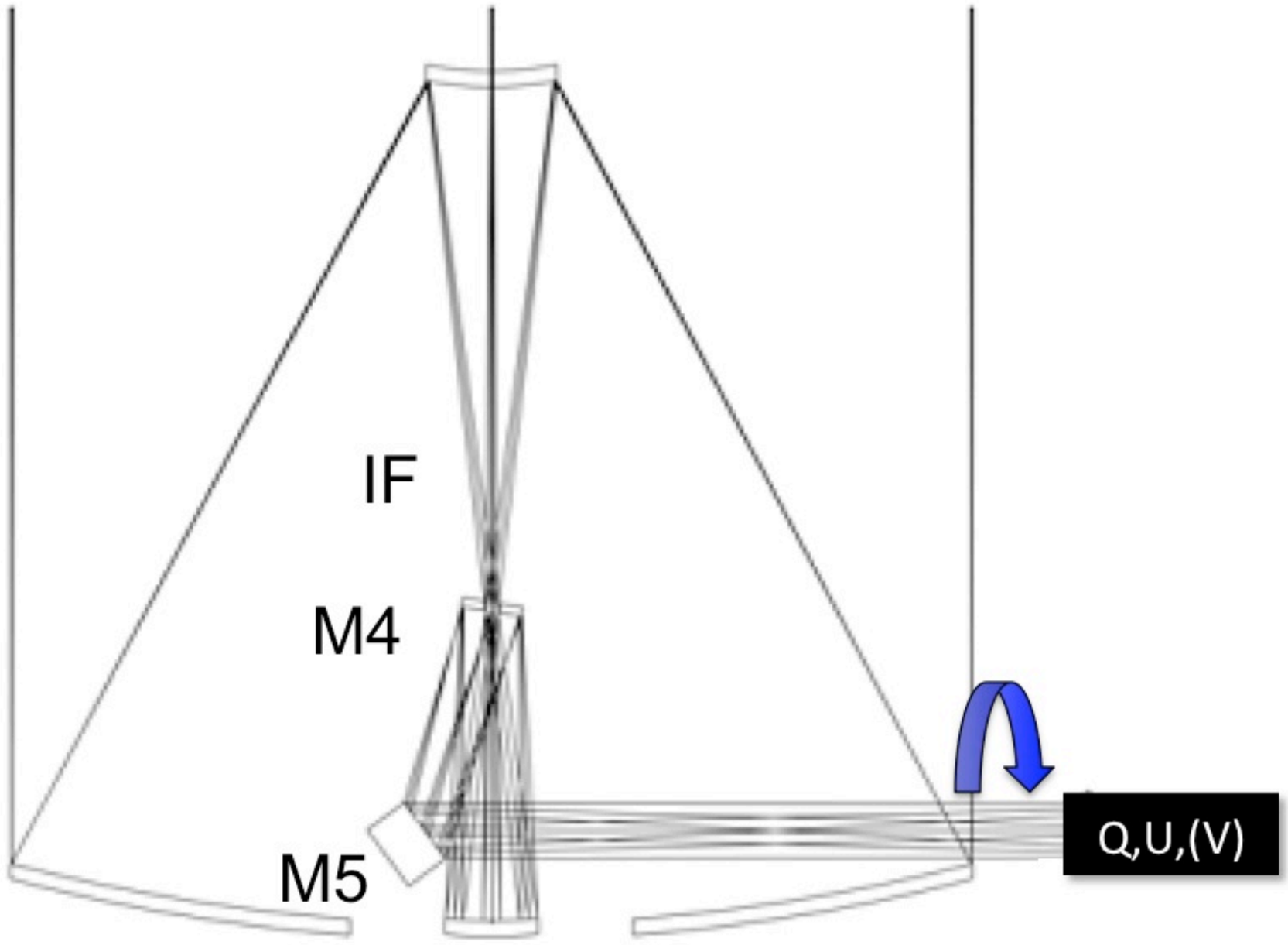
E-ELT M4-6

is it calibrateable?



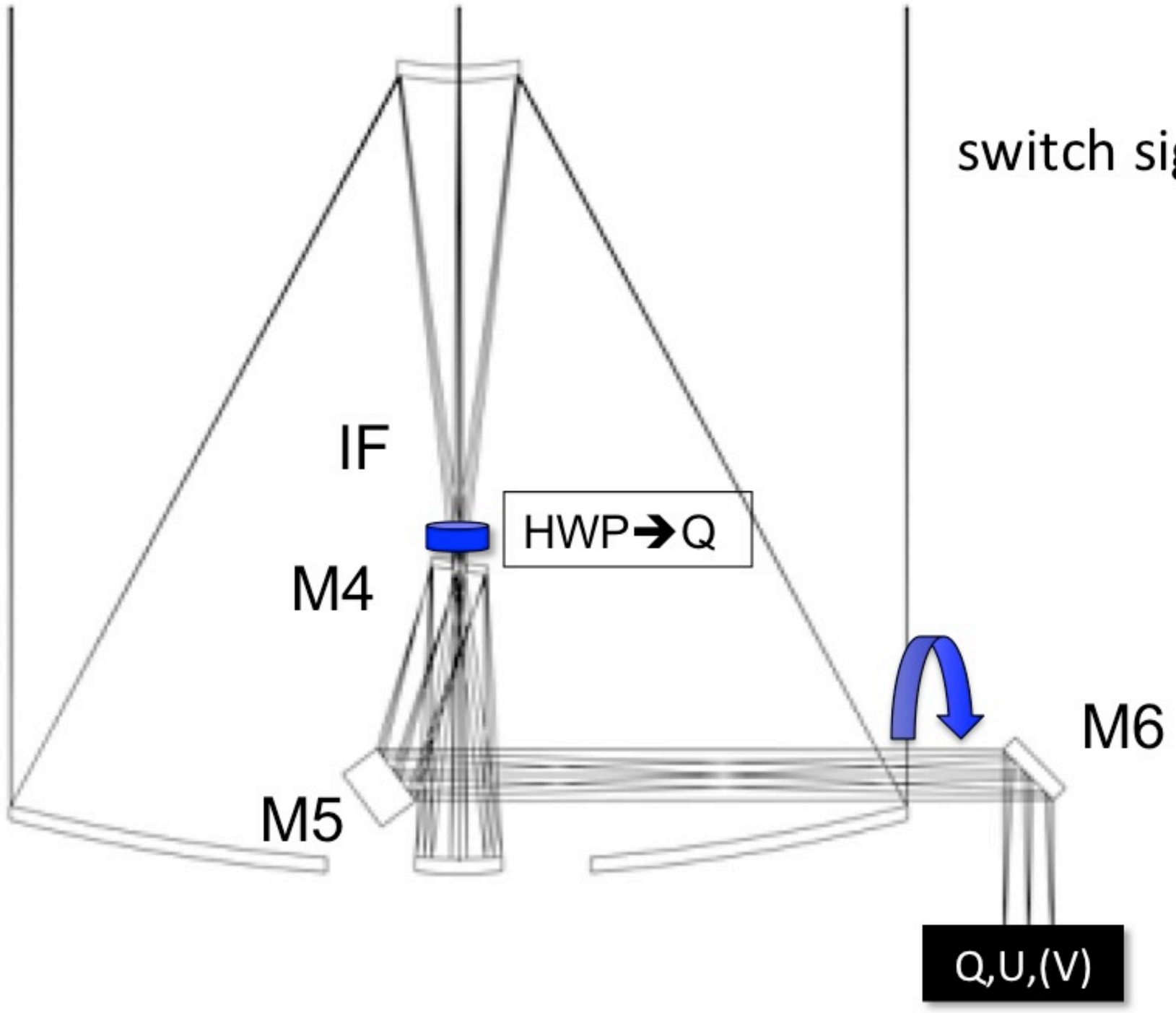
de Juan Ovelar, Snik et al. (2014a)

