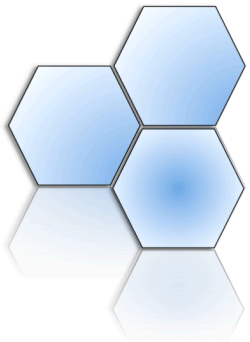


SPEED

Segmented-Pupil Experiment for Exoplanet Detection

LAGRANGE

SPEED

Segmented-Pupil Experiment for Exoplanet Detection

P. Martinez

O. Preis, C. Gouvret, J. Dejonghe, J-B. Daban, A. Spang, F. Martinache, M. Beaulieu, P. Janin-Potiron, L. Abe, Y. Fantei-Caujolle, D. Mattei, S. Ottogalli, M. Carbillet

SPEED objective

Optimize HCI for complex aperture telescopes

SPS module

Tip-Tilt mirror

ASM

DM1

DM2

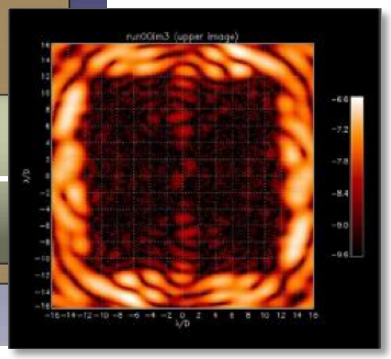
PIAA

PIAA^{-1}

Vis. camera

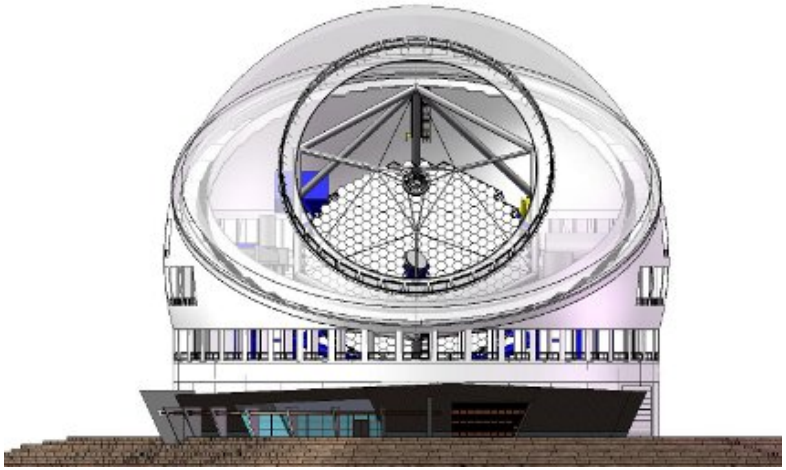
NIR camera

Modular ELT
Up to 163 segments



Brand new challenges for HCI

ELTs significantly change the game for exoplanet detection



- ELTs will start resolving stars
- ELTs pupil is made of various discontinuities
- Missing segments are of major concern
- ELTs require well mastering of Fresnel/Talbot effect
- New scientific targets (M-stars) appeal for (very) small IWA observing mode
- Efficient post-coronagraphic wavefront sensing/correction at small IWA

General context

Space-based missions – SPICES / EXO-C / WFIRST-AFTA…

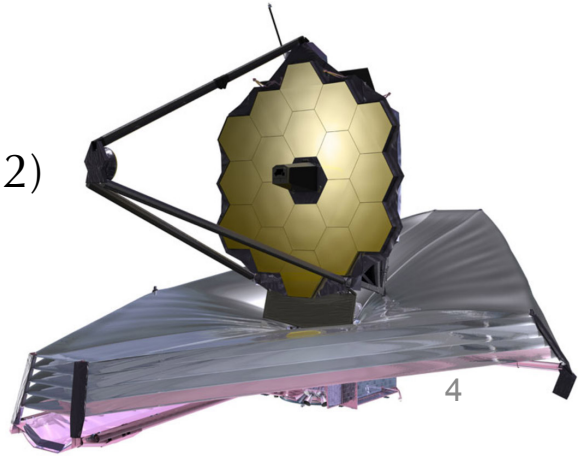
Ground-based observatories - complex pupil & small IWA (E-ELT/VLT)

E-ELT [up to date] context - December 4th 2014: Green light for construction
First light: 2024 => 2026 / 5 inner rings undelivered / 7th sector undelivered

<u>HCI segmented test-benches</u>

1 **Space Telescope Science Institute (STScI / Baltimore, *Soummer et al.)***
- JWST (successor of Hubble / 2018) – HiCAT project

2 **Stanford University (Palo – Alto, *Macintosh et al.*)**
- Preparatory activities for the TMT (successor Gemini / 2022)



SPEED objectives

SPEED main objectives

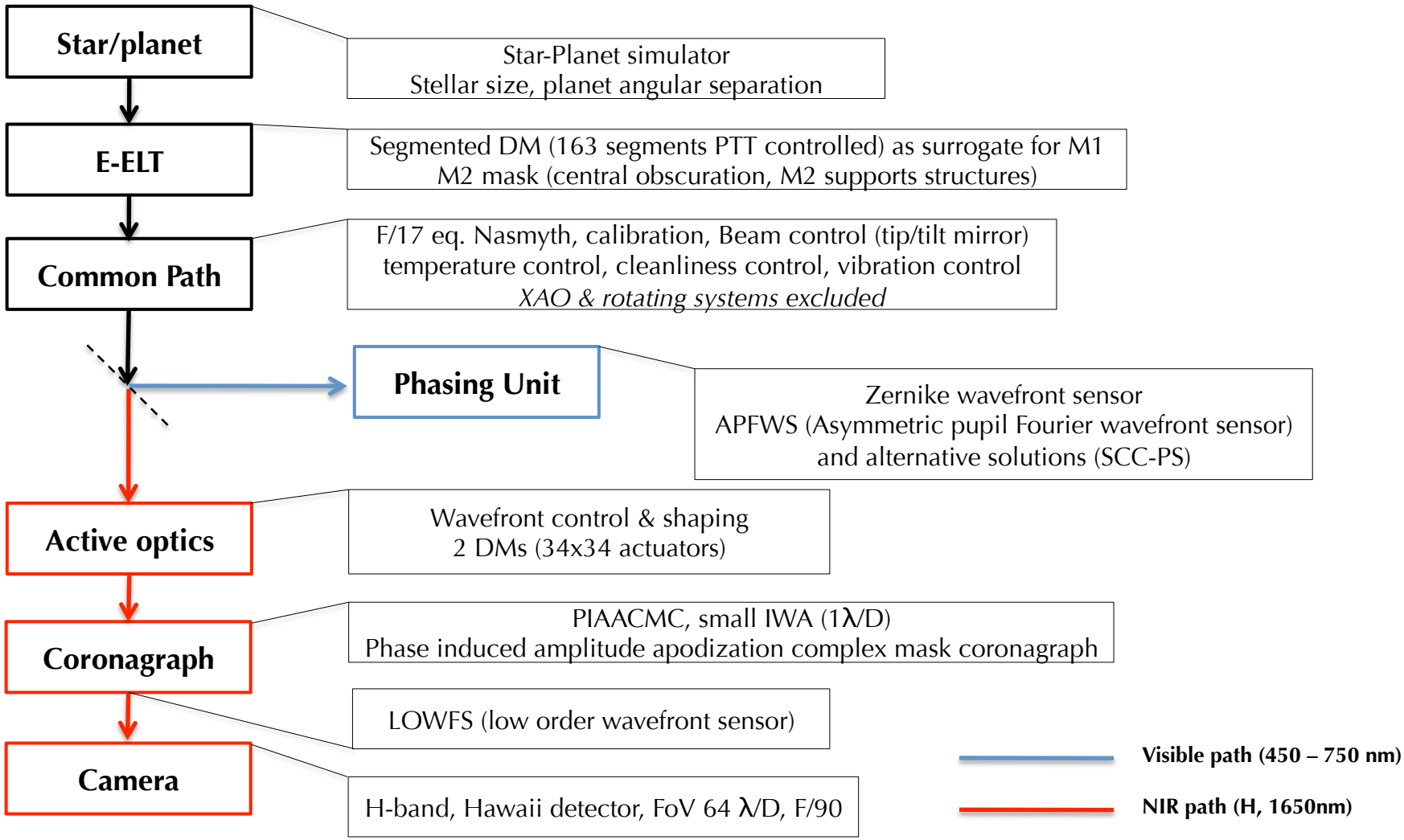
- High contrast imaging at small IWA with unfriendly telescope aperture
    - High contrast imaging with stellar resolution
    - Pupil discontinuities correction (phase & amplitude)

