

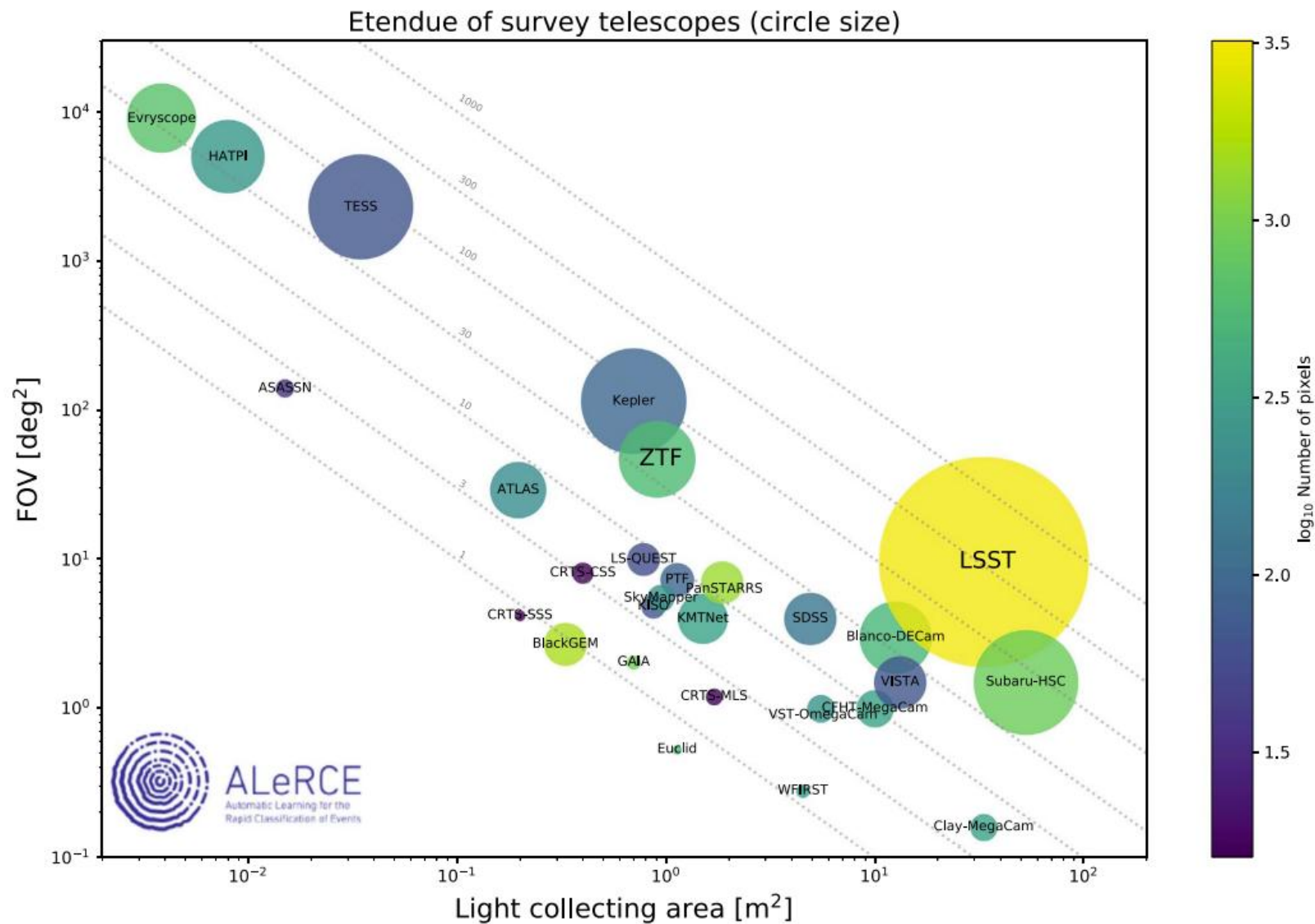


The SOXS instrument: capabilities and performance

P. Schipani

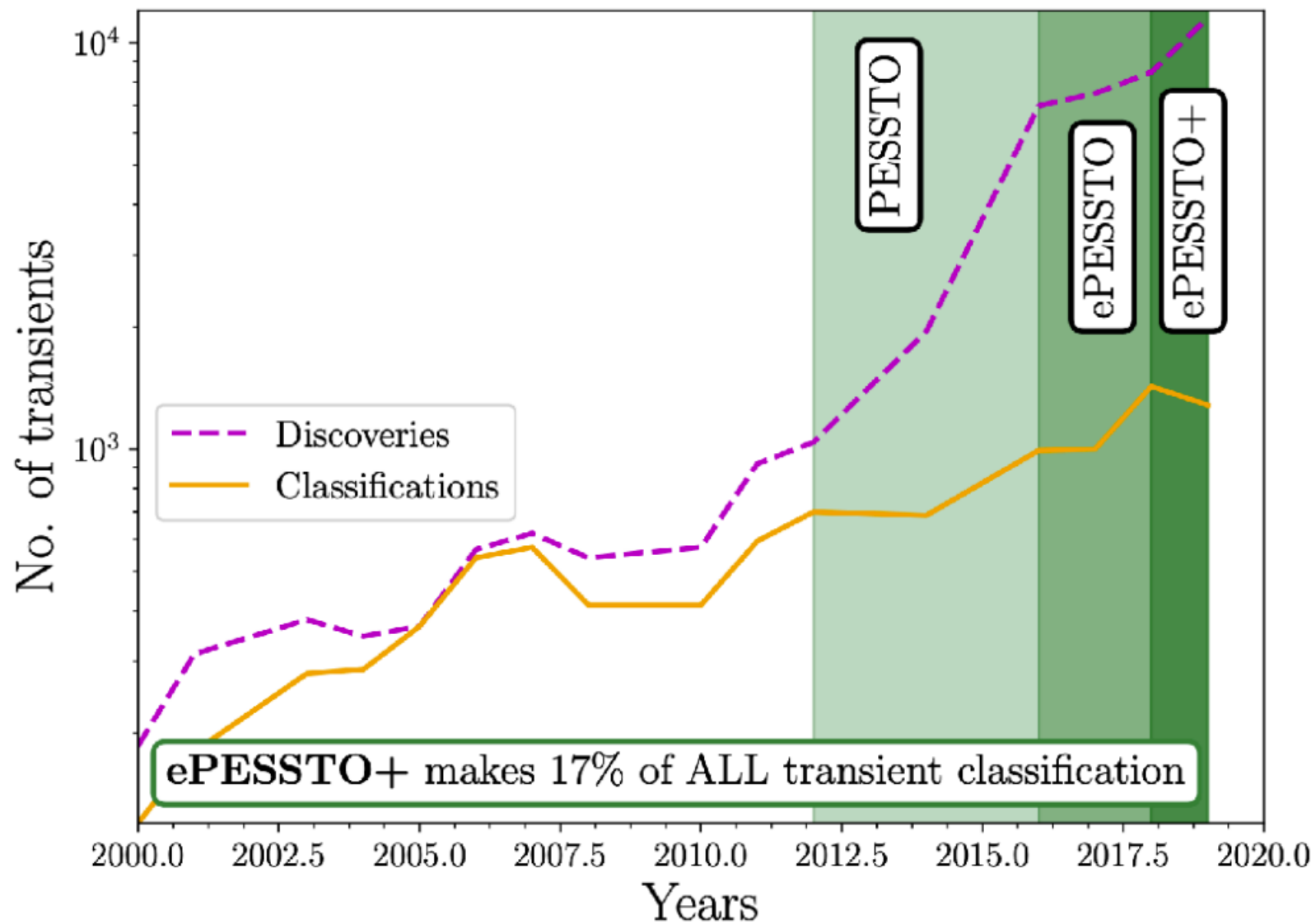
SOXS Day

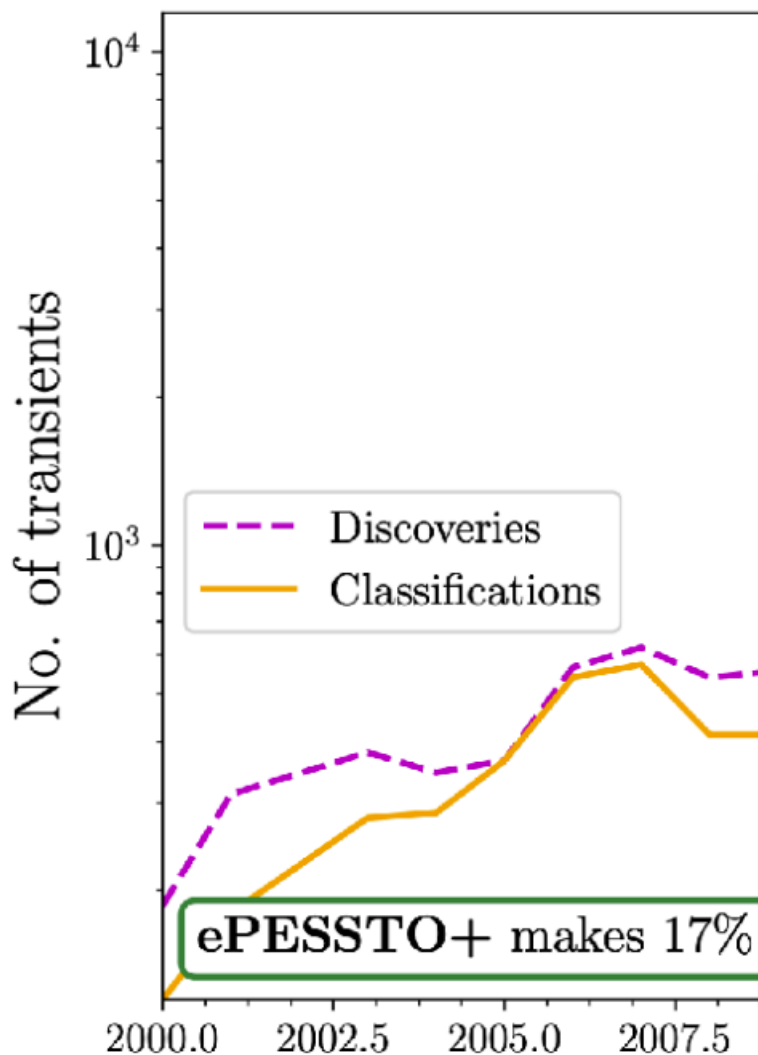
ESO - Garching, 1 July 2025





SOXS



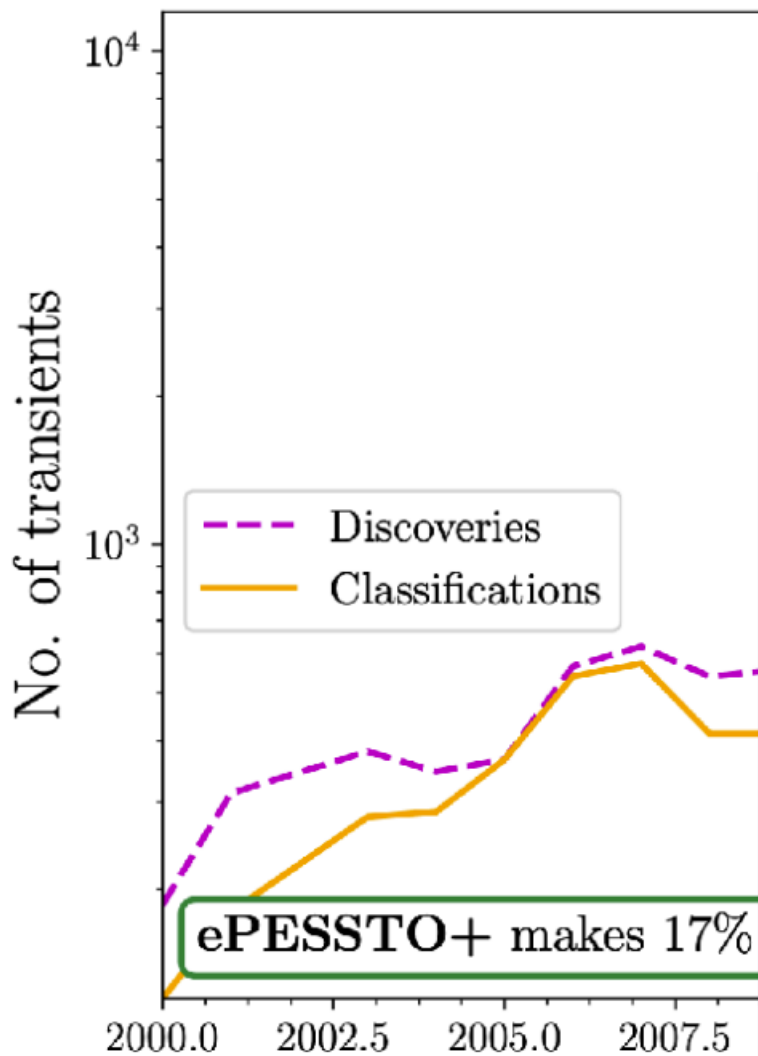


Coming June 23, 2025: First Look at the cosmos with NSF-DOE Vera C. Rubin Observatory

Get ready to join us virtually around the world on **June 23, 2025 at 11:00 a.m. US EDT** as we unveil the first spectacular images from NSF-DOE Vera C. Rubin Observatory! This First Look event will be live streamed via Youtube in English and in Spanish — links will be made available here and via social media. Join us to celebrate the start of a new era in astronomy and astrophysics with the world's newest and most powerful [survey telescope](#).

Over the next ten years, Rubin Observatory will create the ultimate movie of the night sky using the [largest camera ever built](#) — repeatedly scanning the sky to create an ultra-wide, ultra-high-definition time-lapse record of our Universe.

First Look is just the beginning....

