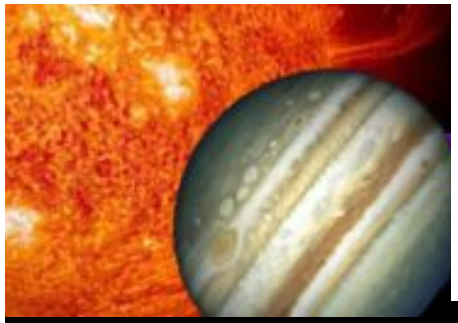


VLT/SPHERE high contrast observations of exoplanets and debris disks

Jean-Luc Beuzit (PI), **David Mouillet** (PS),
Markus Feldt (Co-PI), Pascal Puget (PM), Kjetil Dohlen (SE), F. Wildi (AIT),
and numerous participants from 12 European institutes !

IPAG, MPIA, LAM, ONERA, LESIA, INAF, Geneva Observatory,
Lagrange, ASTRON, ETH-Z, UvA, ESO

Co-Is: G. Chauvin (IPAG, Grenoble), T. Henning (MPIA, Heidelberg), C. Moutou (LAM, Marseille), A. Boccaletti (LESIA, Paris), S. Udry (Observatoire de Genève), M. Turrato (INAF, Padova), H.M. Schmid (ETH, Zurich), F. Vakili (Lagrange, Nice), C. Dominik (UvA, Amsterdam)
T. Fusco (ONERA responsible), M. Kasper (ESO responsible)

SPHERE

What do we need to observe exoplanets and debris disks in optical and NIR ?

« We just need better contrast ! »

(Glenn Schneider, yesterday)

SPHERE

What do we need to observe exoplanets and debris disks in optical and NIR ?

« We just need better contrast ! »

(Glenn Schneider, yesterday)

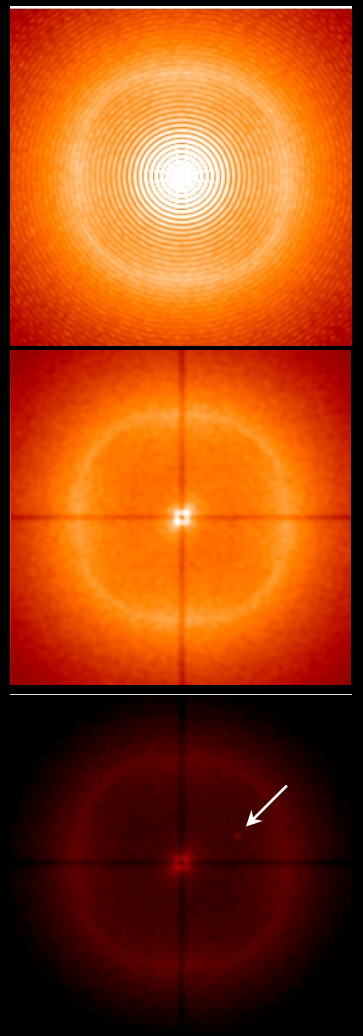
… and long-term motivation:

Thanks to βPic wonderful driver and to all the actors along this constantly renewed 30-year study

SPHERE

Designed for planetary system studies

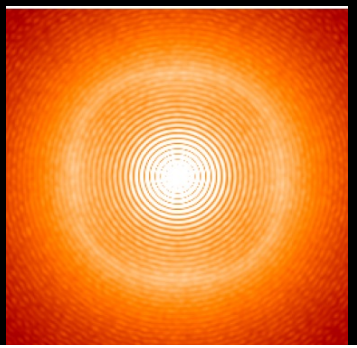
- High contrast detection capability
  - ✓Extreme AO
  - ✓Coronagraphy
  - ✓Differential detection: high image stability, multi-lambda simultaneous observation (IFS, imaging), polarization

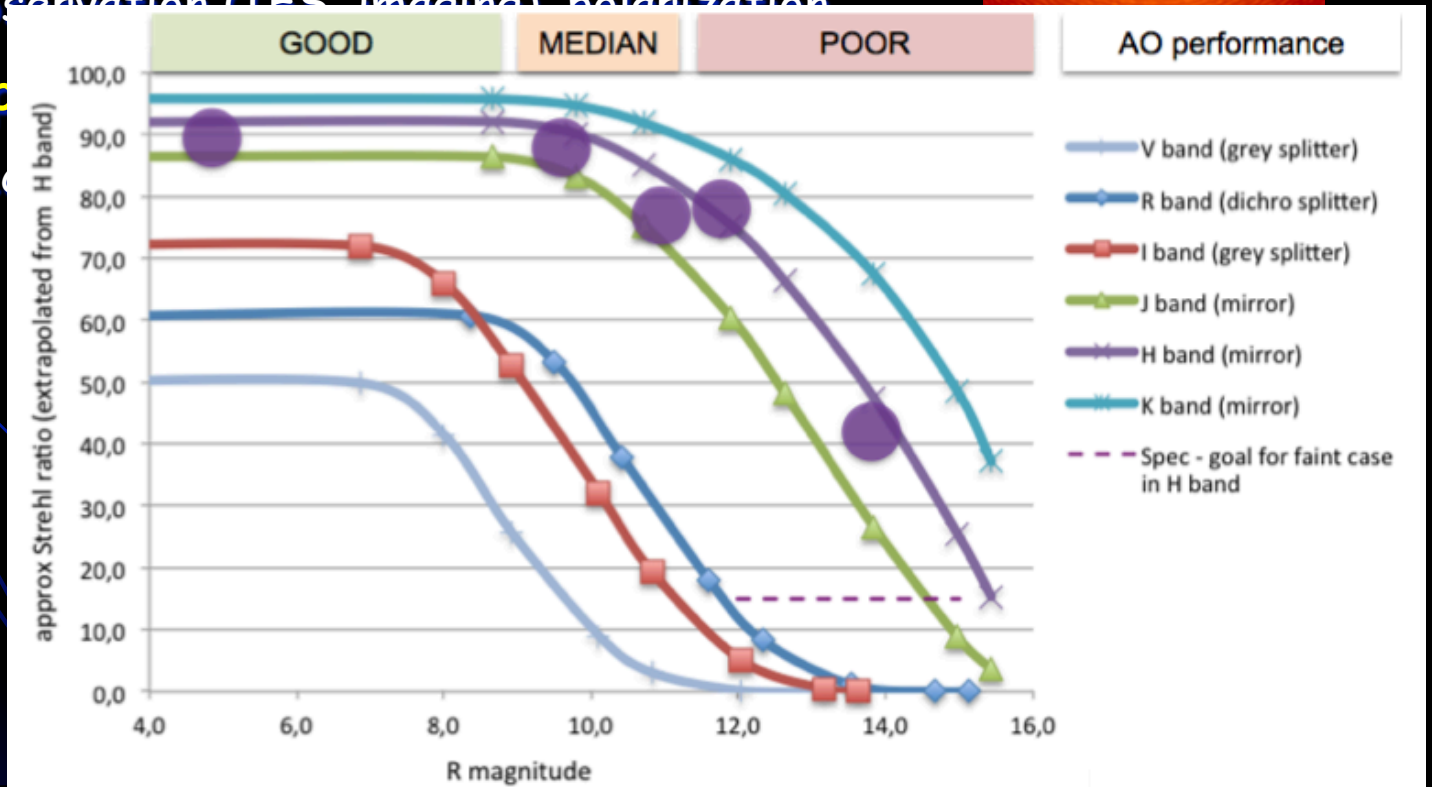


SPHERE

Designed for planetary system studies

- High contrast detection capability
  - ✓Extreme AO
  - ✓Coronagraphy
  - ✓Differential detection: high image stability, multi-lambda simultaneous obs
- for a large samp
  - ✓ optimal corre

