SOXS

Son Of X-Shooter at NTT

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(thanks to Sergio Campana, PI of SOXS)

GSA Cambridge 2011

Massimo Turatto

(Gaia) Supernovae: overview & follow-up

Main Scientific Issues ⟷ Follow-up Requirements

Requirements for (spec) monitoring

- flexible: prompt classification & adaptive scheduling
- broad wavelength range (realistically from atmo cut-off to NIR)
- broad band photometry & low-intermediate-res spectroscopy
- Homogeneity: few, well characterized instrumentation
- (both hemispheres)

THE solution: **MT's "chiodo fisso"**
XShooter-like instrument (+ imaging) on a 4m-class telescope
(Photom by Opt-NIR camera on a 2m-class robotic telescope)

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➡ robotic telescopes (also for spectroscopy !)

➡ “ad hoc” follow-up instrumentation

…….

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…..

Report of the European Telescope Strategy Review Committee on Europe's 2-4m Telescopes over the Decade to 2020 (2010)

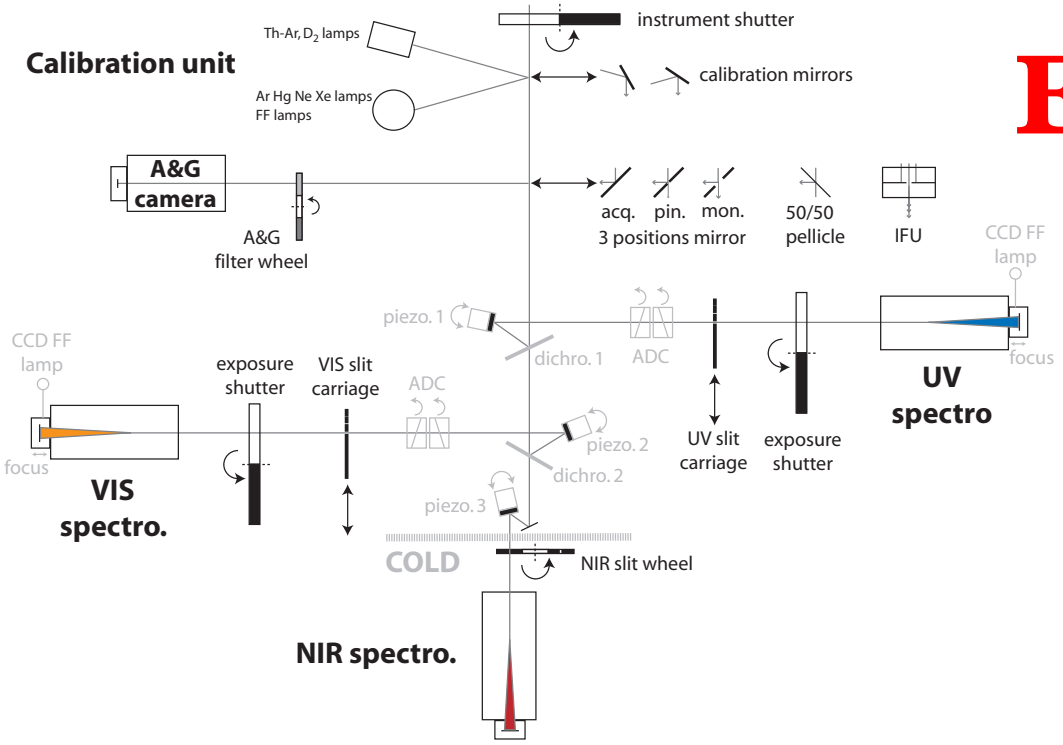
Emphasis on:

- Wide lambda coverage (0.4-2.4mu, at least 1.7mu)
- Override RRM/ToO mode
- 1 north + 1 south

Table 3: A list of identified capabilities that are incompletely/not met, requiring action. Suggestions for remedies and associated timescales are given in column 3.

Capability		Explanation	
ID & hemisphere/aperture		problem	timescale/remedy
1-1: $R \sim 5000$ optical wide-field spectrograph	N/4m	WHT/WYFFOS multiplex + unvignetted field inadequate	~2015 on a 4-m
	S/4m	none available	new VISTA sp'graph after nir surveys
1-2: $R > 20000$ optical wide-field spectrograph	N/4m	not available – needs 2-deg corrector	gain early S experience (below); combine with 1-1 capability
	S/4m	(as north)	AAT/HERMES buy-in and/or VLT/FLAMES use preparatory to new build
2-1: highly stable $R \sim 10^5$ optical echelle sp'graph	N/4m	HARPS-NEF private, temporary, uncertain	alternative from end of MOU (Mauna Kea pref.)
2-3: $R \sim 70000$ nir echelle (with spectropolarimetry)	either/4m	closest matches SPIRou, CARMENES not confirmed	~2015: support SPIRou or CARMENES
3-1: $500 < R < 5000$ opt+nir spectroscopy	S/4m	ageing EFOSC2,SOFI: prospect of **no** 2-4m sp'graph of the class in the south	upgrade needed by 2015
	N/4m	no northern son-of-X-shooter	new build for 2015+
4-1: wide-field nir imager	N/4m	northern cameras have < 0.25 deg^2 FoV UKIDSS loss	1 deg^2 camera on 4-m from 2015

ESO X-Shooter



UVB, range 300-559.5 nm
VIS, range 559.5-1024 nm
NIR, range 1024-2480 nm

UVB			VIS			NIR		
Slit width (″)	Resolution ($\lambda/\delta\lambda$)	Sampling (pix/FWHM)	Slit width (″)	Resolution ($\lambda/\delta\lambda$)	Sampling (pix/FWHM)	Slit width (″)	Resolution ($\lambda/\delta\lambda$)	Sampling (pix/FWHM)
0.5	9100	3.5	0.4	17400	3.0	0.4	11300	2.0
0.8	6300	5.2	0.7	11000	4.8	0.6	8100	2.8
1.0	5100	6.3	0.9	8800	6.0	0.9	5600	4.0
1.3	4000	8.1	1.2	6700	7.9	1.2	4300	5.3
1.6	3300	9.9	1.5	5400	9.7	1.5	3500	6.6
IFU	7900	4.1	IFU	12600	4.2	IFU	8100	2.8

Band	U	B	V	R	I	J	H	K’
mag	21.5	21.7	21.7	21.6	21.2	20.5	20.8	19.3

Continuum spectrum S/N=10 - 1 hr exposure

NOT Transient Explorer – A new work-horse for the Nordic Optical Telescope

A cross-dispersed spectrograph **covering 350-1700 nm, resolution ~4000** (possibly with also a higher-res mode), **single slit** (with different choices for the slit width), including ADC and efficient enough to be sky-limited in 30 min integration.

Visible imager with 5-6 arcmin FOV, 2k x 2k detector, sampling 0.15-0.18 arcsec per pixel.