E-ELT M4-6



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

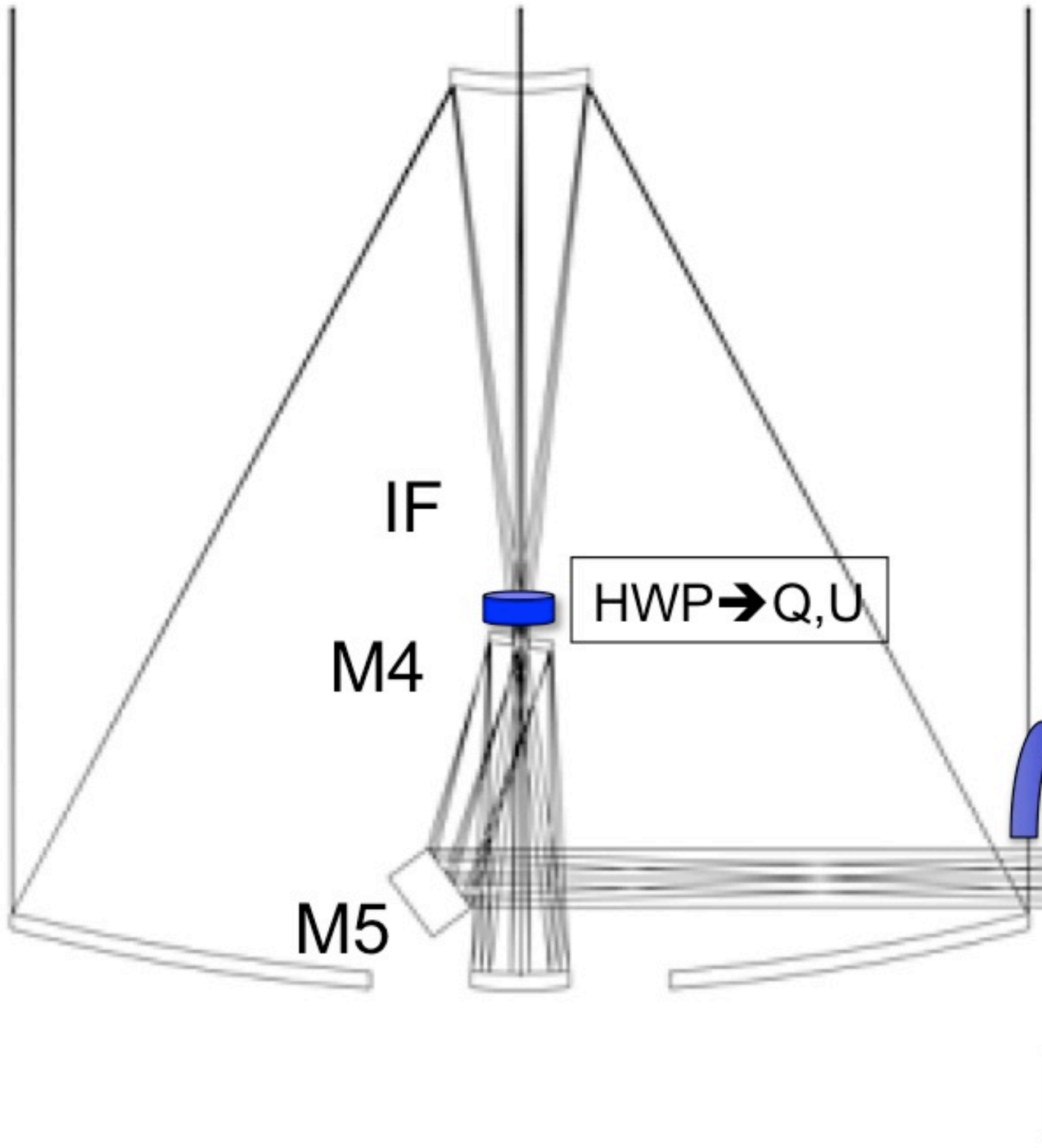
E-ELT M4-6



switch sign of Q,U

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

E-ELT M4-6



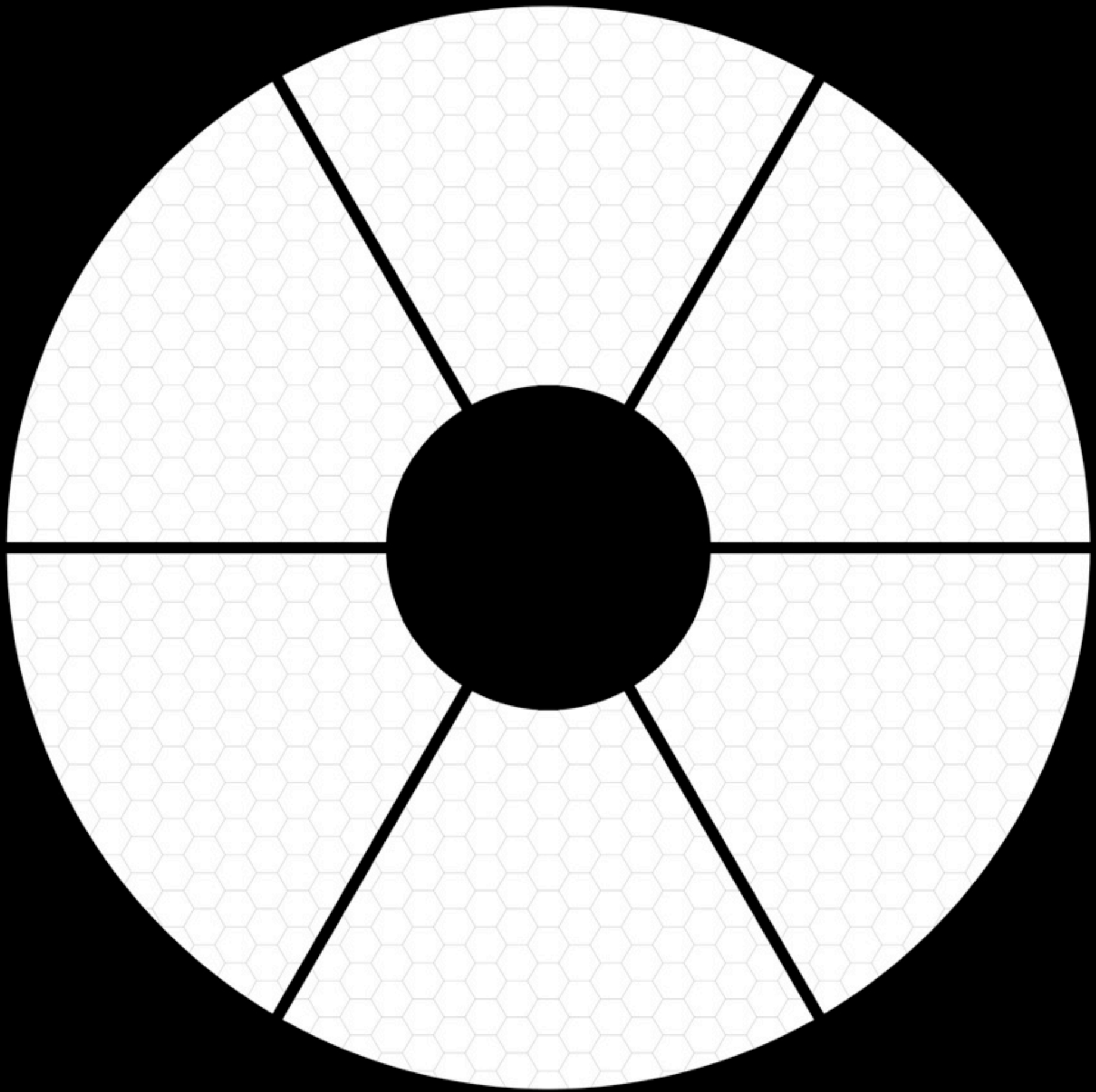
two-stage
modulation

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

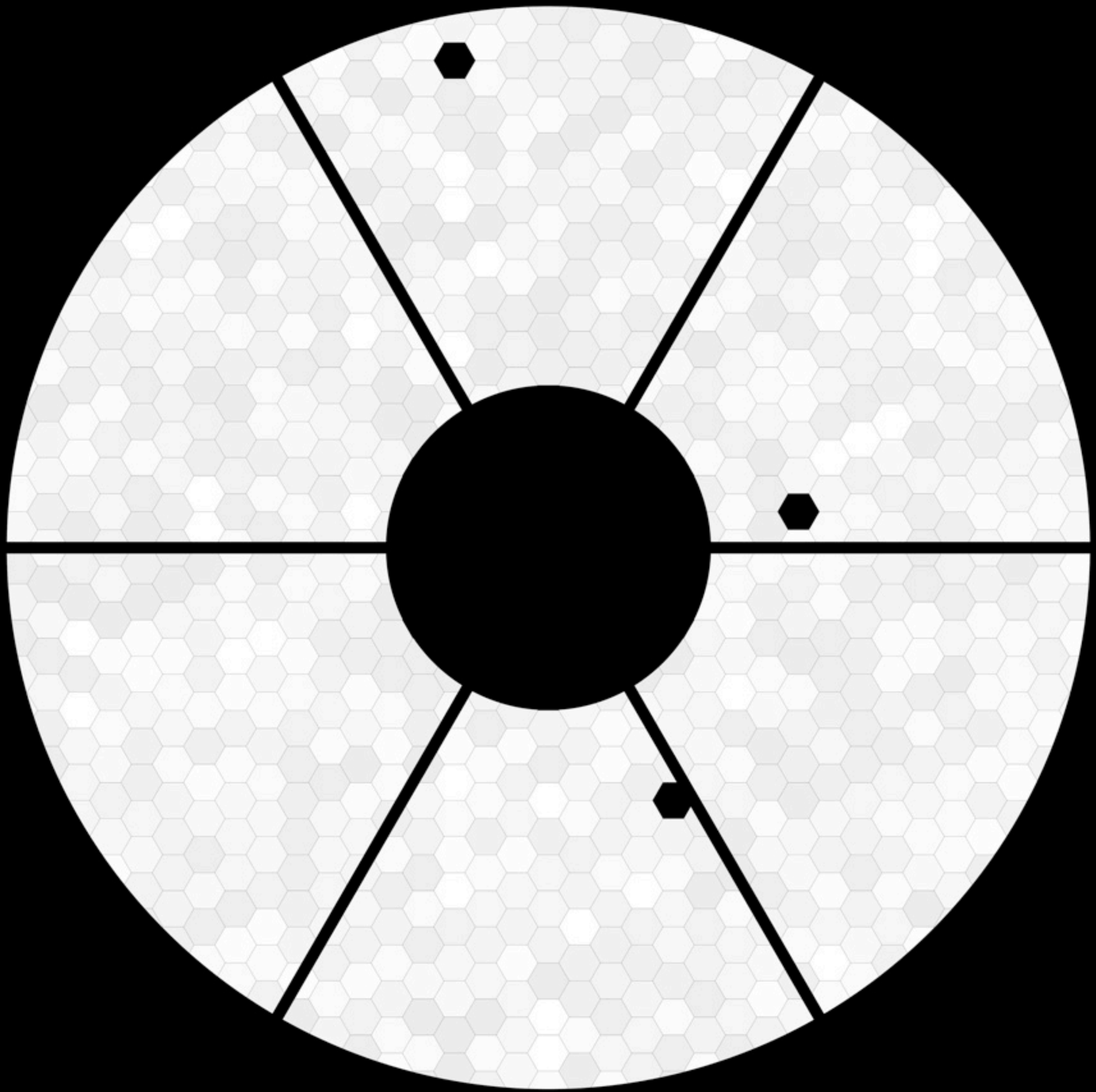
E-ELT M1-3

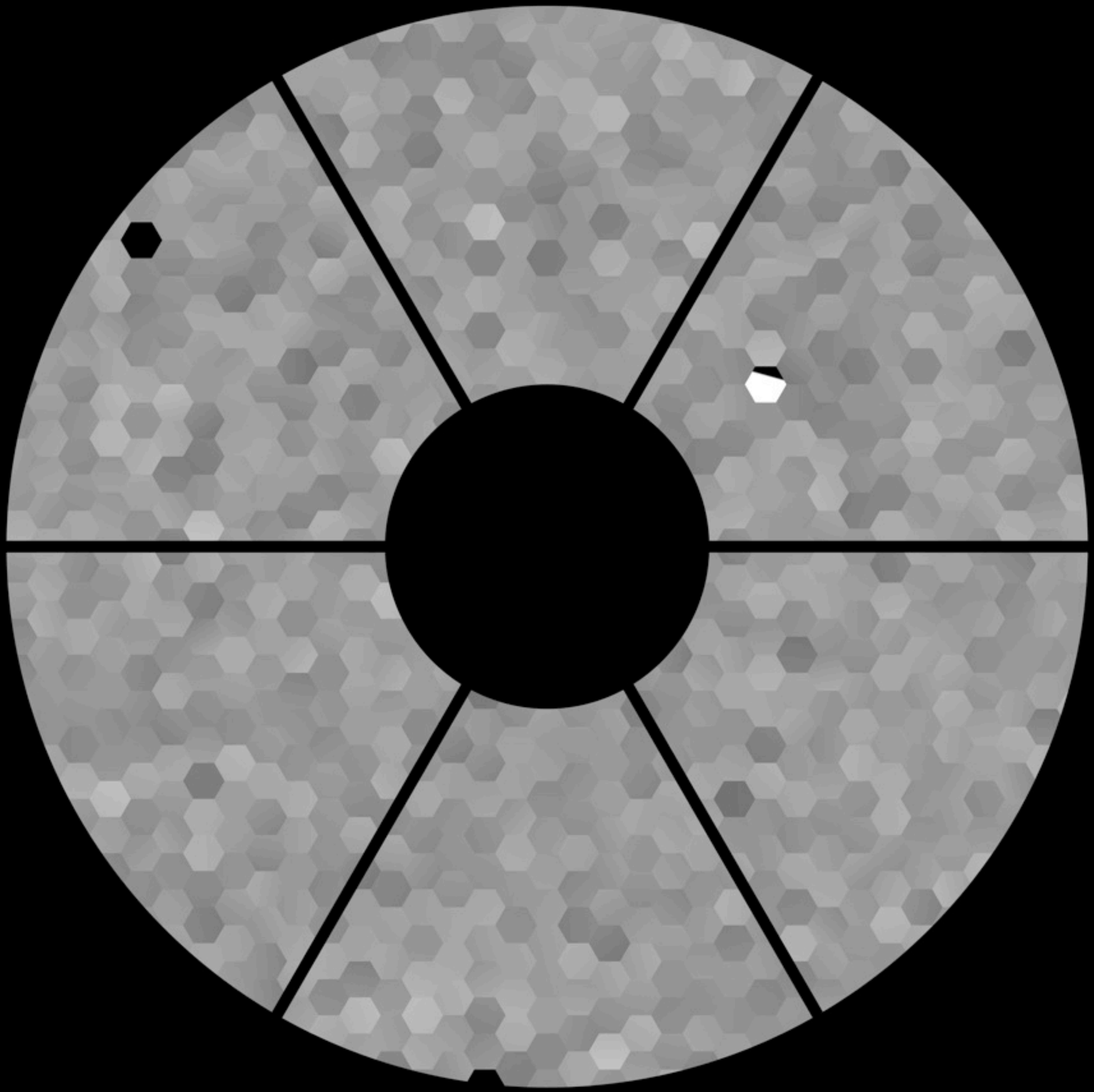
- Fraunhofer diffraction + Jones formalism (*Sanchez Almeida & Martinez Pillet, 1992)*
- amplitude & phase ->
  instrumental polarization & cross-talk
- rotationally symmetric ->
  average polarization is zero

