

VST & SOXS in the current and next decade

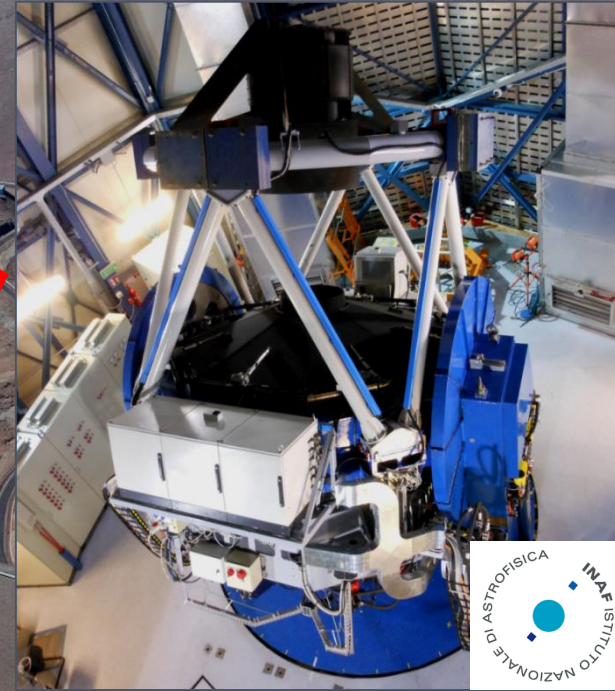


P. Schipani

INAF

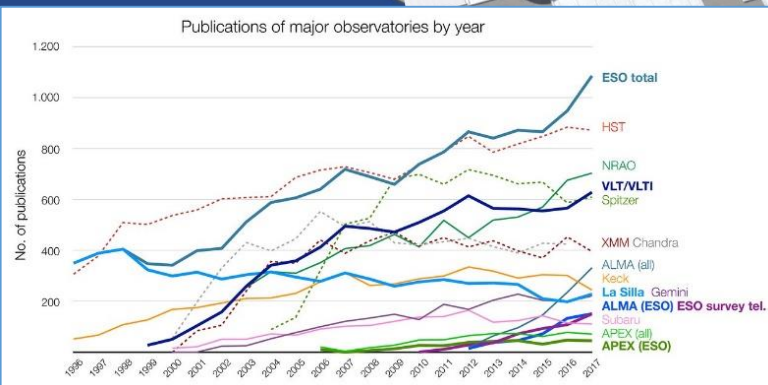
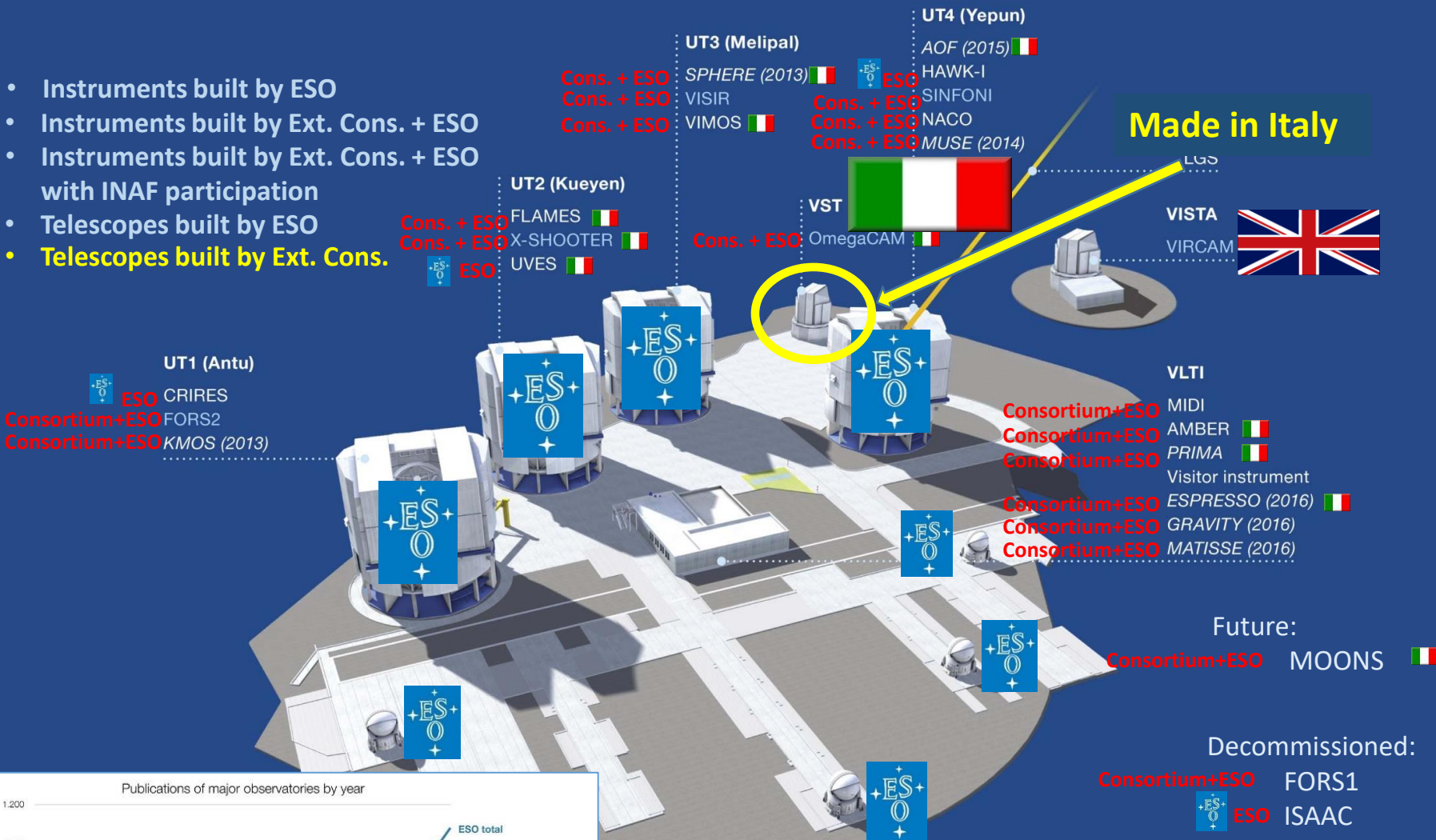
2nd Italy-Ukraine meeting in Astronomy
Multiwavelength Astrophysics from Radio to Gamma-Rays
Kharkiv, 25-27 September 2018

The VST



ESO work-horse for optical surveys

- Instruments built by ESO
- Instruments built by Ext. Cons. + ESO
- Instruments built by Ext. Cons. + ESO with INAF participation
- Telescopes built by ESO
- **Telescopes built by Ext. Cons.**



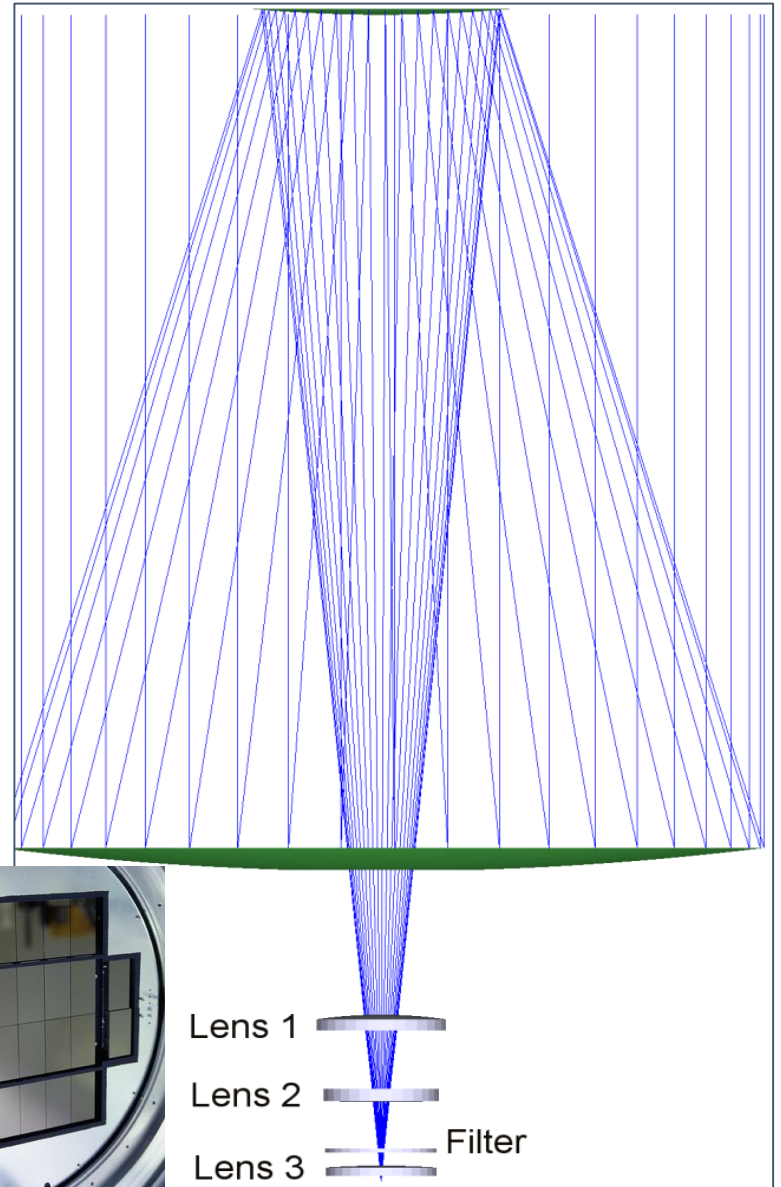
ESO Telescopes & Instruments @ La Silla – Paranal Obs. with Italian Plship:

- VST
- SOXS (2021), MAORY (2024), HIRES

ronomy “Multiwavelength Astrophysics from Radio to Gamma-Rays”, Kharkiv, 25-27 September 2018

VST - Characteristics

- Modified RC
- Primary mirror: 2.6m
- Secondary mirror: 0.9m
- F# 5.5
- Field corrector with 3 lenses (2 in the telescope + 1 in the camera)
- Field: $1^\circ \times 1^\circ$
- Active Optics
- Curvature Wavefront Sensor with in- and out-focus CCDs Active M1 shape control (81 active axial support + 3 axial fixed points)
- Active M2 positioning in 5 dof (hexapod)
- Guiding & Wavefront sensing through the OmegaCAM camera
- Image Quality down to 0.45" FWHM across whole field – Very good
- (Unused) probe & ADC



VST - Management



**Unusual: owned by INAF,
operated by ESO**

- Underwent regular ESO project steps (PDR, FDR, PAE, PAC, FAC)
- Totally integrated within the ESO environment
- But: INAF's property
- Regulated by decadal agreement ESO-INAF
- Available to community since 15 October 2011
- FAC granted 2014