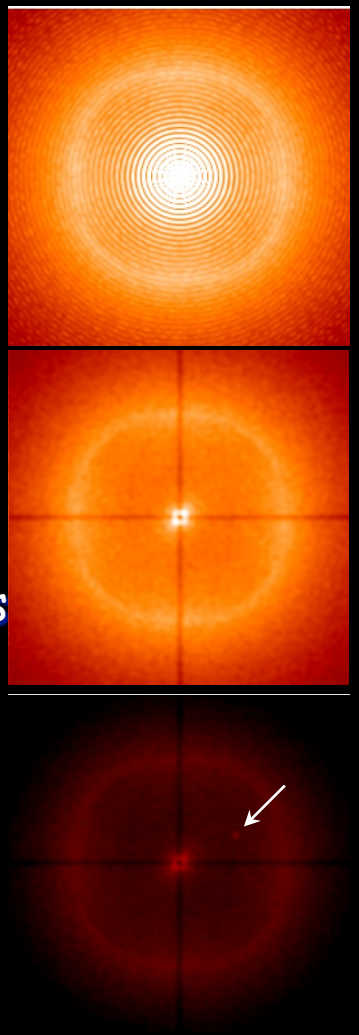




SPHERE

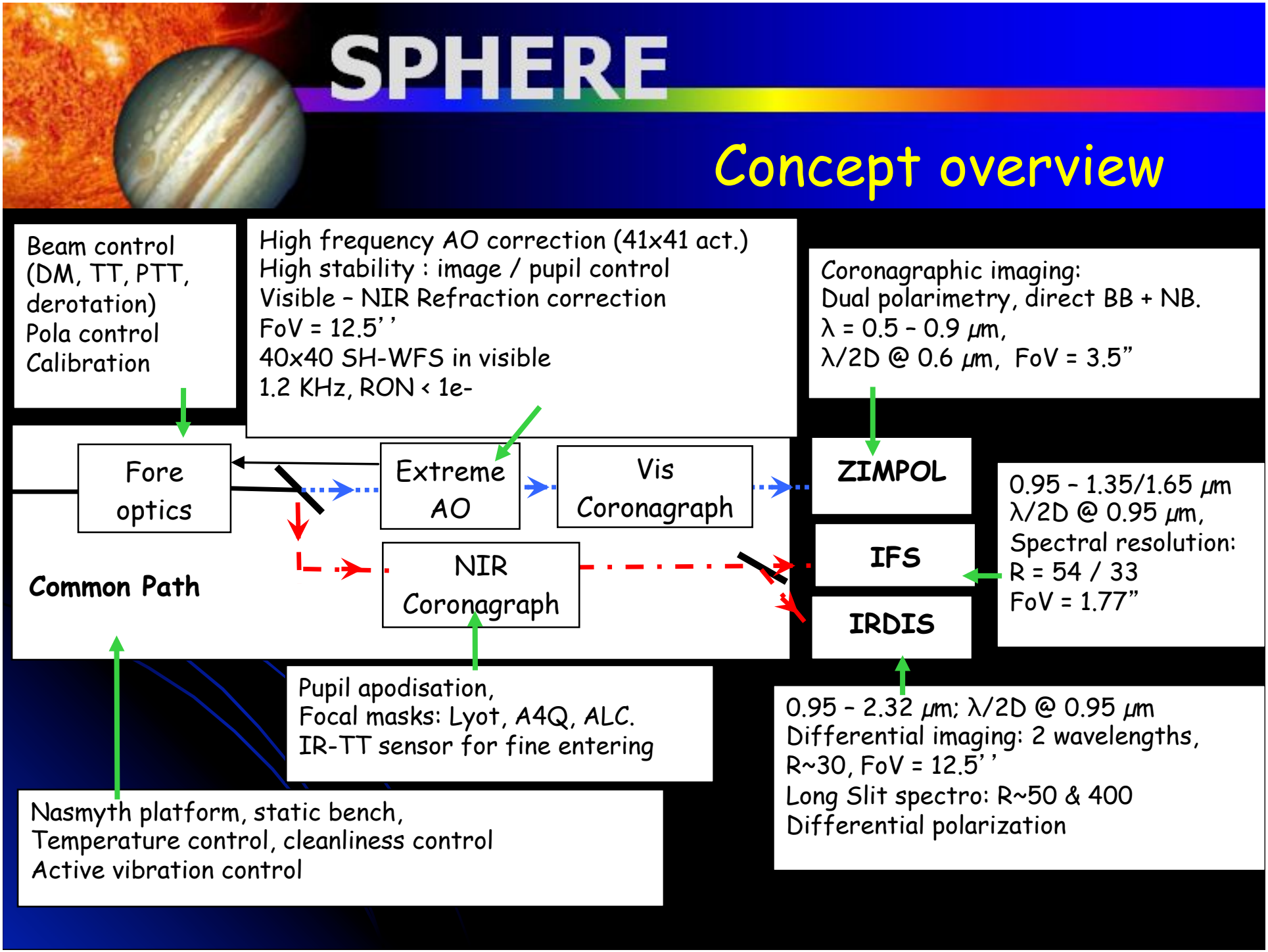
Designed for planetary system studies

- High contrast detection capability
  - ✓Extreme AO
  - ✓Coronagraphy
  - ✓Differential detection: high image stability, multi-lambda simultaneous observation (IFS, imaging), polarization
- for a large sample of bright stars
  - ✓ optimal correction up to R ~ 9-10 (…and up to R>11 !)
- ✓ Separations: optimized for the 0.2 – 0.8" range, with access to separations down to <50mas, and up to 6"
- ✓ Complementary information in Vis and NIR:
  - ✓High angular resolution imaging in a variety of filters
  - ✓Spectral characterisation up to medium resolution
  - ✓Polarization and diff. Imaging in NIR and VIS.



SPHERE

Concept overview



SPHERE

SPHERE: sub-systems main properties

	ZIMPOL	IRDIS	IFS
FoV	Sq 3.5" (instantaneous) Up to 4'' radius (mosaic)	Sq 11"	Sq 1.77"
Spectral Range	0.5 – 0.9 µm	0.95 – 2.32 µm	0.95 – 1.35/1.65 µm
Spectral information	BB, NB	BB, NB Slit spectro: 50/400	50 / 30
Linear Polarisation	Simultaneous on same detector, x 2 arms, exchangeable	Simultaneous dual beam, exchangeable	x

Coronography: no /4Q / Lyot

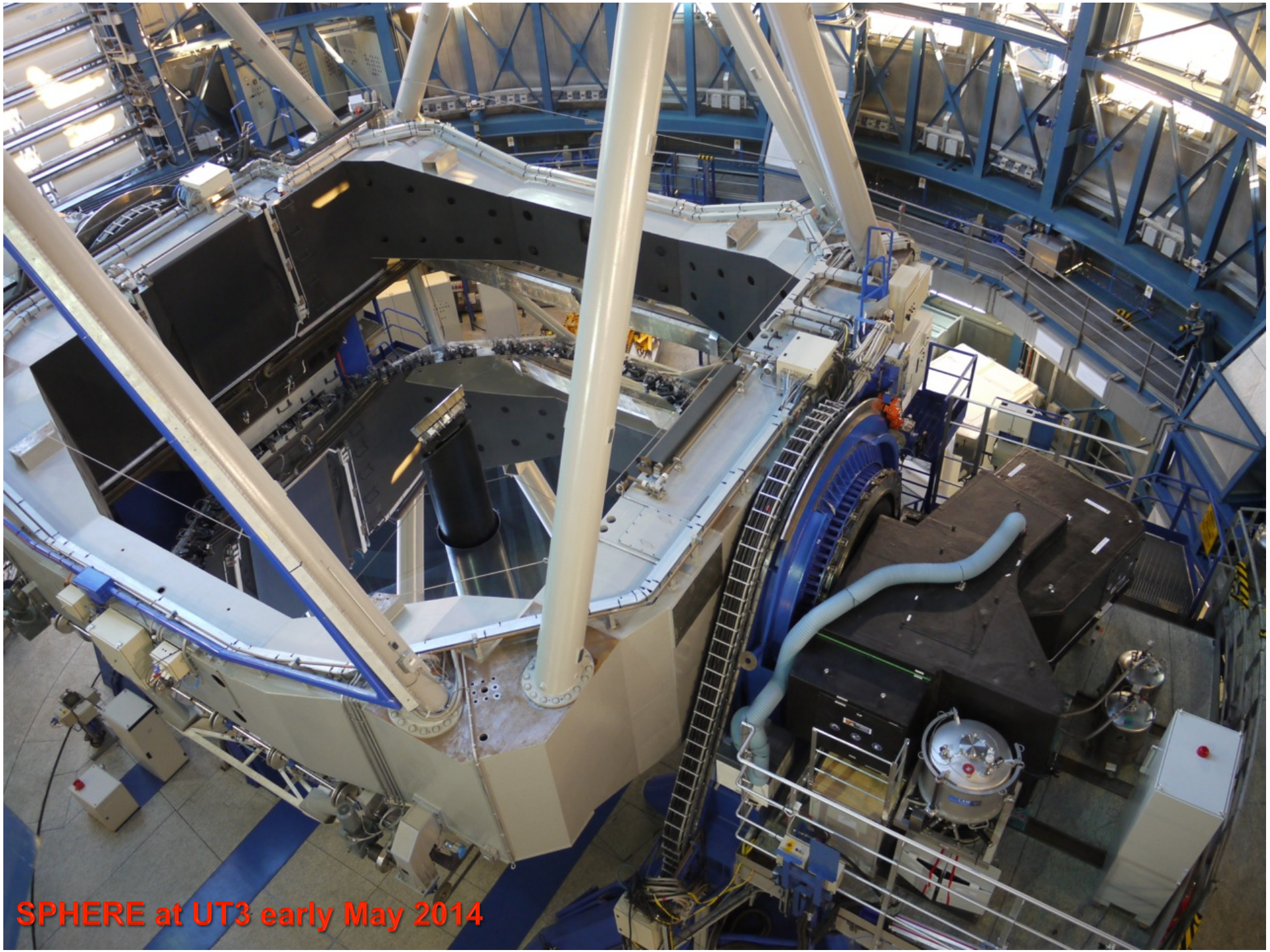
Rotation at Nasmyth:

- Pupil-stab. (instrument fixed wrt tel.)
- Field-stab (slit spectro, long DIT…)
- No rotation: minimize crosstalk…)

AO sensitivity for high contrast: R=9.5 for NIR; R=9 for R; R=7.8 for whole VIS

Separation range where improved contrast: 2 - 20 λ/D, ie 30-300 mas in R, or 80 – 800 mas in H

Mode switching: not VIS and NIR in same night


SPHERE at UT3 early May 2014

SPHERE

First light (May 4th)

- Acceptance in Europe: Dec. 2013
- Packing and shipping: Jan.-Feb. 2014
- AIT in Paranal: March-April 2014
- 1st light: May 4th
- Commissioning: 4x12n May, July, August, October.

- 1st open Call for Proposal: Sept 2014

- Science Verification: Dec 2014

SPHERE

High contrast in the correction area

High resolution PSF

Saturated PSF

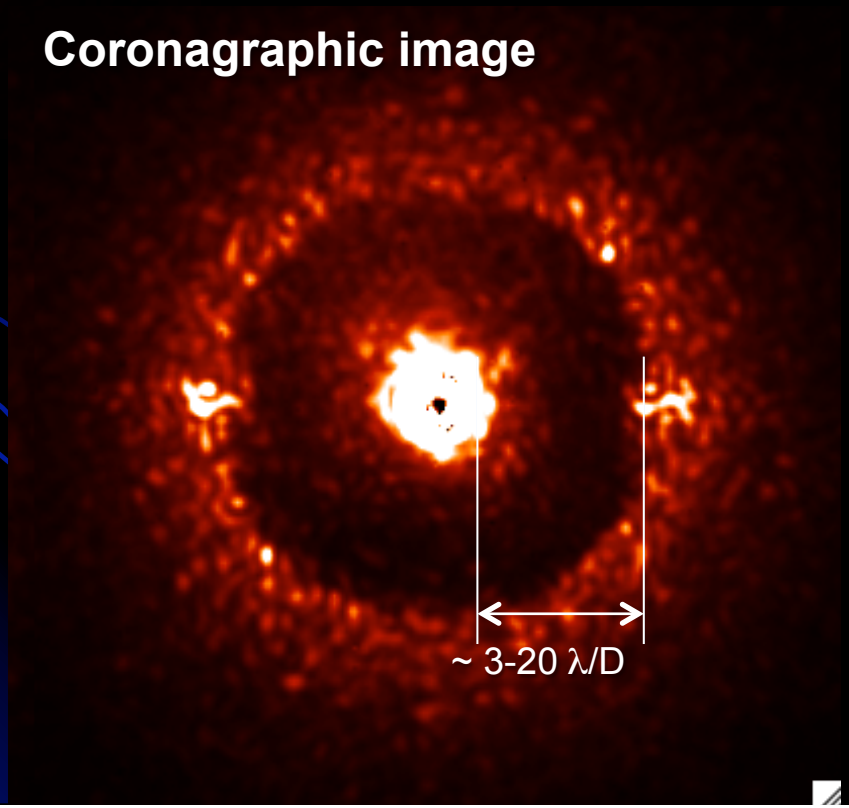


Image at 1.28 μm

SPHERE

Down to very short separations

Y band (1 μm)

H band (1.6 μm)

Ks band (2.2 μm)

Apodised PSFs

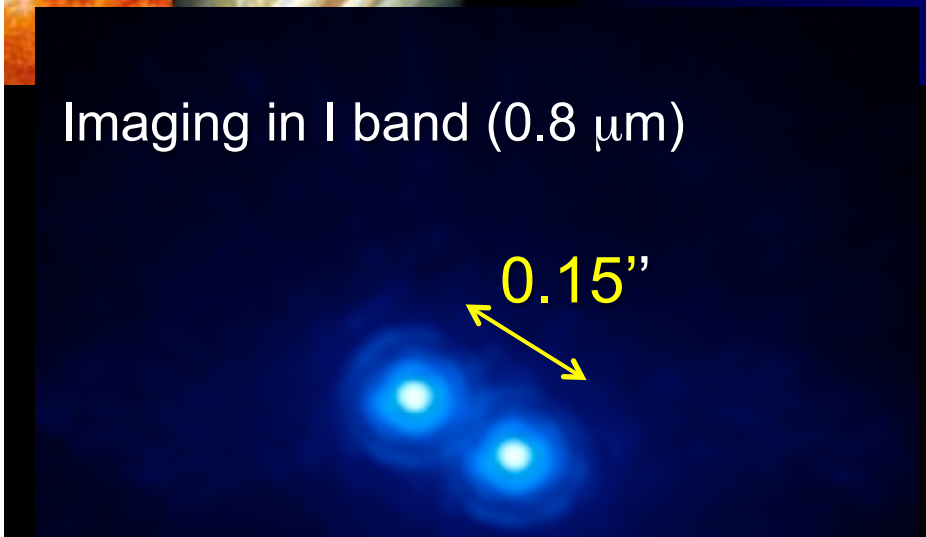
Coronagrpahic images

Moderate contrast Δm~5, at 95 mas !

