Science Goals at the E-ELT: Prospects from the Instrumentation Studies

Sandro D'Odorico
European Southern Observatory

ESO at a crucial passage :

Toward the completion of the ALMA project

- 3 american antennas tested at the summit,several under integration and testing
- 2 european antennas in the last phases of integration
- call for advanced science in 2011

ESO at a crucial passage:

VLT 2nd generation Instruments

- **X-shooter** (2009)- among the top 3 VLT instrument in terms of oversubscription
- **KMOS** (2011 tbc): 24 cryogenic, deployable IFU over a field of 7.2’ , R~3500, λλ 1-2.5 μm

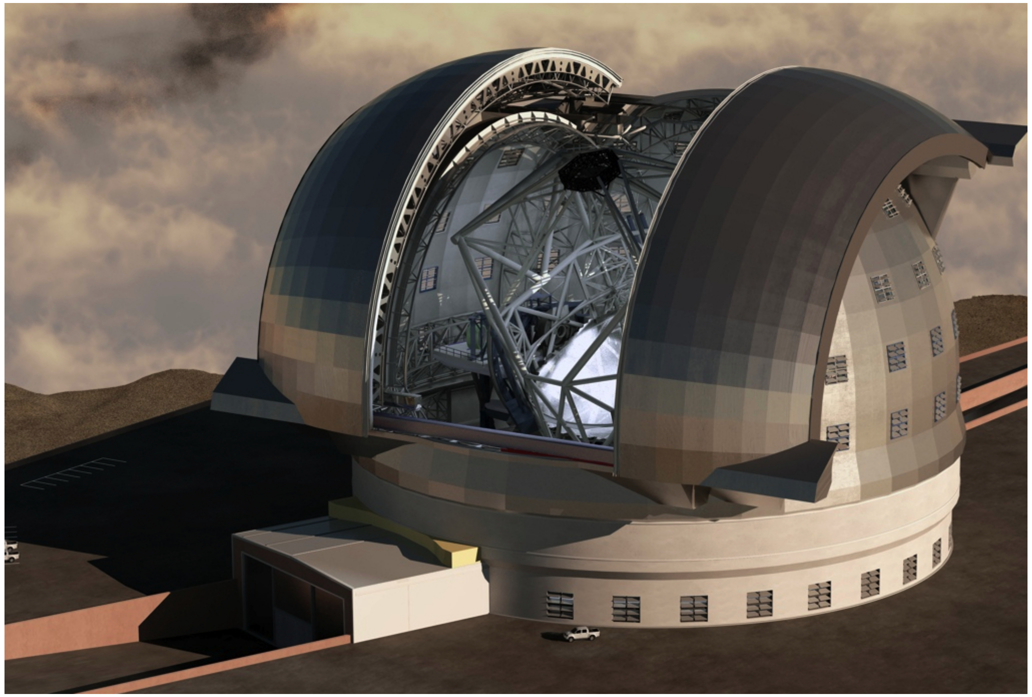
- **MUSE** (2012 tbc): Mono IFU, 1’ or 7” □ field , R ~ 3000, λλ 0.48-0.95 μm

- **SPHERE** (2011 tbc): planet imager-spectrographs with high order AO system

- **ADAPTIVE M2 in UT4** (2014 tbc)→ MUSE,HAWK-I

- **ESPRESSO** (2014 tbc) : high resolution, high stability optical spectrograph at combined focus **(OATs)**

THE E-ELT PROJECT STATUS



- An official ESO project in the study phase, with the goal to keep Europe's lead in ground-based optical astronomy
- Phase B study to be closed in **December 2010 with a construction proposal to Council**
- Start 2011, First light 2019
- Cost: Telescope + 5 instruments: ~ 1 Billion; Operation 50 Ml/year

E-ELT UNIQUE CAPABILITY:

Photon Collecting Power & Angular Resolution of the 42m

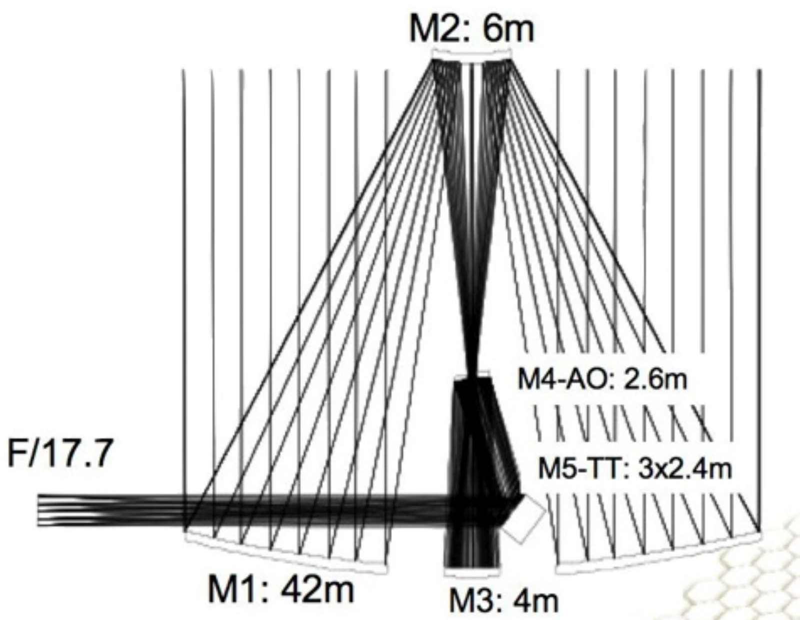
E-ELT DRIVERS:

- Extension of today science (current science case, DRM)
- Sinergy with ALMA, JWST, LSS
- Opening of new parameter space

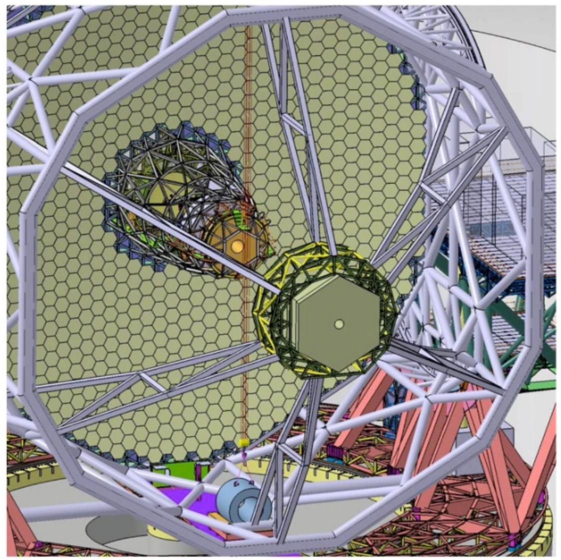
E-ELT SITE CHOSEN BY COUNCIL IN June 2010

ARMAZONES **PARANAL**

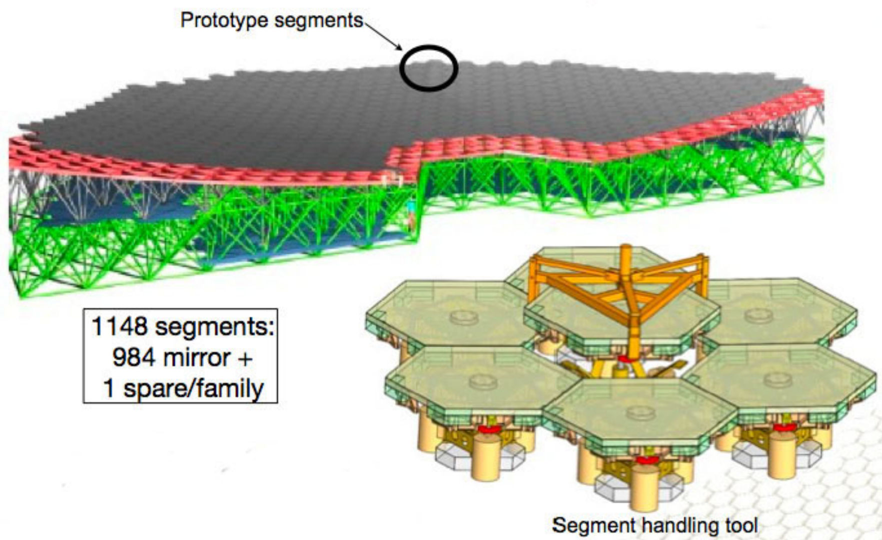
E-ELT CONCEPT



- 5 mirror concept (3 mirror anastigmat + 2 flats)
- diffraction limited over full 10′ FoV
- flat, almost telecentric FoV
- “zoom” capability
  - Nasmyth, gravity invariant, coudé foci
- laser “friendly”

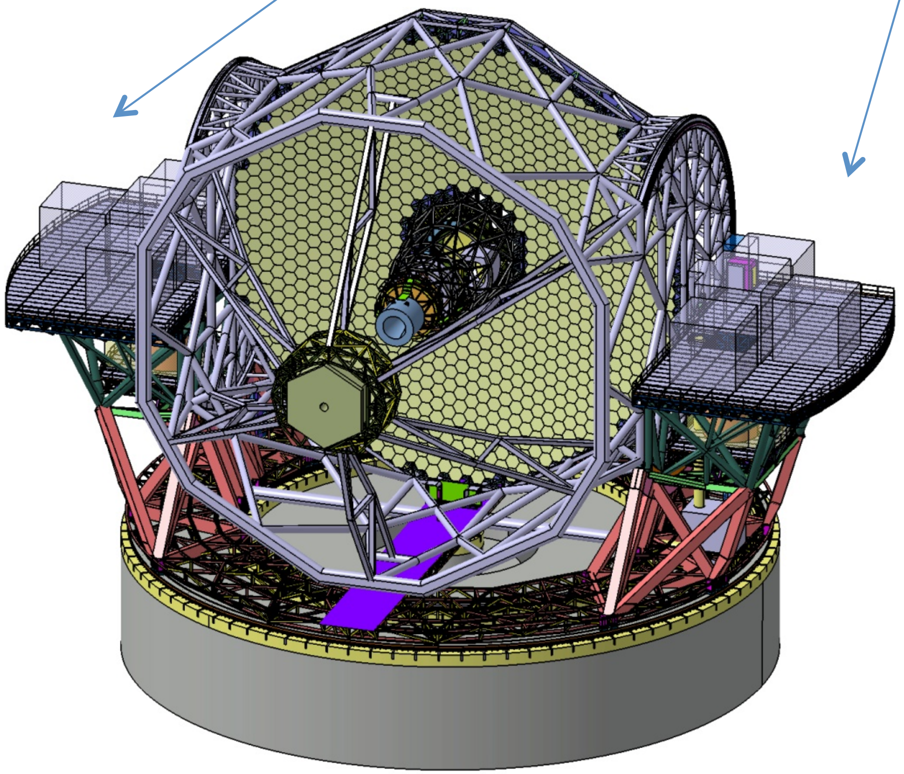


The spider and secondary mirror crown

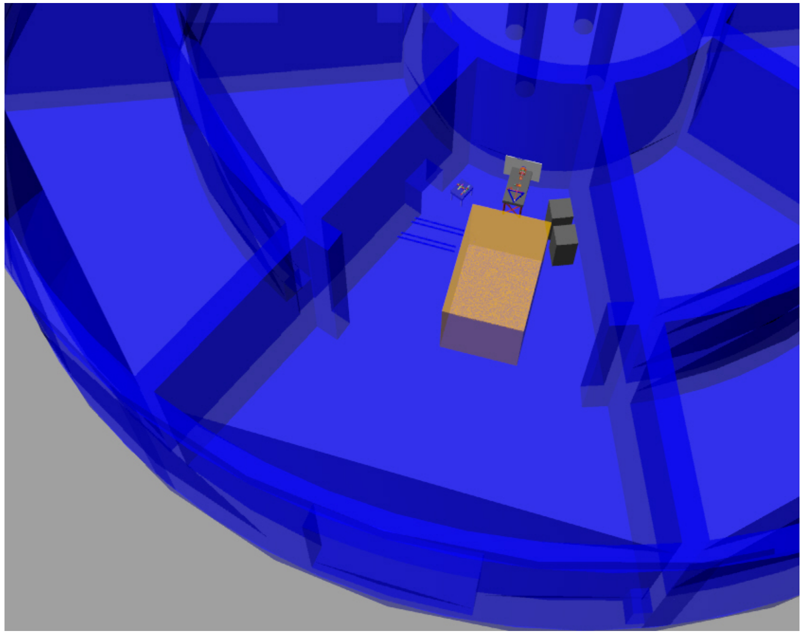


Telescope Focal Stations

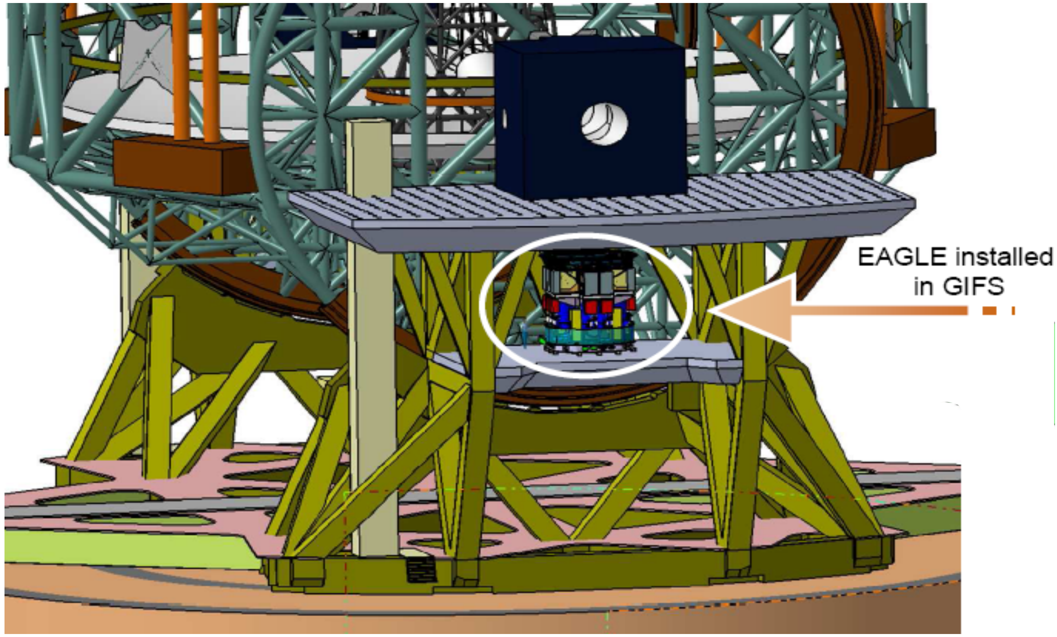
Up to 6 instruments permanently mounted on the Nasmyth platform



Telescope Focal Stations



The coudé room under the dome floor.



The gravity invariant focal station under the Nasmyth platform.

