# SOXS (Son of X-Shooter)
# a fast response follow-up spectrograph on the NTT

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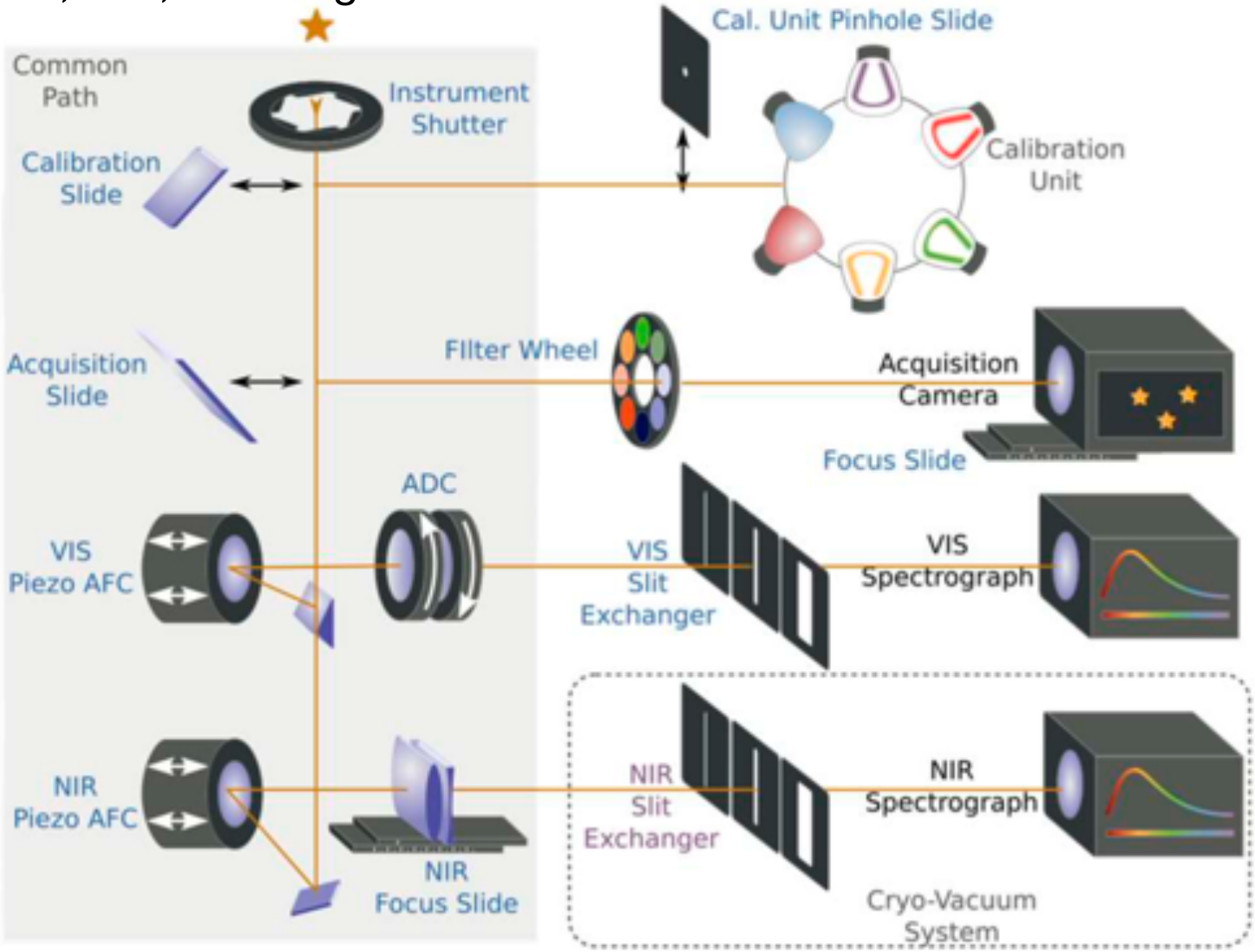
Queen's University Belfast, UK
University of Turku and Finca, Finland
Millenium Institute of Astrophysics, Chile
Niels Bohr Institute (Copenhagen) and Aarhus University, Denmark
European Souther Observatory

LSST:UK Science Centre

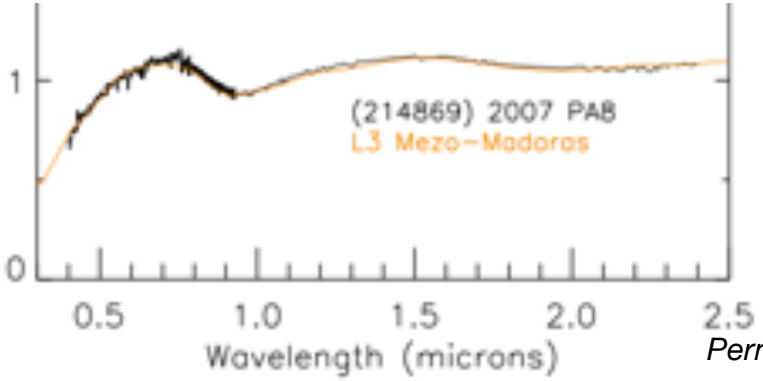
# Instrument Description

High-efficiency spectrograph covering near-UV to near-IR  in single shot.
Replaces SOFI on NTT, EFOSC2 decommissioned after start of SOXS operations.
spectral resolution of 3500-7000.
Slit widths 5.0”, 1.5”, 1.0”, 0.5’, Slit Length 11 arcsec.



