A virtual coronagraphic test bench for SHARK-NIR, the II-generation high contrast imager for the Large Binocular Telescope

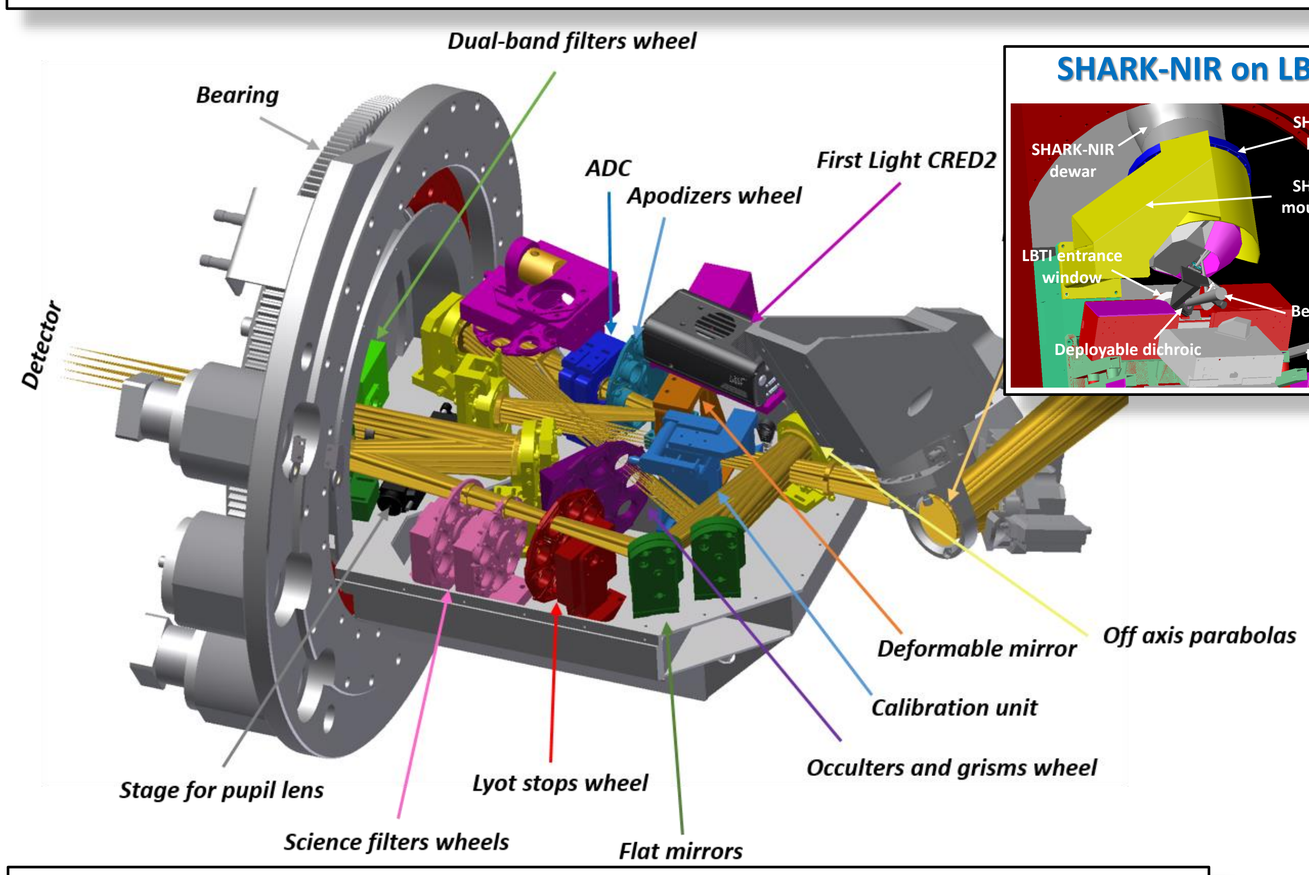
Jacopo Farinato[a,h], Francesca Bacciotti[b], Carlo Baffa[b], Andrea Baruffolo[a], Maria Bergomi[a,h], Andrea Bianco[i], Angela Bongiorno[c], Luca Carbonaro[b,h], Elena Carolo[a,h], Alexis Carlotti[d], Laird Close[e], Marco De Pascale[a], Marco Dima[a,h], Valentina D'Orazi[a], Simone Esposito[b,h], Daniela Fantinel[a], Giancarlo Farisato[a], Wolgang Gaessler[f], Emanuele Giallongo[c,h], Davide Greggio[a,g,h], Olivier Guyon[e], Phillip Hinz[e], Franco Lisi[b], Demetrio Magrin[a,h], Luca Marafatto[a,h], Dino Mesa[a] , Lars Mohr[f], Manny Montoya[e], Fernando Pedichini[c,h], Enrico Pinna[b,h], Alfio Puglisi[b,h], Roberto Ragazzoni[a,h], Bernardo Salasnich[a], Marco Stangalini[c,h], Daniele Vassallo[a,g,h], Christophe Verinaud[d], Valentina Viotto[a,h], Alessio Zanutta[i]