Scope of Instrument and AO Modules Study Plan

- *Carry-out a suitable number of instrument studies to verify that instruments can be built at an affordable cost and that they properly address the scientific goals of highest priority*

- *Work with the ESO community in the instrument studies and to prepare for construction*

- *Work with telescope and operation POs to identify and define interfaces with the other subsystems and the observatory infrastructure*

OVERVIEW OF THE E-ELT INSTRUMENT STUDIES

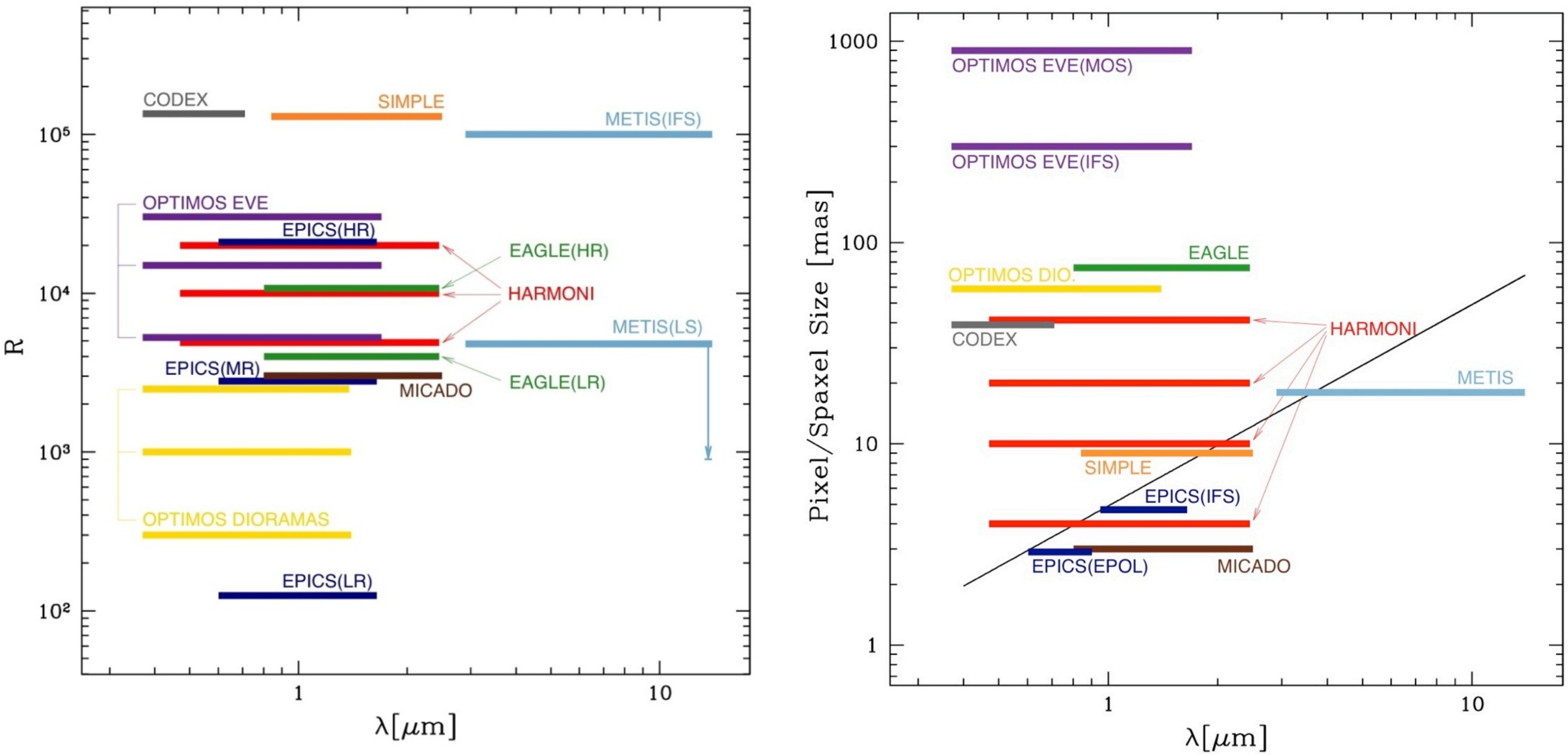
TABLE 1 Overview of Post Focal AO Modules and Instruments Studies

Name	P.I.	Institutes	Procurement of the study	Responsible at ESO	Kick-off	Final Review
PFAO ATLAS	T. Fusco (ONERA)	ONERA, LESIA, GEPI , LAM, UK ATC	Open call with initial module specifications	J. Paufique	19/09/08	2/02/10
PFAO MAORY	E. Diolaiti (INAF OABo)	INAF-OABo, OAA, OAP; Univ.Bo, ONERA	Direct negotiations with external institutes	E. Marchetti	09/11/07	10/12/09
CODEX	L. Pasquini (ESO)	ESO, INAF Trieste & Brera, IAC, IoA Cambridge, Obs. Geneve	ESO coordinates Consortium of Institutes which had done an FP6 E-ELT instrument study	n.a.	16/09/08	23/02/10
EAGLE	J. G. Cuby (LAM)	LAM, OPM GEPI and LESIA, ONERA, UK-ATC, Univ. Durham	Direct negotiations with Consortium of Institutes which had done an FP6 E-ELT instrument study	S. Ramsay	27/09/07	27/10/09
EPICS	M. Kasper (ESO)	ESO, LAOG, INAF-OAPd, ASTRON, Univ. of Oxford, LESIA, NOVA, ETHZ, FIZEAU, LAM	ESO coordinates Consortium of Institutes which had done an FP6 E-ELT instrument study	n.a.	24/10/07	16/03/10
HARMONI	N. Thatte (Oxford)	Oxford University, CRA Lyon, DAMI Madrid, IAC, UK ATC	Open Call with initial instrument specifications	J. Vernet	01/04/08	28/01/10
MICADO	R. Genzel (MPE)	MPE, MPIA, US München, INAF Padova, NOVA -Univ. Leiden and Groningen, LESIA	Open Call with initial instrument specifications	A. Richichi	28/02/08	30/10/09
METIS	B. Brandl (Leiden)	NOVA (Leiden, ASTRON), MPIfA, CE Saclay DSM/IRFU/Sap, KU Leuven, ATC UK	Open Call with initial instrument specifications	R. Sieben-morgen	07/05/08	17/12/09
OPTIMOS-DIORAMAS	O.Lefevre (LAM);G.Dalton (RAL)	LAM, STCF RAL, Oxford, INAF IASF-MI and OATs, Obs. Geneve, AIP, IAC	Open call for a new concept	S. Ramsay	7/10/08	30/03/10
OPTIMOS-EVE	F.Hammer (GEPI) ; L.Kaper (Amsterdam),G. Dalton (RAL)	GEPI, NOVA, RAL ,INAF OATs and Brera, NBI Copenhagen	Open Call for a new concept	S. Ramsay	7/10/08	30/03/10
SIMPLE	L.Origlia (INAF OABo)	INAF OA Bologna, Arcetri & Roma,Univ. Bologna, UAO, TLS, PUC (Chile)	Open Call for a new concept	U. Kaeufl	30/10/08	4/03/10

40 Institutes in 10 ESO member states and Chile (1) involved in E-ELT Instrumentation . More than 200 Engineers & Astronomers

From Belgium, Denmark, France, Germany, Italy ,UK, Spain, The Netherlands, Sweden, Switzerland , + Chile

Parameter space for E-ELT instruments under study



Instrumentation Studies Reviews 2009-2010

OVERVIEW OF THE E-ELT INSTRUMENT STUDIES

PREAMBLE/REMINDER

- ❑ Not all the observing capabilities can be implemented in the first generation (Science main driver of the priorities)

- ❑ the chosen instruments will not match 1 to 1 the studied concepts (scientific , technical evaluation, cost → updating of the specifications)

- ❑ the Consortia which will built the instruments will not necessarily coincide with the ones which carried out the studies (need to use optimally resources and expertise in the community)

CODEX: high stability, high spectral resolution visible spectrograph

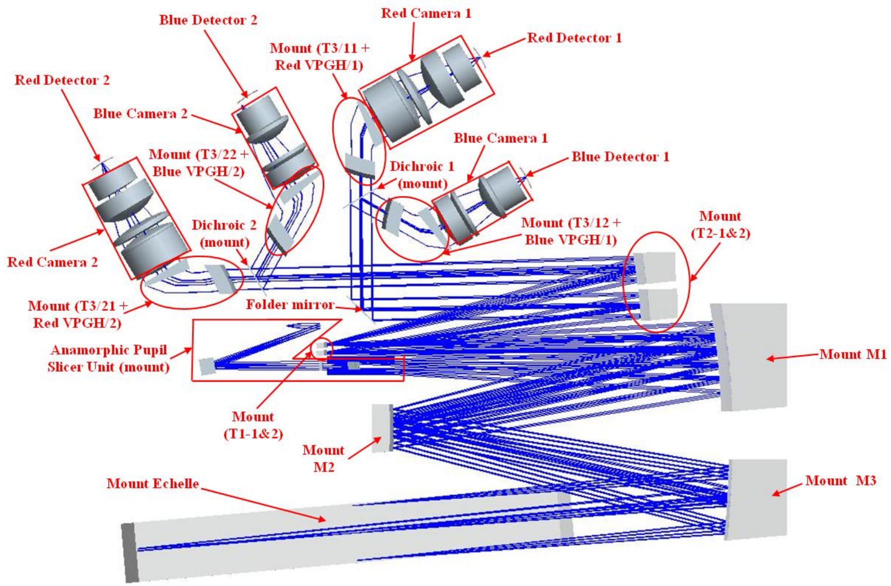
- **PI: Luca Pasquini, ESO**
- **PM: A. Manescau ,ESO**
- **Project Scientist: M. Haehnelt , Cambridge**
- **System Engineer: F. Zerbi , INAF Brera**

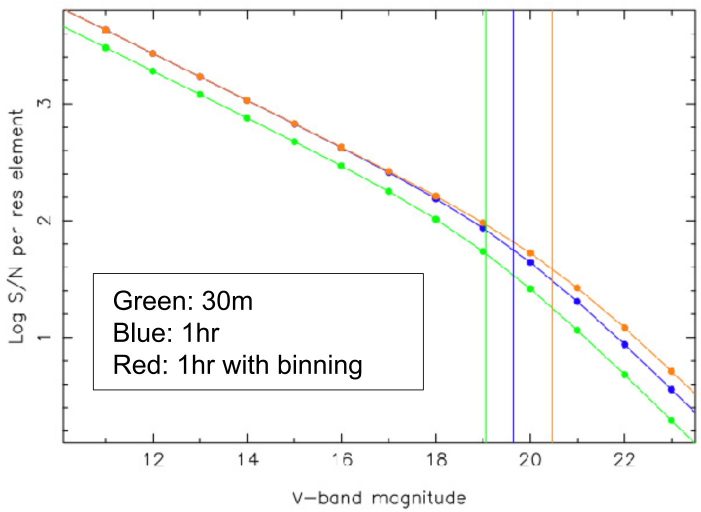
Brera, OATs

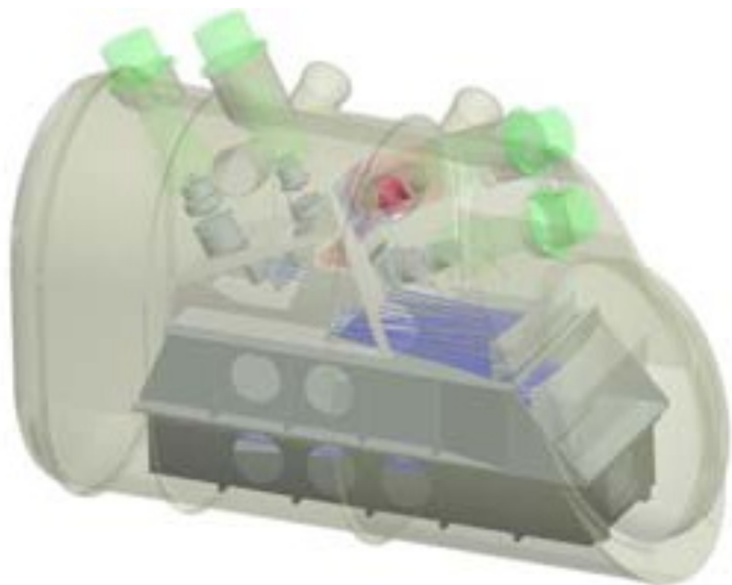
CODEX concept and performance

Specifications

- Mirror coude train,then fiber input
- field of view (0.82”)
- 0.37-0.71mm
- R~130,000
- ~2cms^{-1} Doppler precision over 30yrs
- no adaptive optics

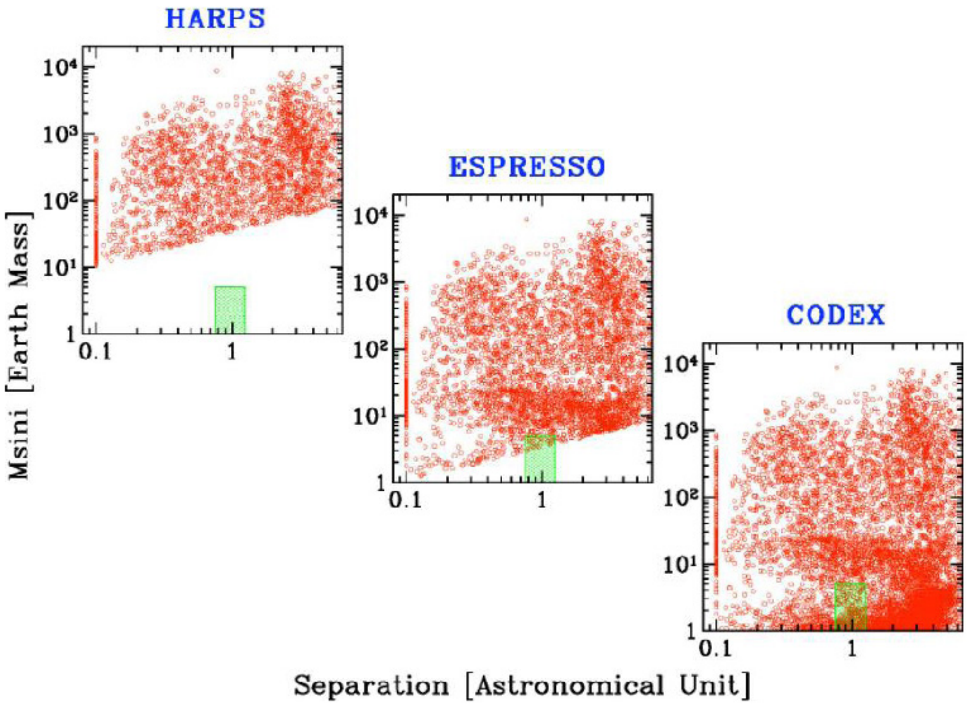






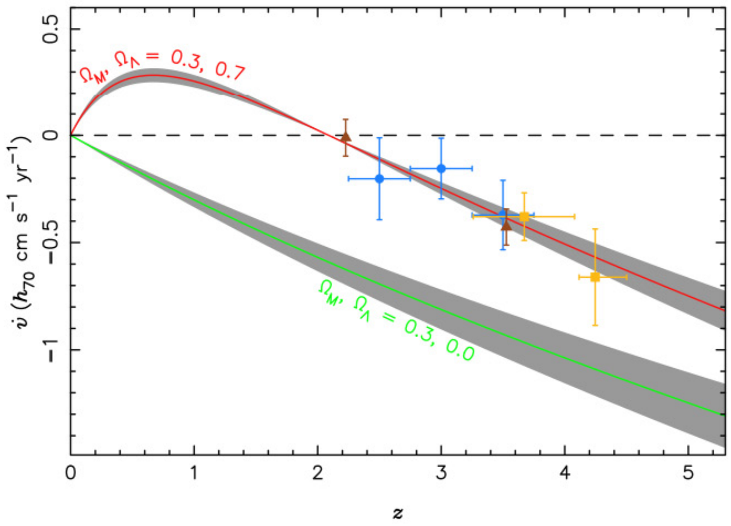
CODEX science case

- Extrasolar Twin Earths
- Dynamical measurement of Universal expansion
- Variability of Physical Constants



CODEX science case

- **Extrasolar Twin Earths**
- **Dynamical measurement of Universal expansion**
- **Variability of Physical Constants**



Liske et al. 2008

Fig. 1.Monte-Carlo simulations of three different implementations of a redshift drift experiment as outlined in the text. Plotted are values and errors of the "measured" velocity drift $\dot{v}$, expected for a total experiment duration of $\Delta t_0 = 30$ yr, a total integration time of 4000 h and for standard cosmological parameters ($h_{70} = 1$, $\Omega_M = 0.3$, $\Omega_\Lambda = 0.7$).