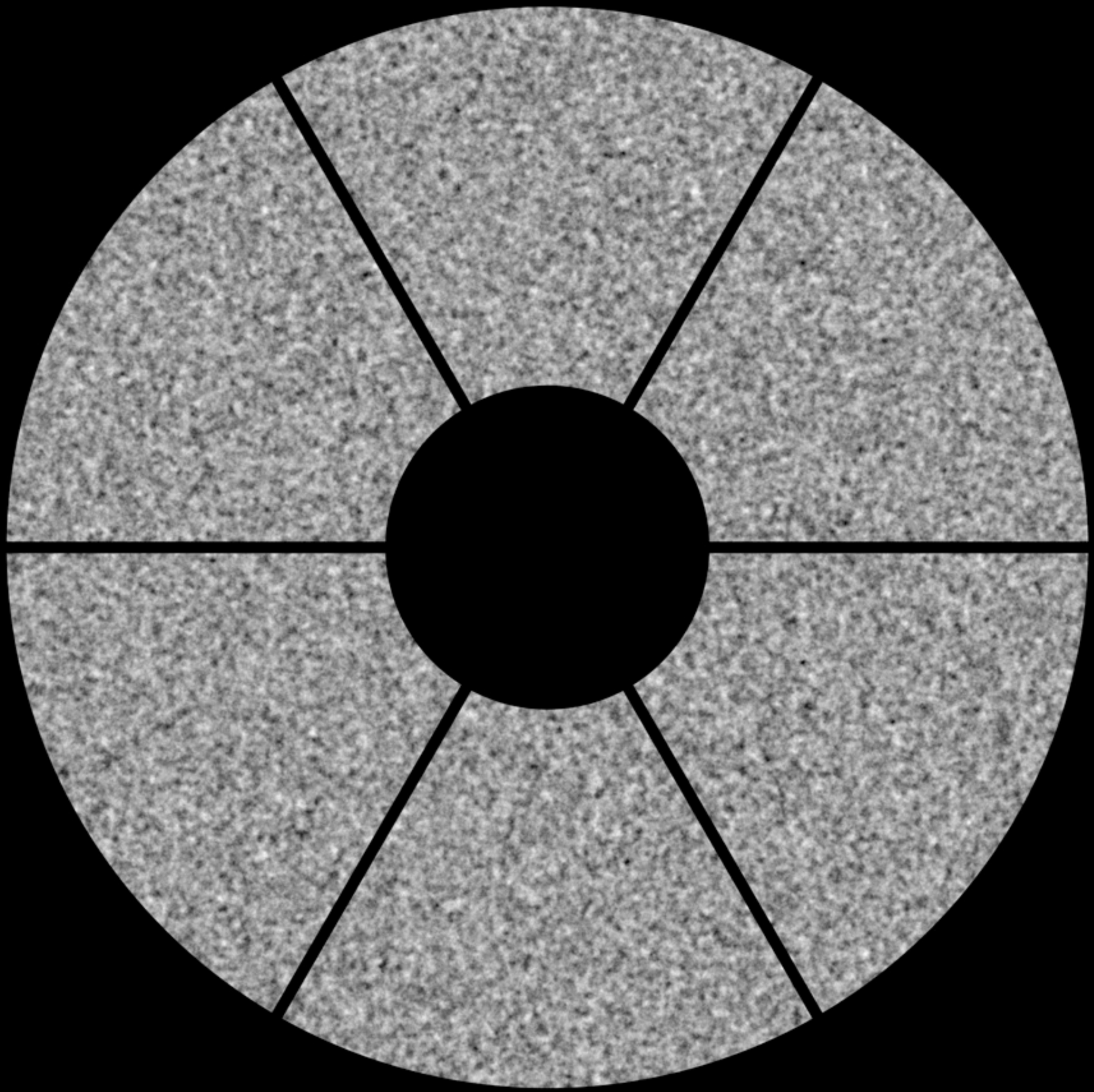
- no vector-diffraction (3D) effects



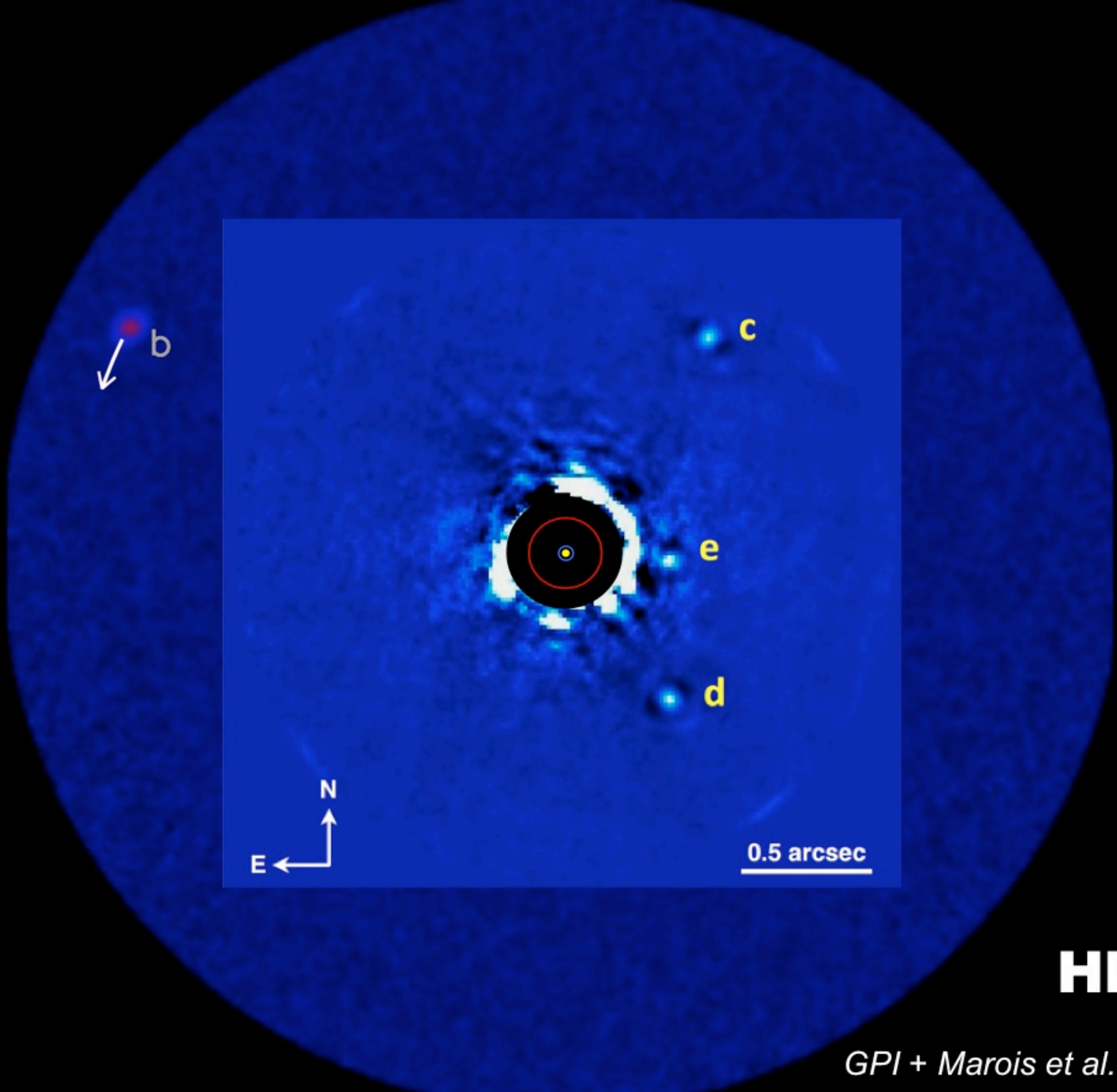
max pol ≈ 1%








Sirius A&B



HR8799

GPI + Marois et al. (2008,2010)

8-m VLT, solar system at 10 parsec, λ=600 nm

star

excellent natural seeing

Earth

Jupiter

log(contrast)

0
-1
-2
-3
-4
-5
-6
-7
-8
-9
-10
-11

0.0
0.1
0.2
0.3
0.4
0.5
0.6

separation from central star (arcsec)

8-m VLT, solar system at 10 parsec, λ=600 nm

star

excellent natural seeing

polarized flux

Jupiter

Earth

log(contrast)

0 -1 -2 -3 -4 -5 -6 -7 -8 -9 -10 -11

0.0 0.1 0.2 0.3 0.4 0.5 0.6

separation from central star (arcsec)

8-m VLT, solar system at 10 parsec, λ=600 nm

star

control radius = $\lambda/d_{subap.}$

extreme adaptive optics (scale renormalized)

Earth

Jupiter

log(contrast)

0 -1 -2 -3 -4 -5 -6 -7 -8 -9 -10 -11

0.0 0.1 0.2 0.3 0.4 0.5 0.6

separation from central star (arcsec)

8-m VLT, solar system at 10 parsec, λ=600 nm

star

coronagraphy

inner working angle = a few λ/D

Earth

Jupiter

log(contrast)

0
-1
-2
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-6
-7
-8
-9
-10
-11

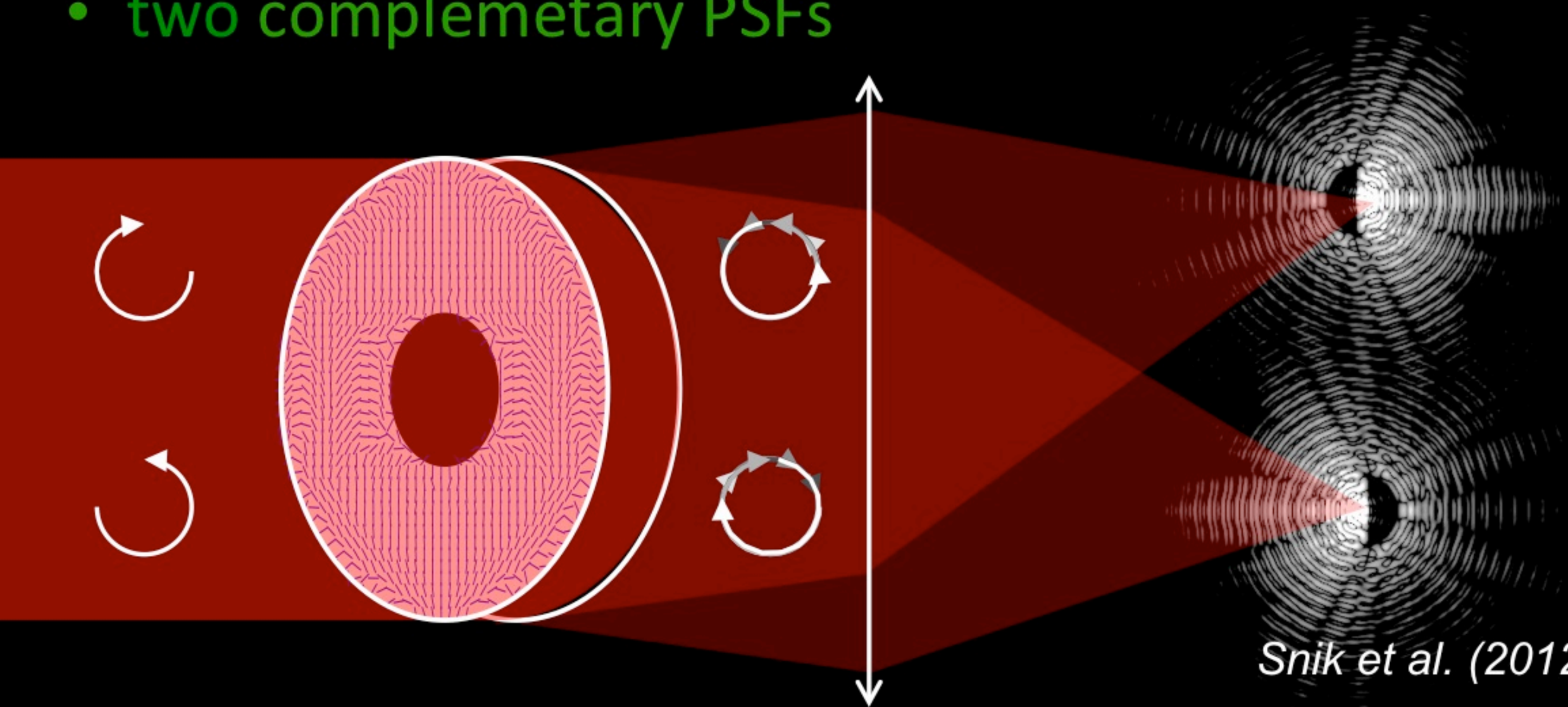
0.0
0.1
0.2
0.3
0.4
0.5
0.6

separation from central star (arcsec)