AGREEMENT

on the **GUARANTEED OBSERVING TIME**, the **LOAN** and the
OPERATION of the **2.6-m VLT SURVEY TELESCOPE**
(hereinafter referred to as **VST**)
at the **ESO Paranal site of the La Silla Paranal Observatory**
(Chile)

BETWEEN

the **European Organisation for Astronomical Research in the Southern Hemisphere**, hereinafter referred to as **ESO**, having its Headquarters at Karl-Schwarzschild Str. 2, D-85748 Garching bei München (Germany),

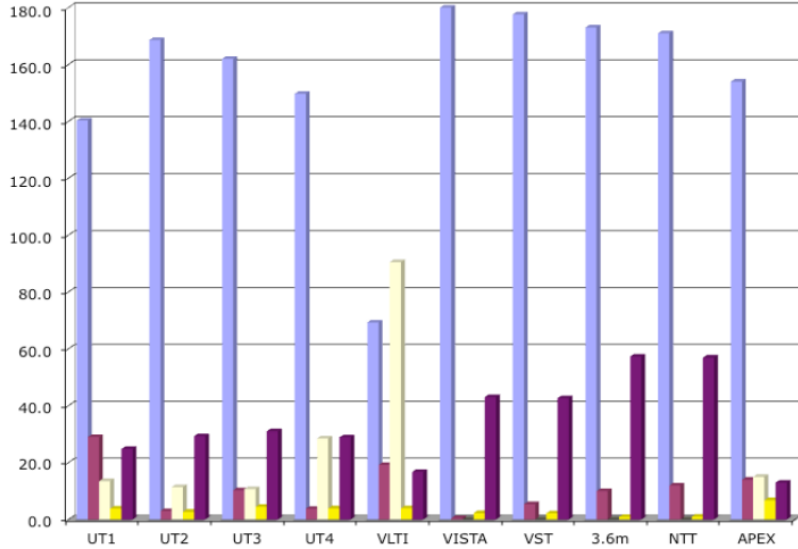
on the one hand,

AND

the **Istituto Nazionale de Astrofisica**, hereinafter referred to as **INAF**, whose registered address is at Viale del Parco Mellini n.84 - 00136 Roma (Italy).

VST - ESO LPO Statistics

Telescope Statistics P97 (April 2016 - September 2016)

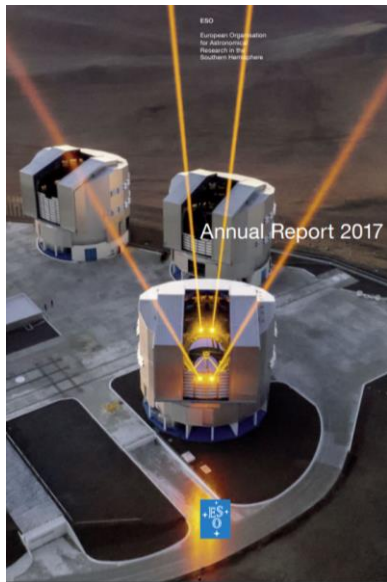
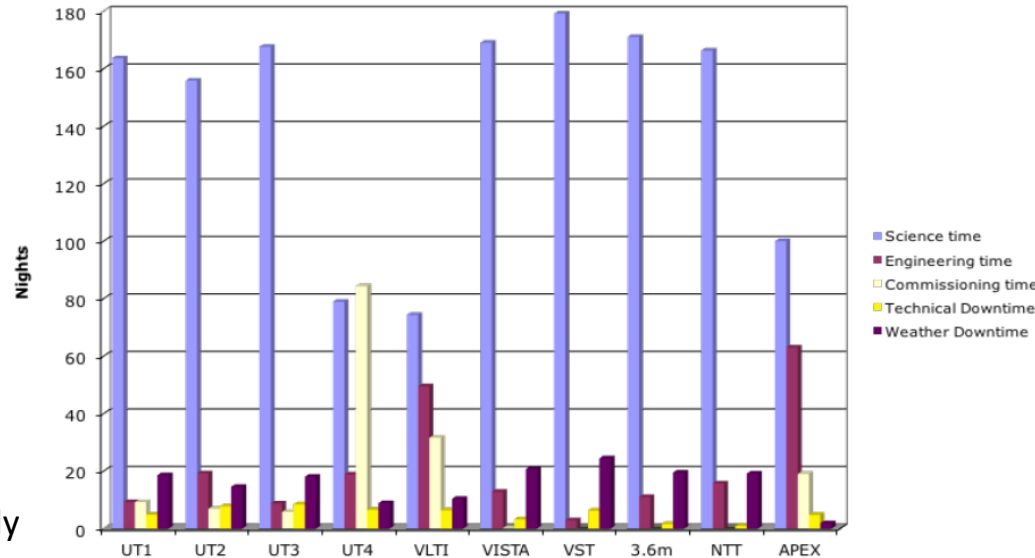


P97

“The technical losses of VISTA and VST were 2.2% and 2.1%, respectively; a reduction from previous years and significantly smaller than at the UTs.”

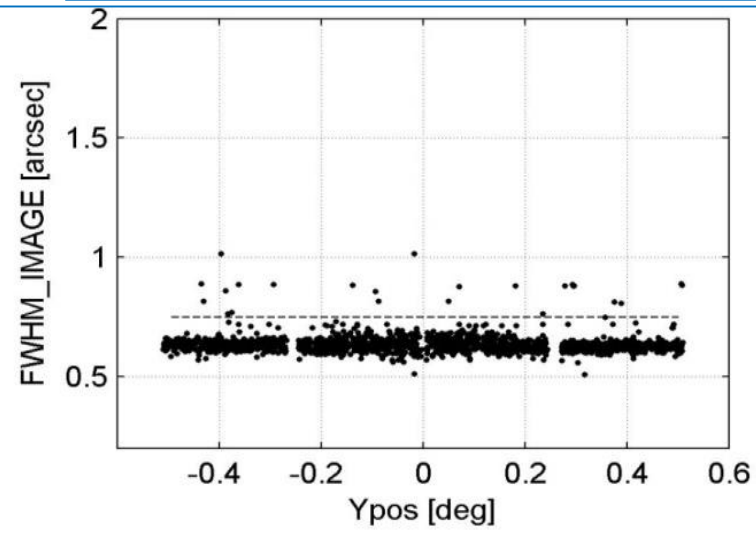
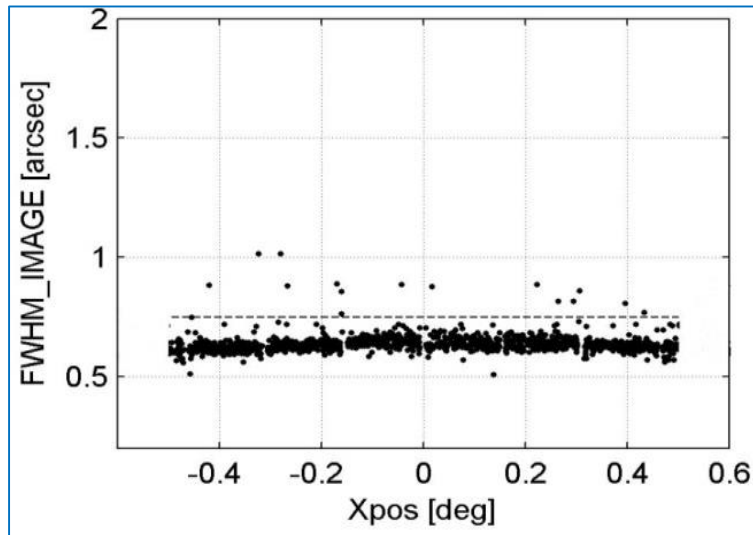
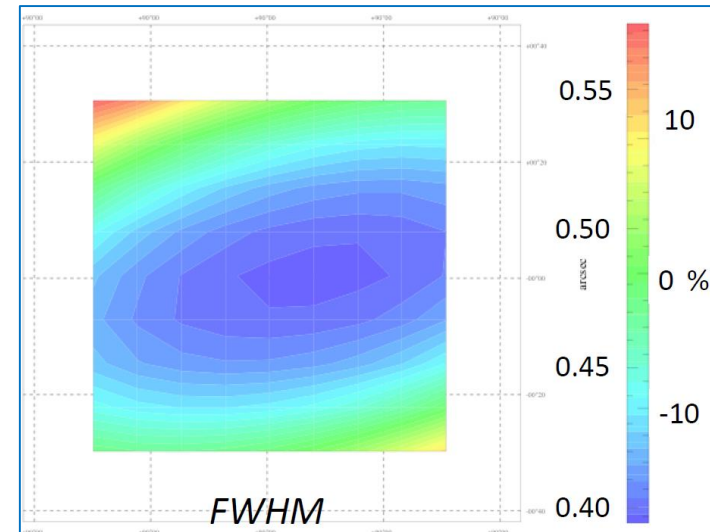
P98

Telescope Statistics P98 (October 2016 - March 2017)



VST - Image Quality

VST regularly delivers images
down to **0.45'' FWHM**
uniformly over the whole
field, small ellipticities