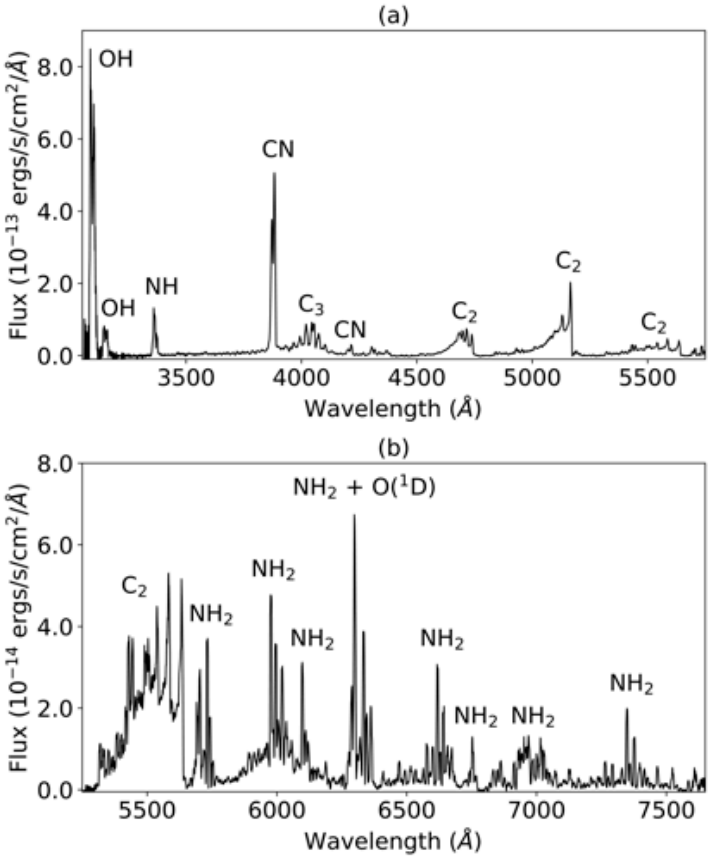
# Why SOXS?

**Asteroid/icy body** spectra contain solid-state absorption bands from ~0.4 - 2.0 um, giving compositions.




*Perna et al. 2016*

**Cometary** spectra contain resolvable gas emission from ~0.4 - 1.0 um, plus dust grain scattering at across optical/NIR.