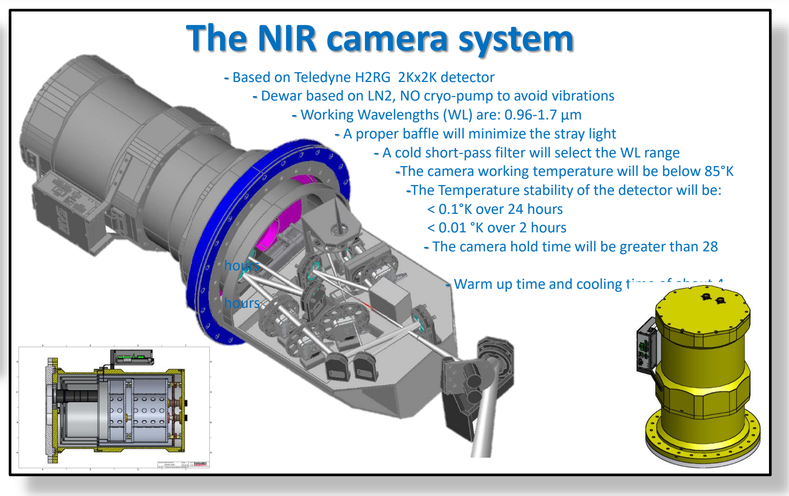
[a] INAF Padova, [b] INAF Arcetri, [c] INAF Roma, [d] IPAG, [e] University of Arizona/Steward Observatory, [f] MPIA, [g] Università di Padova, [h] ADONI: National Laboratory for AO, [i] INAF Brera
mail to : daniele.vassallo@oapd.inaf.it

LABORATORIO NAZIONALE ADONI OTTICA ADATTIVA

SHARK-NIR

SHARK-NIR is one of the two coronagraphic instruments proposed for the **LBT**, in the framework of the call for second generation instruments, issued in 2014. Together with the SHARK-VIS channel, it will allow **direct imaging**, **coronagraphic imaging** and **coronagraphic low resolution spectroscopy** covering a wide wavelength domain, going from 0.6µm to 1.7µm (Y to H band).
The current design will exploit in this way the synergy with other LBT instruments such as LBTI, which is actually covering wavelengths greater than L' band, and it will be soon upgraded to work also in K band, and LUCI, offering direct imaging in a 30"x30" FoV in J, H and K bands.
SHARK-NIR successfully passed the final design review, receiving the green light for successive construction and installation at LBT.
The current design foresees two **intermediate pupil planes** that will allow to implement coronagraphic techniques very efficient in term of contrast and vicinity to the star, increasing the instrument performance.
High contrast is necessary to properly exploit the **search of giant exoplanets**, which is the main science case and the driver for the technical choices of SHARK-NIR. We also emphasize that the LBT AO SOUL upgrade will further improve the AO performance, making possible to extend the exo-planet search to target fainter than normally achieved by other 8-m class telescopes, and opening in this way to other very interesting scientific scenarios, such as the **characterization of AGN and Quasars** (normally too faint to be observed) and increasing considerably the sample of **disks and jets** to be studied.
Finally, we emphasize that SHARK-NIR will offer XAO direct imaging capability on a FoV of about 18"x18", and a simple coronagraphic spectroscopic mode offering spectral resolution ranging from one hundred to one thousand.