VST - Image Quality

2

Tom Shanks

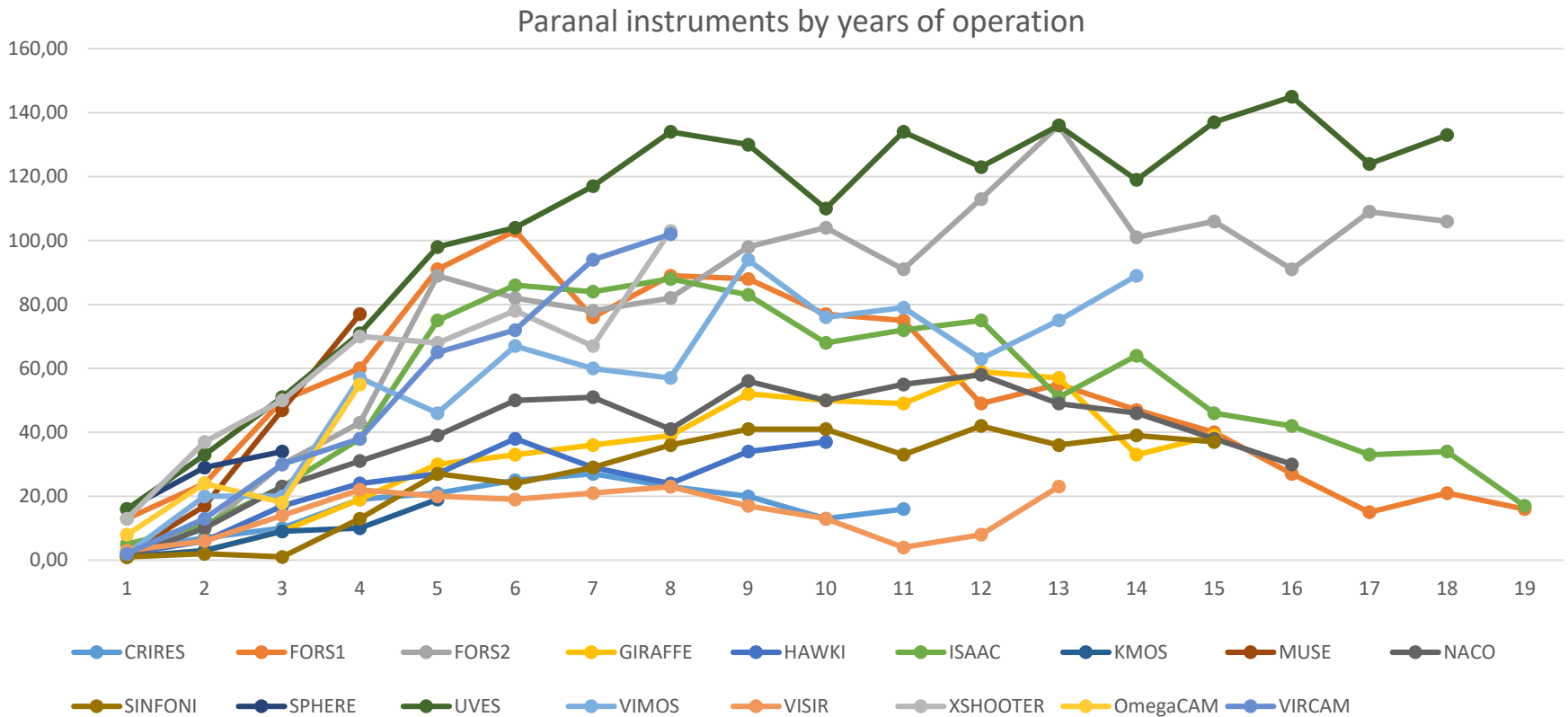
Survey	Type	Epoch	Bands	Lim. Mag.	deg ²	N/S	Seeing (arcsec)
DENIS	NIR	1997-03	iJK	$K \approx 12$	20000	South	3
SDSS	Visible	2000-05	<i>ugriz</i>	$r \approx 22.7$	14500	North	1.2
CFHT RCS2	Visible	2002-09	<i>grz</i>	$r \approx 24.8$	830	N+S	0.9
CFHTLS Wide	Visible	2003-12	<i>ugriz</i>	$r \approx 25$	157	North	0.9
2MASS	NIR	1997-01	<i>JHK</i>	$K \approx 14.3$	All sky	N+S	1.5
UKIDSS	NIR	2005-12	<i>YJHK</i>	$K \approx 18.4$	7500	North	0.9
WISE	Mid-IR	2010-12	$3.4 - 22\mu\text{m}$	$W1 \approx 17$	All Sky	N+S	6
Pan-Starrs 3π	Visible	2010-14	<i>grizy</i>	$r \approx 22.8$	30000	N+S	1.1
SkyMapper	Visible	2009-	<i>uvgriz</i>	$r \approx 22.0$	20000	South	2.5
VST ATLAS	Visible	2011-	<i>ugriz</i>	$r \approx 22.7$	4700	South	0.9
VST KiDS	Visible	2011-	<i>ugri</i>	$r \approx 24.6$	1500	South	0.7
VISTA VHS	NIR	2010-	<i>YJK</i>	$K \approx 18.4$	18000	South	0.7
VIKING	NIR	2010-	<i>zYJHK</i>	$K \approx 19.5$	1500	South	0.9
DES	Visible	2013-	<i>grizy</i>	$r \approx 25.0$	5000	South	0.9
DECaLS	Visible	2015-	<i>grz</i>	$r \approx 23.6$	9000	North	1.2
HSC Wide	Visible	2015-	<i>grizy</i>	$r \approx 26.0$	1400	South	0.7

Table 1 Recent Optical and NIR extragalactic imaging sky surveys with an area of $> 100\text{deg}^2$. Magnitude limits are quoted in r_{AB} and K_{Vega} .

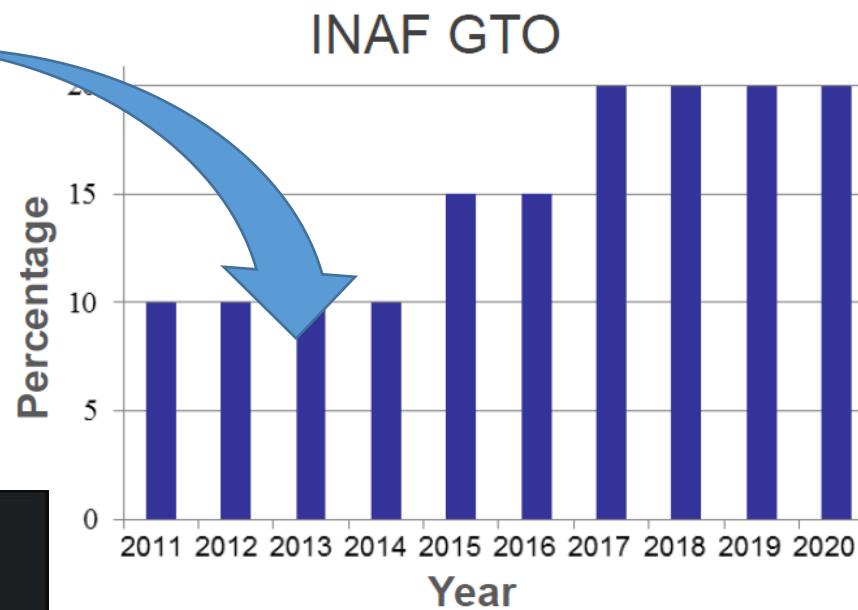
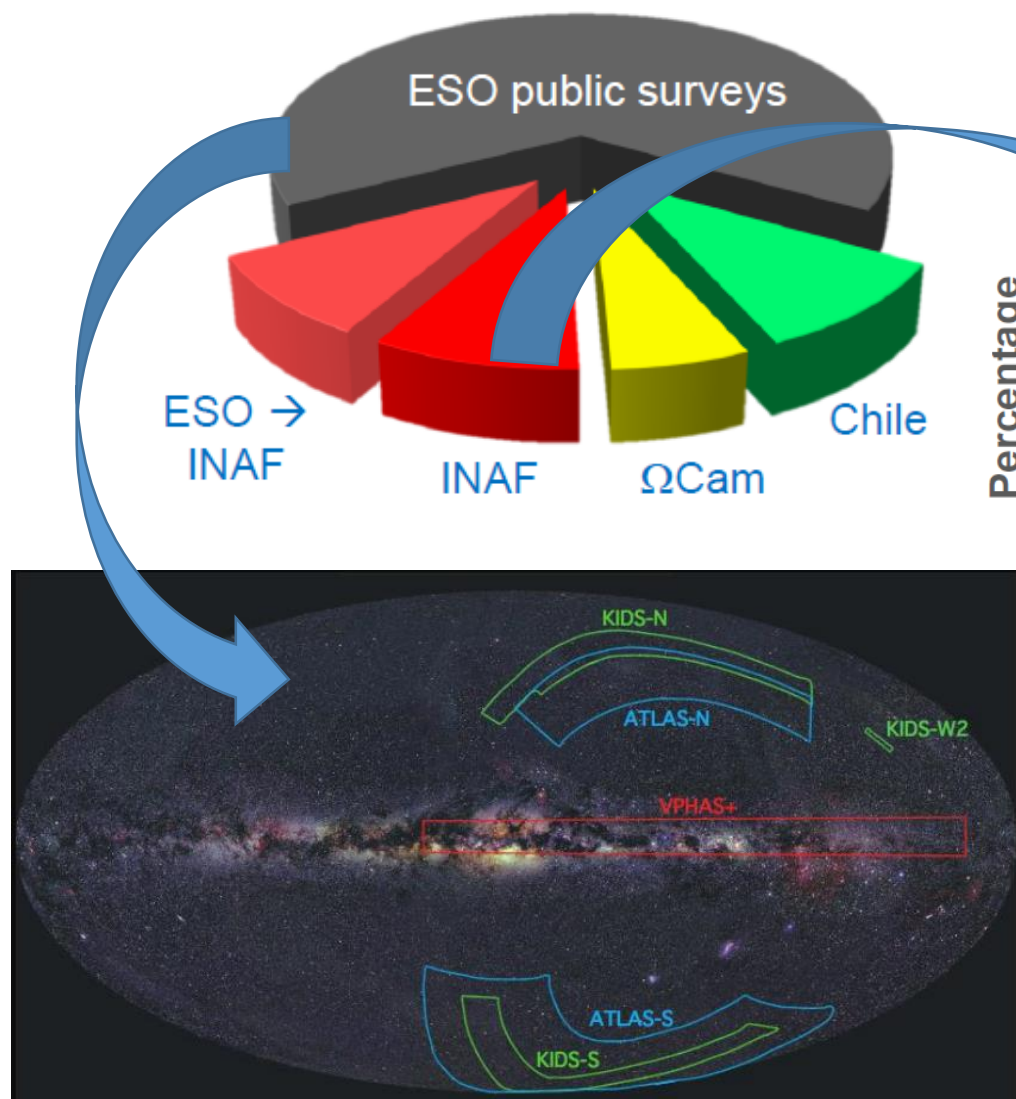
...VST delivers top image quality among all wide field telescopes in the world

VST - Productivity

- Increasing number of papers, good slope
- 55 papers in 2017
- Contributed to the no.1 most cited astronomy papers both 2017 & 2018 (source: ADS)