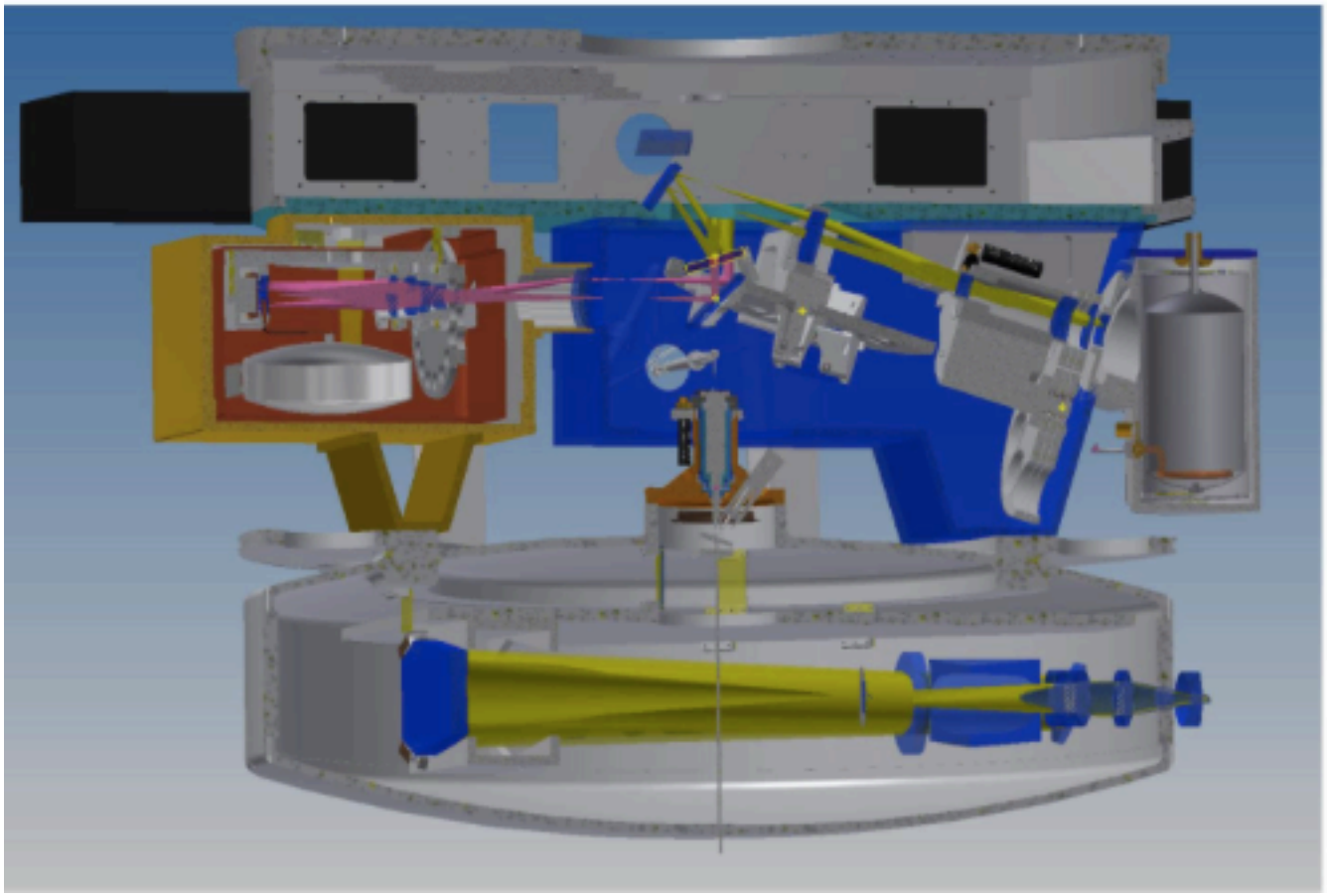
Near-IR imager using a 2k x 2k HAWAII-II detector with same FOV and sampling as in the visible.

De-scoped version: imaging reduced to a visible slit-viewing camera with FOV of 3 arcmin (similar to StanCam).

Nordic (Denmark Sweden, etc.) + Italian collaboration

Table 1: *Main characteristics of NTE spectrograph mode.*

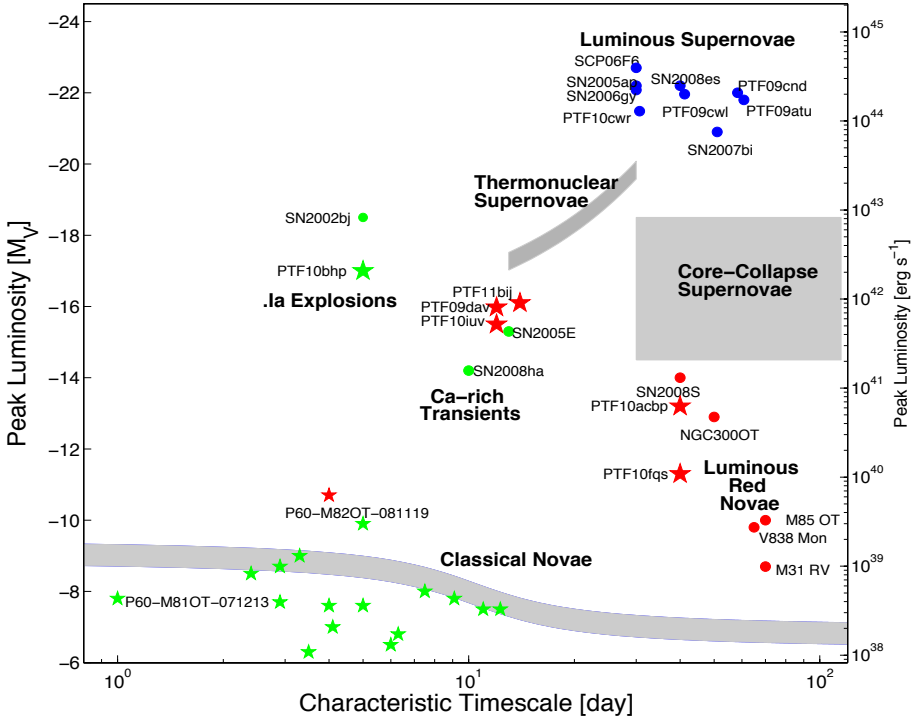
Wavelength coverage	0.32 – 1.77 μm
Spectral resolution	4,500
Slit length	20"
Pixel scale	~0.4"/pix
Optical/NIR wavelength crossover	0.76 μm
Average blaze peak efficiency	> 30%
Time to reach the sky limit	~15 min