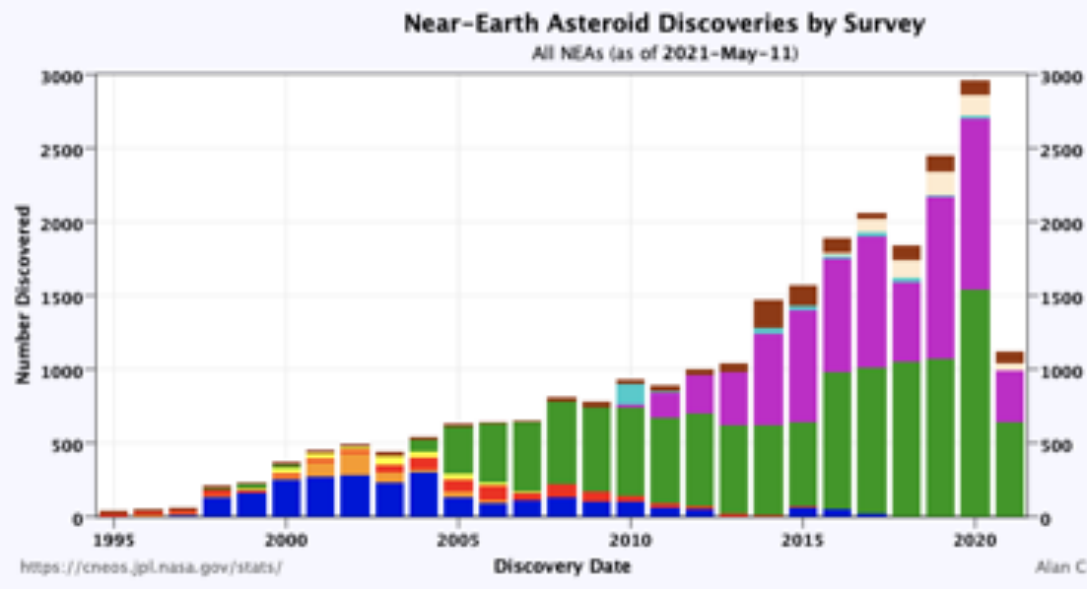



**SOXS is highly applicable to Solar system spectroscopy (but with caveats).**

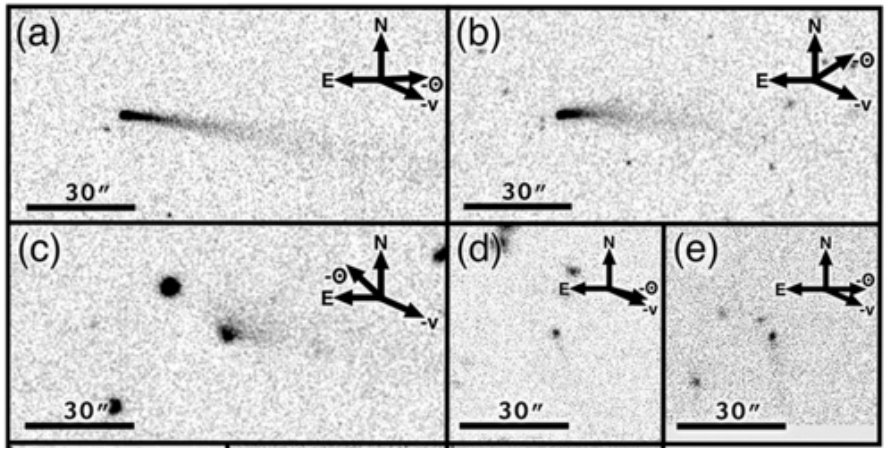
*Caveat 1!*

SOXS is clearly suited to brighter LSST discoveries.

