First Results from SPHERE-ZIMPOL

Hans Martin Schmid, Inst. Astronomy, ETH Zurich,

- SPHERE project overview
- First pretty polarization images
- Performance example:

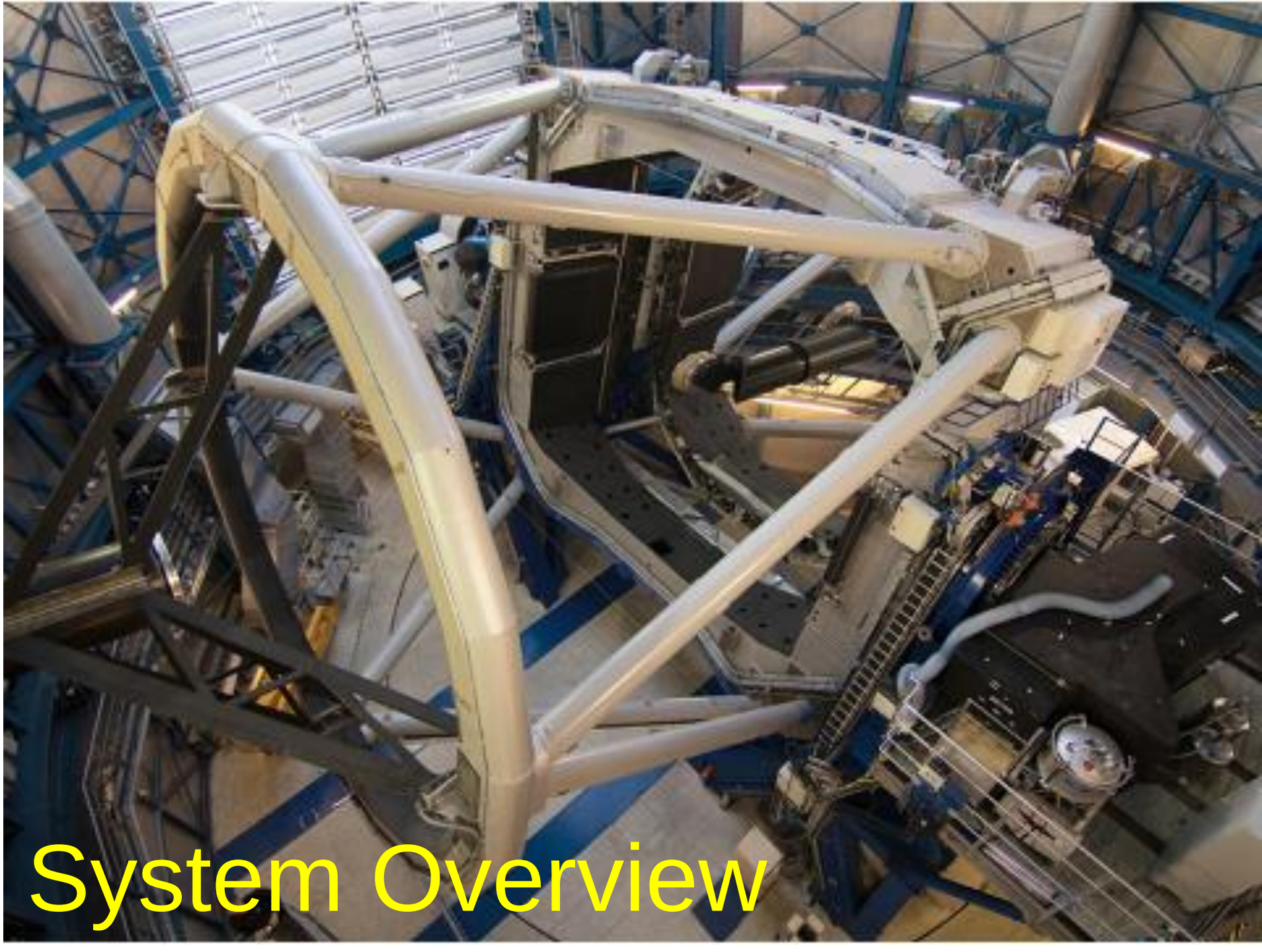
  R Aqr scattering polarization
  - beam-shift and resolving 30 mas structures
  - Dynamic range
- Outlook

SPHERE VLT “planet finder”

J.L. Beuzit, M. Feldt, D. Mouillet, K. Dohlen, P. Puget, G. Chavin, A. Boccaletti, C. Dominik, T.Henning, M. Kasper C. Moutou, M. Turatto, H.M. Schmid, S. Udry, A. Bazzon, R. Rolfsema, C. Keller, etc., etc

Project duration: 2002 – 2014
~ 50 persons, F, I, D, CH, NL
250 FTE, >10 Mio Euros

