PCS: E-ELT Planet finder

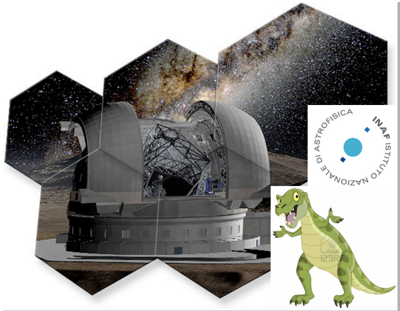
Raffaele Gratton

INAF-Osservatorio Astronomico di Padova

T-REX Meeting, Bologna,
14/01/2013

PCS

- Results of the EPICS phase A study
- PCS within the E-ELT instrumentation plan
- The PCS roadmap
- Italian activity for PCS



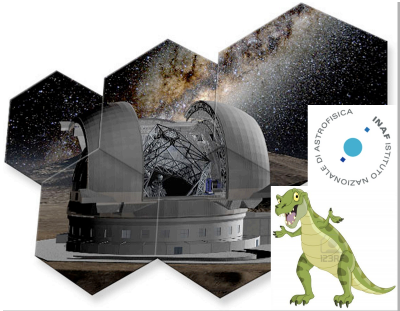
EPICS – high-contrast imaging of Exoplanets with the E-ELT

Markus Kasper

ESO

Results of Phase A study Oct 2007-Mar 2010

- Funded in parts by ESO and by the European Framework Programme 7 (FP7)
- About **20 FTEs** were invested by the consortium.



Consortium

ESO: Markus Kasper, Emmanuel Aller-Carpentier, Norbert Hubin, Florian Kerber, Natalia Yaitskova, Patrice Martinez, Enrico Fedrigo

LAOG: Jean-Luc Beuzit, Christophe Verinaud, Visa Korkiaskoski, Patrick Rabou, Jacopo Antichi, Olivier Preis

Padova Observatory: Raffaele G. Gratton, Mariangela Bonavita, Dino Mesa

ASTRON: Lars Venema, Ronald Roelfsema, Rieks Jager, Hiddo Hanenburg

University of Oxford: Niranjan Thatte, Mattias Tecza, Graeme Salter

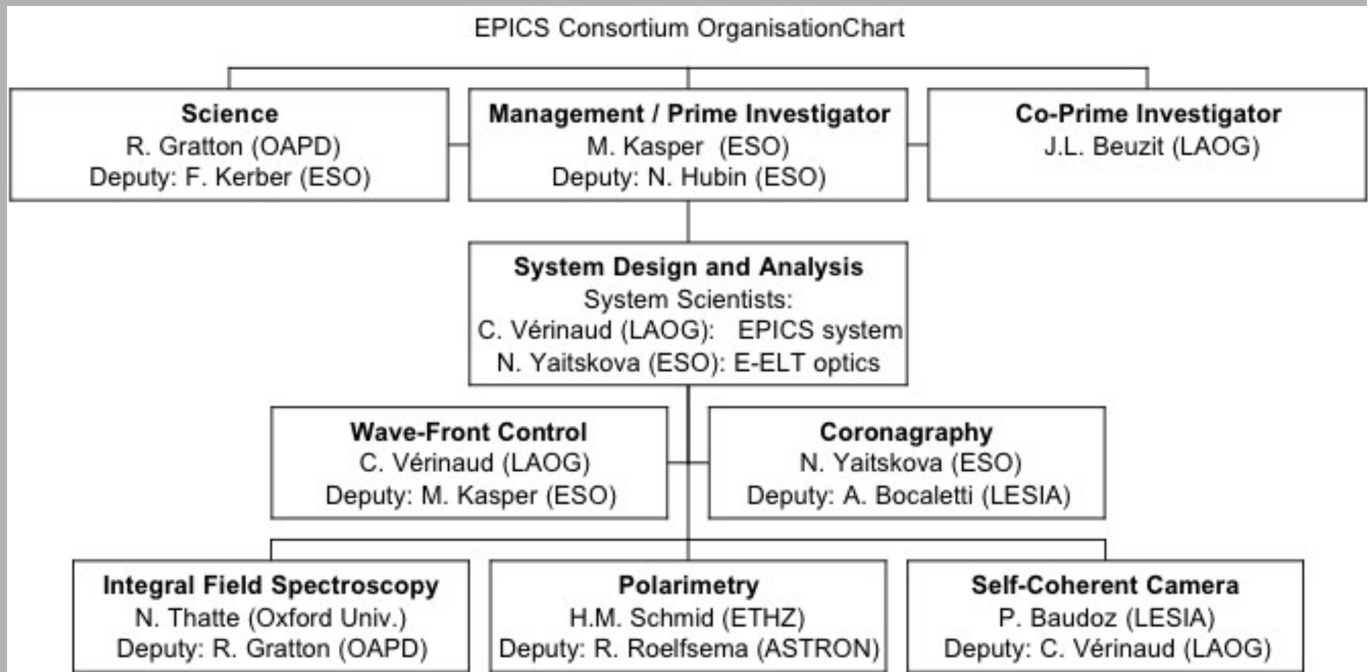
LESIA: Pierre Baudoz, Anthony Boccaletti