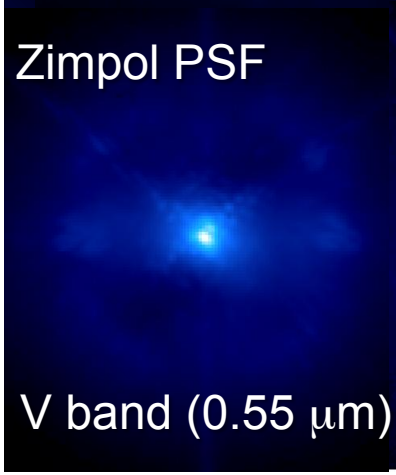
SPHERE

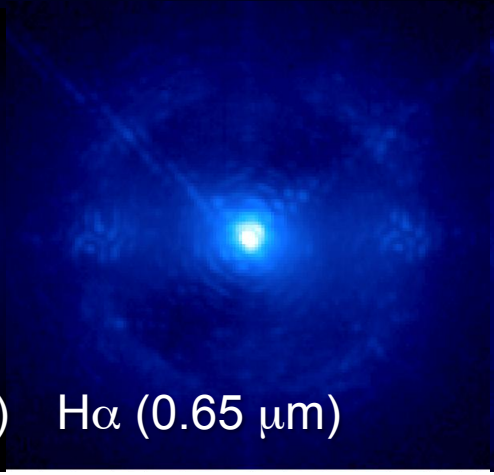
Down to very short separations

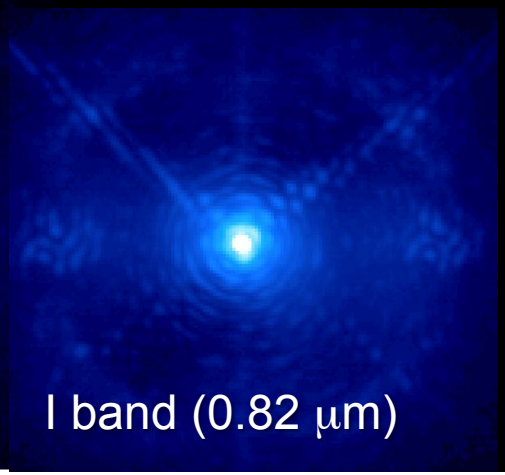
Imaging in I band (0.8 μm)



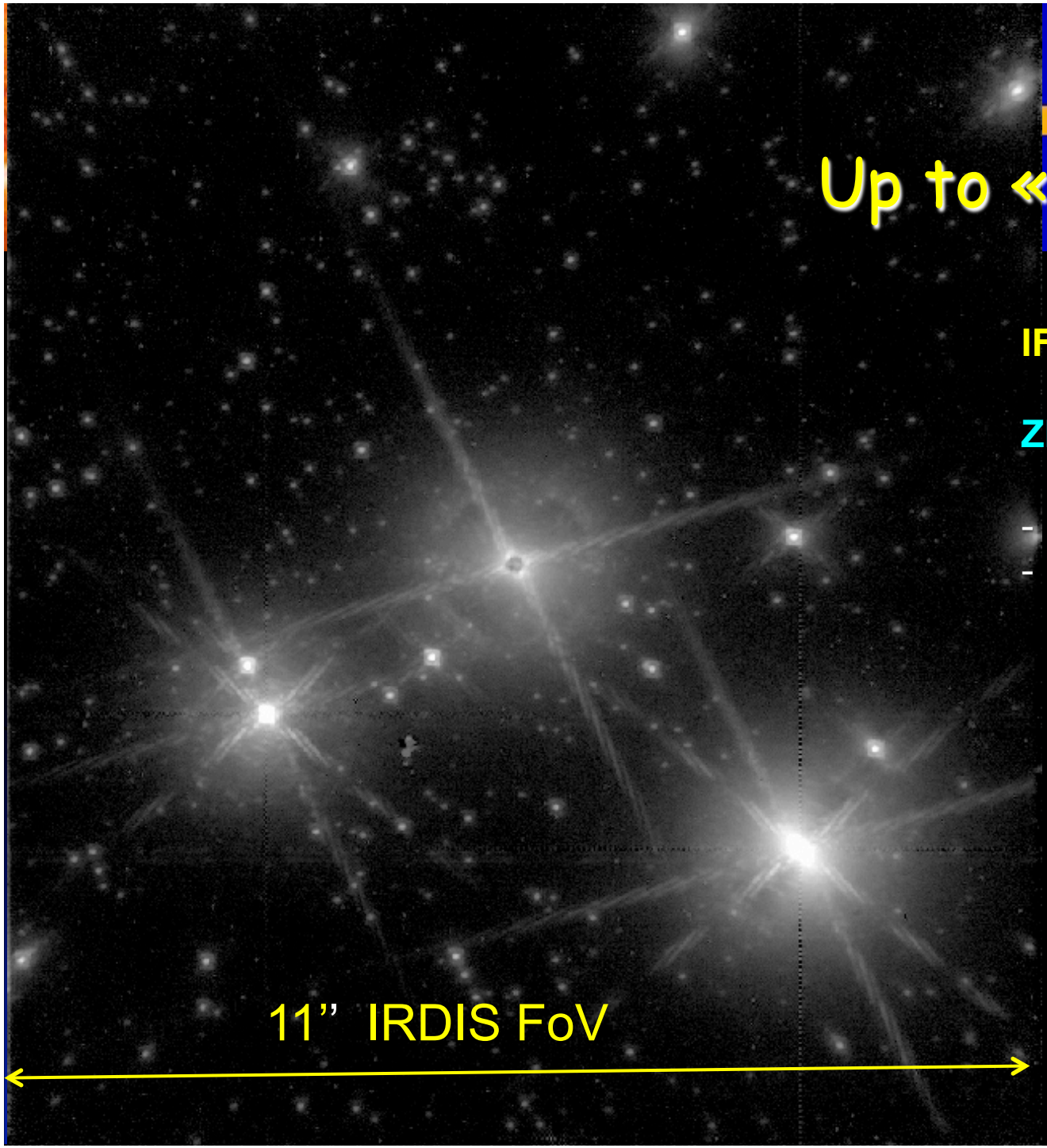
Zimpol PSF


V band (0.55 μm)


Hα (0.65 μm)


I band (0.82 μm)

Up to « wide field »



IFS: 1.8 ‘’ FoV

ZIMPOL:

- 3.5’’wide instantaneous
- up to 8’’ diameter with off-axis mosaic (not offered in P95)

SPHERE

High contrast in the correction area

Role of AO spatial filter

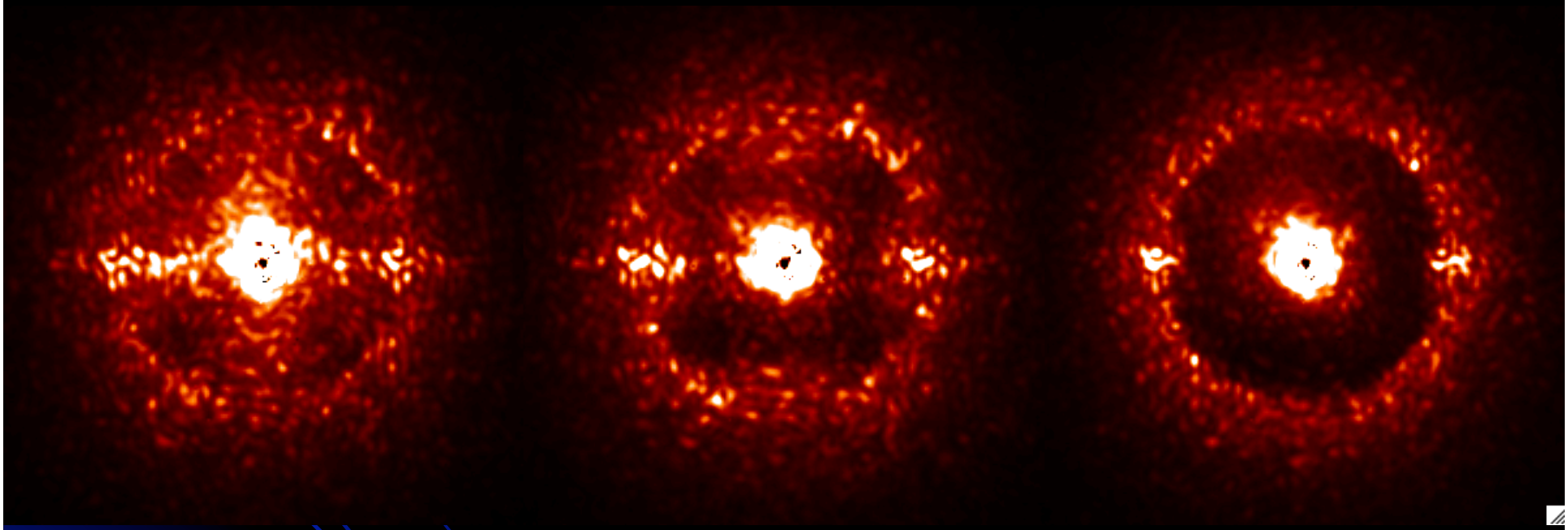
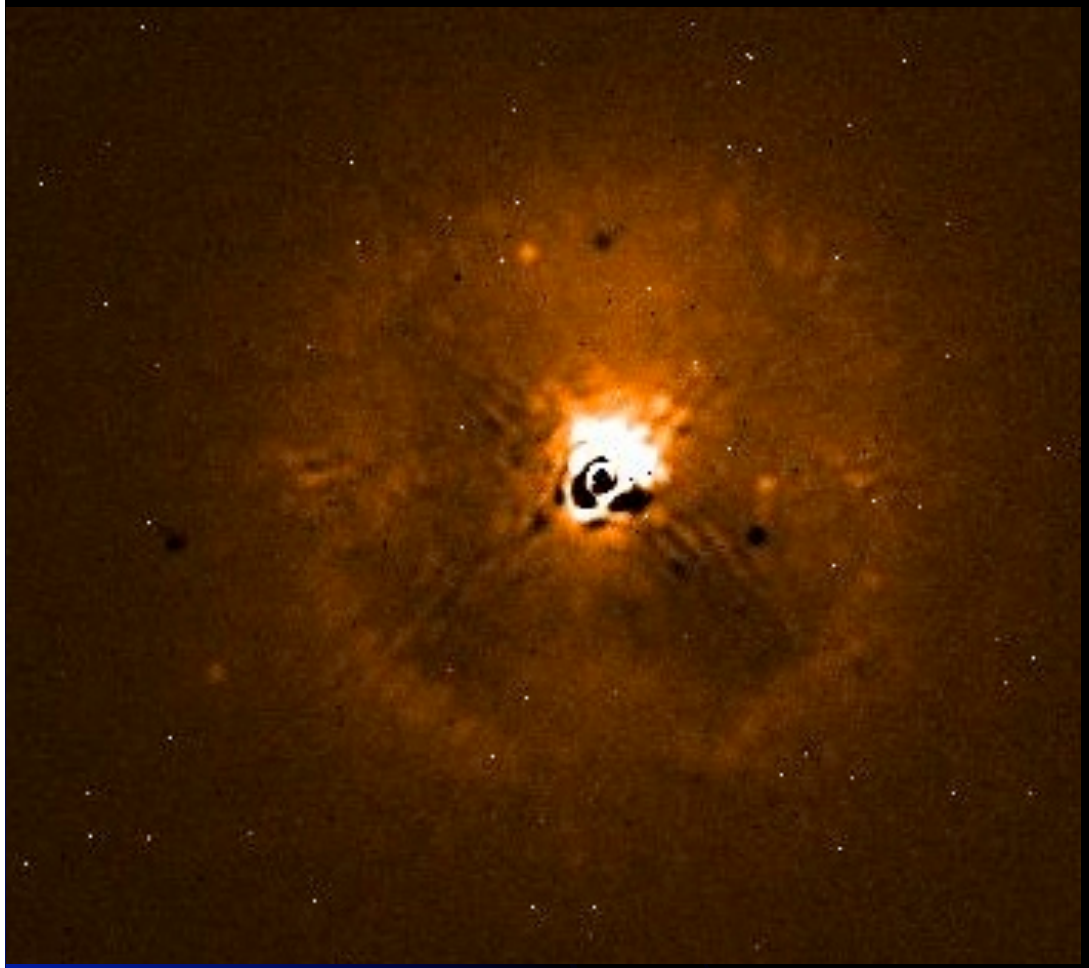


