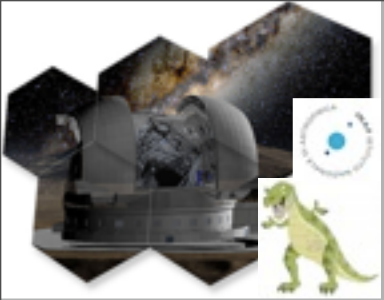


Multi Object Spectroscopy @ E-ELT
How and Why

Adriano Fontana on behalf of the T-REX MOS Unit

Unit Leader: B. Garilli

This presentation heavily relies on contribution from
Bono, Fiore, Held, Li Causi, Longhetti, Maccagni, Pedichini, Pentericci, Zibetti...

Background: a strong italian participation to the first proposals of MOS instruments at ELT (OPTIMOS-EVE (Obs Paris) and OPTIMOS-DIORAMAS (Obs. Marseille))

First action: a dedicated science meeting aimed at:

- collecting the science cases;
- defining technological involvments;
- discuss various tradeoffs for optimization (slit vs fiber, resolution, IR vs Opt etc)

Meeting held at INAF HQ on Dec 19.

OPTIMOS-EVE

Observatoire de Paris, RAL-UK, NL-Nova, University of Copenaghen, etc.

Builds on consortium experience with VLT instruments:

- FLAMES/GIRAFFE, fibre-fed, medium res. instrument with multiplexing of 132 + multi-IFU,
- X-shooter, large spectral coverge, medium res.

Fiber-fed instrument = versatility

Spectral range from 370 to 1600nm

R>4000 (5000-30000)

Multiplex>200 on 7’ (goal 10’)

Different aperture on sky and spatially resolved spectroscopy

DIORAMAS

Use EELT natural seeing of GLAO corrected beam

Wide field: 7x7 arcmin

0.37-1.6 um, 2 VIS and 2 NIR channels, simultaneous

Imaging

Spectroscppy mean slit 0.5”, min 0.1”

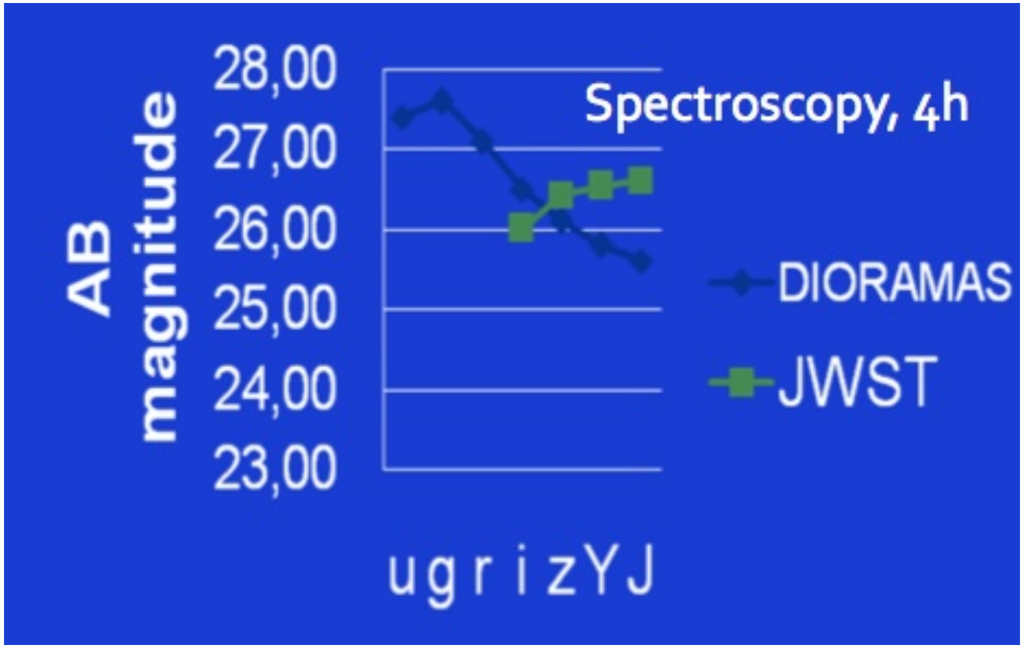
Multiplexing: 480 slits at R~300, 160 slits at R~2000-3000

GLAO: from 0.7 to 0.4 arcsec over FOV

Limiting mag. in spectroscopy: AB~26.5

MOS@E-LELT VS JWST

gain@1um compared to NIRSPEC
X5 multiplex
X2.5-5 fov at equivalent depth/unit time



MOS@E-ELT will be competitive also during and after the JWST era.
"Sweet spot" science cases involve the study of:

- faint (24<m28) ***and***
- relatively rare (≤ 1/arcmin^2)
- targets

Italian researchers (theo.+obs.+tech.) interested in developing science cases on nearby stellar populations for MOS@E-ELT

Why Carina dSph?

