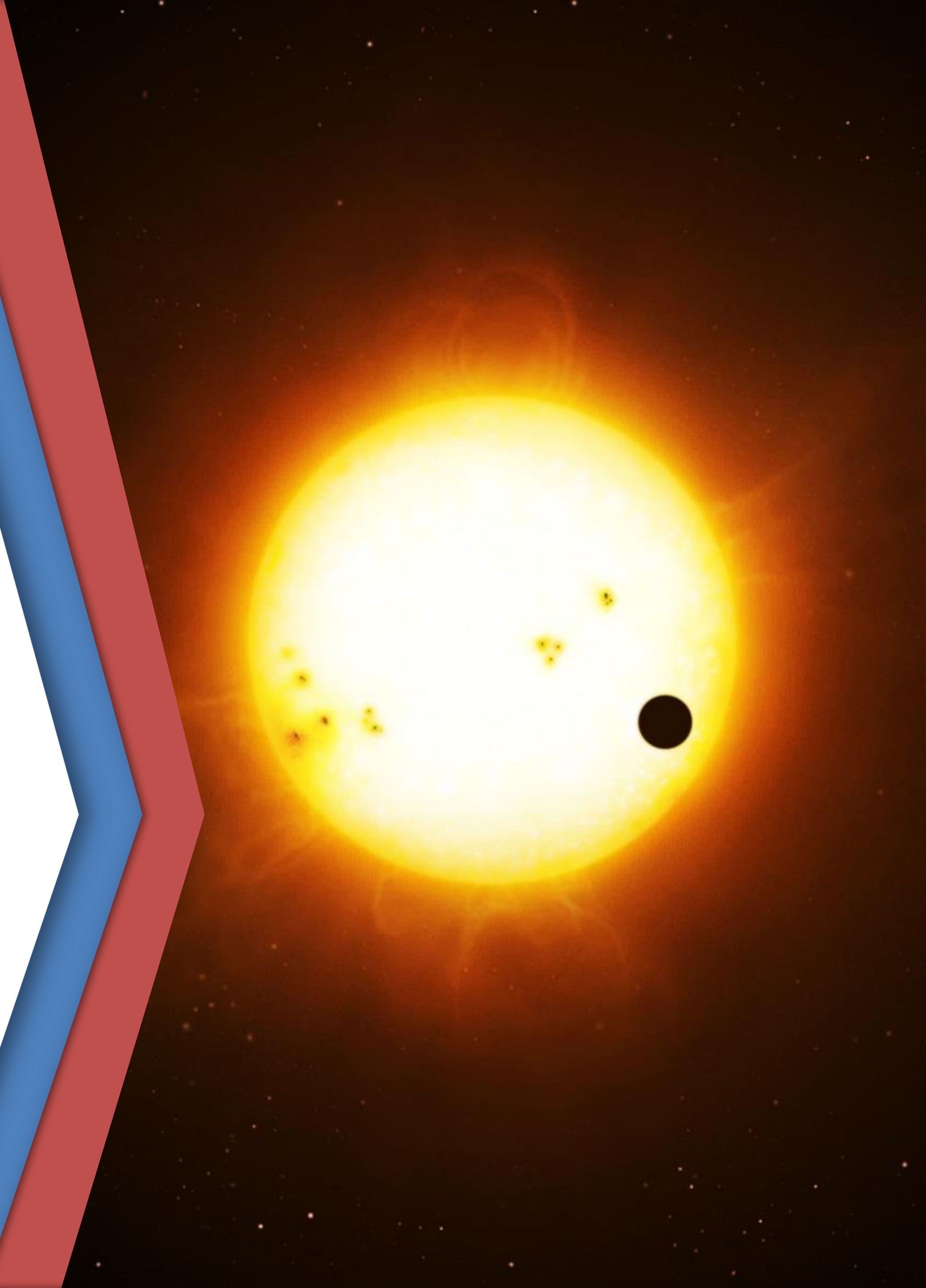
SHARK-NIR, the coronagraphic camera for LBT, moving toward construction

Jacopo Farinato



SHARK-NIR Team

The SHARK-NIR Team: J.Farinato, Guido Agapito, Simone Antoniucci, Francesca Bacciotti, Carlo Baffa, Andrea Baruffolo, Serena Benatti, Maria Bergomi, Federico Biondi, Mariangela Bonavita, Angela Bongiorno, Mickael Bonnefoy, Luca Borsato, Enzo Brocato, Pietro Bruno, Enrico Cappellaro, Luca Carbonaro, Alexis Carlotti, Elena Carolo, Gael Chauvin, Riccardo Claudi, Laird Close, Johanan Codona, Ian Crossfield, Philippe Delorme, Marco De Pascale, Silvano Desidera, Marco Dima, Valentina D'Orazi, Simone Esposito, Daniela Fantinel, Jacopo Farinato, Giancarlo Farisato, Fabrizio Fiore, Adriano Fontana, Wolfgang Gaessler, Emanuele Giallongo, Teresa Giannini, Valentina Granata, Raffaele Gratton, Davide Greggio, Olivier Guyon, Thomas Henning, Phil Hinz, Markus Kasper, Francesco Leone, Luigi Lessio, Gianluca Li Causi, Franco Lisi, Demetrio Magrin, Anne-Lise Maire, Luca Malavolta, Jared Males, Luca Marafatto, Elena Masciadri, Fabrizio Massi, Massimiliano Mattioli, Dino Mesa, Giusi Micela, Manny Montoya, Matteo Munari, Valerio Nascimbeni, Brunella Nisini, Isabella Pagano, Fernando Pedichini, Enrico Pinna, Giampaolo Piotto, Linda Podio, Elisa Portaluri, Alfio Puglisi, Roberto Ragazzoni, Marcia Rieke, Bernardo Salasnich, Eleonora Sani, Gaetano Scandariato, Salvo Scuderi, Elena Sissa, Alessandro Sozzetti, Marco Stangalini, Vincenzo Testa, Massimo Turatto, Daniele Vassallo, Christophe Verinaud, Valentina Viotto, Stefano Zibetti, Alice Zurlo

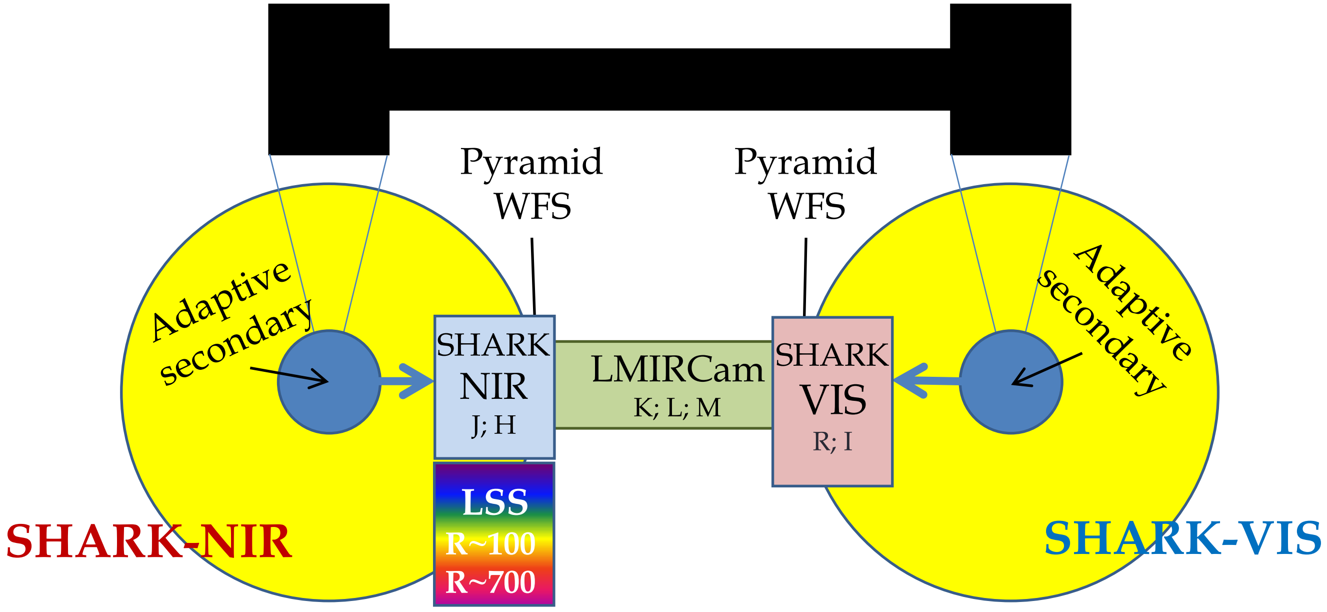
THE SHARK-NIR TEAM

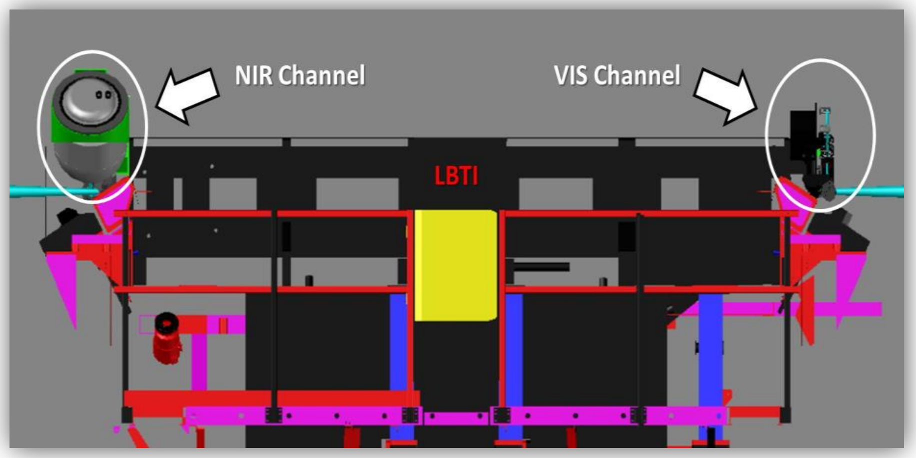
- ✓**INAF-Padova** (Project Responsible, Opto-Mechanics, Pipeline and DRS, INS Software)
- ✓**Steward Observatory** (LBTI interfaces, NIR camera sub-system)
- ✓**MPIA** (for motors electronics and SW design support – thanks to Tom and NIRVANA)
- ✓**IPAG** (CORO mask design)
- ✓**INAF-Brera** (Dispersive elements design)
- ✓**INAF-Trieste** (Data archiving)
- ✓**INAF-Arcetri** (AO Interaction and NIR camera testing support)
- ✓**INAF-Roma** (Coordination with VIS Channel)
- ✓**Science team** (astronomers from 12 institutes)

WHAT IS SHARK?