vector-APP coronagraph

geometric phase

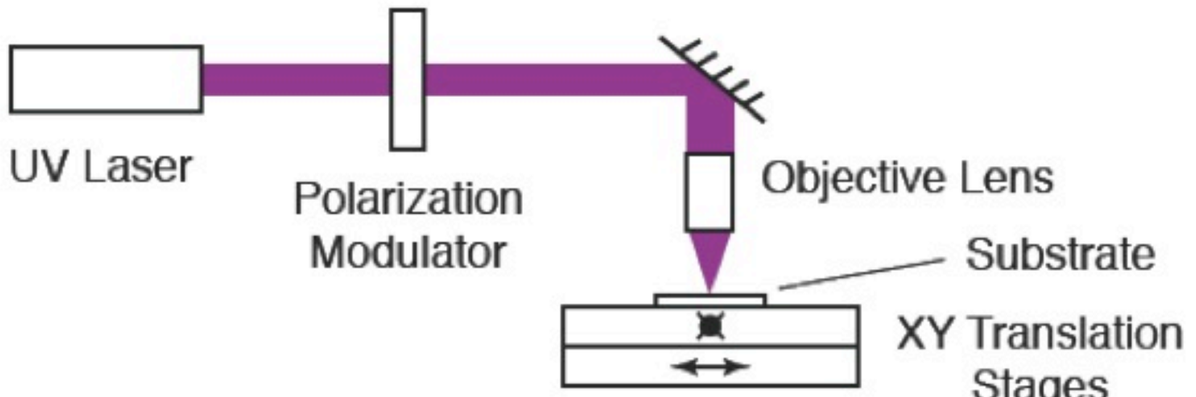
- inherently achromatic chromatic
- use liquid crystals for extreme patterns
- two complemetary PSFs



Snik et al. (2012)

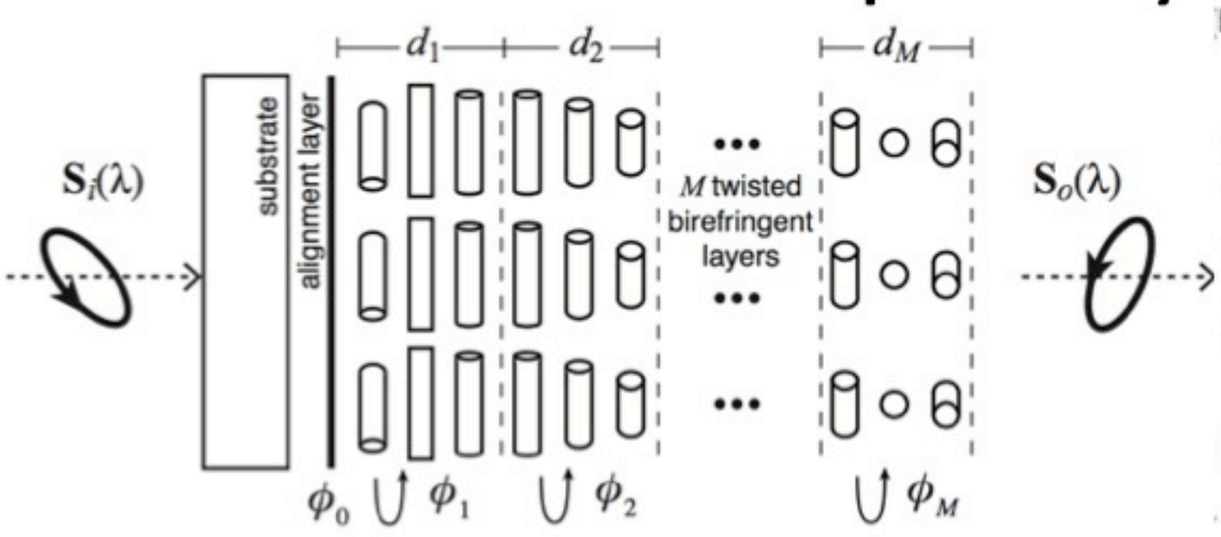
the vector-APP

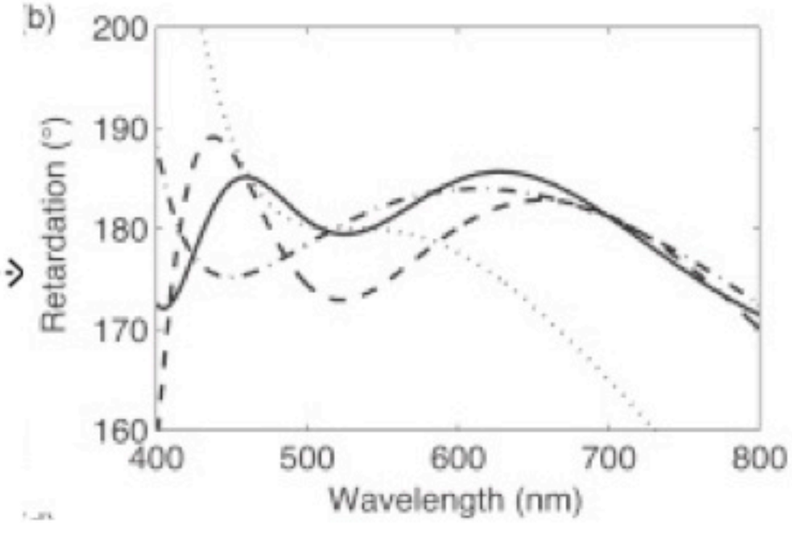
1. **any phase pattern** thanks to direct-write technique



Miskiewicz & Escuti (2014)

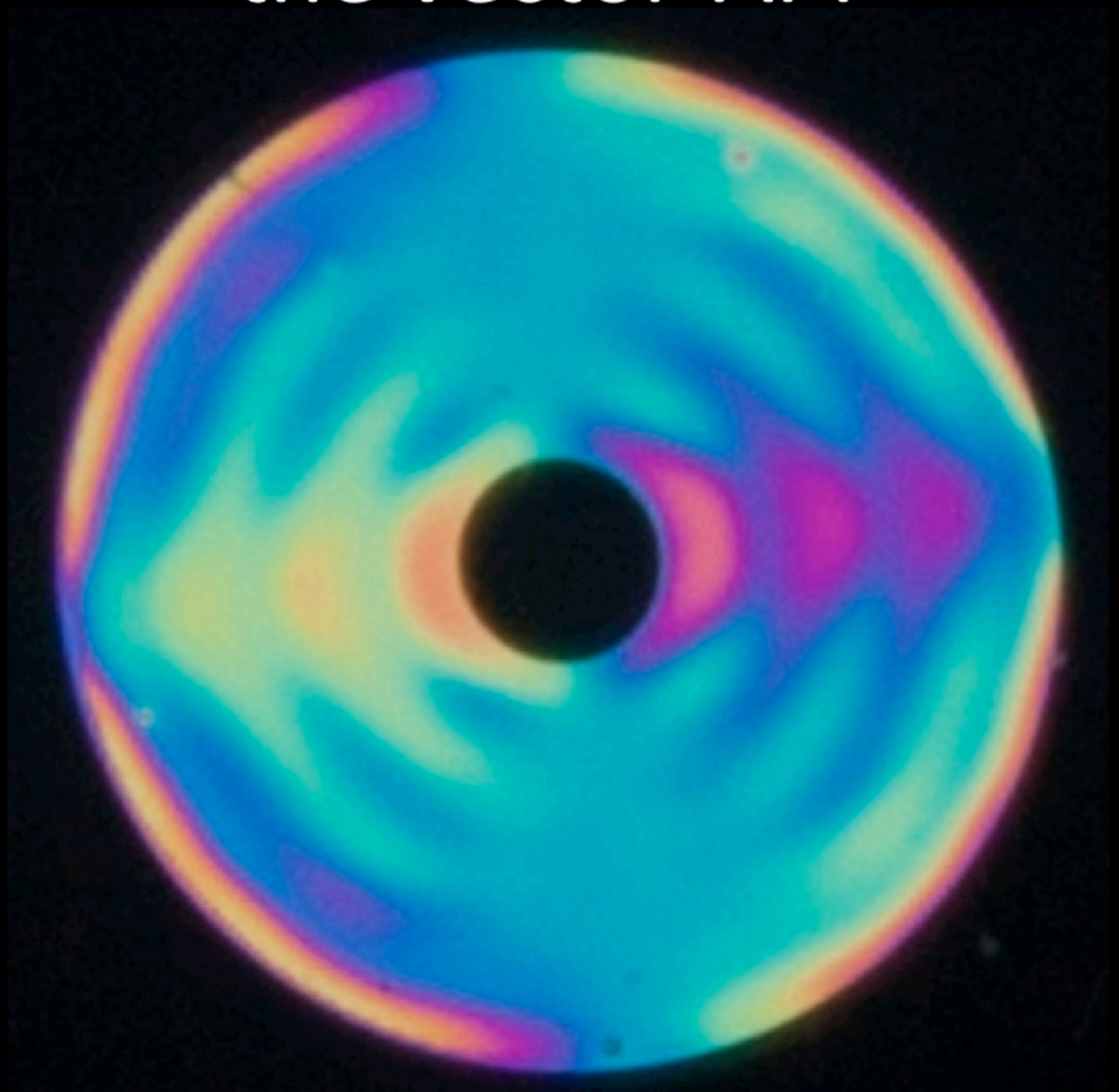
2. **achromatization** thanks to self-aligning multi-twist liquid crystal retarder





Komanduri et al. (2013)