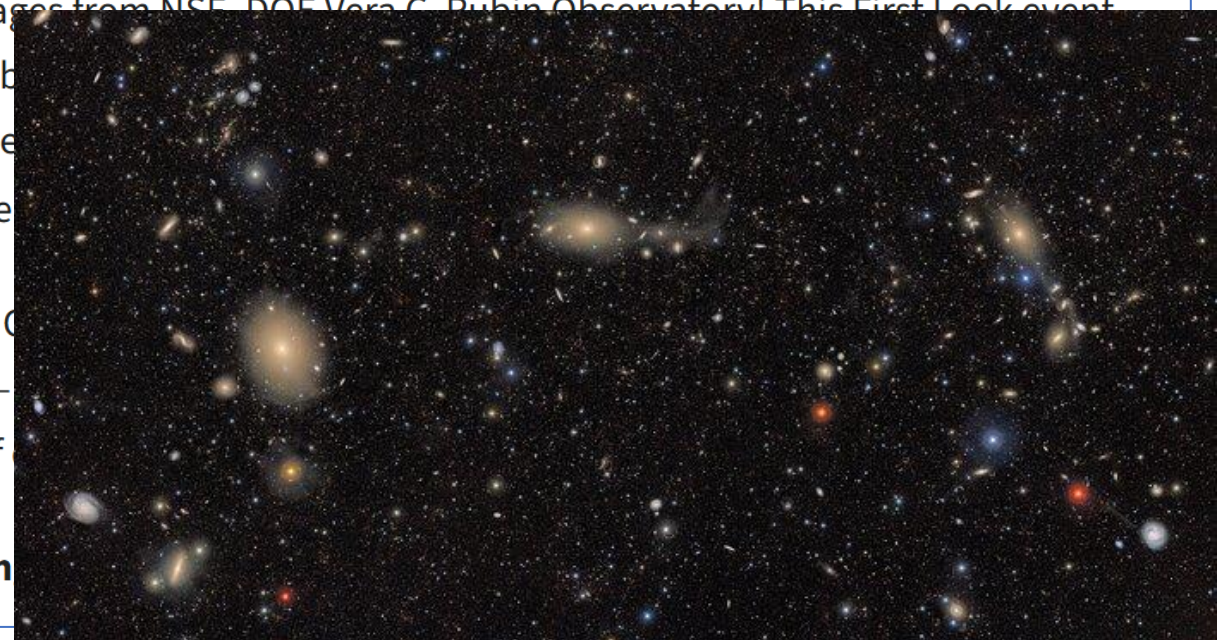


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Over the next ten years, Rubin Observatory will create the largest camera ever built — a definition time-lapse record of

First Look is just the beginning





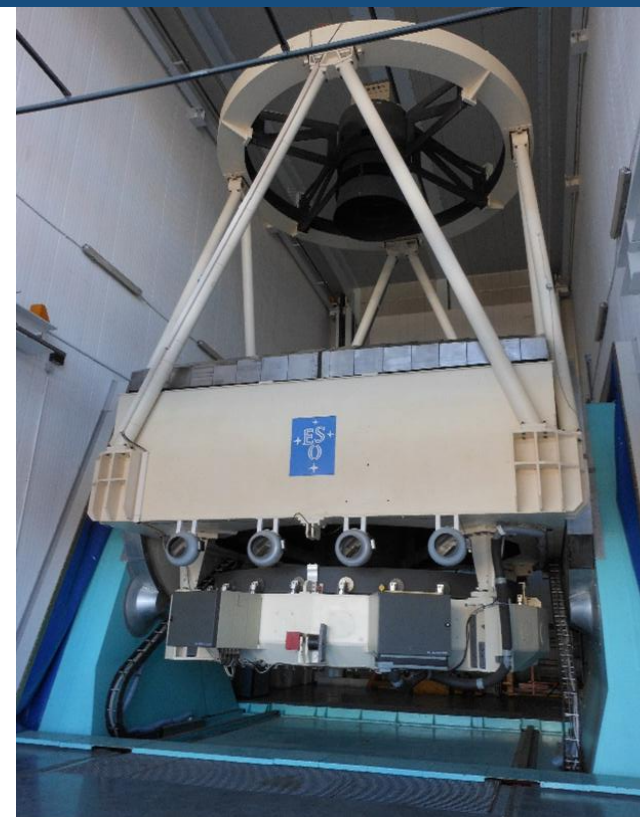


SOXS



Son Of X-Shooter

- ❑ Single-object wide band spectrograph from U to H band @ESO-NTT 350-2000 nm
- ❑ '*Similar*' to X-Shooter @VLT
- ❑ Two arms (VIS + NIR) with partial overlap around 800 nm to cross-calibrate spectra
- ❑ $R \sim 4,500$ (3,500-6,000)
- ❑ Acquisition camera to perform photometry ugrizY-V ($3.5' \varnothing$ FoV)



ESO La Silla (LPO)



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Consortium

Institutes from 6 Countries

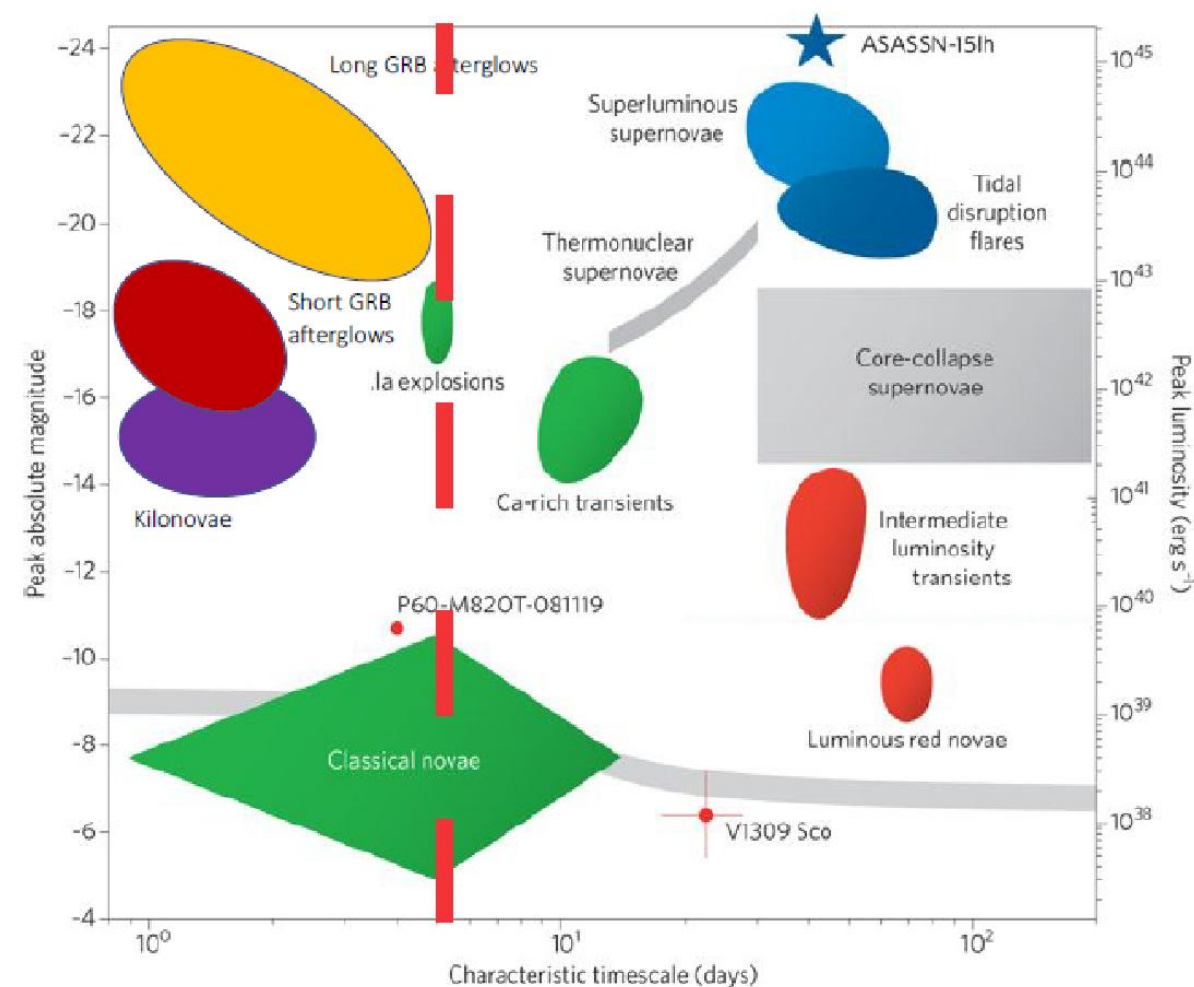
- ❑ Istituto Nazionale di AstroFisica (INAF), Italy
- ❑ Department of Particle Physics and Astrophysics, Weizmann Institute of Science, Rehovot, Israel
- ❑ Instituto de Alta Investigación, Universidad de Tarapacá, Chile
- ❑ FINCA - Finnish Centre for Astronomy with ESO & Turku University, Turku, Finland
- ❑ Queen's University Belfast, Oxford University, UK
- ❑ Tel Aviv University, Israel
- ❑ Niels Bohr and Aarhus University, Copenhagen, Denmark





Spectroscopic follow up of transients

- ☐ Classification of transients
- ☐ Supernovae (all flavours)
- ☐ Gravitational Wave and neutrino events
- ☐ GRB and FRB
- ☐ Blazars and AGN
- ☐ Nuclear transients and Tidal Disruption Events
- ☐ Transient X-ray binaries, magnetars, ultra - luminous X-ray sources (NS & BH)
- ☐ Novae and cataclysmic variables
- ☐ Young Stellar Objects, stellar variability, exoplanets
- ☐ Asteroids and Comets
- ☐ The Unknown





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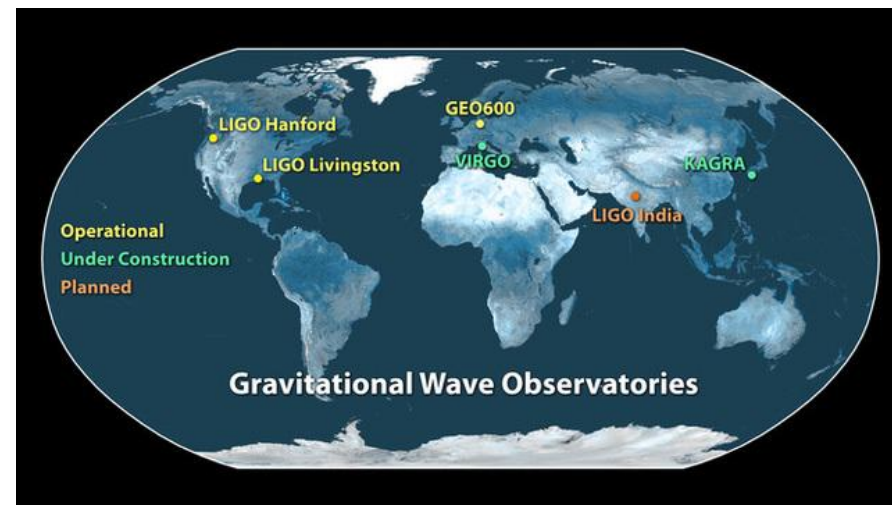


Synergies

SOXS will have 180 n/yr (for ≥ 5 yr)

A spectroscopic machine for the transient sky

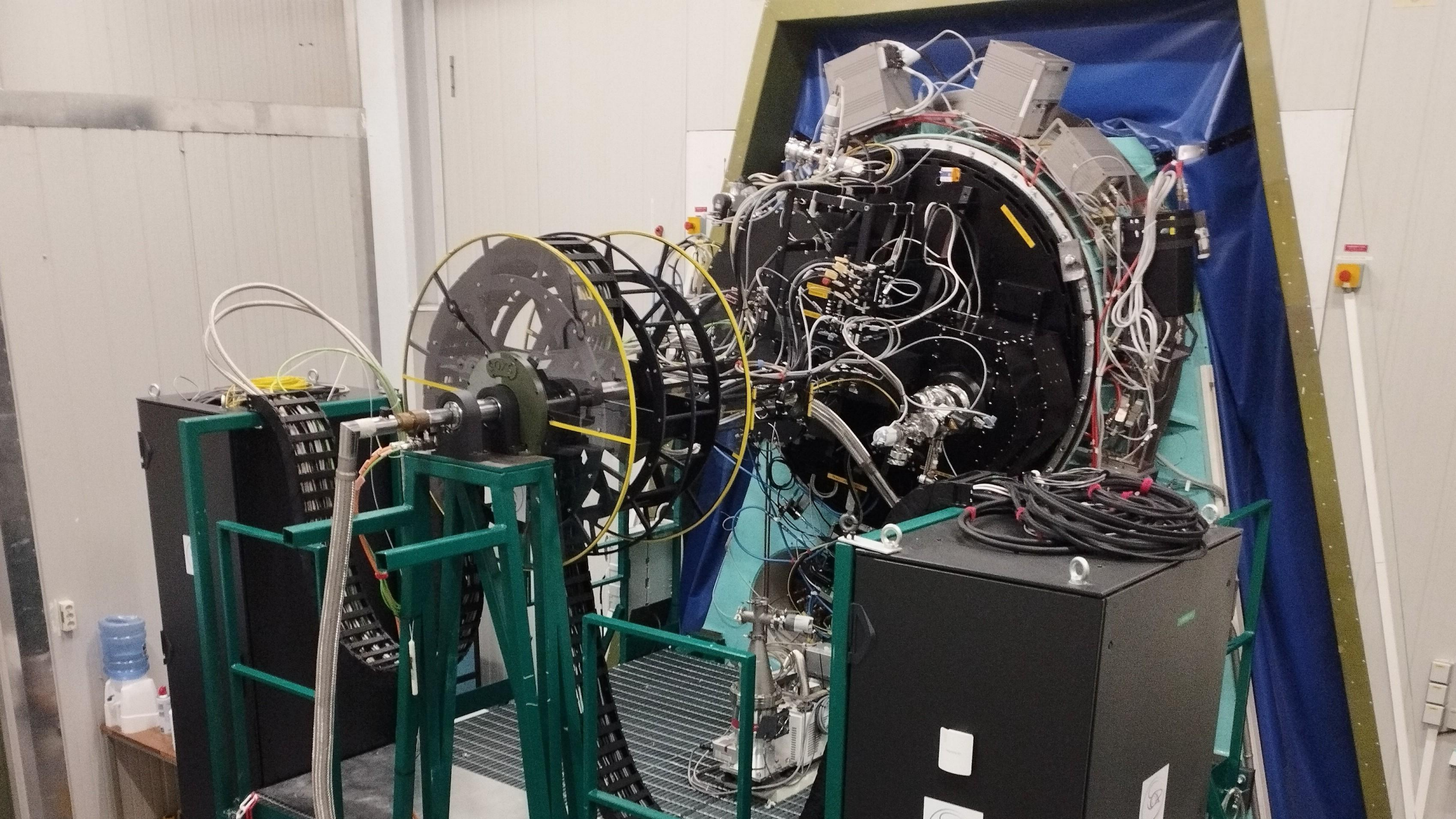
- ☐ New deeper survey: Vera Rubin, LAST, PanSTARSS, DES, ATLAS, ZTF
- ☐ Space optical missions: Gaia, EUCLID
- ☐ Space high-energy missions: Swift, Fermi, SVOM, Einstein Probe
- ☐ Radio new facilities: MeerKAT, SKA
- ☐ VHE: CTA
- ☐ Messengers: aLIGO-Virgo, KM3Net, ANTARES