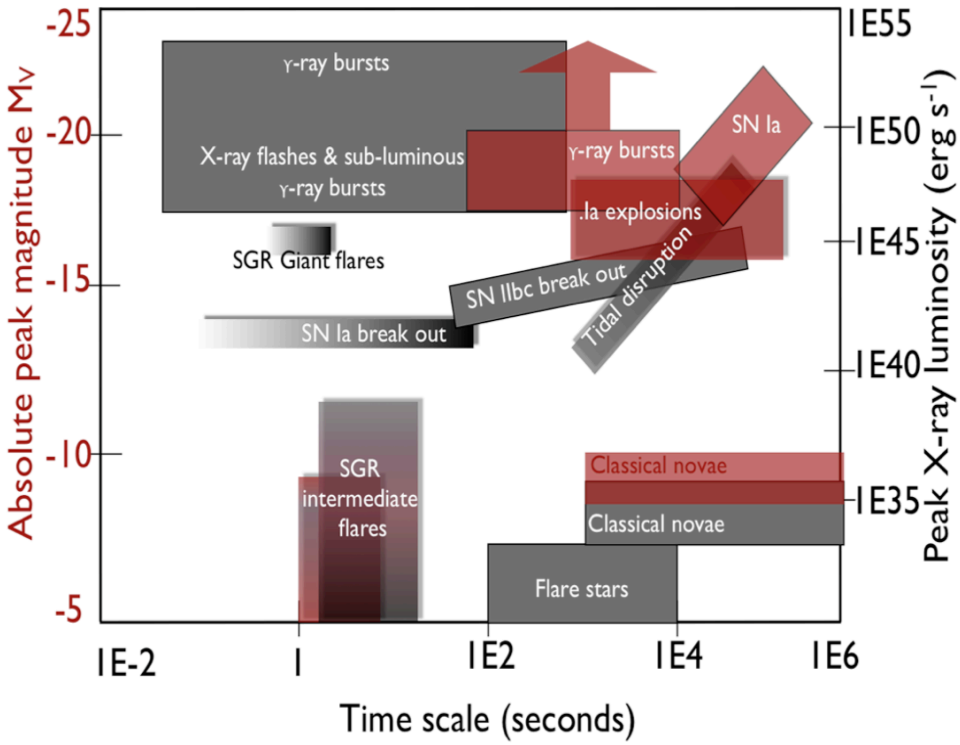


ESO's SOXS project

- ESO call for new instruments at NTT (06/2014)
- Proposal submission (02/2015)
- SOXS selected by ESO (05/2015) out of 19

SOXS Main Science case: the transient sky



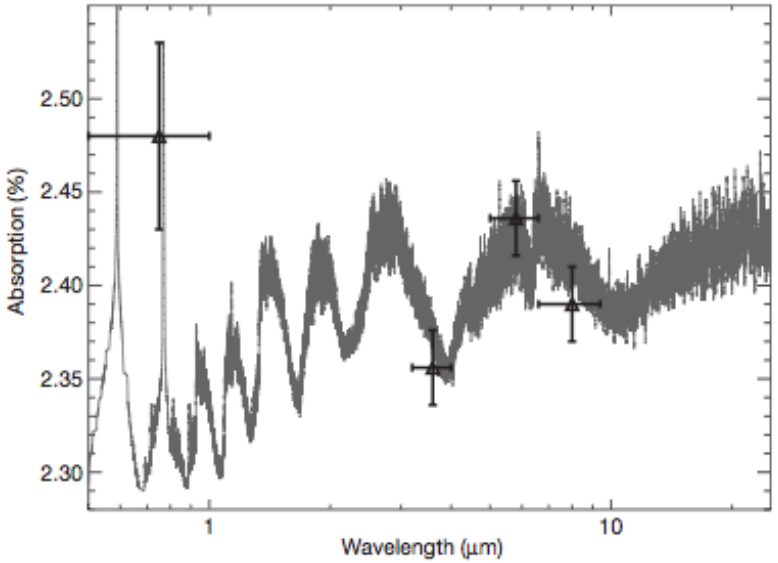


Just a few science cases

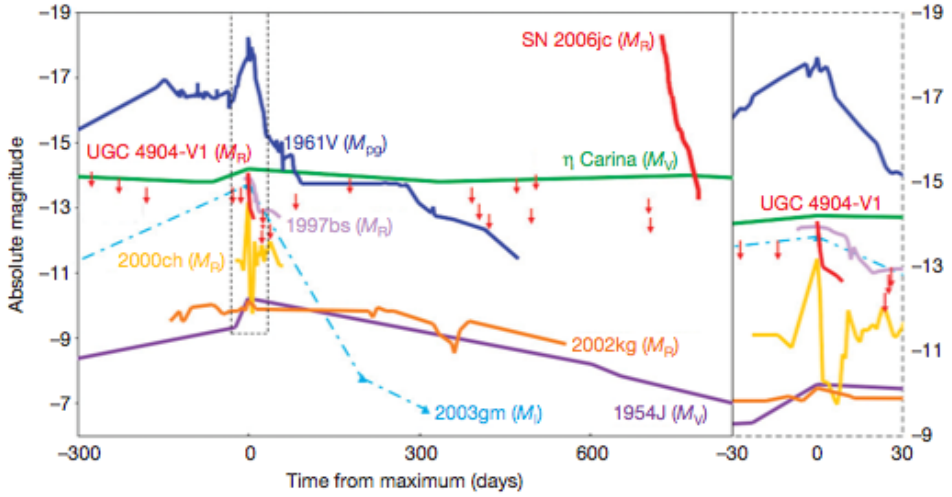
- Minor planets and asteroids
- Young stellar objects
- Planetary transits
- X-ray binary transients
- Novae
- Magnetars
- Supernovae (Ia, CC)
- GRB
- TeV transients
- GW & neutrino EM counterparts
- Radio sky transients & fast radio bursts

Discovery space

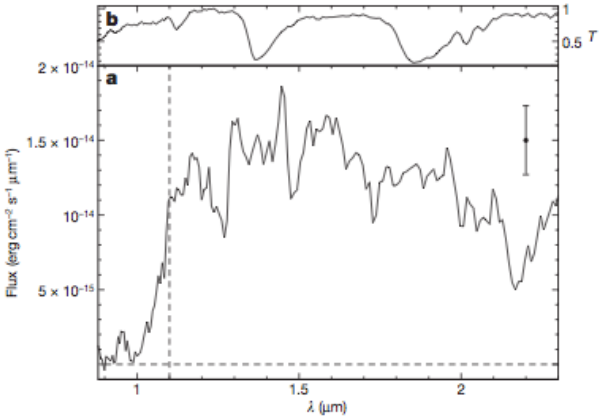
First SN shock break out (GRB060218 /SN2006aj)



Water vapor in the atmosphere of a transiting planet



Major outburst 2 yr before the SN explosion (SN2006jc)



The most distant object in the Universe (at the time of discovery; GRB090427 z=8.2)

A working example

During 2005-2013 Nature published ~180 astronomical papers with more than 50 citations.

Among them **36%** are on transients objects.