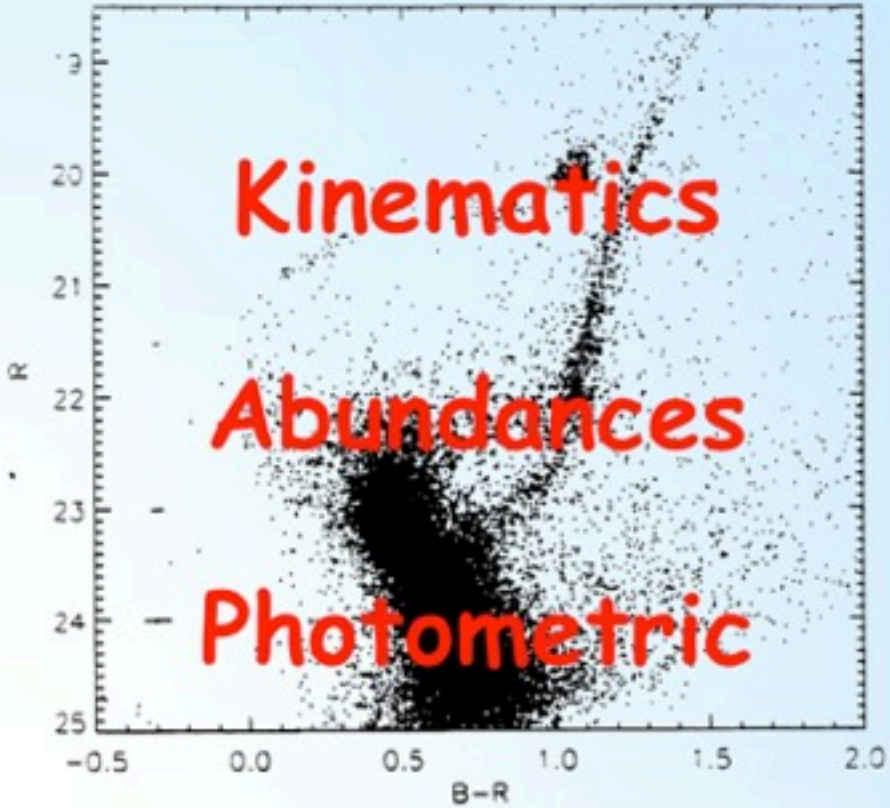
Close ~100kpc

Low density ρ = 0.17 $M_{\odot}$/ pc^3

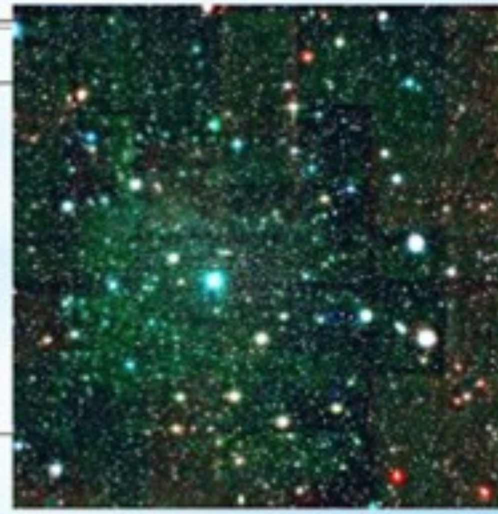
Well separated radial velocity peak from field stars