- Wavefront control and correction at the coronagraph level

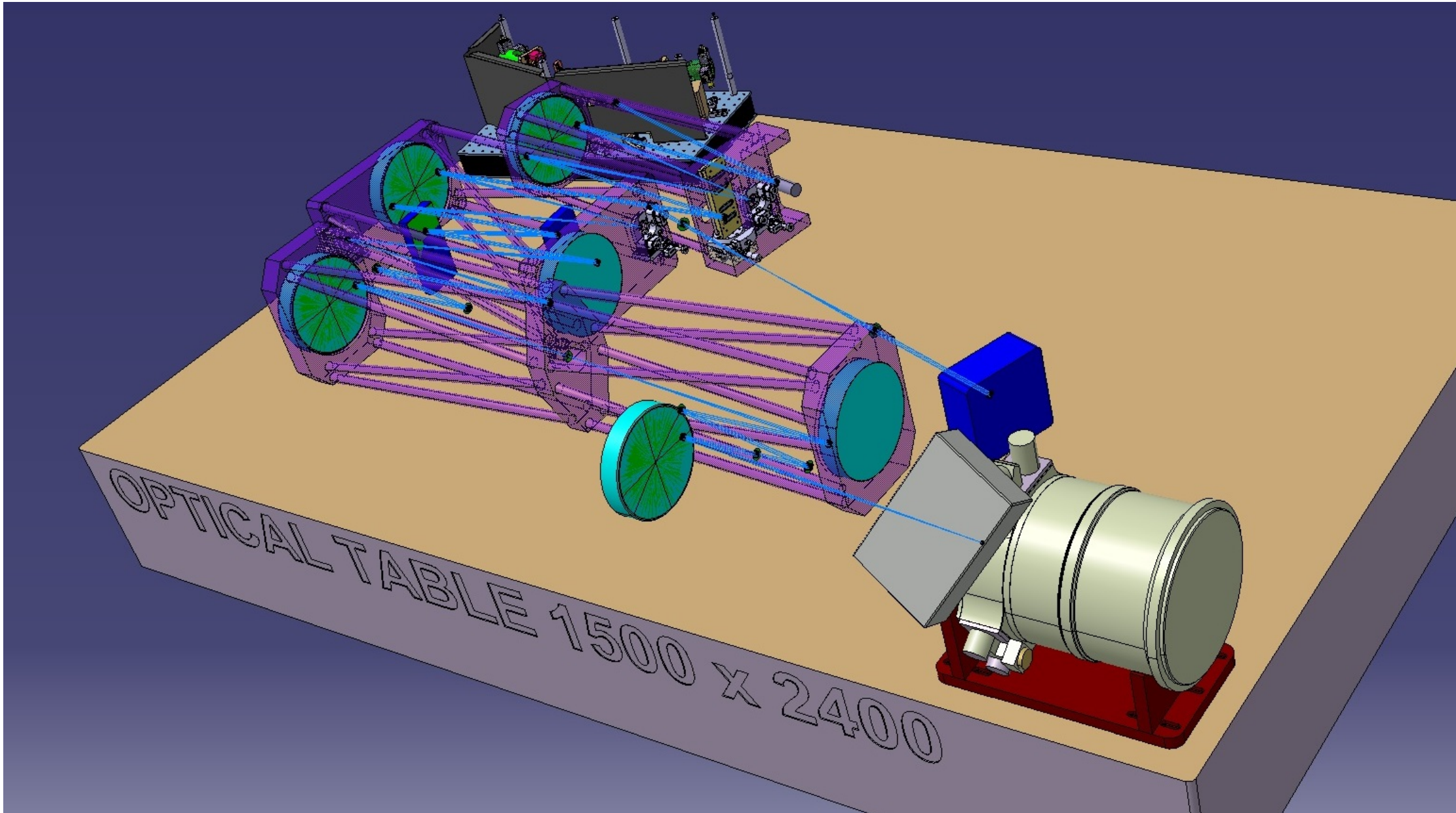
- Study of error propagation and impact for high contrast imaging (missing segments, island effect, phasing errors, etc.)