PESSTO

An already working example

- ~20% of selected candidates from SN searches enter into the observing queue
- ~ 50% of the transients are eventually observed and classified

90% remain unclassified

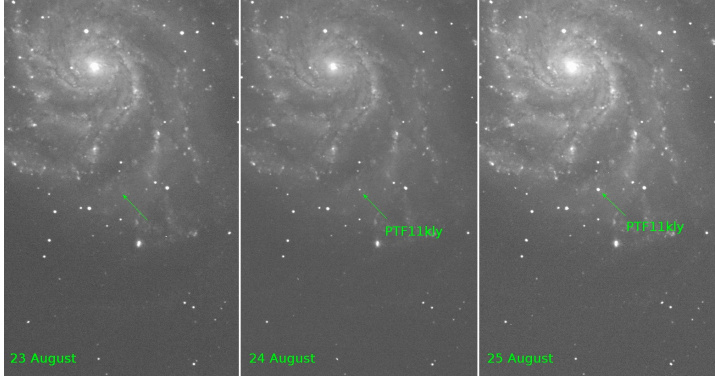
GAIA is coming

GAIA Transient Alerts

	alerting object	5-yrs (Entire Mission)	main location
interesting	Supernovae <19 mag	6000	out of plane
	Microlensing (bulge)	~1000	bulge/plane
	Microlensing (all sky)	~700	out of plane
	GRB optical counterparts	~hundreds (?)	out of plane
	R CrB-type stars	~hundreds (?)	gal. plane
	CN	150	gal. plane
	FU Ori	14	gal. plane
contaminants(?)	Eclipsing binaries	a million (?)	gal. plane
	AGNs	500,000 (?)	out of plane
	Asteroids	thousands (?)	out of plane
	Be stars	thousands (?)	gal. plane
	Long period variables/Miras	thousands (?)	gal. plane
	M-dwarf flares	2000	gal. plane
	DN (U Gem) (except rare big flares)	500 (?)	gal. plane

Why SOXS

Spectroscopic machine for the transient sky.



Sexy:
2005-2013 Nature published ~180 astronomical papers with > 50 citations.
Among them 36% are on transients objects.

Needed:
Now (PESSTO, Asiago, … in place) >70% of newly discovered transients without spectroscopic follow-up.

Near future many transient surveys:

- WF surveys (GAIA-alters, iPTF, DES, Pan-STARRS, LSST)
- high-energy transients (Swift, INTEGRAL, MAXI)
- GW-alters etc.

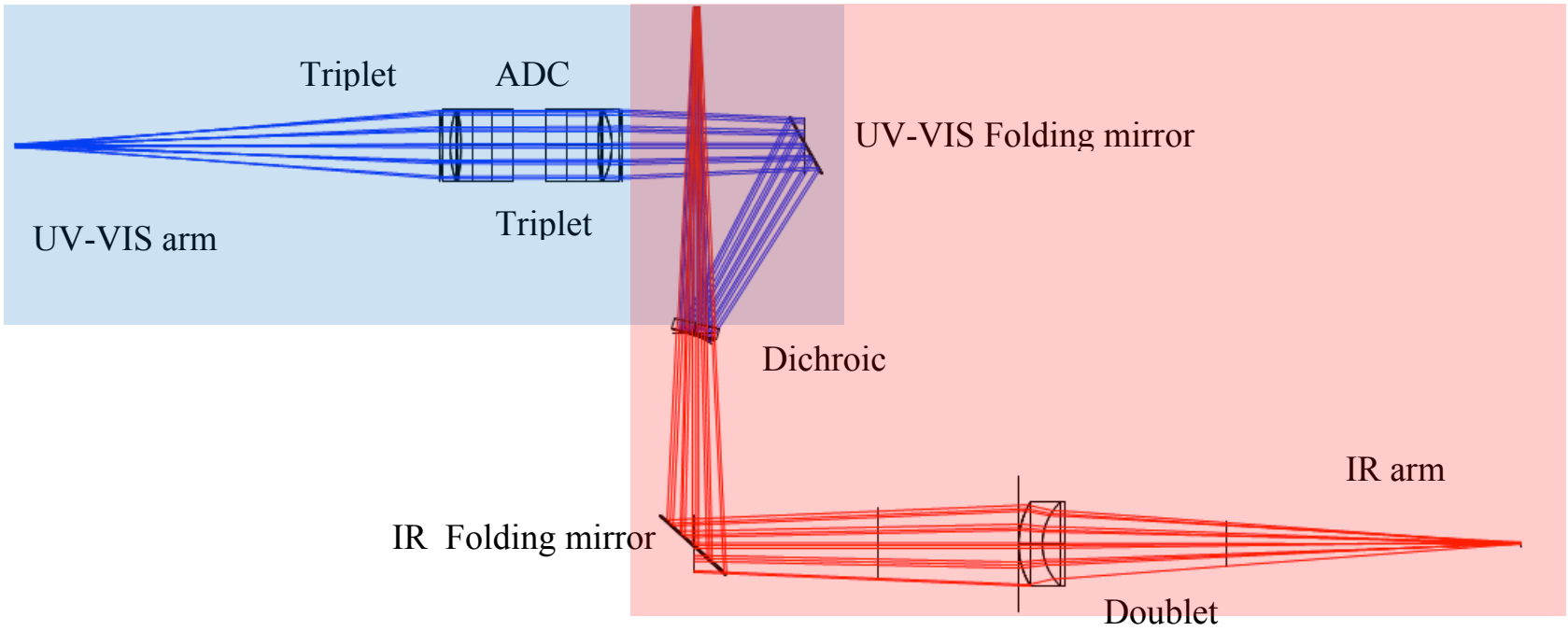
but very limited spectroscopic follow-up

SOXS @ NTT

Proposal to **build** and **operate** a spectrograph:

- wide spectral coverage (**0.35-1.75 μm**) **on two arms**
- good spectral resolution (**R~4500**)
- to **characterize** and **follow-up** in depth any kind of **transient**