# SOXS has been developed for transient/discovery followup

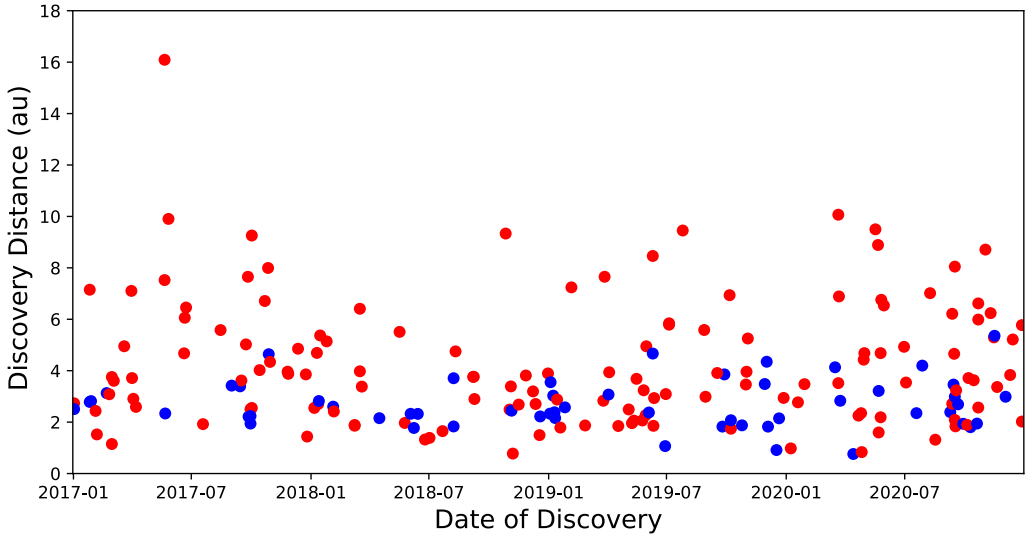



Main Belt Comets — 313P/Gibbs

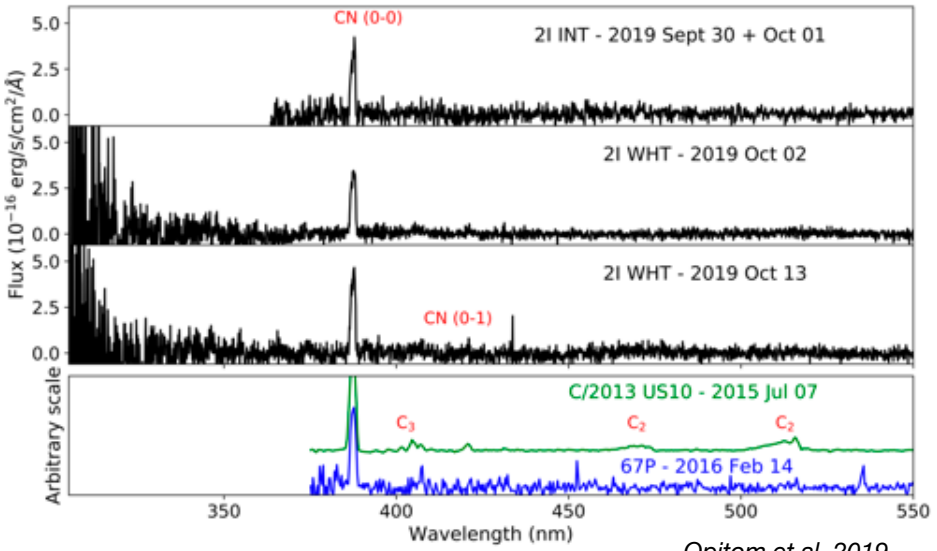



*Hsieh et al. 2015*

Comet Discoveries 2017–2020




Interstellar Objects - 2I/Borisov




*Opitom et al. 2019*

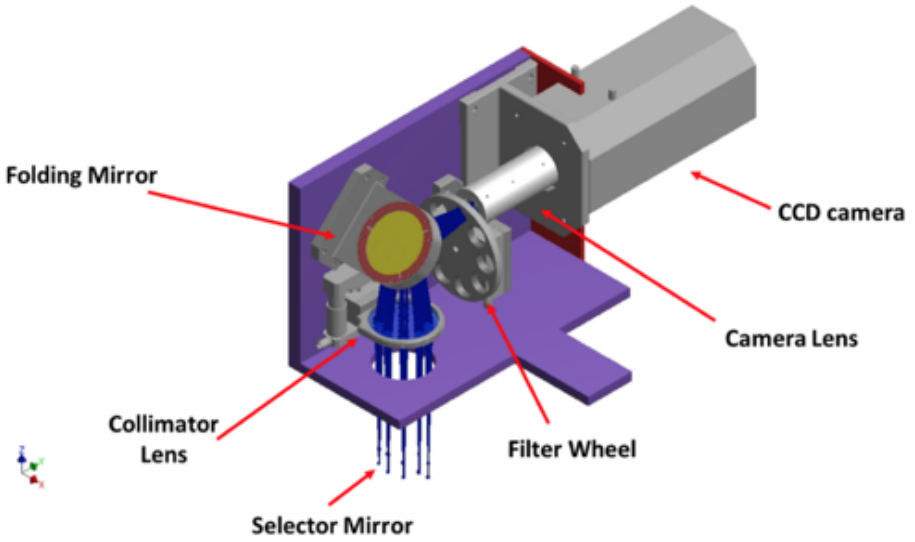
# Instrument Description

## A&G Camera

Used for acquisition, secondary guiding, photometry.

BEX2-DD 1024x1024 13um pixels
pixel scale 0.205 ‘’/pix, 3.5x3.5 arcmin fov

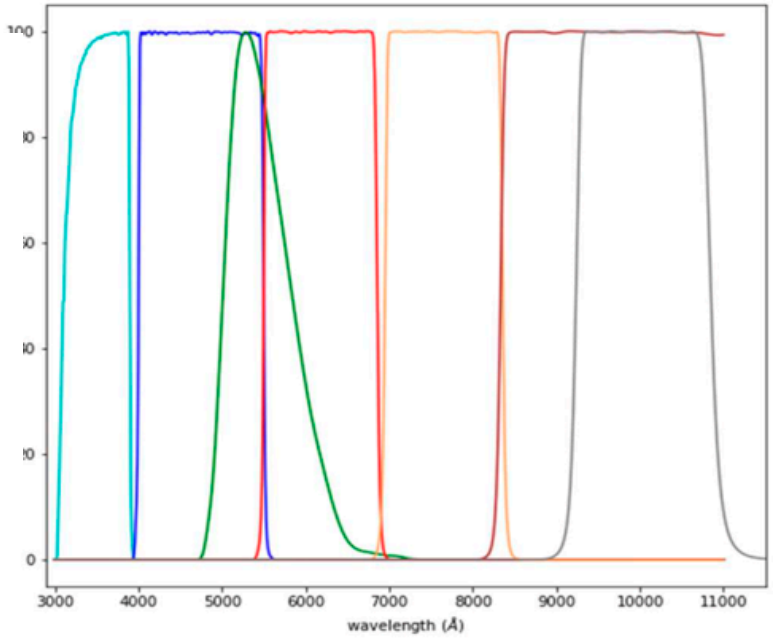
ugriz+V+Y filters.