NOVA: Christoph Keller

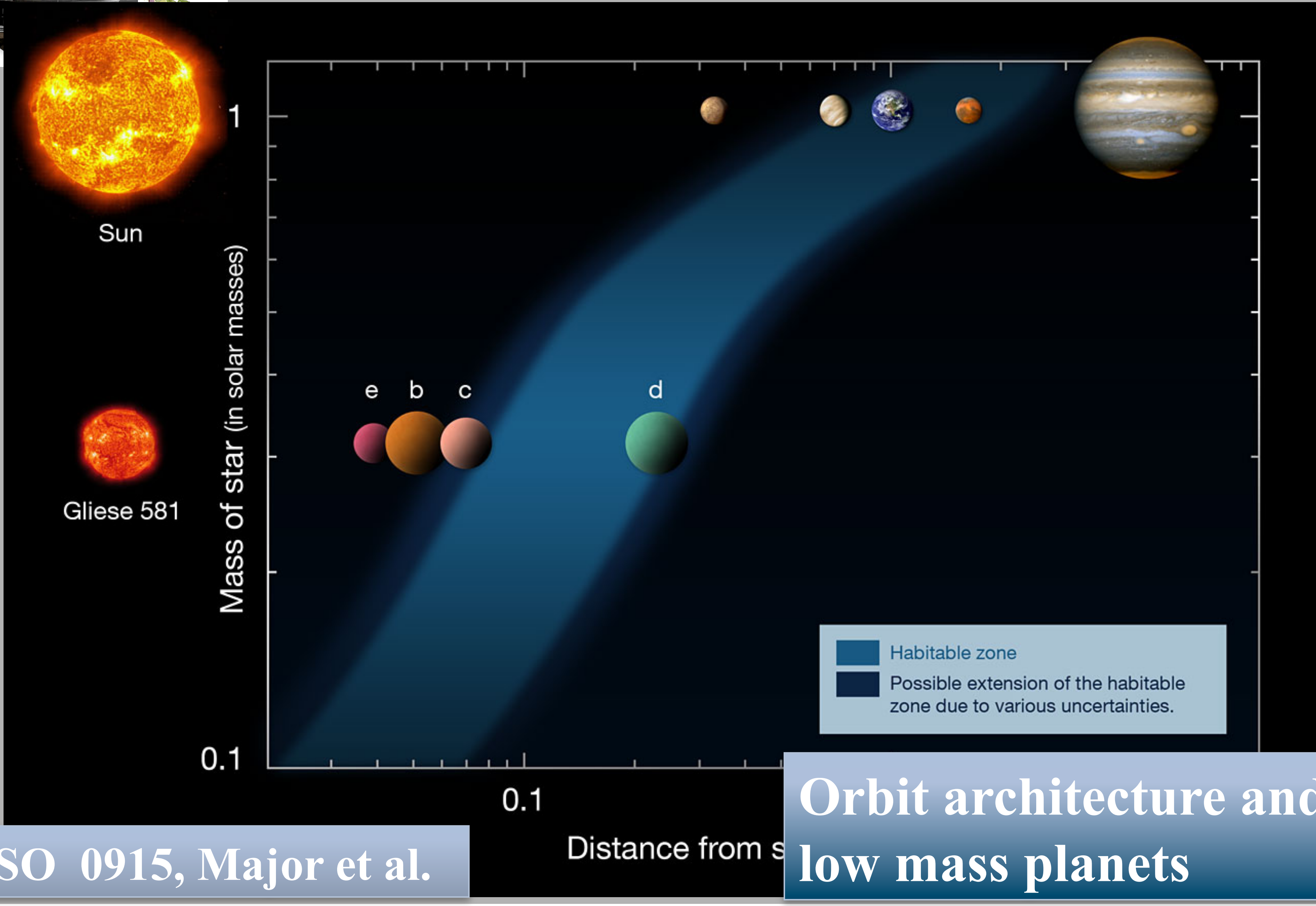
ETH Zürich: H.M.Schmid

FIZEAU: Lyu Abe

LAM: Kjetil Dohlen



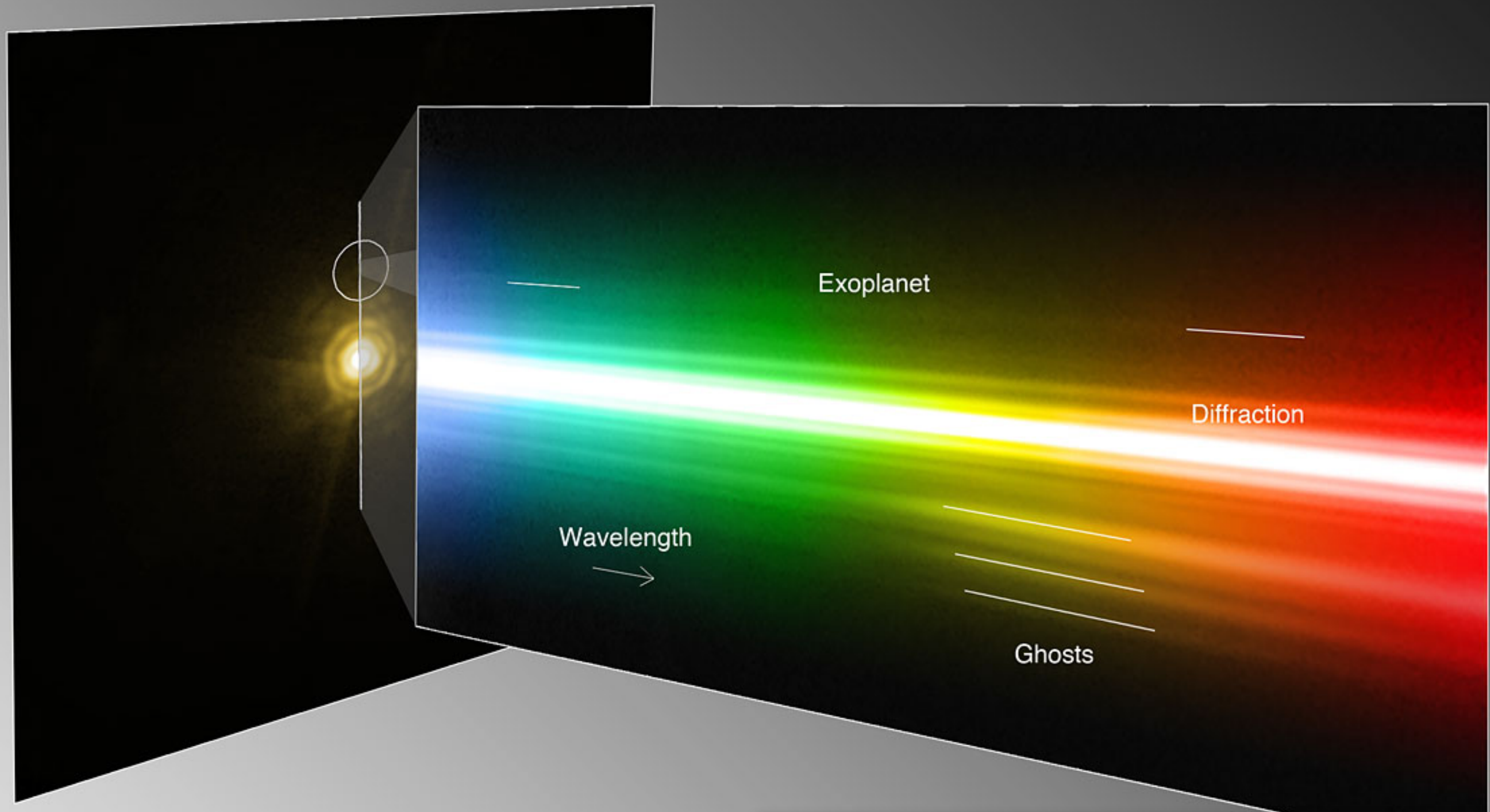
Science Goals



ESO 0915, Major et al.