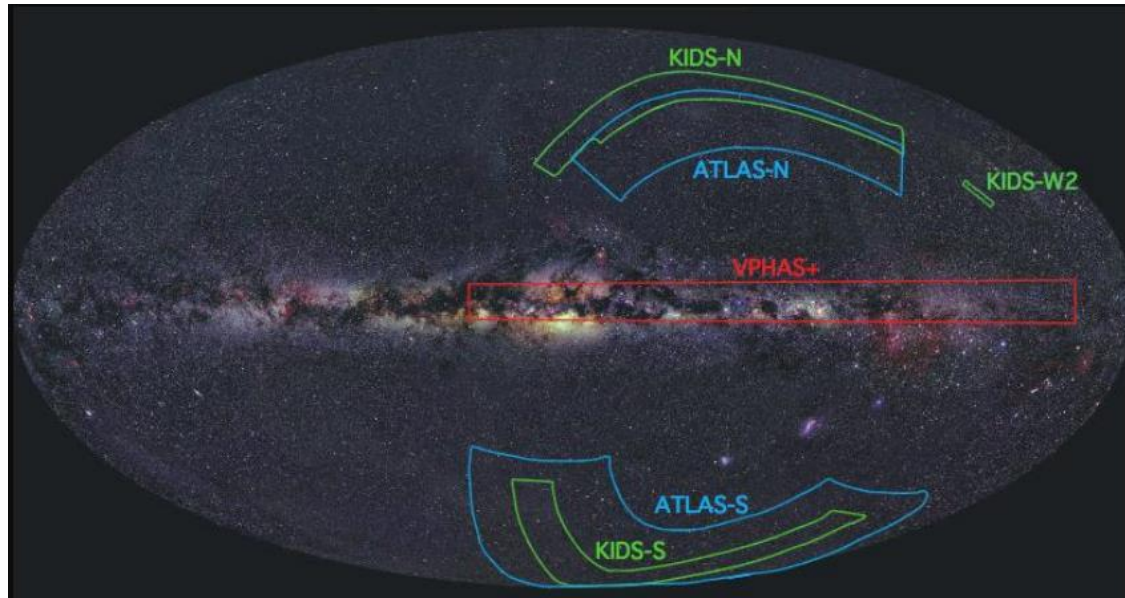
VST - Observing Time 2011-2021



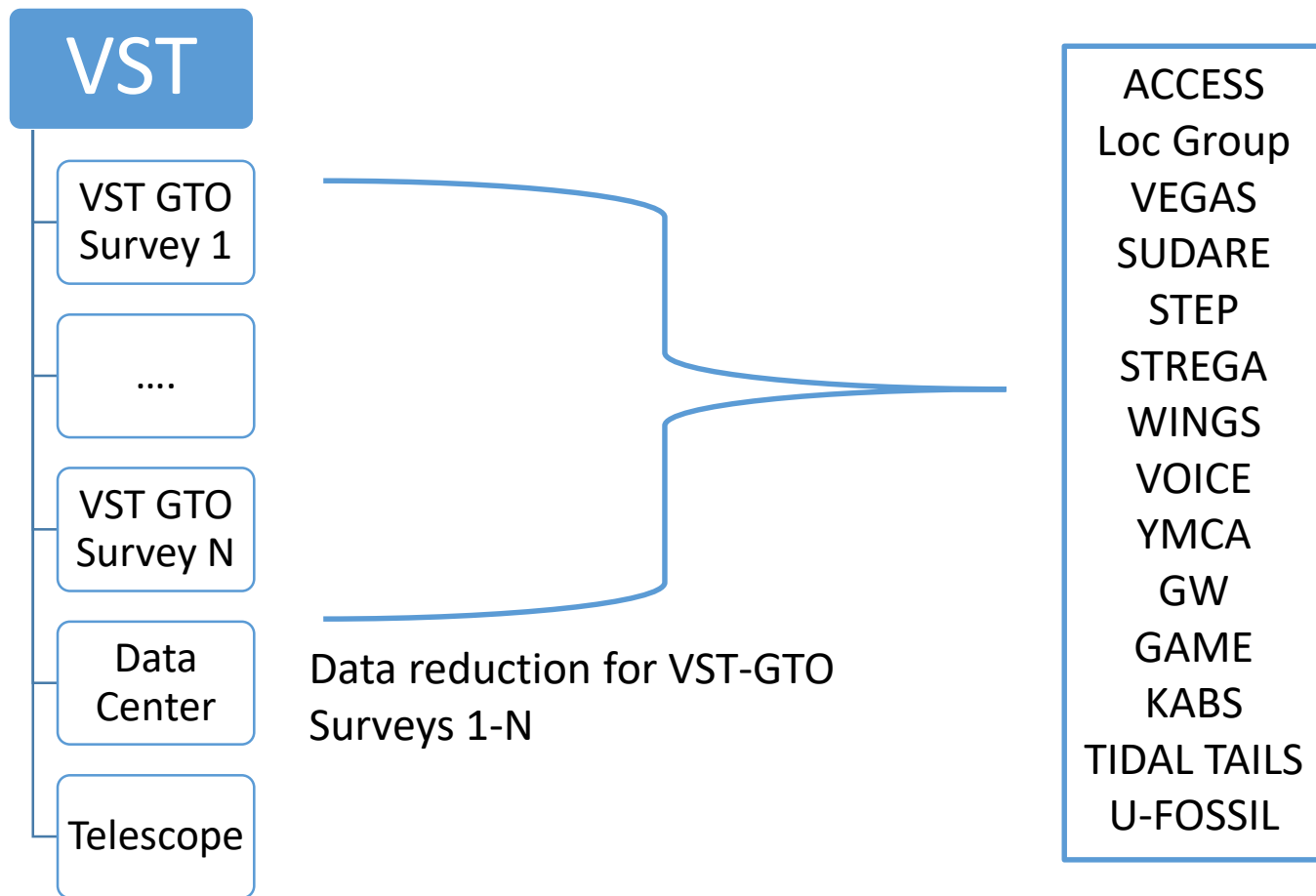
GTO in return for the contributions to the VST

HUGE

VST ESO Public Surveys



- ❑ Kilo-Degree Survey (KiDS) to study dark matter halos and dark energy with weak lensing, galaxy evolution and to search galaxy clusters and high-redshift quasars
- ❑ ATLAS, with the primary science driver of determining the dark energy equation of state
- ❑ VST Photometric H α Survey of the Southern Galactic Plane (VPHAS+), which combines H α and broad-band u, g, r and i imaging to produce a catalogue of around 500 million objects (including greatly enhanced samples of rare evolved massive stars, Be stars, Herbig and T Tau stars, post-AGB stars, compact nebulae, white dwarfs and interacting binaries)



VST Project Resources

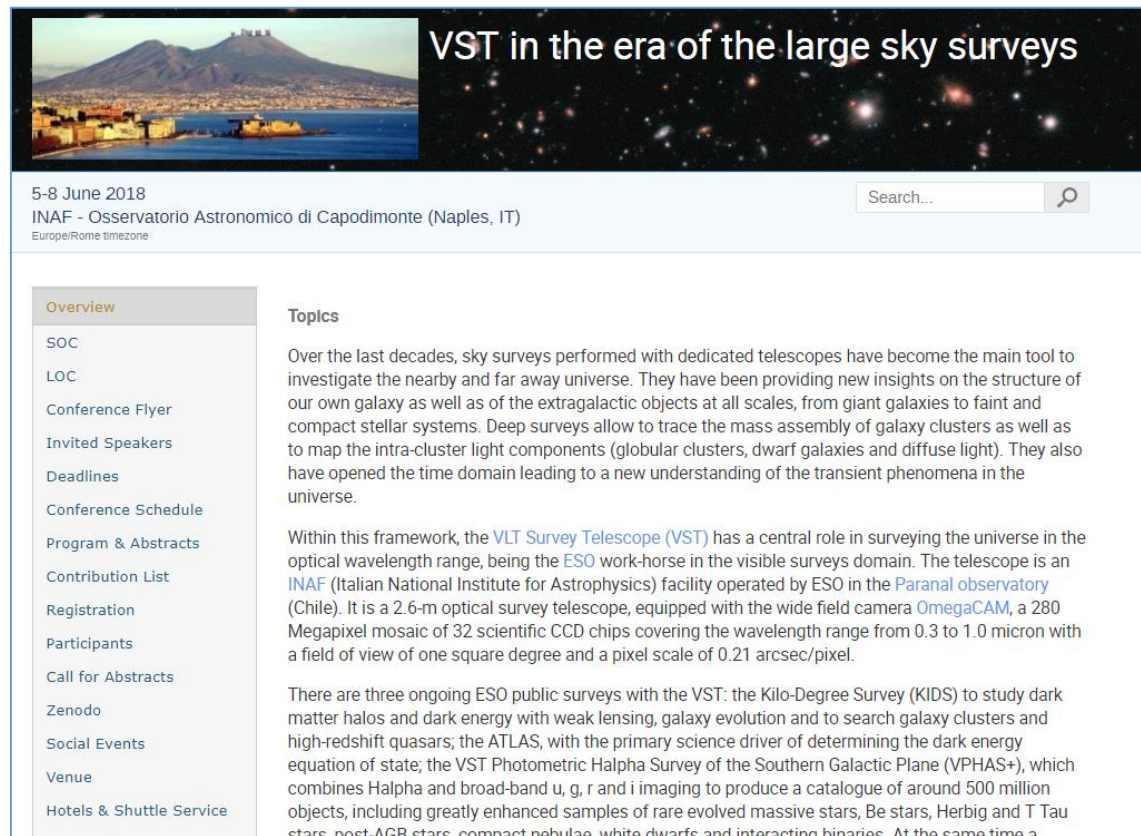
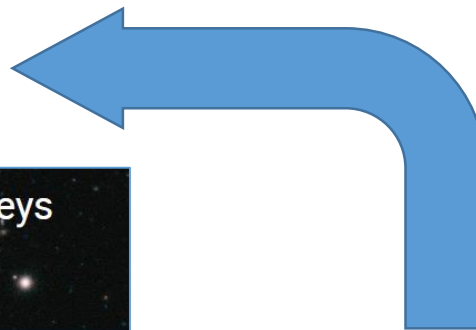
20% of observing time, personnel, machines, *telescope*

VST – Review of Science Programs

Conference “VST in the era of the large sky surveys”

<https://indico.ict.inaf.it/e/VST2018>

Naples, 5-8 June 2018



VST in the era of the large sky surveys

5-8 June 2018
INAF - Osservatorio Astronomico di Capodimonte (Naples, IT)
Europe/Rome timezone

Search...

Overview

- SOC
- LOC
- Conference Flyer
- Invited Speakers
- Deadlines
- Conference Schedule
- Program & Abstracts
- Contribution List
- Registration
- Participants
- Call for Abstracts
- Zenodo
- Social Events
- Venue
- Hotels & Shuttle Service

Topics

Over the last decades, sky surveys performed with dedicated telescopes have become the main tool to investigate the nearby and far away universe. They have been providing new insights on the structure of our own galaxy as well as of the extragalactic objects at all scales, from giant galaxies to faint and compact stellar systems. Deep surveys allow to trace the mass assembly of galaxy clusters as well as to map the intra-cluster light components (globular clusters, dwarf galaxies and diffuse light). They also have opened the time domain leading to a new understanding of the transient phenomena in the universe.

Within this framework, the **VLT Survey Telescope (VST)** has a central role in surveying the universe in the optical wavelength range, being the **ESO** work-horse in the visible surveys domain. The telescope is an **INAF** (Italian National Institute for Astrophysics) facility operated by ESO in the **Paranal observatory** (Chile). It is a 2.6-m optical survey telescope, equipped with the wide field camera **OmegaCAM**, a 280 Megapixel mosaic of 32 scientific CCD chips covering the wavelength range from 0.3 to 1.0 micron with a field of view of one square degree and a pixel scale of 0.21 arcsec/pixel.