- Fundamental HCI limitations at high contrast level

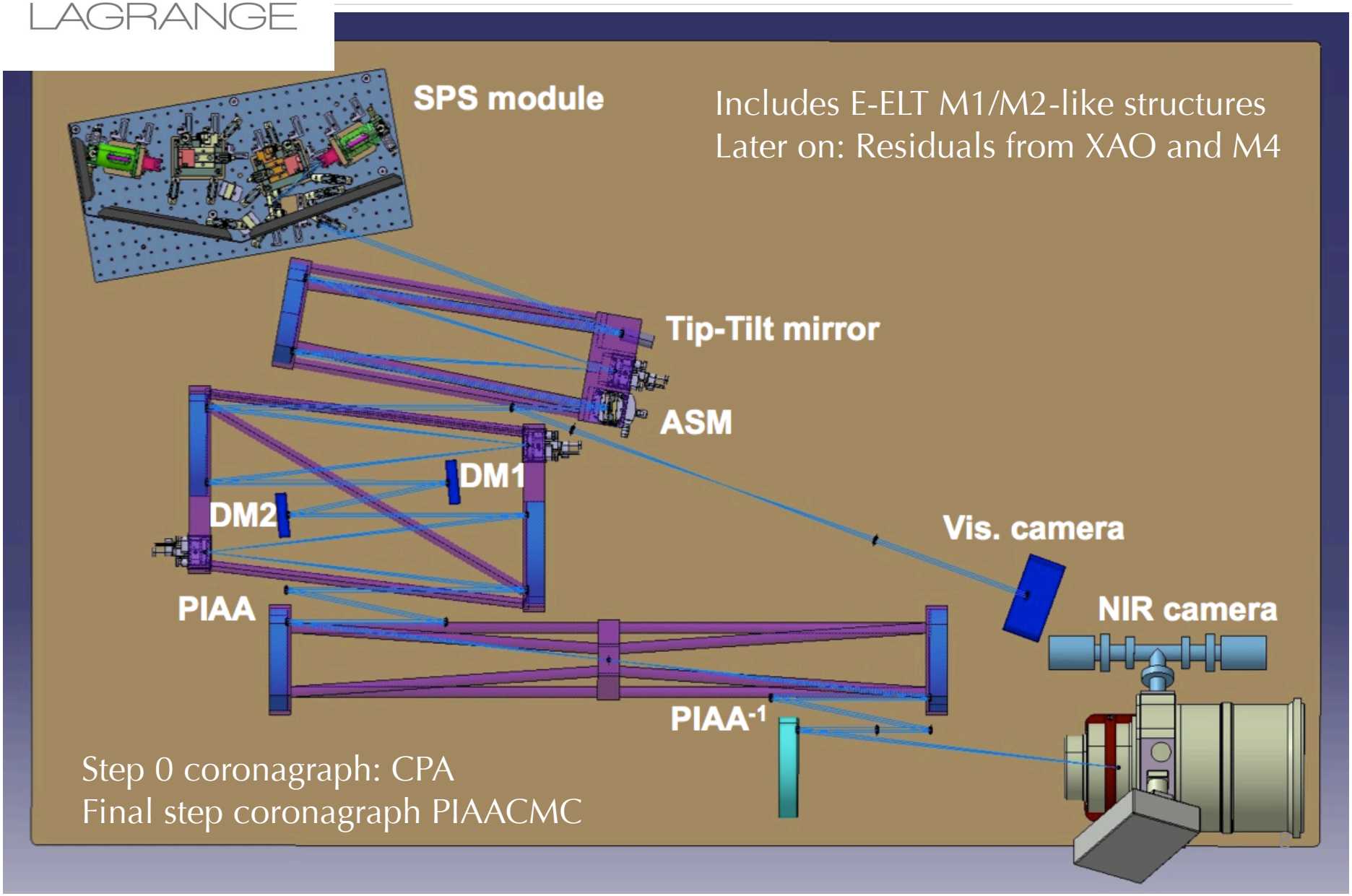
SPEED: concept overview



SPEED preliminary opto-mech. design

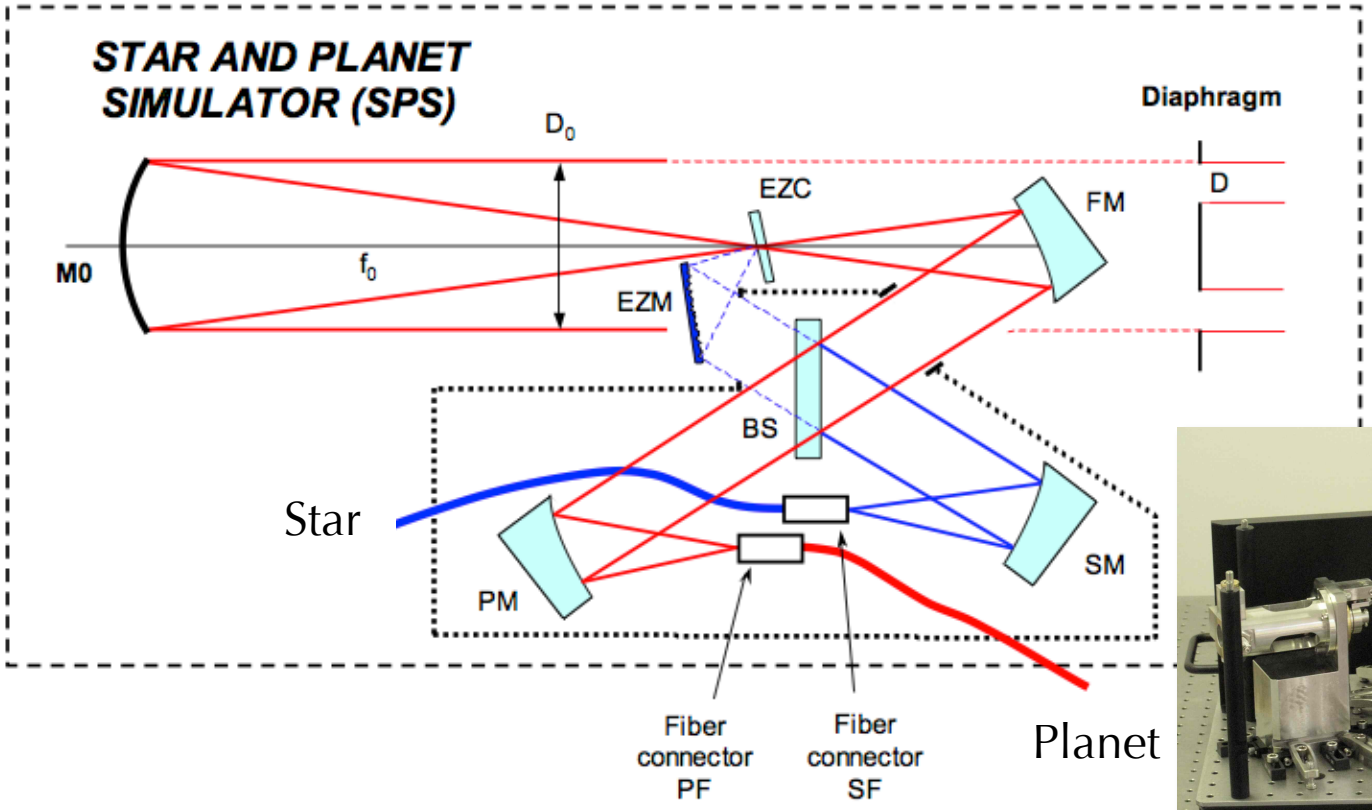


Preliminary opto-mechanical design

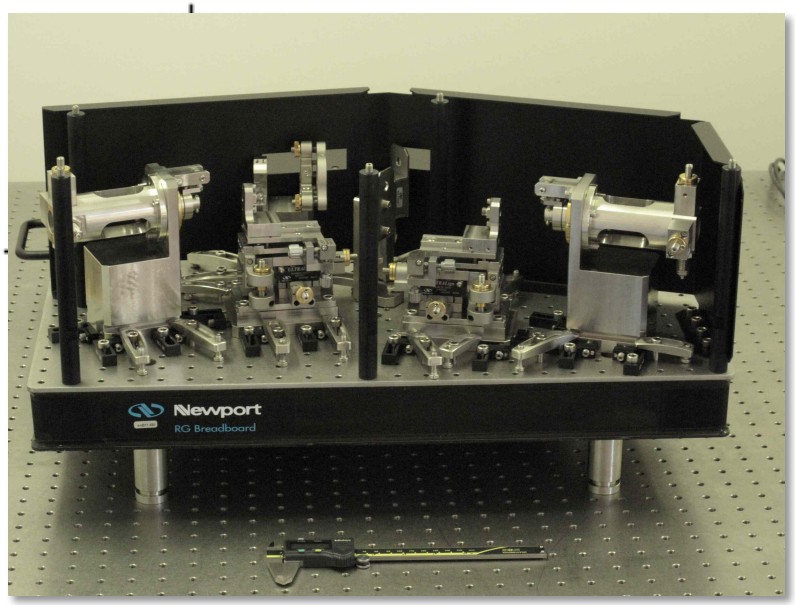


Star/planet simulator

Inherited from the PERSEE bench (developed by Lagrange, PERSEE at LESIA)
Henault et al. 2010