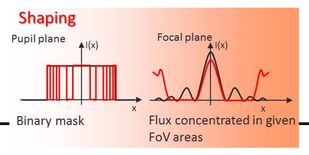


SHARK NIR Main Characteristics

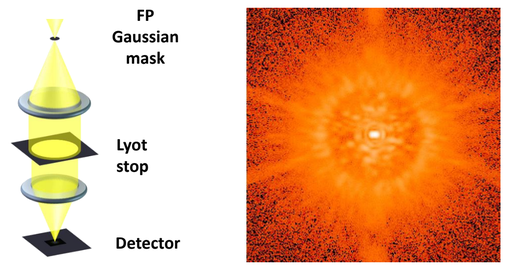
Observing Modes	**Imaging/Coronagraphy/Spectroscopy/ DBI**
Wavelength (WL) range [µm]	0.96-1.70
Spectroscopic Mode	R=100, R=700 over the full WL range
Coronagraphic Mode	Gaussian Lyot, Shaped Pupil, Apodized Lyot
Detector Type	Teledyne H2RG 2048x2048
FoV in X and Y ["]	18
FoV along the diagonal ["]	25
Scale [mas/pixel]	14.5
Airy Radius @ 0.96 µm [pixel]	2.0
# of mirrors in the camera	8 (3 flat, 1 TTM and 4 OAPs)
ADC	Yes
Nominal Strehl at <18" FoV diameter (in all bands)	>98%

The simulation tool: a coronagraphic test bench

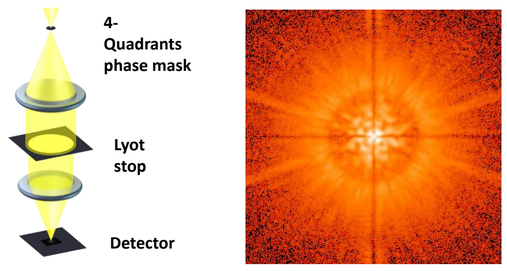
Fresnel end-to-end propagation
+ Closed-loop atmospheric residuals for different seeing conditions and guide star magnitudes
+ Non Common Path Aberrations and Telescope Vibrations
+ Polychromatic imaging