*Claudi et al. 2016*

Table 3. Limiting Magnitude of the CAM system for a SNR=10 in SDSS band.

| SDSS Band | 1 sec | 2 sec | 3 sec | 5 sec | 10sec | 15 sec | 20 sec |
|---|---|---|---|---|---|---|---|
| u’ (355.7nm) | 15.9 | 16.7 | 17.5 | 17.7 | 18.4 | 18.7 | 19.1 |
| g’ (482.5nm) | 18.2 | 18.9 | 19.4 | 19.8 | 20.5 | 20.8 | 21.0 |
| r’ (626.1nm) | 18.0 | 18.6 | 19.0 | 19.5 | 20.0 | 20.3 | 20.4 |
| i’ (726.2nm) | 16.4 | 17.1 | 17.5 | 17.9 | 18.4 | 18.6 | 18.8 |
| z’ (909.7nm) | 15.3 | 15.9 | 16.2 | 16.5 | 16.9 | 17.2 | 17.4 |



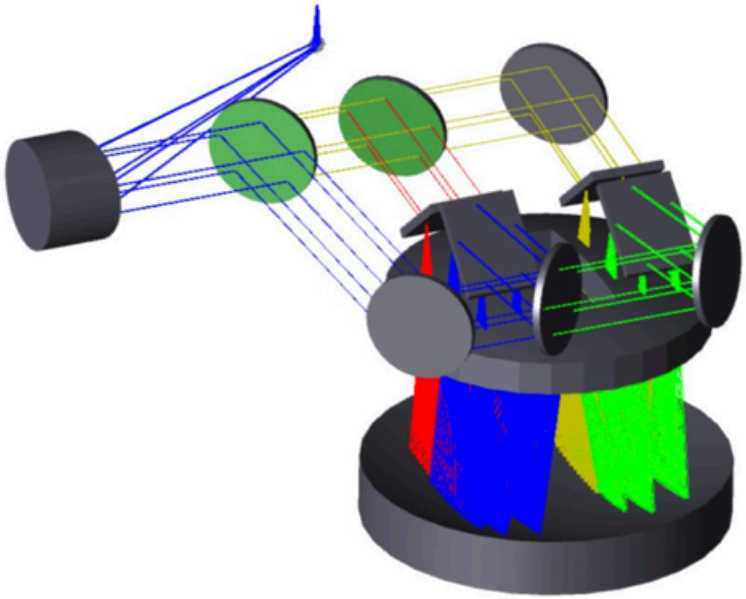

*Caveats*

Only standard broad-band filters, no changes.

# Instrument Description

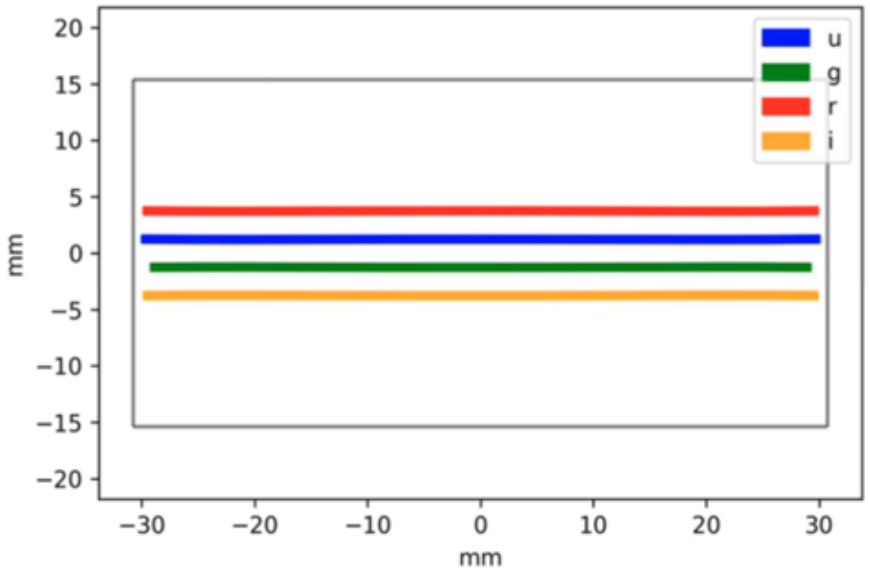
**UV-VIS ARM**

3 Dichroics split 350nm – 850nm onto four independent gratings.
Resulting spectra are simultaneously imaged on single E2V CCD.
Spectra are linear (spatial direction inclined by 8º).



*Claudi et al. 2016*

Covers brightest part of any small body reflectance spectrum plus most bright cometary emissions.