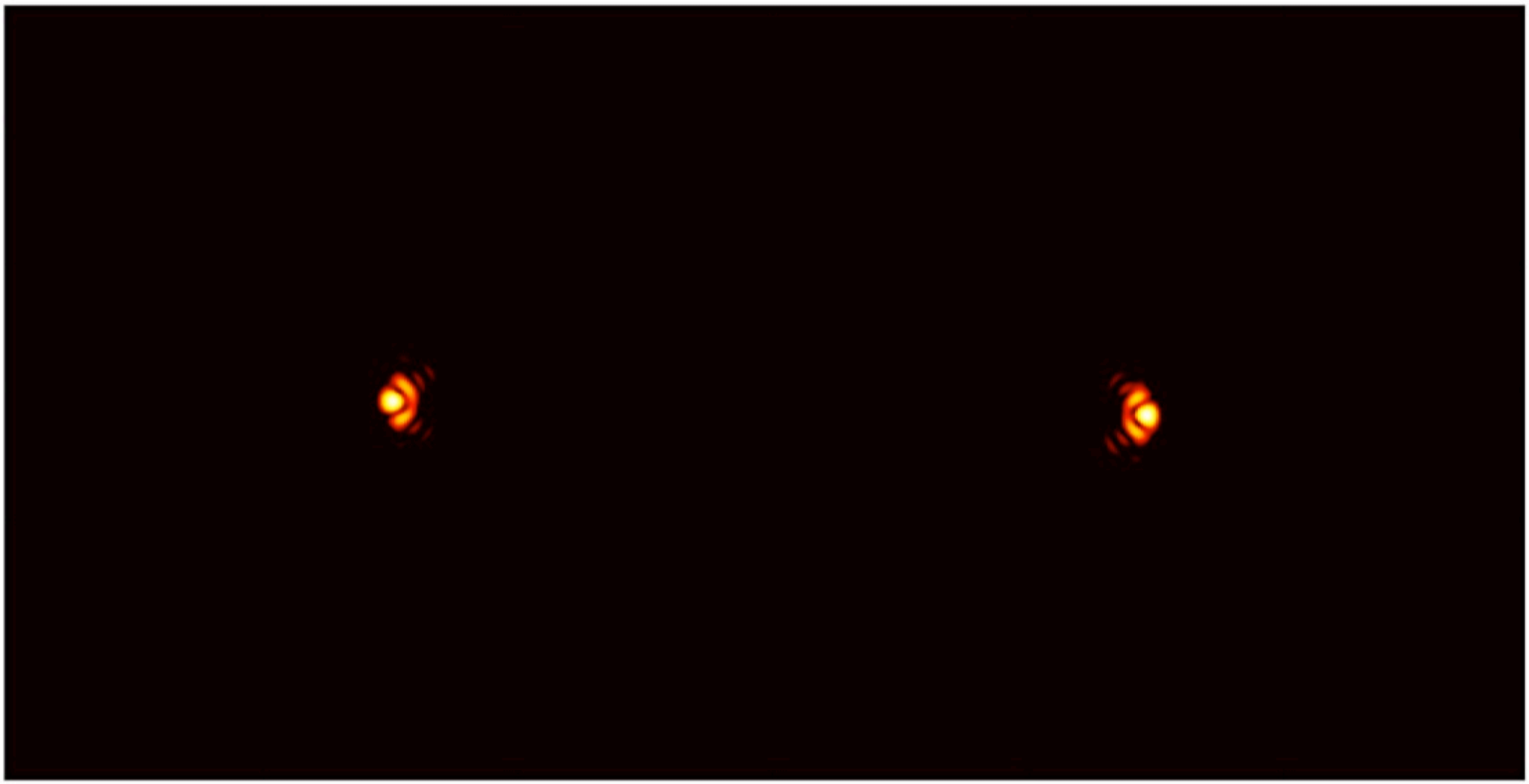
the vector-APP



the vector-APP

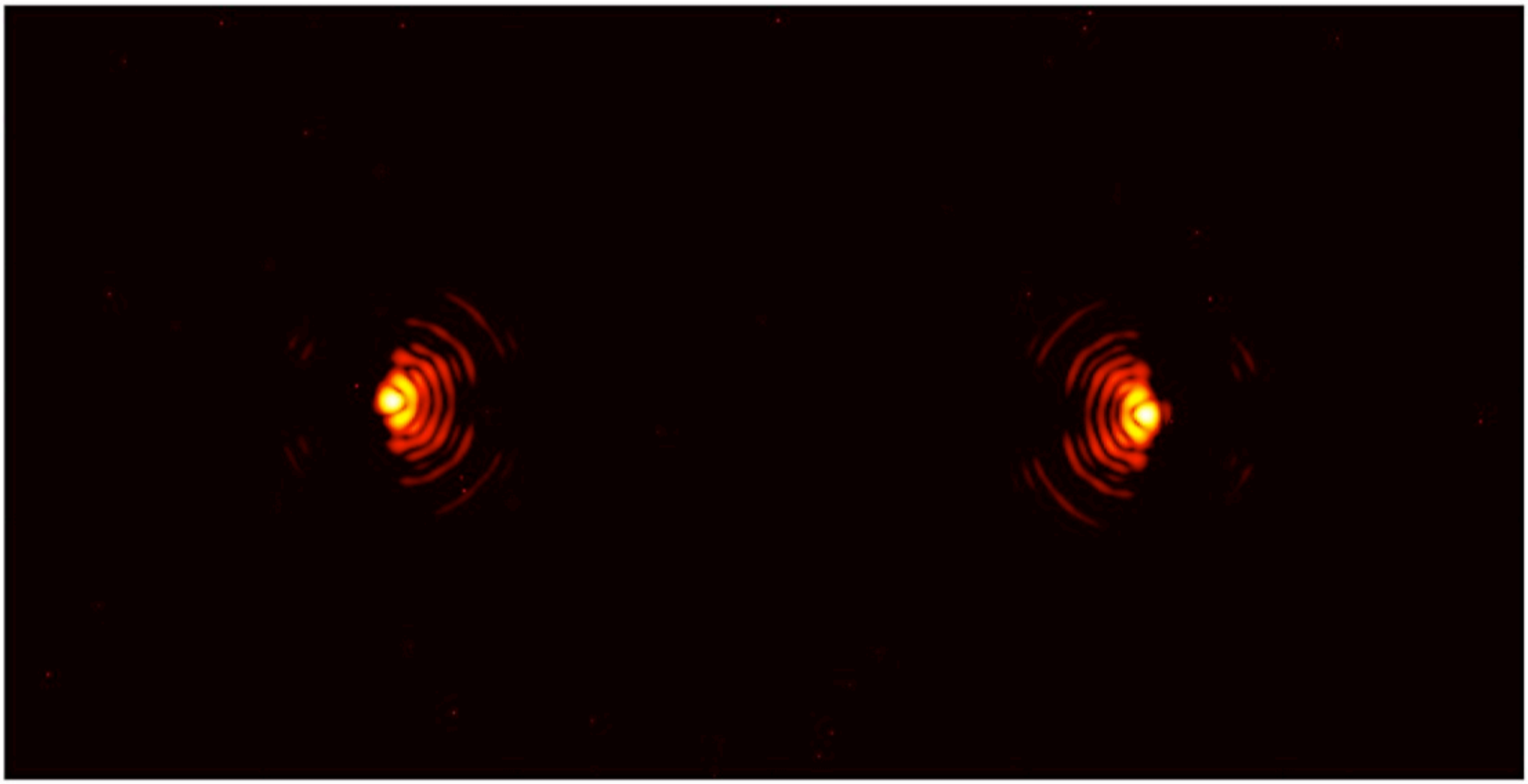
Otten, Snik, et al. (2014)

the vector-APP



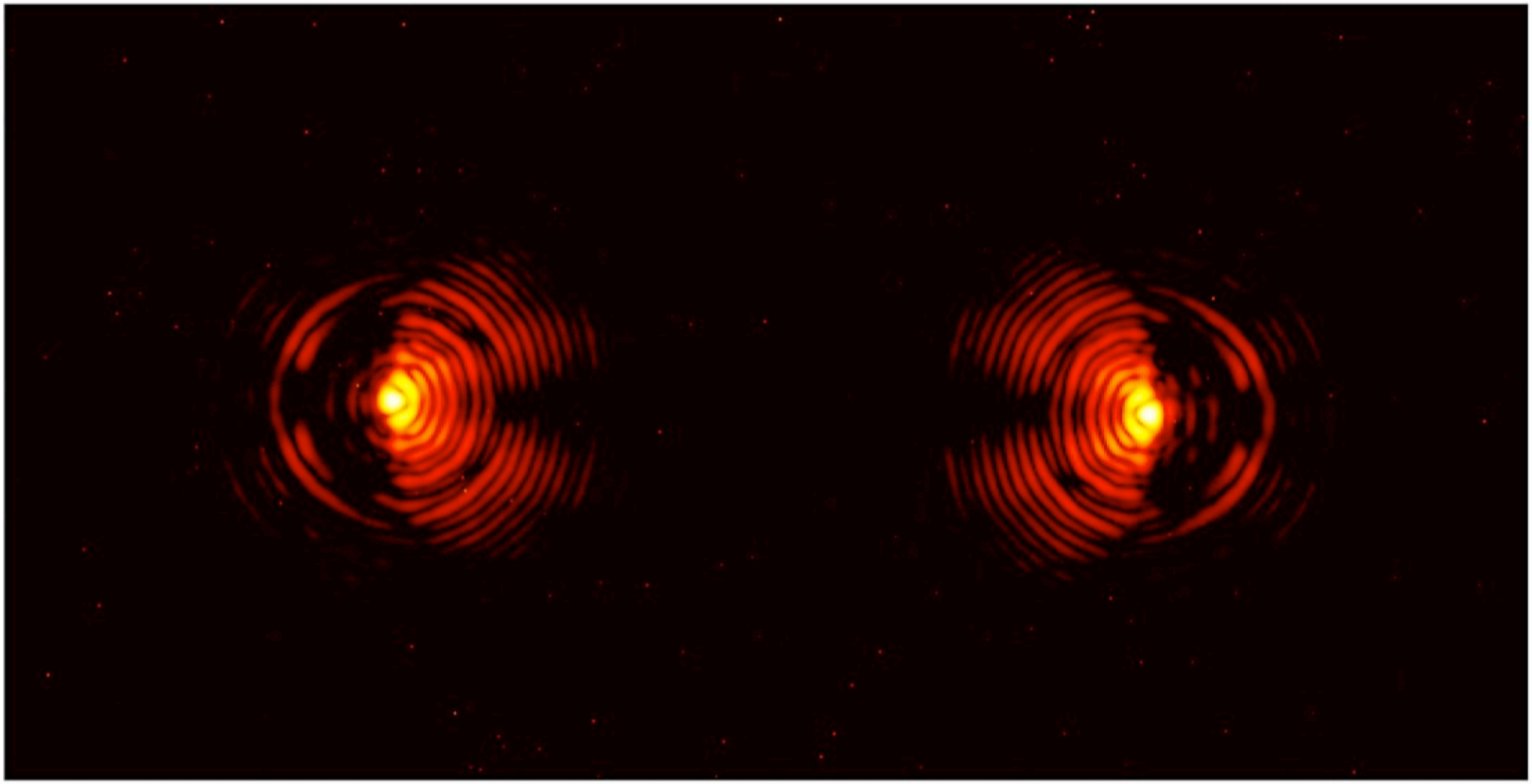
Otten, Snik, et al. (2014)