A possible optical layout of the Common Path



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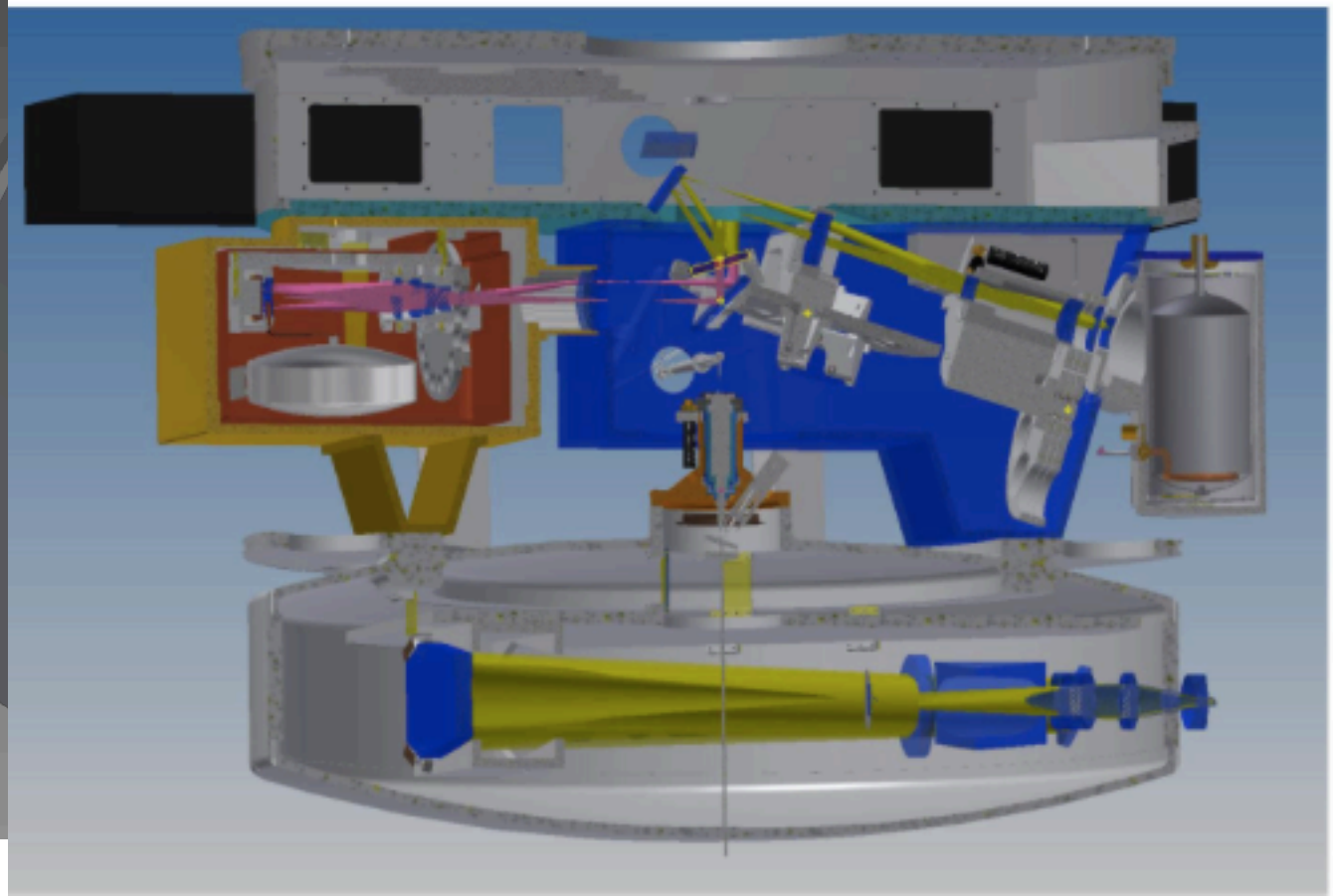
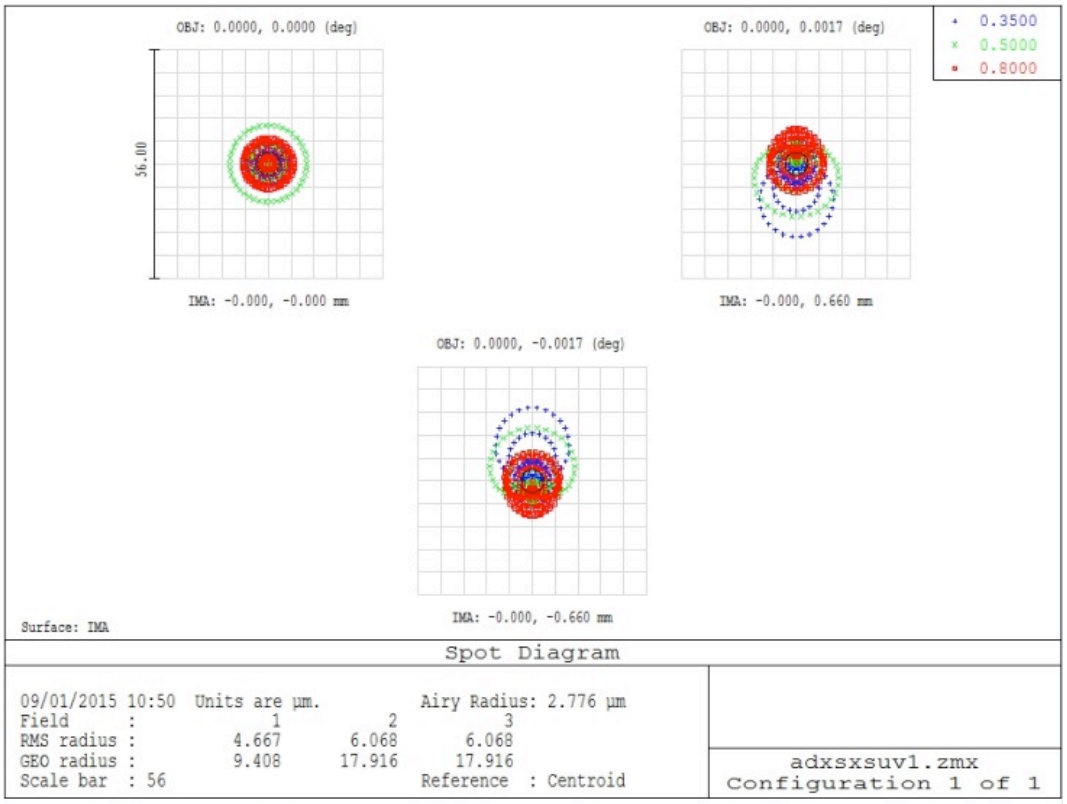