SHARK-NIR

- Coronagraphic camera with spectroscopic capabilities
- Extreme adaptive optics correction of FLAO (soon upgraded with SOUL)
- Synergy with other LBT instruments: SHARK-VIS, LMIRCam





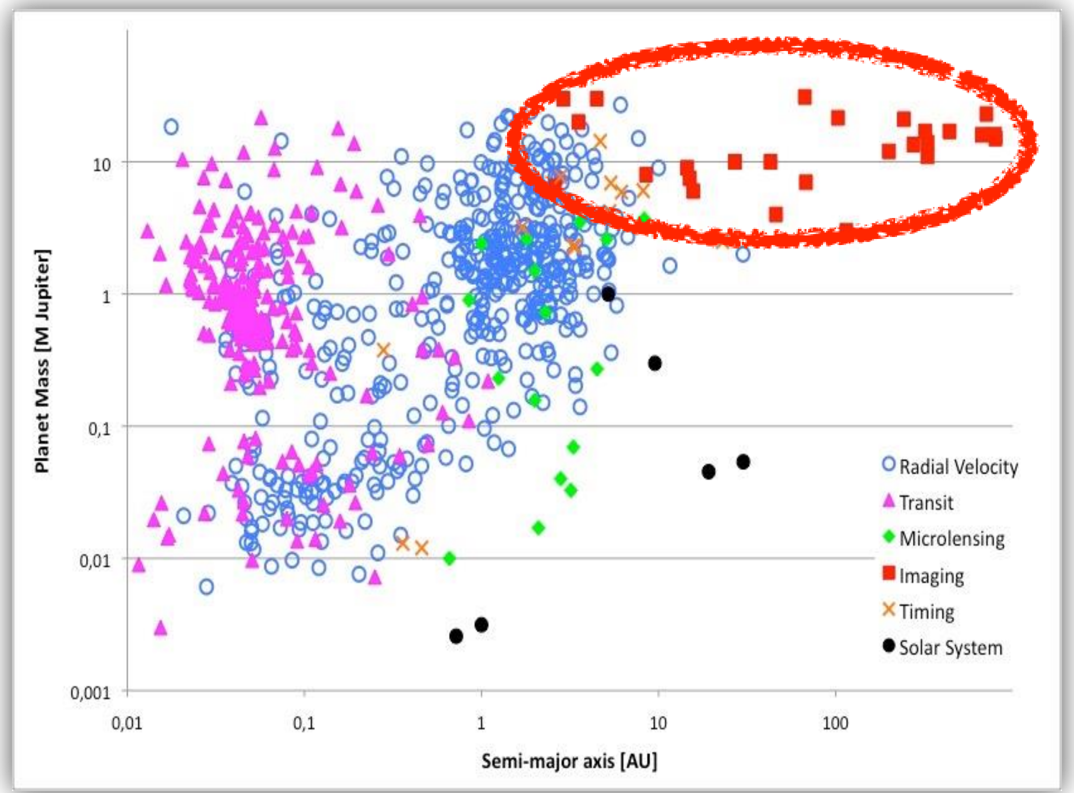
SHARK – SCIENCE TARGETS

Main science target: direct imaging of exo-planets (detection and characterization)

Other science:

- Brown dwarfs
- Protoplanetary disks
- Stellar jets
- AGN

See talk by VALENTINA D'ORAZI

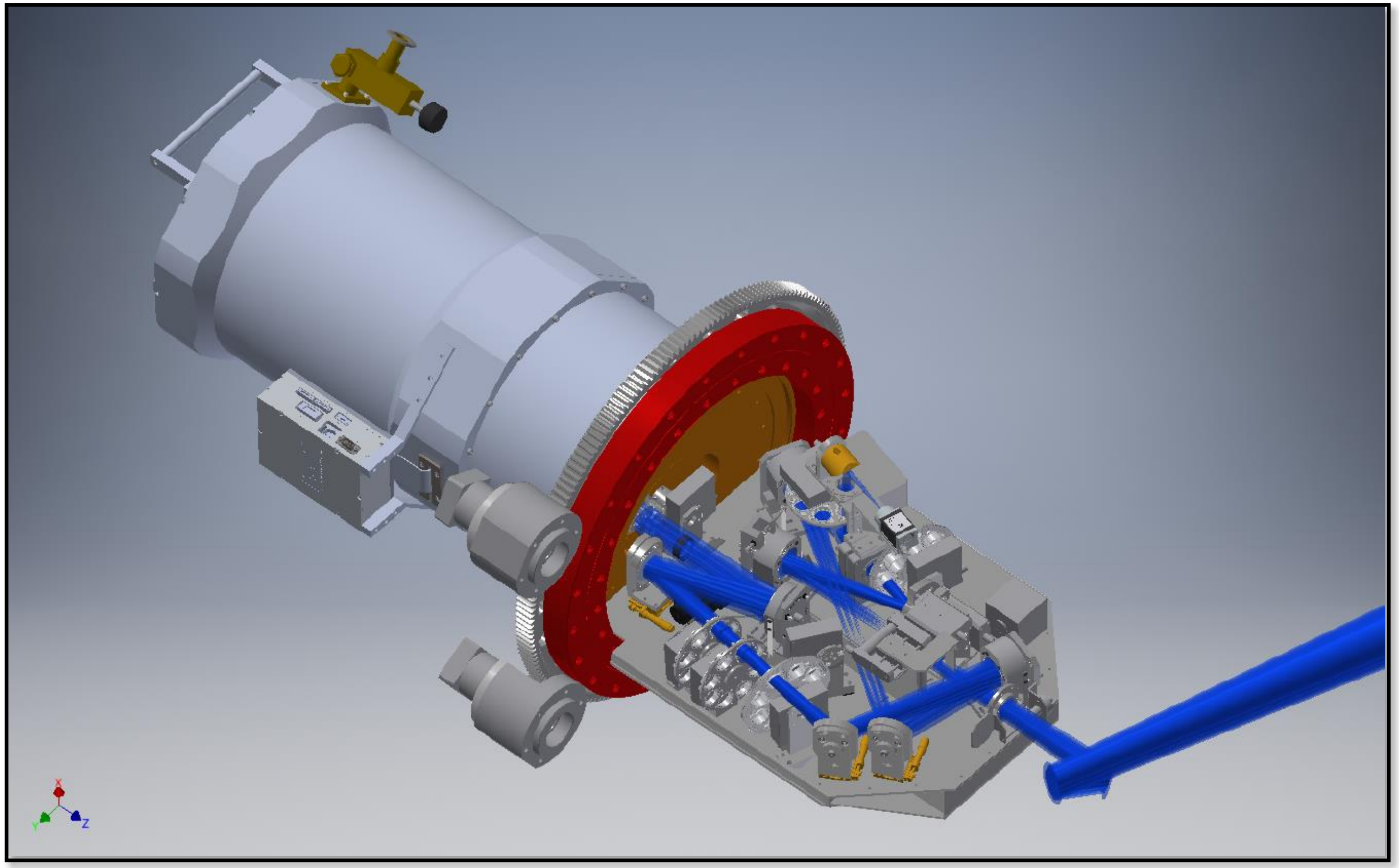


INSTRUMENT SPECIFICATIONS

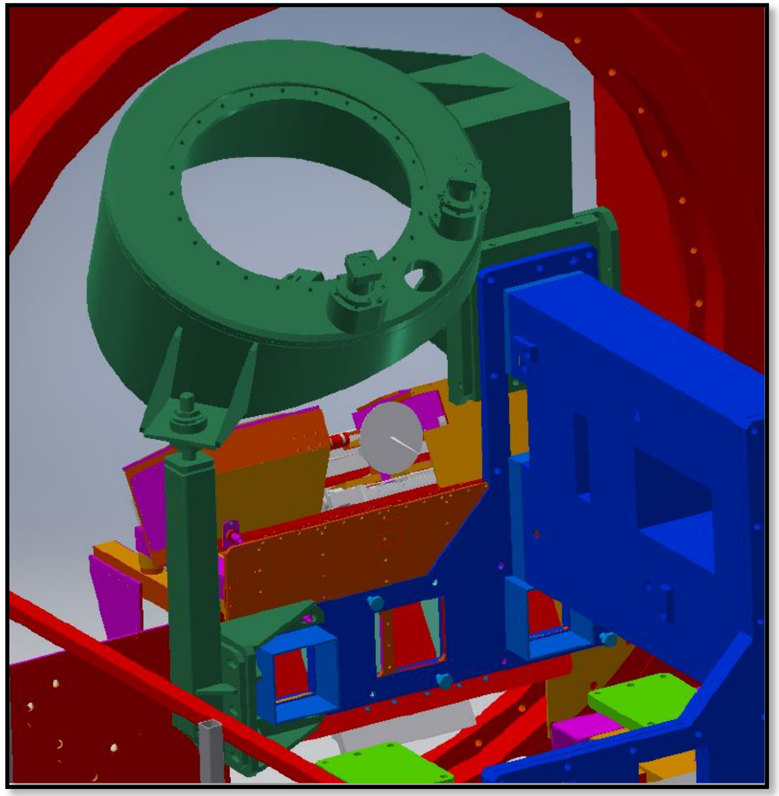
SHARK NIR main characteristics	
Observing Modes	Imaging/Coronagraphy/Spectroscopy/DBI
Detector format [px]	2048x2048 (≈1220x1220 used area)
Waveband [µm]	0.96 – 1.7
FoV x ["]	18
FoV y ["]	18
FoV along the diagonal ["]	25.5
Plate scale [mas/px]	14.5
Airy Radius @ 0.96 micron [px]	2
# of mirrors in the camera	8 (3 flat, 1DM and 4 OA parabolas)
ADC	Yes
Nominal Strehl at <18″ FoV diameter (in all Bands)	>98%