the vector-APP



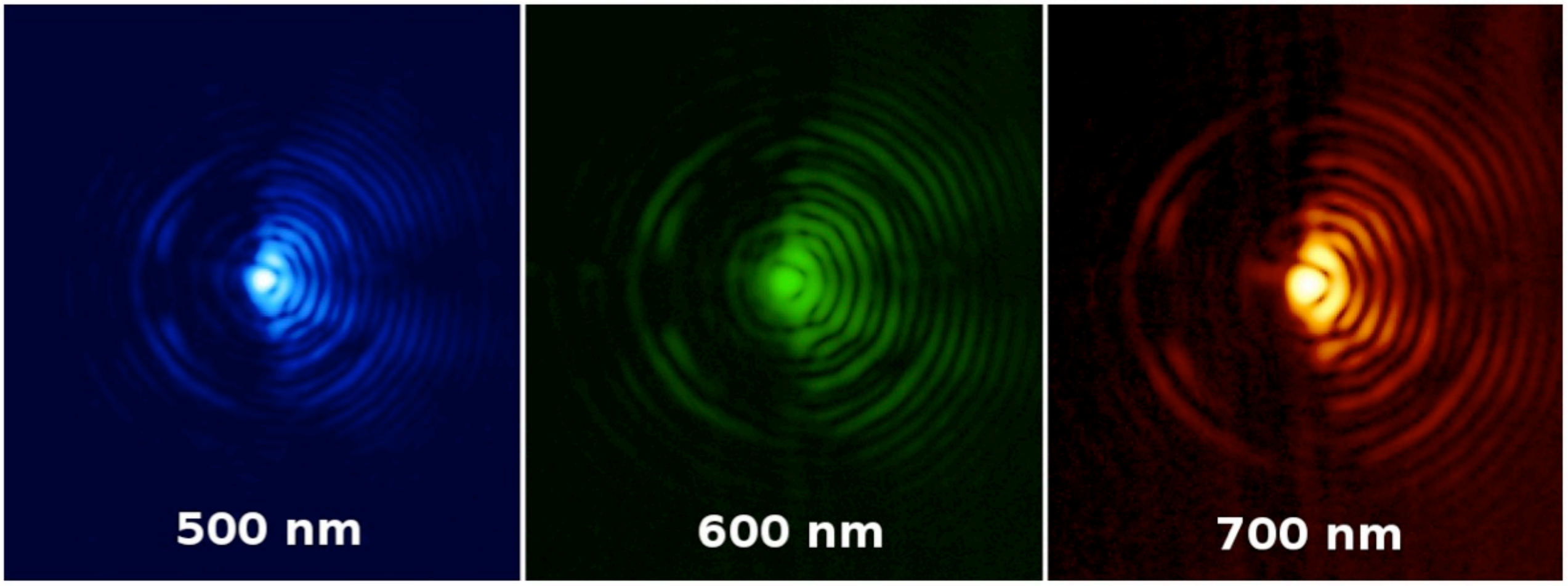
Otten, Snik, et al. (2014)

the vector-APP



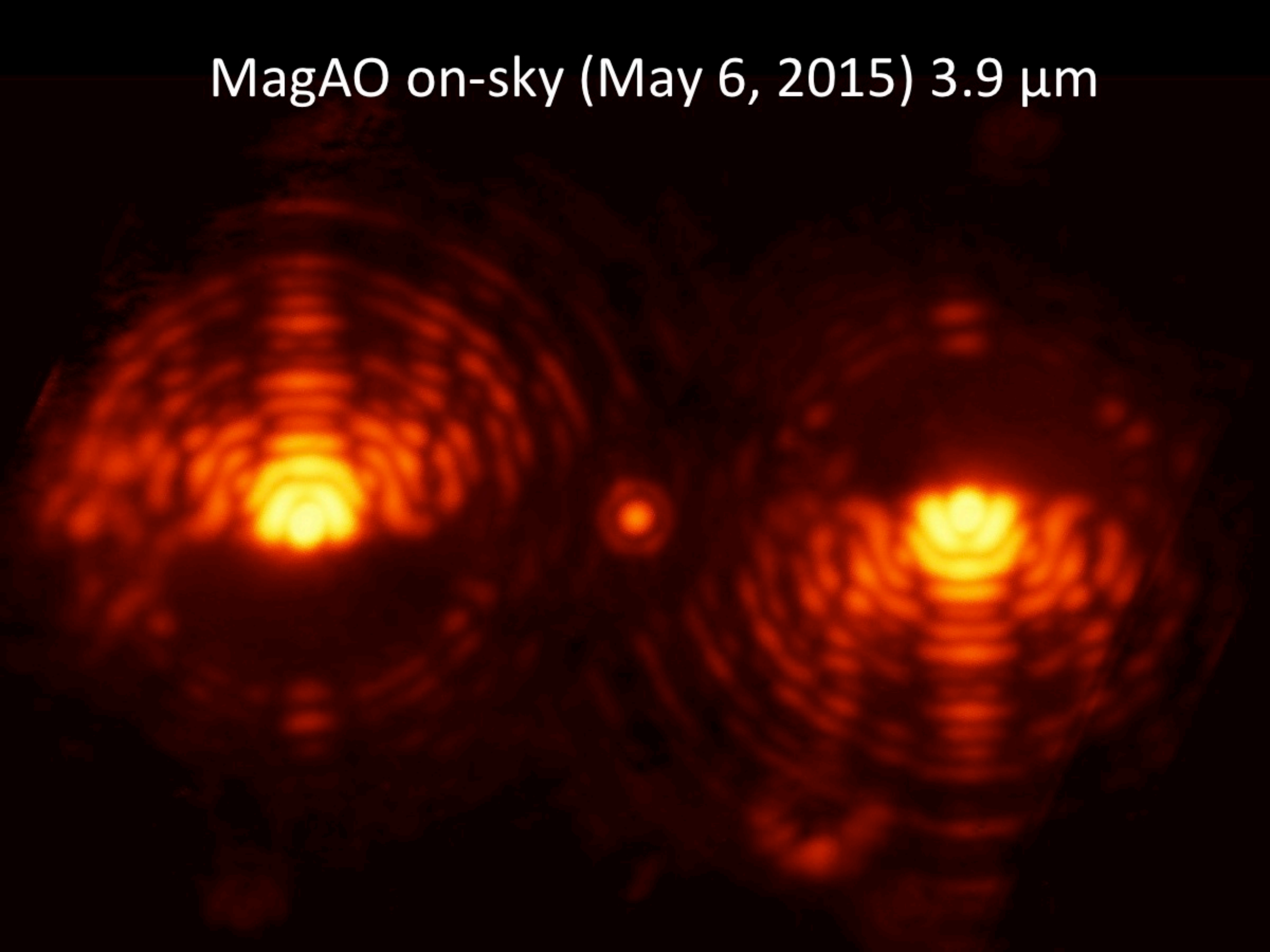
Otten, Snik, et al. (2014)

the vector-APP



Otten et al. (2014a)

MagAO on-sky (May 6, 2015) 3.9 µm



8-m VLT, solar system at 10 parsec, λ=600 nm

star

data reduction tricks: ADI & optimal extraction

Earth

Jupiter

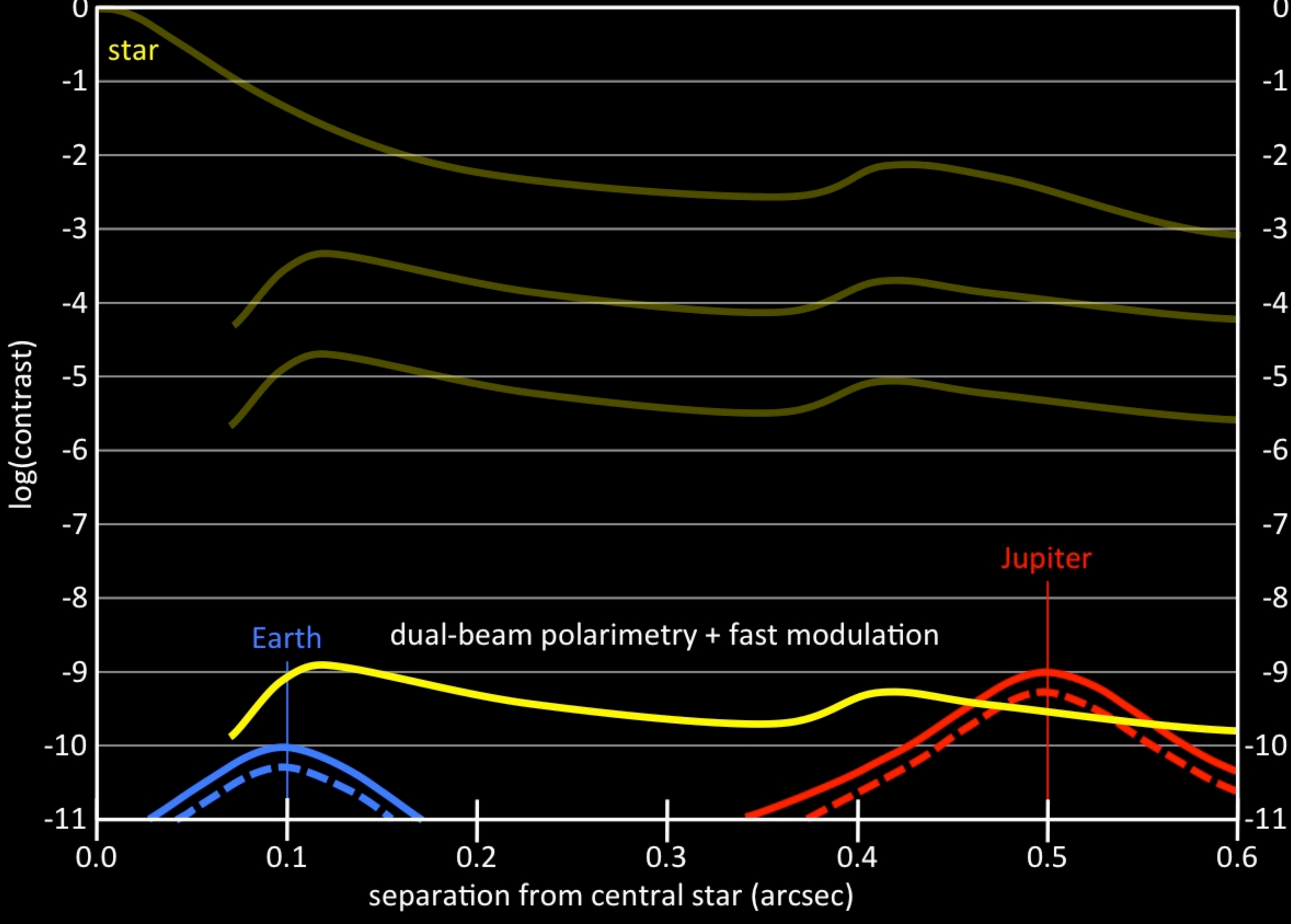
log(contrast)