	UV-VIS	NIR
Spectral range	350-850 nm	800-2000 nm
Resolution (1" slit)	>3600 (\approx 4500 avg)	5000
Slit widths	0.5 - 1 - 1.5 - 5 arcsec	0.5 - 1 - 1.5 - 5 arcsec
Slit height	12 arcsec	12 arcsec
Detector	e2V CCD44-82 2Kx4K	Teledyne H2RG 2Kx2K
Pixel Size	15 μ m	18 μ m
Detector Scale	0.28"/pixel	0.25"/pixel

	Camera
Spectral range	360-970 nm
Detector	Andor iKon M-934 1Kx1K
Field of View	3.5'
Pixel Size	13 μ m
Detector Scale	0.205"/pixel





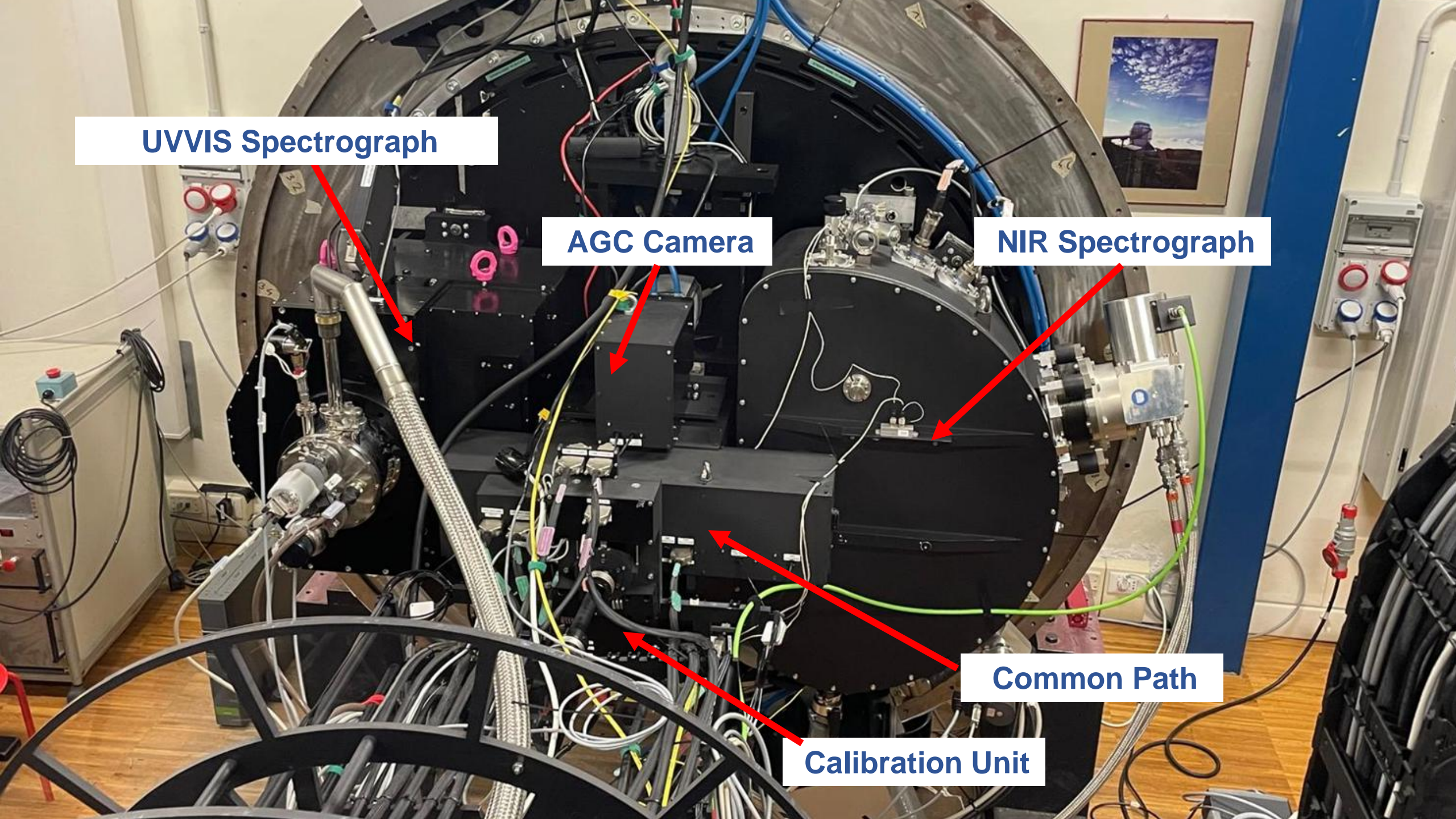
UVVIS Spectrograph

AGC Camera

NIR Spectrograph

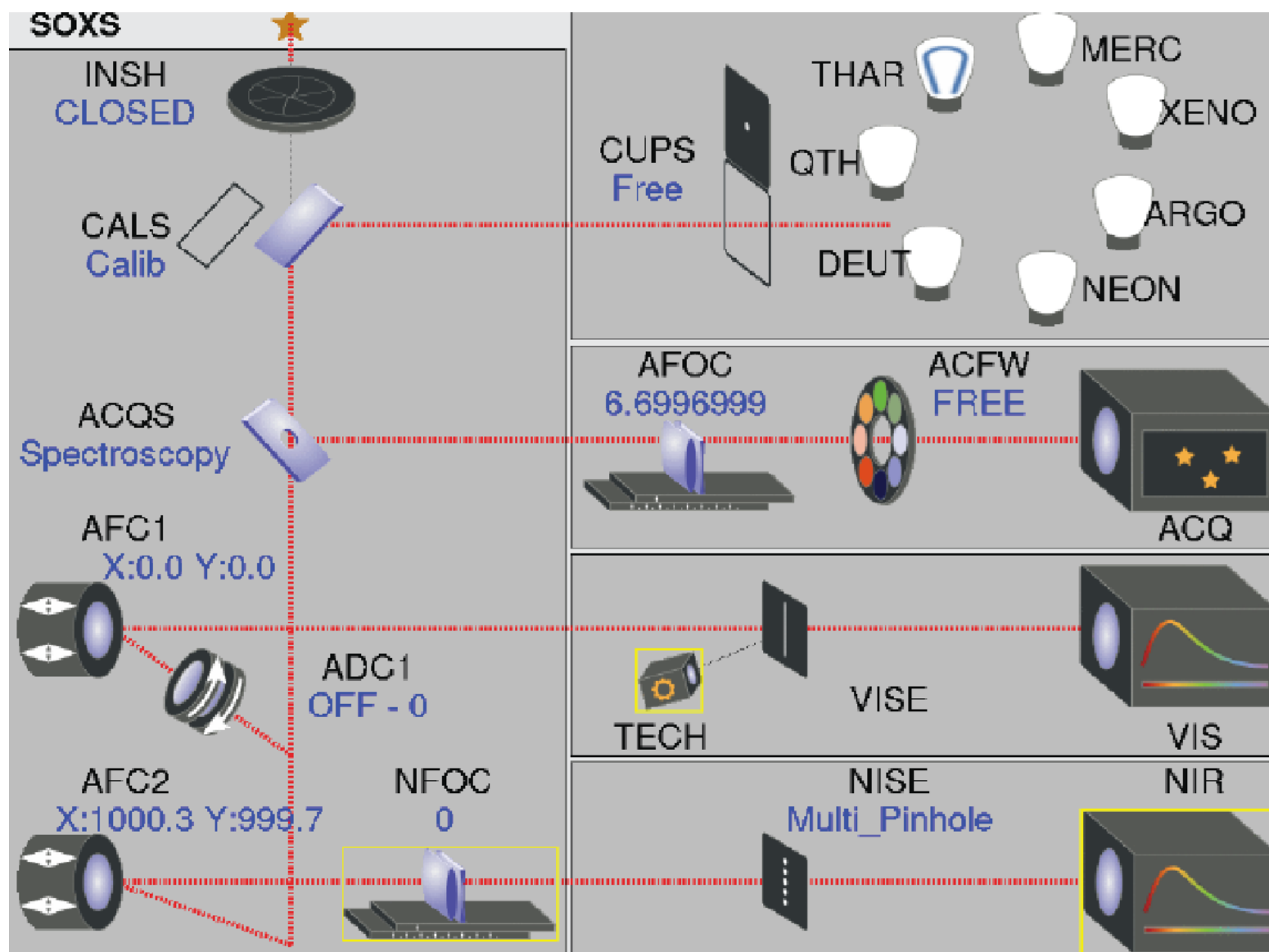
Common Path

Calibration Unit





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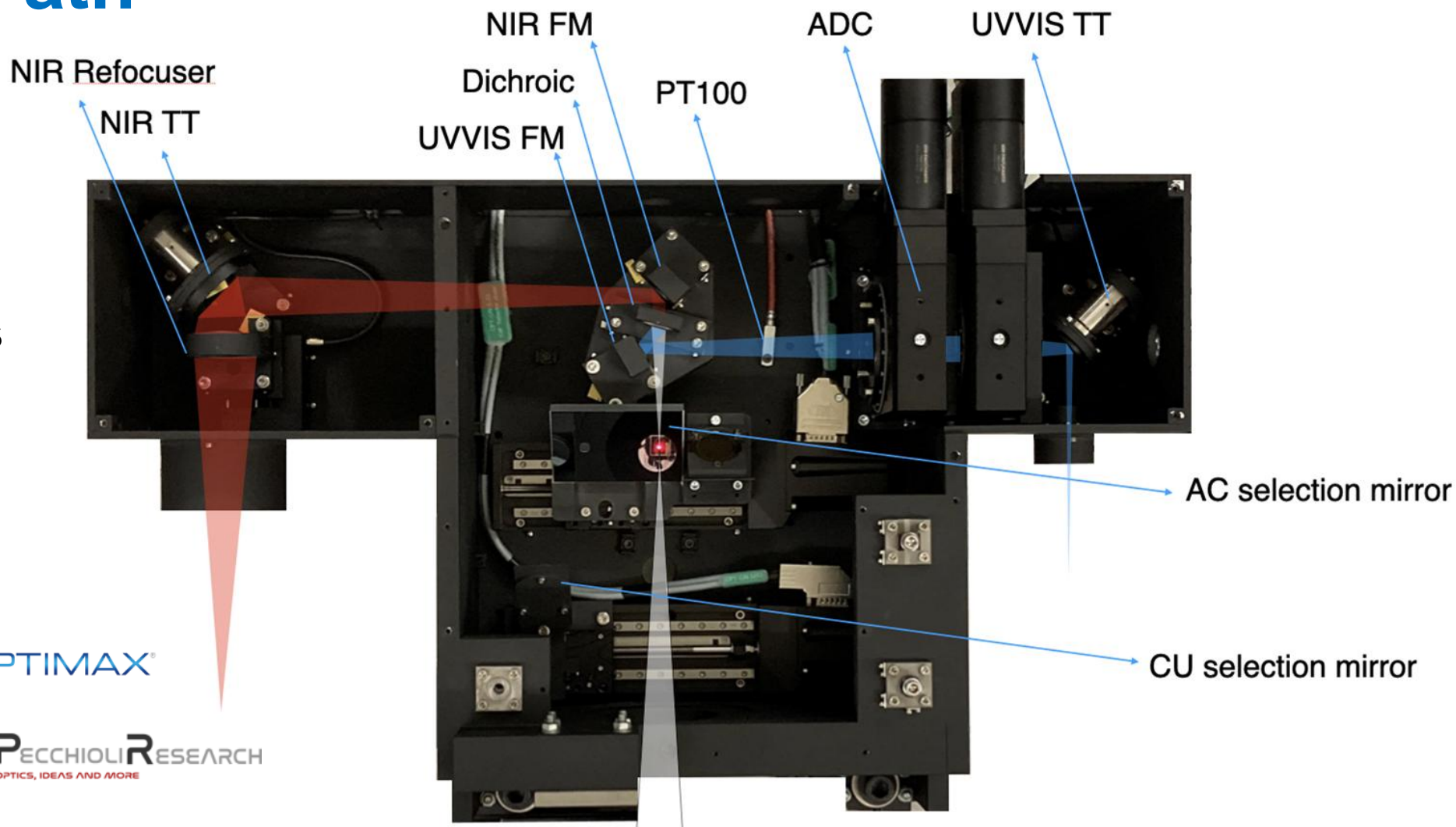


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Common Path

Receives F/11
beam from the
telescope and feeds
the spectrographs
with F/6.5 beam



Archer OpTx
Optical Precision. Optimal Outcome.