There are three ongoing ESO public surveys with the VST: the Kilo-Degree Survey (KIDS) to study dark matter halos and dark energy with weak lensing, galaxy evolution and to search galaxy clusters and high-redshift quasars; the ATLAS, with the primary science driver of determining the dark energy equation of state; the VST Photometric Halpha Survey of the Southern Galactic Plane (VPHAS+), which combines Halpha and broad-band u, g, r and i imaging to produce a catalogue of around 500 million objects, including greatly enhanced samples of rare evolved massive stars, Be stars, Herbig and T Tau stars, post-AGB stars, compact nebulae, white dwarfs and interacting binaries. At the same time a

- Ongoing science programs
- Proposals for the future

VST - What's next in 2020s



A New Scenario

- Current programmes (public, GTO) will be over
- Current MoU will be over (2021)
- New imaging survey facilities from ground & space (e.g. LSST, EUCLID, etc.)
- New wide-field spectroscopic facilities (e.g. 4MOST, WEAVE)
- New large-scale facilities (e.g. ELT, CTA, SKA)

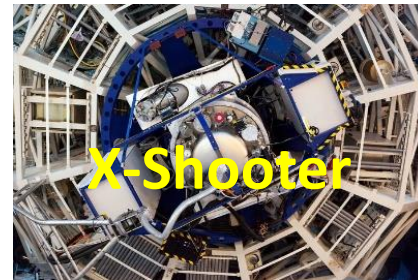
Start now to plan the future

- Science drive is essential*
- Ideas take time to become projects
- Scientific ideas in the 2020 scenario
- Instrumentation upgrades
- Scientific Synergies

Let's build the
future!

SOXS in a nutshell

- ❑ 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 800nm to cross-calibrate spectra
- ❑ $R \sim 4,500$ (3,500-6,000)
- ❑ S/N ~ 10 spectrum - 1 hr exposure for $R \sim 20$
- ❑ Acquisition camera to perform photometry ugrizY (3.5'x3.5')



SOXS Consortium



Institutes from 6 Countries

- ❑ Common Path, NIR Spectrograph, Control Software & Electronics, Vacuum and Cryogenics, Detectors control (INAF)
- ❑ UV/VIS Spectrograph (Weizmann)
- ❑ Acquisition Camera (Un. Andres Bello- MAS)
- ❑ Calibration Unit (Turku University)
- ❑ Data Reduction (Queen's Un. Belfast)
- ❑ Tel Aviv University
- ❑ Dark Cosmology Center



SOXS - Project History



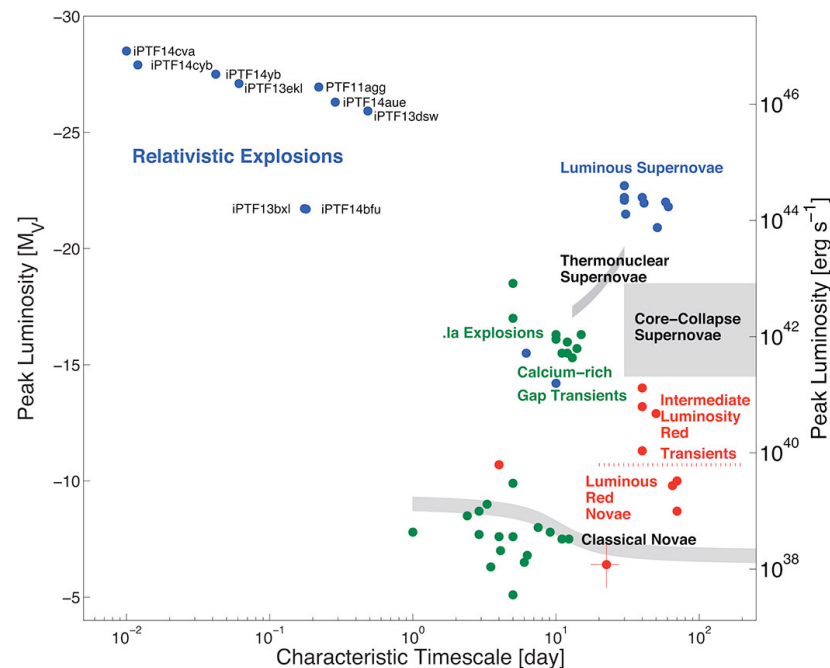
- ESO Call for new instruments at NTT (2014)
- Proposal submission (02/2015)
- Selected by ESO (2015) out of 19
- Kick-off (2016)
- PDR ok (07/2017)
- Currently in Final Design Phase (till 2018)
- MoU to be signed for a 5-year agreement

ESO Strategy for La Silla

SOXS @NTT: Transients, NIRPS @3p6: Exoplanets

SOXS - Follow up of transients

- Classification of transients
- Supernovae (all flavours)
- Gravitational Wave events
- Neutrino events
- Nuclear transients and Tidal Disruption Events
- Gamma-ray Bursts and Fast Radio Bursts
- X-ray binaries and novae, magnetars
- Asteroids and Comets
- Young Stellar Objects & stars
- Blazars and AGN
- The Unknown



SOXS - synergies

Spectroscopic machine for the transient sky.

Even now with PESSTO in place >70% of newly discovered transients remain without spectroscopic follow-up.

In the near future years there will be many imaging survey wide-field telescopes (iPTF, DES, Pan-STARRS, LSST) as well as high-energy transients (Swift, INTEGRAL, MAXI), GAIA-alerts GW-alerts, TeV alerts, etc. but very limited spectroscopic follow-up



SOXS@NTT will have ~900 nights (≥ 5 yr)
~3,000-4,000 spectra/yr



SOXS - Project Schedule



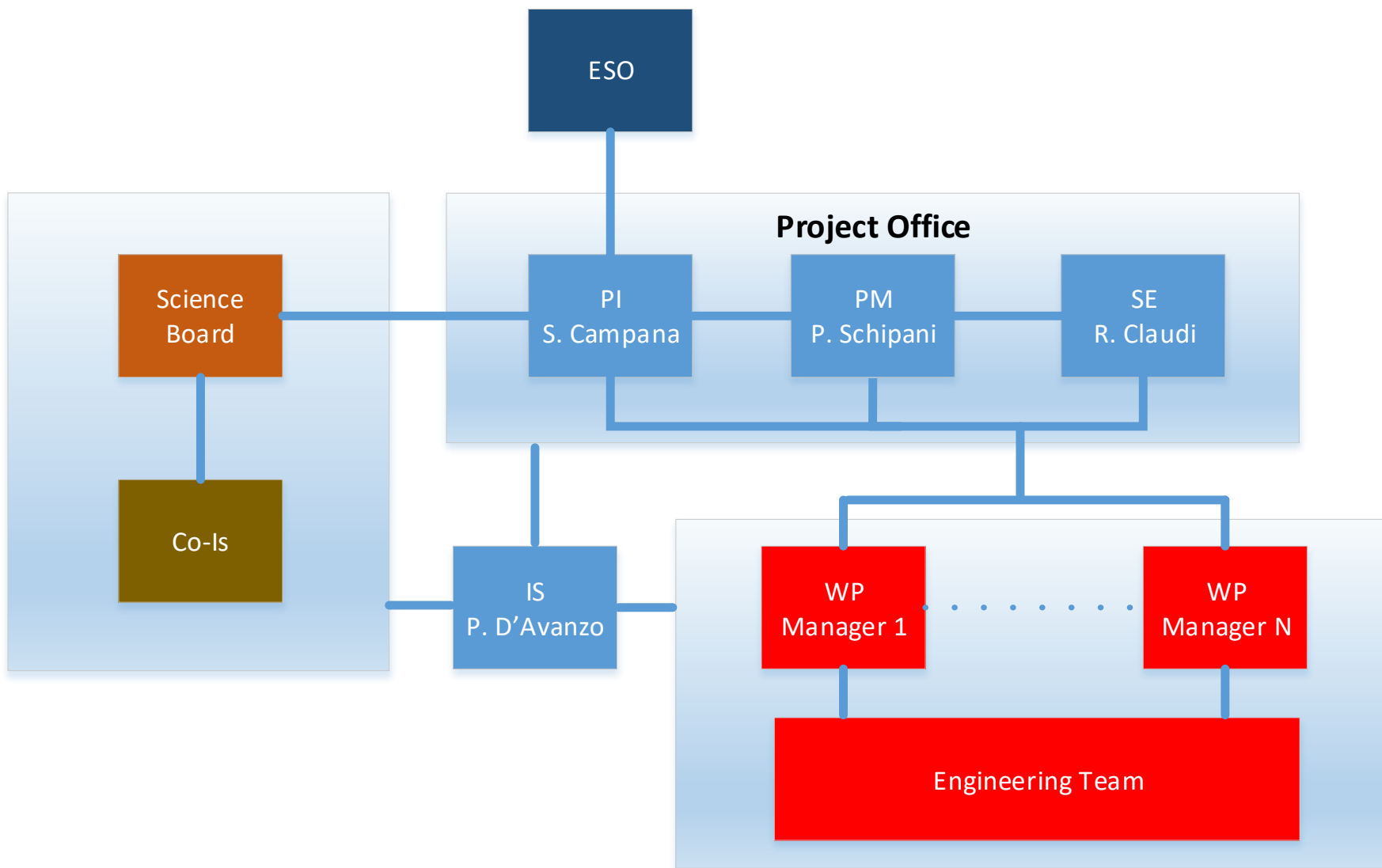
Project Phase	Start	End	Duration
Preliminary Design	08/2016	07/2017	12 months
*Final Design	08/2017	07/2018	12 months
MAIT	02/2018	06/2020	29 months
Inst. & Commissioning (Chile)	09/2020	03/2021	7 months
Operations	2021		TBD