OPTO-MECHANICAL LAYOUT

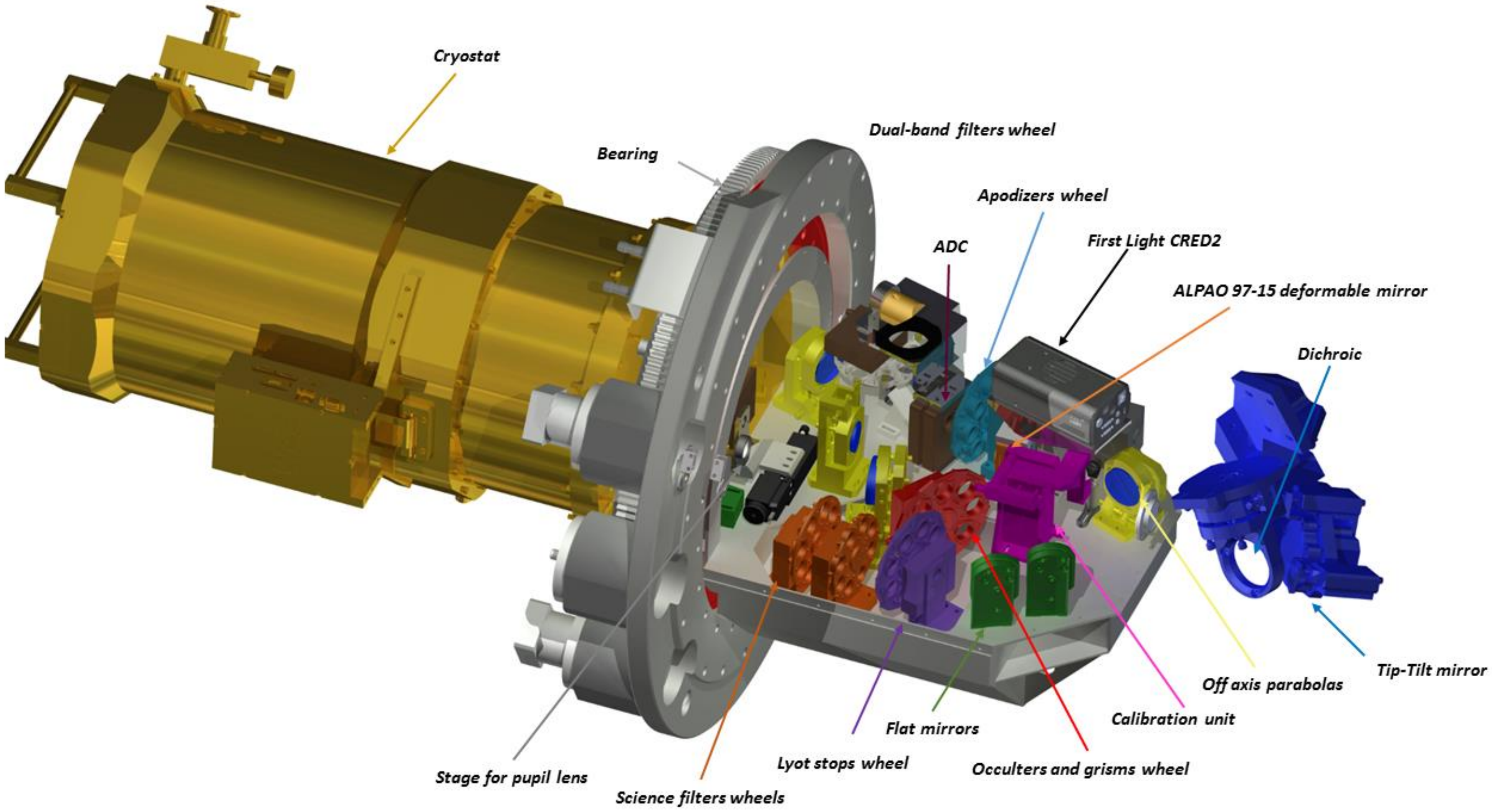
Optical bench + Cryostat



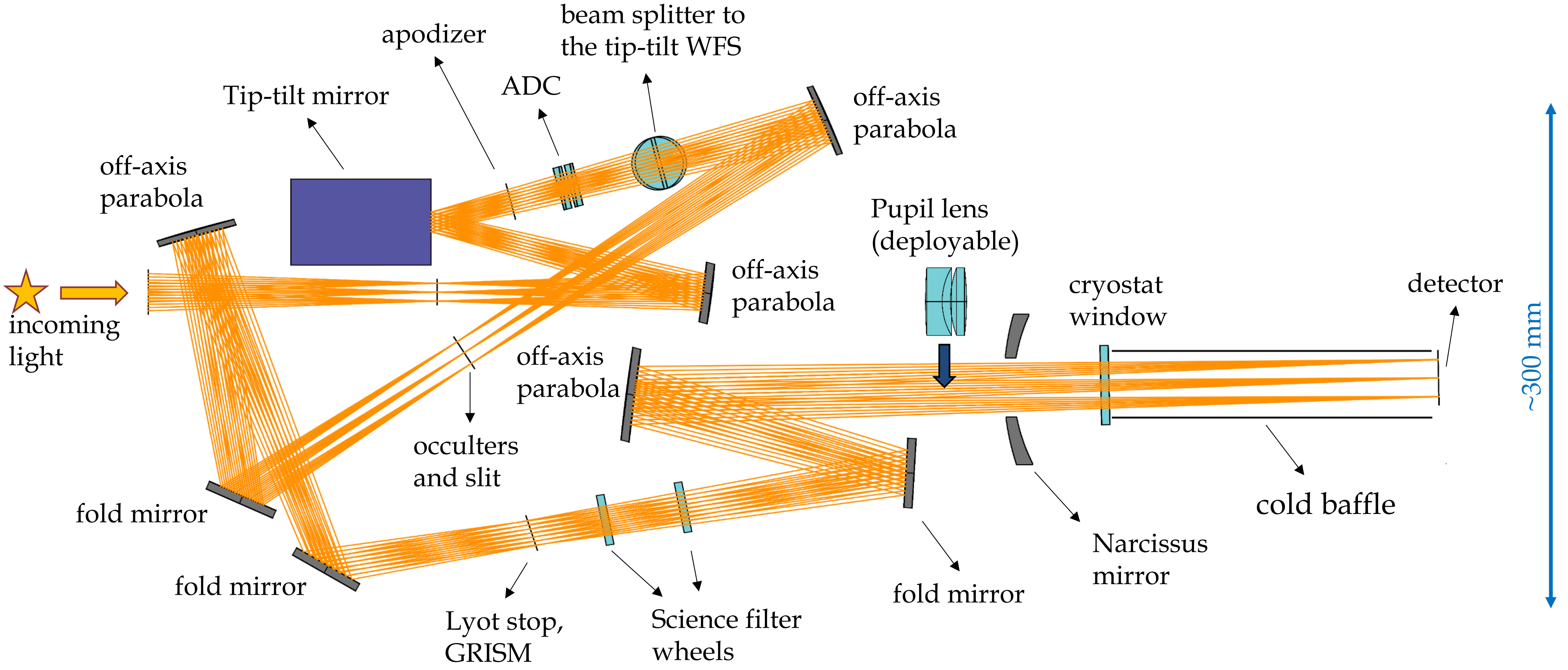
SHARK Holding structure



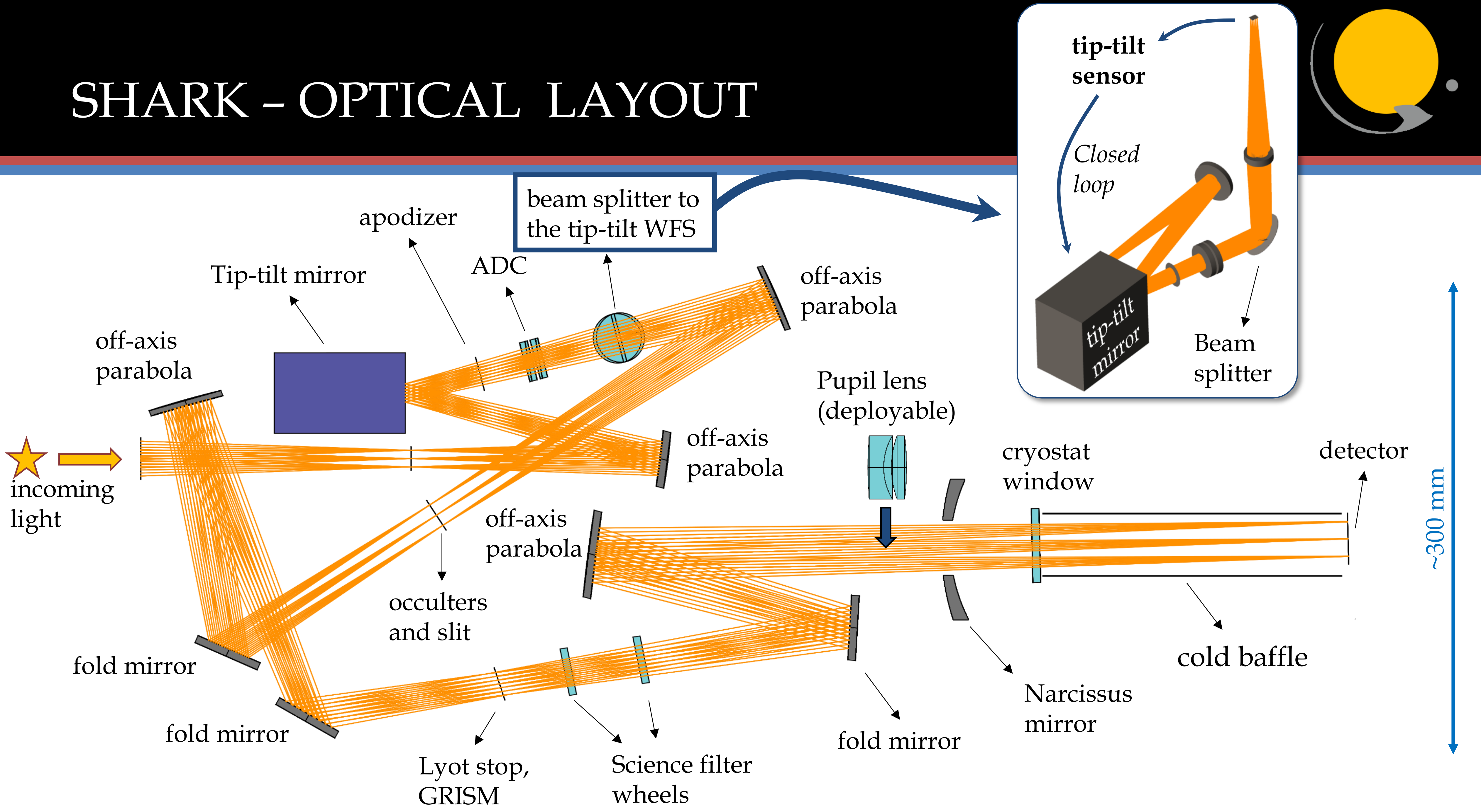
INSTRUMENT DESCRIPTION



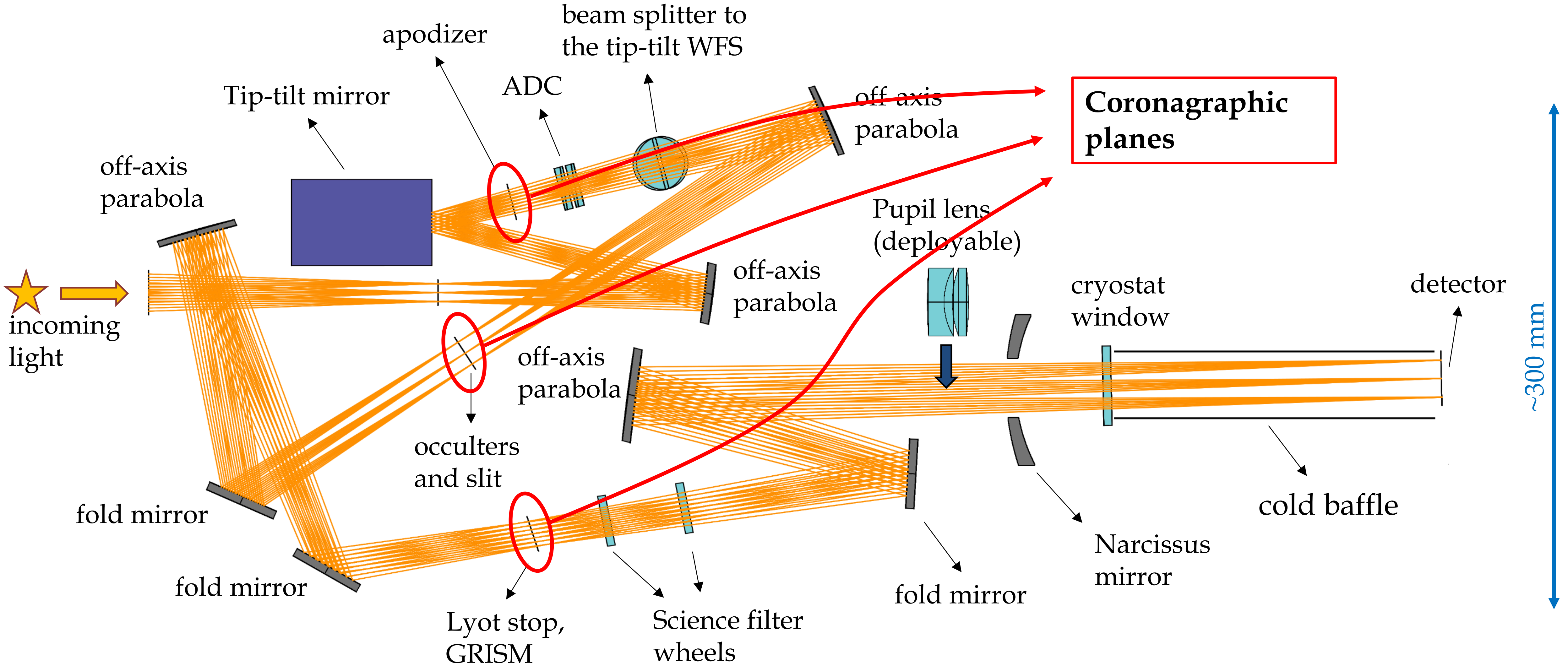
SHARK – OPTICAL LAYOUT



SHARK – OPTICAL LAYOUT



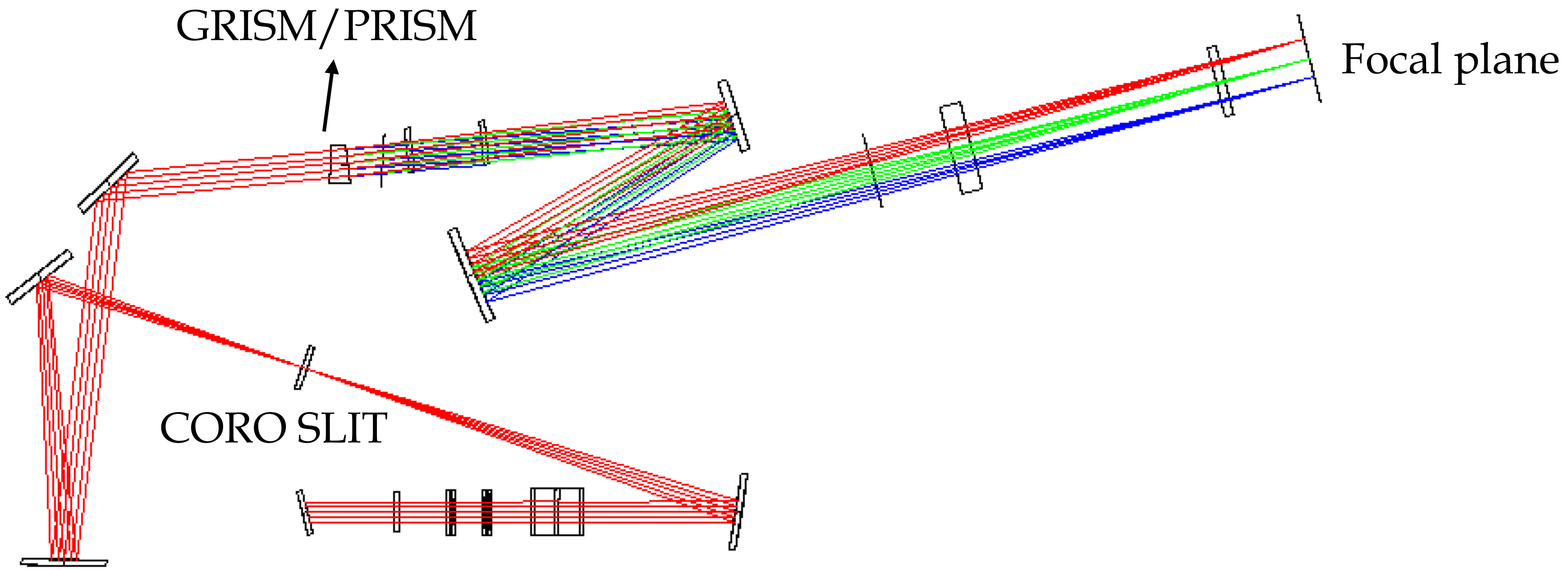
SHARK – OPTICAL LAYOUT



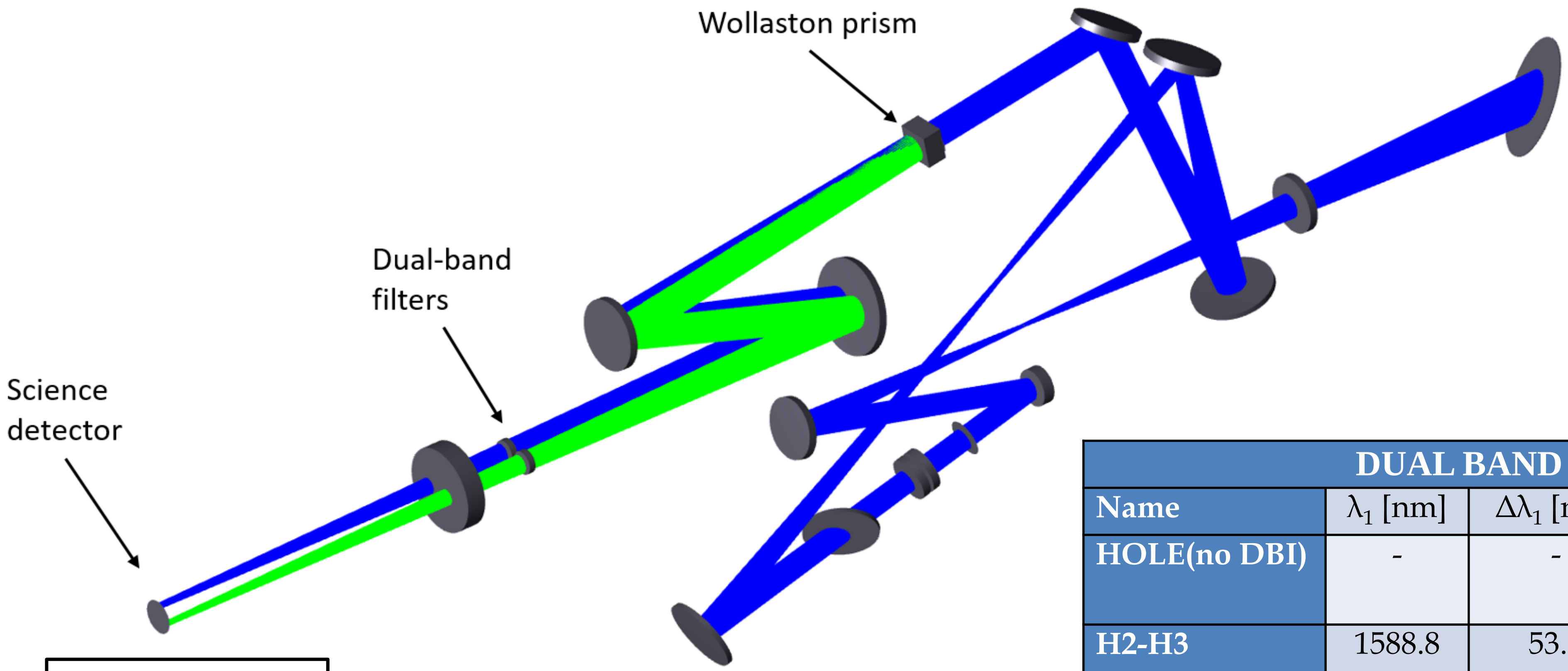
SPECTROSCOPIC MODE

DISPERSIVE ELEMENTS		
	Low Res	Medium Res
Dispersing element	Prism	Grism
R	100	700

CORO SLITS WITH OCCULTER		
	Slit width	Occulter size