Image at 1.28 μm

SPHERE

Deep companion search

- « raw contrast » already helps a lot !



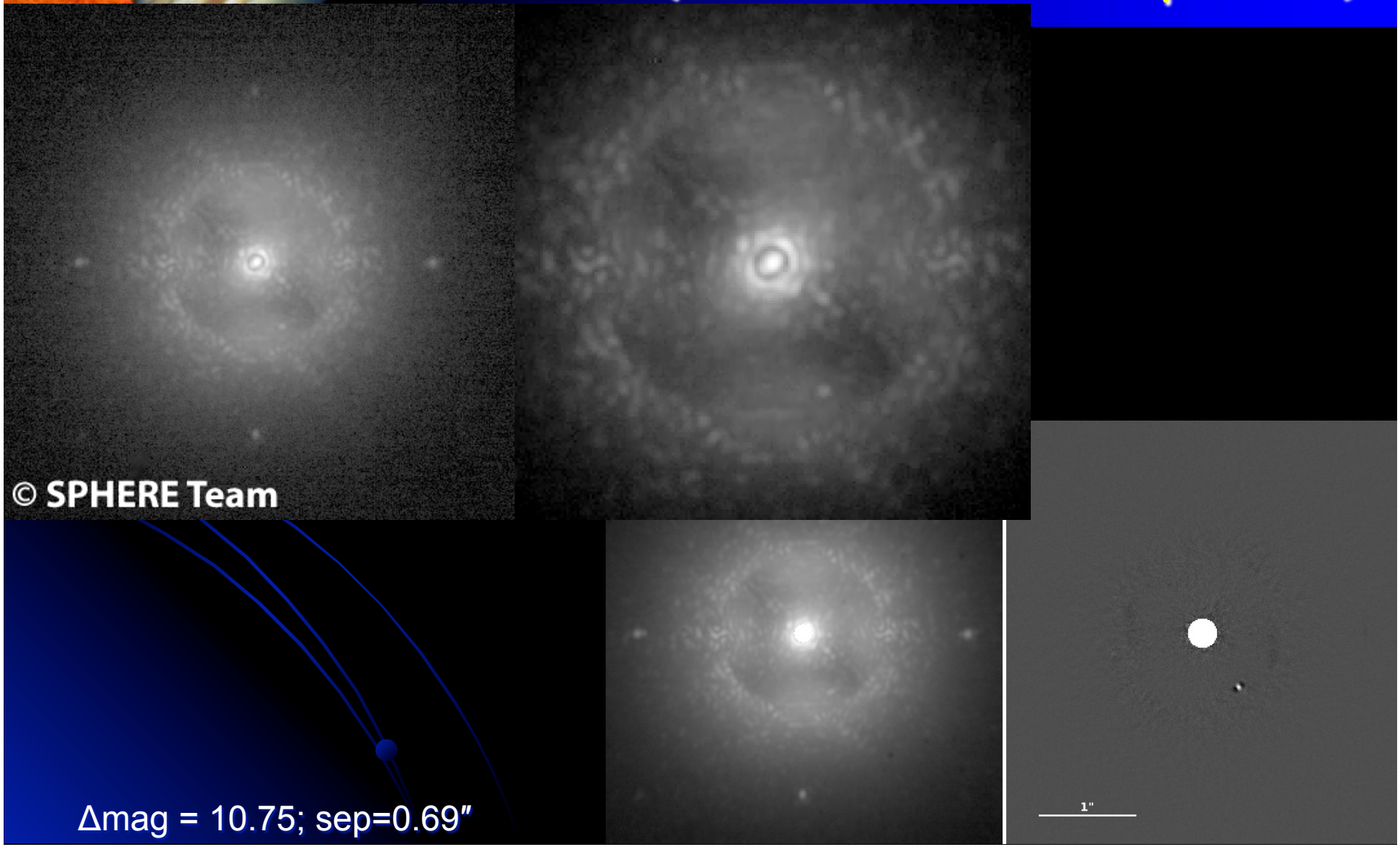
Real-time display: subtraction of 2 single frames

Reduction: none !

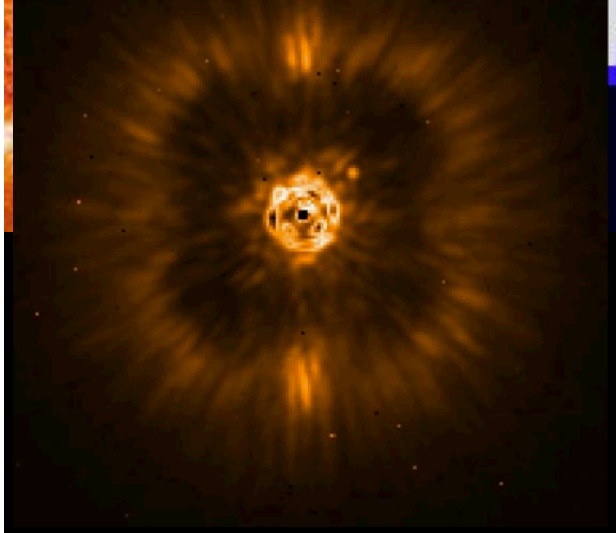
Conditions: moderate to poor

SPHERE

HD114174 (white dwarf companion)

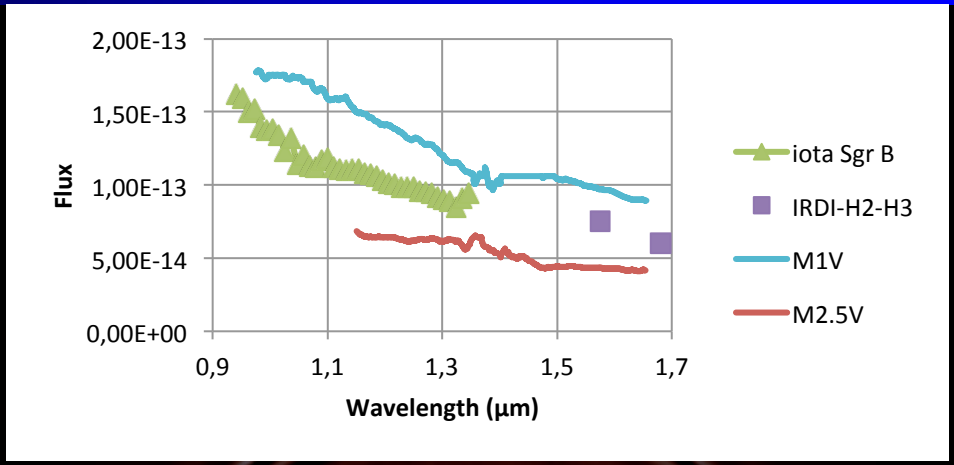


J band snapshot image

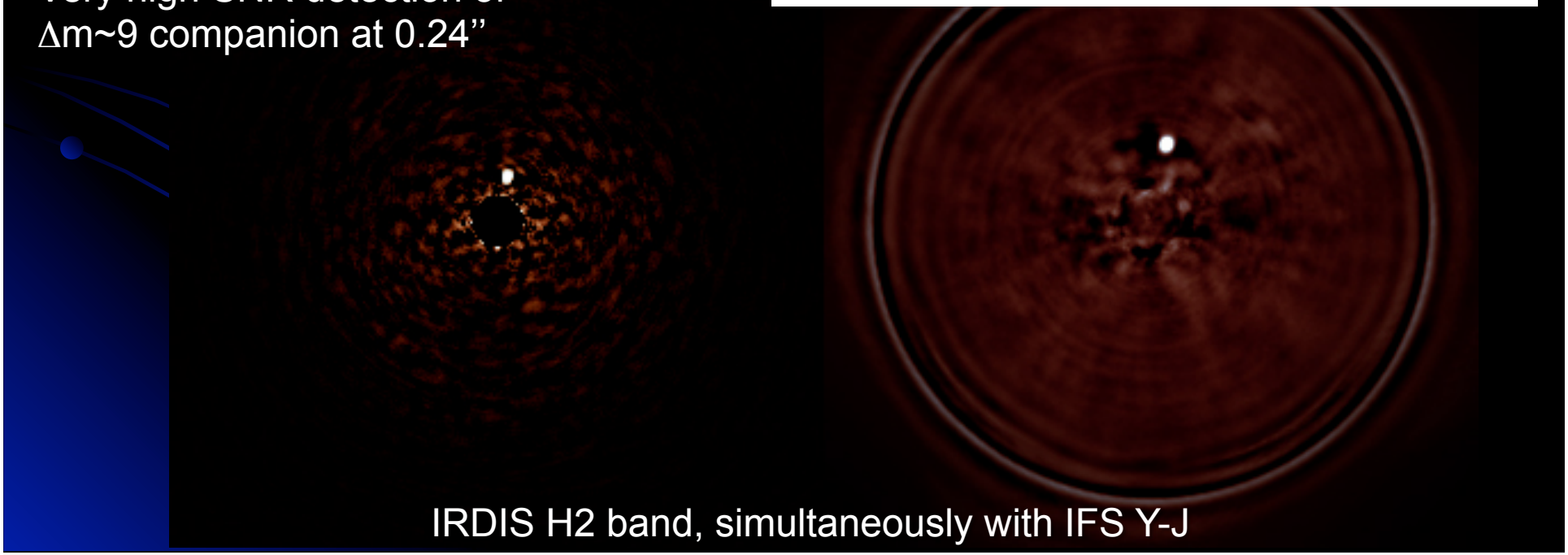


PHERE

HR7581 (IRDIFS mode)