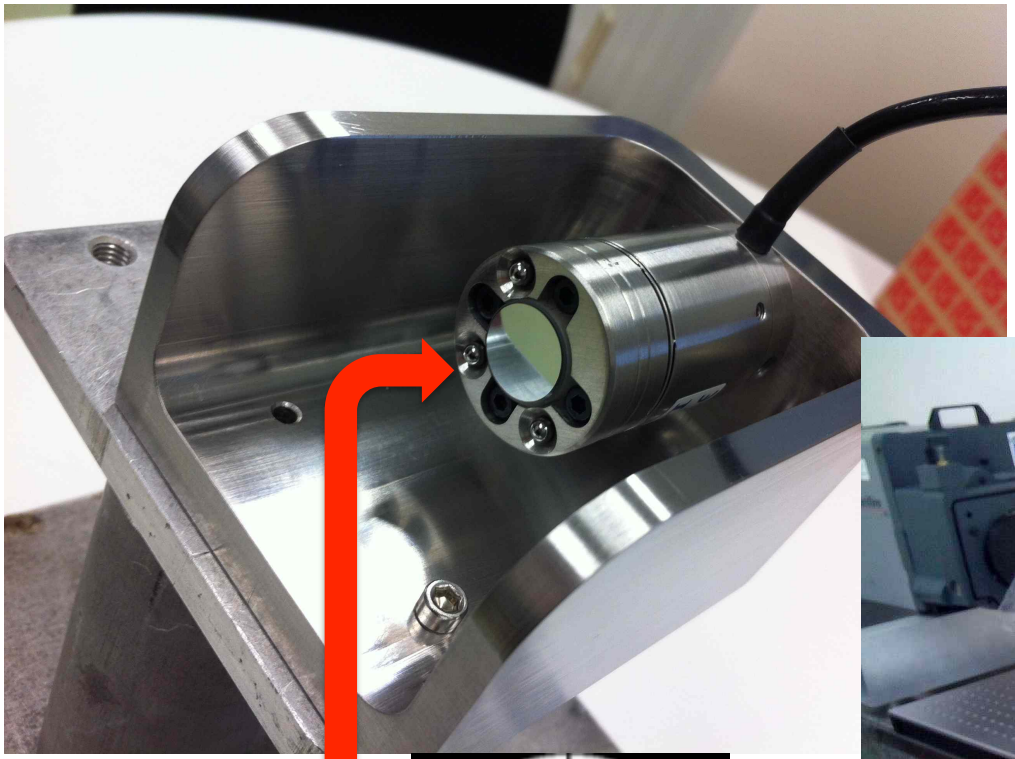


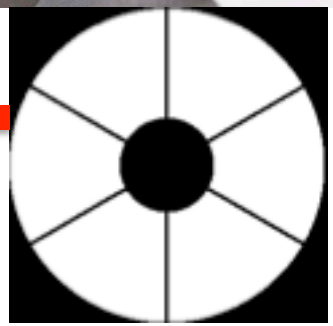
In house June 2014



To be re-tested & characterized 1st semester 2015

Tip/Tilt module



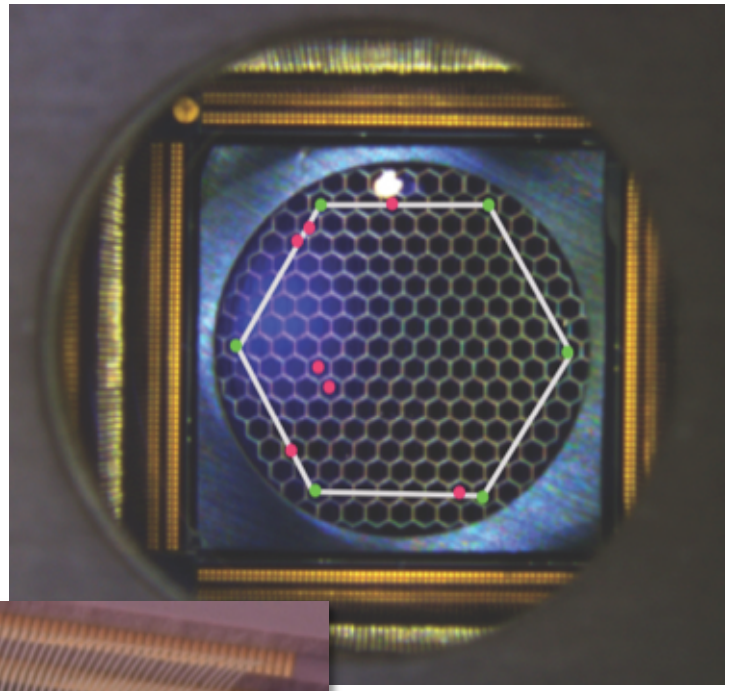


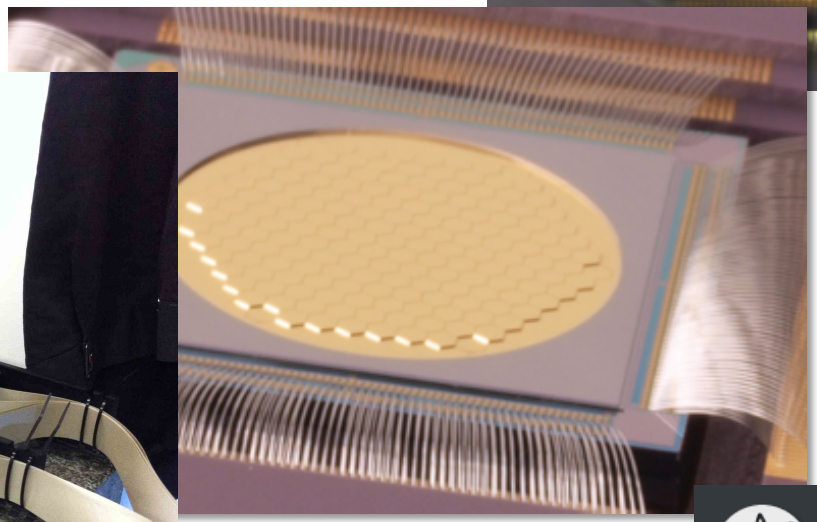
Delivered October 2014
Tested and accepted Novembre 2014

IRIS AO PTT489 DM

IRIS AO PTT489

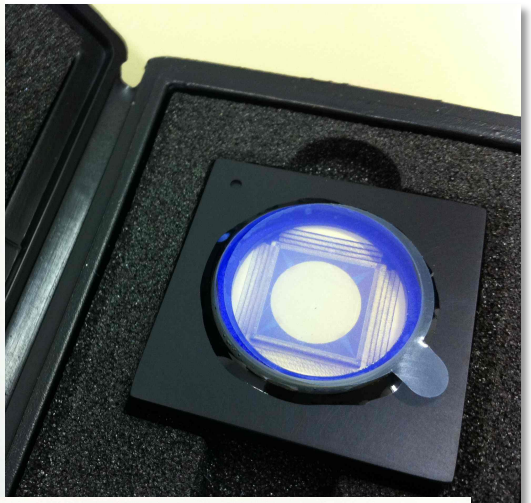
163 segments
3 actuators per segments (piston, tip/tilt)
+/- 4 mrad tip-tilt
Total stroke PV 5um
Prototype under tests at Lagrange (7 rebel segments)
Final DM under manuf. process
Expected delivery March 2015