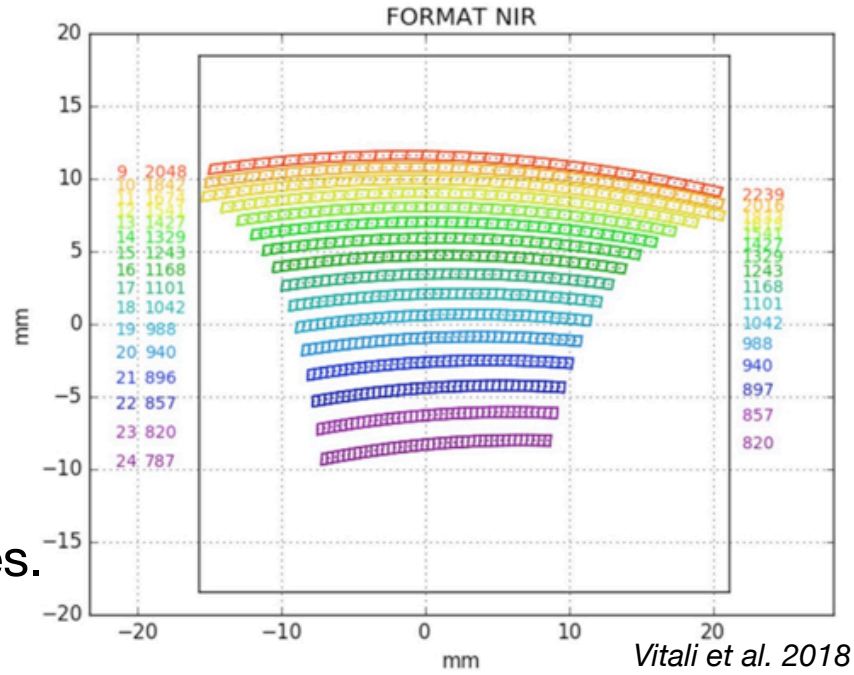



*Caveats*
Misses NH,OH in comets.
Misses minimum of 1-um silicate absorption band (but appears in NIR arm)

# Instrument Description

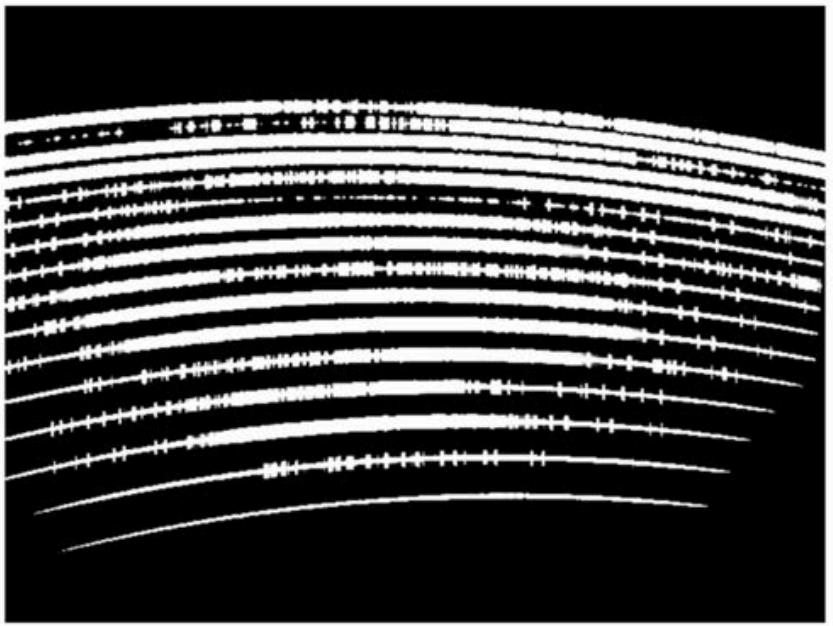
## NIR ARM

Cross-Dispersed Echelle covering 0.79μm to 2.01μm
Resulting spectra are simultaneously imaged on single Hawaii 2RG 2Kx2K.
Excellent sky line correction for unresolved sources.