OPTIMAX®

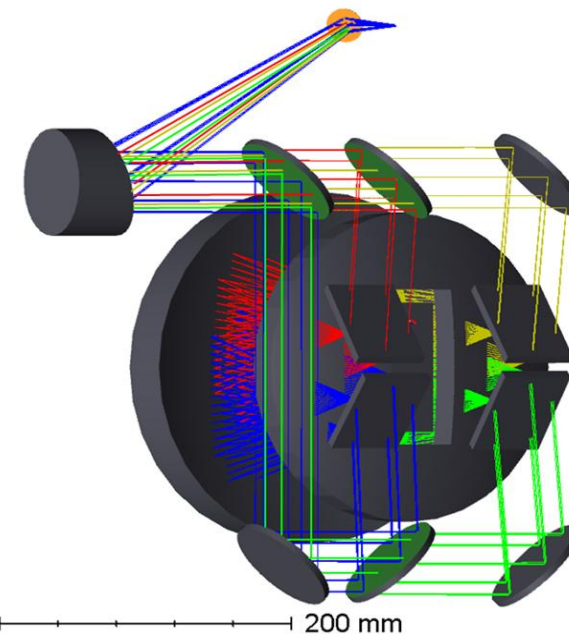
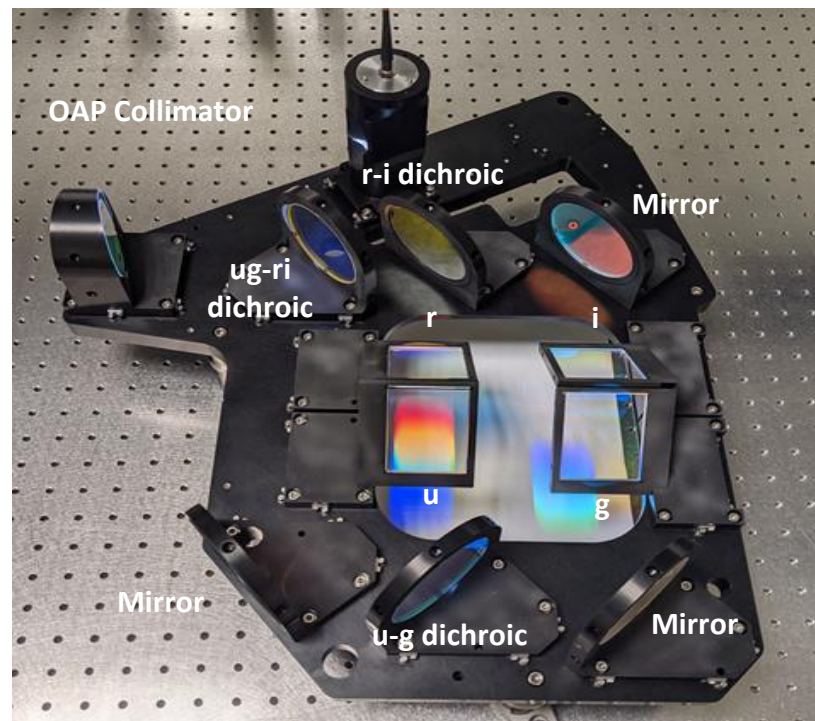
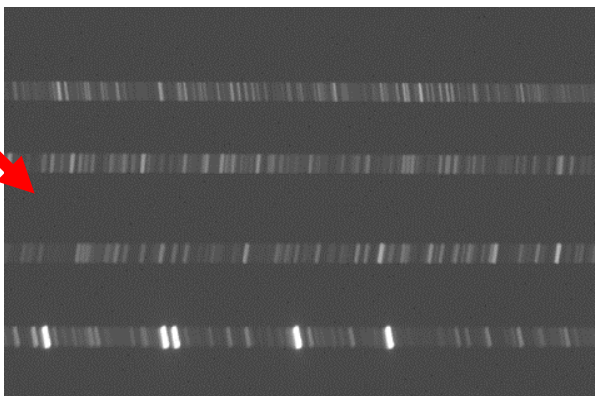
ASAHI SPECTRA USA

PECCHIOLI RESEARCH
OPTICS, IDEAS AND MORE



UV-VIS Spectrograph

- ☐ Collimated beam is divided to 4 bands using 3 dichroics.
- ☐ Each band has its own optimized disperser
- ☐ Single camera
- ☐ 1st order dispersion,
 $\mathcal{R} \sim 4500$ at α_{Lit} .
- ☐ 4 bands quasi-orders are imaged onto a single 4k×2k CCD.



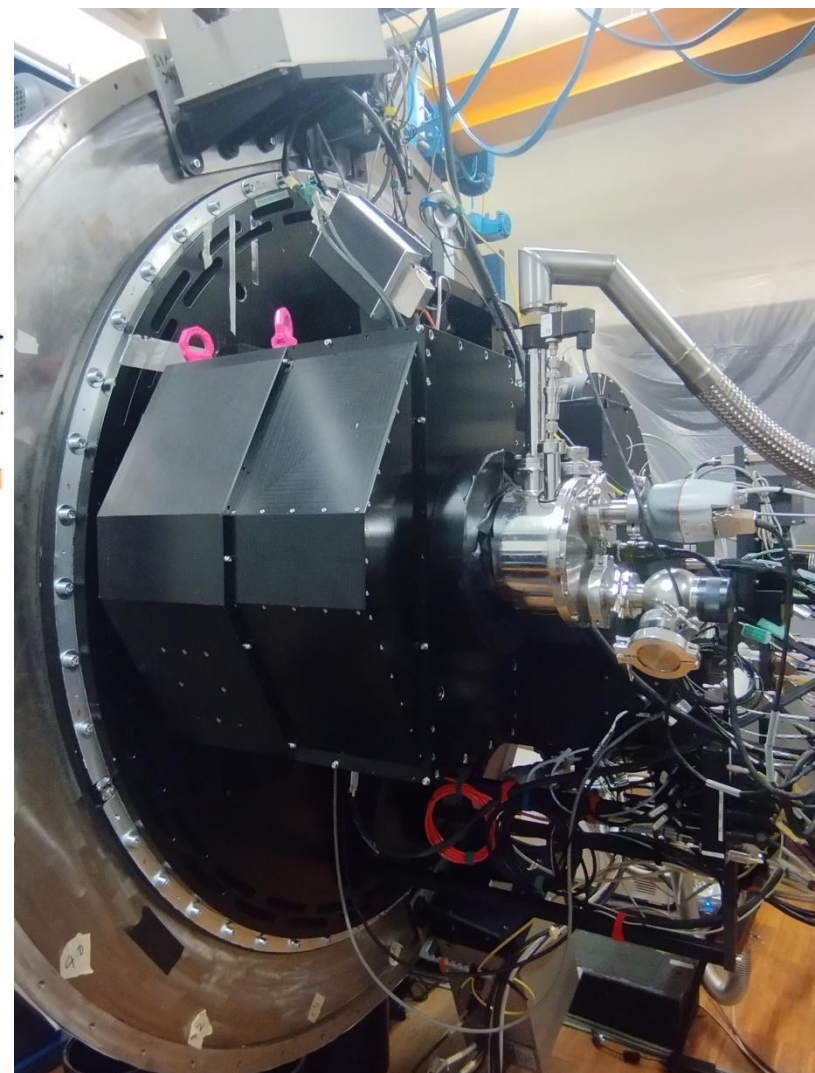
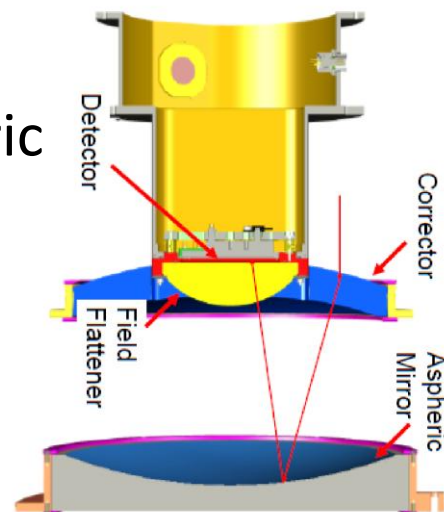
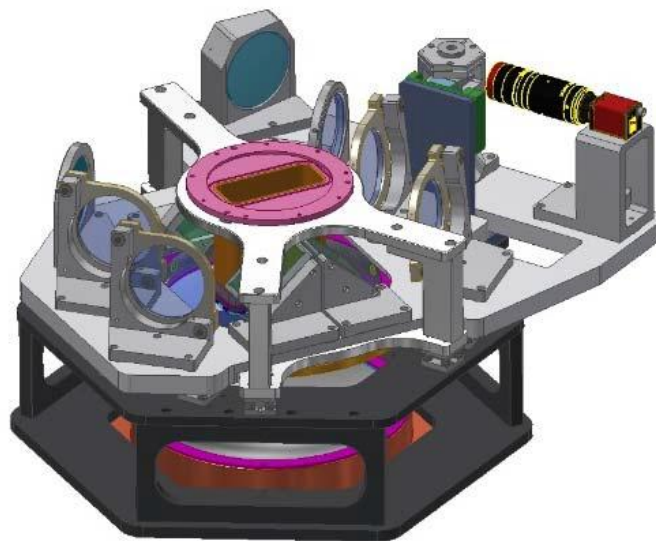
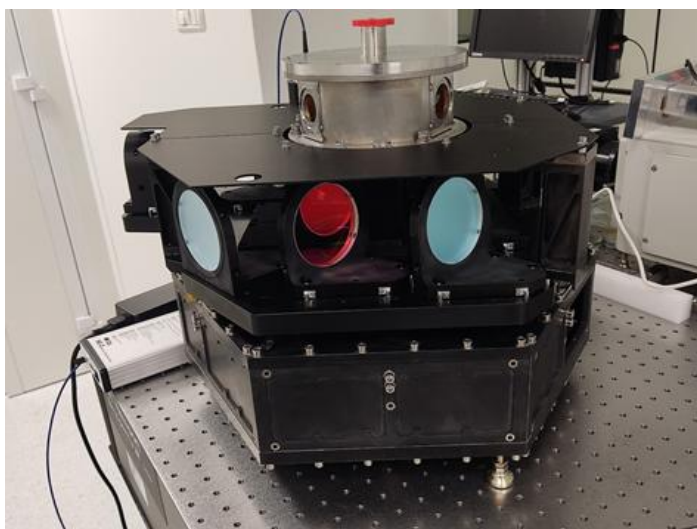
Quasi-Order	Wavelength Range [nm]
u	350 – 439.5
g	427 - 547
r	527 - 680
i	664 – 850



UV-VIS Camera

- ❑ Three element catadioptric camera - all aspheric
- ❑ Used as 4 off axis F/3.1 cameras.
- ❑ CaF₂ corrector + Fused Silica Field Flatteners
- ❑ Low CTE=>Athermal camera

Feed + Camera





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UV-VIS Spectrograph



UV-VIS four traces when fed through the CP using SOXS CBX arclamps.