EPICS EELT Planetary Imaging Camera Spectrograph

ESO: Markus Kasper (PI)

LAOG: Jean-Luc Beuzit, (CoPI), Christophe Verinaud (System Scientist)

INAF Padova Observatory: Raffaele G. Gratton (Science Team Chair)

ASTRON: Lars Venema

University of Oxford: Niranjan Thatte

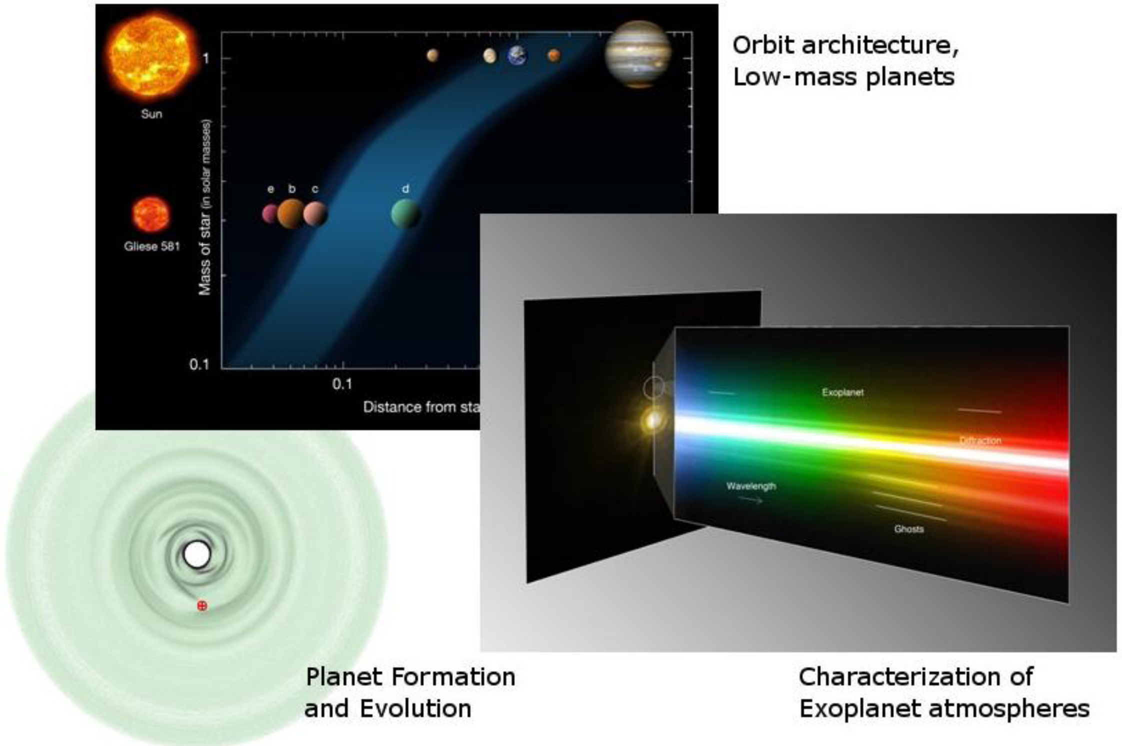
LESIA: Pierre Baudoz, Anthony Boccaletti

NOVA: Christoph Keller

ETH Zürich: Hans Martin Schmid

FIZEAU: Lyu Abe

LAM: Kjetil Dohlen



Orbit architecture, Low-mass planets

Planet Formation and Evolution

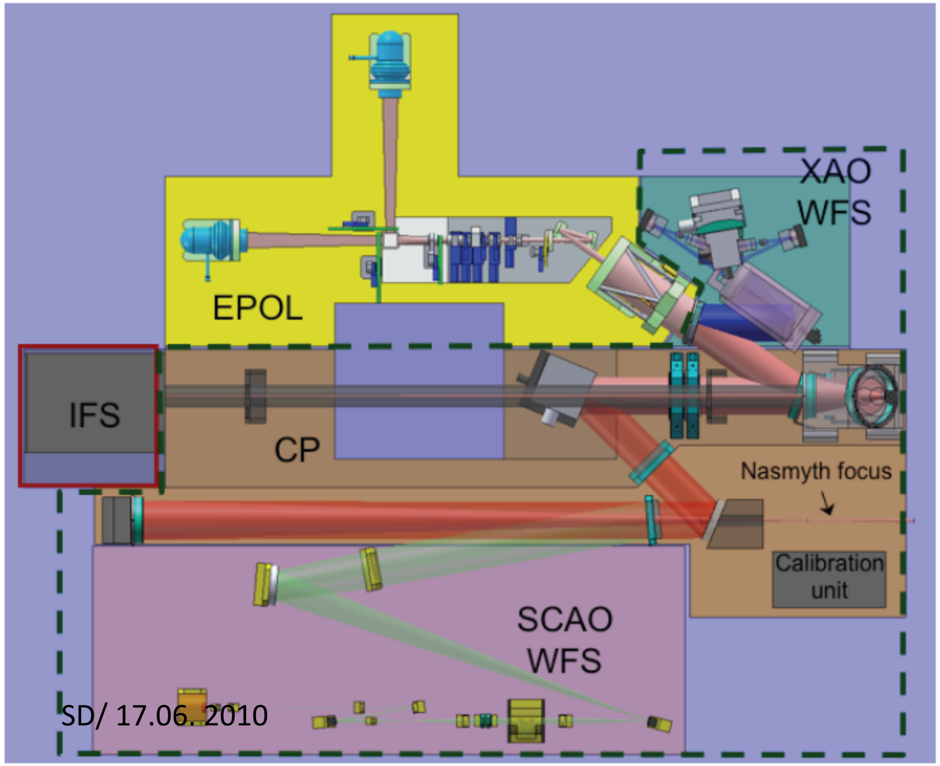
Characterization of Exoplanet atmospheres

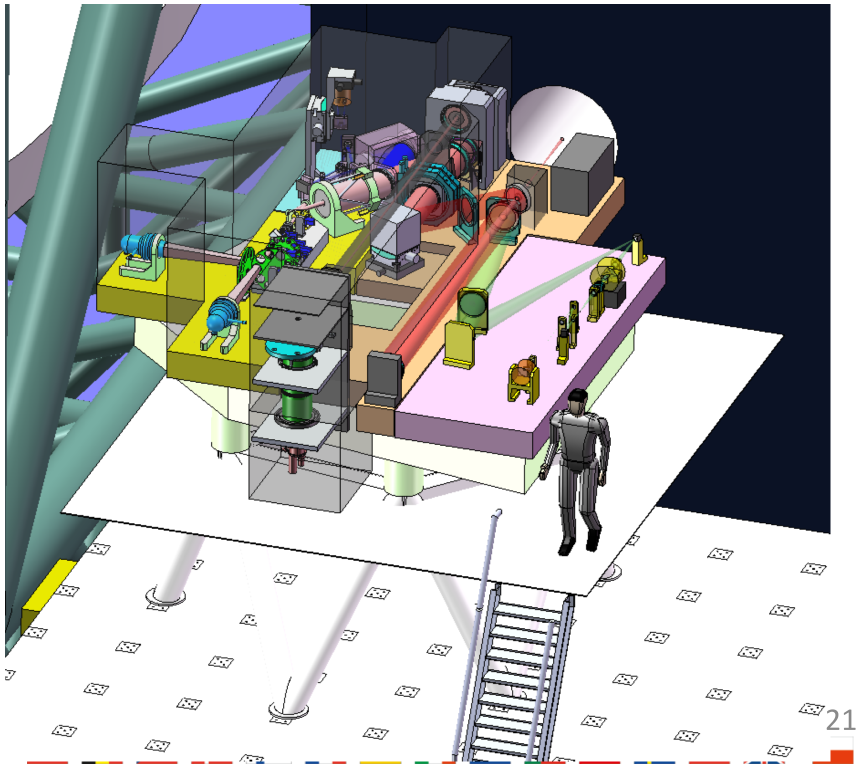
EPICS specification and concept

IFS 0.95-1.65µm
FOV: 0.8" x 0.8''/2.33mas
0.8" x 0.014'' long slit
R = 125, 1400 and 20000

EPOL 0.6-0.9µm
Coronagraphic polarimeter
FOV: 2" x 2''/1.5mas

Contrast ratios – 10^{-8} – 10^{-9}
XAO – very high (90%) Strehl





SD/ 17.06.2010

EPICS performance (contrast)

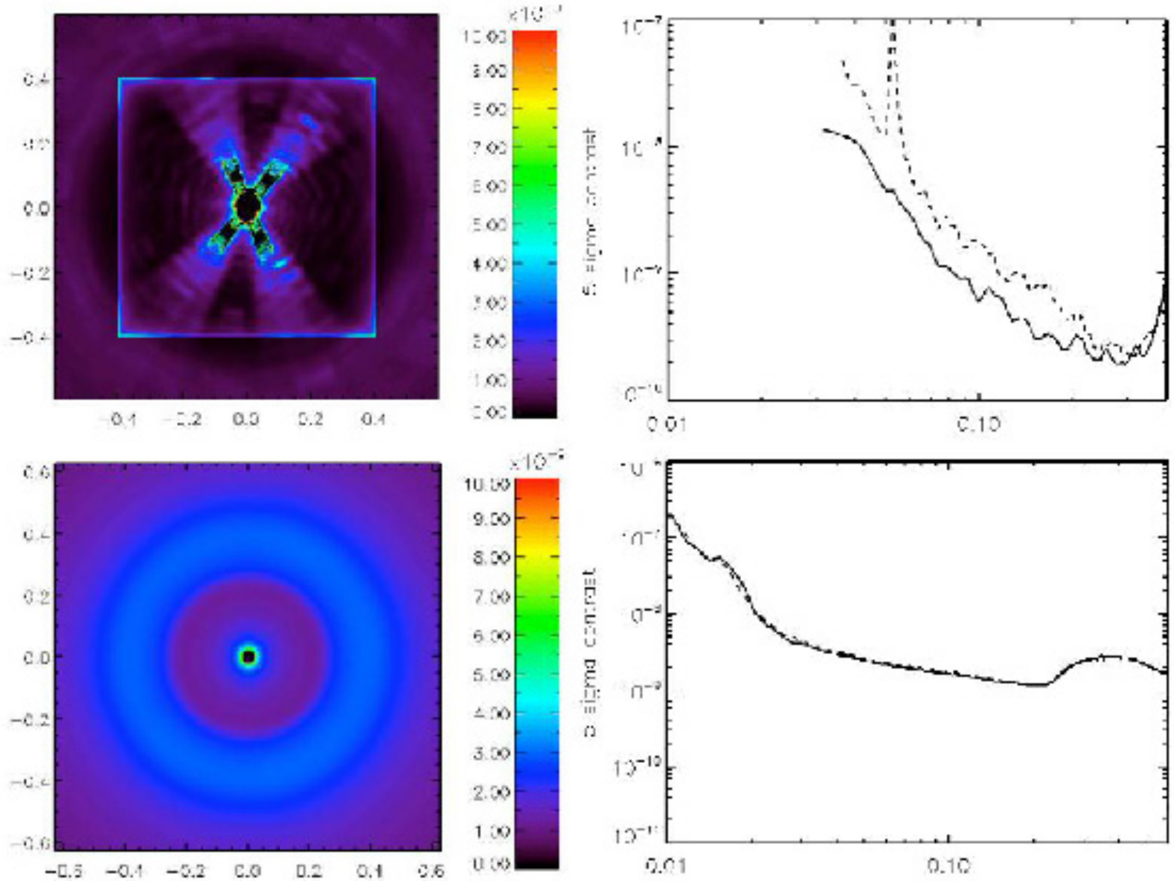
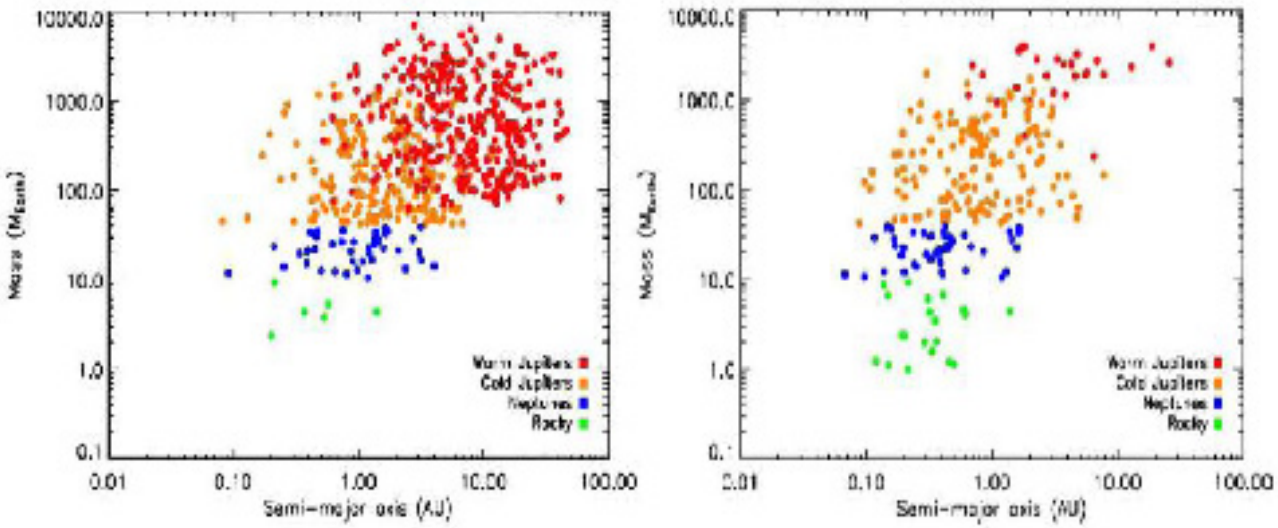