Orbit architecture and low mass planets

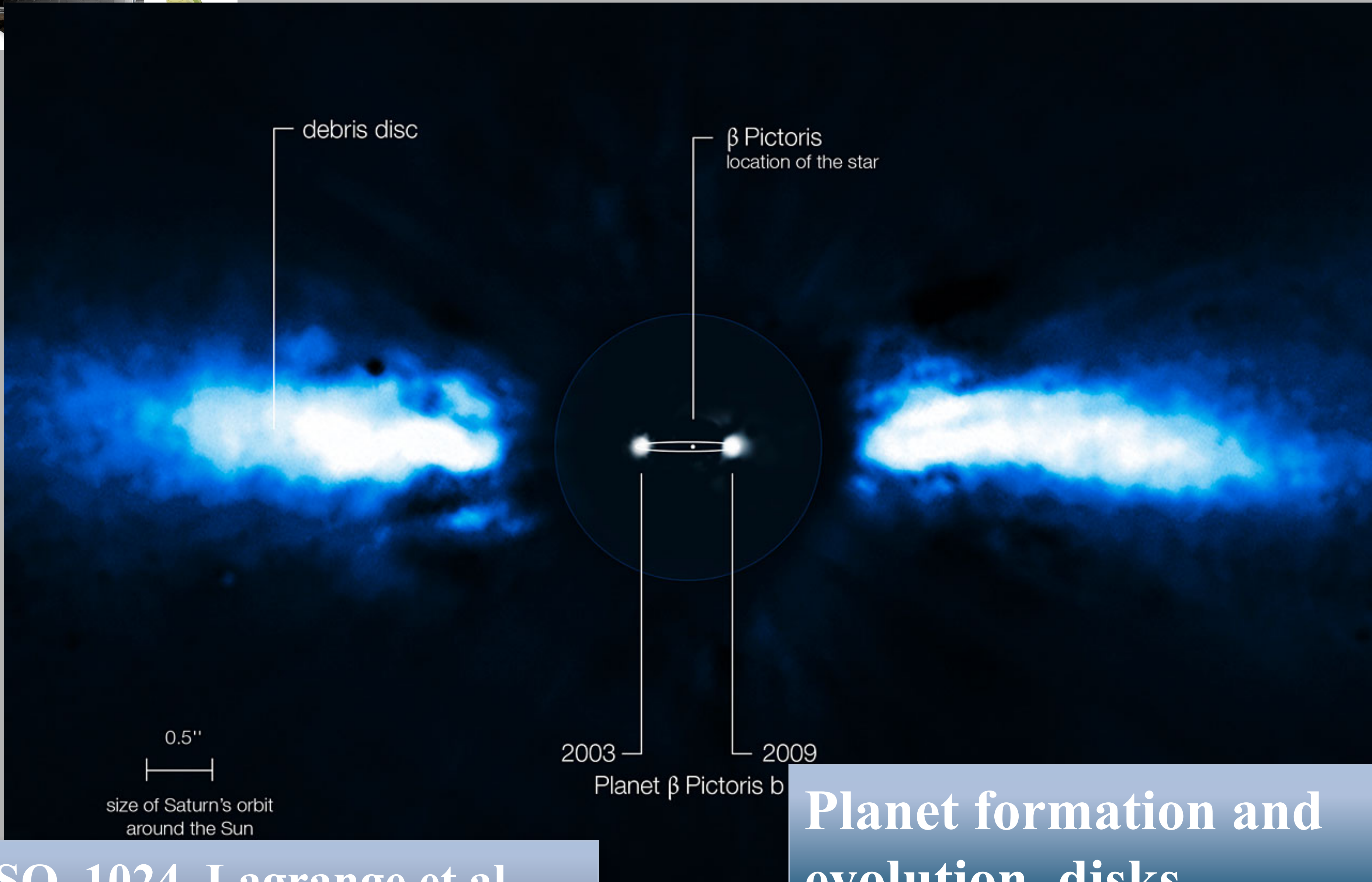
Science Goals



ESO 1002, Janson et al.

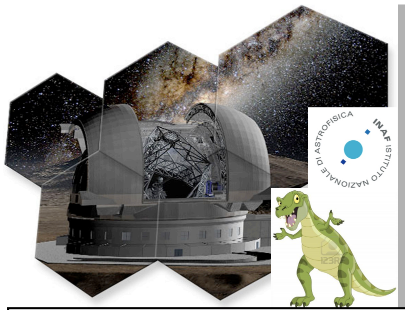
Characterization of Exoplanet atmospheres

Science Goals



ESO 1024, Lagrange et al.