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UV-VIS Spectrograph

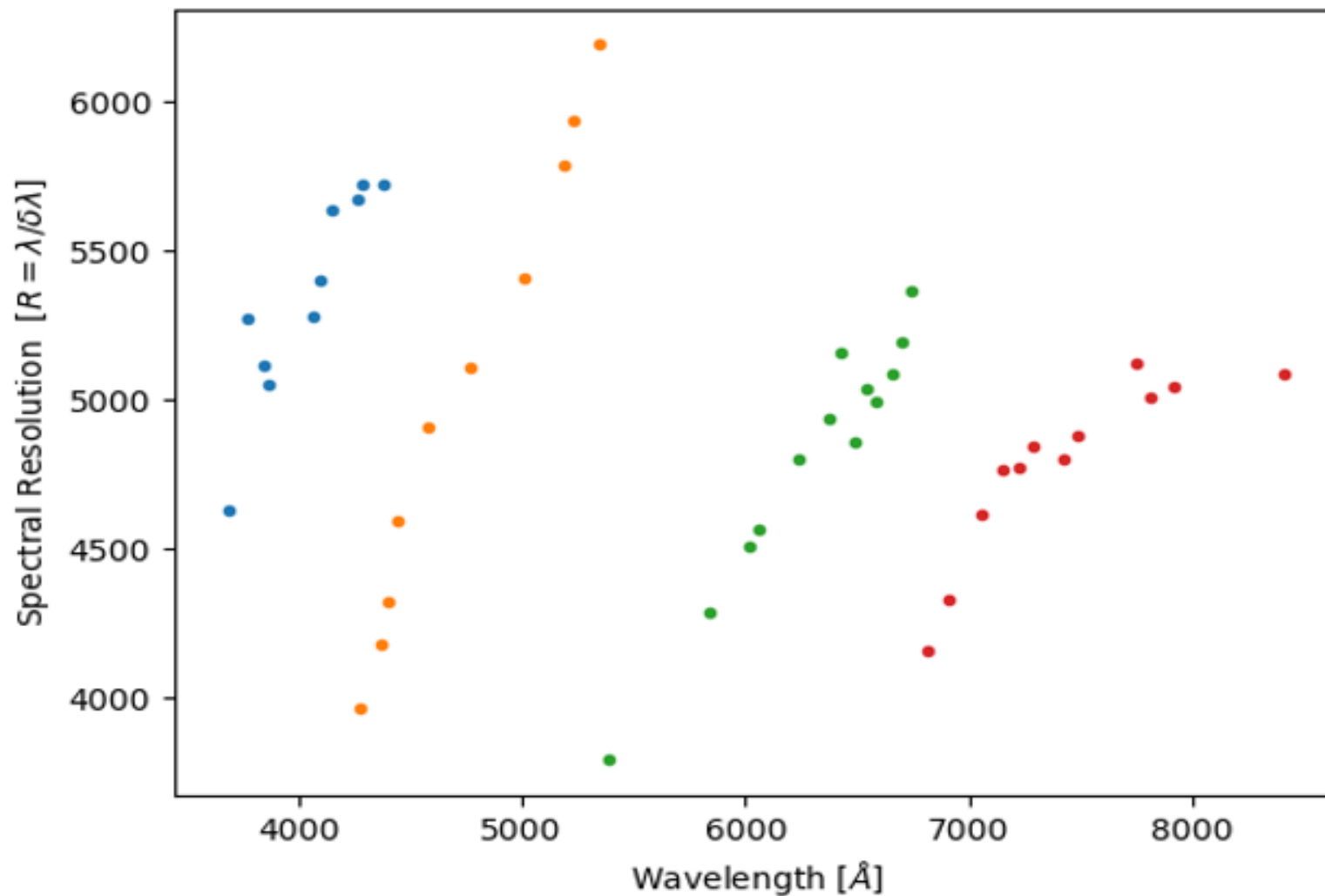
$$R = \lambda / \Delta\lambda$$

u - 5350

g - 5040

r - 4810

i - 4780





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NIR Spectrograph

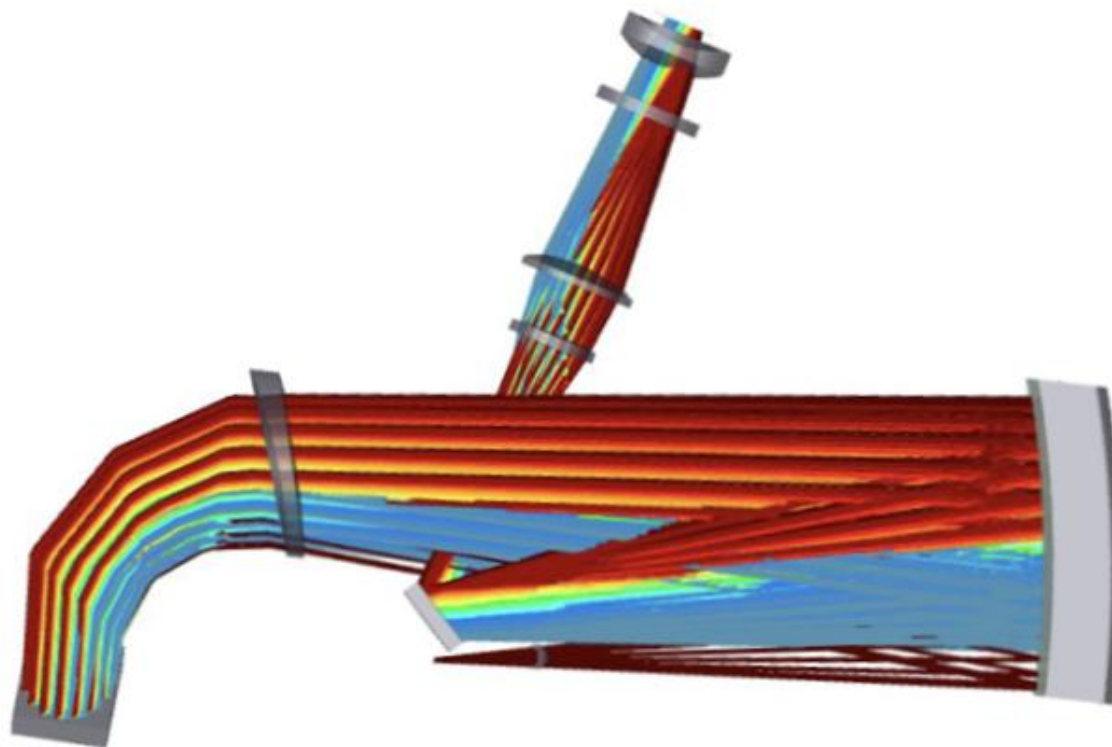
4C Design

Spectrograph with
Collimator Compensation
of Camera Chromatism
Echelle Cross-Dispersed

$R \sim 5000$, $0.25''/\text{px}$

F/3.7 camera, H2RG +

NGC





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NIR Spectrograph

4C Design

Spectrograph with
Collimator Compensation
of Camera Chromatism
Echelle Cross-Dispersed

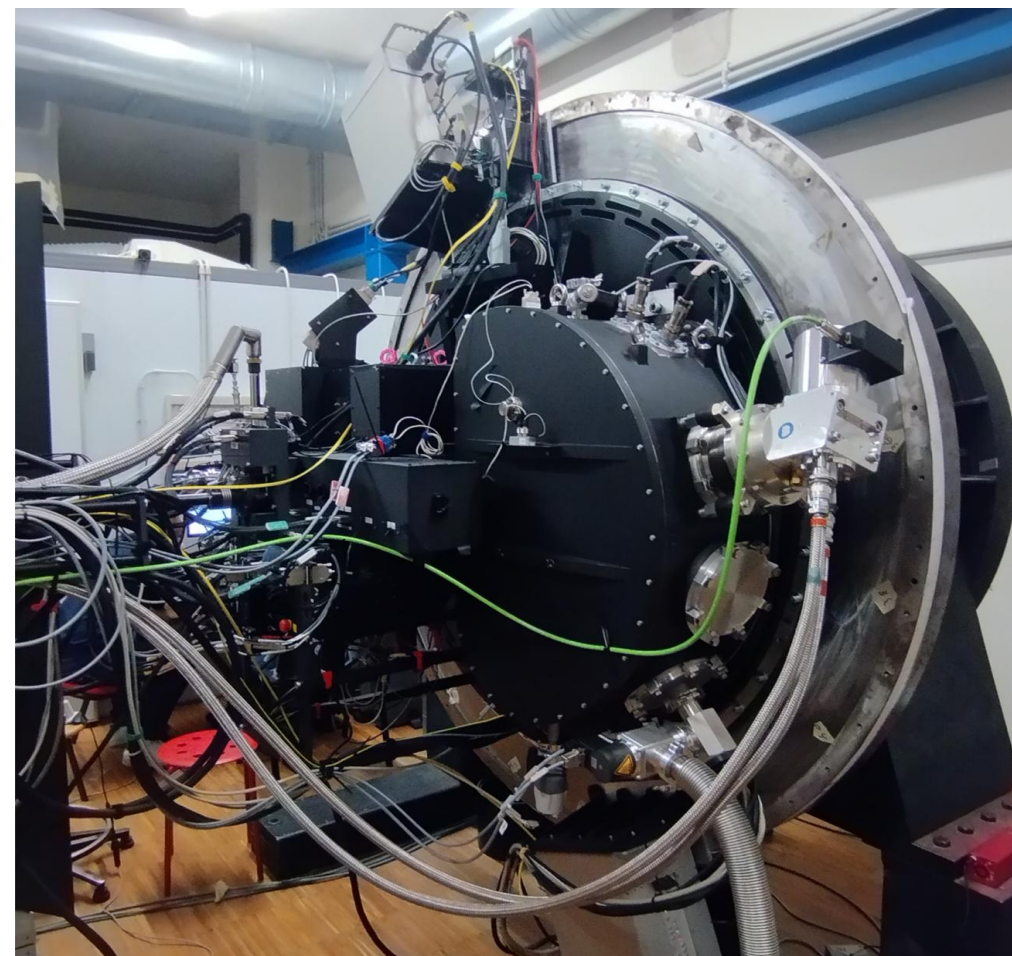
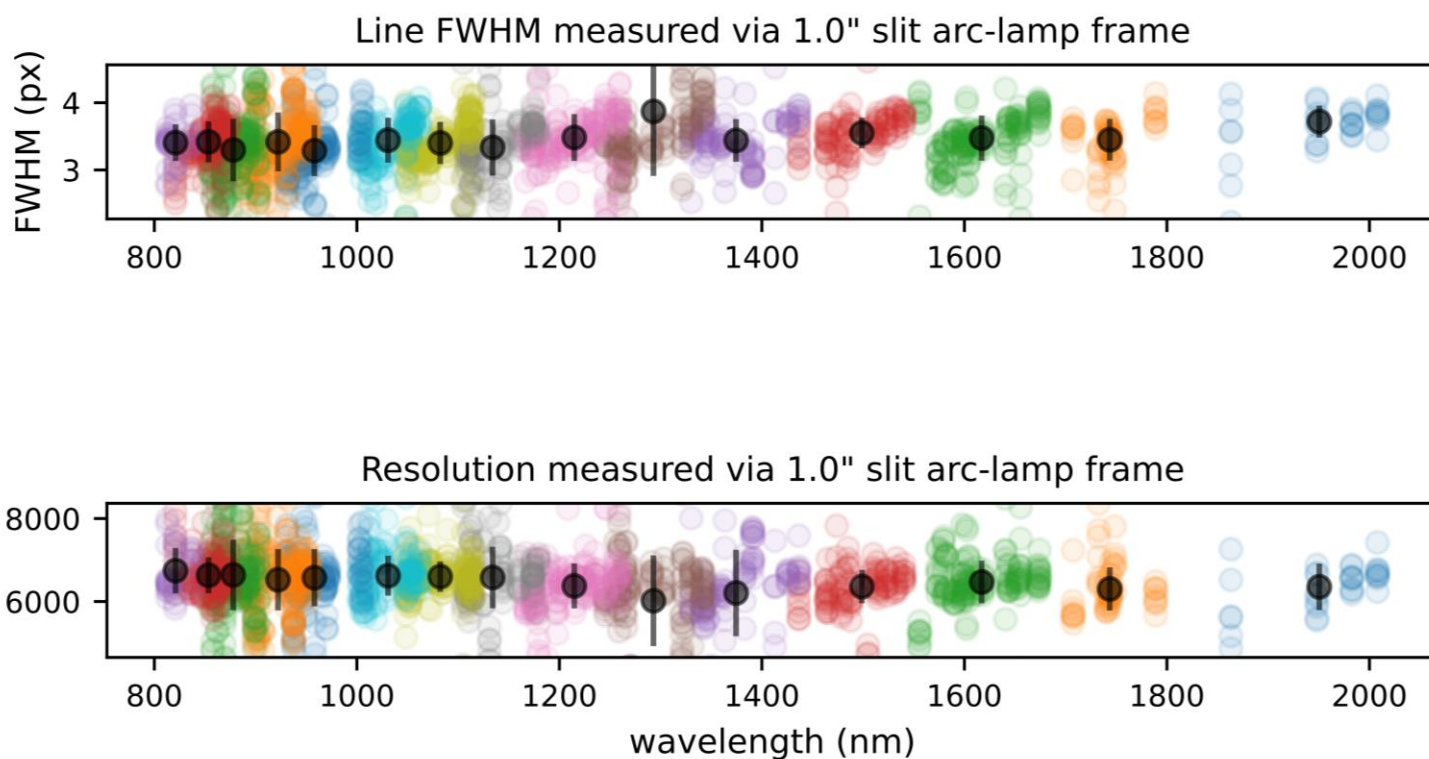
$R \sim 5000$, $0.25''/\text{px}$

F/3.7 camera, H2RG +
NGC





NIR Spectrograph





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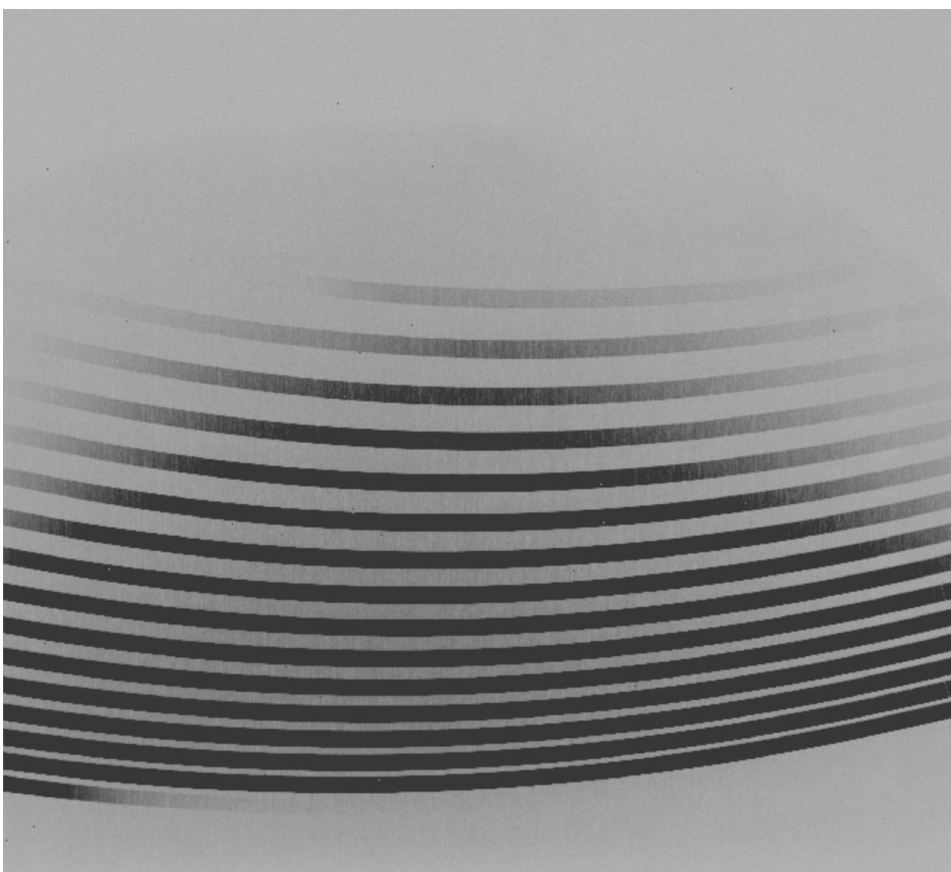