Figure 5. *2D contrast map vs separation [arcsec] and cuts along x-y for I=2.3 G2 star (10H exposure, field rotation) for the IFS (top) and EPOL (bottom).*

EPICS science goals



Group	Expected detections				
	Mp>300 M_{Earth}	100<Mp<300 M_{Earth}	40<Mp<100 M_{Earth}	10<Mp<40 M_{Earth}	Mp<10 M_{Earth}
IFS	362	147	107	41	6
E-POL	79	50	55	55	19

Figure 6. EPICS detections predicted by the simulation software used to explore the EPICS requirements, MESS

EAGLE: a wide-field multi-IFU AO assisted NIR spectrograph

PI : Jean-Gabriel Cuby (LAM), Co-I PI: Simon Morris (Durham)

Project Scientist: M. Lehnhert (GEPI)

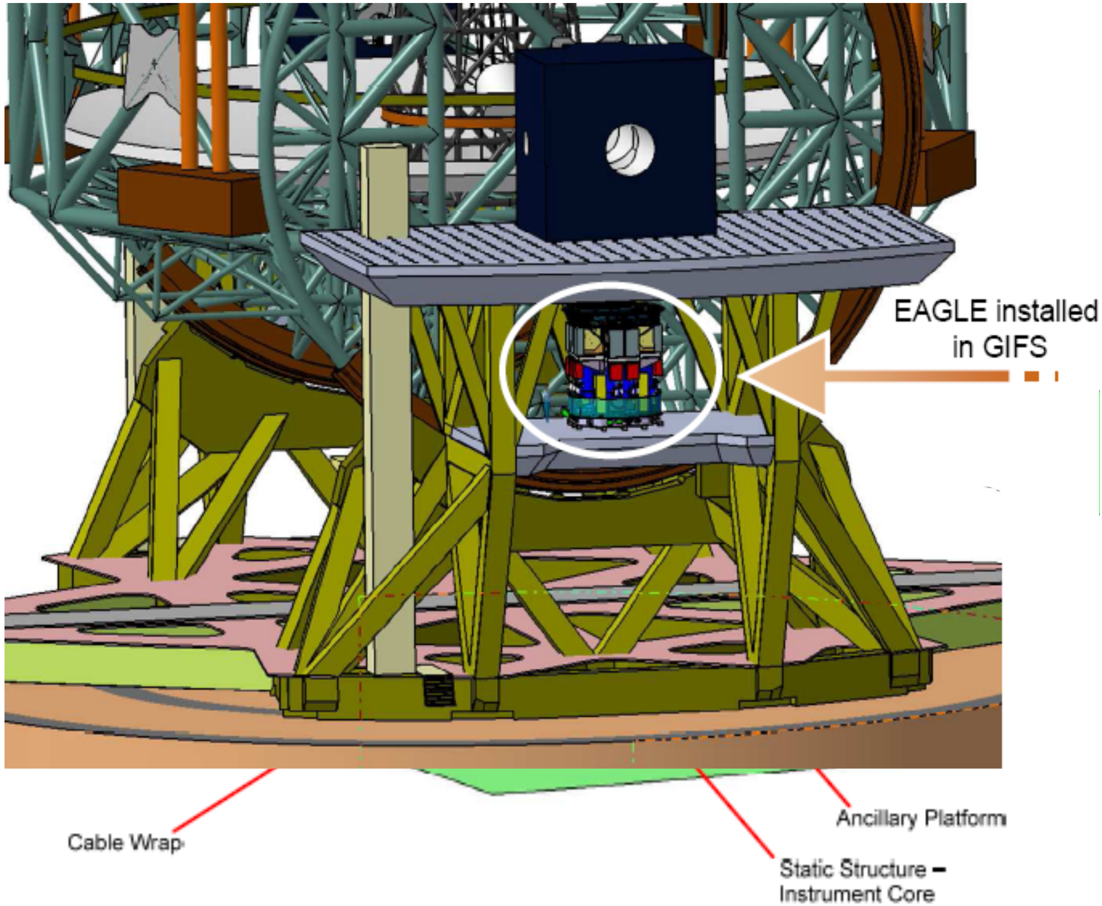
P.M. P. Parr-Burman (ATC) ;

Sys.Engineer: H. Schnetler (ATC)

Durham University	l'Observatoire de Paris — GEPI Galaxies Étoiles Physique et Instrumentation	l'Observatoire de Paris — LESIA
ONERA THE FRENCH AEROSPACE LAB	LAM LABORATOIRE D'ASTROPHYSIQUE DE MARSEILLE	Science & Technology Facilities Council UK Astronomy Technology Centre

EAGLE specifications and concept

- Near-infrared:
  - 0.8-2.45mm
- Patrol field
  - 38arcmin^2
- 20-IFU fields
  - 1.65”x1.65”
- R~4000,10000
- MOAO delivers>30% EE within 75mas in H

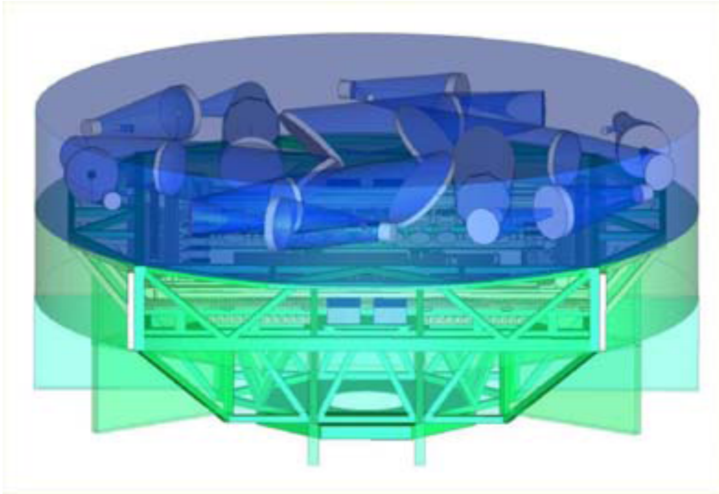


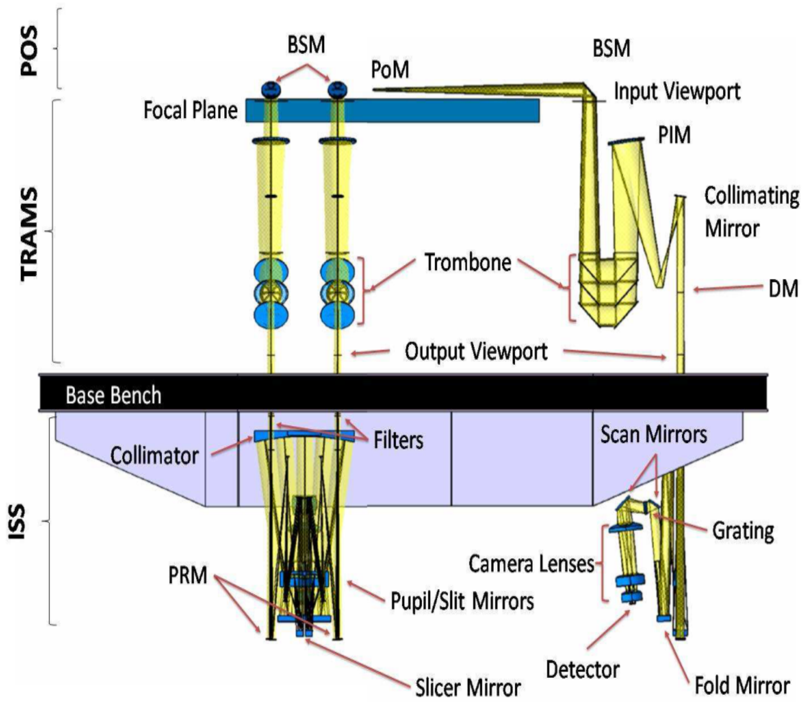
EAGLE Subsystems

6 Laser GS with associated WFS

5 Natural GS on instrument focal plane

20 Pick-off mirrors directing the target fields to the DM, the slicers and 10 spectrographs.





EAGLE: a wide-field, multi-IFU AO assisted NIR spectrograph

- Physics and evolution of high z galaxies (z= 2→10?)

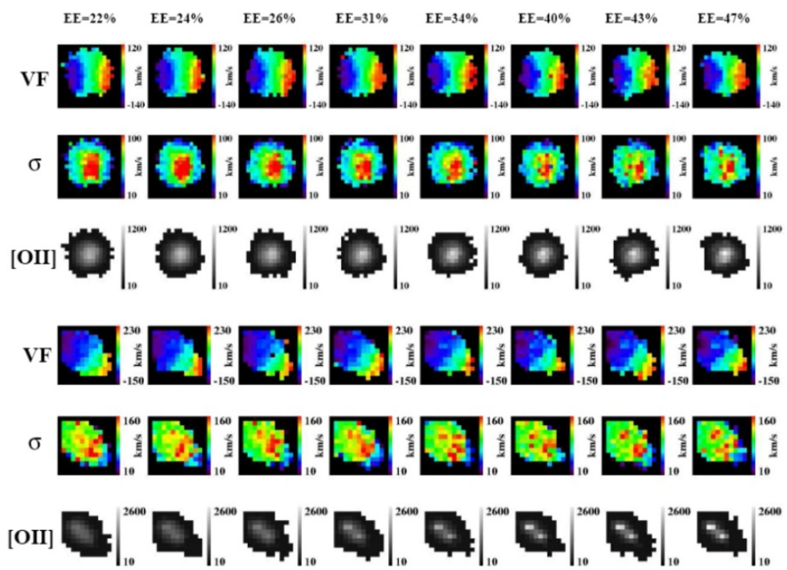
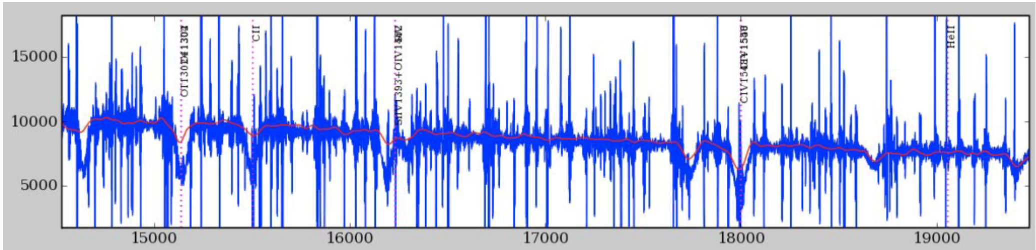
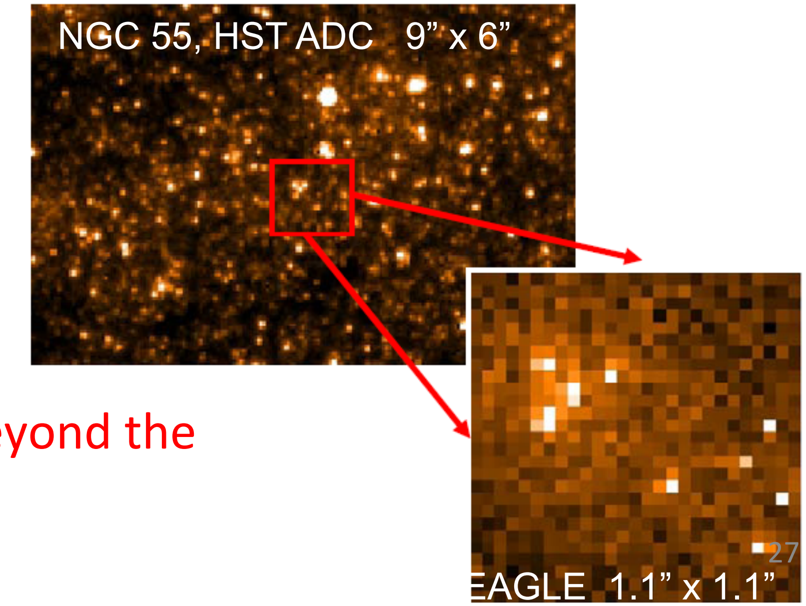


Figure 3-3 Analogue of rotating disk and merger with 75 mas pixel[-1]



- Simulated UV spectrum of a z=10, 30hr exp.,. J(AB)=24



- Galaxy evolution via stellar archaeology beyond the local group

HARMONI

PI: Niranjan Thatte, **PM:** Frazer Clarke; **IS** : Mathias Tecza (Oxford)

Consortium: Oxford, CRA (Lyon), CSIC (Madrid) , IAC, ONERA and UK ATC

Single field, IFU, VIS-NIR spectrometer for the follow up of single, faint targets . With AO module operating at DL of telescope.

PRIMARY SCIENCE GOALS

Stellar population in galaxies of the Local Universe

High Redshift Galaxies

AGN/Intermediate mass black holes

Distant Type 1a supernovae

High z GRB

HARMONI specifications and performance

- Wavelength range 0.47-2.45µm
- 3 Spectral resolving power
  - R ≈ 4000, 10000, 20000
- 4 spatial scales
  - 4mas, 10mas, 20mas, 40mas
- 4 fields of view
  - 0.5'' x 1.0'' , 1.25'' x 2.5'' 2.5'' x 5'', 5'' x 10''
- AO modes
  - GLAO (VIS)
  - LTAO (to reach DL)