*Split in 3 intermediate steps

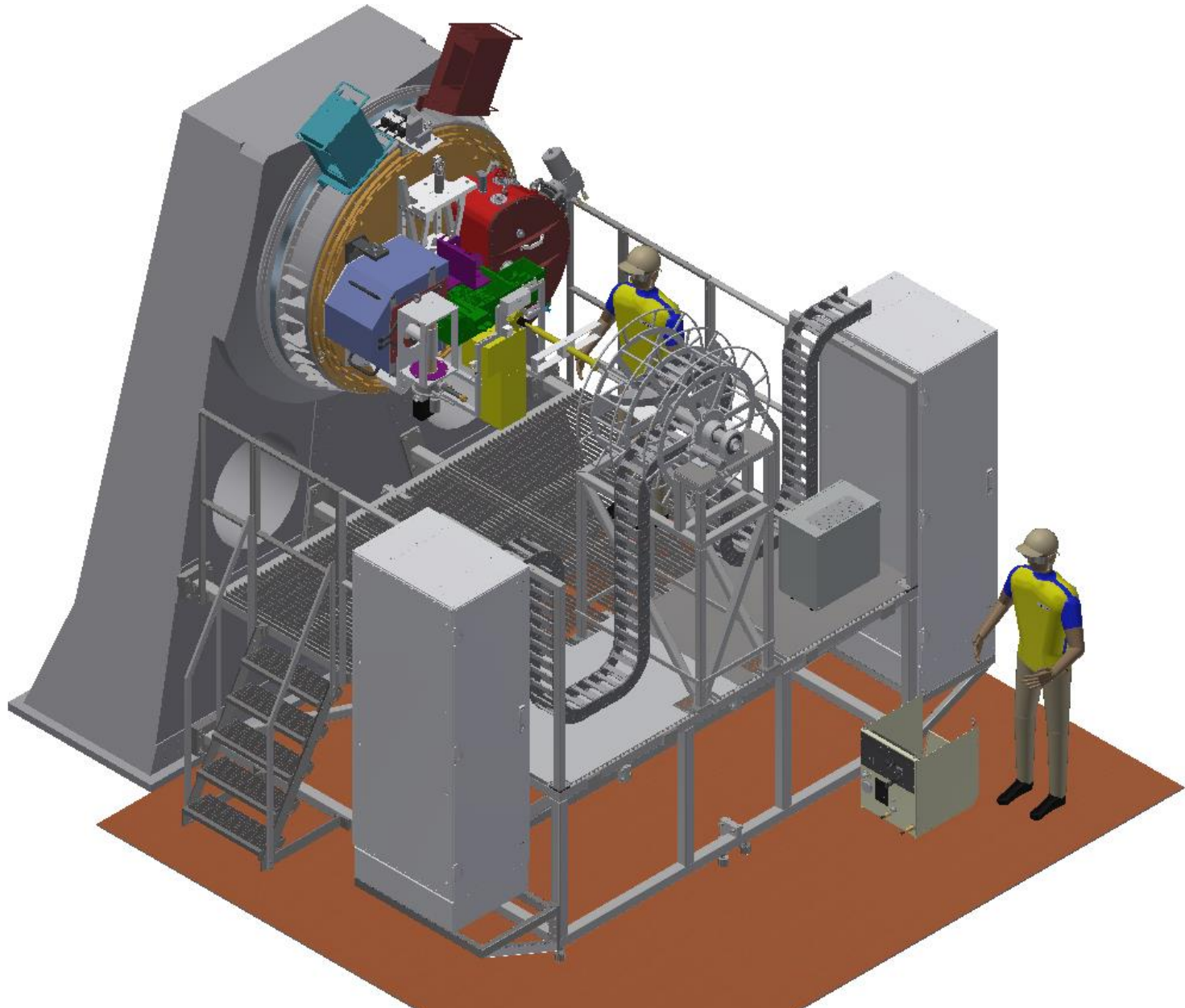
In SOXS case, consortium duties go after the instrument realization

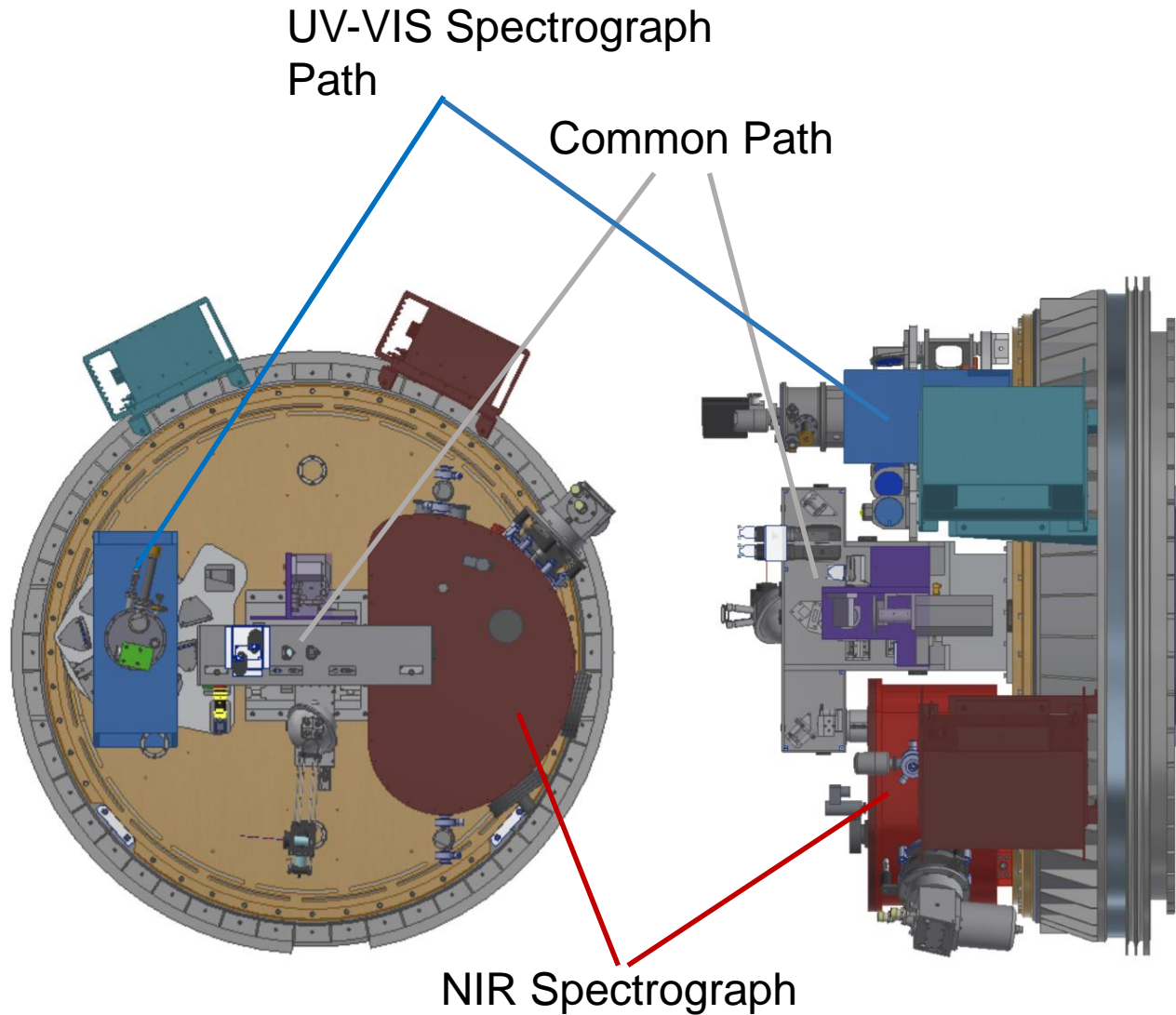
- ❑ Flexible scheduling, 365 days/yr, by SOXS consortium
 - Dynamical merging of GTO targets and ESO targets
- ❑ Observations carried out by ESO operator
- ❑ SOXS people on call
 - in case of real need, and/or of new, interesting transients
- ❑ GTO proposals will go to OPC, as usual
 - Defining triggers clearly will be crucial
- ❑ Consortium data: 12-month proprietary period

SOXS - Organization



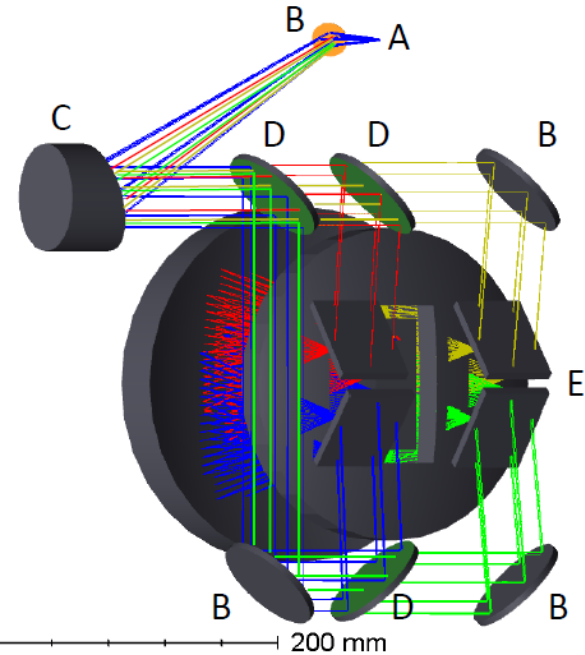
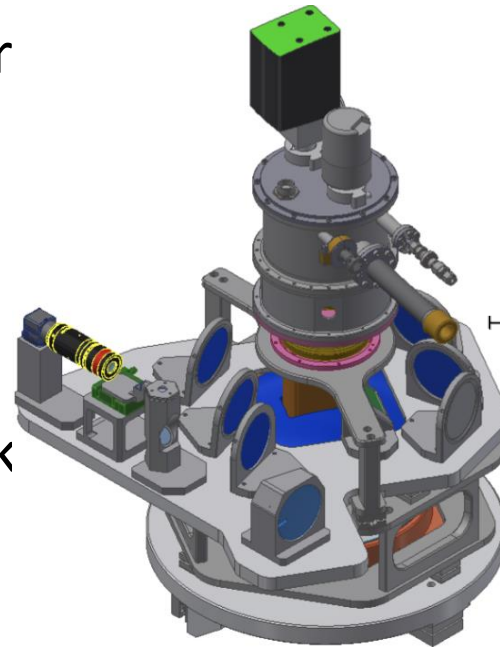
SOXS @ NTT





SOXS UV-VIS: Multi-Imager Spectrograph

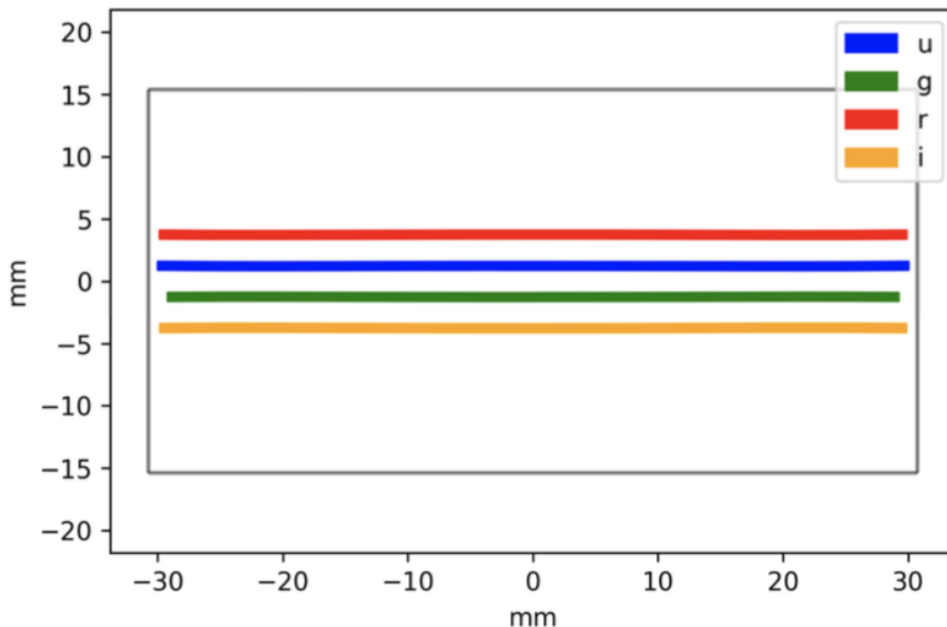
- ❑ Collimated beam is divided to 4 bands using 3 dichroics.
- ❑ Each band has its own optimized optics (disperser camera).
- ❑ 1st order dispersion, $\mathcal{R} \sim 4500$ at α_{Lit} .
- ❑ 4 bands quasi-orders are imaged onto a single 4kx2k CCD.