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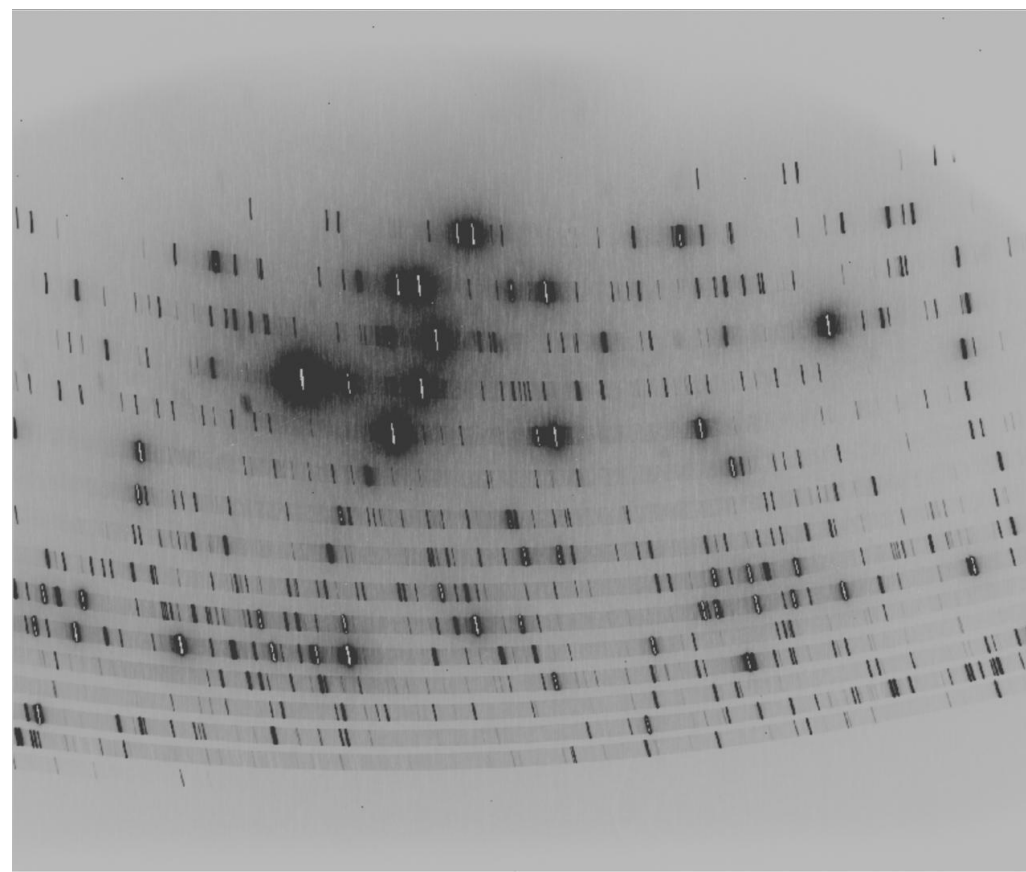


NIR Spectrograph

QTH 5s exp. raw frame

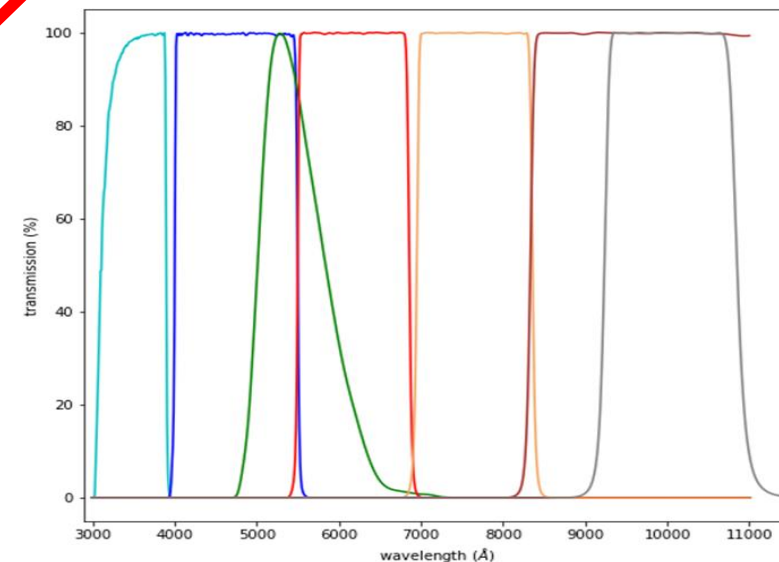
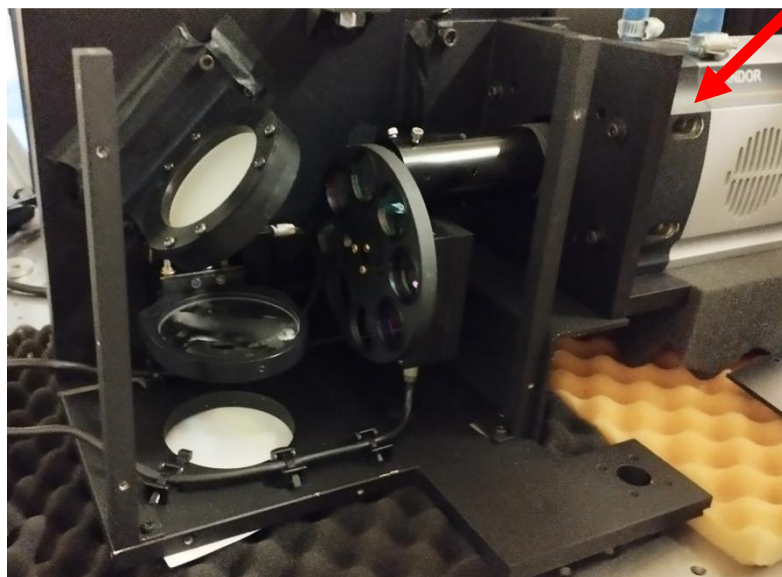
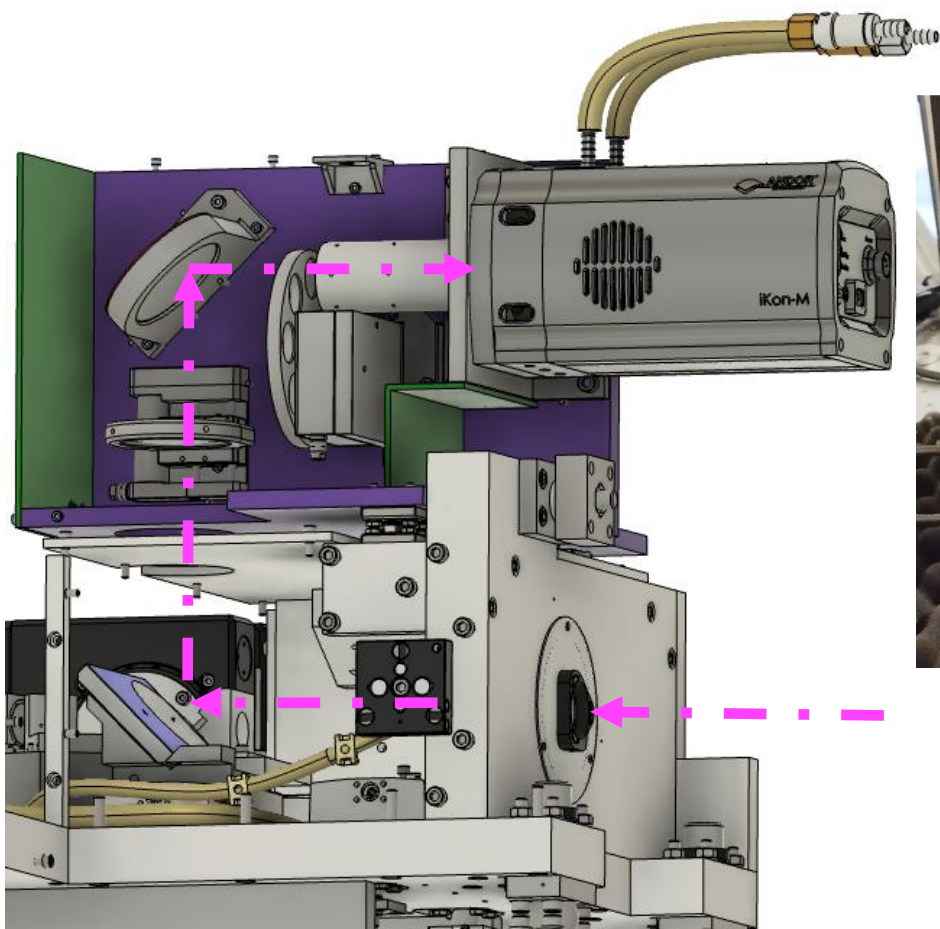


Arc lamps 15s exp. raw frame 0.5'' slit



A&G Camera

Andor iKon M934 1024x1024
13 μ m/px 0.205 "/px

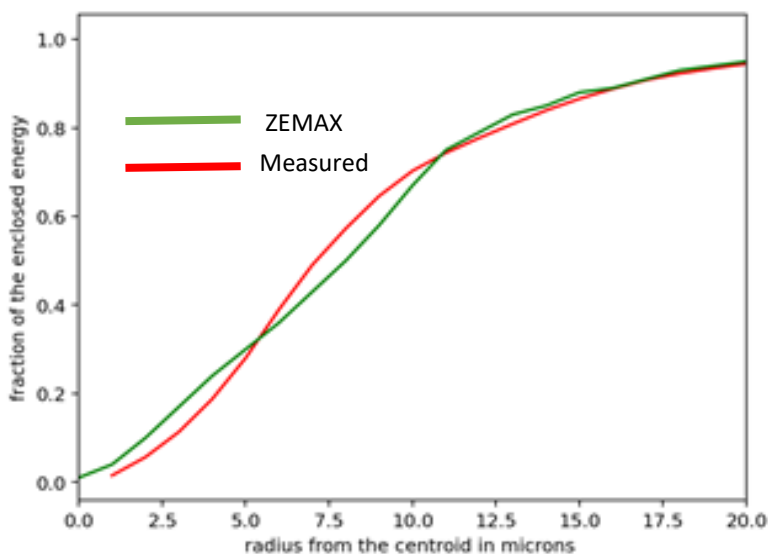


- ☐ Target Acquisition
- ☐ Secondary guiding
- ☐ Photometry

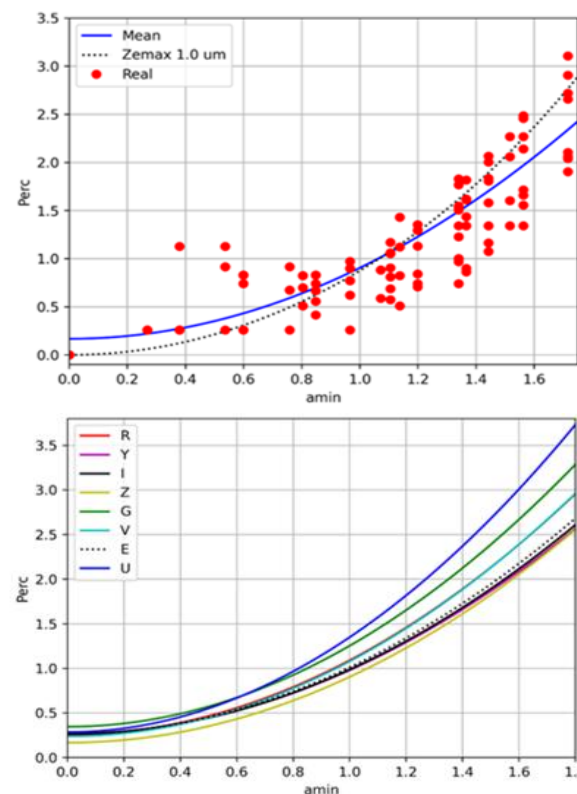
Filters: ugrizY + V
FoV: 3.5'
Grade A CCD

A&G Camera performance

Encircled Energy



Distorsion



Distorsion measurement: a) Actual measurements of each pattern with the Z filter along with the fitted line, and b) numerically fitted curves for all filters.