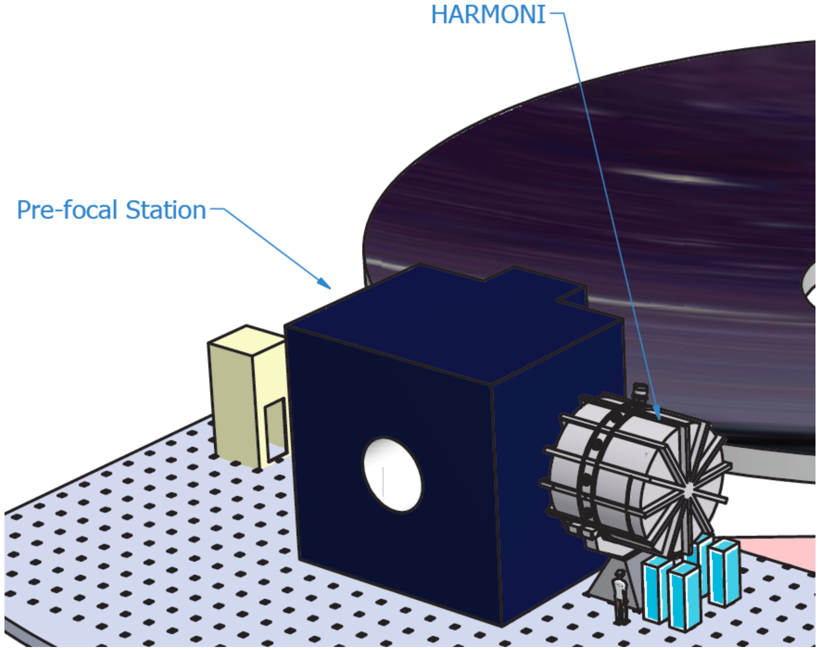
2 VIS spectrograph

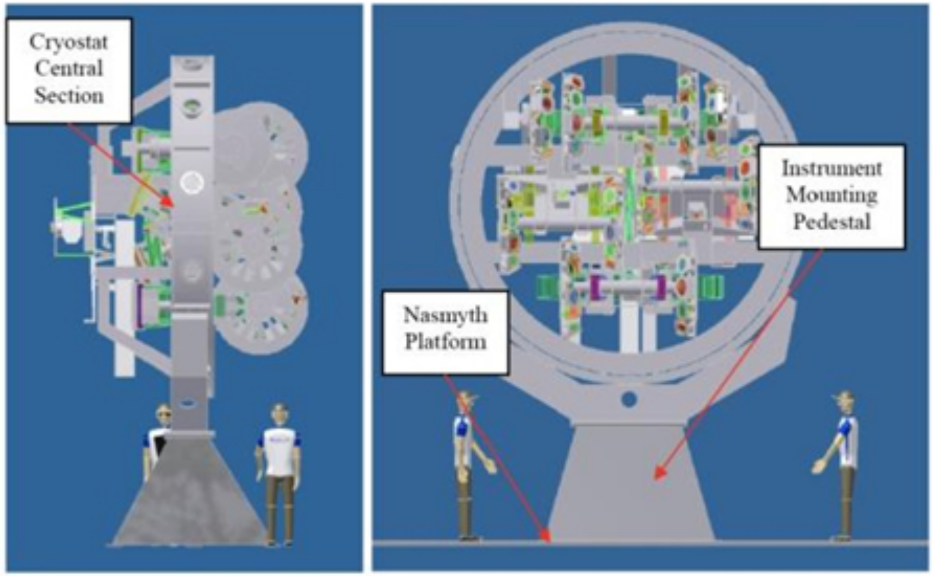
8 NIR spectrographs

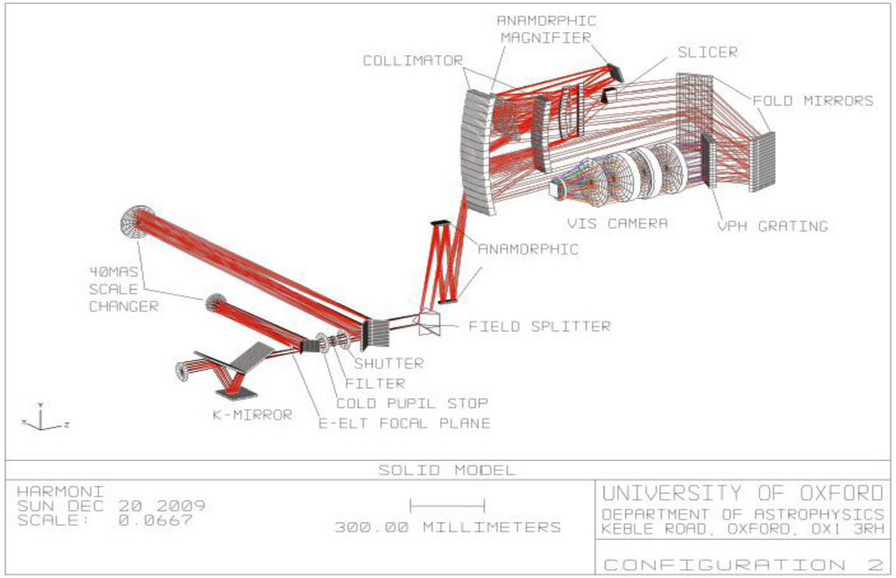
- Signal-to-noise of 5 per spectral pixel, for pt. sources or per spectral and spatial pixel (extended source) in 5 hours
- 0.8″ atmospheric seeing, airmass = 1.0, LTAO correction, 900 sec individual exposures, RON of $8e^-$ (near-IR), $2e^-$ visible.

Spectral	4 mas		10 mas		20 mas		40 mas	
Resolution	R_{AB}	H_{AB}	R_{AB}	H_{AB}	R_{AB}	H_{AB}	R_{AB}	H_{AB}
	Point source (mag)							
4000	24.2	26.6	25.3	27.4	25.3	27.4	25.4	27.0
10000	23.2	25.6	24.4	27.1	25.0	26.7	25.0	26.4
20000	22.5	25.4	23.5	26.6	24.1	26.5	24.4	26.1
	Extended source (mag / sq. arcsec)							
4000	19.2	18.2	21.0	19.3	21.9	20.3	22.7	21.1
10000	18.2	17.8	20.1	18.9	21.5	19.8	22.3	20.6
20000	17.5	16.7	19.5	18.5	21.0	19.4	22.2	20.3

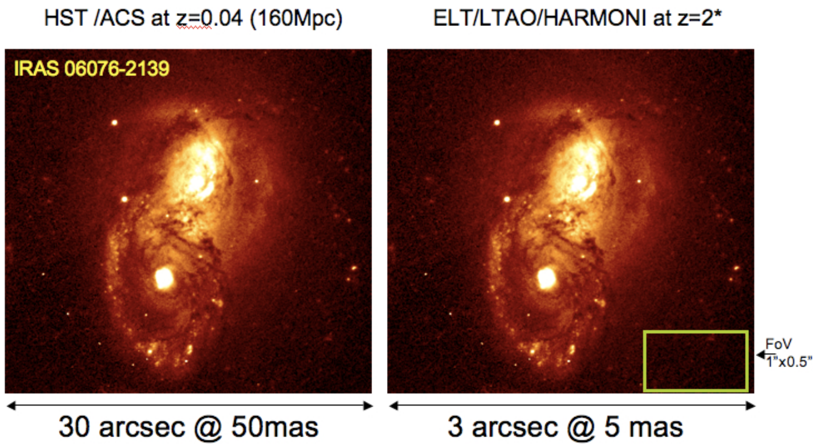
HARMONI concept

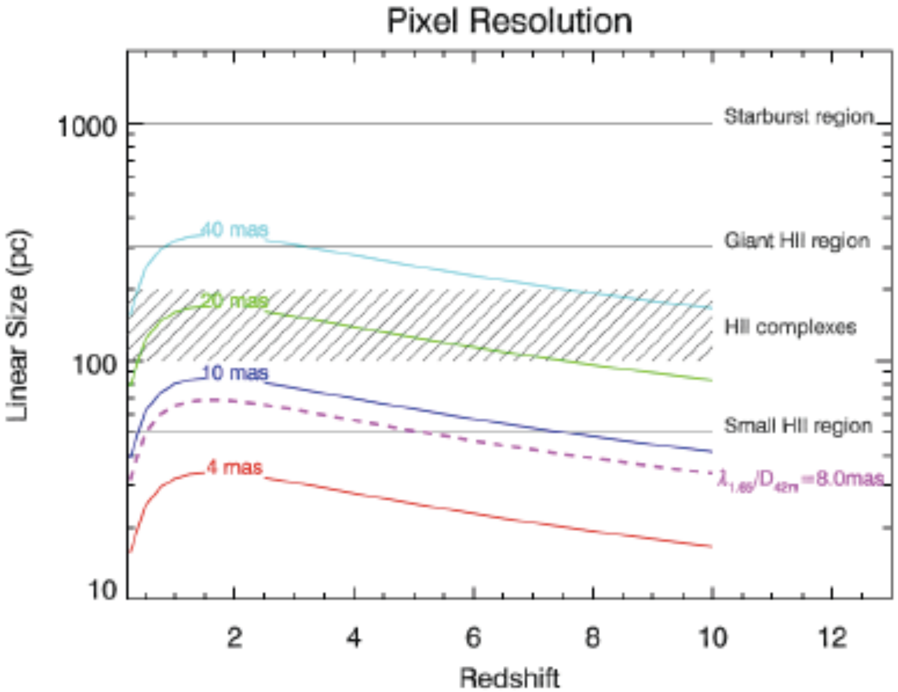






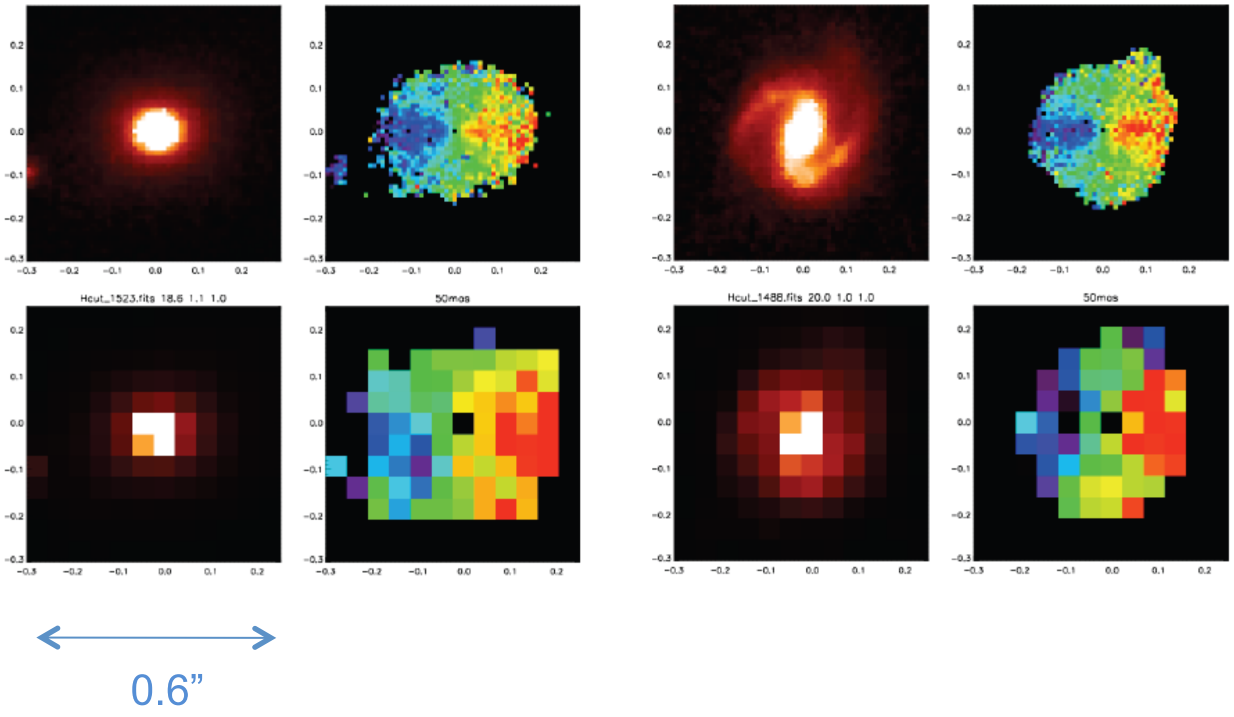
HARMONI science case





HARMONI science case

Simulation of 2 HUDF galaxies observed at 5 (upper row) and 40 mas scale (lower row). Intensity (left) and velocity maps (right).



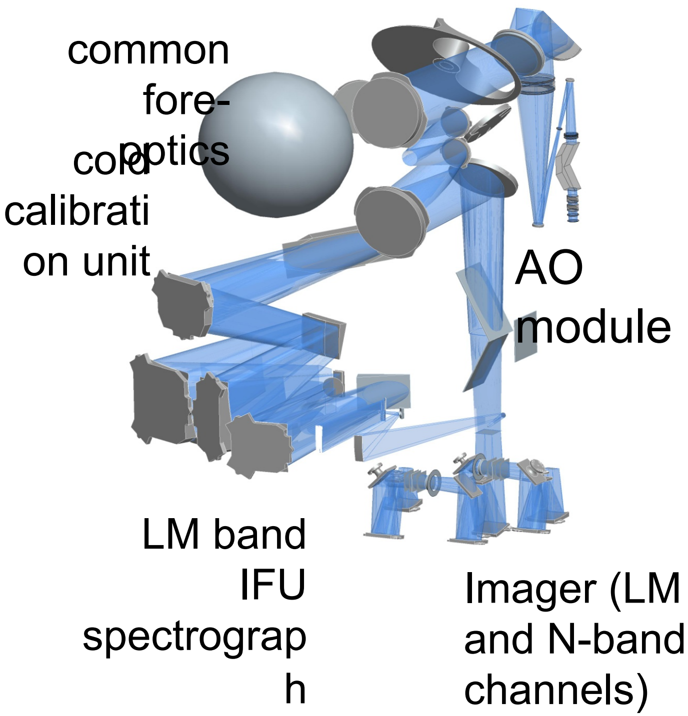
METIS Study

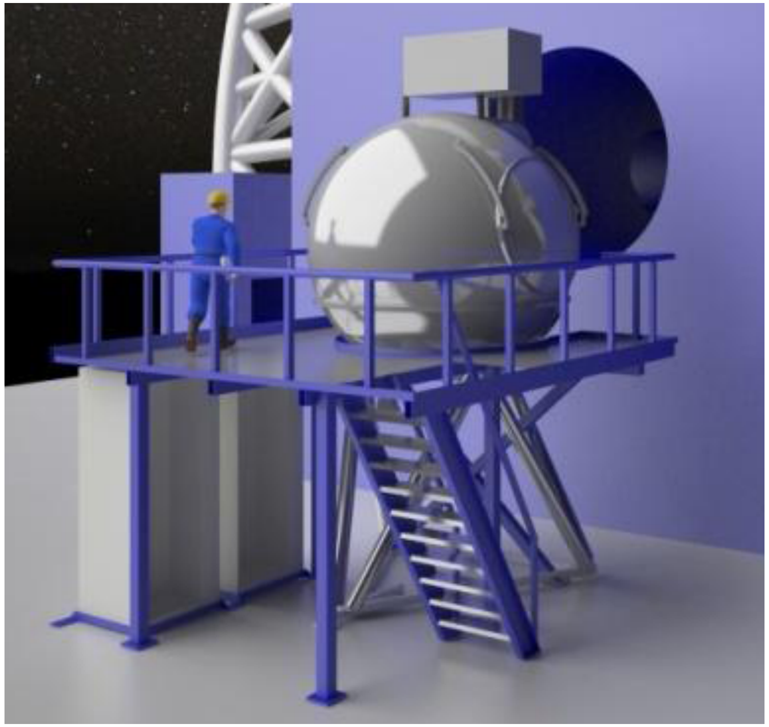
Table 1-1 Overview of the METIS partners (without the technical team).