0 -1 -2 -3 -4 -5 -6 -7 -8 -9 -10 -11

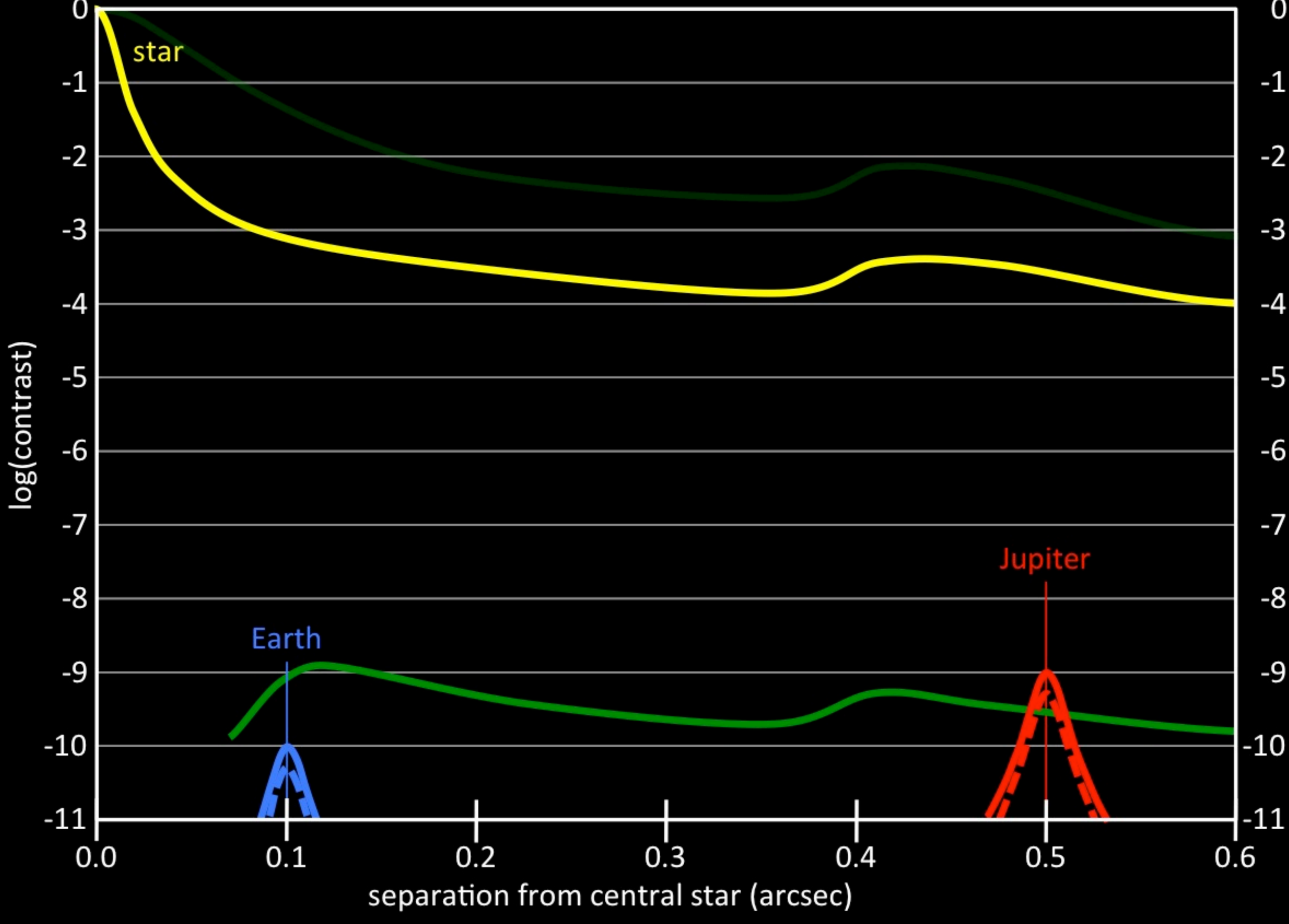
0.0 0.1 0.2 0.3 0.4 0.5 0.6

separation from central star (arcsec)

8-m VLT, solar system at 10 parsec, λ=600 nm



40-m ELT, solar system at 10 parsec, λ=600 nm



40-m ELT, solar system at 10 parsec, λ=600 nm

star

Earth

Jupiter

log(contrast)

0
-1
-2
-3
-4
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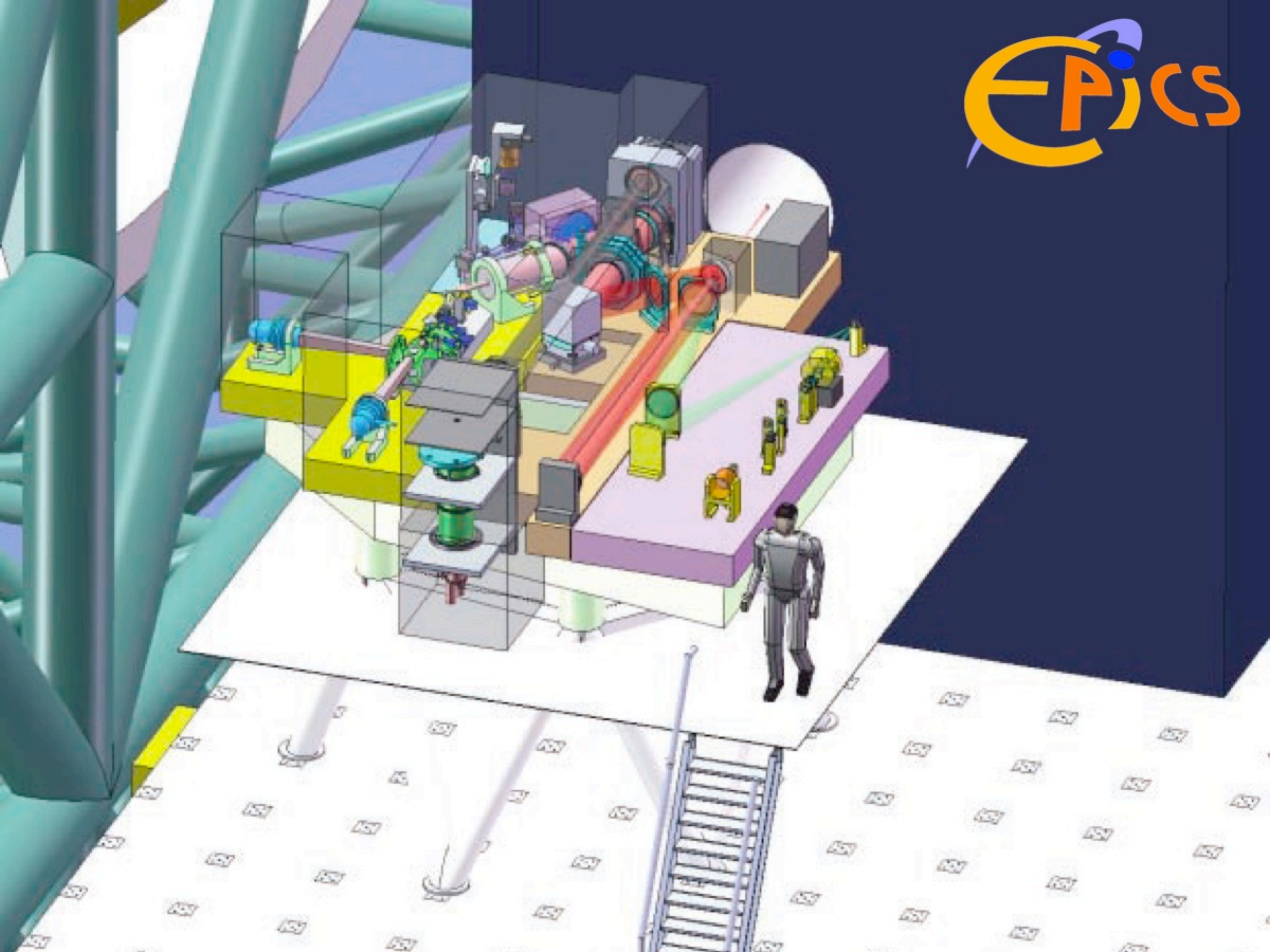
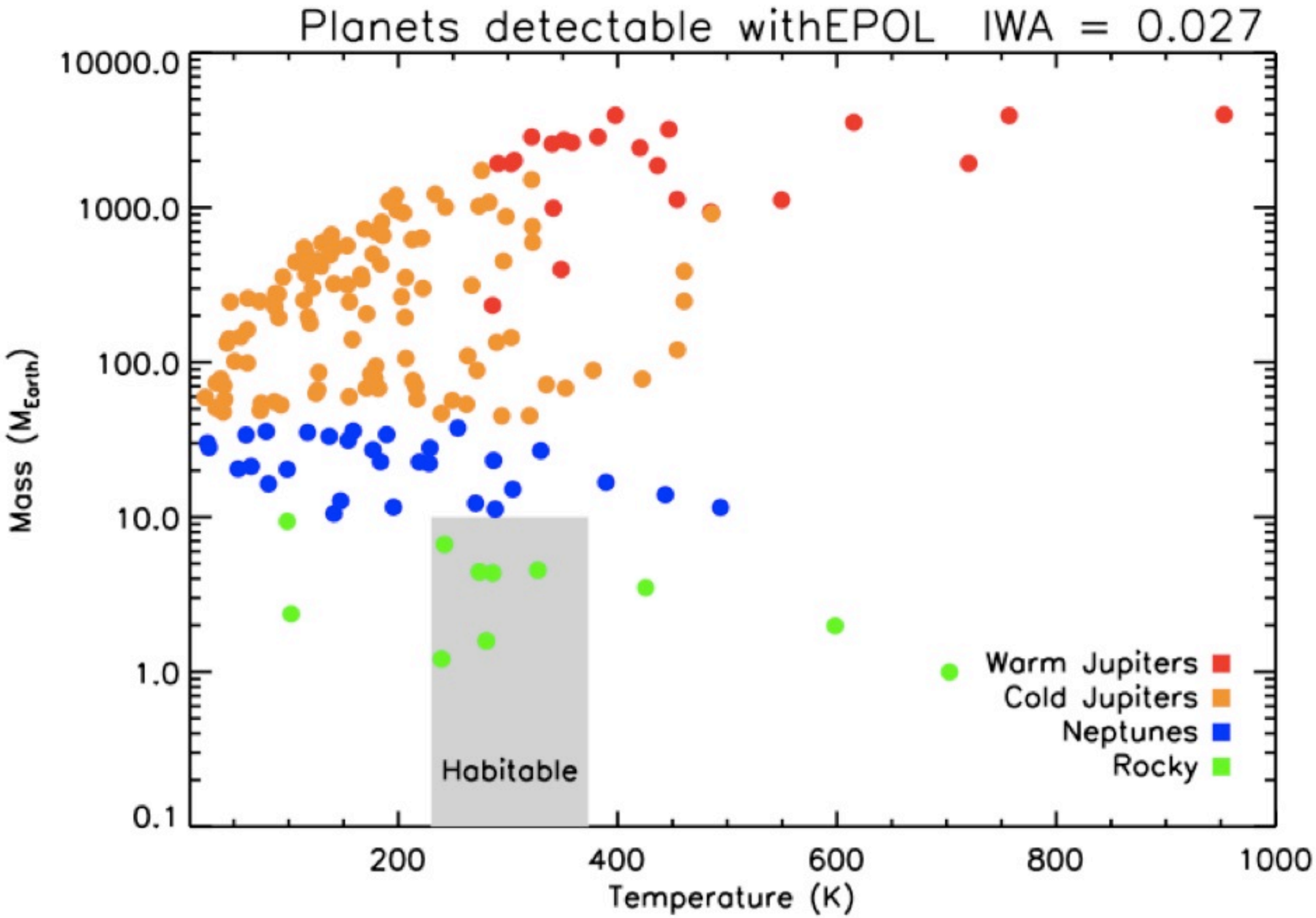
-6
-7
-8
-9
-10
-11

0.0
0.1
0.2
0.3
0.4
0.5
0.6

separation from central star (arcsec)