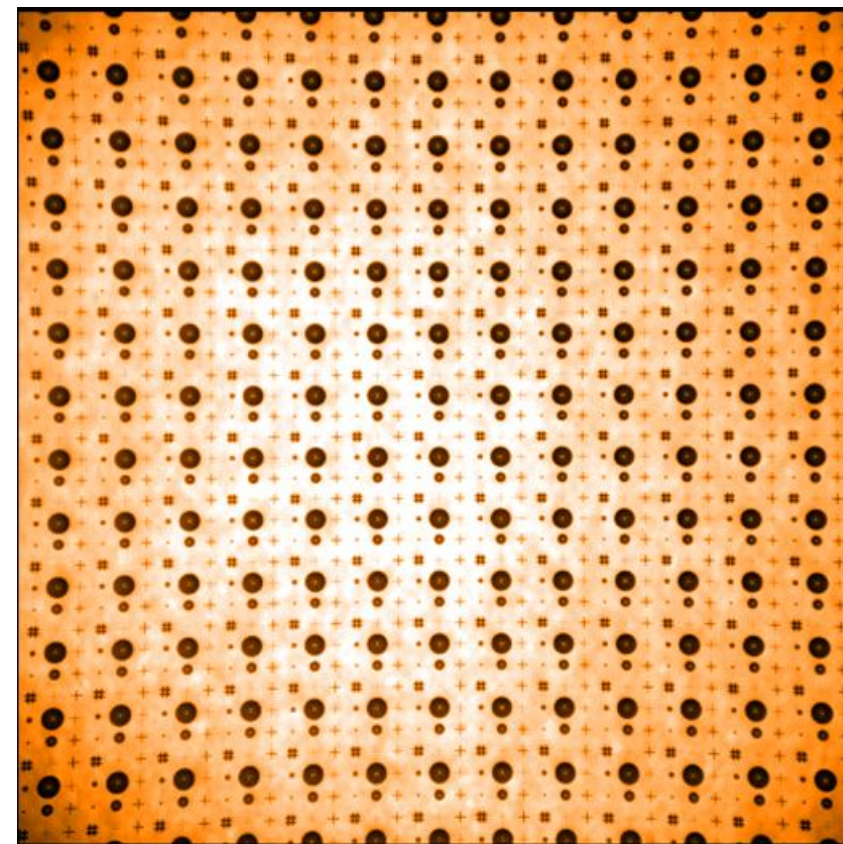
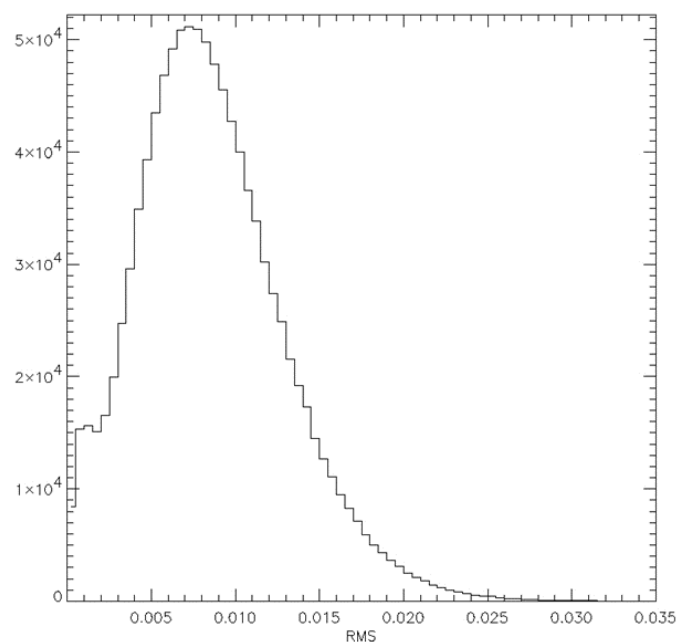


Image of the distortion chart covering the complete 3.5'x3.5' FoV

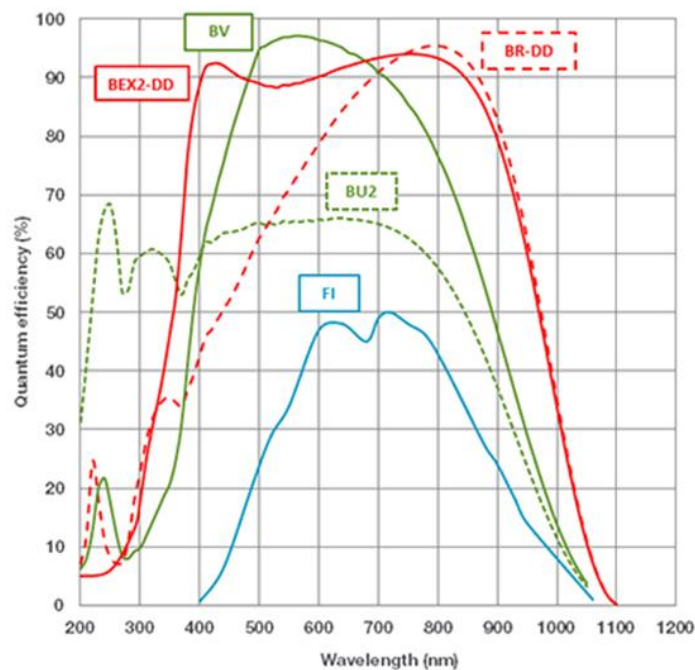
A&G Camera performance

Linearity



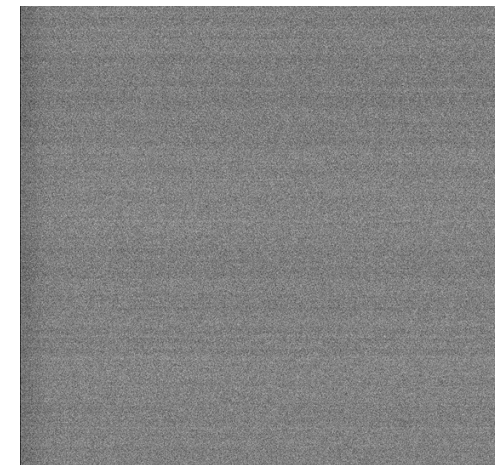
Distribution of the standard deviation respect to perfect linearity for each pixel of the ANDOR frames

Quantum efficiency



BEX2-DD (red solid) is our CCD

Example of bias



Quantity	Specification	Measured
Read Out Noise (e ⁻)	3.3	3.09 ± 0.02
Dark Current (e ⁻ /s) (@ -80°)	0.017	0.021 ± 0.003
Linearity	Better than 99%	Better than 99% for 58% of the pixels



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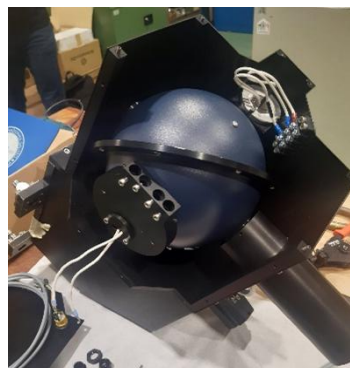
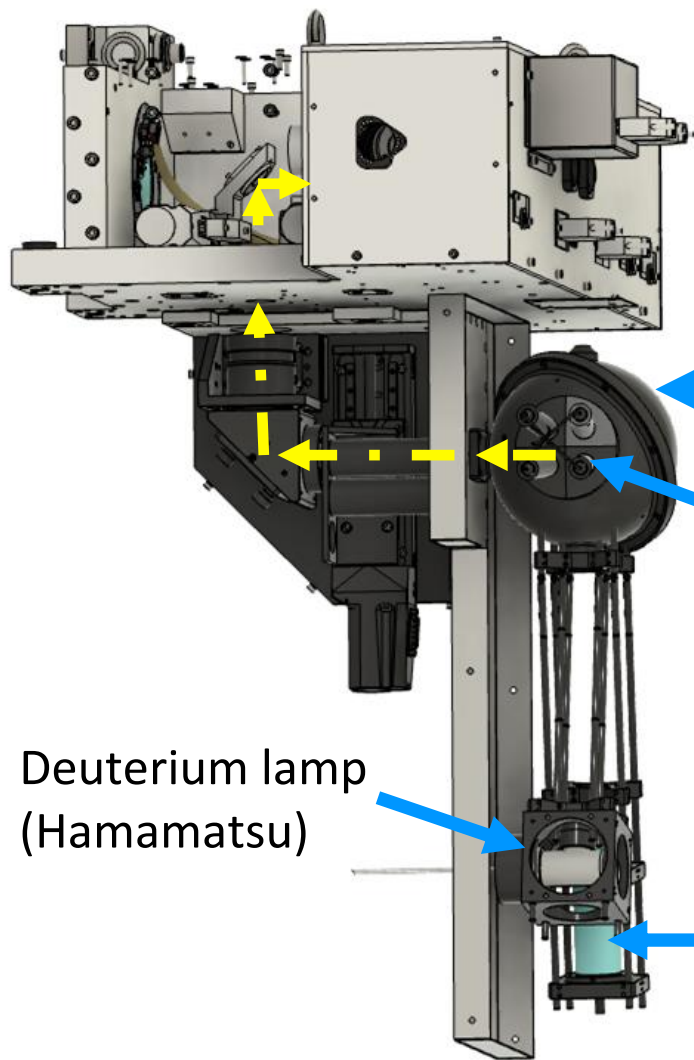
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Calibration Unit



QTH lamp
(Osram)
NeArHgXe
Penray
lamps
(Newport)

Deuterium lamp
(Hamamatsu)

Th-Ar lamp
(Photron)



Ctrl Electronics

- Motors
- Lamps

Ctrl Electronics

- Cryovacuum
- Detectors
- Co-rotator





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Electronic cabinets





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Instrument Software

Based on VLT Common SW (v.2024)

SOXS State: **ONLINE** idle Op. mode: **NORMAL** ICDFBs **OK**

Imaging and Spectroscopy \ NIR Sensors \ Other Sensors \

acfw	ONLINE	SIM	0	0.00	SDSS-u		
cups	ONLINE	SIM	0	0.00	Free		
cals	ONLINE	SIM	0	0.00	Calib		
acqs	ONLINE	SIM	0	0.00	Spectroscopy		
visc	ONLINE	SIM	Blank	0	0.00	Slit_0.5	
nisc	ONLINE	SIM	Slit_0.5	0	0.00	Slit_0.5	
afoc	ONLINE	SIM	0	mm			
nfoc	ONLINE	SIM	0	mm			
adc1	ONLINE	SIM	OFF	0.0	0.0	OFF	
adc2	ONLINE	SIM	OFF	0.0	0.0	OFF	
crot	ONLINE	SIM	ON	Active	Fault	Standstill	Touched

Piezo and Calibration \

insh	ONLINE	SIM	CLOSED		
qth	ONLINE	SIM	OFF	OFF	
deut	ONLINE	SIM	OFF	OFF	
neon	ONLINE	SIM	OFF	OFF	
argo	ONLINE	SIM	OFF	OFF	
xeno	ONLINE	SIM	OFF	OFF	
merc	ONLINE	SIM	OFF	OFF	
thar	ONLINE	SIM	OFF	OFF	
afc1	ONLINE	SIM			
Mode		REF	Set	0.0	0.0
		REF	Cur	12.3	56.8
afc2	ONLINE	SIM			
Mode		REF	Set	0.0	0.0
		REF	Cur	12.3	56.8

Command Feedback Window Options

```

14:39:45 SIMULAT > REPLY/ L Successfully put device: CROT in requested mode
14:39:51 ONLINE > INVOKED "-function crot"
14:39:52 ONLINE > REPLY/ L OK
  
```

SOXS Status - @wsxs

File Std. Options Help

SOXS Status

Ins Mode **Undefined**
State **LOADED**
Substate **idle**

TCS

State **ONLINE** Tracking **ENABLED**
Substate **IDLE** RA 104.89044
Access **IGNORE** DEC -795221.276

Shutter and calibration slides

INSH	LOADED	HW	CLOSED
CALS	LOADED	HW	FAIL 122
CUPS	LOADED	HW	FAIL 16

Calibration Lamps

QTH	LOADED	HW	OFF
DEUT	LOADED	HW	OFF
NEON	LOADED	HW	OFF
ARGO	LOADED	HW	OFF
XENO	LOADED	HW	OFF
MERC	LOADED	HW	OFF
THAR	LOADED	HW	OFF

Sensors

CVTS P	2.49
CVTS T	2.49
CPTS T	350.00
CRAC	■
CRNF	■
CRMS	■
CRSW	■

NIR - Near Infrared Spectrograph

NIR **ONLINE** LCU-SIM idle
Exposure inactive DIT 5.00
Remaining 0 NDIT 1
AFC2 **LOADED** HW X 0 Y 0
NFOC **LOADED** HW FAIL 99899
NISE **STANDBY** SIM 0

VIS - Visible Spectrograph

VIS **ONLINE** HW-SIM idle
Exposure 1 DIT 0.00
Remaining 0 NDIT F
AFC1 **LOADED** HW X 0 Y 0
ADC1 **LOADED** HW ERROR
ADC2 **STANDBY** SIM STANDING
VISE **STANDBY** SIM 2
TECH **ONLINE** SIM IDLE

ACQ - Acquisition Camera

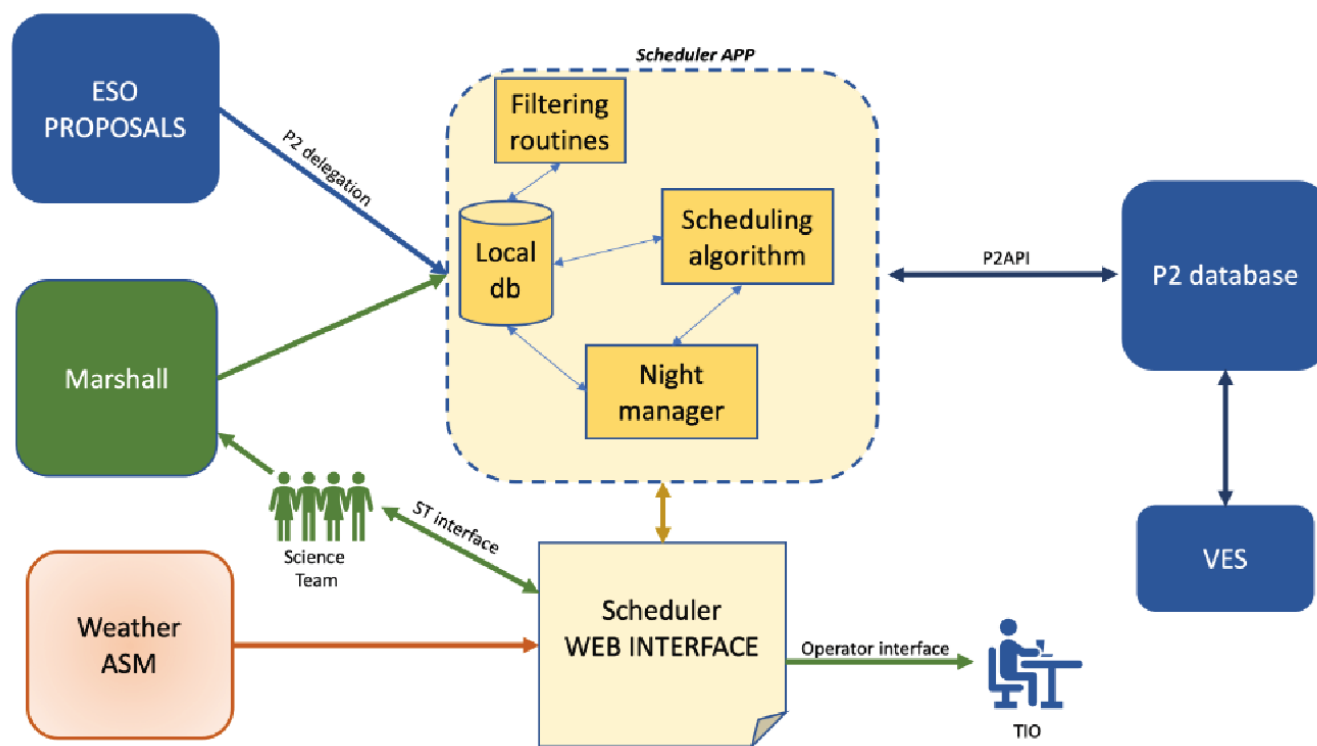
ACQ	ONLINE	SIM	IDLE
ACQS	LOADED	HW	FAIL 106
ACFW	LOADED	HW	571151
AFOC	LOADED	HW	FAIL 54671