Coro slit 1	100 mas	100 mas
Coro slit 2	100 mas	200 mas



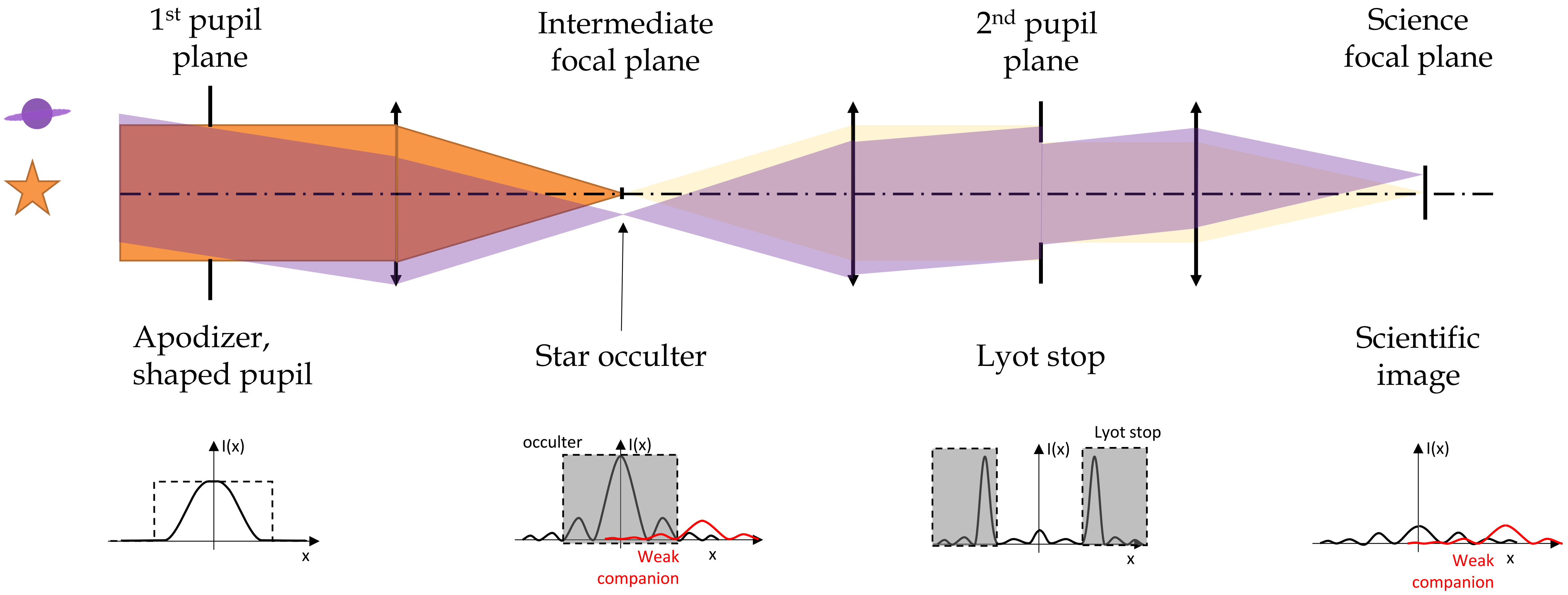
DUAL BAND IMAGING MODE



Radial FoV 1″

DUAL BAND FILTERS				
Name	λ_1 [nm]	$\Delta\lambda_1$ [nm]	λ_2 [nm]	$\Delta\lambda_2$ [nm]
HOLE(no DBI)	-	-	-	-
H2-H3	1588.8	53.1	1667.1	55.6
ContJ-Pa β	1215.7	18.3	1281.3	20.9
ContH-Fe II	1557.8	24.1	1645.5	26.1
Phase diversity				

CORONAGRAPHY IN SHARK



CORONAGRAPHIC TECHNIQUES

- ✓ Gaussian Lyot
- ✓ Shaped pupil (both symmetric and asymmetric discovery space)
- ✓ 4 Quadrant/Vortex/APP/APLC under evaluation