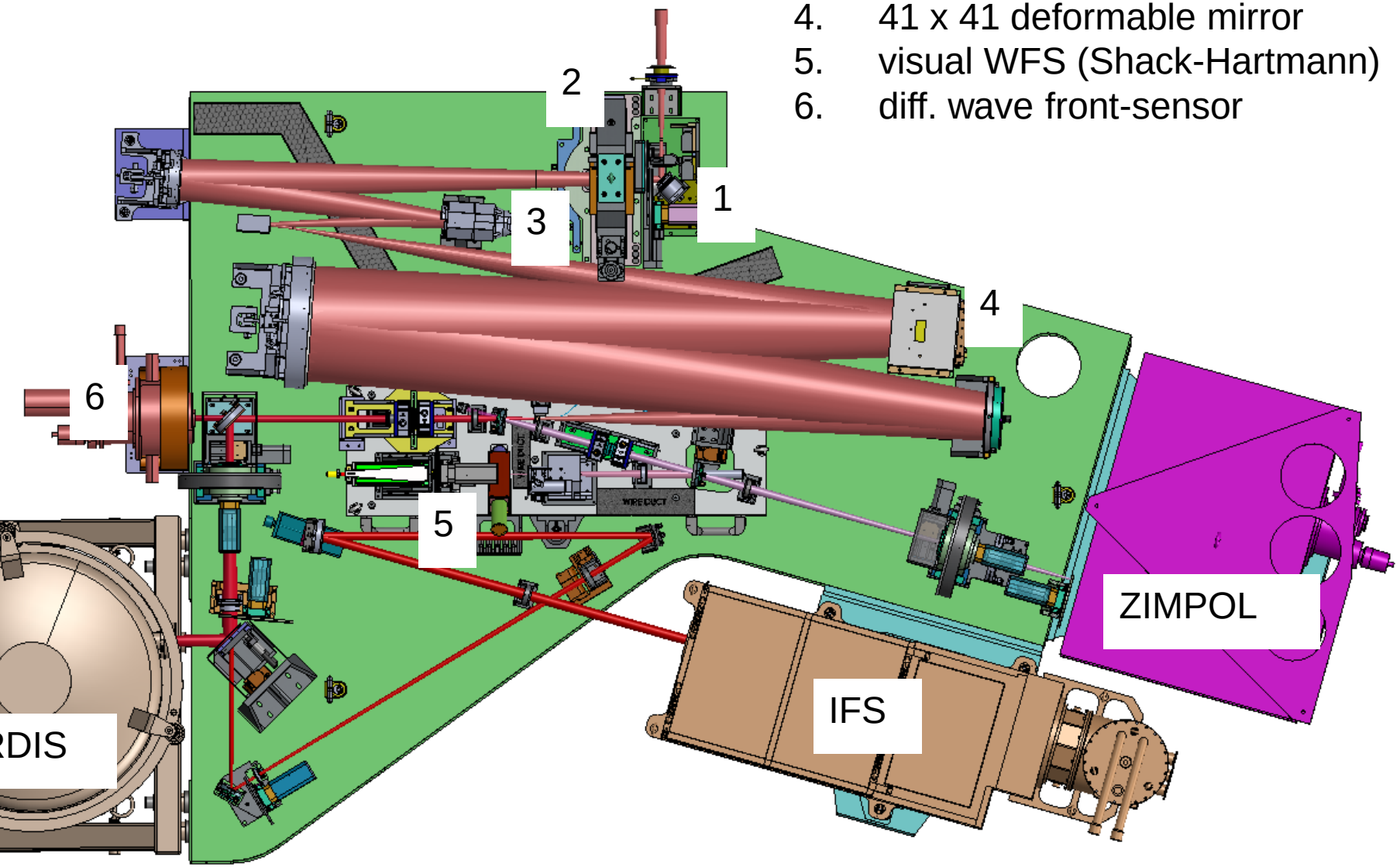
Members


System Overview

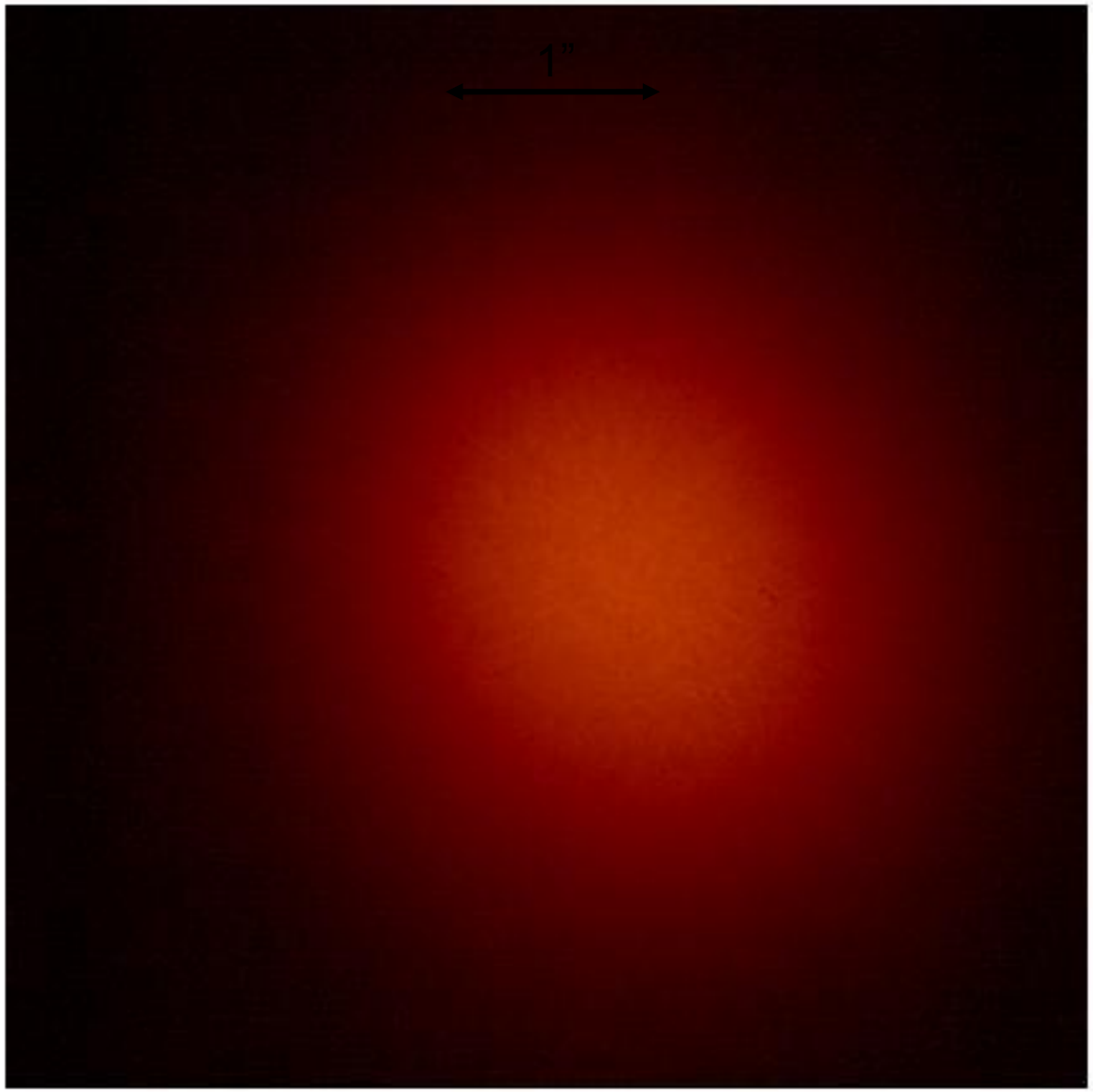
SPHERE-AO design

Extreme AO system (~1.3 kHz)

1. pupil shift corrector
2. (pupil derotator)
3. fast tip-tilt mirror
4. 41 x 41 deformable mirror
5. visual WFS (Shack-Hartmann)
6. diff. wave front-sensor




Nitrile Gloves



max:
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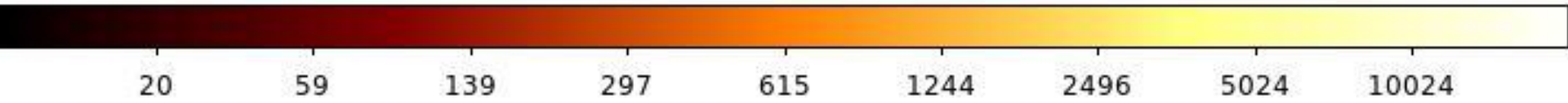