Scheduler

- ❑ Schedule is updated daily
- ❑ Telescope operator on site

- ❑ P2 system, vOT interface with ESO
- ❑ Web based app



■ Presentation of M. Landoni

The screenshot shows the SOXS Scheduler web interface. At the top, it displays the current night status: "Opened Night: 27-07-2023" and "30-08-2023 09:50:16 UTC". Below this, there are tabs for "SCHEDULE", "OBSERVABLE OB", and "FOLLOWUP ESO & URGENT OB". The "SCHEDULE" tab is active, showing a table of scheduled observations. The table has columns for ID, Scheduled, Target, Type, Obs. Start, Obs. End, and Actions. The table lists several observations, including ATLAS23jcc, AT2022nph, AT2022nwl, AT2022now, AT2022ekx, and two "No Name" ESO observations.

ID	Scheduled	Target	Type	Obs. Start	Obs. End	Actions
8973	+	ATLAS23jcc	ESO OB	2023-07-27 23:31:09.894	2023-07-28 00:31:09.894	[Icons]
7294	+	AT2022nph	CLASSIFICATION	2023-07-28 00:31:09.704	2023-07-28 00:41:09.704	[Icons]
7241	+	AT2022nwl	CLASSIFICATION	2023-07-28 00:41:09.704	2023-07-28 02:06:09.704	[Icons]
7280	+	AT2022now	CLASSIFICATION	2023-07-28 02:06:09.704	2023-07-28 03:36:09.704	[Icons]
7924	+	AT2022ekx	CLASSIFICATION	2023-07-28 03:36:09.704	2023-07-28 04:06:09.704	[Icons]
9131	+	No Name	ESO OB	2023-07-28 04:06:09.894	2023-07-28 04:56:09.894	[Icons]
9129	+	No Name	ESO OB	2023-07-28 04:51:09.894	2023-07-28 05:46:09.894	[Icons]

Marshall

Feeders:

- ❑ ZTF, ATLAS, PanStarrs, LSST-Lasair, etc.
- ❑ TNS, Atel, GCN, etc.



SOXS



SOXS ETC

Available: <http://192.167.38.34/>

Operational (to be refined using on sky data)

Pipeline

- Pipeline extensively tested first with XSH and now with SOXS data
- It works with full automation (data are reduced as soon arrive on the workstation)
- Installed in La Silla
- Code available here <https://github.com/thespacedoctor/soxspipe>
- Presentation of S. Smartt

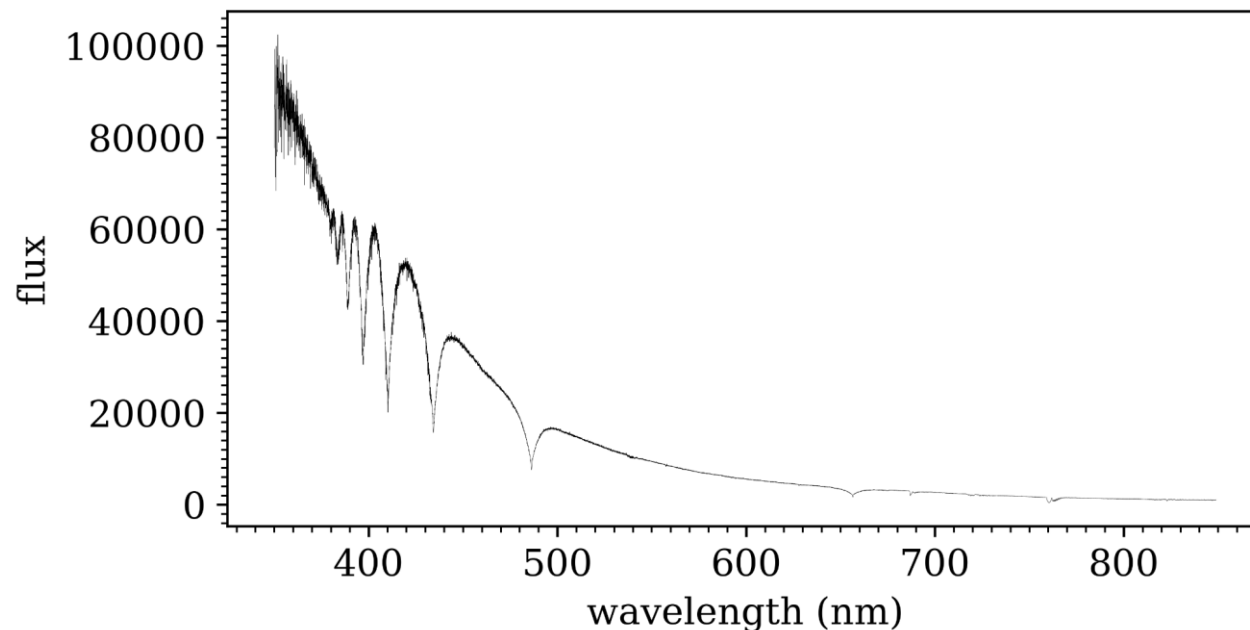


Pipeline commissioning

- Easy installation, clear instructions for running, and data products documented - more than 10 postdocs and students from Queen's and Oxford installed and ran pipeline v.0.13.1 successfully, all from documentation
- Detailed documentation available
- After download of appropriate data - one command shown to reduce a full night of data
- SOXS UV-VIS : runs successfully (>90% of time) if the correct calibrations are downloaded by the user and available. No persistent, repeatable and obvious failures.
- Both stare and nodding modes data run through pipeline successfully
- User has control of many parameters

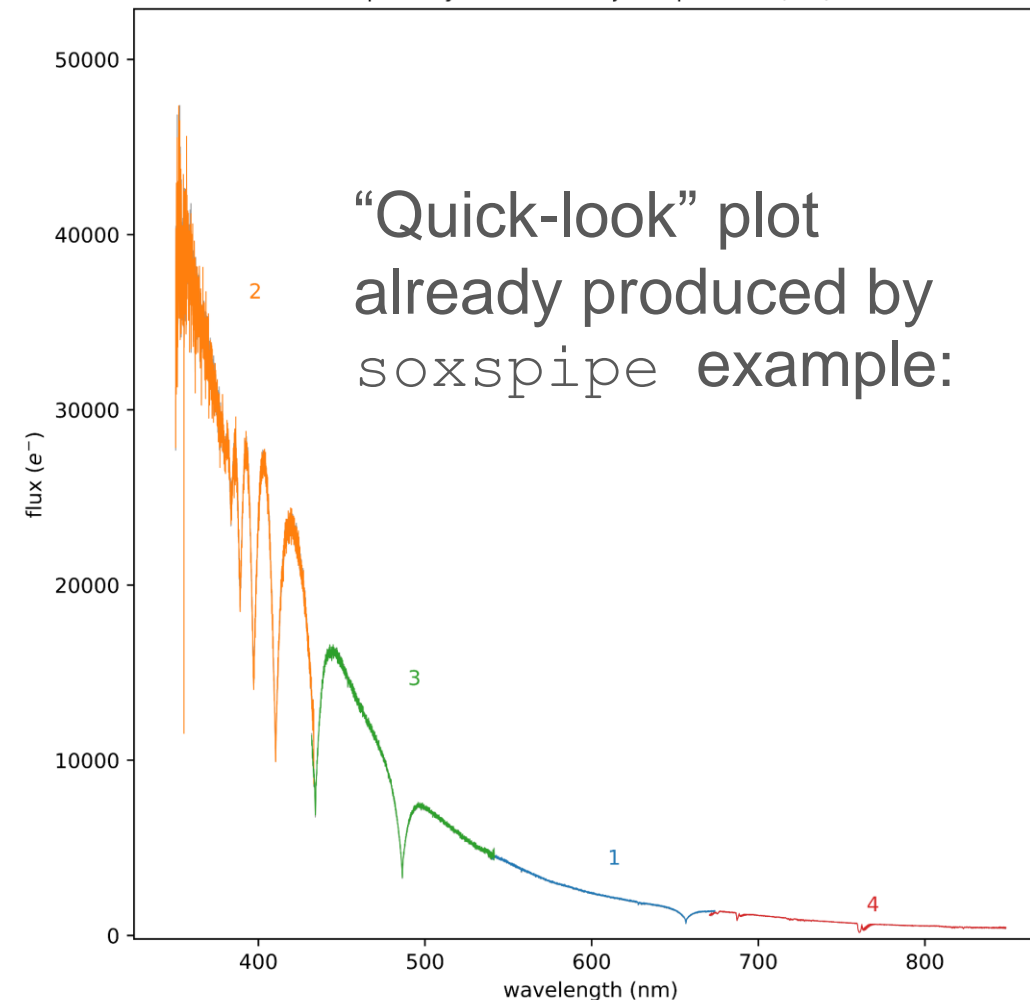


CD-30 17706



- Good stitching of orders
- Lamp flat-fielding works for stitching (compare with unflattened data for throughput)
- Wavelength solution mostly reliable - some glitches to be investigated
- Flux calibration not yet implemented

Optimally Extracted Object Spectrum (VIS)



November,
2023



March,
2025





Commissioning is ongoing

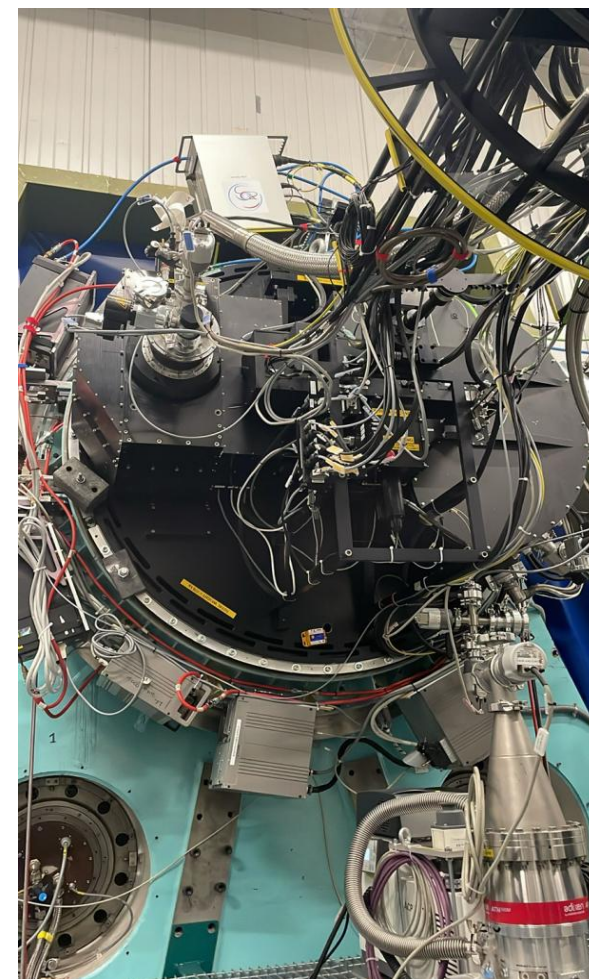
- May 2025 run (done)
- June 2025 run (done)
- September 2025 run (scheduled)
- Other TBD commissioning runs in fall

Operations will be addressed as well



Commissioning tasks

- ✓ Alignment
- ✓ Resolution
- ✓ ACQ & UV-VIS detector characterisation
- ✓ Focus parameters
- ✓ Acquisition procedure
- ✓ Lookup tables
- ✓ Calibration OB / end of night procedure
- ✓ p2ls working
- ✓ Ingestion of data into ESO SAF
- ✓ INS & templates test
- ✓ Observations of spectrophotometric & photometric STDs
- ✓ Skyflats OB
- ✓ soxspipe @ La Silla and tested (up to the latest version)
- ✓ Updated ETC





Commissioning tasks

- ❑ Fix issues
- ❑ Characterisation and tests of NIR arm
- ❑ More tests on ACQ & UV-VIS (in light of the results obtained so far)
- ❑ Check focus parameters
- ❑ Check stability of calibrations
- ❑ Check keywords and archive I/F
- ❑ Implement procedures for QC parameters visualization and storage
- ❑ Pipeline update
- ❑ TIOs training
- ❑ Update manuals