Field stabilized mode (de-rotator ON) requires circular symmetric masks (Classical Lyot and Gaussian Lyot).

Shaped Pupil (not symmetric) is used in Pupil stabilized mode (de-rotator OFF)

PROJECT STATUS 1

- **FDR:** January 2017

Very positive, with the final recommendation of the FDR panel **to proceed as soon as possible to the fabrication stage**.

Nevertheless, the panel also identified a few reason of concerns, some regarding the management of the project and some other concerning a few technical issues.

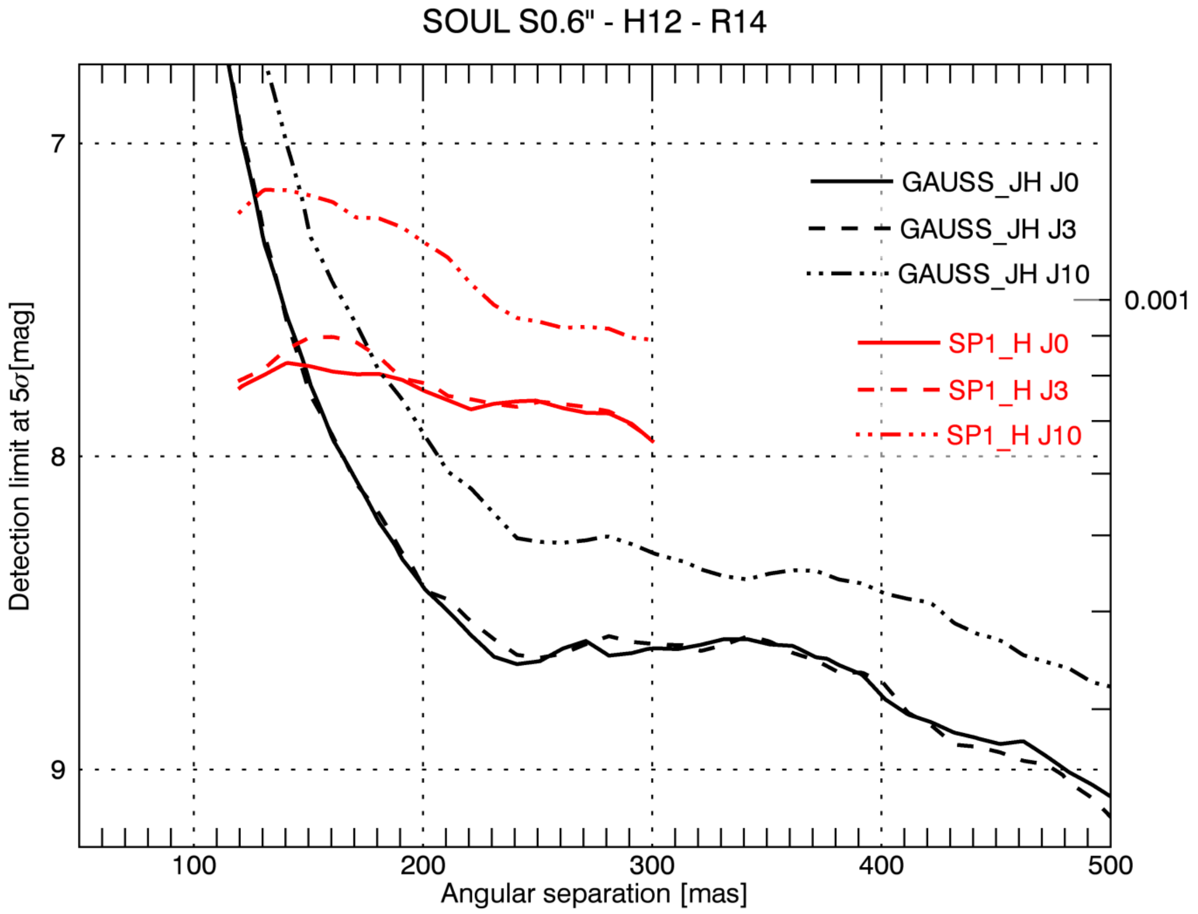
PROJECT STATUS 2

Main technical concerns:

- The panel indicates to evaluate the possibility to have a local fast Tip-Tilt (T-T) correction, that will require also a dedicated fast T-T sensor, to possibly address jitter larger than the one considered in the FDR error budget; this would also allow to improve the coronagraphic performance, allowing to reach smaller inner working angles
- The panel asked to investigate what the effect on the AO performance may be when removing the NCPA with the Adaptive Secondary Mirror (ASM); in fact, if the NCPA to be removed are not negligible, their removal with the ASM will degrade the PSF quality on the pyramid, fact that may impact the AO performance

POST FDR STUDY (3 months)

Concerning the residual jitter…



Concerning the NCPA…

Contributor	NCPA rms WFE [nm]	Aberration type/spectrum
Optical design nominal WFE	16	
Dichroic nominal transmitted WFE	31	~28nm chromatic dispersion. ~13nm astigmatism.
Dichroic manufacturing transmitted WFE	28	The expected PSD is ~f^{-2} [cycles/pupil].
Dichroic manufacturing reflected WFE	23	The expected PSD is ~f^{-2} [cycles/pupil].
Manufacturing (dichroic excluded) tolerances	90	The expected PSD is ~f^{-2} [cycles/pupil].
Alignment tolerances	35	29nm astigmatism 2nm coma 3nm spherical ab.
ADC @ ZA=50°	8.7	Chromatic dispersion
Thermal effect (defocus)	3	Defocus
TOTAL	~110	

POST FDR STUDY CONCLUSION

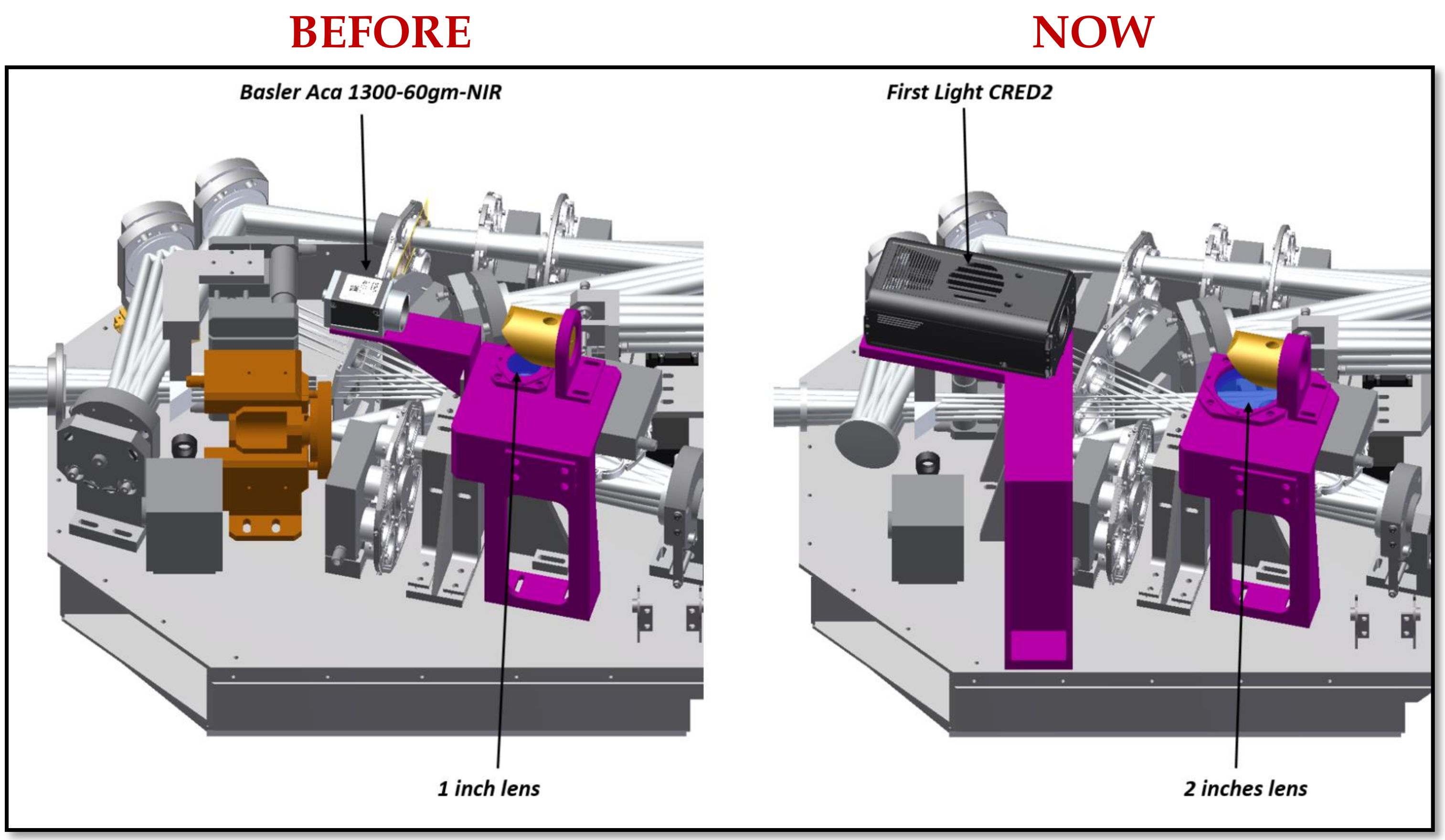
To follow the suggestion given by the FDR panel

- Replacing the TT sensor with a more sensitive one in J-H band
- Replacing the low frequency TT mirror with a low order DM, allowing both fast TT correction (up to 2.4KHz) and local NCPA correction

RECENT UPDATES – FAST TT SENSOR

Tip-tilt WFS upgrade

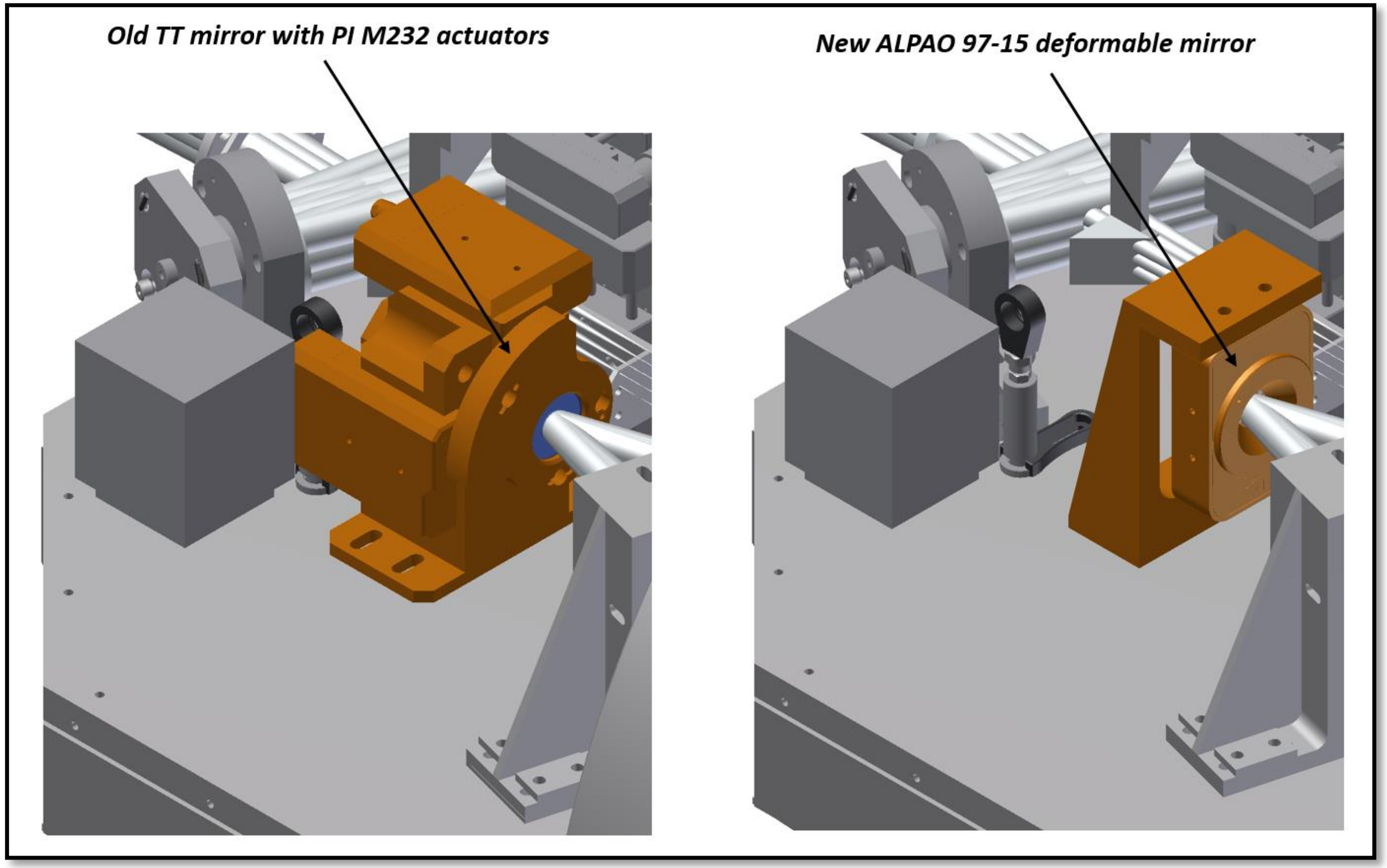
- New InGaAs camera (C-RED2)
- Sensitive in the full SHARK-NIR waveband (0.96-1.7 μm)
- Frame-rate up to 14KHz (with 32X32 px window)
- Same FoV as before (11″x13″)
- Low RON (<25e⁻)
- 3 mas precision up to mag=12 @ 1KHz