Project Board	Insitutions & co-Is	Science Team members
Principal Investigator Bernhard Brandl	***NOVA*** – *the Netherlands* Bernhard Brandl	Ewine van Dishoeck Paul van der Werf
Instrument Scientist Rainer Lenzen	***MPIA*** – *Germany* Rainer Lenzen	Thomas Henning Wolfgang Brandner
Project Manager Frank Molster	***CEA Saclay*** – *France* Eric Pantin	Pierre-Olivier Lagage
Systems Engineer Lars Venema	***KU Leuven*** – *Belgium* Joris Blommaert	Christoffel Waelkens Maarten Baes
	UK ATC – *United Kingdom* Alistair Glasse	Jim Hough Toby Moore
		Hermann Böhnhardt (MPS) Ulli Käufl (ESO)

Mid-Infrared Diffaction Limited Imager, Medium and High Resolution Spectrograph

METIS Concept and specifications





Diffraction limited imager [18″×18″]

- L/M (3.0-5.3μm)
- N band (7.0-14.0μm) Includes coronography, R=5000 slit spect., polarimetry

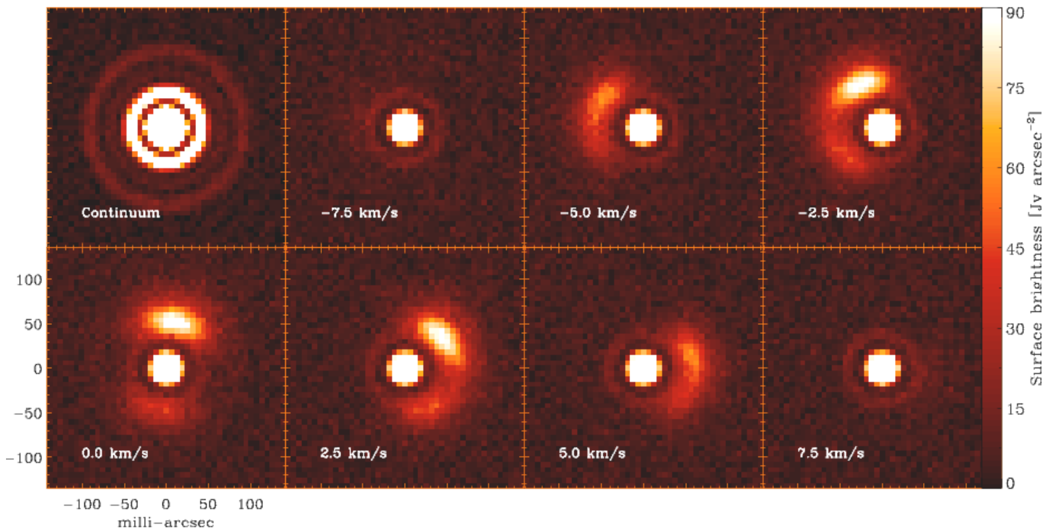
- High resolution spectrograph for L/M
- (R ~ 100,000), IFU [≥ 0.4″×1.5″]
- On board SCAO for bright targets; LTAO for full sky coverage

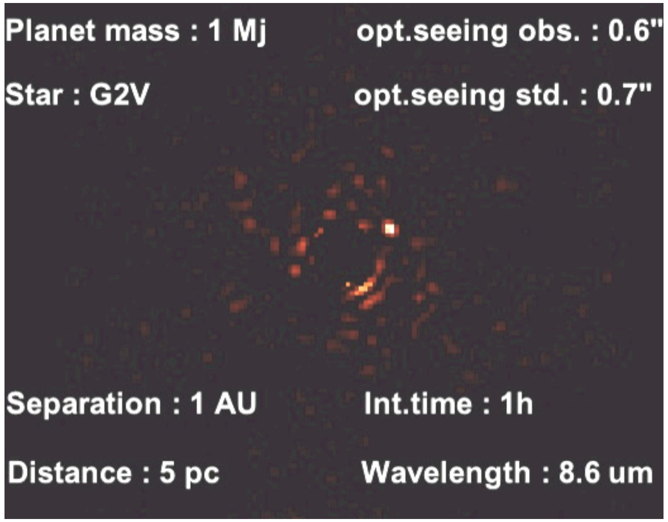
METIS Science goals and performance

- *Proto-planetary disks and formation of planets*
- *Physical and chemical properties of exo-planets*
- *The growth of supermassive black holes*
- *Morphologies and dynamics of high-z star forming, dusty galaxies*
- *Brown dwarfs, evolved stars, formation of high-mass stars*

Limiting magnitude (point source, 1 hour, 10-σ, Paranal-like site)	*Imaging [mag]: 21.7 (L), 18.4 (M), 15.3 (N)* *Imaging [μJy]: 0.6 (L), 7 (M), 28 (N)* *Medium R spectroscopy [μJy]: 15 (L), 46 (M), 507 (N)* *High R IFS line sensitivity [10^{-21} W/m^2]: 0.9 (L), 2.6 (M)*

METIS Science Goals





Left: Simulation of a METIS image cube of the CO P(8) line from SR 21 for an assumed distance of 125 pc (Pontoppidan et al. 2009).

Right: Simulated 1 hr METIS coronagraphic observation at 8.6 μm of a 5 Gyr old, 1 M_{Jup} exoplanet at 1AU separation from the star, which is at 5 pc distance.

MICADO

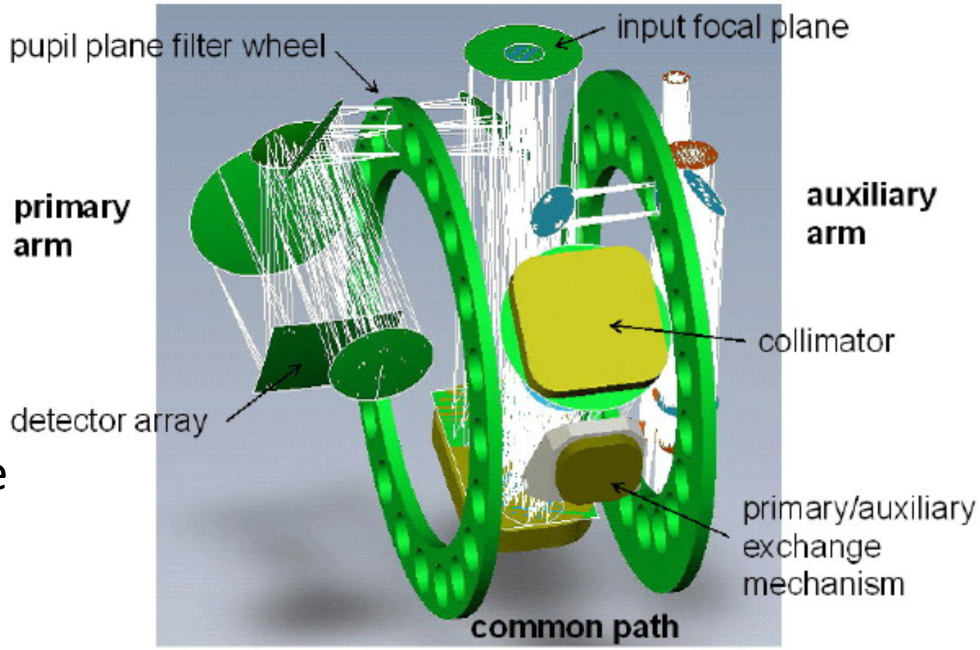
PI: Reinhard Genzel, **PM**: R. Davies (both MPE

Camera for diffraction limited imaging with simple slit spectroscopy capability

- *The Galactic Center*
- *Astrometry of GC and Dwarf Spheroidal Galaxies*
- *Resolved stellar population up to Virgo*
- *Resolved structure and Physical Properties of high z galaxies*

Formation & evolution of Galactic Nuclei and Black Holes

MICADO

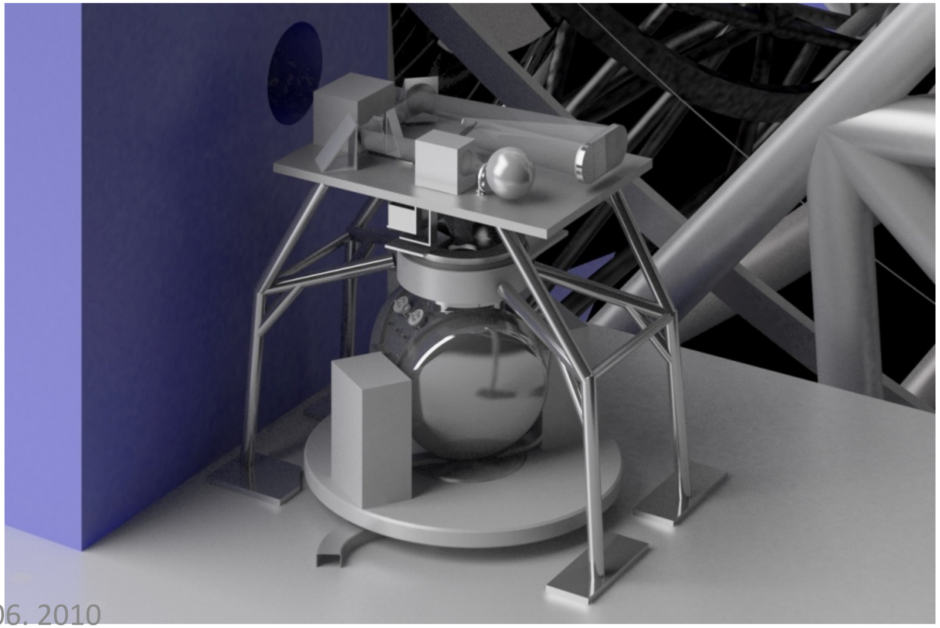


Primary Imaging Field

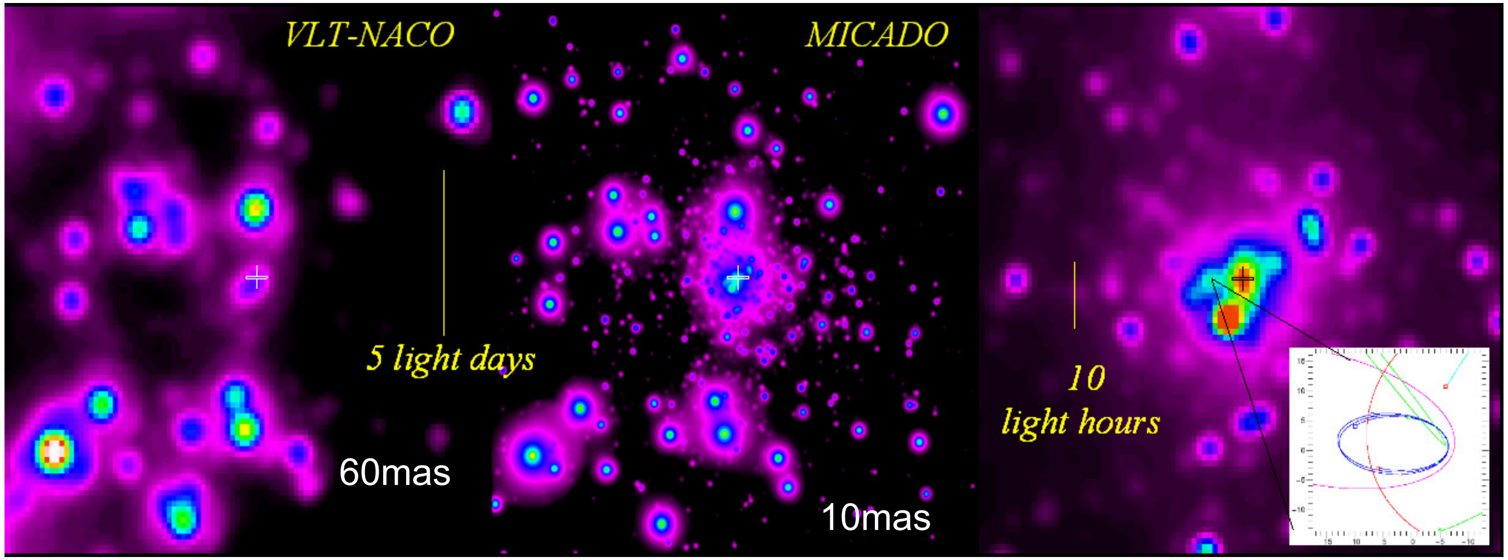
- 53" x53", 3mas pixels on 4x4 $4k^2$ NIR arrays
- SCAO initially. MCAO baseline
- high throughput 0.8-2.5 μm
- ~20 filter slots

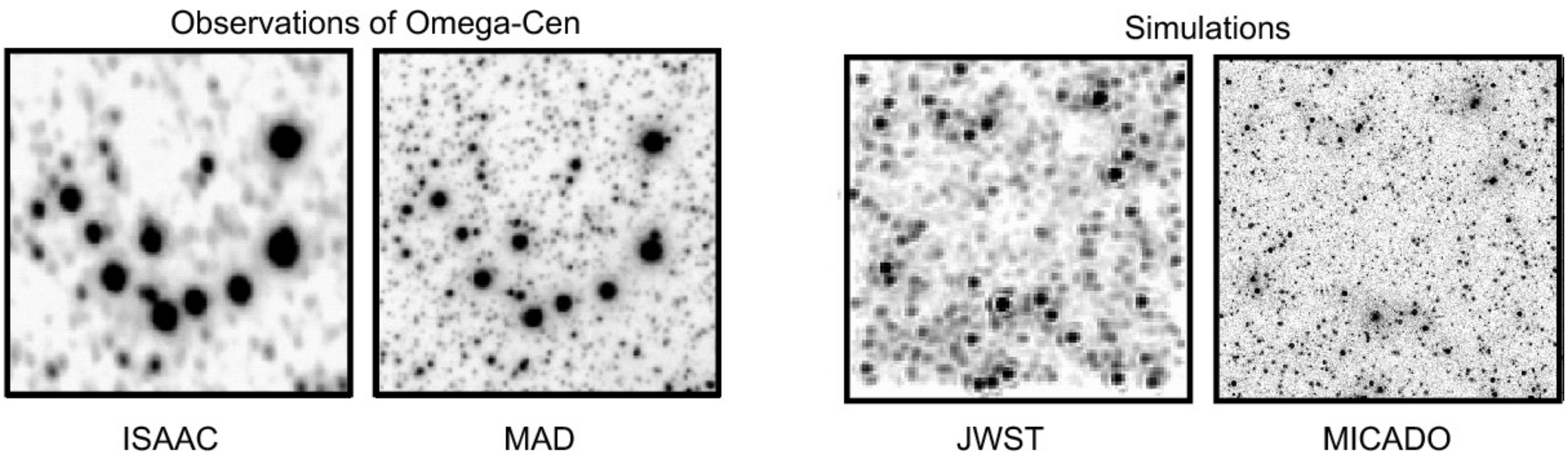
Auxiliary Arm

- 1.5mas & 4mas pixels
- imaging & long slit spectroscopy R=3000 with 12mas width
- ~20 filter slots
- potential for additional options (HTR, tunable filter)



MICADO


VLT-NACO
MICADO
5 light days
60mas
10mas
10
light hours


Observations of Omega-Cen
Simulations
ISAAC
MAD
JWST
MICADO

OPTIMOS: an advanced concept study for a visible-NIR multi-object spectrograph

Two different implementations

- OPTIMOS-EVE fibre-based
- OPTIMOS-DIORAMAS: slits, 4 channel focal-reducer

Sharing "service " workpackages

- Detectors, control electronics (RAL)
- Control software (INAF-Obs.Trieste)

OPTIMOS-DIORAMAS Study

PI: Olivier Le Fèvre (LAM)

coPI: D. Maccagni (IASF), S.Paltani (Obs.Geneve), G.Dalton (RAL)

Instr. Scientist: B. Garilli (IASF) , PM: D. LeMignant (LAM), SE: L.Hill (LAM)