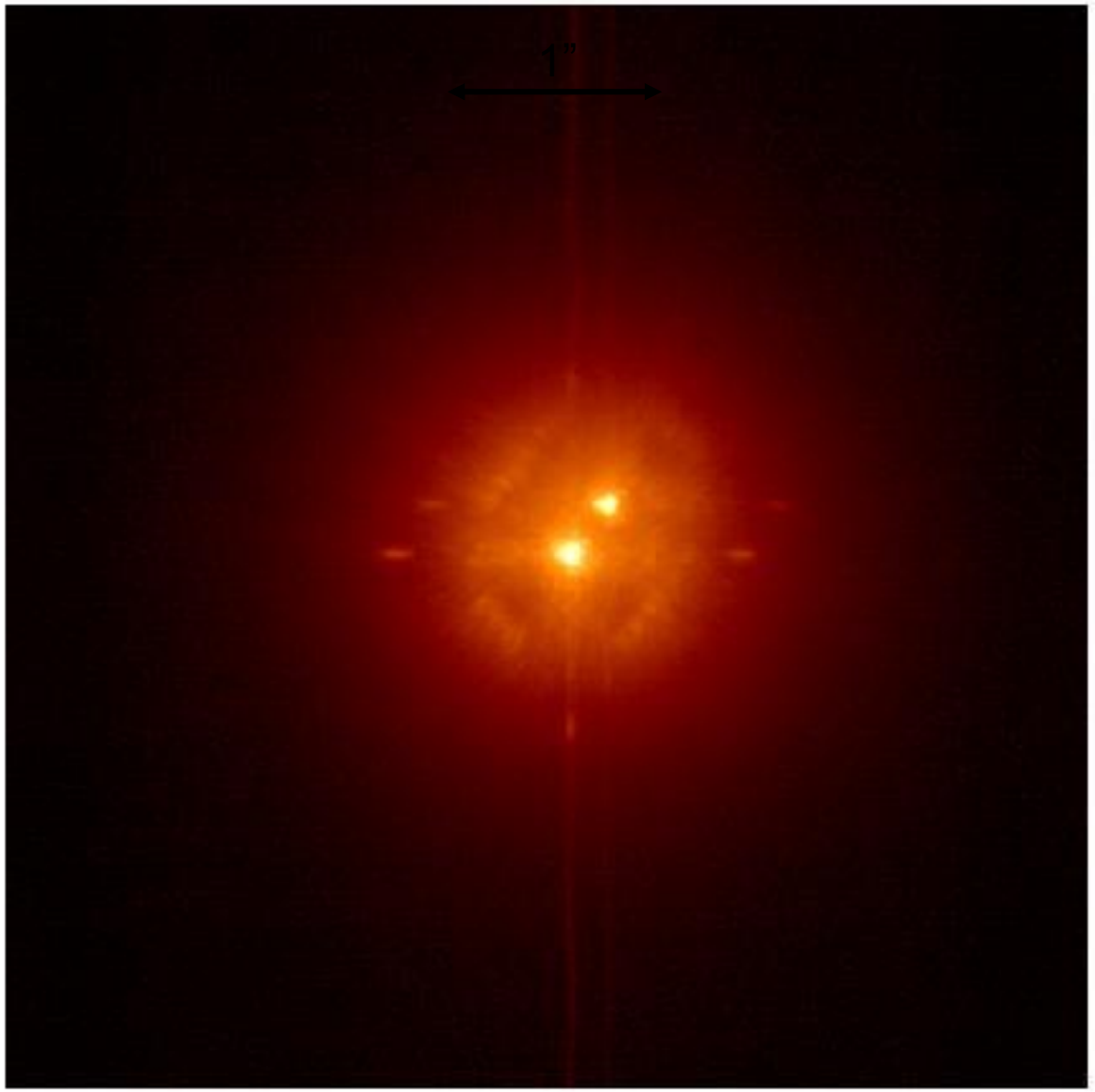

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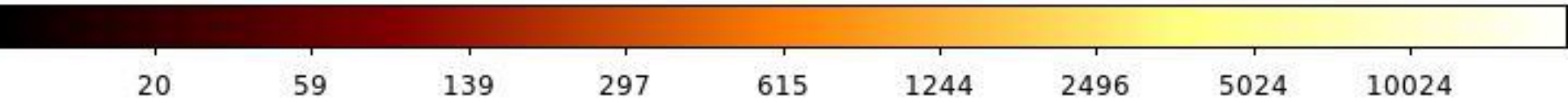
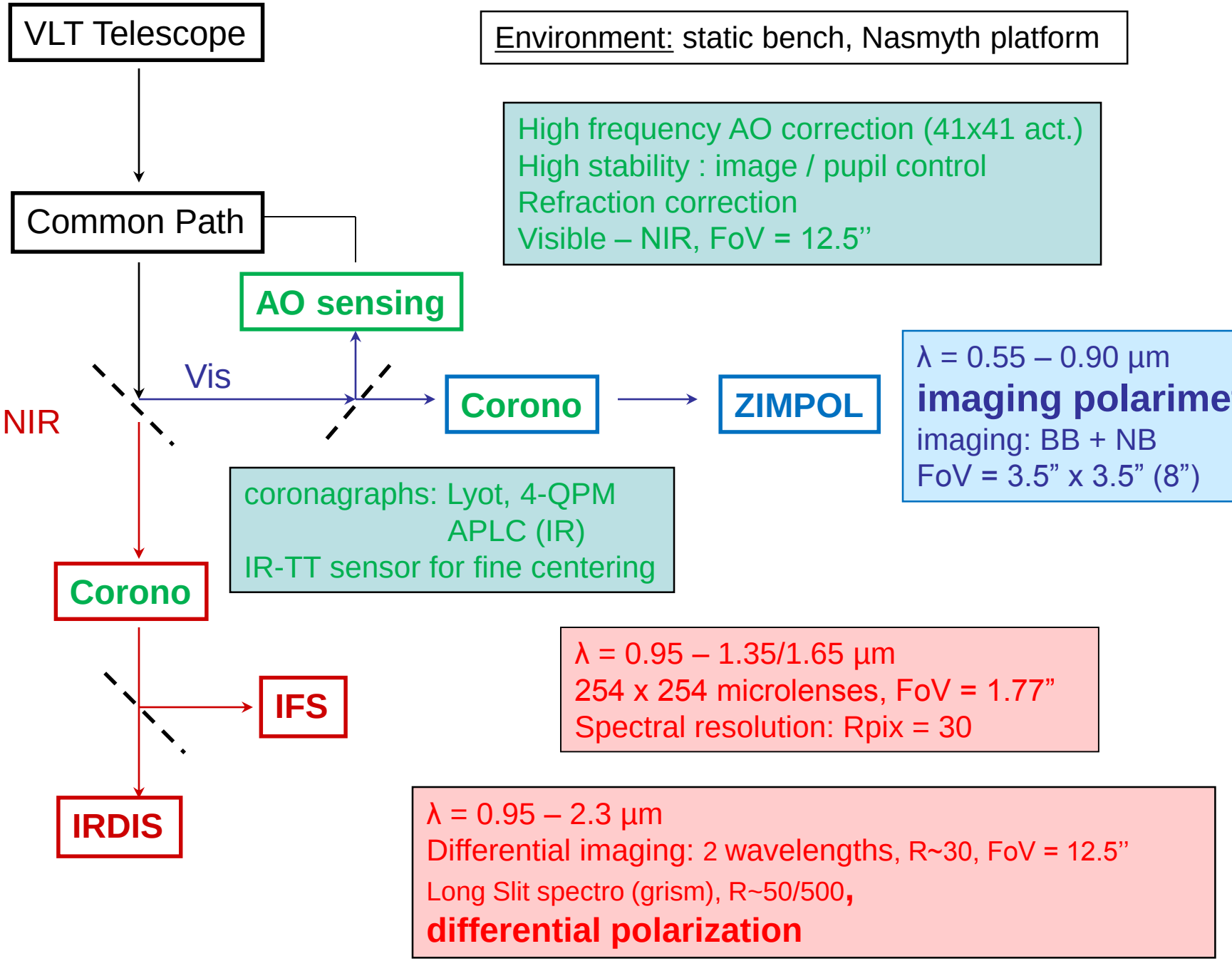
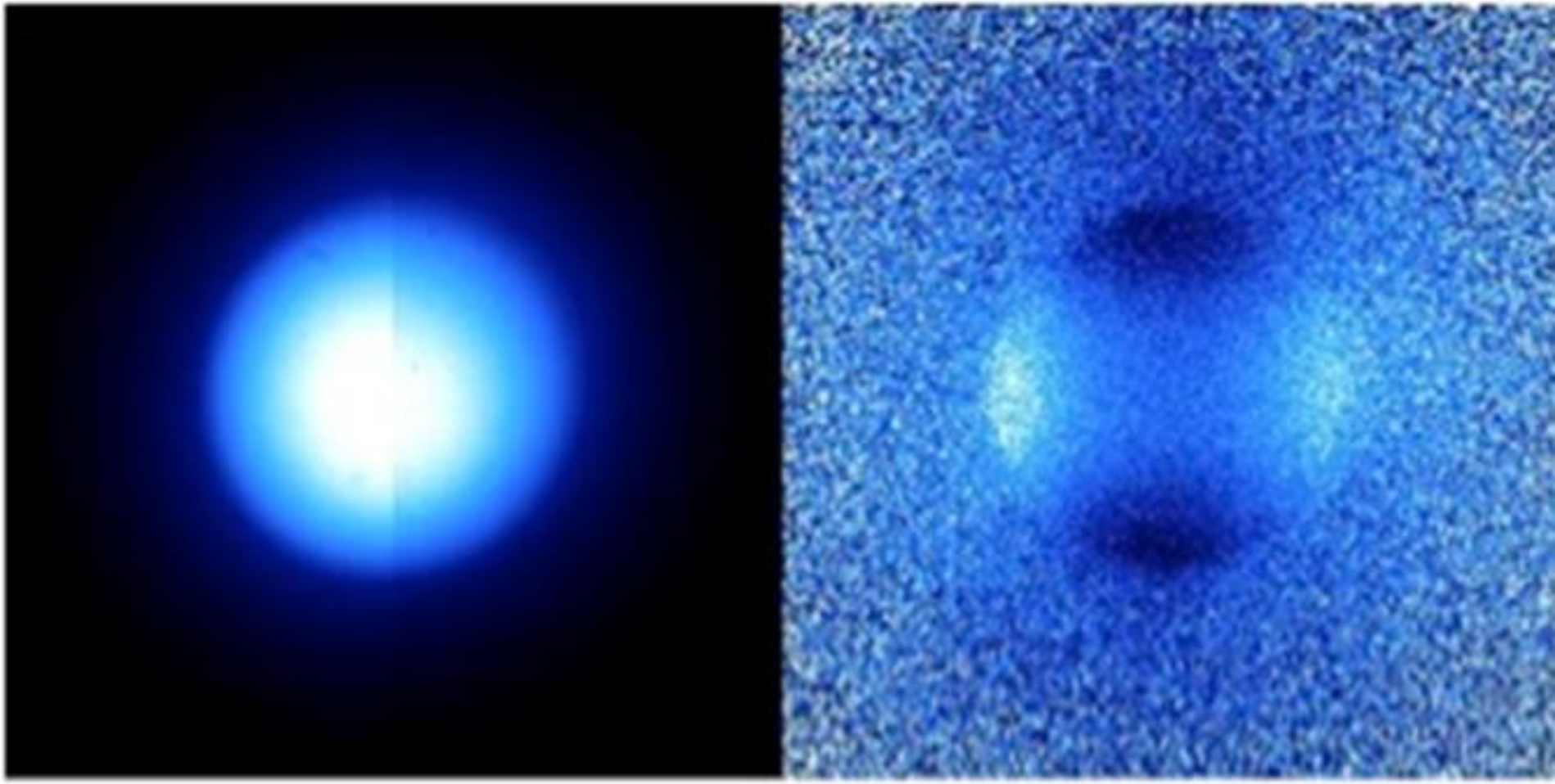
HD 196524
sep = 0.2”




VLT Telescope
Environment: static bench, Nasmyth platform
Common Path
High frequency AO correction (41x41 act.)
High stability : image / pupil control
Refraction correction
Visible – NIR, FoV = 12.5”
AO sensing
Vis
NIR
Corono
ZIMPOL
λ = 0.55 – 0.90 µm
imaging polarimetry
imaging: BB + NB
FoV = 3.5” x 3.5” (8”)
coronagraphs: Lyot, 4-QPM
APLC (IR)
IR-TT sensor for fine centering
Corono
IFS
λ = 0.95 – 1.35/1.65 µm
254 x 254 microlenses, FoV = 1.77”
Spectral resolution: Rpix = 30
IRDIS
λ = 0.95 – 2.3 µm
Differential imaging: 2 wavelengths, R~30, FoV = 12.5”
Long Slit spectro (grism), R~50/500,
differential polarization