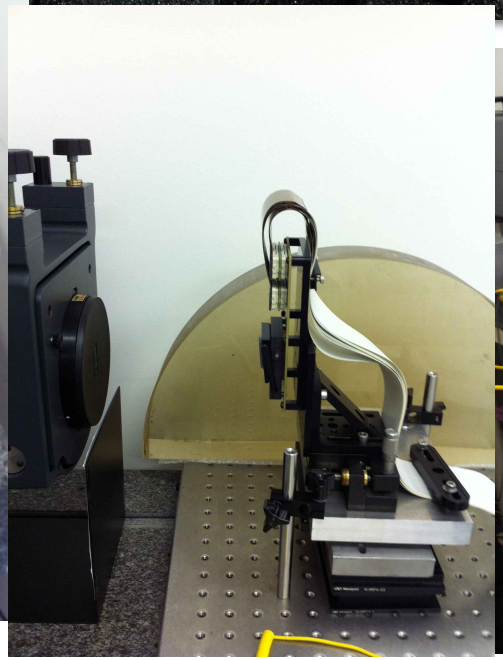


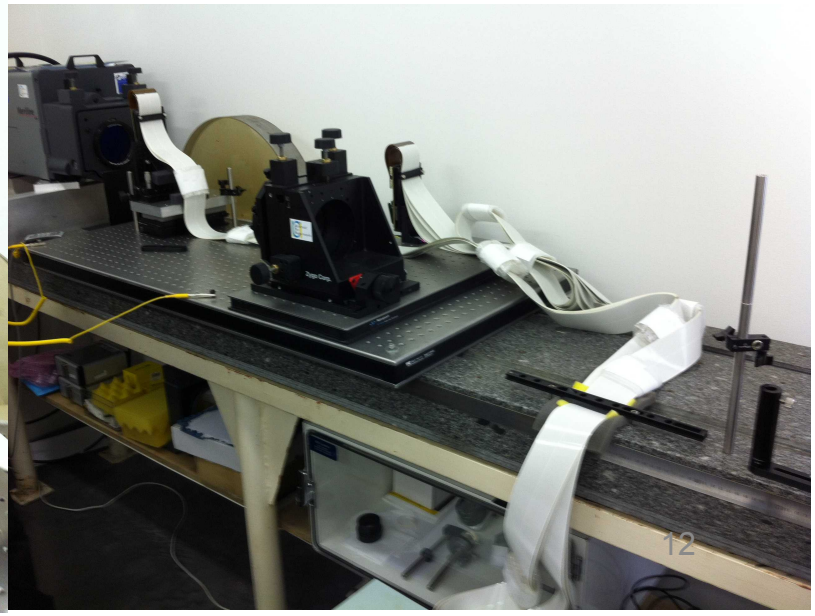


IRIS AO, INC.
ADAPTIVE OPTICS MADE EASY

BMC Kilo-C-DMs





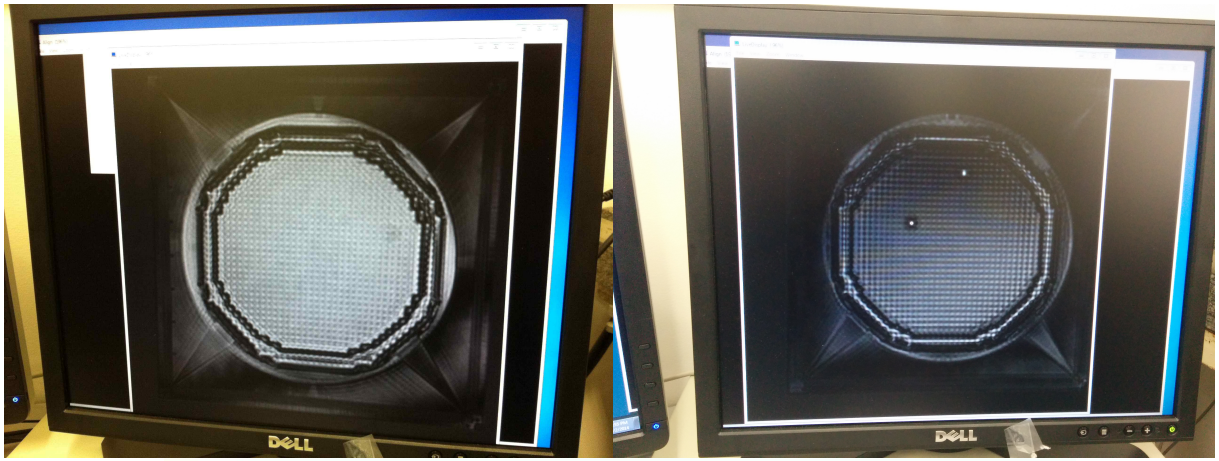


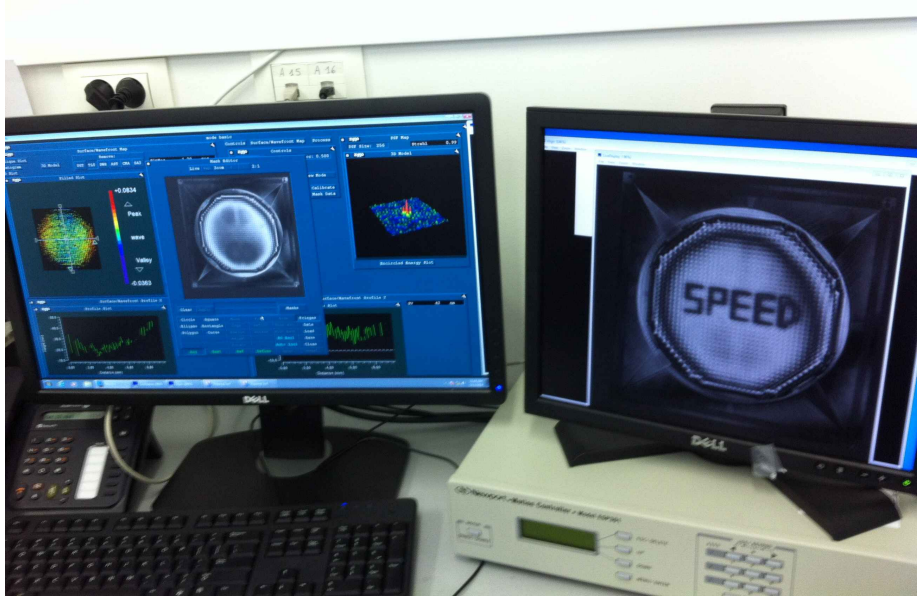
Boston M. Kilo-C-DMs

2 devices w/ 34x34 actuators
100% working actuators
Stroke 1.5um
Pitch: 300 um

Delivered April 2014
Accepted November 2014

BMC Kilo-C-DMs

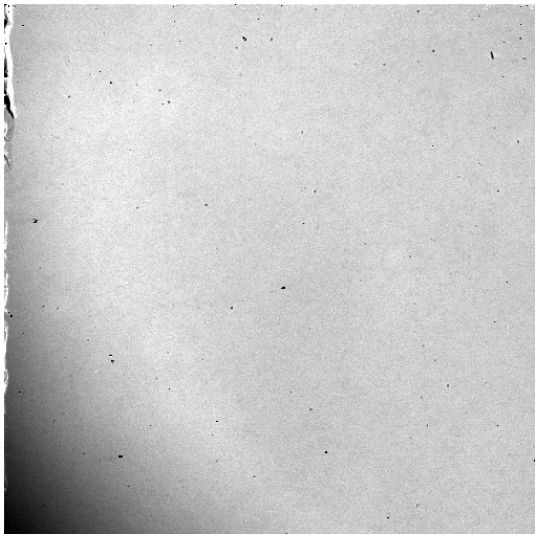




BOSTON MICROMACHINES CORPORATION

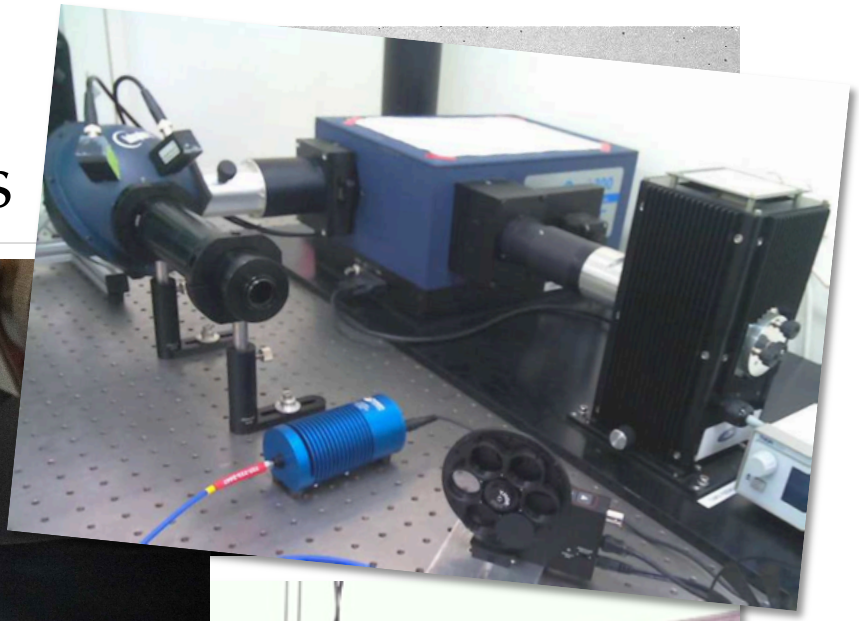
Detectors

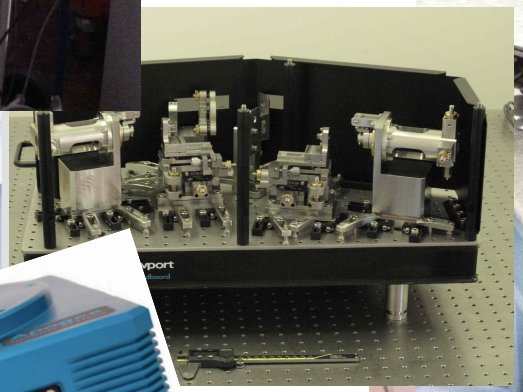
Vis. APOGEE ALTA camera
1024 x 1024 pixels
E2V detector
QE >95%
Noise 3.2 e- rms