Initial performances

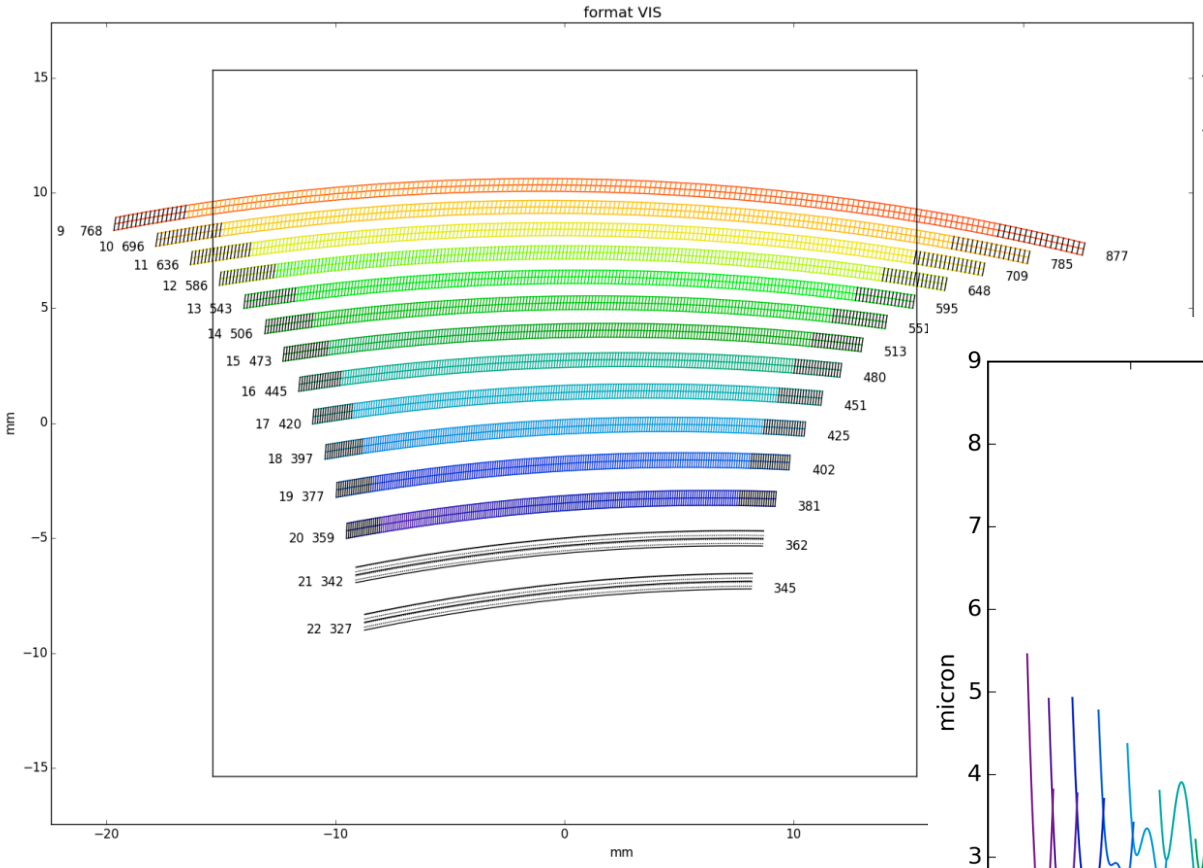


BLUE arm (0.35 to 0.8)