Planet formation and evolution, disks



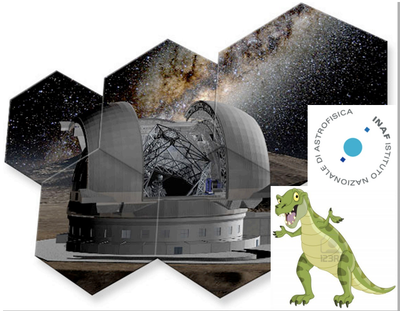
Contrast requirements

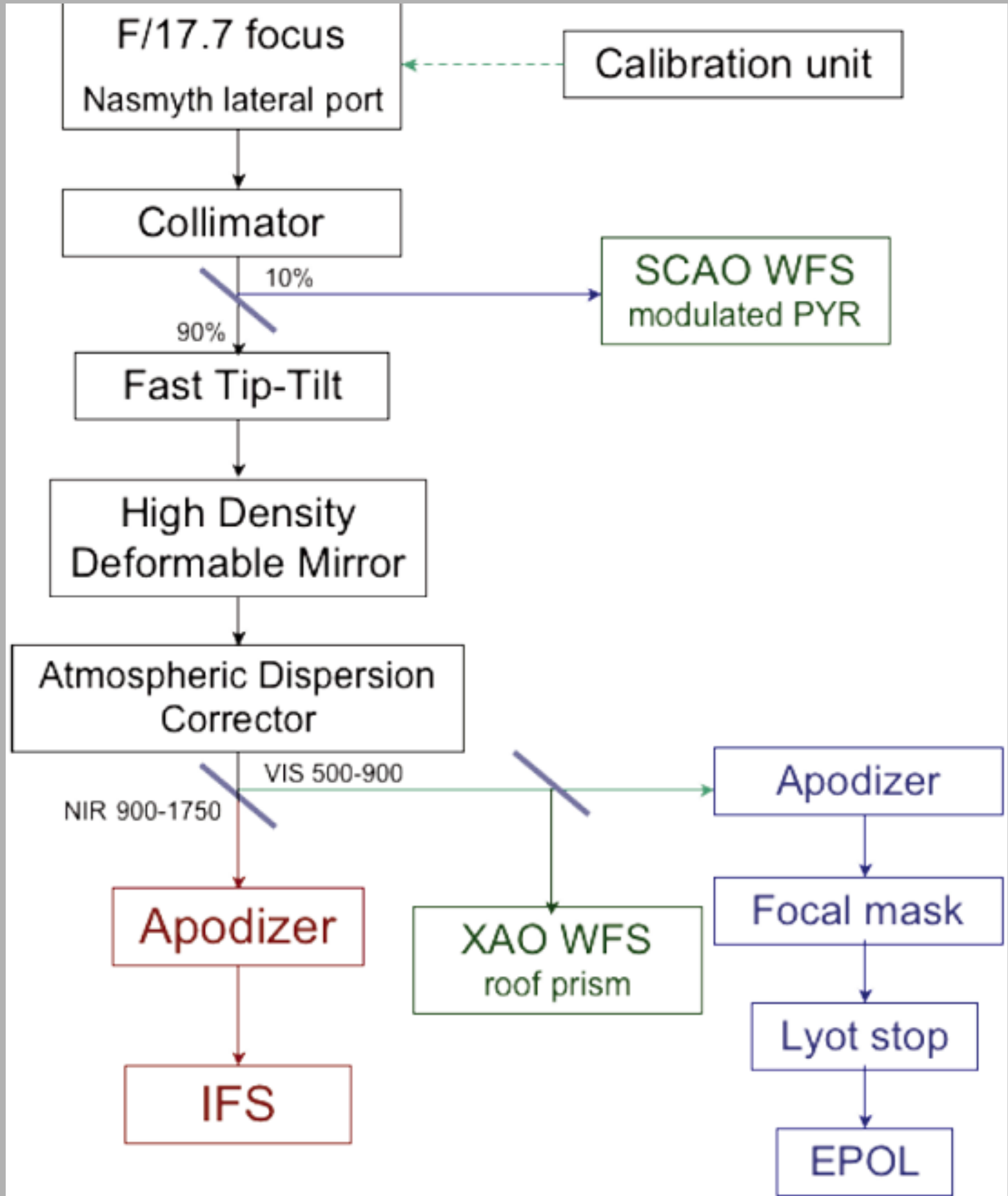
6. **a) Contrast requirements Y-H band** (10h telescope time, reference seeing conditions, 5σ detection):