RECENT UPDATES – INTERNAL NCPA CORRECTION

Tip-tilt mirror upgrade

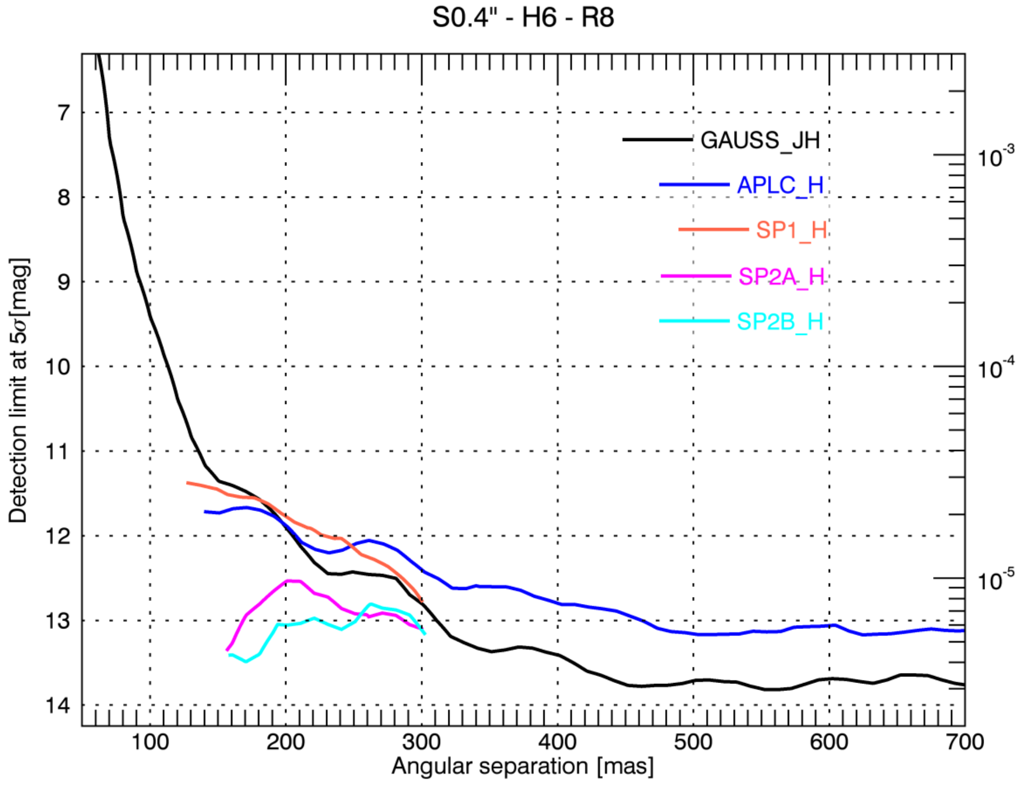
- Tip-tilt mirror replaced by ALPAO DM 97-15
- 97 actuators, 13.5 mm pupil, up to 2.5KHz speed
- NCPA can be corrected internally without affecting pyramid's performance
- Smaller volume
- NCPA measured with phase diversity on science image