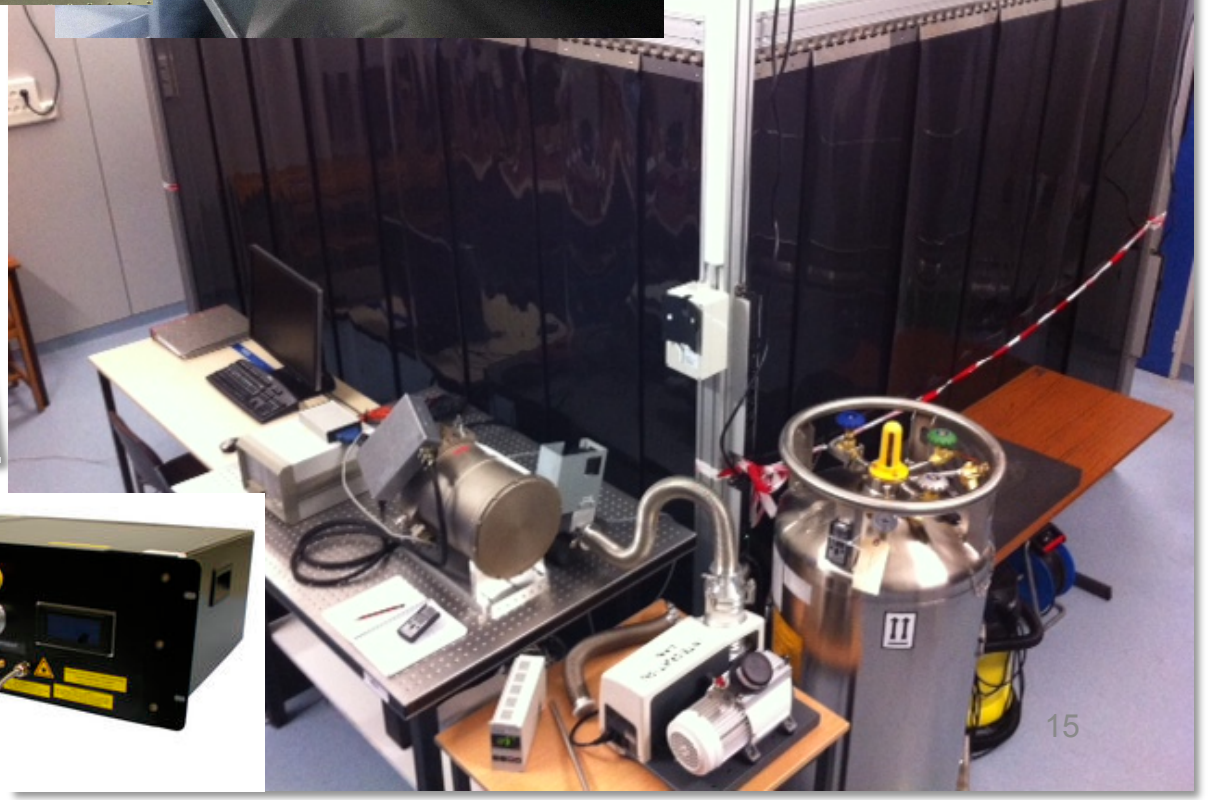


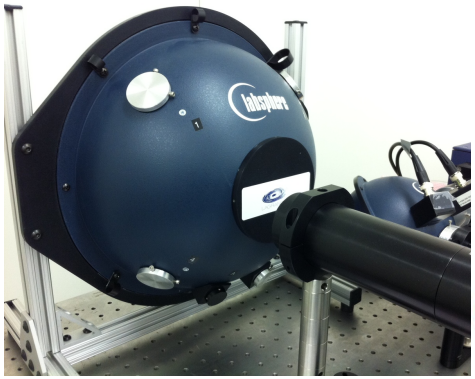
NIR ESO camera
RON 12 e- rms/pixel
QE > 60%
1 cooled NIR filter
Hawaii detector 1kx1k
(512x512 usable)
18.5 um pixel
H-band BB filter
(CILAS)