Brightness ratio at distance: [mas]	30	100	300	Limiting stellar Magnitude I band:
Science Case 1	10^{-6}	10^{-6}	10^{-6}	**9 (goal: 10)**
Science Case 2		**$2\ 10^{-9}$ (goal 10^{-9})**	**10^{-9} (goal $4\ 10^{-10}$)**	7 (goal: 8)
Science Case 3	**10^{-8}**	**10^{-9}**	10^{-6}	7 (goal: 8)
Science Case 4	$2\ 10^{-9}$ (goal 10^{-9})	10^{-9} (goal $4\ 10^{-10}$)	$5\ 10^{-10}$ (goal $2\ 10^{-10}$)	5 (goal: 6)

b) Contrast requirements I band (10h telescope time, reference seeing conditions, 5σ detection, for differential signal contrast $(I_1(planet)-I_2(planet))/(I_1(star)+I_2(star))$ where I_1 and I_2 are fluxes in two spectral bands (on/off CH_4 absorption) or I(parallel) and I(perpendicular) for polarimetry]:

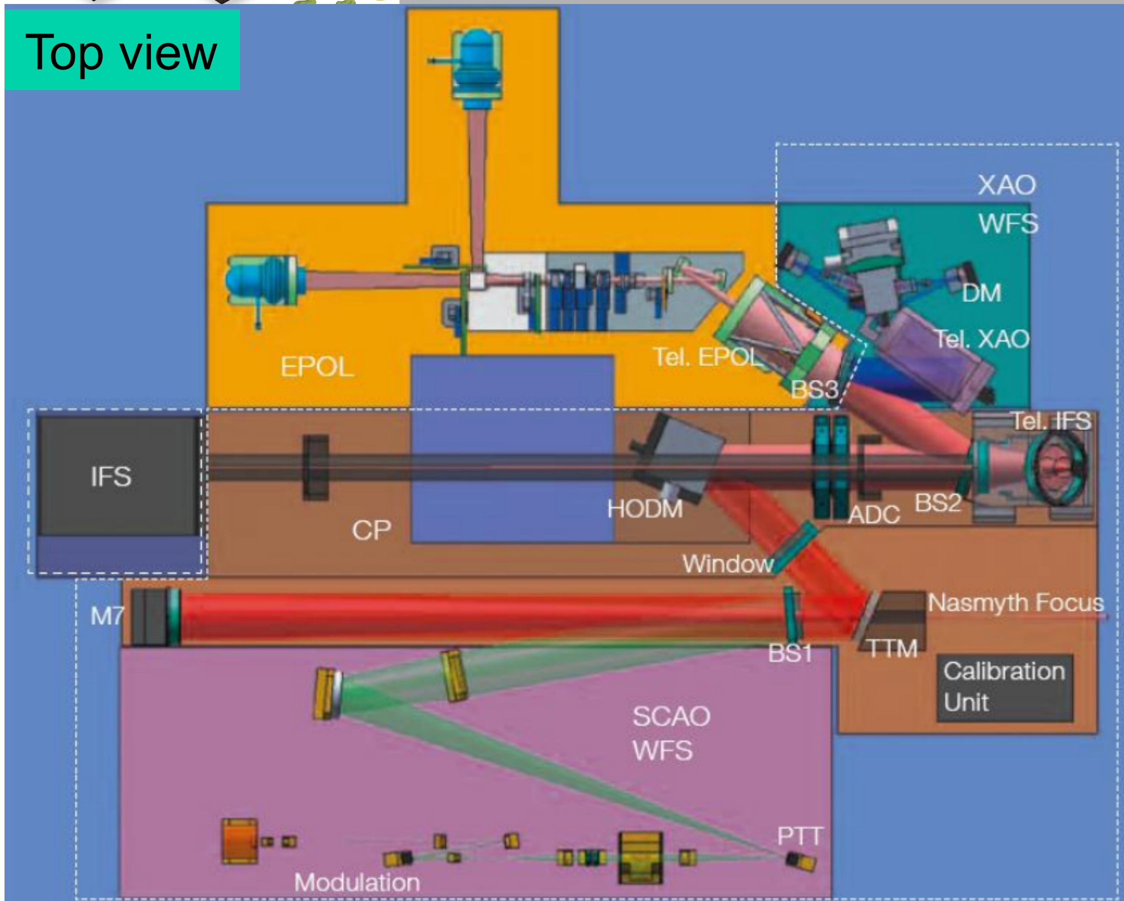
Brightness ratio at distance: [mas]	30	100	300	Limiting stellar Magnitude I band:
Science Case 2		**$2\ 10^{-9}$ (goal 10^{-9})**	**10^{-9} (goal $4\ 10^{-10}$)**	7 (goal: 8)
Science Case 4	$2\ 10^{-9}$ (goal 10^{-9})	10^{-9} (goal $4\ 10^{-10}$)	$5\ 10^{-10}$ (goal $2\ 10^{-10}$)	5 (goal: 6)