Quasi-Order	Wavelength Range [nm]
<i>u</i>	350 - 438
<i>g</i>	438 - 552
<i>r</i>	552 - 700
<i>i</i>	700 - 850

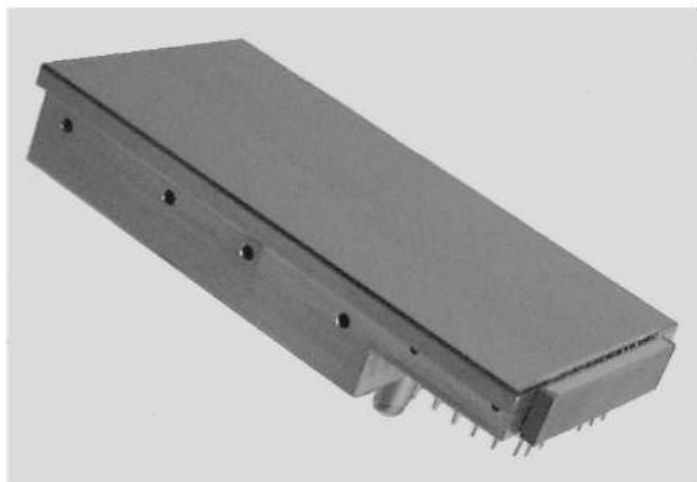
SOXS UV-VIS Spectral Format

4 quasi orders images along the long axis of the detector

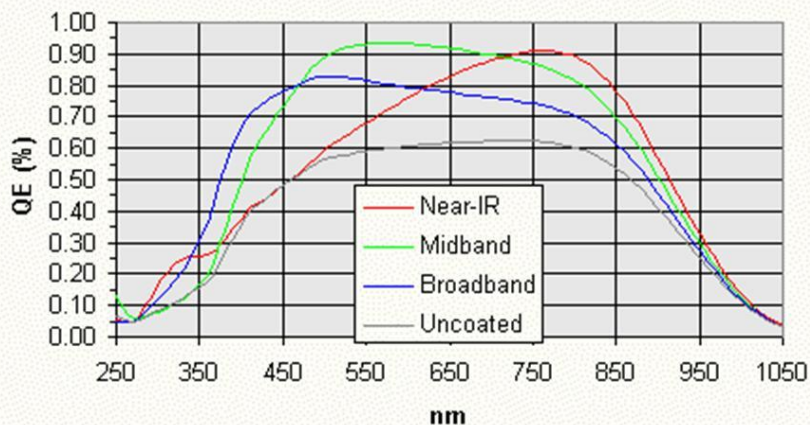


- Efficient use of detector
- Large separation between quasi orders: no overlap/leak between orders.
- No inherent curvature – linear trace, easy data reduction.

SOXS - VIS Detector E2V CCD44-82



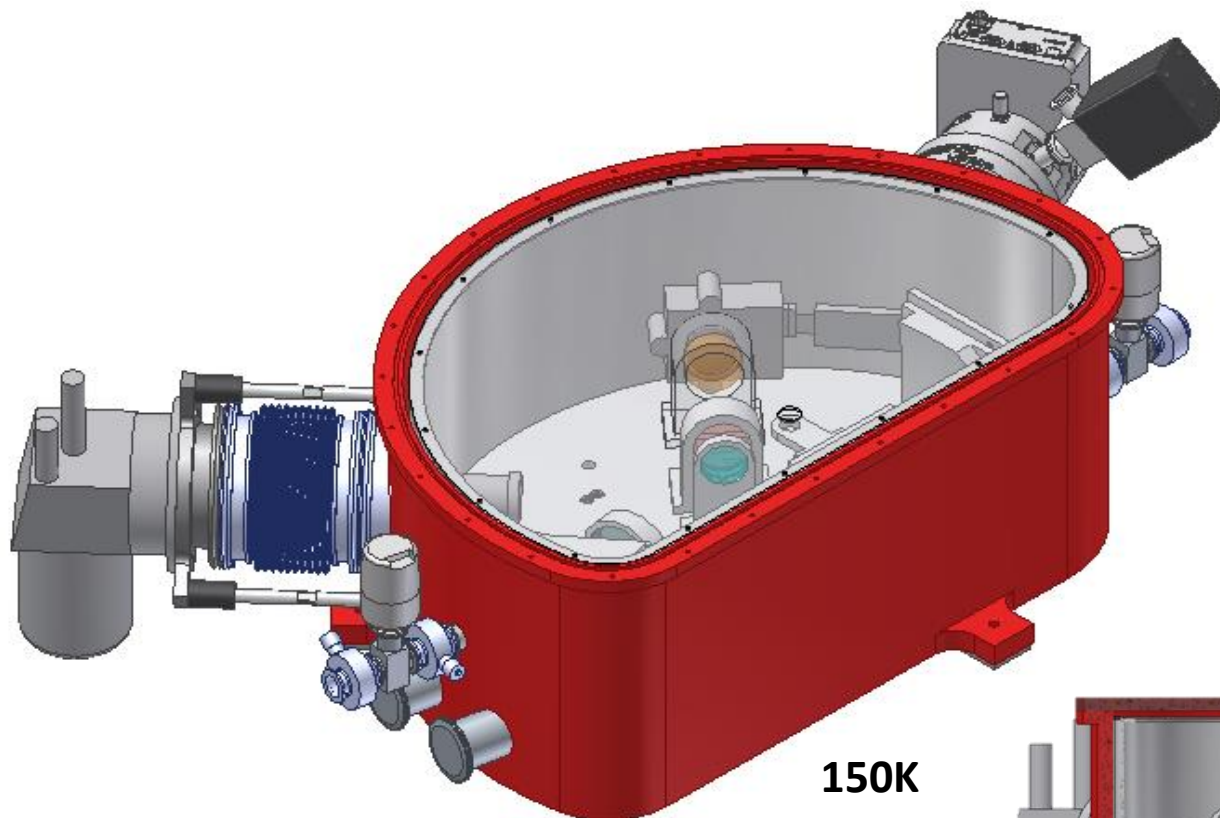
Typical spectral response
deep depletion, basic -100C



Detector	CCD44-82
Chip type	Thinned back illuminated
Pixel size	15 μm
Area (pixels)	2048 x 4096
Area (mm)	30.7 x 61.4
QE at 500 nm	90%
Coating	yes
Flatness	Better than 20 μm peak to valley
Peak signal	200 K e^-/pixel
CTE	99.9995%

ESO NGC Controller

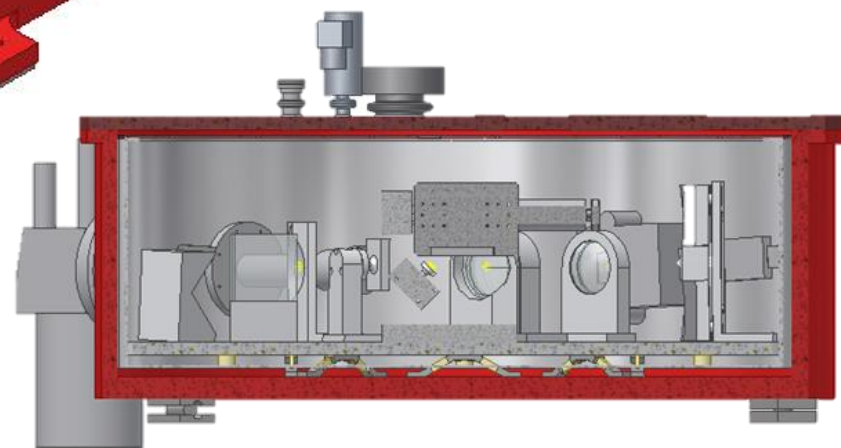
SOXS - NIR spectrograph



Hawaii H2RG 2K x 2K
Substrate removed
40K

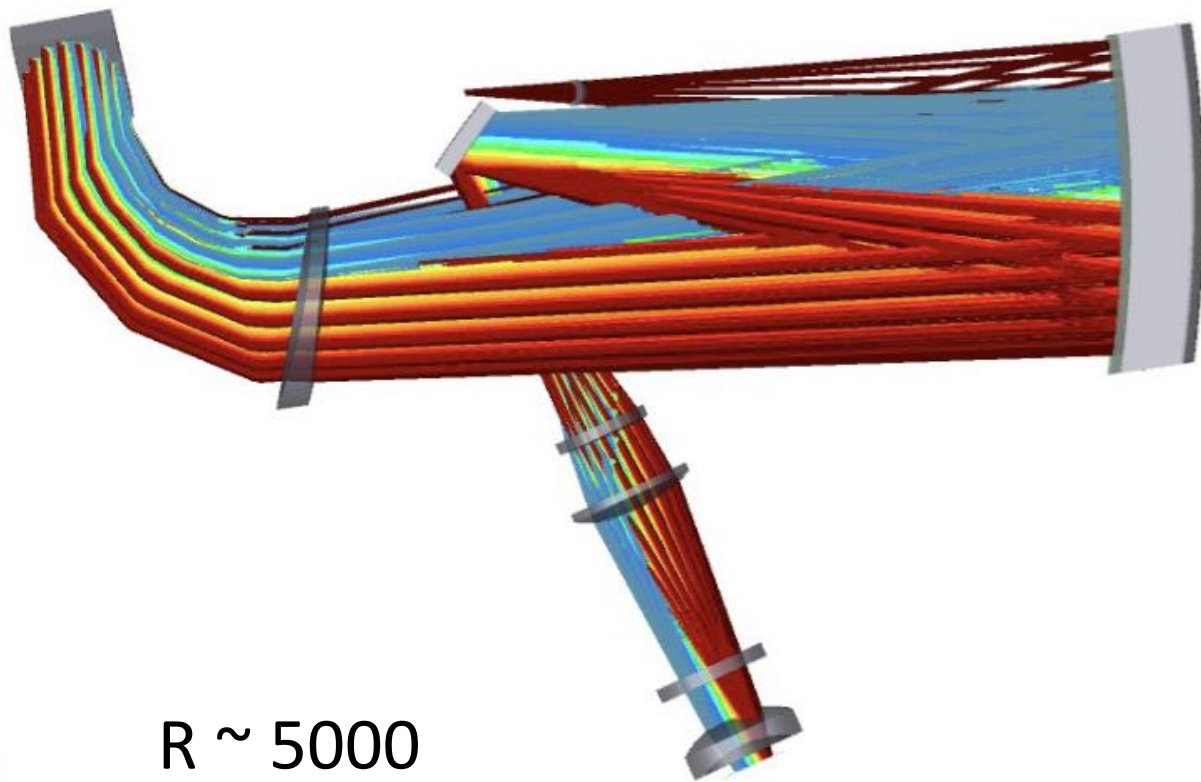


ESO NGC Controller



SOXS - NIR 4C Design

Spectrograph with
Collimator
Compensation of
Camera
Chromatism
(Delabre)