Pretty polarization pictures

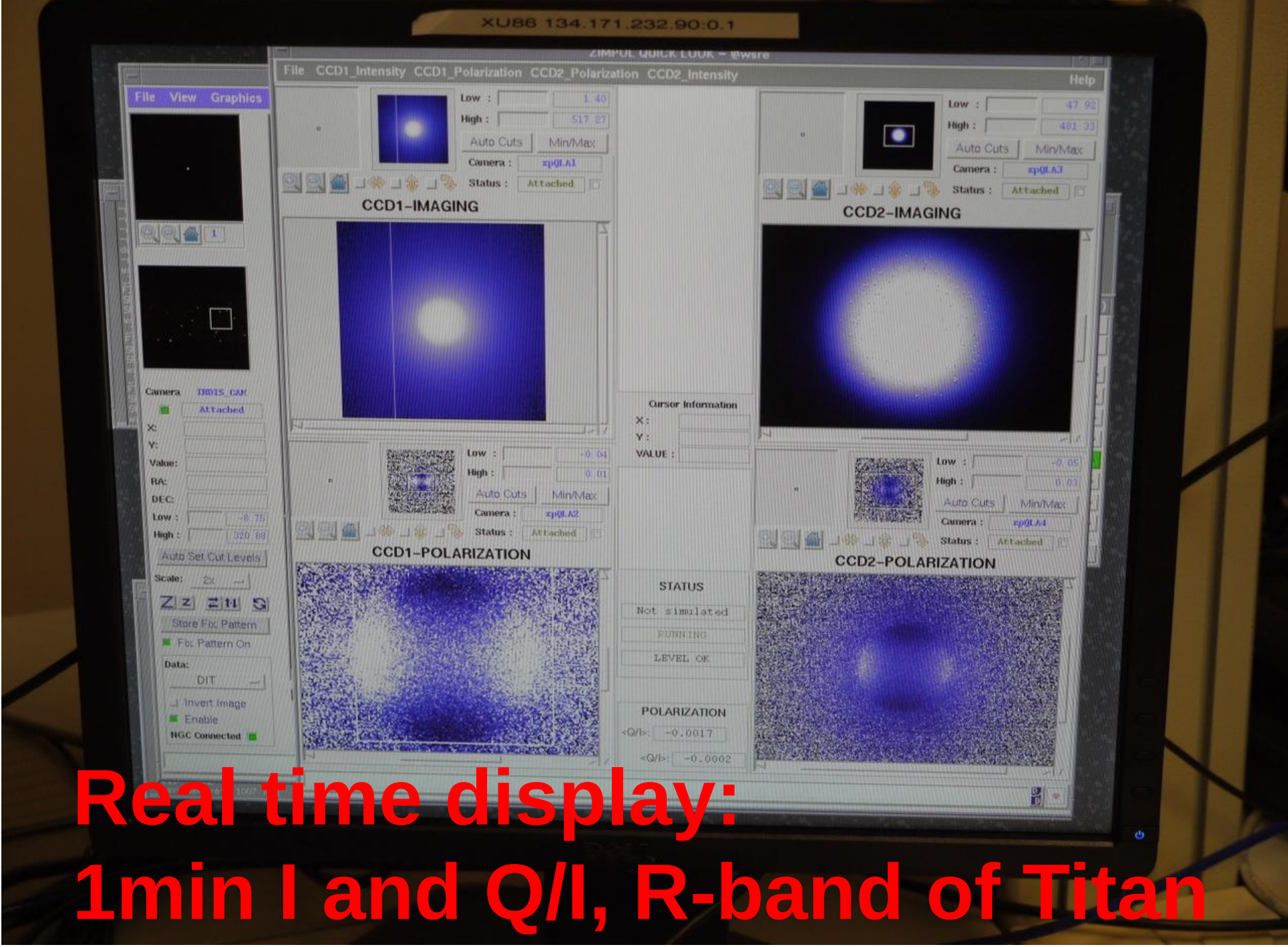


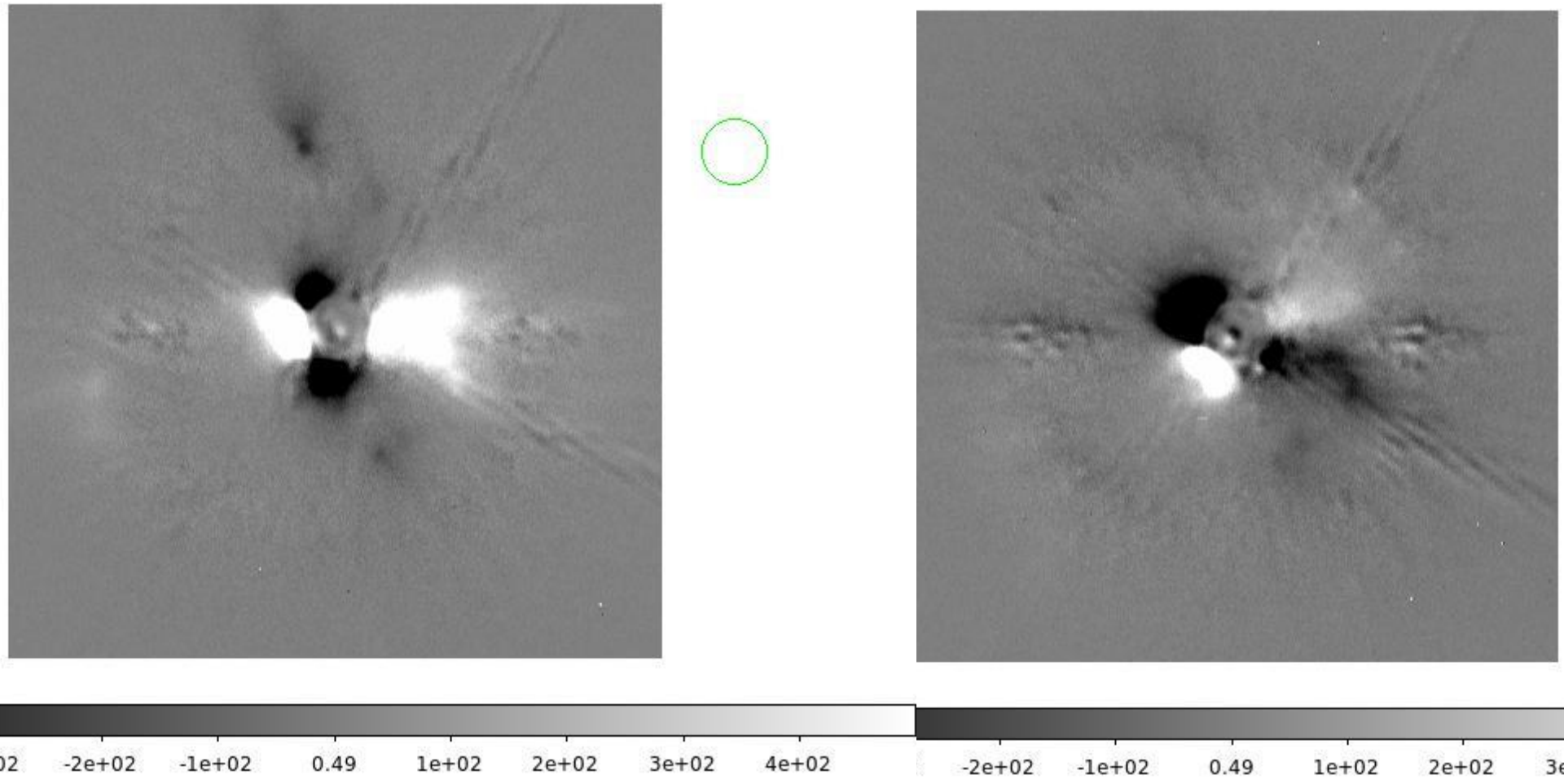
Stokes I
I_0+I_{90}

Titan

Stokes -Q
$-I_0+I_{90}$


Commissioning runs

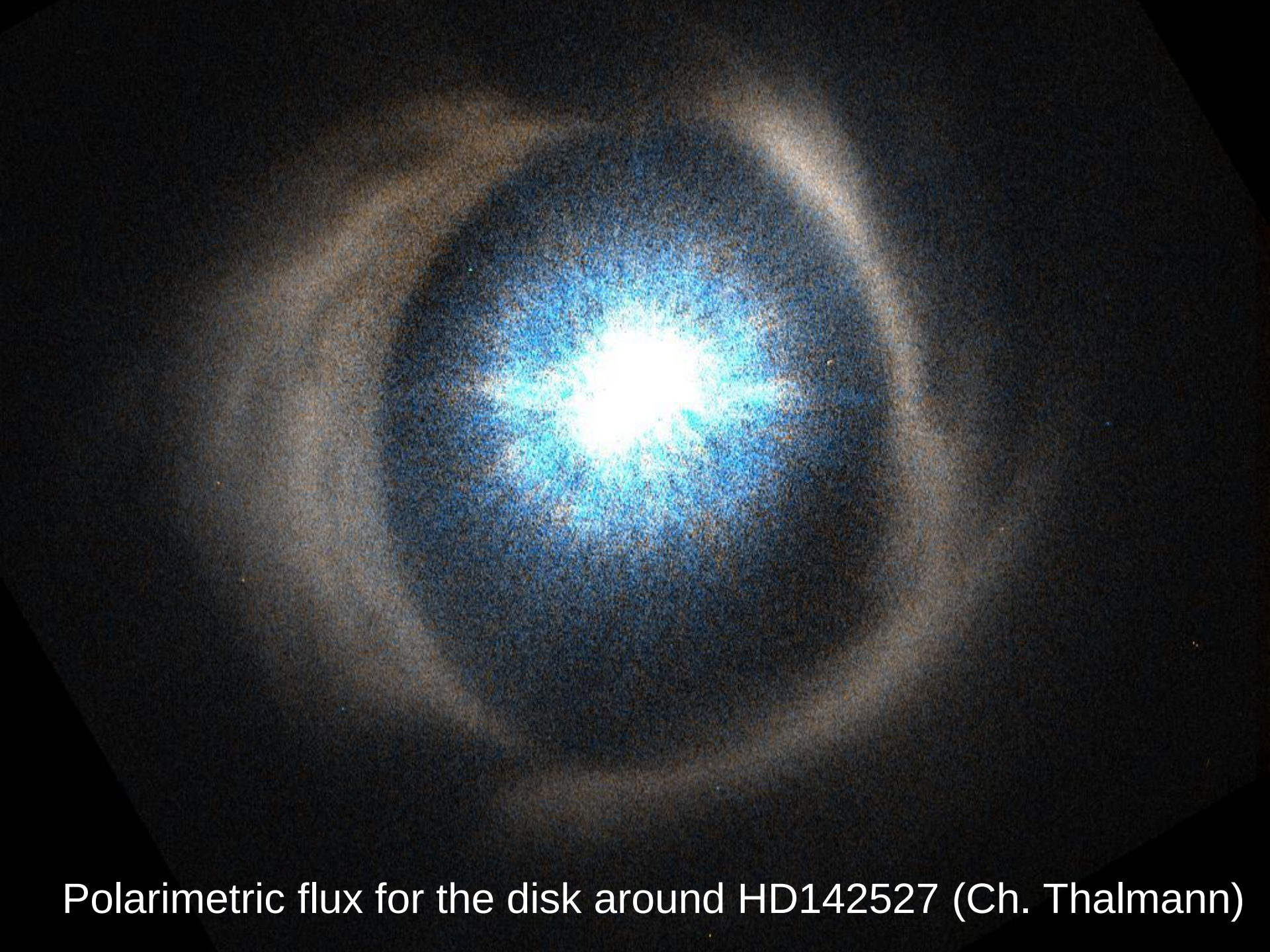

XUB6 134.171.232.90:0.1
File CCD1_Intensity CCD1_Polarization CCD2_Polarization CCD2_Intensity Help
File View Graphics
CCD1-IMAGING
CCD2-IMAGING
CCD1-POLARIZATION
CCD2-POLARIZATION
Auto Cuts
Min/Max
Camera :
Status :
Attached
Cursor Information
X :
Y :
VALUE :
STATUS
Not simulated
RUNNING
LEVEL OK
POLARIZATION
<Q/I>: -0.0017
<U/I>: -0.0002
Auto Set Cut Levels
Store Fix Pattern
Fix Pattern On
Invert Image
Enable
NGC Connected
Real time display:
1min I and Q/I, R-band of Titan



Stokes Q
$I_0 - I_{90}$

Stokes U
$I_{45} - I_{135}$