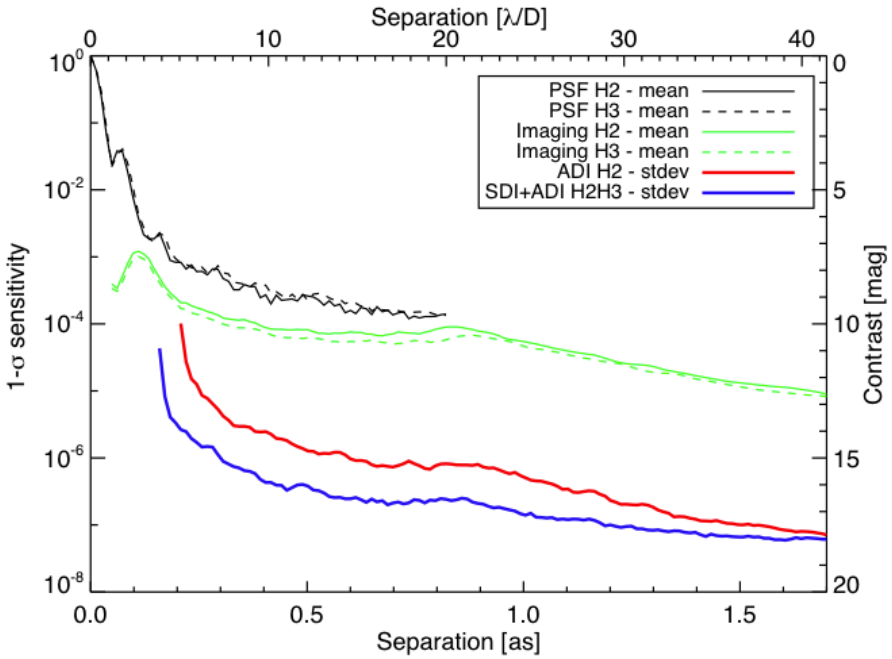


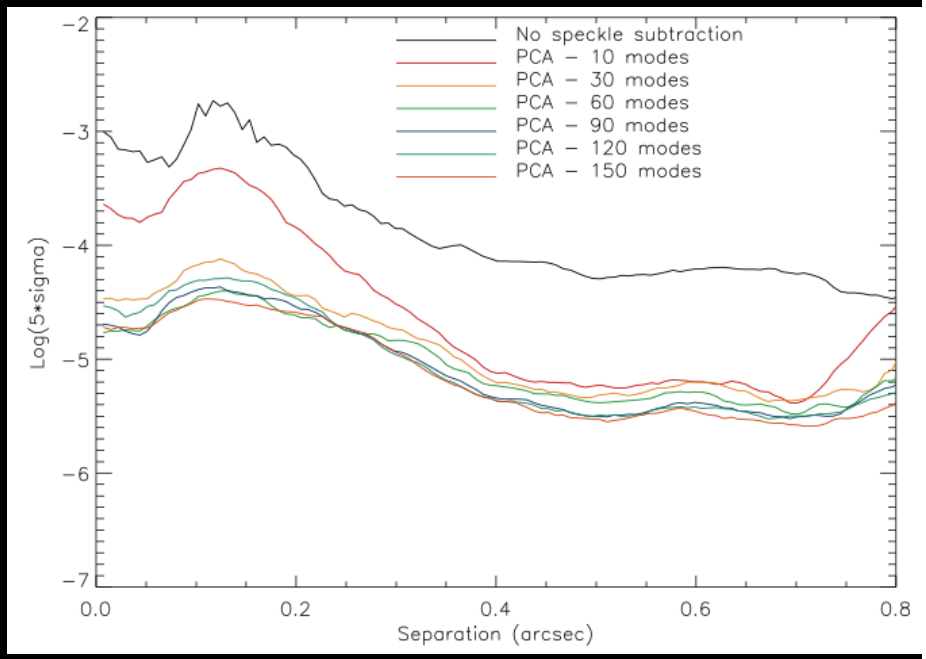
Very high SNR detection of
Δm~9 companion at 0.24”



IRDIS H2 band, simultaneously with IFS Y-J

SPHERE



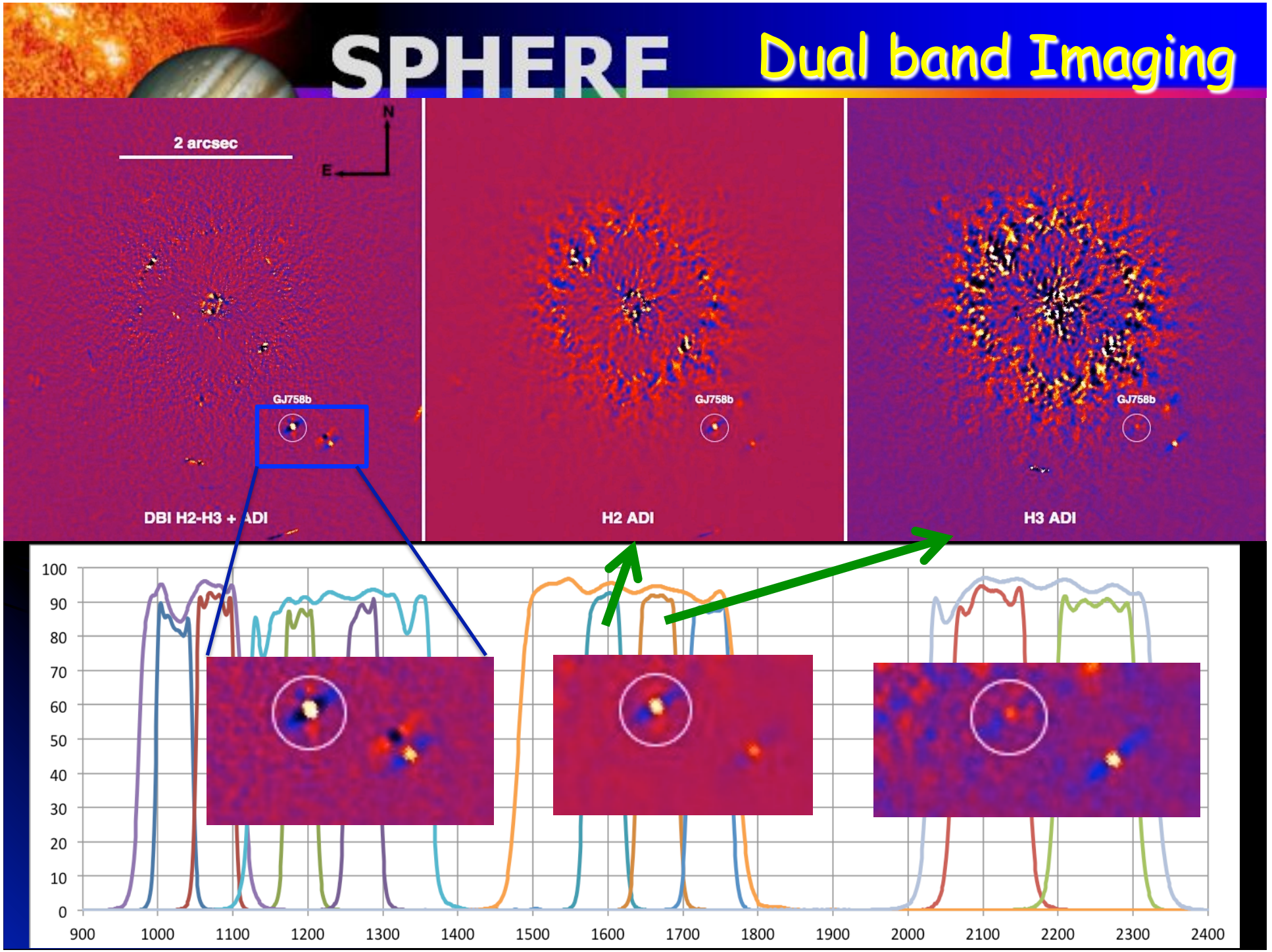


Full automatic operations and high performance already demonstrated

Ultimate performance: … following steep learning curve !

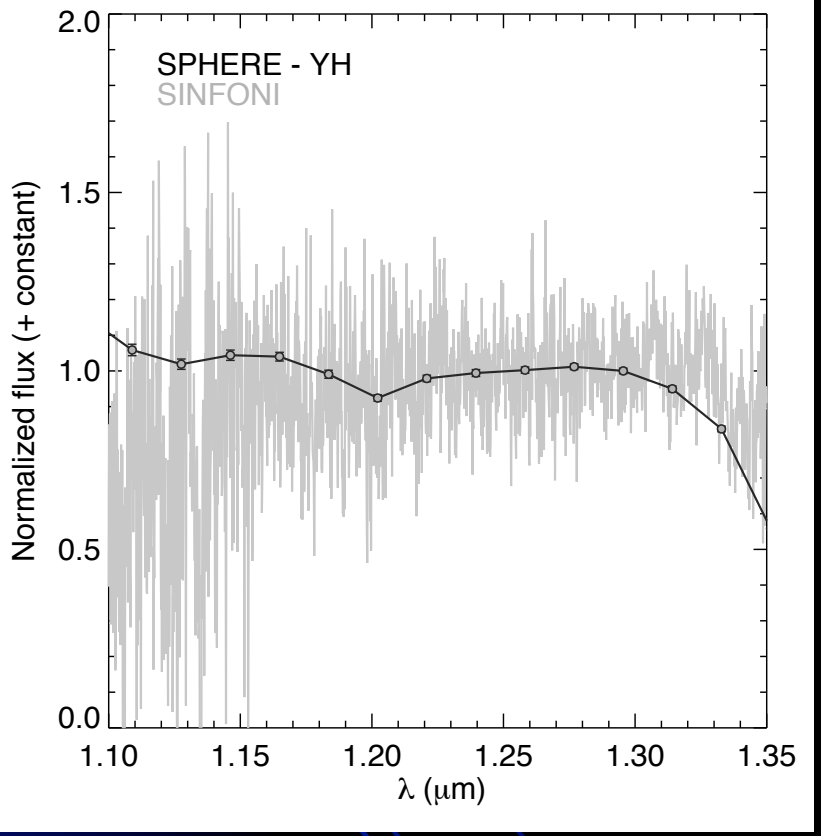
IRDIS H2 band, simultaneously with IFS Y-J

