SHARK-NIR, a status update

Luca Marafatto on behalf of SHARK-NIR team

Wavefront sensing in the VLT/ELT era, 4th edition, June 18 2019
WHAT IS SHARK-NIR?

- Camera for high-contrast imaging and spectroscopy in the NIR, mainly dedicated to detection and characterization of exoplanets

- Observing modes:
  - Classical Imaging
  - Coronagraphic imaging
  - Long Slit spectroscopy
  - Dual Band Imaging
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  - Classical Imaging
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  - Long Slit spectroscopy
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- Synergy with other LBT instruments
  (SHARK-VIS, LMIRCAM)
**SHARK-NIR main characteristics**

<table>
<thead>
<tr>
<th>Observing Modes</th>
<th>Imaging/Coronagraphy/Spectroscopy/DBI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Detector format [px]</td>
<td>2048x2048 (≈1220x1220 used area)</td>
</tr>
<tr>
<td>Waveband [μm]</td>
<td>0.96 – 1.7</td>
</tr>
<tr>
<td>FoV [&quot;]</td>
<td>18 x 18</td>
</tr>
<tr>
<td>FoV along the diagonal [&quot;]</td>
<td>25.5</td>
</tr>
<tr>
<td>Plate scale [mas/px]</td>
<td>14.5</td>
</tr>
<tr>
<td>Airy Radius @ 0.96 micron [px]</td>
<td>2</td>
</tr>
<tr>
<td>Nominal Strehl at &lt;18” FoV diameter (in all Bands)</td>
<td>&gt;98%</td>
</tr>
</tbody>
</table>
Weight: 350 kg
Size: 1500 x 800 x 800 mm
OPTO-MECHANICAL LAYOUT

- DM apodizer
- ADC
- Beam splitter to the tip-tilt WFS
- Off-axis parabola
- Off-axis parabola
- Off-axis parabola
- Off-axis parabola
- Fold mirror
- Fold mirror
- Fold mirror
- Occulters and slit
- Lyot stop, GRISM
- Science filter wheels
- Pupil lens (deployable)
- Cryostat window
- Detector
- Cold baffle
- NaI mir
- Incoming light
- OPTOMECHANICAL LAYOUT
OPTO-MECHANICAL LAYOUT

- ** incoming light
- ** fold mirror
- ** fold mirror
- ** fold mirror
- ** fold mirror
- ** Pupil lens (deployable)
- ** cryostat window
- ** cold baffle
- ** detector
- ** ~300 mm
- ** ~600 mm
- ** Coronagraphic planes

- ** apodizer
- ** apodizer
- ** beam splitter to the tip-tilt WFS
- ** ADC
- ** off-axis parabola
- ** off-axis parabola
- ** off-axis parabola
- ** off-axis parabola
- ** occulters and slit
- ** oculters and slit
- ** Lyot stop, GRISM
- ** Science filter wheels
- ** Science filter wheels
### Spectroscopic Mode

#### Dispersive Elements

<table>
<thead>
<tr>
<th></th>
<th>Low Res</th>
<th>Medium Res</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dispersing element</td>
<td>Prism</td>
<td>Grism</td>
</tr>
<tr>
<td>R</td>
<td>100</td>
<td>700</td>
</tr>
</tbody>
</table>

#### Coro Slits with Occulter

<table>
<thead>
<tr>
<th></th>
<th>Slit width</th>
<th>Occulter size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coro slit 1</td>
<td>100 mas</td>
<td>100 mas</td>
</tr>
<tr>
<td>Coro slit 2</td>
<td>100 mas</td>
<td>200 mas</td>
</tr>
</tbody>
</table>

![Diagram showing the dispersing elements and coro slits with an occulter in the focal plane.](image)
DUAL BAND IMAGING MODE

DUAL BAND FILTERS

<table>
<thead>
<tr>
<th>Name</th>
<th>$\lambda_1$ [nm]</th>
<th>$\Delta\lambda_1$ [nm]</th>
<th>$\lambda_2$ [nm]</th>
<th>$\Delta\lambda_2$ [nm]</th>
</tr>
</thead>
<tbody>
<tr>
<td>HOLE (no DBI)</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>H2-H3</td>
<td>1588.8</td>
<td>53.1</td>
<td>1667.1</td>
<td>55.6</td>
</tr>
<tr>
<td>ContJ-Pa $\beta$</td>
<td>1215.7</td>
<td>18.3</td>
<td>1281.3</td>
<td>20.9</td>
</tr>
<tr>
<td>ContH-Fe II</td>
<td>1557.8</td>
<td>24.1</td>
<td>1645.5</td>
<td>26.1</td>
</tr>
<tr>
<td>Phase diversity</td>
<td></td>
<td></td>
<td>Window</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Defocusing lens</td>
<td></td>
</tr>
</tbody>
</table>
THE HIGH-CONTRAST IMAGING FORMULA

How do we obtain high contrast in the vicinity of such bright stars?