Simulations by: Mariangela Bonavita

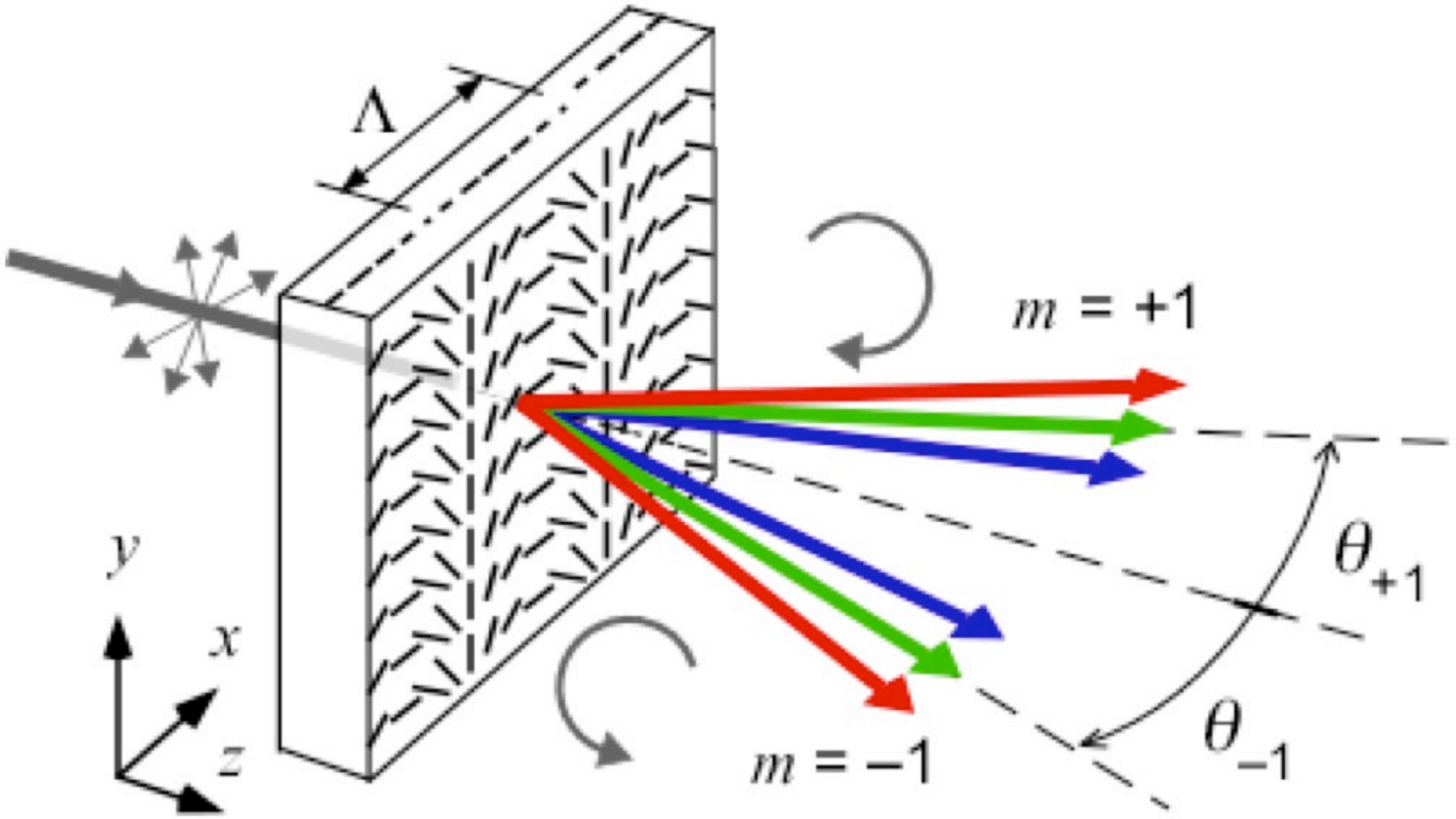
why we need polarimetry

- 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

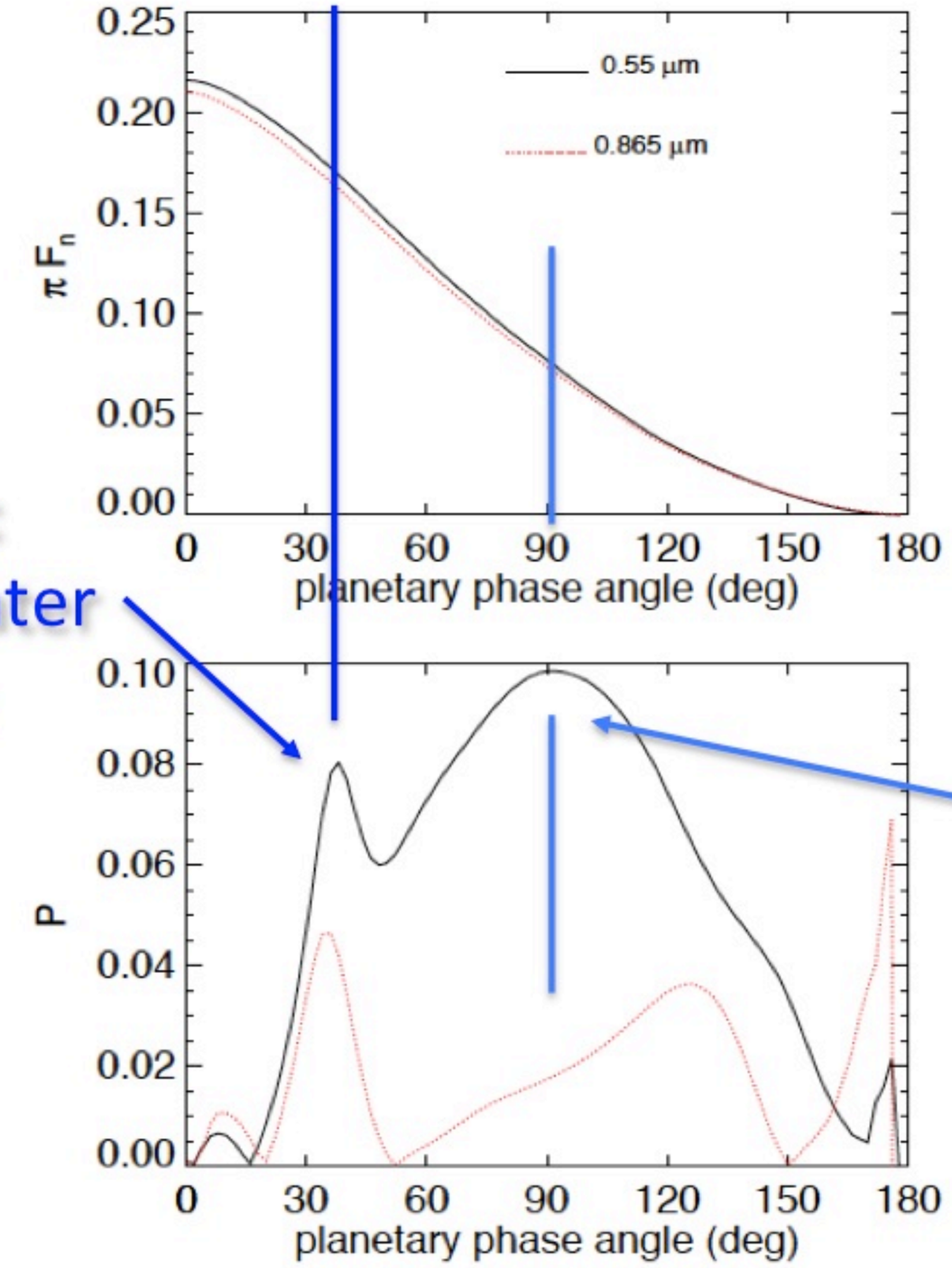
the polarization grating



courtesy:
Michael Escuti (NCSU)

credit: Studio Roosegaarde, Frans Snik, Michiel Rodenhuis

finding extraterrestrial life

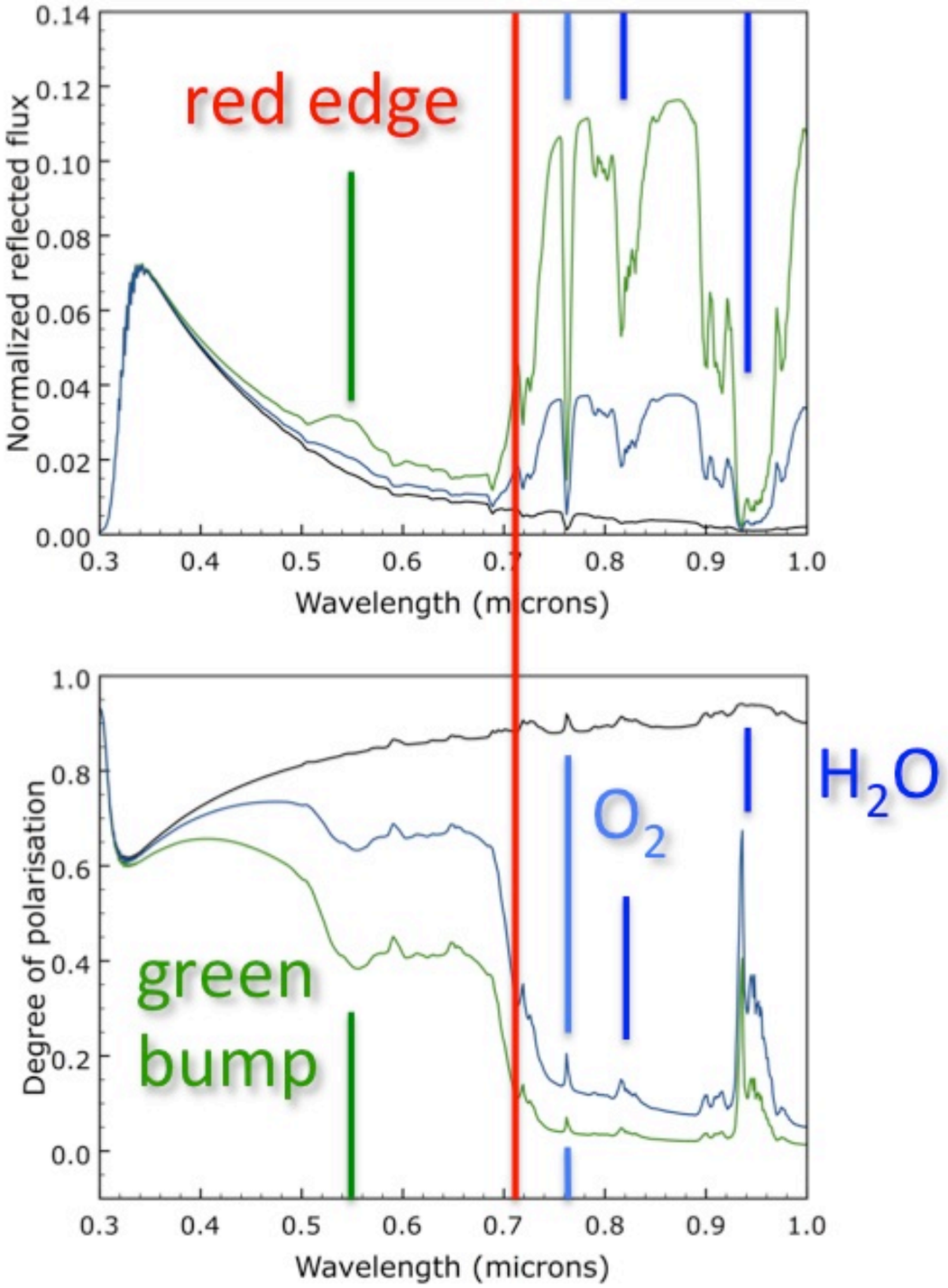


rainbow: liquid water droplets

Rayleigh scattering

Karalidi et al. (2012)

finding extraterrestrial life



Stam et al. (2008)

Looking for extraterrestrial life?

Put on polarized glasses!