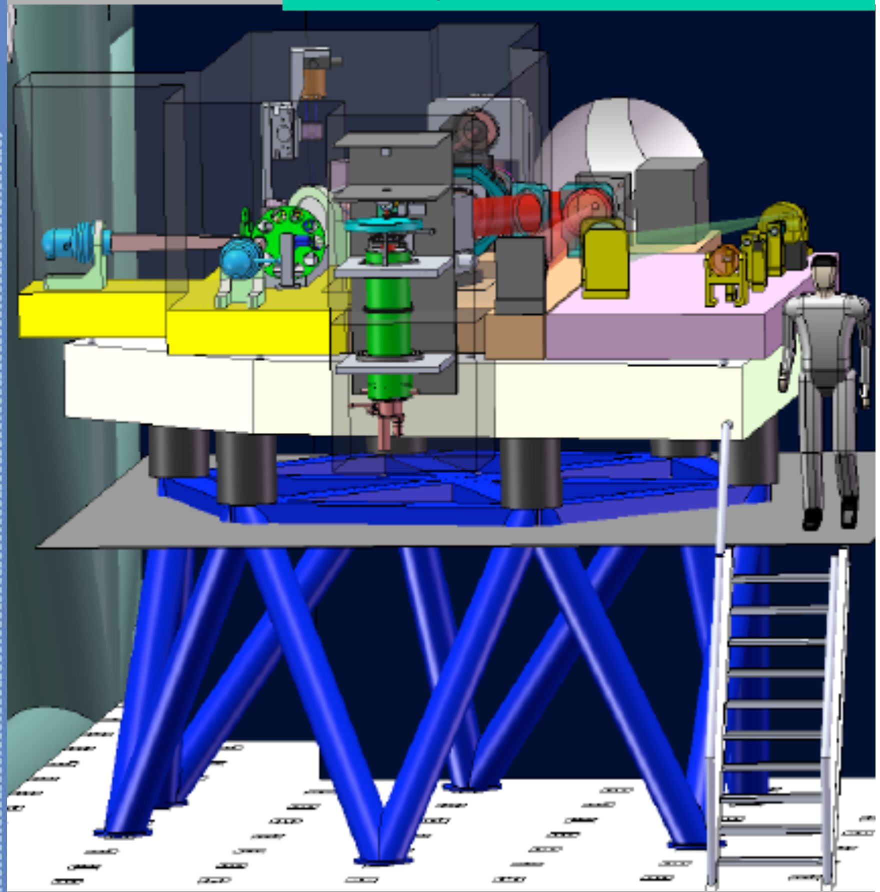

F/17.7 focus
Nasmyth lateral port
Calibration unit
Collimator
10%
90%
SCAO WFS
modulated PYR
Fast Tip-Tilt
High Density
Deformable Mirror
Atmospheric Dispersion
Corrector
VIS 500-900
NIR 900-1750
Apodizer
Apodizer
XAO WFS
roof prism
Focal mask
Lyot stop
IFS
EPOL

Concept

Top view



Nasmyth implementation

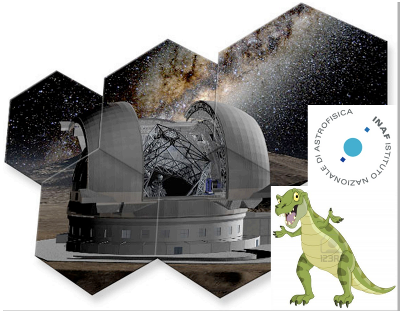


NIR imaging: 950-1650 nm, 0.8″ FoV, 2.33 mas/px

NIR IF spectroscopy: R = 125, 1400, 20.000

Vis imaging: 600-900 nm, 2″ FoV, 1.5 mas/px

Vis polarimetry



Concept Highlights

1. Superb XAO and wave-front control
- Turbulence residual halo ~10^{-5} at 30mas <10^{-6} further out
- QSS about 10x below AO residuals

2. Good temporal stability
- All moving or rotating optics are in the common path.
- Cover providing thermal inertia and dust protection.