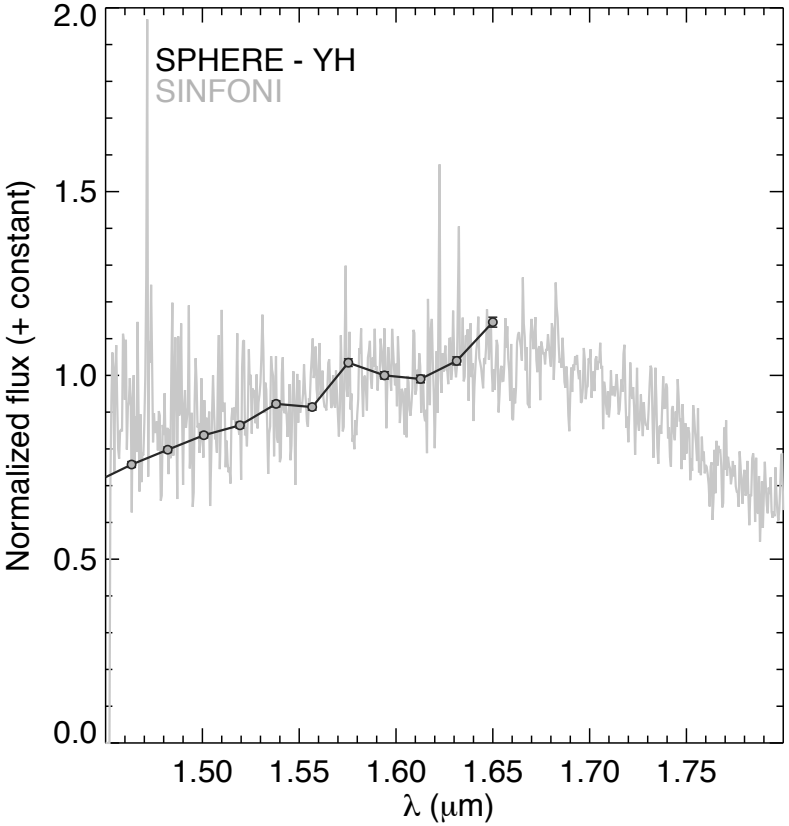
SPHERE Dual band Imaging



SPHERE

IFS spectral characterization

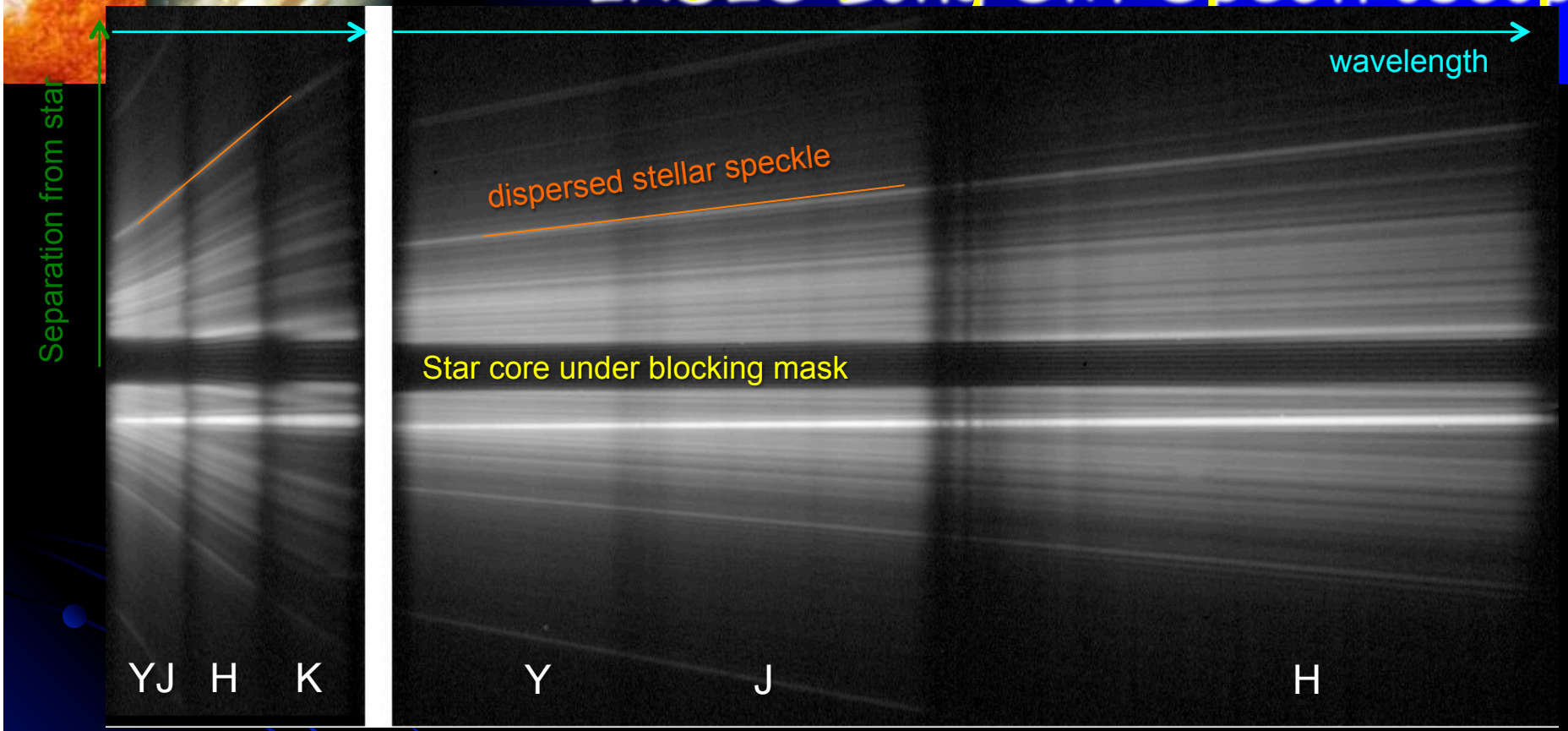




Test case: PZ Tel b (on-going IFS data analysis: Maire, Gratton, Bonnefoy, Vigan..)

SPHERE

IRDIS Long Slit Spectroscopy



LRS R~50

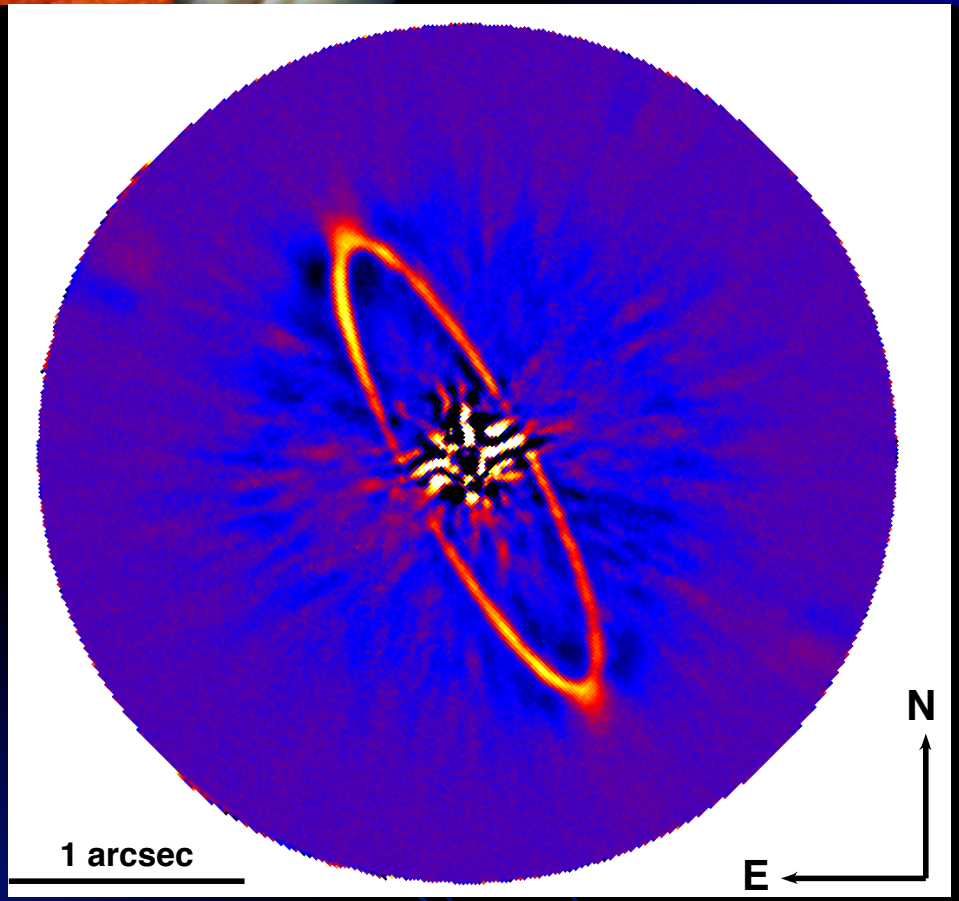
MRS R~350

Spectral information up to Ks, or up to R~350
Speckle subtraction down to >~ 10^5 contrast

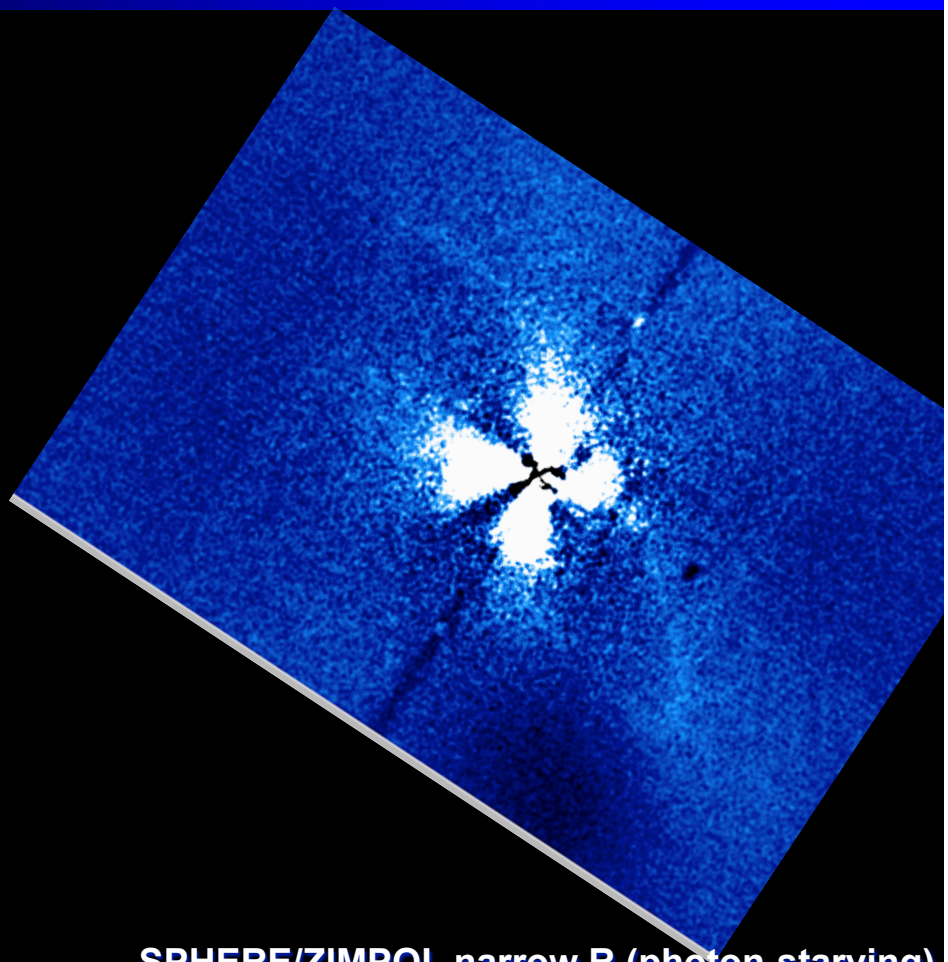
(on going analysis; A. Vigan)

SPHERE

HR 4796 disk in IR and visible



SPHERE/IRDIS BH band (1.45-1.71μm)
ADI intensity image (not corrected from ADI artefacts)
(Milli, Vigan et al: on-going)