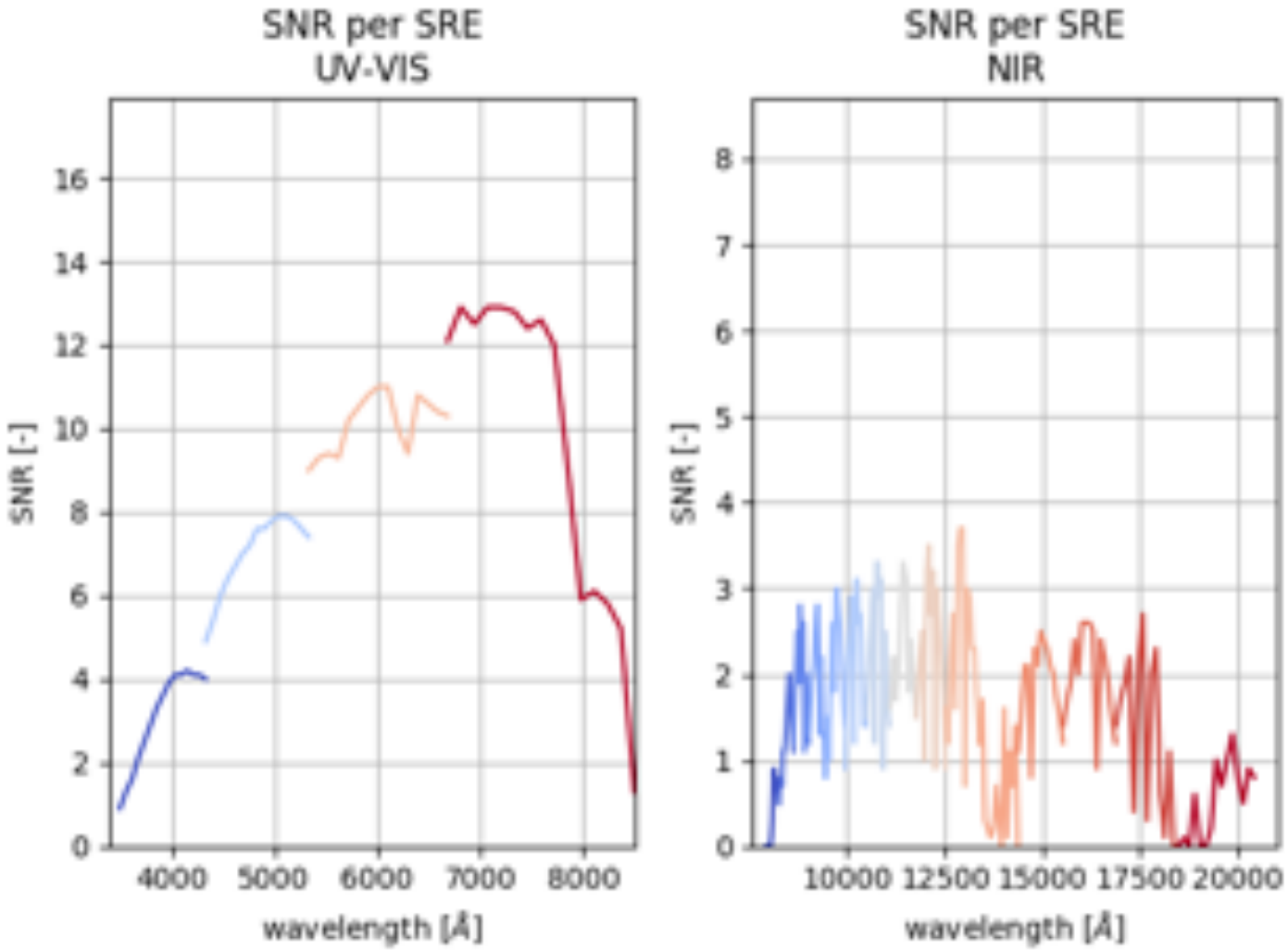

*Vitali et al. 2018*

*Caveats*
15 Orders (!), similar to X-Shooter
Cut-off at 2μm causes problems for silicate absorption diagnostics.
Resolution too low for cometary $H_2O$ lines.



# Capability

SNR per Spectral Resolution Element
(SRE ~1Ang for UV-VIS, ~0.003μm for NIR)
V=20 G0V star, 1800sec exposures



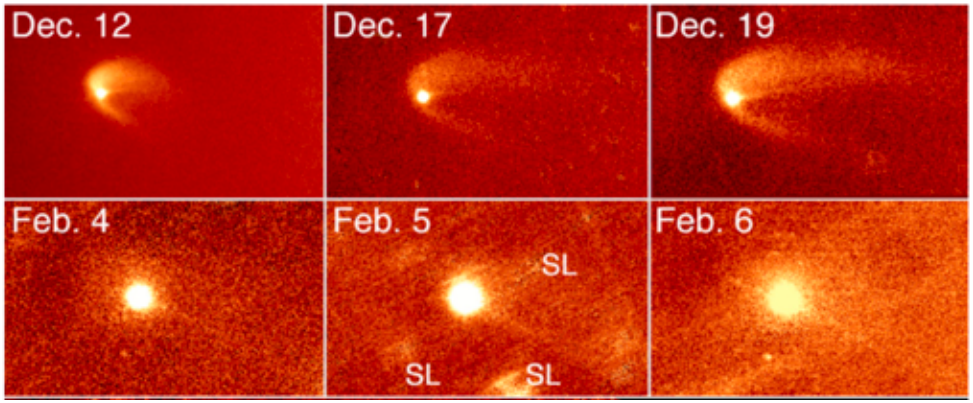
# Operations & Summary

**First 5 years (2022/3–2027/8):**
50% SOXS Consortium time, 50% open time through OPC.
Consortium handles all observing during this time on a ranked queue basis, no visitor mode.
Ability to include new (approved) observations on timescales <24 hours.
Automated reduction pipeline under development (Dave Young, QUB), fully reduced 1-D spectra available within 30 minutes of archive deposit.

**Summary**
SOXS is a near-UV to NIR intermediate resolution spectrograph (plus imager).
It will be available by start of Rubin Observatory observations for LSST.
Suitable for brighter Solar System discoveries and transients.