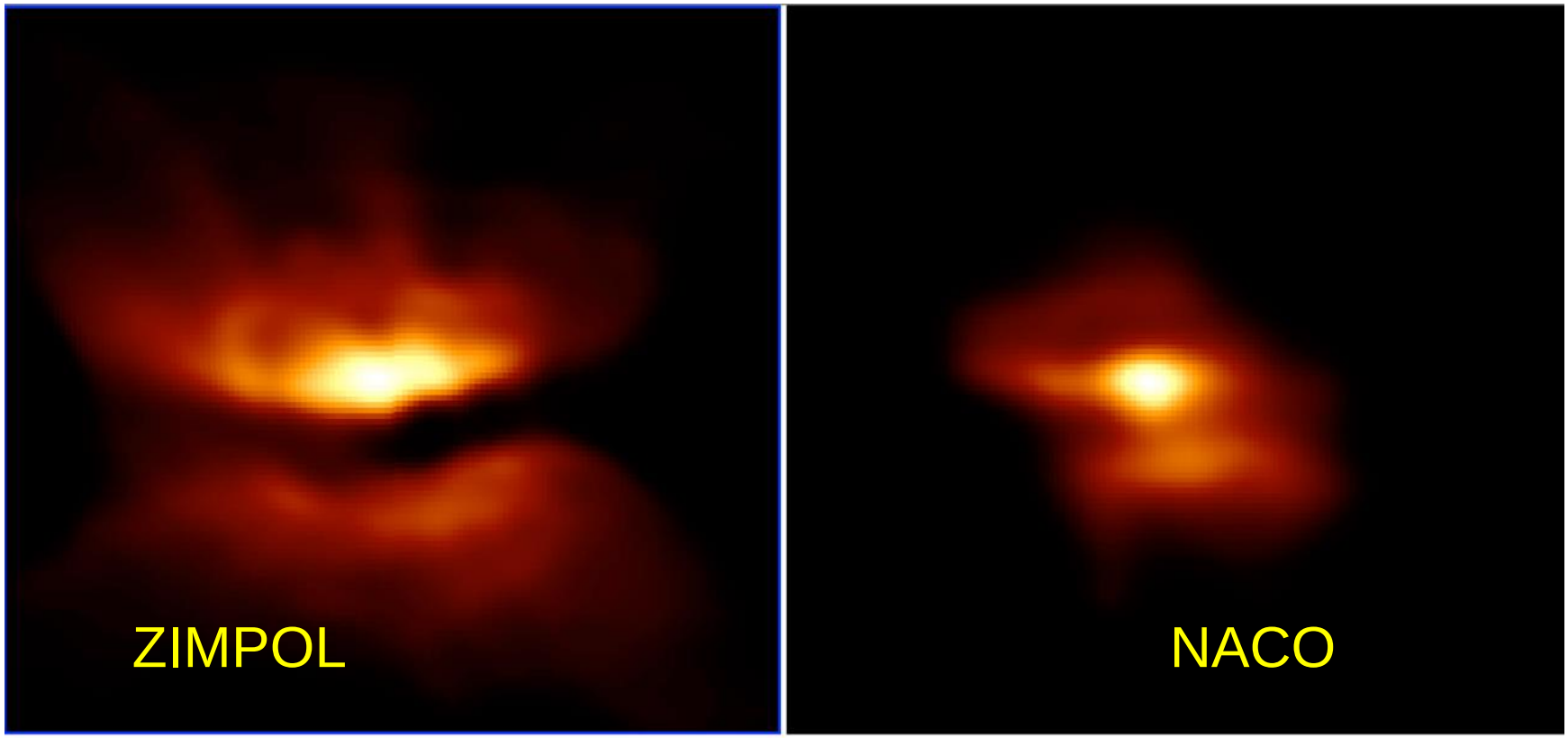
R Aqr: light scattering by the circumstellar dust within 0.3 arcsec



Polarimetric flux for the disk around HD142527 (Ch. Thalmann)

First papers - ESO science verification

(Kervella et al., 2015)



L2 Pup in polarized intensity

(dust disk around AGB star)

Polarized flux with IRDIS

M. Benisty et al.: Asymmetric features in the protoplanetary dis

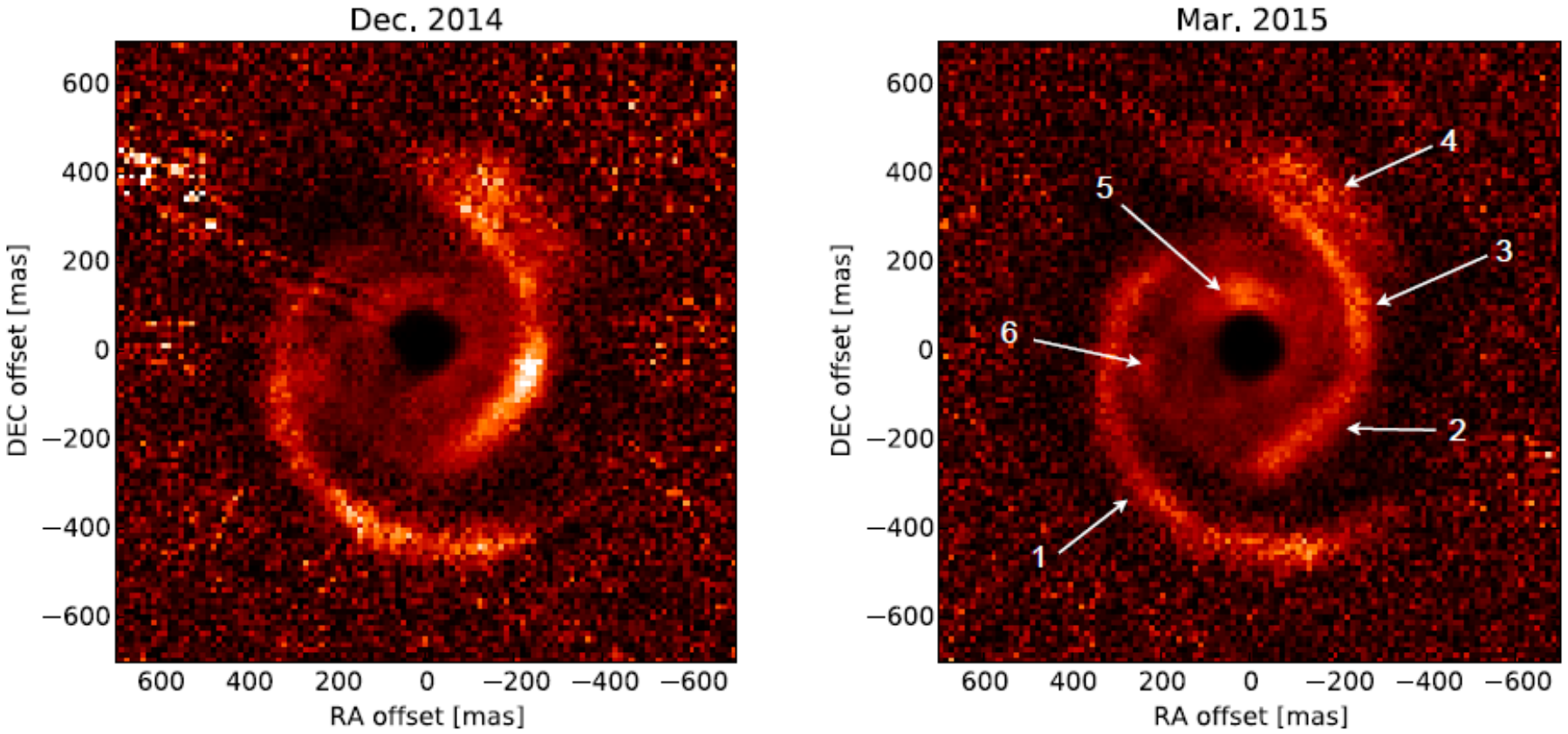


Fig. 1. *Left and middle*: polarized intensity images (Q_ϕ) obtained in December 2014 and March 20
radial map of the deprojected Q_ϕ image from March 2015 using $i = 21°$ and PA = 65°. The dashed
been scaled with the square of its distance from the star, r^2, to compensate for the r^{-2} dependenc
arbitrary.