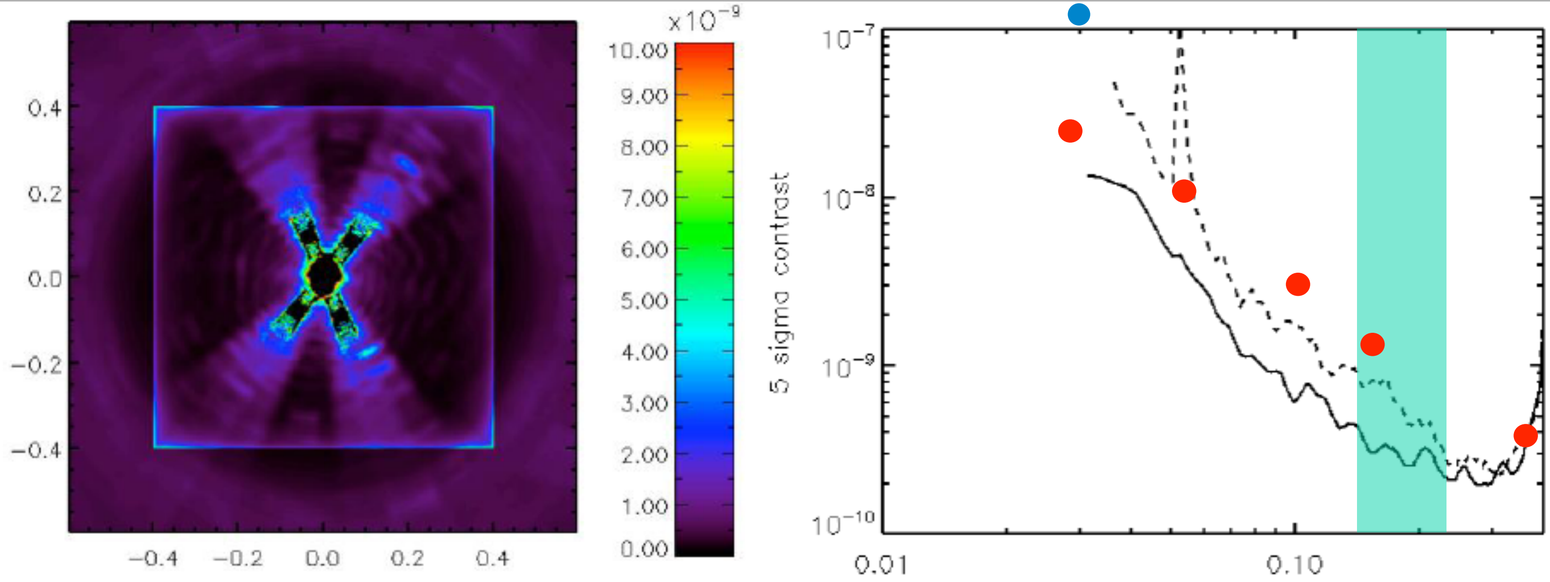
2. Very efficient calibration of PSF residuals
- Small and known chromaticity for spectral deconvolution
- Small instrumental polarization and efficient calibration for differential polarimetry

=> EPICS is photon noise limited

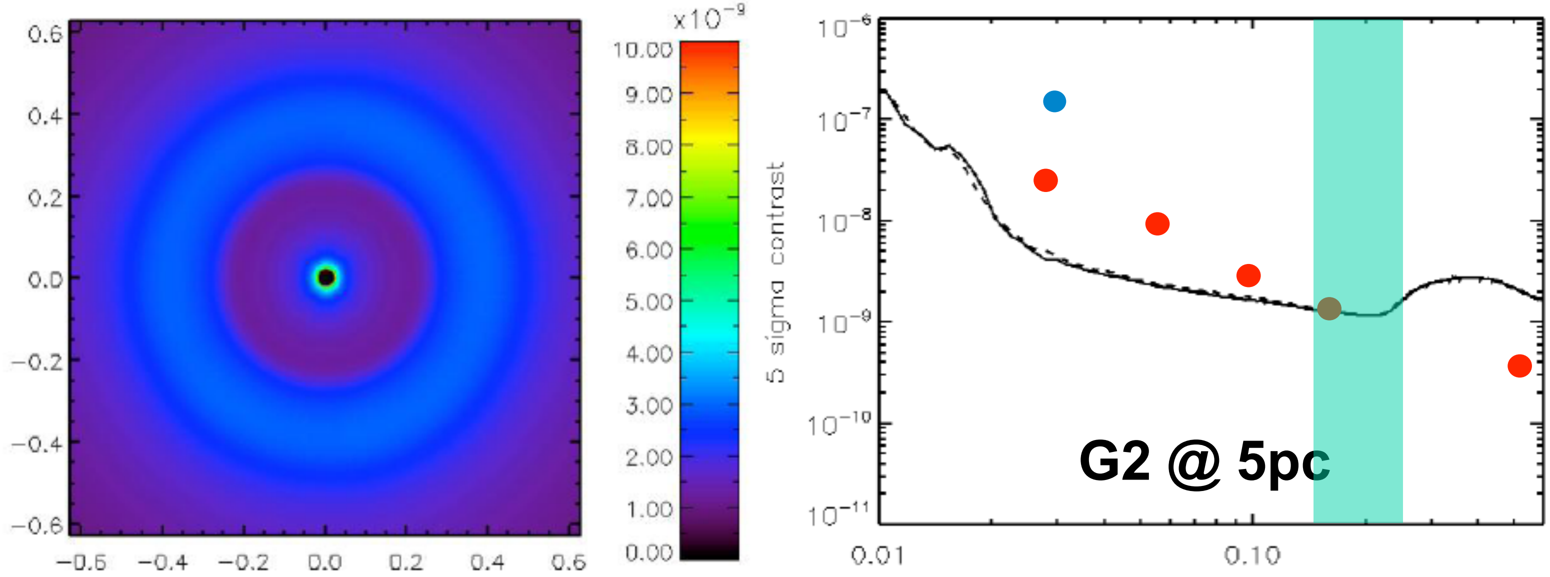
Analysis (E2E)