# SOXS has been developed for discovery/transient followup

Asteroid Collision - (596) Sheila




*Ishiguru et al. 2011*

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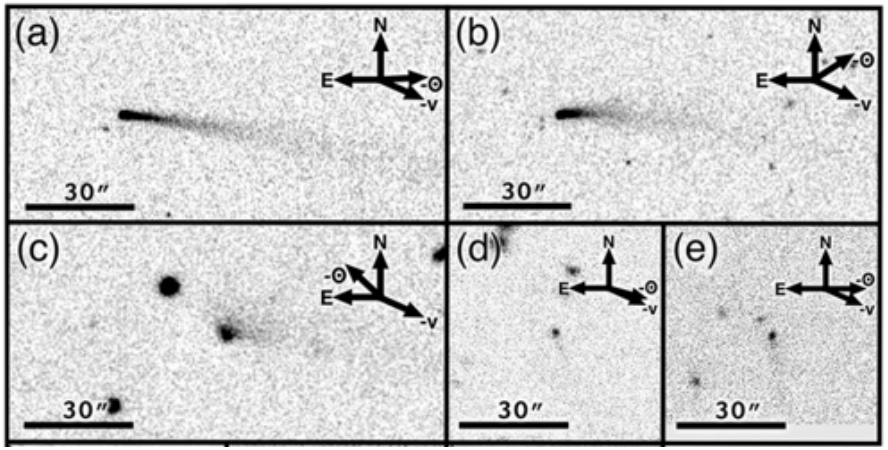
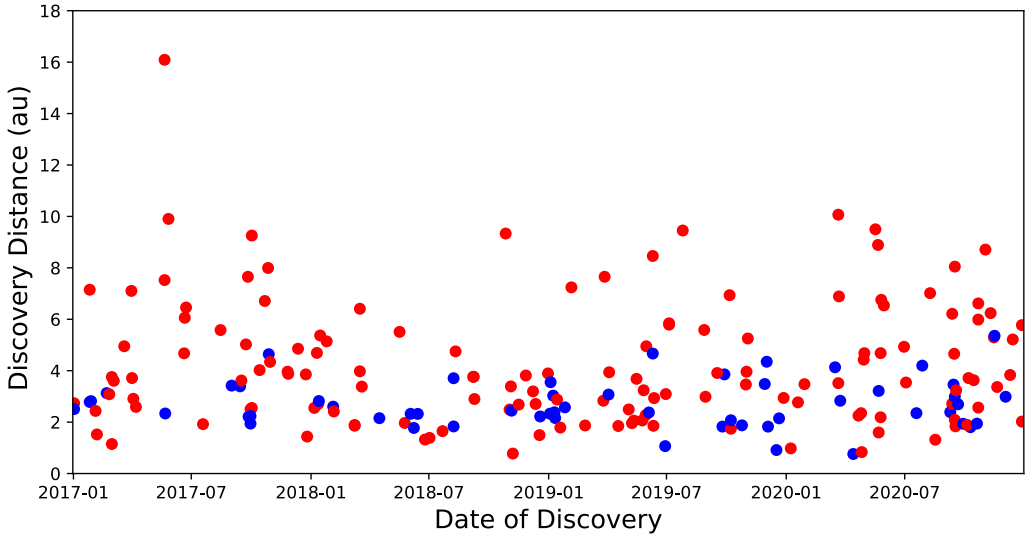



*Hsieh et al. 2015*

Comet Discoveries 2017–2020

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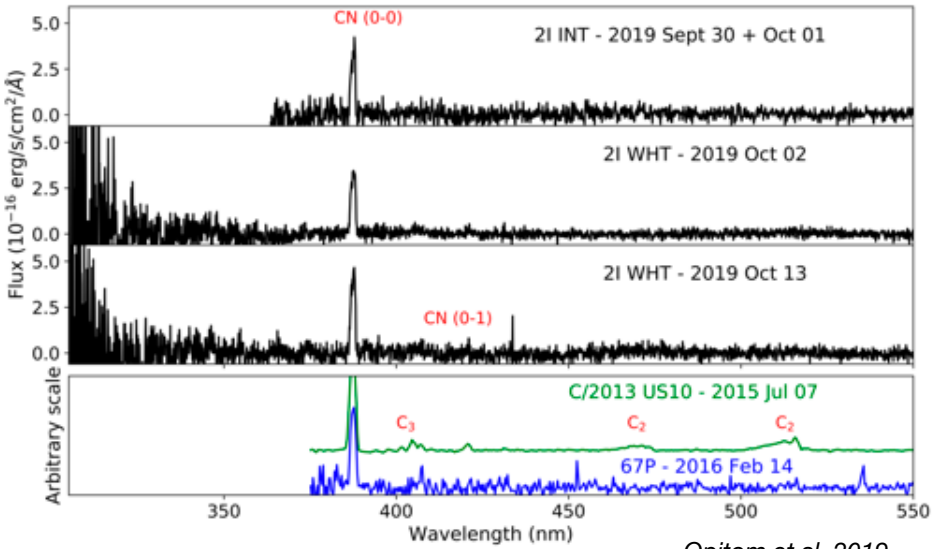


*Opitom et al. 2019*