SPHERE AO-assisted differential polarimetric imaging

SPHERE: R = 10mag star for AO in the field center

Infrared (IRDIS): 1.0 – 2.3µm

- “classical” two channel imaging polarimeter
- very high Strehl ratio (0.6-0.9)
- Linear polarization with HWP (0,45,22.5,67.5 degr)
- “larger” field of view 10” x 10”

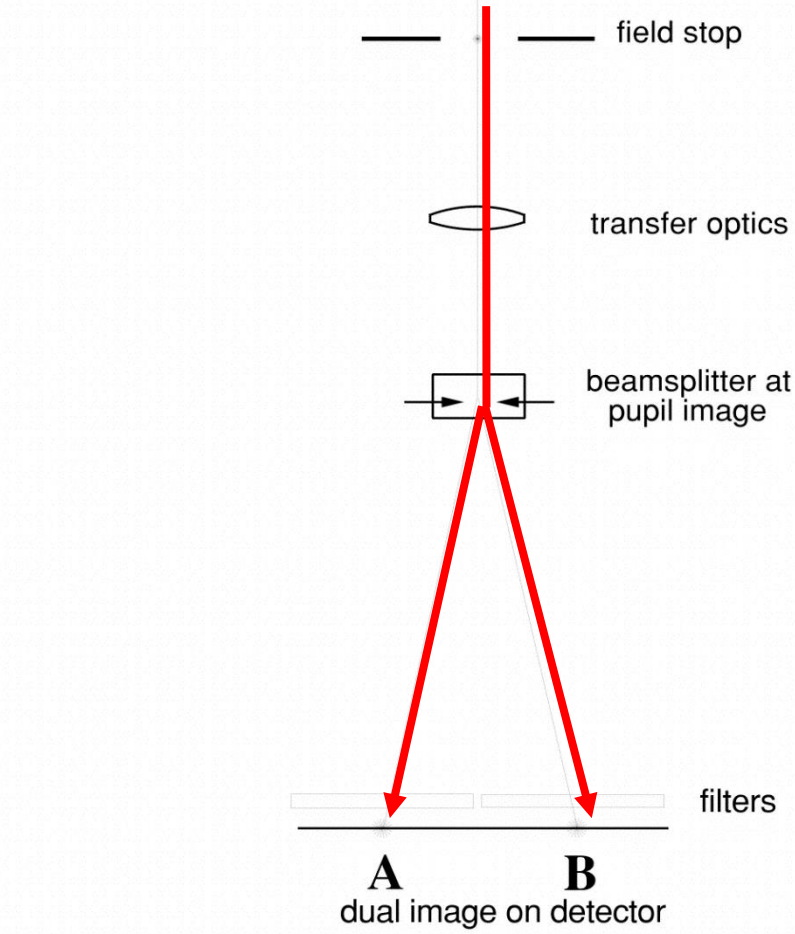
→ High performance AO with “standard” polarimetry

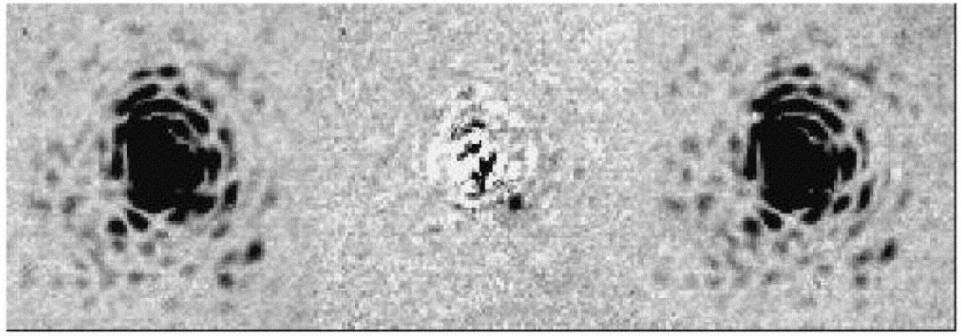
Optical (ZIMPOL): 0.52 - 0.9µm

- Fast modulation imaging polarimetry (linear polarization only)
- Lower Strehl ratio (0.1-0.5) → strong halo
- Polarimetry with active control of telescope and instrument polarization
- Small field of view 3.5” x 3.5”

→ High performance polarimetry to overcome strong AO-halo

From Racine et al. 1999





Differential imaging for high contrast observations

- slowly changing diffraction
- strongly variable speckles

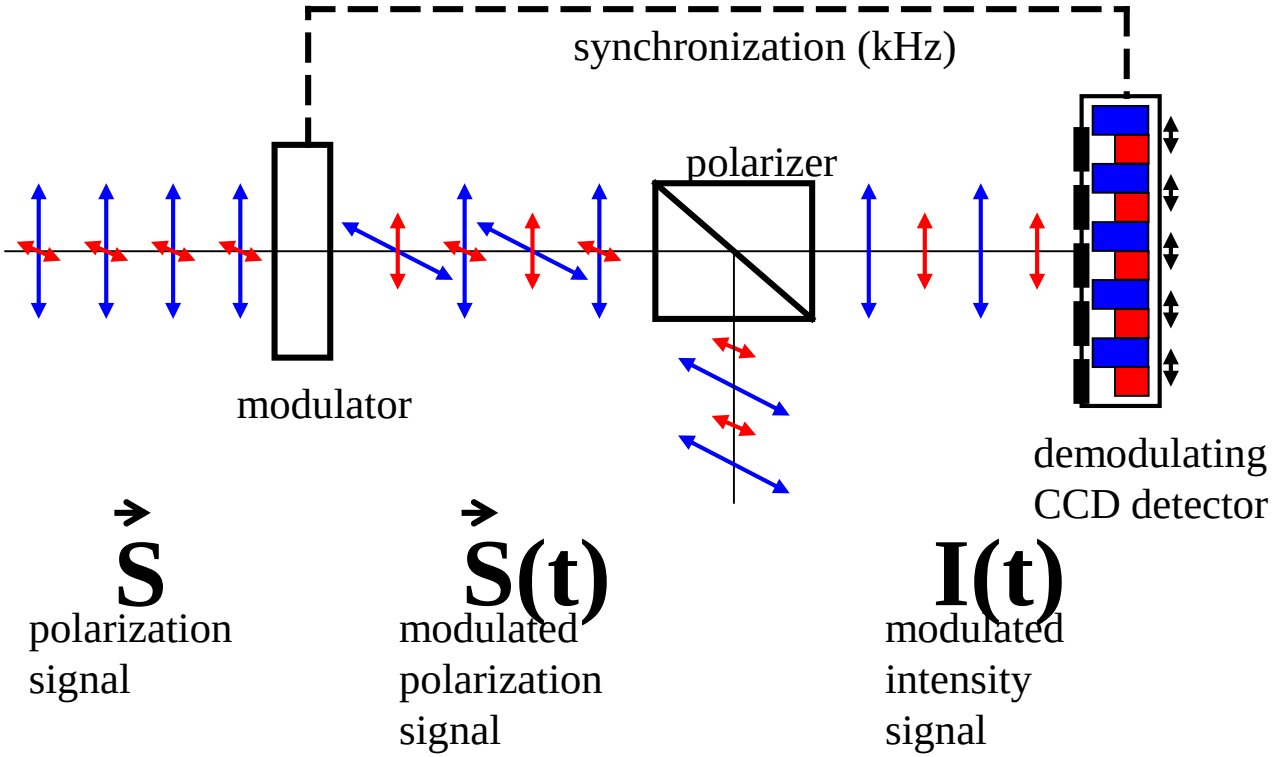
non-simultaneous frames
- PSF subtraction
- angular differential imaging

simultaneous frames
- spectral
- polarimetric

Standard pol. techniques
- double beam (Wollaston)
- fast modulation / single beam (e.g. PEM)

The ZIMPOL principle

(fast modulation imaging polarimetry, Povel et al. 1990)