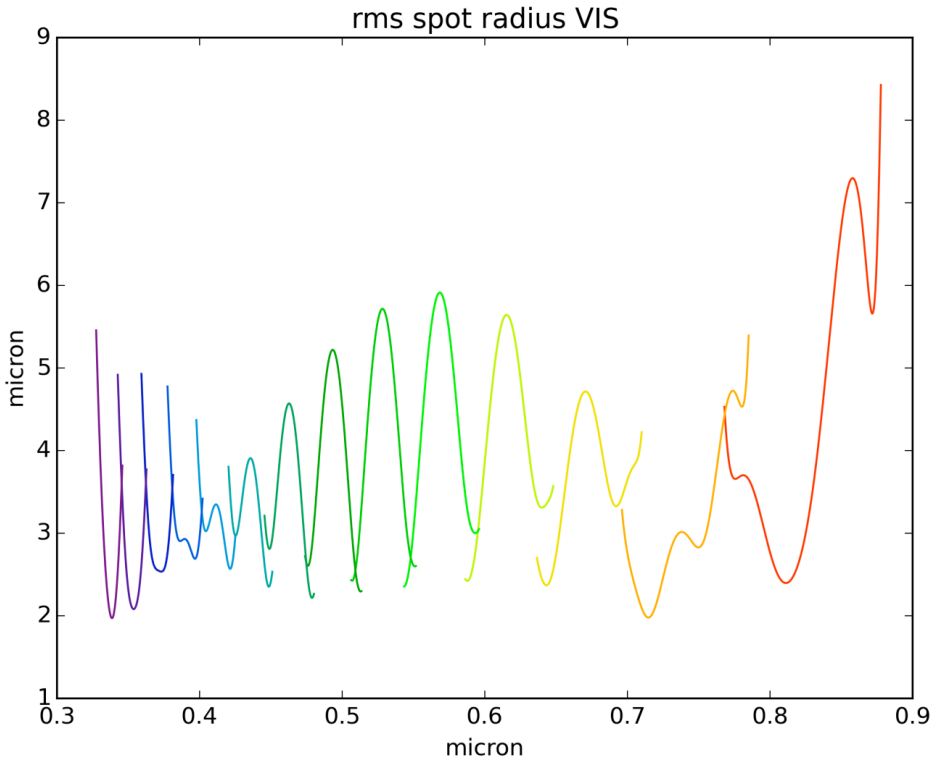
0.5 arcsec box

0 and ±12arcsec positions

BLUE spectrograph



Pixel size 15 micron
2048x2048



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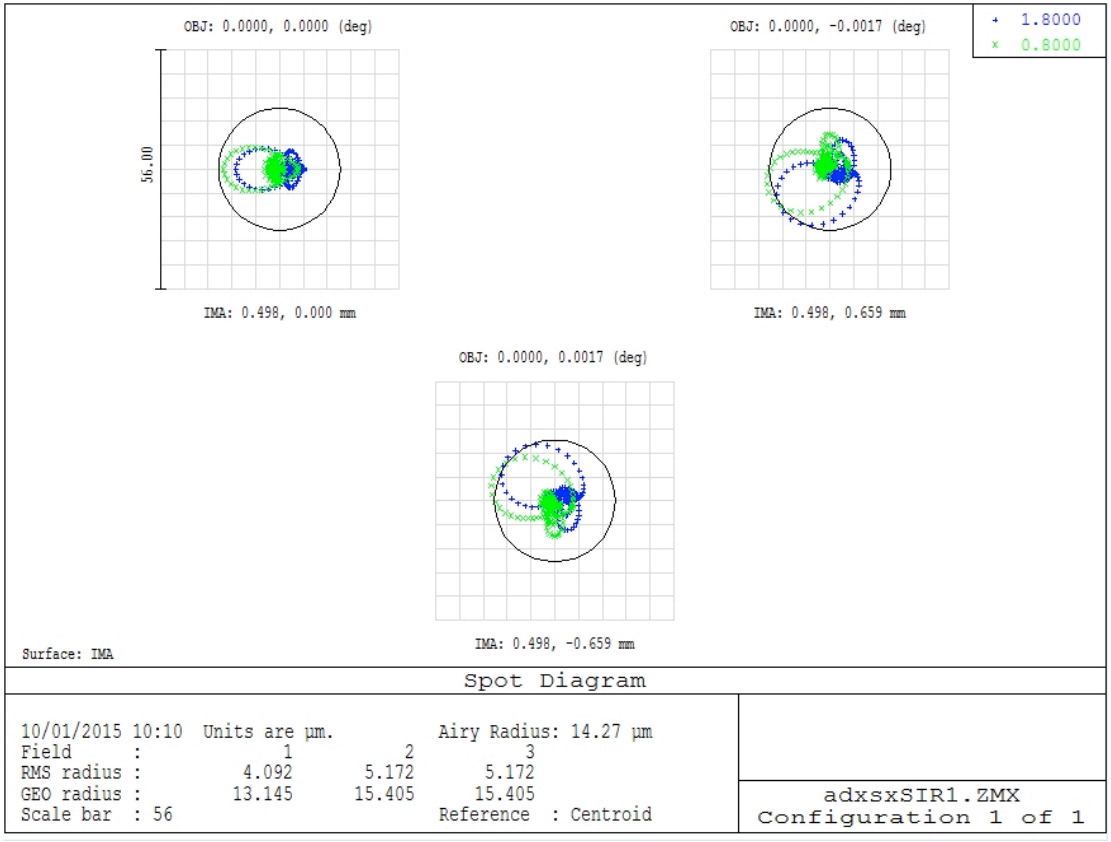
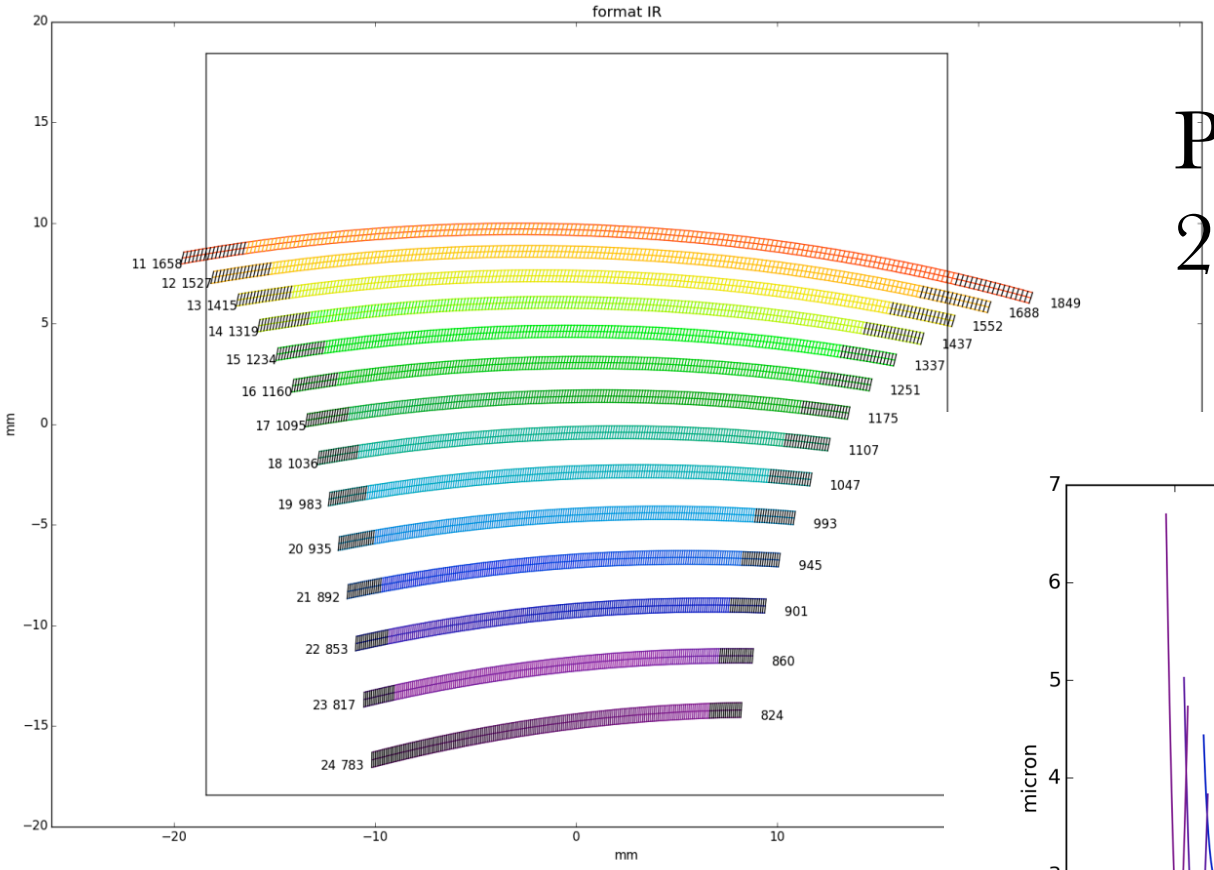


RED arm (0.8 to 1.8)