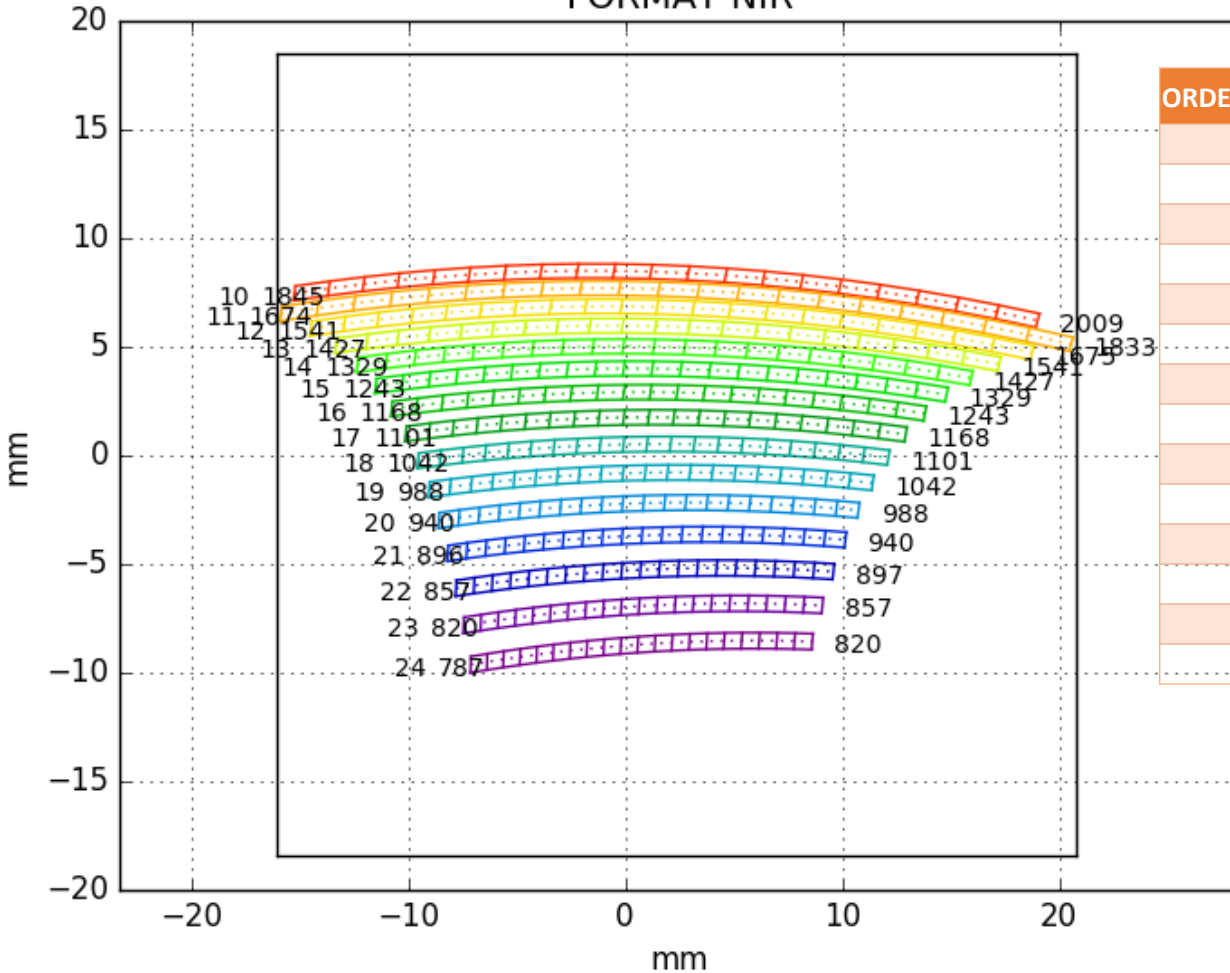


Echelle
Cross-Dispersed

$R \sim 5000$
0.25 arcsec/px
F/3.7 camera

SOXS - NIR Spectral Format

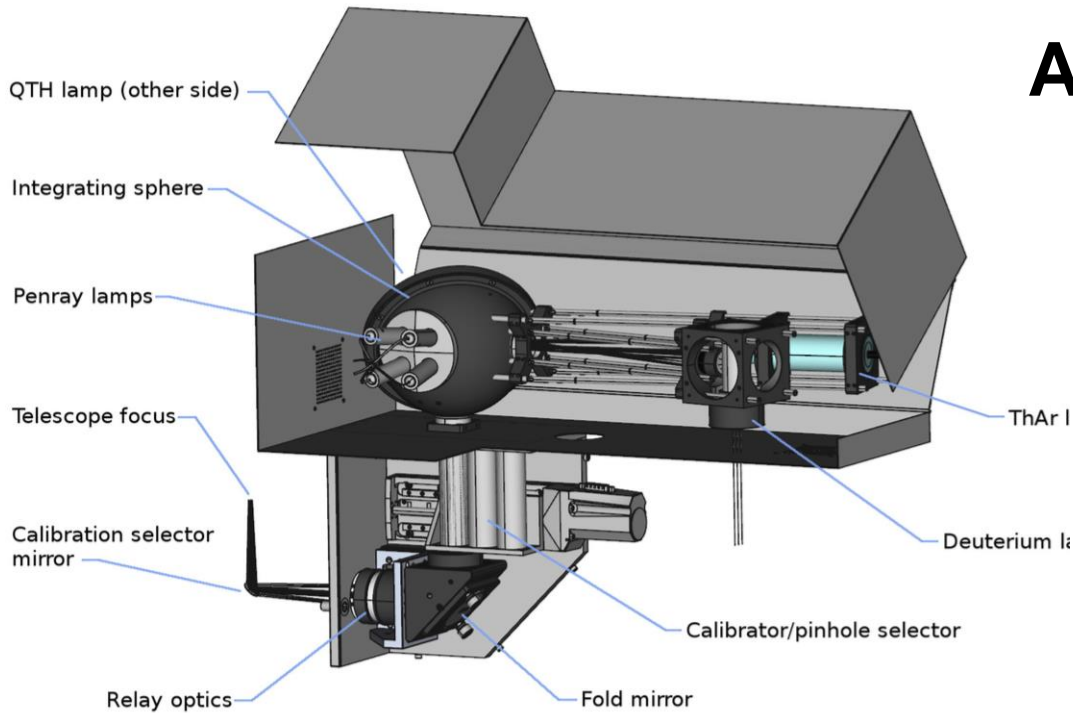
FORMAT NIR



ORDER	FSR	MIN WL	BLAZE WL	MAX WL
11	0.159	1.674	1.754	1.834
12	0.134	1.541	1.608	1.675
13	0.114	1.427	1.484	1.541
14	0.098	1.329	1.378	1.428
15	0.086	1.244	1.286	1.329
16	0.075	1.168	1.206	1.244
17	0.067	1.102	1.135	1.168
18	0.06	1.042	1.072	1.102
19	0.053	0.989	1.016	1.042
20	0.048	0.941	0.965	0.989
21	0.044	0.897	0.919	0.941
22	0.04	0.857	0.877	0.897
23	0.036	0.821	0.839	0.857
24	0.034	0.787	0.804	0.821

- 15 Orders
- 0.787-2.009 μm

SOXS - Subsystems

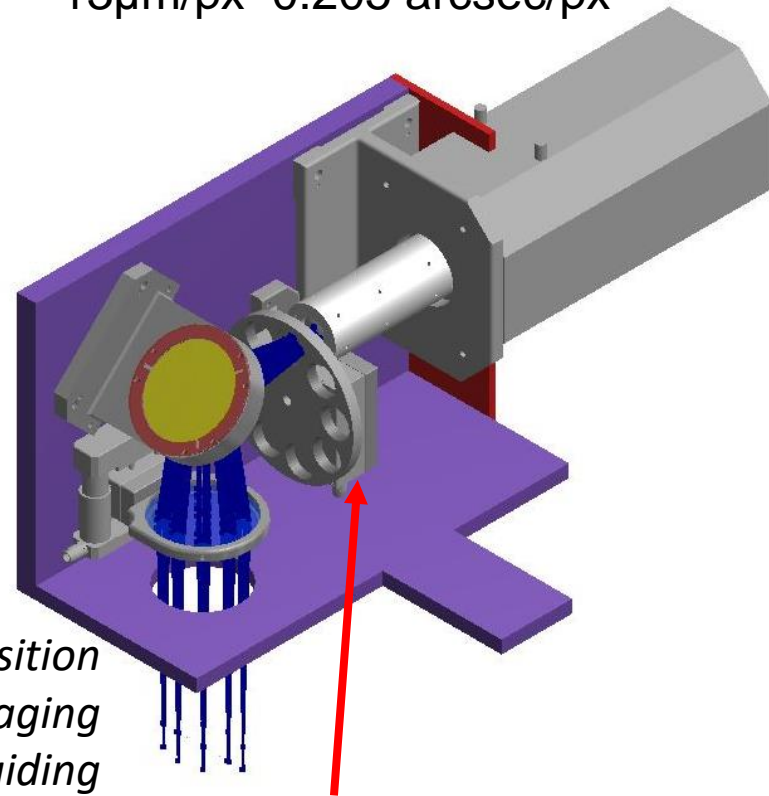


CALIBRATION UNIT

Flux Calibration
Wavelength Calibration

ACQUISITION CAMERA

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



ugrizy LSST + V Johnson