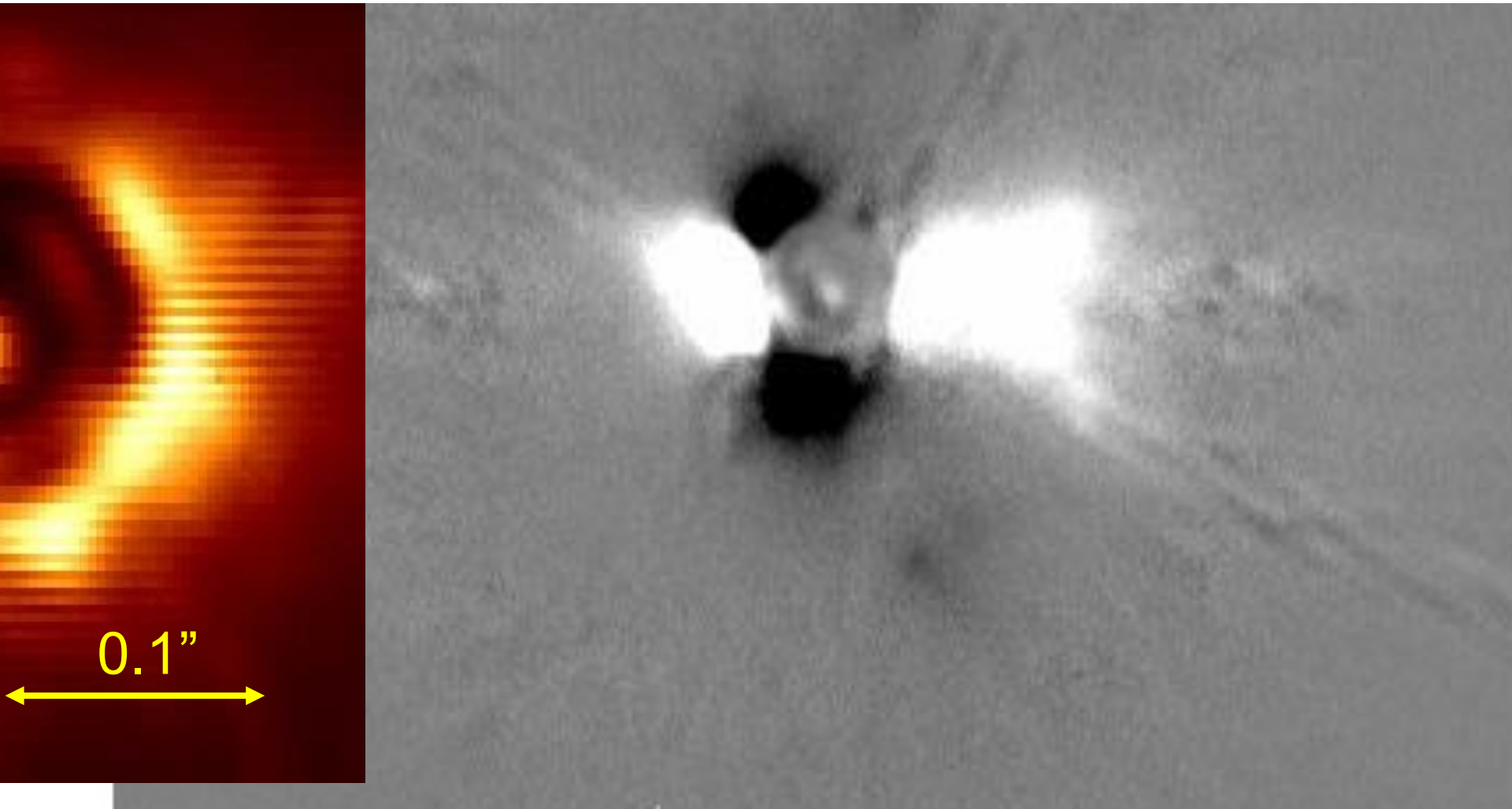
Advantages:

- images of two opposite polarization modes are created almost simultaneously
  → modulation faster than seeing variations
- both images are recorded with same pixel
- both images are subject to almost exactly the same aberrations
- integration over many modulation cycles without readout (low RON)

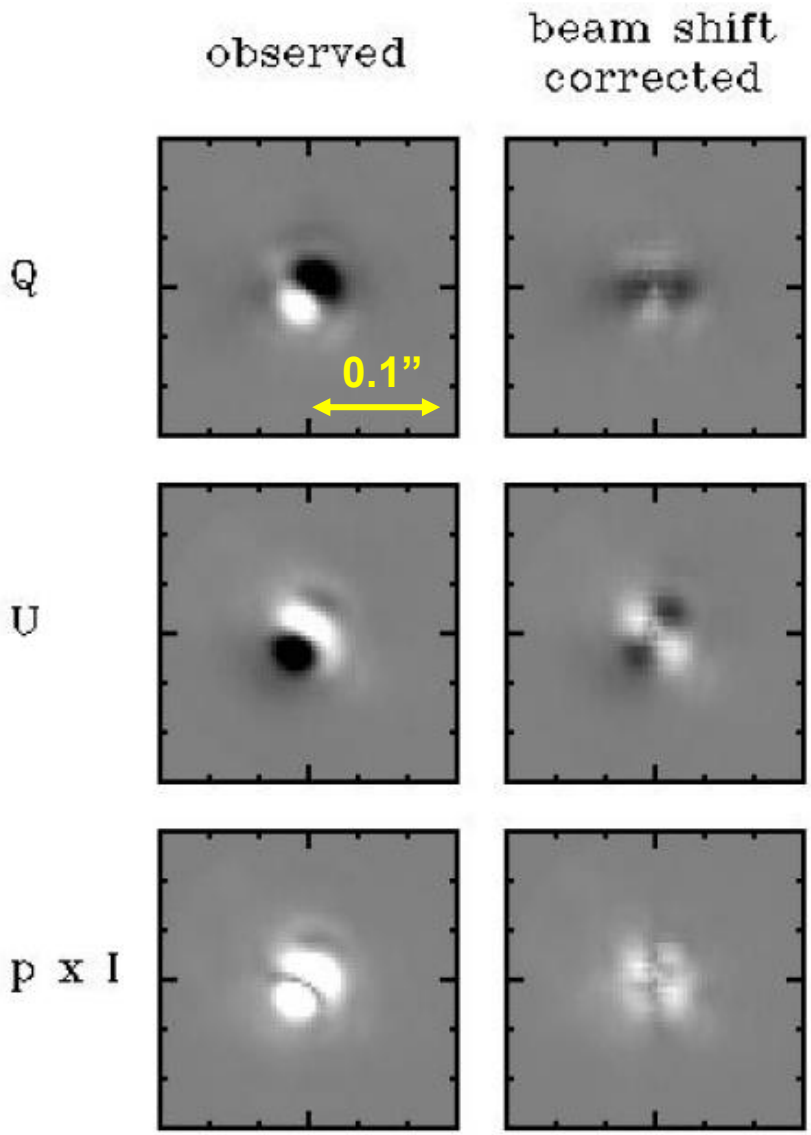
ZIMPOL coronagraphic polarimetry

Left: raw frame with even and odd rows with I_0 and I_{90}

Right: reduced image I_0-I_{90}



Performance: R Aqr scattering polarization



VLT and SPHERE produce a differential polarimetric beam shift of about 0.5 mas

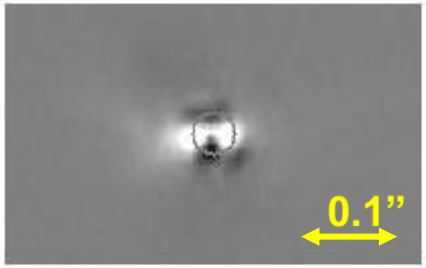
→ Can be corrected if PSF is well observed
(and assuming that peak is not polarized)

→ Allows measurement of circumstellar polarization down to separations of ~30 mas