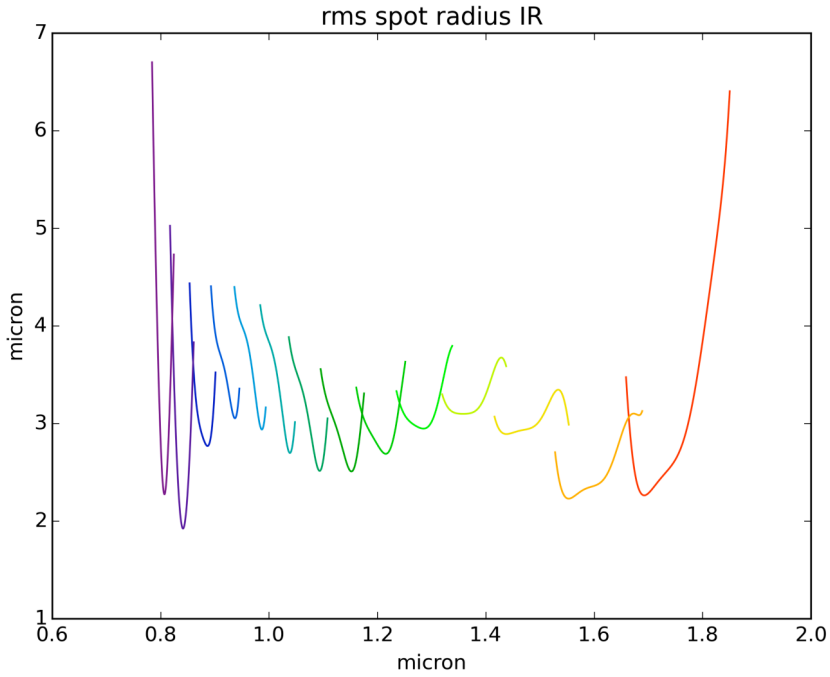
0.5 arcsec box

0 and ±12arcsec positions

RED spectrograph



Pixel size 18 micron
2048x2048



SOXS performances

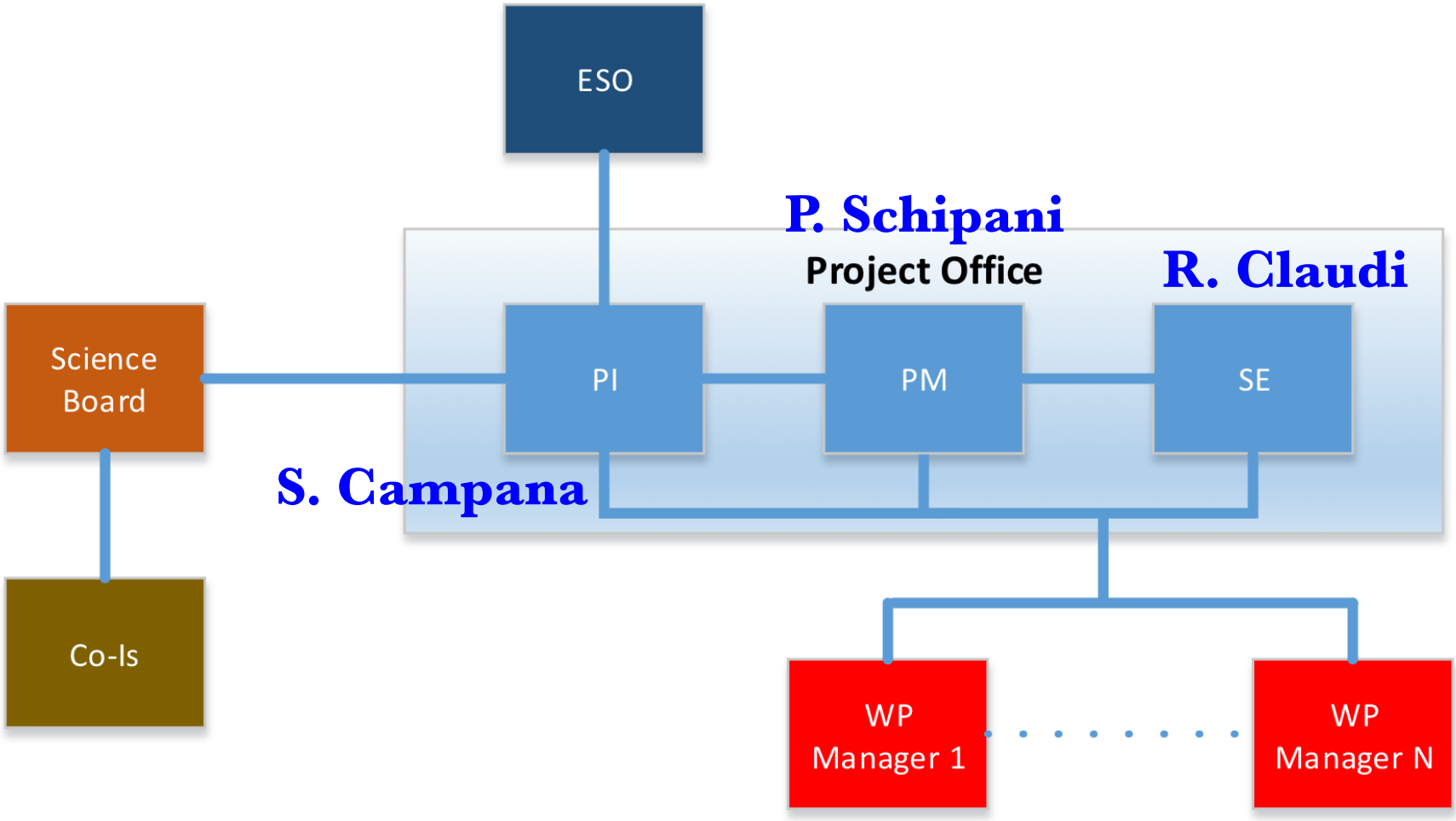
- Goal:

continuum spectrum R~20-20.5, S/N=10 in 1 hr

nicely matching the limiting magnitude of current (e.g. iPTF, GSA) synoptic surveys

"Extended" guiding camera to use as imaging (optical) instrument >3 arcmin FOV

Consortium structure



Science Board

S. Campana (INAF-OABrera) - Italy
E. Cappellaro (INAF-OAPadova) - Italy
M. Della Valle (INAF-OANapoli) - Italy
A. De Ugarte Postigo (IAA-CSIS) - Spain
J. Fynbo (Dark-NBI) - Denmark
M. Hamuy (Millenium Inst.) - Chile
G. Pignata (Millenium Inst.) - Chile
S. Smartt (Univ. Belfast) – UK
S. Basa (LAM) – France
L. Le Guillou (LNPHE) – France
B. Schmidt (ANU) – Australia
M. Colles (ANU) – Australia
A. Gal-Yam (Weizmann Inst.) – Israel
S. Mattila (FINCA) – Finland

Funds

>84% secured

Remaining to be approved by national agencies

Timeline 2016-2020

Project phase	Aprrox. start	Approx end	Duration
Phase A	12/2015	04/2016	5 months
Phase B	05/2016	10/2016	5 months
Phase C	11/2016	08/2017	10 months
Phase D	09/2017	12/2019	28 months
Phase E	12/2019	>2023	

Operations

ESO will reward the consortium with NTT GTO
(likely ~150 n/yr for TBD years)

From 2018 at existing EFOSC2+SOFI
then (mid-2019) at SOXS.
(urgent GW, GSA, etc.)

Observers on-site for instantaneous response to alerts

Source class	Obs. Time	Key project & Aim
All	500 hr	Fast characterization of transients from other surveys
Open	500 hr	Open time for spectroscopic ToO observations
Asteroids & TNO	200 hr	Characterization of populations of minor bodies, input to models of solar system formation and mitigation of impact hazard
Comets and new comets	100 hr	
Planetary transits	200 hr	Monitor of >5 bright stars for primary and secondary eclipses
Young stellar objects	100 hr	
Stars	100 hr	
X-ray binary transients	200 hr	Derive the mass function of >10 XRB transients in outburst
Magnetars	50 hr	Fast follow up of >10 magnetar's flares
Novae	100 hr	
ILOT	300 hr	
SN Ia	500 hr	Statistical sample of >150 SNe Ia in the low-z Universe to study the local properties and dust extinction
CC-SN	500 hr	
Super-luminous supernovae	500 hr	Build a statistical spectroscopic sample of SLSN
Prompt GRB	100 hr	Fast spectroscopy of >50 GRBs to probe the galaxy host medium
High-z (z>5) GRB	50 hr	Transmission spectra of >5 high-redshift GRBs
GRB-SNe	100 hr	Follow the evolution of >5 SN associated to nearby (z<0.3) GRBs
Active galactic nuclei and blazars	200 hr	
Tidal disruption events	100 hr	Study the spectral evolution of >10 TDEs
Gravitational Wave triggers	200 hr	Spectroscopic follow up of candidate GW counterparts. This includes kilonovae from short GRBs.
Neutrino triggers	100 hr	Spectroscopic follow up of candidate neutrino counterparts
Unknown	300 hr	

Data policy

<5% of the consortium time open to the community as fast ToO (Swift-like) observations (public data)

Relevant information (redshift, peculiar sources, etc.) announced in real time through GCN, ATEL, IAUC, etc.

Consortium data public after a short (1-3 months TBD) proprietary period.