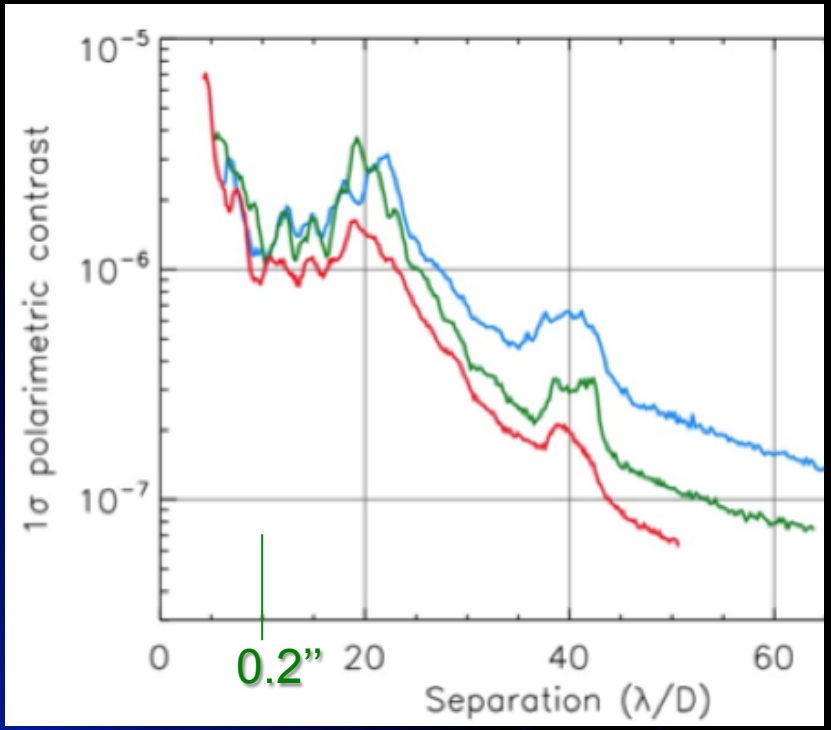


SPHERE/ZIMPOL narrow R (photon-starving)
Polarized intensity image
(Avenhaus, Thalmann et al, on going)

SPHERE

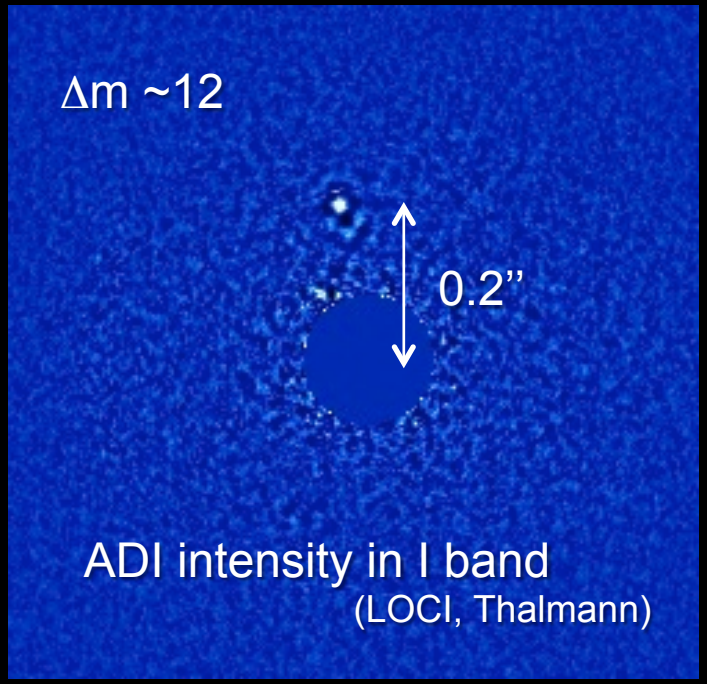
Contrast in visible

speckle subtraction in dual-polarization demonstrated down to few 10^{-6}
(without ADI or other technique)



ADI imaging also very efficient

Plus Spectral Differential Capability
(eg simultaneous Hα – Cnt Hα)

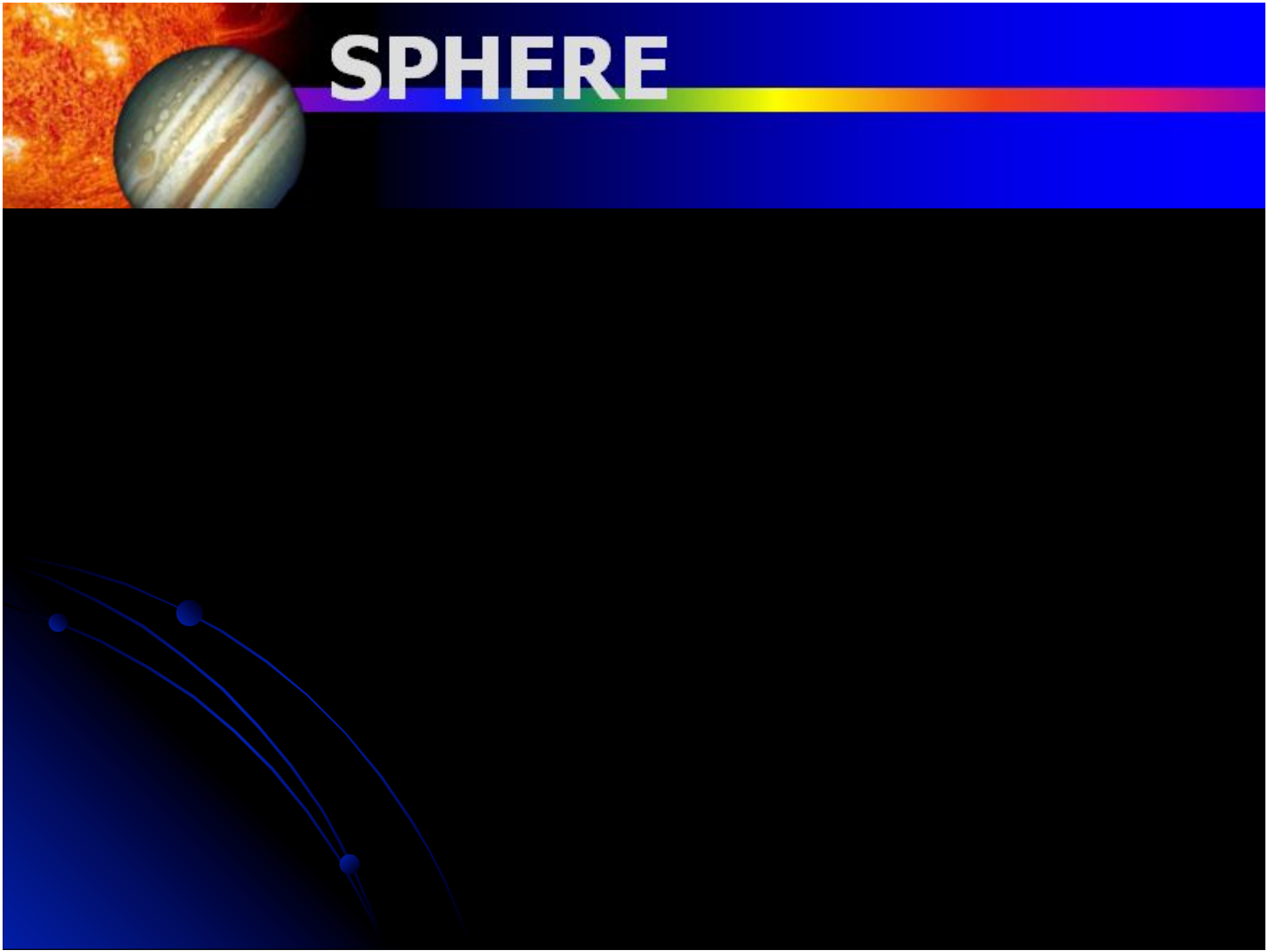


SPHERE

- 1st open Call for Proposal: Sept 2014
- Science Verification: Dec 2014

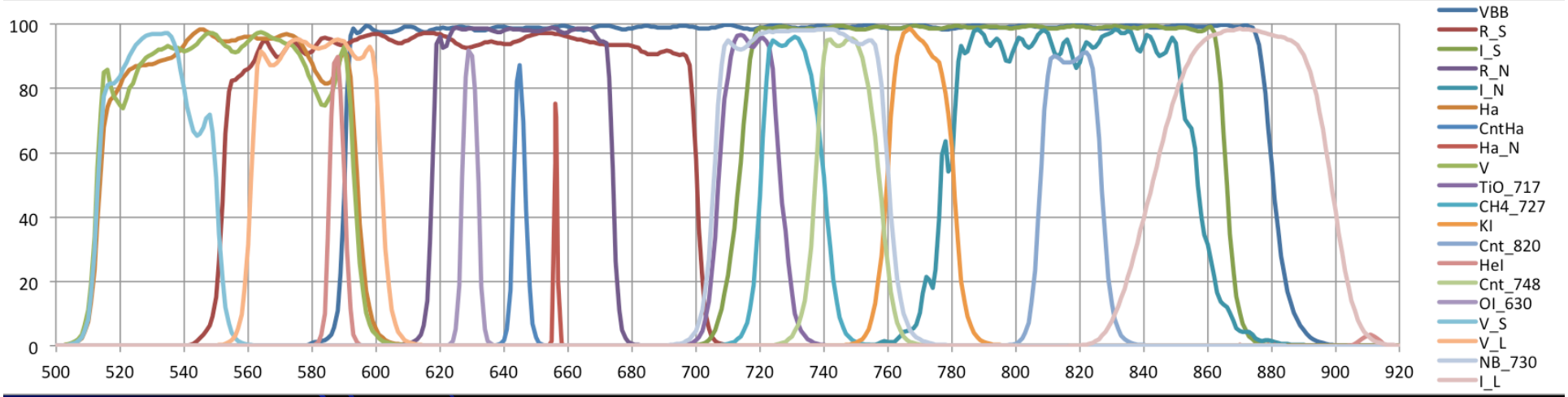
- A great step forward in contrast wrt previous generation
- Comprehensive set of complementary mode
  - Colour information (BB, NB) from V to Ks band
  - Spectroscopy (IFS, slit spectro)
  - Polarization information(*)
  - Various PSF subtraction possible approaches