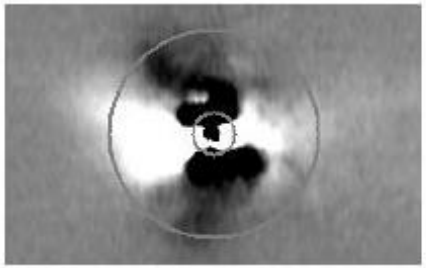
ZIMPOL: large dynamic range

R Aqr Stokes Q signal

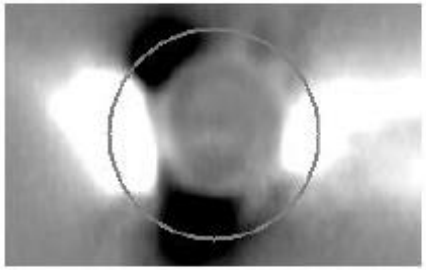
Narrow band (820nm filter) of PSF peak

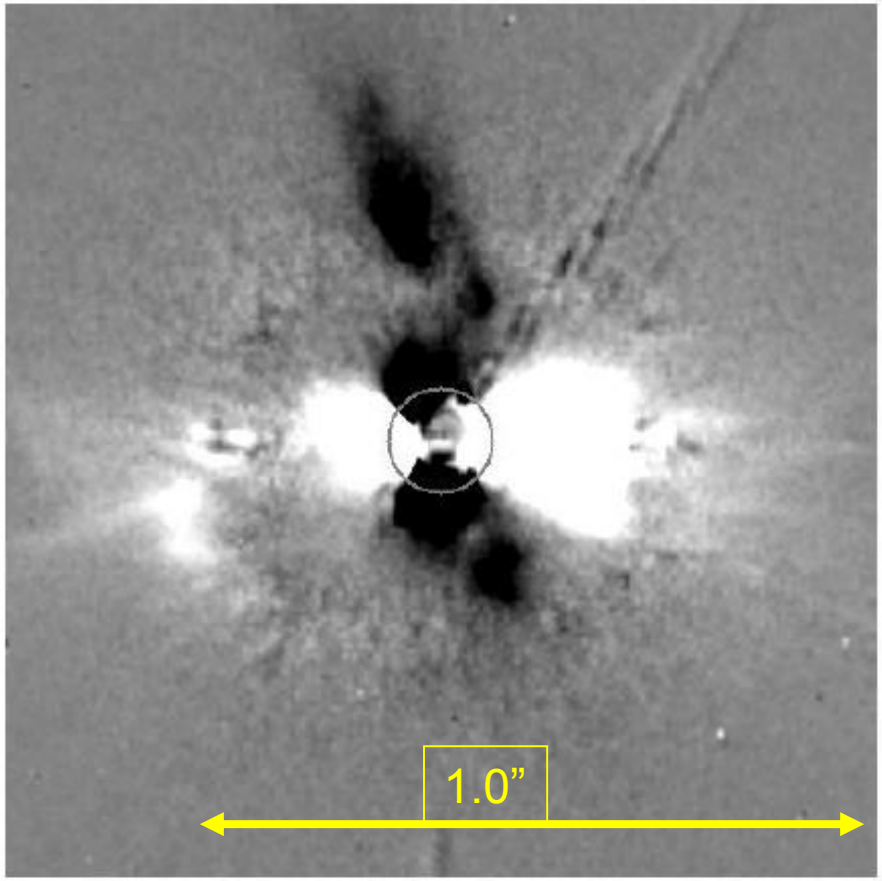


Broad-band I short saturated exposure

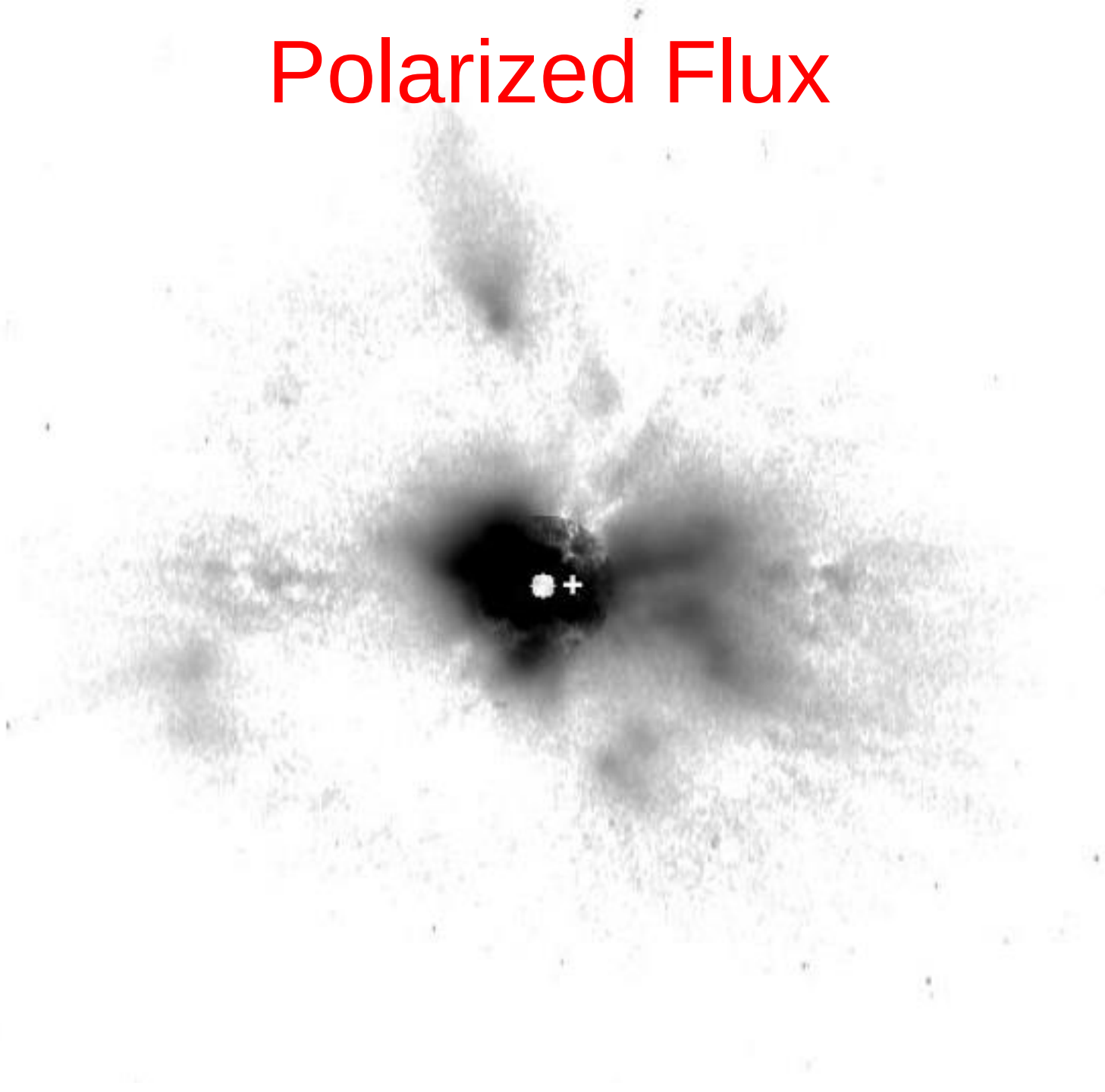


Broad-band I, deep coronagraphic exposure

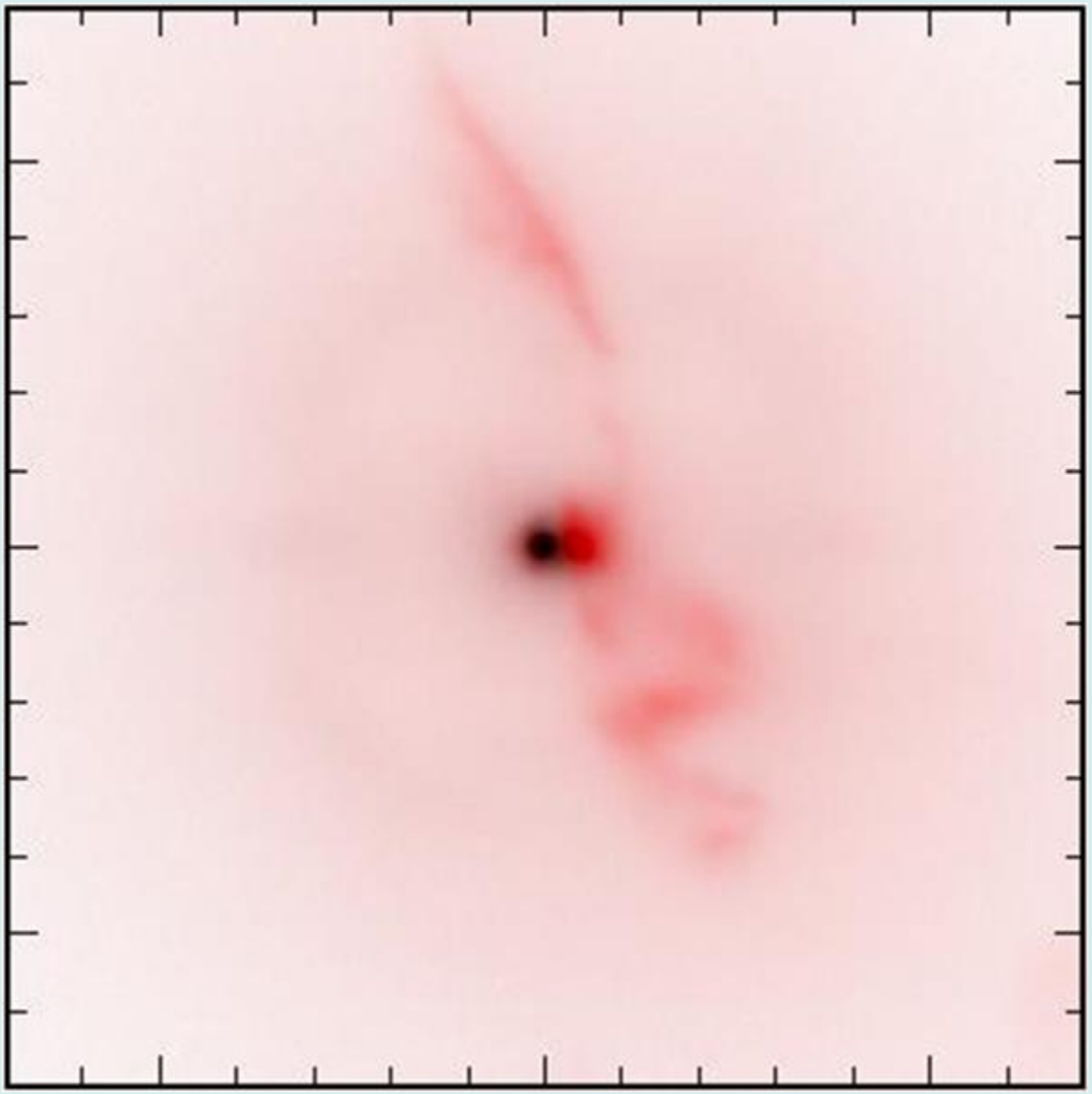




Polarized Flux



Continuum (black) and Hα map (red)



Outlook

- SPHERE/ZIMPOL is build for the search of reflected (polarized) light planets around the nearest stars → search is ongoing in GTO
- it is offered to the community through open time proposals

If this proves to be a very successful instrument (you can participate)

→strong support for similar E-ELT instrument !