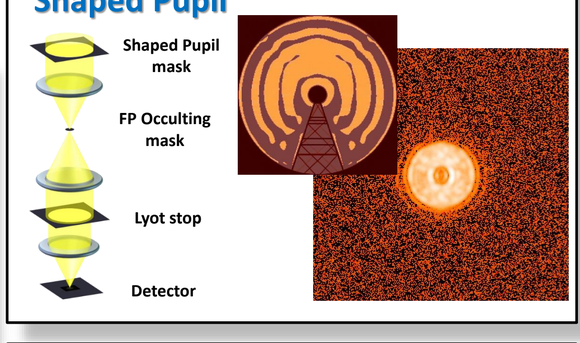
Gaussian Lyot



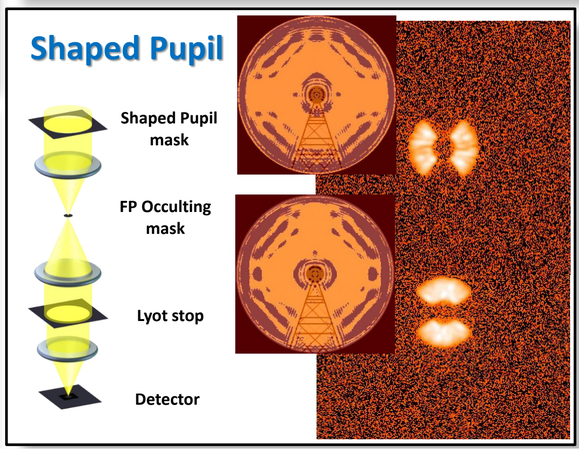
Four-Quadrant Phase-Mask



Shaped Pupil



Shaped Pupil

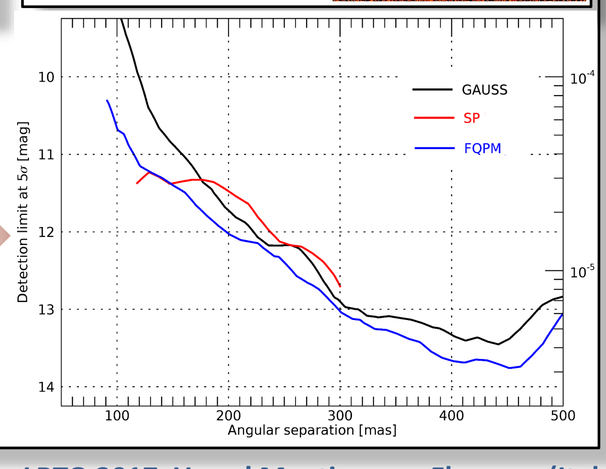


Post-processing pipeline

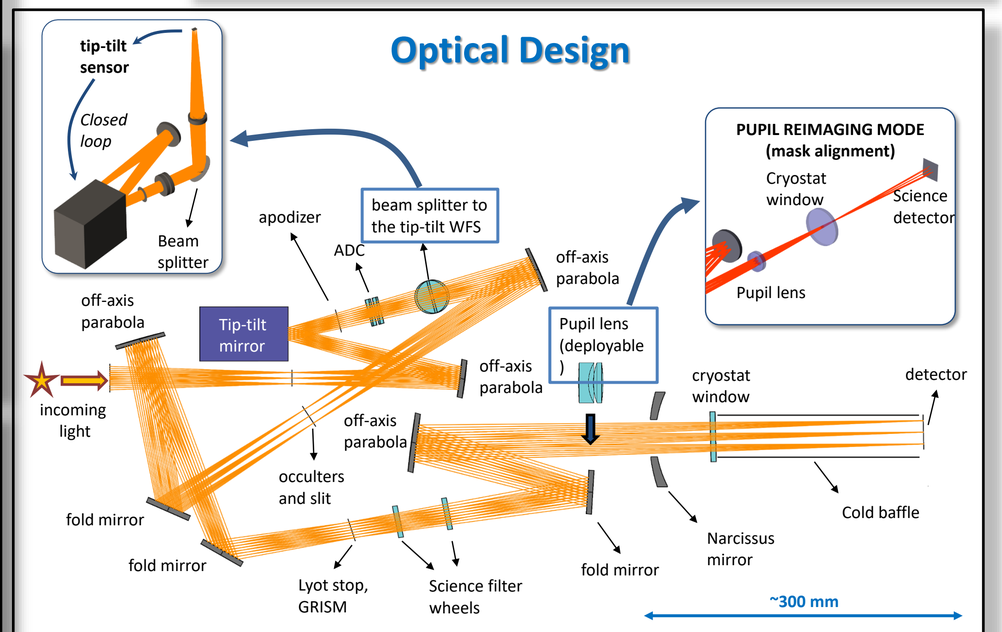
Angular Differential Imaging

- Sequences up to 100 images
- Optimized reference PSF subtraction as a function of angular separation (classical, multi-median, PCA)
- Correction for photometric bias

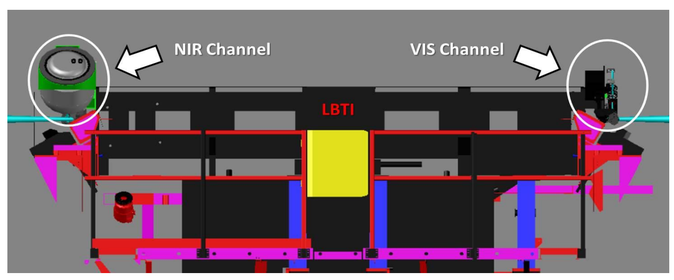
Seeing: 0.4''
R = 8
H = 6
DIT: 1 s
Images: 30
FoV rotation: 90°
Jitter: 3 mas rms
NCPA: 30 nm



Optical Design



SHARK location on LBTI



Spectroscopic Mode

LOW RESOLUTION MODE:
- Dispersive element: PRISM
- R ≈100
- Spectral coverage: 0.96-1.7µm

MEDIUM RESOLUTION MODE:
- Dispersive element: GRISM
- R≈ 700
- Spectral coverage: 0.96-1.7µm

Project Milestones

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