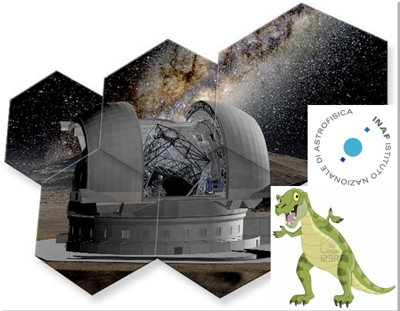
α Cen Bb and all τ Ceti proposed planets are detectable by PCS, including *e* in the HZ !!

IFS



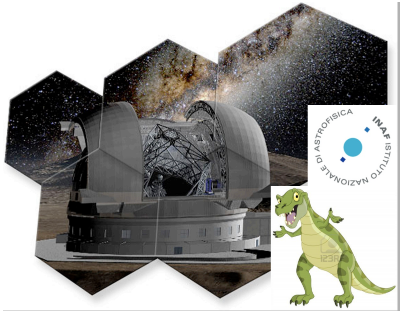
EPOL





Summary

1. EPICS is the Exoplanet imager for the E-ELT
2. EPICS provides direct imaging contrasts down to 10^{-8} at 0.03” and 10^{-9} at 0.1″…
3. … and it provides it with the E-ELT baseline design



PCS within the E-ELT instrumentation plan

Year	ELT-IFU	ELT-CAM	ELT-MIR	ELT-4 (MOS or HIRES)	ELT-5 (MOS or HIRES	ELT-6	ELT-PCS
2012	Decide science requirements, AO architecture.		VISIR start on-sky	Develop science requirements for MOS/HIRES			Call for Proposals for ETD
2013			TRL Review	Call for Proposals for MOS/HIRES			
2014							
2015				Selection ELT-MOS/HIRES		Call for Proposals	
2016							
2017							TRL check
2018							TRL check
2019						Selection	TRL check
2020							TRL check
2021							TRL check
2022 Tel. technical first light							
(grey)	Pre-studies taking the form of phase A or delta phase A work and/or ESO-funded Enabling Technology Development (ETD)						
(orange)	Decision point						
(green)	Development of Technical Specifications, Statement of Work, Agreement, Instrument Start.						

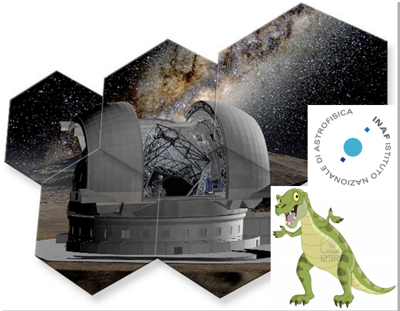
T-REX kick off meeting, Bologna, 28/09/2012

The roadmap to PCS

- Revision and update of science objectives and requirements
- Instrumentation challenges
    - XAO + wavefront control
    - Diffraction control
    - Speckle control
- SPHERE lessons
    - Commissioning: Q3 2013

Update of science objectives and requirements

- State-of-the art (FLAO results)
- Identify select science cases, work out quantitative requirements
- diameter of stars, planet brightness, number of photons, polarized flux
- Based on EPICS documents, include M-star HZ case



Instrumentation challenges: XAO + wavefront control

- WFS, error budget, how to deal with temporal and refractive index chromaticity, $N_{actuators}$ vs Strehl and correction radius
- Wavefront control / speckle nulling, implementation - linearity issues of WFS
- Requirements and technological readiness
- Baseline choices for EPICS:
    - roof WFS
    - 210actuators across
    - 3kHZ
    - auxiliary DMs in WFS path for NCP corrections
    - NCP calibration offline but regularly

Instrumentation challenges: Diffraction control

- Apodization / Shaped pupils vs Coronagraphy (ghost and stray light issues with former but simple to implement and use)
- IWA vs source size/pointing sensitivity
- Chromaticity and how to cope with it
- Comparison between various coro- concepts
- Requirements and technological readiness
- Baseline choices for EPICS (to be revised):
  - Apodizer for IFS
  - APLC for EPOL

Instrumentation challenges: speckle calibration

- (S/P/C/A)DI, SD features and comparison
- Quasi-static and atmospheric Speckle life-times
- Requirements and technological readiness
- Baseline choices for EPICS (to be revised):
    - SD for IFS
    - PDI for EPOL
    - CDI offline (NCP cal) and supplementary ADI

Italian activity for PCS

- Science
  - Update of science case (e.g. A-stars, multiple planets, planet atmospheres)
  - Detailed study of nearby M-stars
  - Science as a function of updated performance evaluation
- Technology - IFS
  - Pupil apodization in lenslet design
  - Re-evaluation of slicer option (requires some prototyping)
  - Final comparison between lenslet and slicer options

Italian groups in PCS

- OAPD
  - Areas: Science, lenslet IFS
  - People: Gratton, Desidera, Claudi, Mesa, Bonavita
- OACT
  - Areas: slicer IFS
  - People: Scuderi, Leone, Munari, Bruno, Martinetti