SPEED in progress

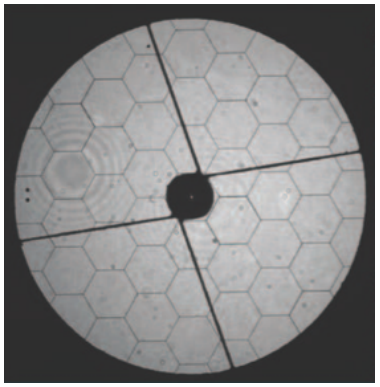


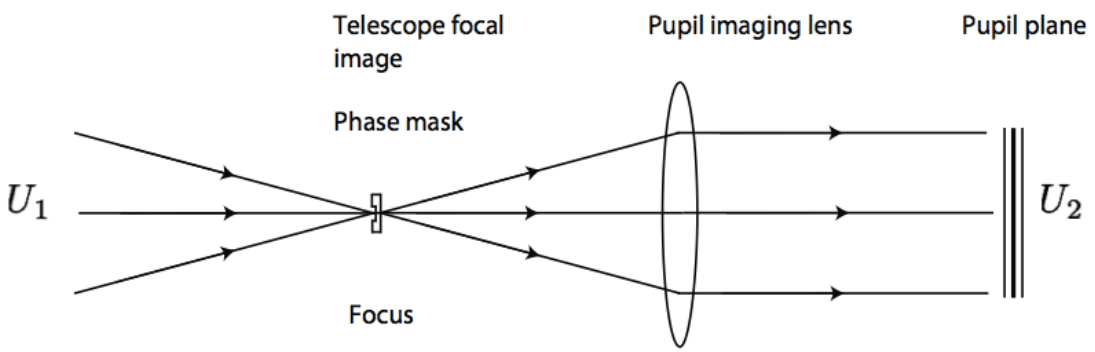


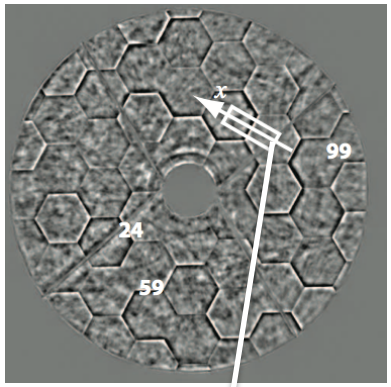




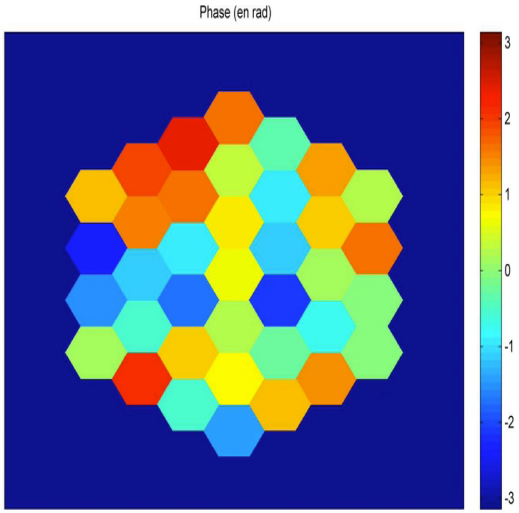
Thesis #1 Phasing segmented aperture

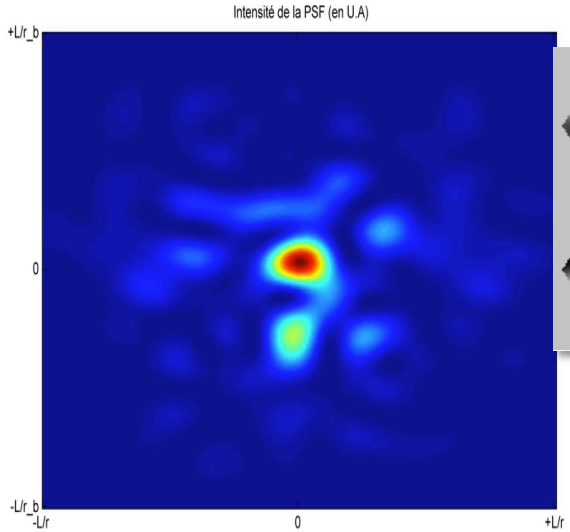


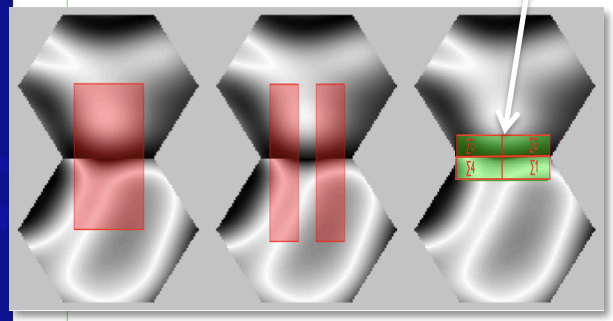




ZEUS phase mask w/ OPD lambda/4 (π/2)
Pupil plane analysis, Calibration matrix, SVD, estimators K_0, K_1, K_2, closed-loop
(Yaitskova et al. 2005, Surdej et al., upon APE experience by LAM/ESO)



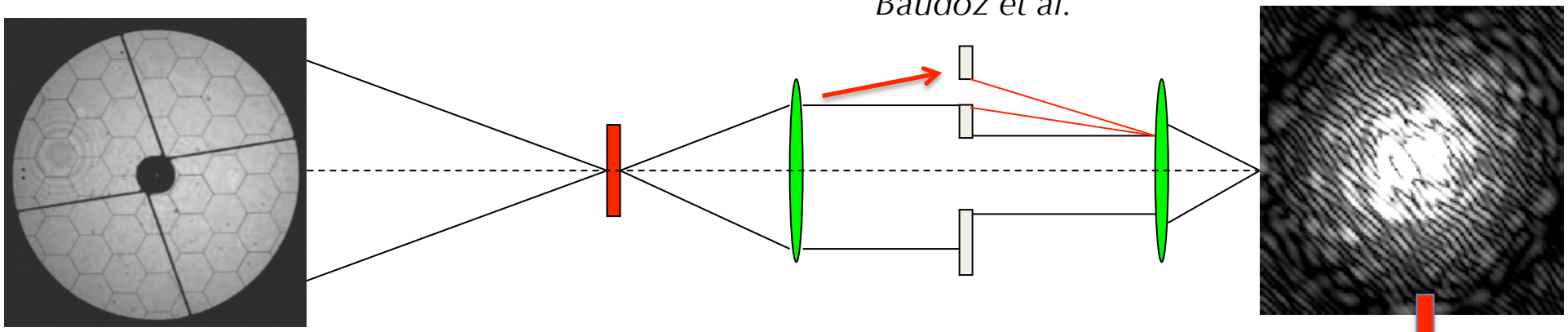




(Pierre Janin-Potiron)

Thesis #1 Phasing segmented aperture

Baudoz et al.

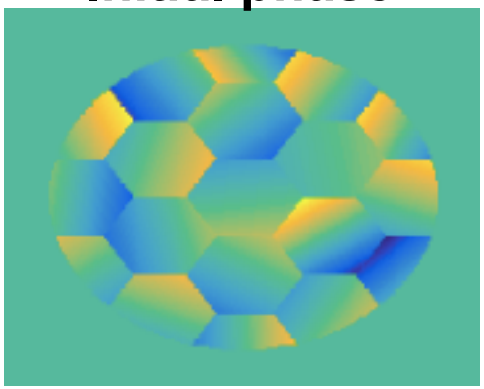


SCC-PS phase mask w/ OPD lambda/2 (π) (or alternative designs, FQPM, etc…)
Focal plane analysis, Calibrating matrix, SVD, estimators, closed-loop

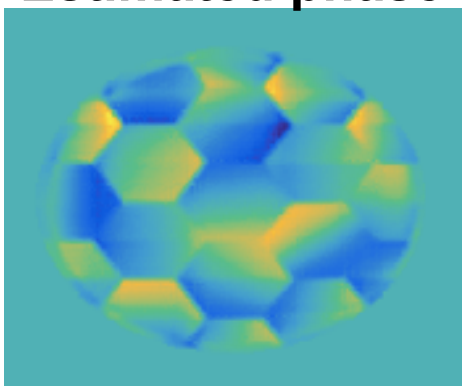
TF^{-1}

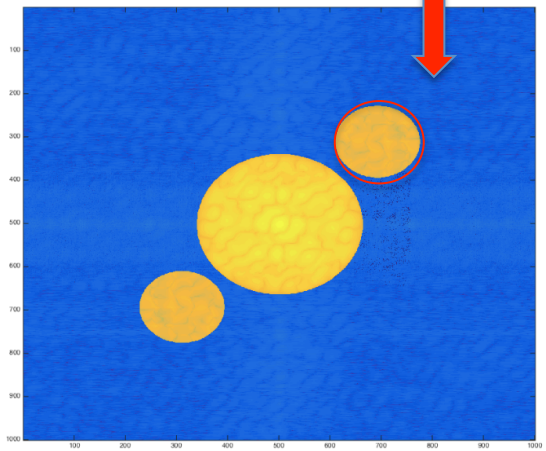
Mazoyer et al. 2014

Initial phase



Estimated phase





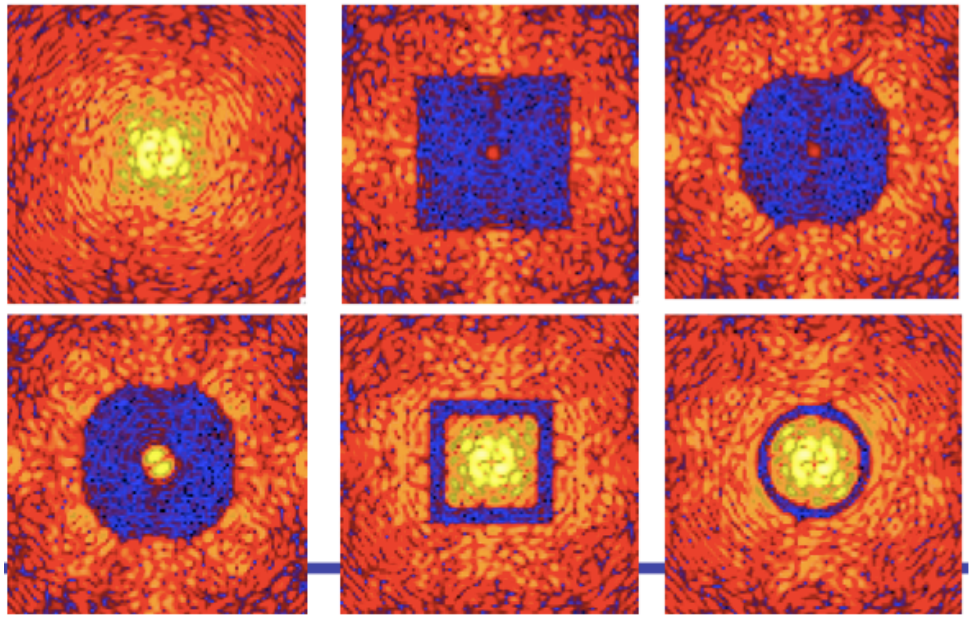
(Pierre Janin-Potiron)