- Science to be produced by a large community


SPHERE

SPHERE

ZIMPOL filters

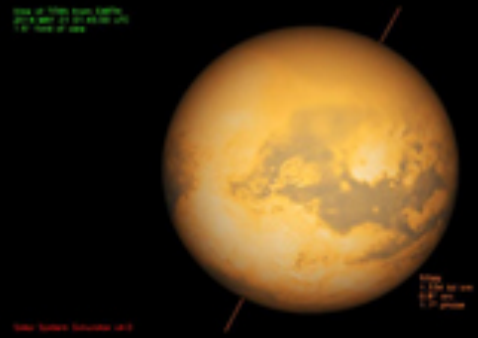


SPHERE

Titan in NIR and visible

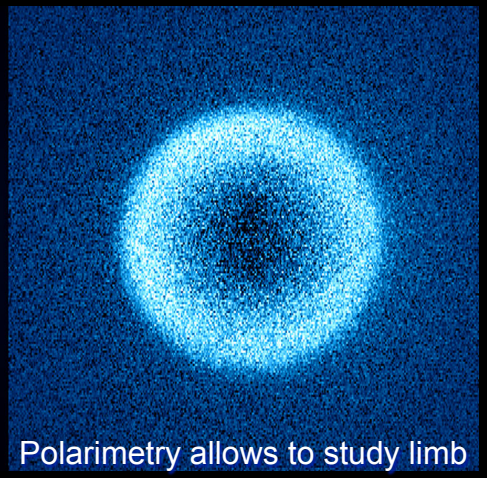
Methane band at 1.59 µm

Mistral deconvolved image



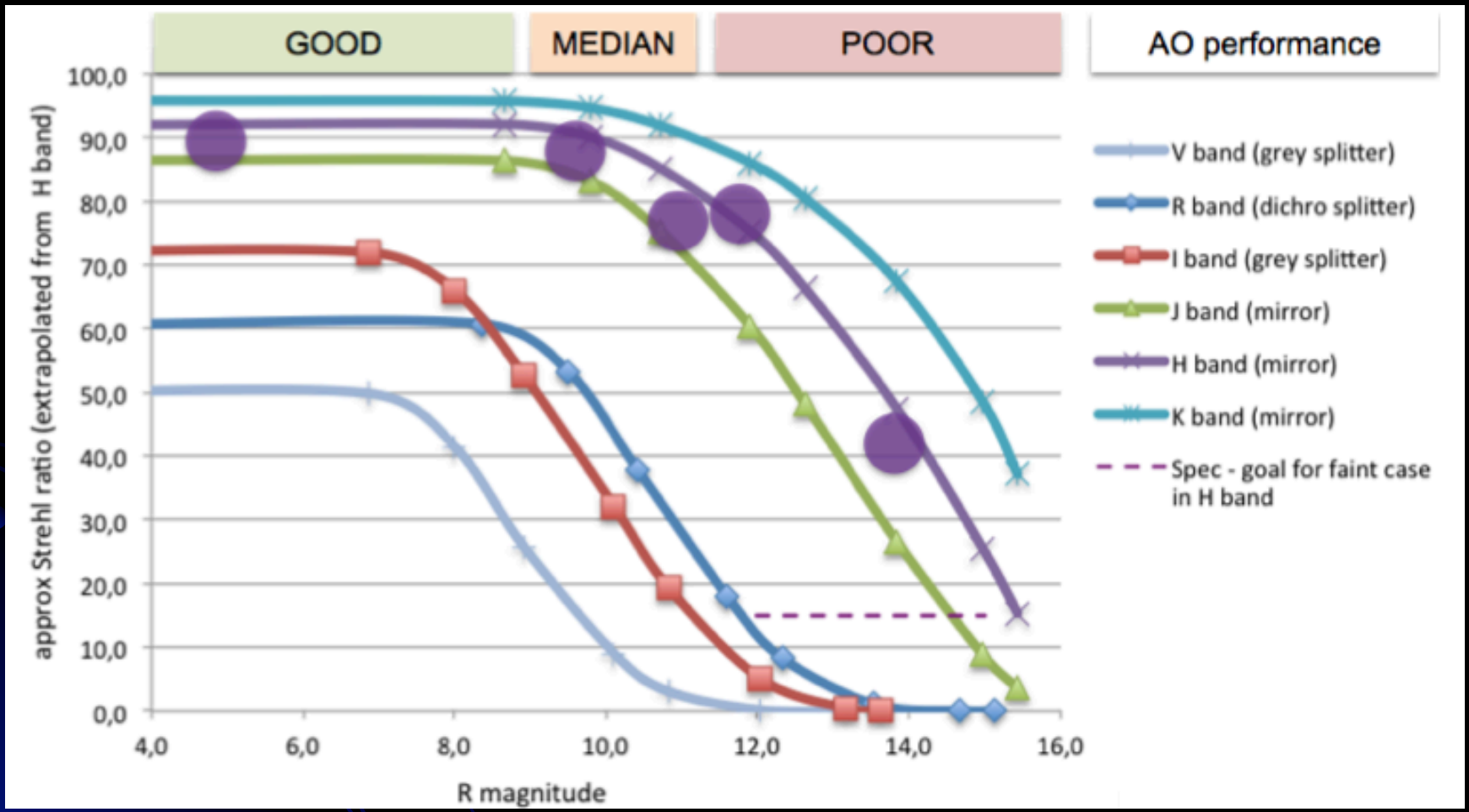
Cassini synthetic data

Thick polar haze

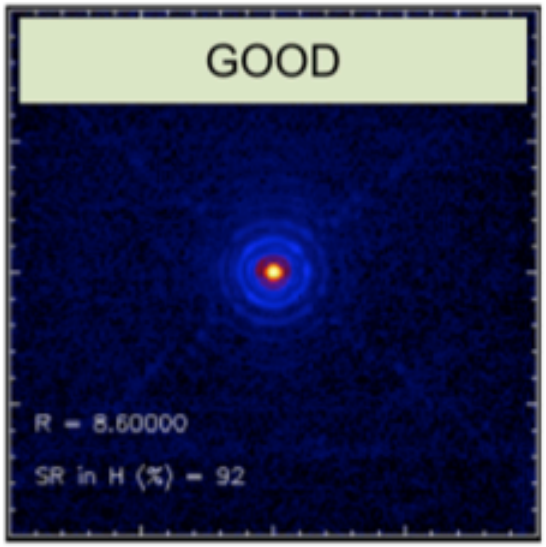


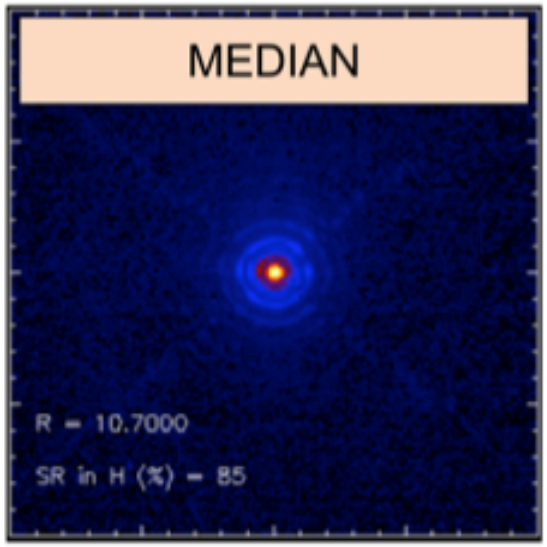
Polarimetry allows to study limb

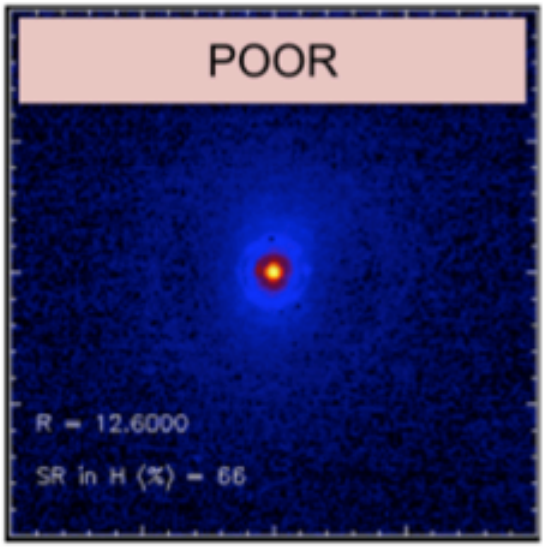
SPHERE

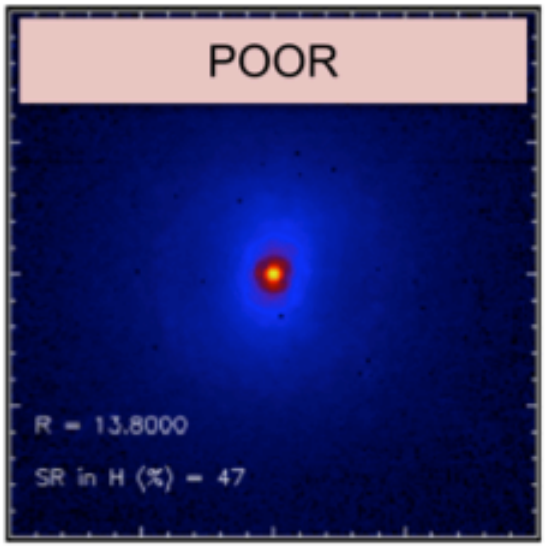

GOOD
MEDIAN
POOR
AO performance
approx Strehl ratio (extrapolated from H band)
100,0
90,0
80,0
70,0
60,0
50,0
40,0
30,0
20,0
10,0
0,0
4,0
6,0
8,0
10,0
12,0
14,0
16,0
R magnitude
V band (grey splitter)
R band (dichro splitter)
I band (grey splitter)
J band (mirror)
H band (mirror)
K band (mirror)
Spec - goal for faint case in H band

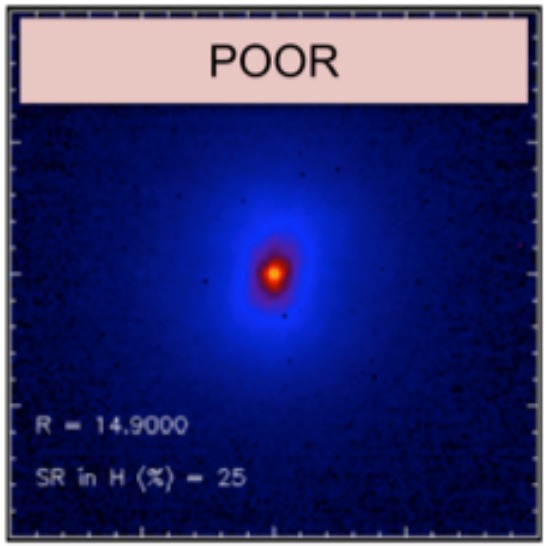
SPHERE

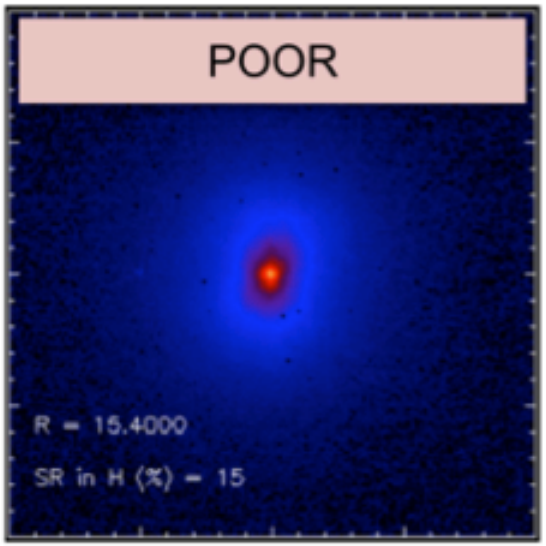

GOOD
R = 8.60000
SR in H (%) = 92


MEDIAN
R = 10.7000
SR in H (%) = 85


POOR
R = 12.6000
SR in H (%) = 66


POOR
R = 13.8000
SR in H (%) = 47


POOR
R = 14.9000
SR in H (%) = 25


POOR
R = 15.4000
SR in H (%) = 15

SPHERE