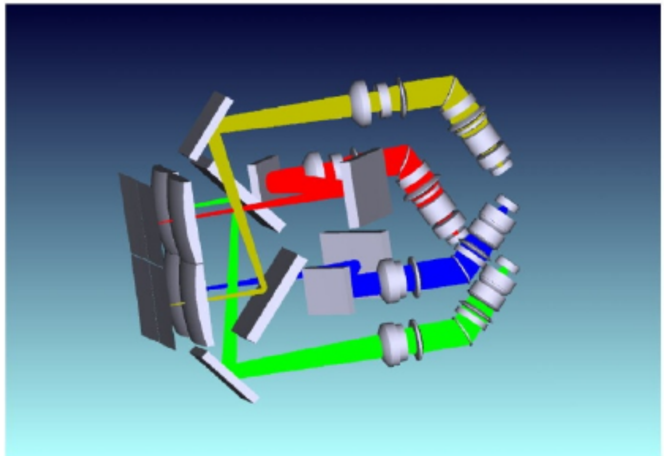
At ESO: S.Ramsay, F. Zerbi

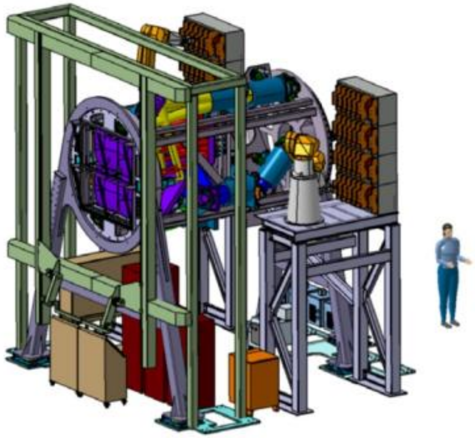
Four channel imager and slit (via mask) visual+J spectrograph

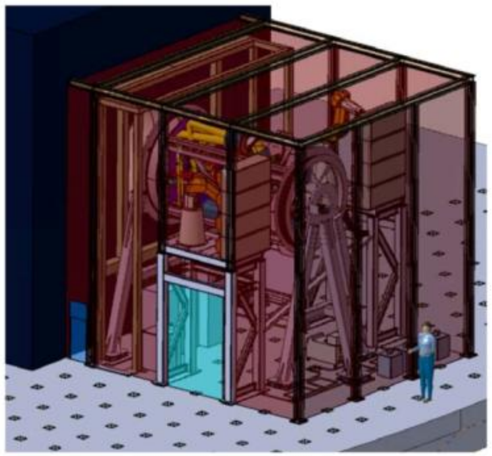
IASF Mi, OATs

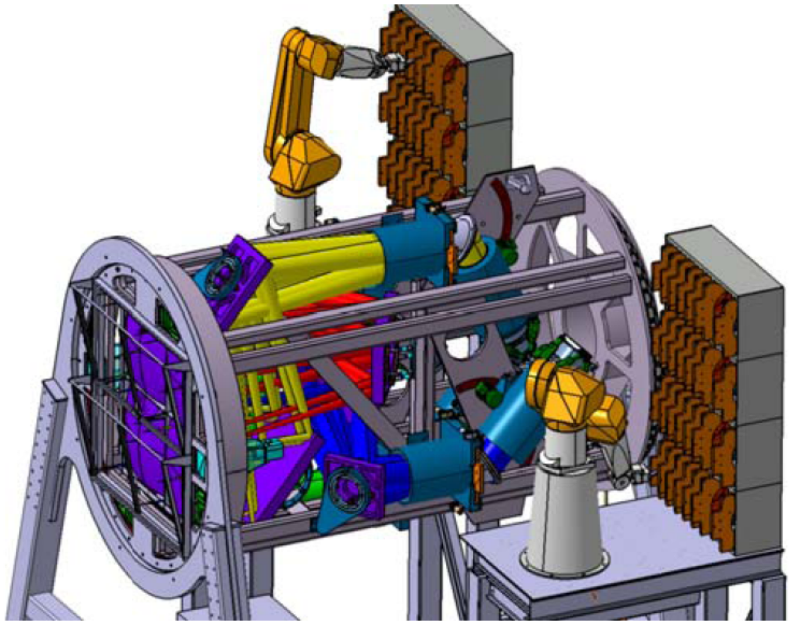
Specification and concept

- 4 channels MOS and Imager over 6.8'x6.8' FOV
- Spectral range 0.37-1 µm for the 2 V channels, 0.6-1.4 µm for the 2 NIR
- Standard visible and NIR filters for imaging
- Max 480 slits in the visible range, 120 for NIR
- R~300, ~1000, ~2500
- Seeing-limited or GLAO









OPTIMOS-DIORAMAS Simulations

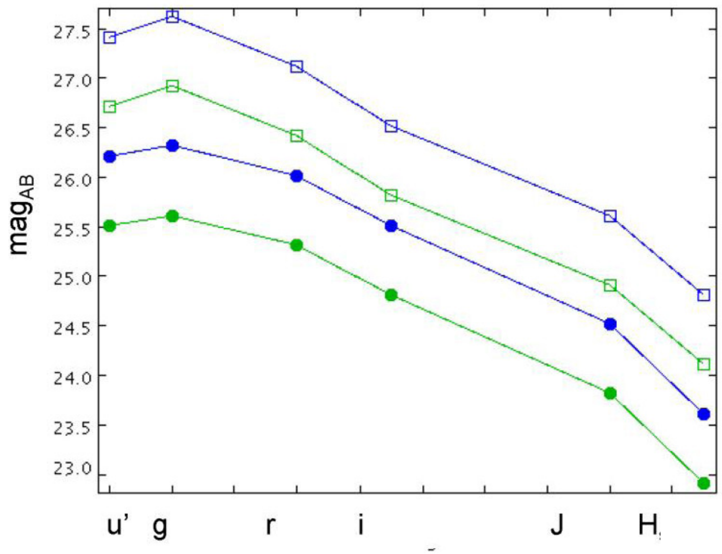
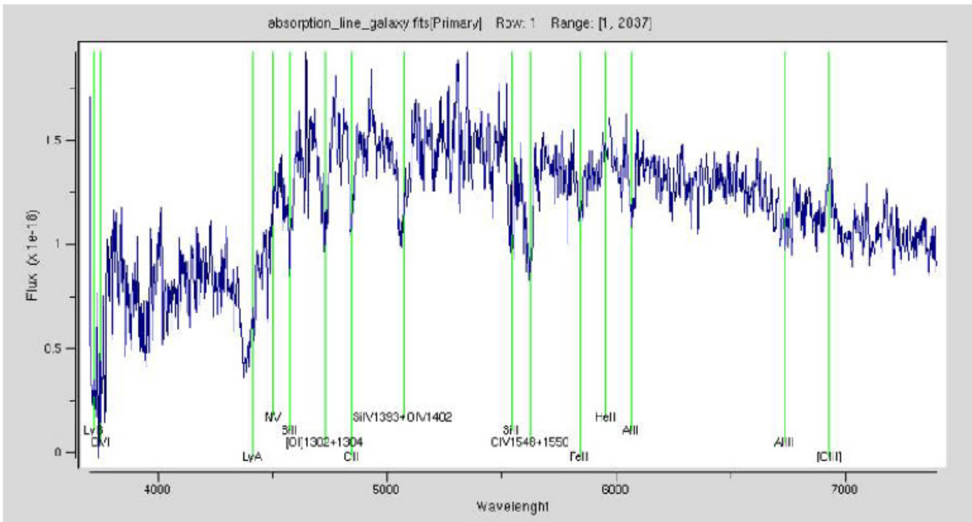


Fig.1. Continuum limiting magnitudes in spectroscopy for 4hrs integration, 3σ. Natural seeing FWHM 0.75" ; Slit width 0.5"
Extended source 2" Ø.
Squares: R=300;
Circles R=3000; Blue: point sources; green extended sources



Simulated spectrum of a galaxy with I_{AB}~ 24 at z~3 observed for 40min in the LR VIS mode with DIORAMAS

OPTIMOS-EVE study

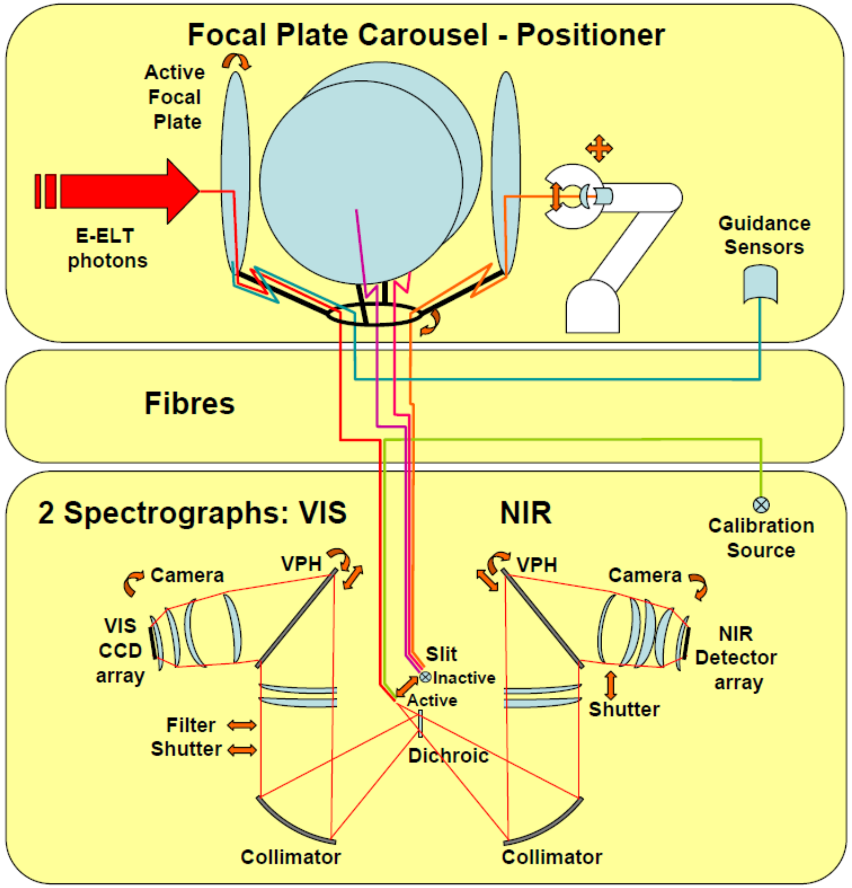
PI: F. Hammer (GEPI)
coPI: L. Kaper (UvA), G. Dalton (Oxford); **Project Scientist**: P. Bonifacio (GEPI)

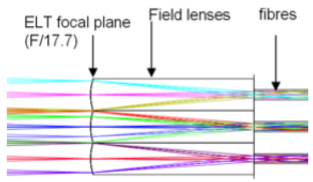
GEPI (France)
NOVA (The Netherlands)
RAL (UK)
NBI (Denmark)
INAF (**Obs. Trieste** and Brera)

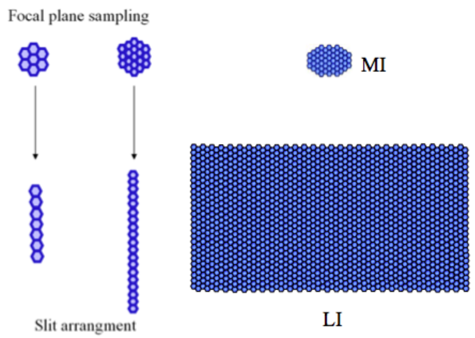
Multi-fiber, multi-dispersion VIS+J ,H spectrograph for the 7’ unvignetted field of E-ELT

EVE Specifications and Concept

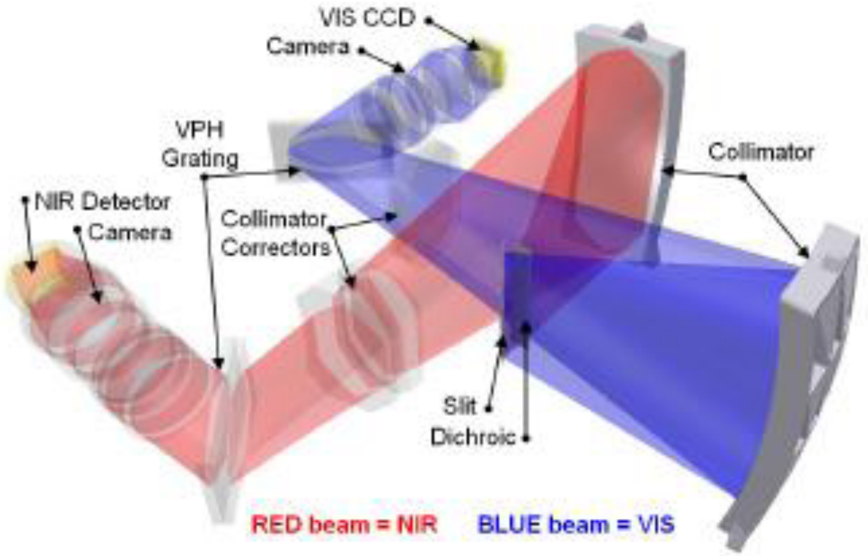
- 0.37μm-1.7μm
- Patrol field - ~7arcmin
- 240 single fibres /R~5000/.9”
- 70 fibre bundles / R~15000
- 40 fibre bundles / R~30000
- 30 IFUs 1.8” x 3” (R=5000)
- 1 IFU 7.8”x13.5” (R-5000)
- *5s10h: V=26.2; I=25.8; J=25.3; H=24.8 @ R=5000*
- Seeing-limted or GLAO