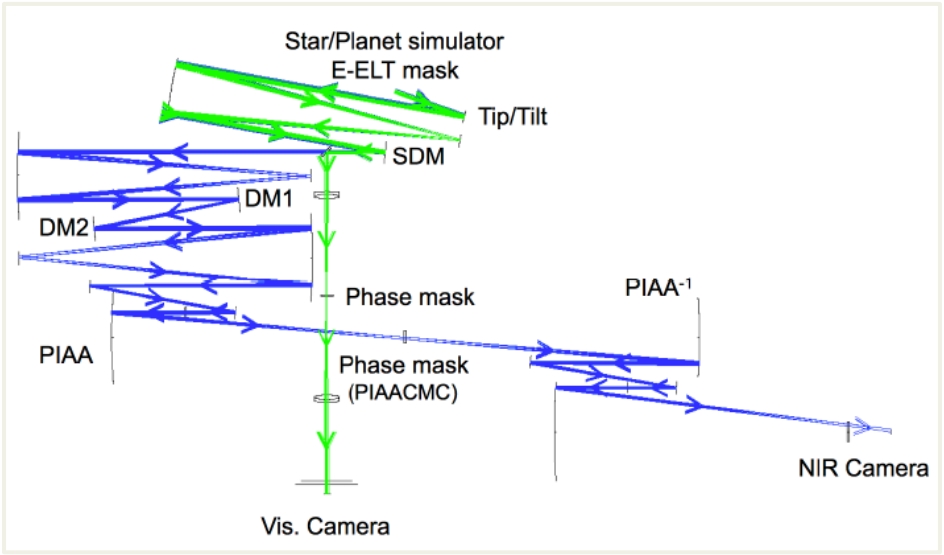
Thesis #2 High contrast imaging

Instrumental and contrast design – HCI end-to-end simulator code for SPEED

- Fresnel optical propagation, multi-DM architecture, SPEED June 2014 design, coronagraph, EFC…

- Optimize: DMs location, optical design (focal length, optics sizes, optics quality…)



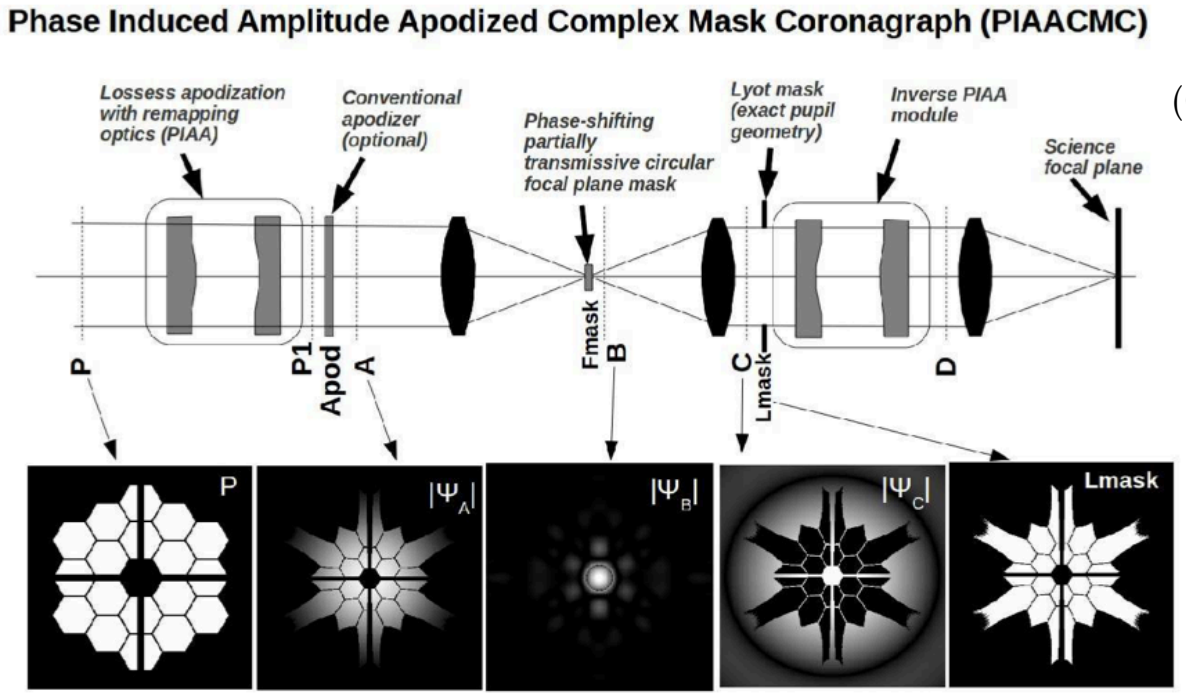


(Mathilde Beaulieu)

Thesis #2 High contrast imaging

PIAACMC developpement

- Optimized for E-ELT pupil (correction of pupil discontinuities)
- Towards very small IWA (1λ/D or sub-λ/D, w/ C = 10^{-7} a IWA)
- Stellar resolution accounted for (up to 0.5mas)



(Guyon et al. 2013)

(Mathilde Beaulieu)

SPEED byproduct

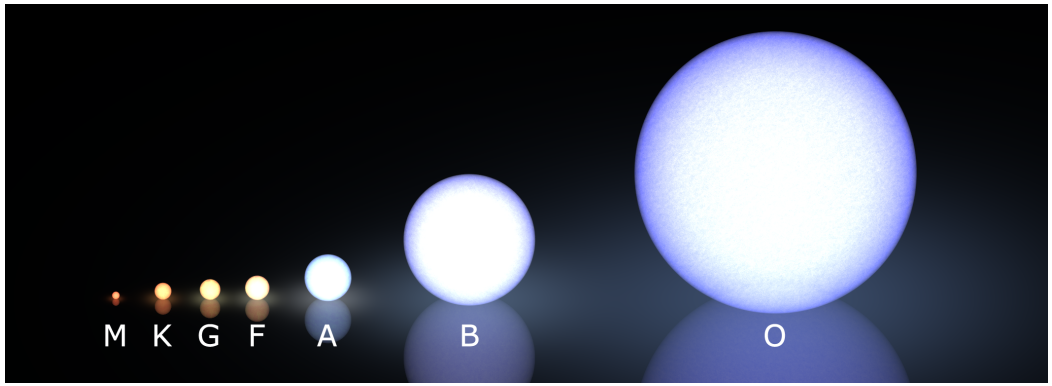
PRIS²M: Planet **R**esearch **I**mager at **S**mall **S**eparations around **M**-dwarfs

- For 8-m telescope scientific purpose
- Use 8-m telescope as test bed for ELT instrumentation that also leverage scientific gain
- On-sky demonstration of PCS technologies

Exploratory program for exoplanet direct imaging for ELT-PCS

Science case

Hunting down low-mass planets in areas very close from the M-dwarfs in the NIR



$0.07 < \text{mass} < 0.6\ M_{SUN}$

Dominate our local neighborhood by number >80%

Summary

- Project kick-off mid-2013
- Opto-mechanical design finalization March 2015
- AIT starts fall 2015 / early 2016
- R&T CNES 2015 w/ LESIA
- Région PACA 2014 w/ LAM
- Mid-2016 SPEED moves at the Nice University (ISO7 room w/ separated control room)
- SPEEDing up R&D for HCI w/ ELTs

SPIE 2014, Vol. 9145
The Messenger (March 2015, n° 159)