XAO correction + External: SOUL (talk by Agapito)

Optimized wavefront control strategy + Internal (talk by Biondi)

Coronagraph(s) + Internal: Shaped Pupils, Gaussian, 4QPM

Post-processing pipeline =

High contrast
A deformable mirror to correct for instrumental aberrations and to stabilize the PSF

**WFS Camera**

- InGaAs camera (C-RED2)
- Sensitive in the full SHARK-NIR waveband (0.96-1.7 \( \mu \)m)
- Frame-rate up to 14 kHz (with 32X32 px window)
- Low RON (<30 e\(^{-}\))
- 3-5 mas precision up to 1KHz

**Deformable Mirror**

- ALPAO DM 97-15
- 97 actuators, 13.5 mm pupil, up to 2 kHz speed
- NCPA can be corrected internally without affecting pyramid’s performance
- NCPA measured with phase diversity on science image
**CORONAGRAPHS**

**Apodizer Mask**
- First pupil plane

**Occulter Mask**
- Intermediate focal plane

**2nd pupil plane**
- Second pupil plane

**Lyot Stop**
- Weak companion

**Scientific image**
- Weak companion

**Exoplanets**
- **FQPM**
  - Working in H-band
  - Access to the whole 18 x 18'' FoV
  - Very small IWA (~50 mas)
  - High throughput
  - Very sensitive to low-order aberrations

**Disks/Jets/AGN**
- **SHAPED PUPIL**
  - Working in H-band
  - Small field (100-300 mas)
  - High contrast near to the star
  - Robust to low-order aberrations

- **GAUSSIAN LYOT**
  - Optimized for both J and H band observations
  - Moderate contrast
  - Access to the whole FoV
CORONAGRAPHYS - ON-GOING ACTIVITIES

Coronagraphic masks characterization, performance analysis, alignment procedure

Fake planet, Lyot stops, Apodizers, 4QPM
CORONAGRAPHICS - ON-GOING ACTIVITIES

Apodizer image  Occulter image

SP1 - FPM decenter sensitivity

SP1 - FPM defocus sensitivity
### CORONAGRAPHS - ON-GOING ACTIVITIES

<table>
<thead>
<tr>
<th>Coronagraphic mask technique</th>
<th>IWA [µm]</th>
<th>OWA [µm]</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>theoretical</td>
<td>measured</td>
</tr>
<tr>
<td>SP1, FPM, H</td>
<td>196</td>
<td>198</td>
</tr>
<tr>
<td>SP2a, FPM, H</td>
<td>262</td>
<td>266</td>
</tr>
<tr>
<td>SP2b, FPM, H</td>
<td>247</td>
<td>250</td>
</tr>
</tbody>
</table>
CORONAGRAPHs - ON-GOING ACTIVITIES

Fake planet

SP1

Normalized intensity

Angular separation [mas]

10^{-4}

S/N = 36

S/N = 36
CORONAGRAPHS - ON-GOING ACTIVITIES

Pupil plane

FP w/o Lyot Stop

4QPM centering procedure

FP w/ Lyot Stop
CORONAGRAPHES - ON-GOING ACTIVITIES

\[ \frac{\lambda}{D} = (9.7 \pm 0.1) \text{ px} \]

Padova
R = \( \frac{\lambda}{\Delta \lambda} \) \( \sim \) 14
550 nm
Rej. = 40!

LESIA
R \( \sim \) 100
1650 nm
Rej. = 400

Rejection on 25\( \frac{\lambda}{D} \) Square box \( \rightarrow R^2 \)

Rej. (Padova)
Expected 8 (from R ratio)
Measured 40!
CLEAN ROOM - ON-GOING ACTIVITIES

Alignment beams (collimated laser beam for refractive optics alignment, converging beam for OAPs alignment) available.

Rough mechanical mirrors pre-alignment completed.
SCIENTIFIC CAMERA

Infinite shipping issues

2.5 Days of camera at 81 K (Padova is at sea level):
- Functional tests performed
- Cooling down, warming up procedure tested
- Cryostat can hold 52 hours in worst configuration
- VPN setup in order to allow remote connection from Steward to debug SW issues
NEXT STEPS

2019  Nov.?  Delivery of the NIR camera sub-assembly from SO to INAF
2019  Dec.  Delivery of dispersive element
2020  May  End of AIV phase
2020  Jun.  PAE review
2020  Mid  Start of commissioning at LBT
2020  Fall  SHARK-NIR in operation
Thank you for your attention!