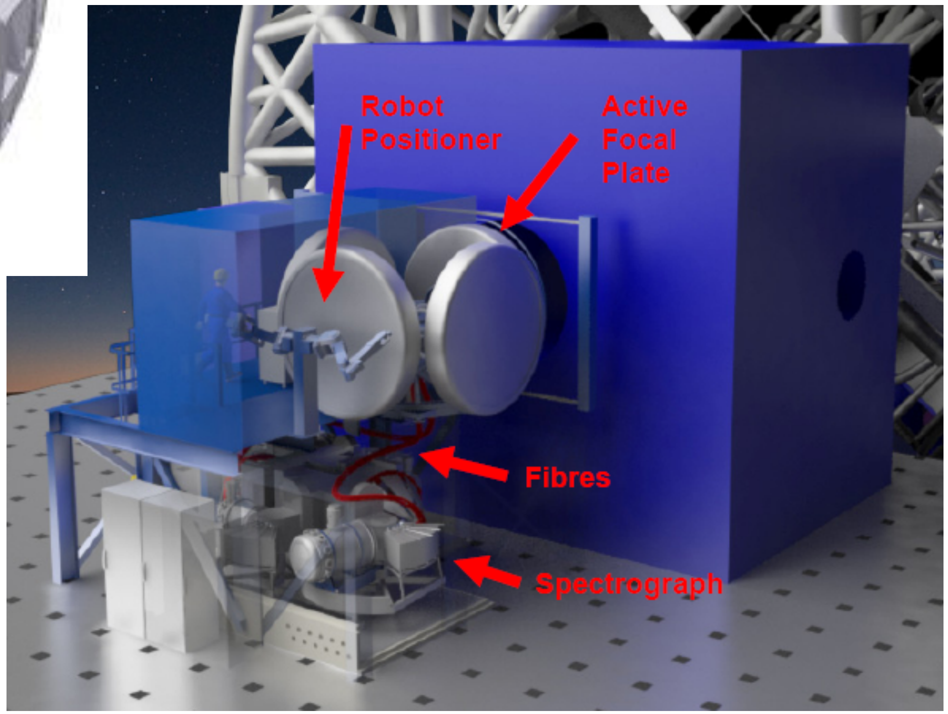




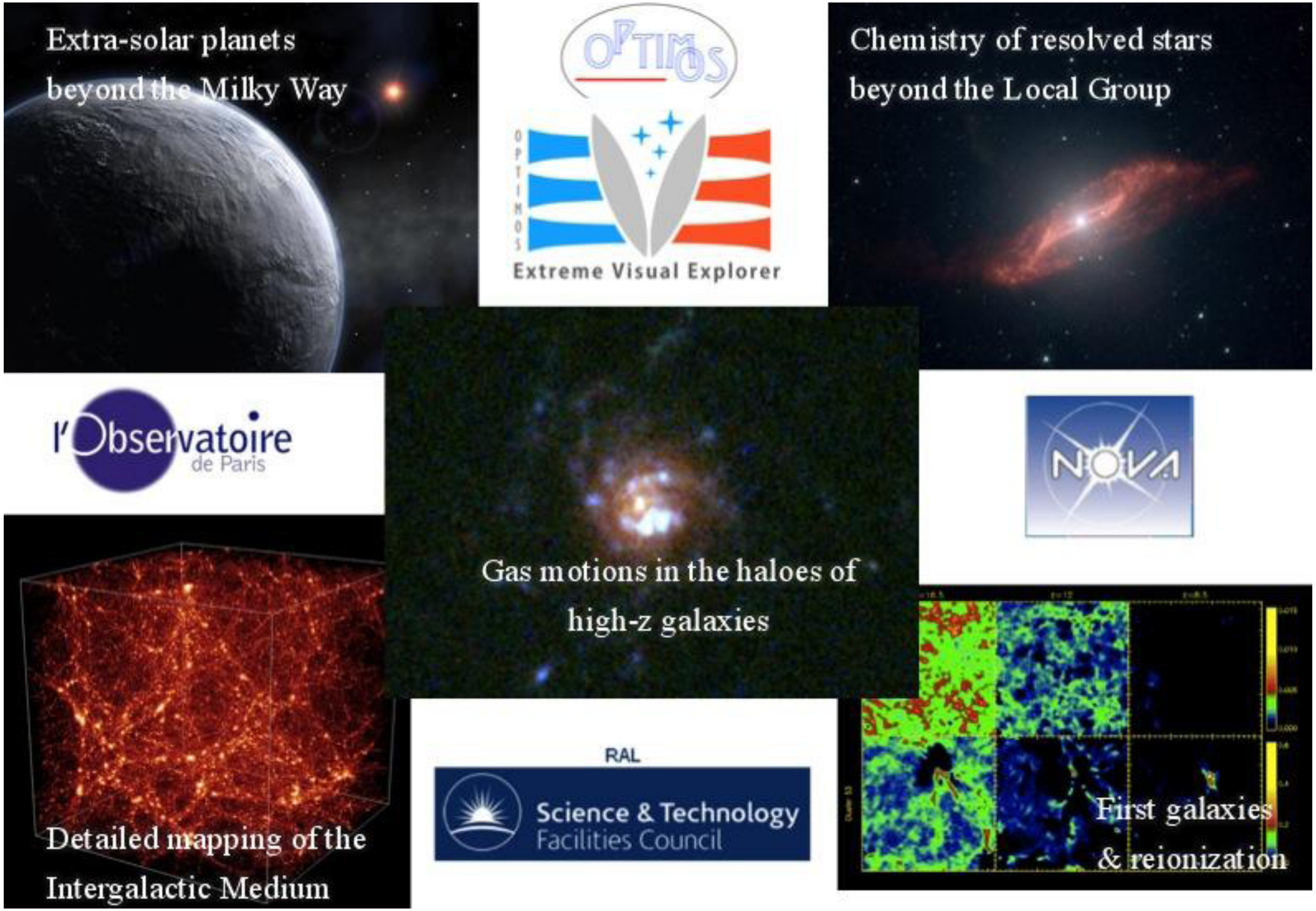


EVE Concept


VIS CCD
Camera
VPH
Grating
NIR Detector
Camera
Collimator
Correctors
Collimator
Slit
Dichroic
RED beam = NIR
BLUE beam = VIS


Robot
Positioner
Active
Focal
Plate
Fibres
Spectrograph

EVE Science Goals



SIMPLE study

PI: Livia Origlia INAF OBo)

P.M. & System Engineer: T.Oliva (INAF Arcetri)

Science Team Chair: B. Gustavson

INAF Obs. Bologna, Arcetri, Roma

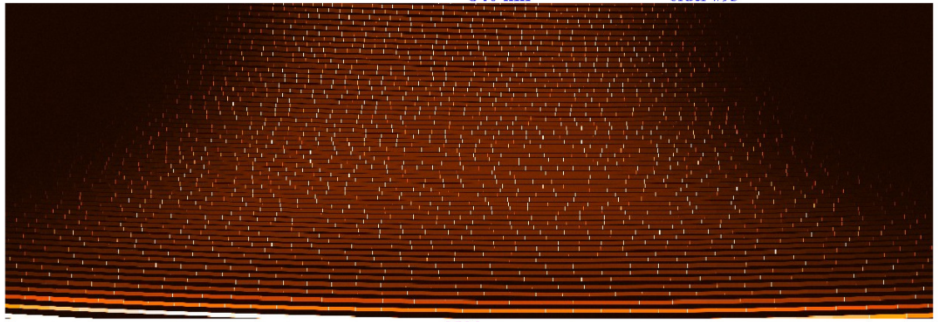
Uppsala Astronomical Observatory and University

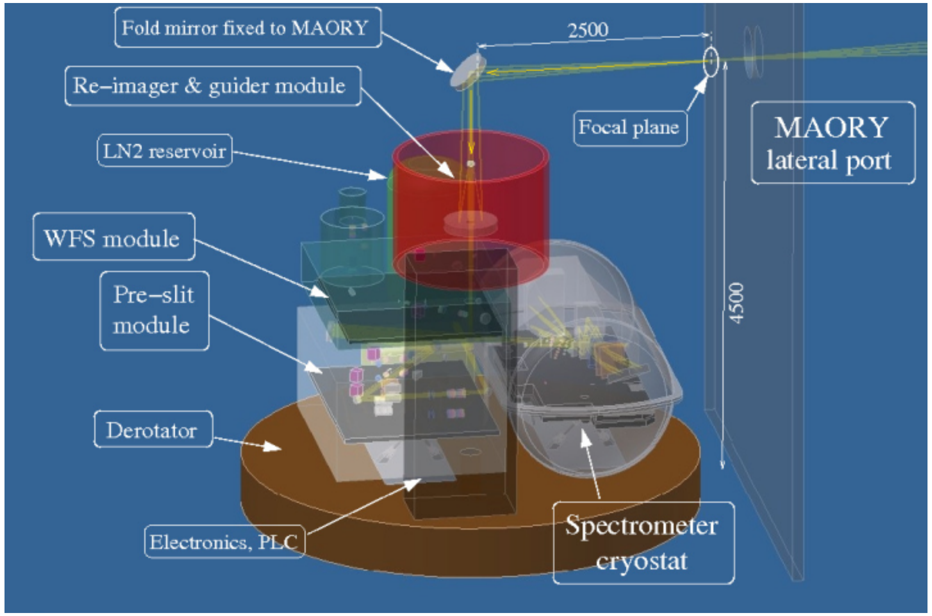
Thüringer Landessternwarte Tautenburg

Pontificia Universidad Catolica (Chile)

High Resolution NIR echelle spectrograph

SIMPLE concept and performance





- 0.84-2.5μm instantaneous coverage
- 9 mas spatial sampling
- R~130,000 with 27x450mas slit
- Wider slits with corresponding lower resolution
- 4”long slit with reduced λ coverage
- spectro-polarimetry
- SCAO for bright sources, LTAO for full

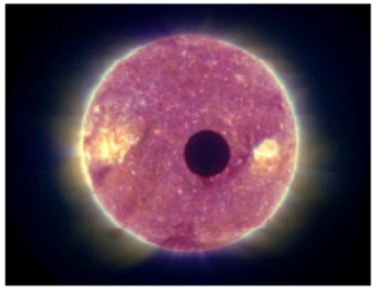
Table 5.5.3: Limiting Vega-magnitudes(1) for spectra at R=130,000(2) with on-source integration time=2hr.

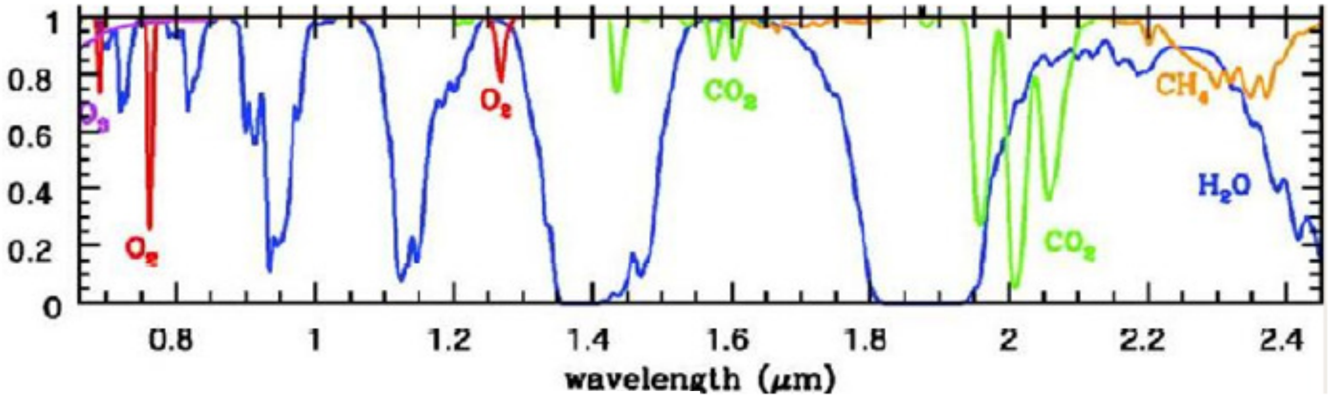
Band (λ)	S/N values					
	10	20	50	100	300	10^3
I (0.90 μm)	19.6	18.7	17.5	16.4	14.3	11.7
Y (1.05 μm)	20.3	19.4	18.2	17.1	15.0	12.4
J (1.25 μm)	20.6	19.8	18.6	17.5	15.4	12.8
H (1.65 μm)	20.8	20.0	18.8	17.7	15.6	13.0
K (2.20 μm)	20.4	19.6	18.4	17.4	15.3	12.8

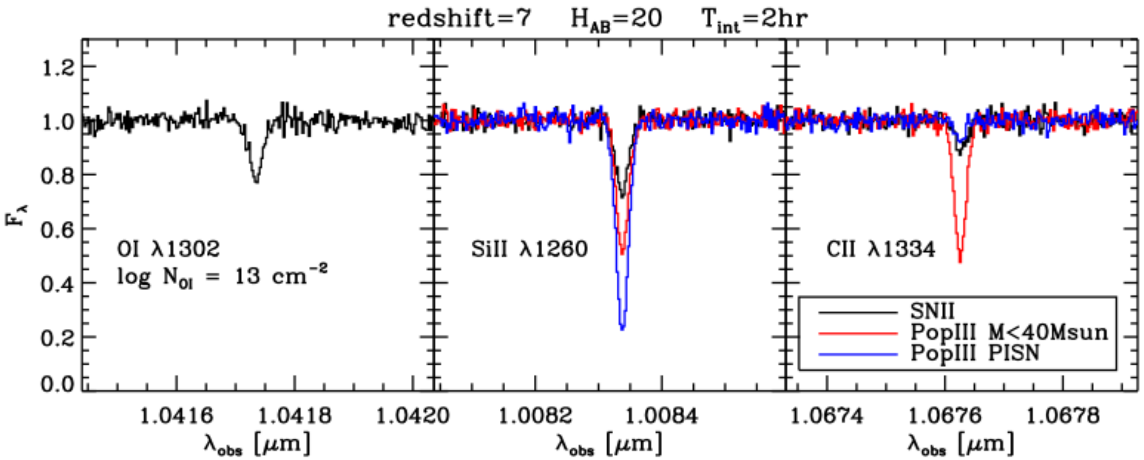
Notes
(1) S/N ratio is computed per spectral resolution element.
(2) The entrance aperture is 27 *mas* x 54 *mas*. LTAO/MCAO image correction is assumed.

SIMPLE science goals

- Exoplanets (inc atmospheres)
- Cool stellar populations
- Metallicity evolution at high z
- Extragalactic star clusters
- Galactic Centre stars







Different abundance patterns of the intervening proto-galaxy. The black line is for abundances typical of SNe II; the red line is for abundances expected from Population III stars with masses M<40 M while the blue line is for abundances from Population III Pair Instability Sne.

E-ELT Instrumentation Studies and Plan

Instrument and AO modules Study Plan (STC 430, April 2007)

- Study Plan for 8 instruments and 2 AO modules studies 2007-2010
- **2.3 Ml** Budget 2007-2010, 30 ESO FTE for Study Phase

11 studies completed and reviewed. Instr. Plan in writing. First completed draft by July 2010

- Overall instrumentation budget in construction proposal presently at **100 Ml** including ESO FTE
- 2 instruments identified in the Construction Proposal, other 3-4 to be selected in 2012 and 2014

INSTRUMENTATION PLAN FOR THE E-ELT CONSTRUCTION PROPOSAL

ESO/COU 1275, December 2009

Nr.	Evaluation Criteria for E-ELT instrument selection
1	**Scientific Merit :** (a) the instrument addresses science goals identified as of highest priority for the E-ELT (b) the instrument can be conceived as an E-ELT workhorse to be used for a variety of programmes, leading to a broad spectrum of potential discoveries (c) the instrument will benefit and complement observations of other major facilities in astrophysics like ALMA and the JWST , which will be already in operation at the time of first light
2	**Proven Technical Feasibility and Simulated Performance:** the instrument feasibility and its expected performance have been properly demonstrated in the study
3	**Affordability:** (a) the instrument cost is well estimated and justified (b) the cost to ESO falls within or close to the preliminary budget envelope.
4	**Timely Match to the telescope + PFAO performance**: the instrument schedule of implementation is well matched to the path of the telescope +AO to full performance. The instrument includes the possibility to do prime science even during the time when the telescope cannot operate with AO.

CURRENT ESO PROPOSAL FOR E-ELT INSTRUMENTATION (June 2010)

- Two first light instruments: HARMONI (simplified version) and MICADO, to be launched in 2011

- Other observing capabilities to be included in first batch:
  - high resolution, high stability optical spectroscopy
  - mid-infrared imaging and spectroscopy
  - MOS facility
  - High angular resolution, high contrast camera-spectrograph for planet detection

  Priority to be revisited in 2012

- Other capabilities under study: near IR high spectral resolution, high time resolution

- By 2027 complement of 7 instruments of which any time 5 in operation


Thank you