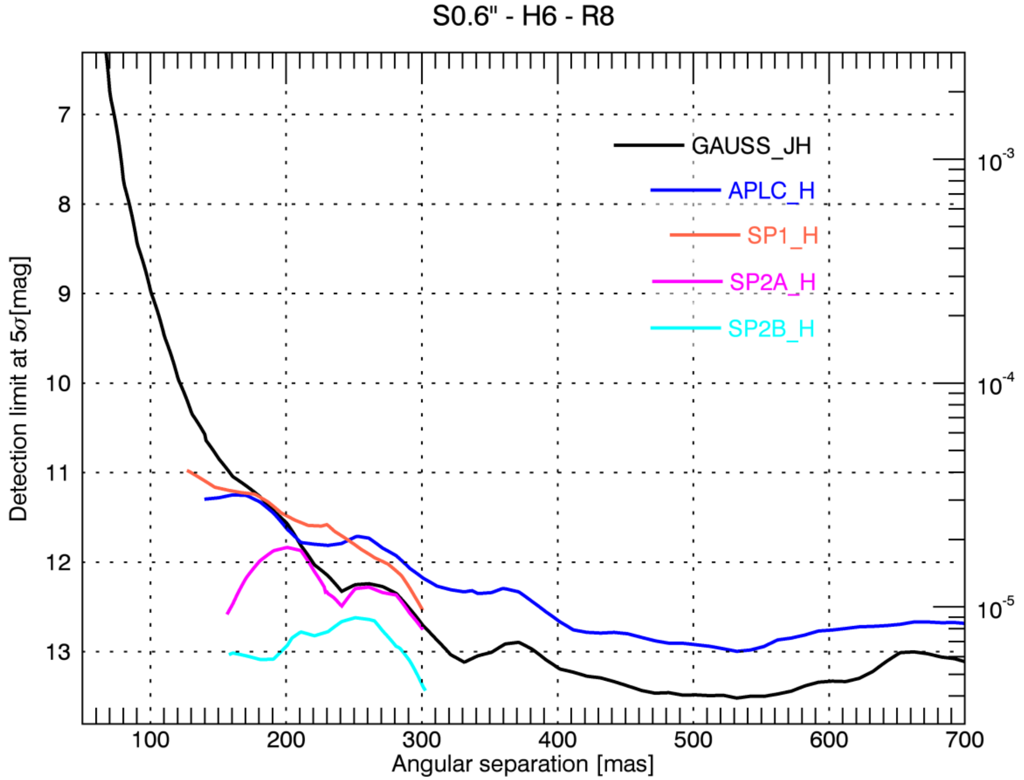
CORONAGRAPHIC PERFORMANCE

5-σ detection limit in H band for Rmag=8 with SOUL

Seeing 0.4″



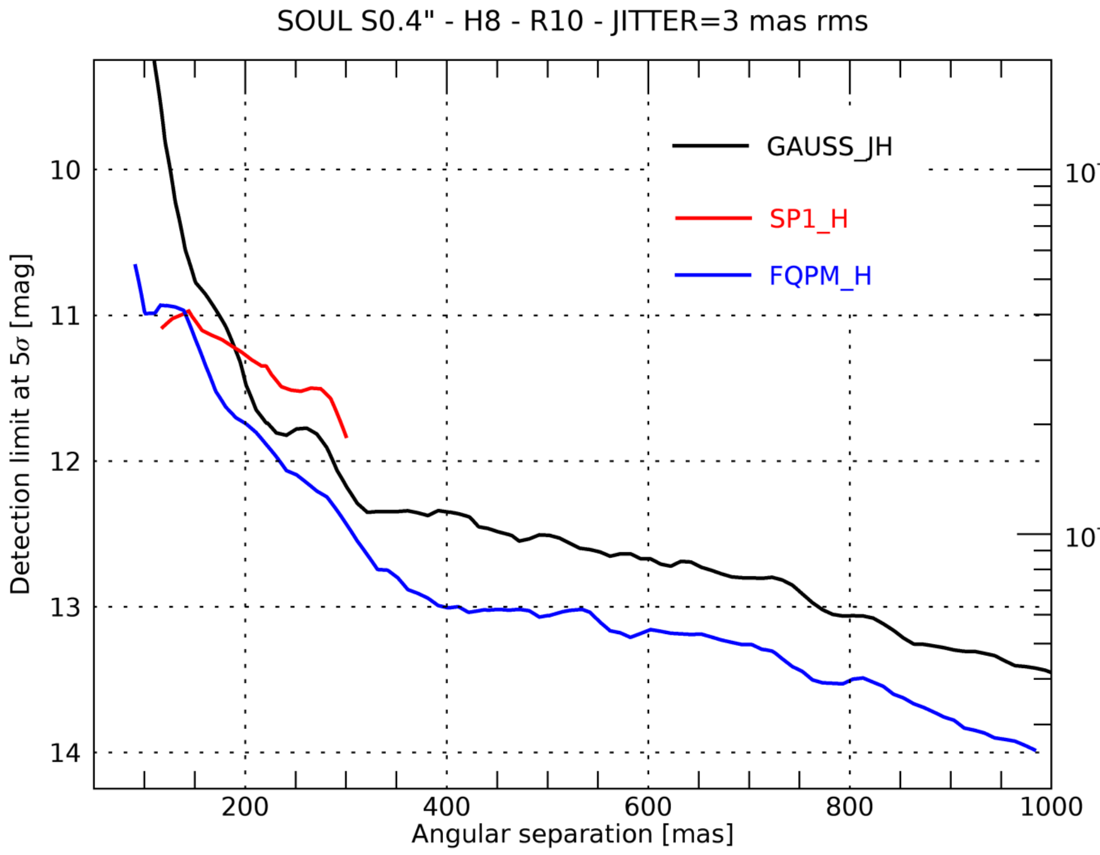
Seeing 0.6″



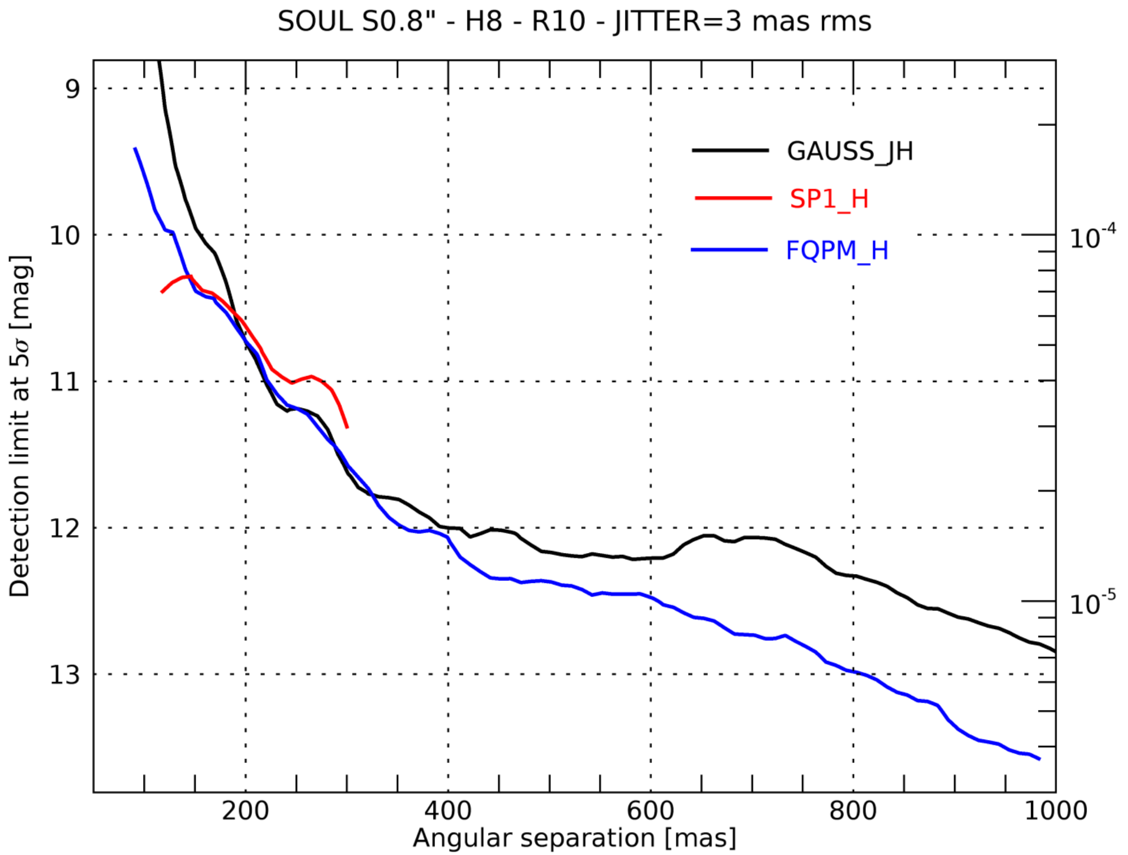
CORONAGRAPHIC PERFORMANCE

<u>5-σ detection limit in H band for Rmag=10 with SOUL</u>

Seeing 0.4″

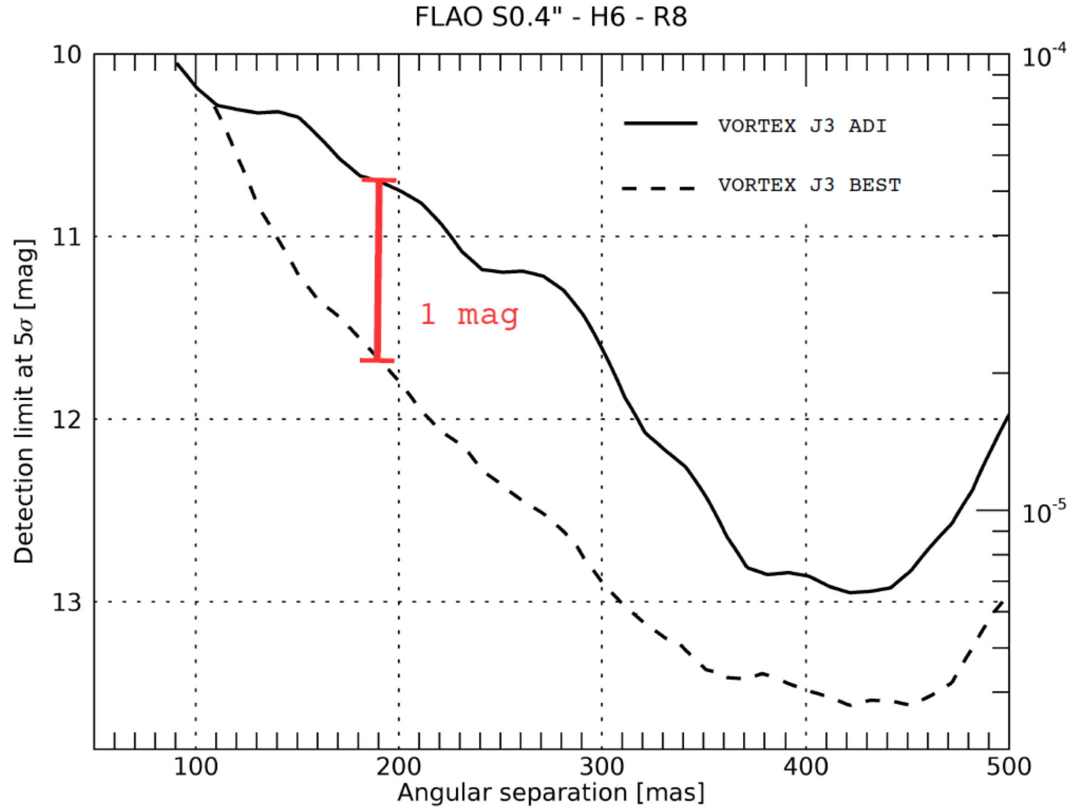


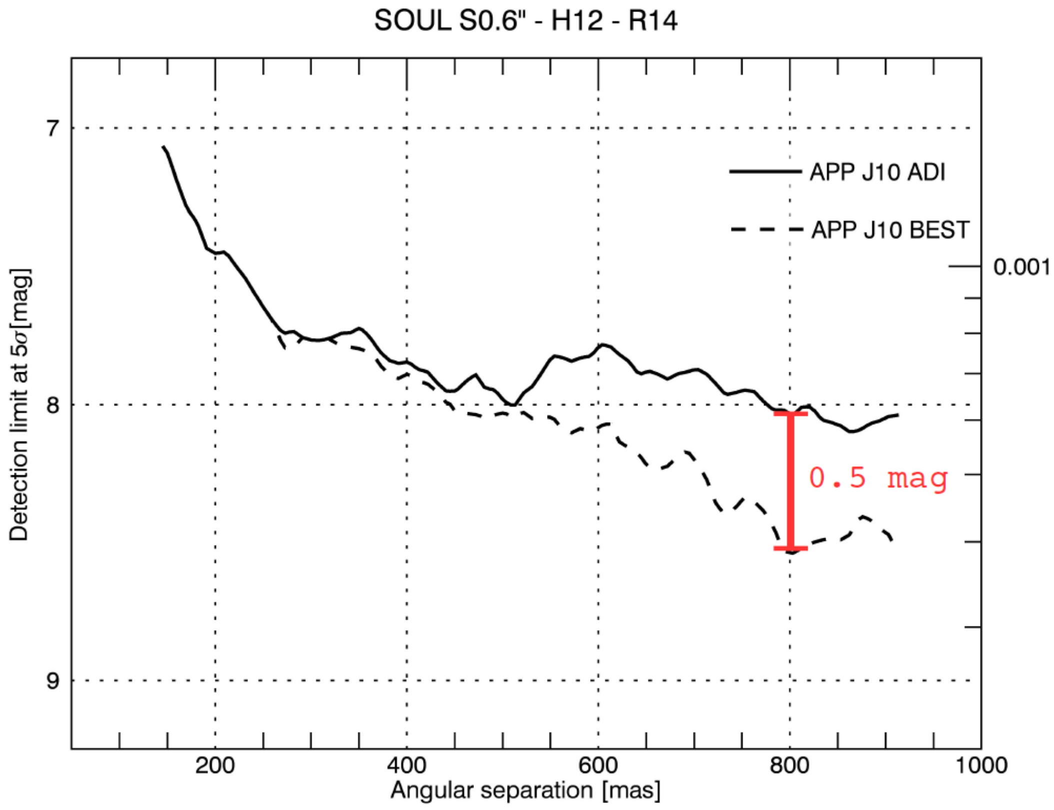
Seeing 0.8″



CORONAGRAPHIC PERFORMANCE

5-σ detection limit in H band with normal ADI vs an optimized data reduction technique taking into account the distance from the star





NEXT STEPS

- **LBT board approval:** June 2017
- **Procurement phase:** end of June 2017 – September 2018
- **AIV phase**: September 2017 – January 2019
- **Preliminary Acceptance Europe:** January 2019
- **Commissioning start:** June 2019
- **SHARK-NIR operation:** October 2019

Science is coming!