Multiple separated star formation episodes

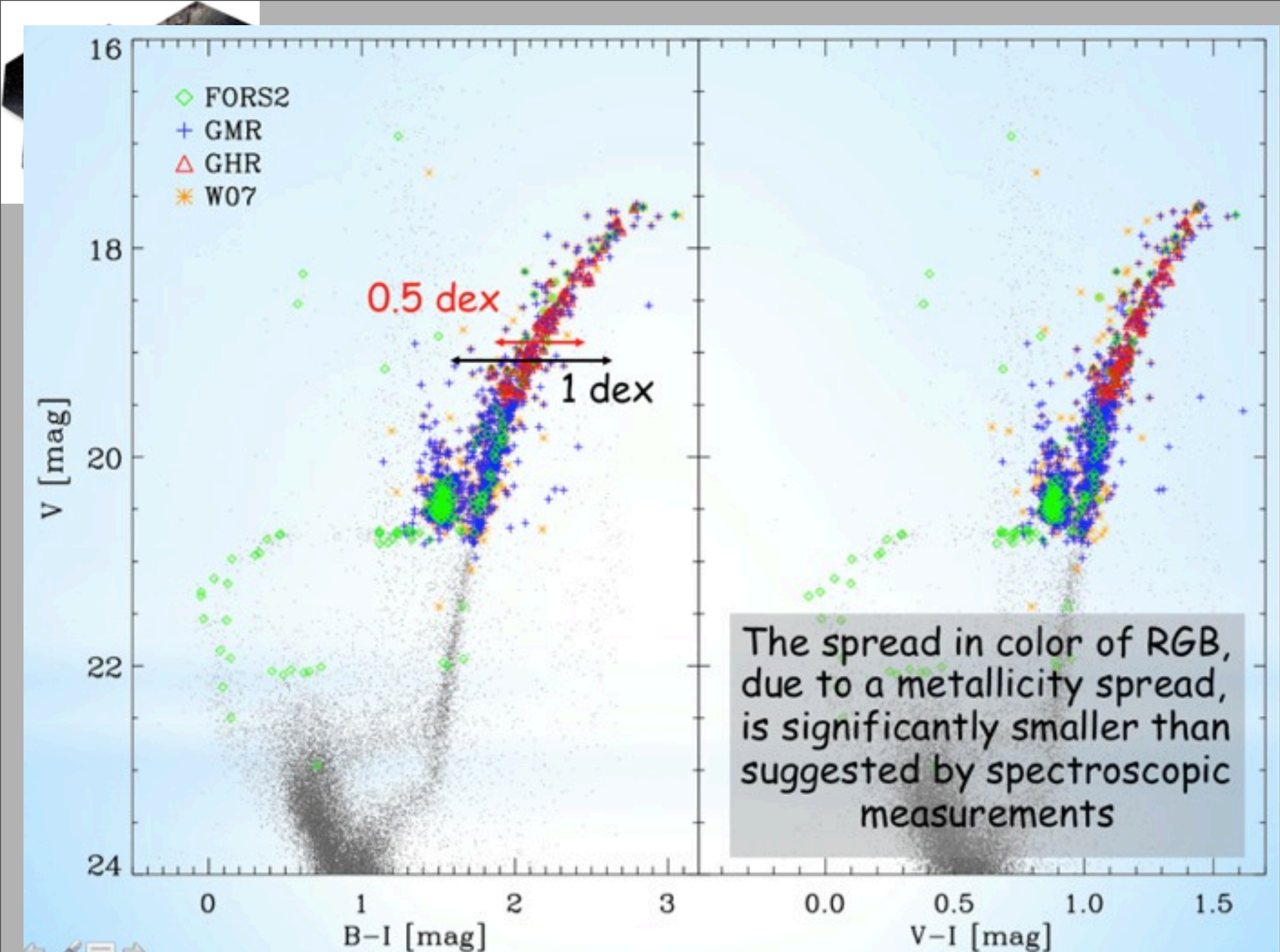
Metallicity distribution from ~-2.5 to ~0.5 dex



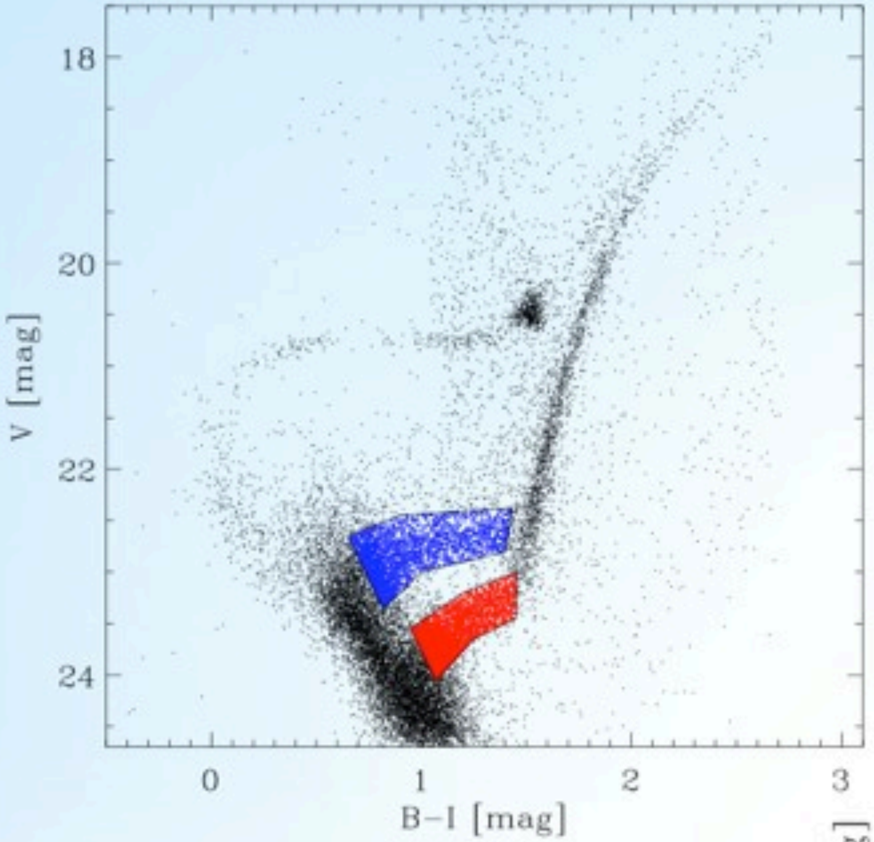
Parameter	Values
α (J2000)	06 41 37
δ (J2000)	−50 58 00
M_V[a] (mag)	−8.9
r_c[b] (arcmin)	11.96 ± 1.5/14[c]
r_t[d] (arcmin)	22.54 ± 1.4/32[c]
e[e]	0.32 ± 0.04
P.A.[f] (deg)	64 ± 2.5
σ_V[g] (km s^{-1})	6.8 ± 1.6
[Fe/H][h]	−2.0 ± 0.30
$E(B-V)$[i]	0.04 ± 0.02
$(m-M)_0$[j] (mag)	20.03 ± 0.09

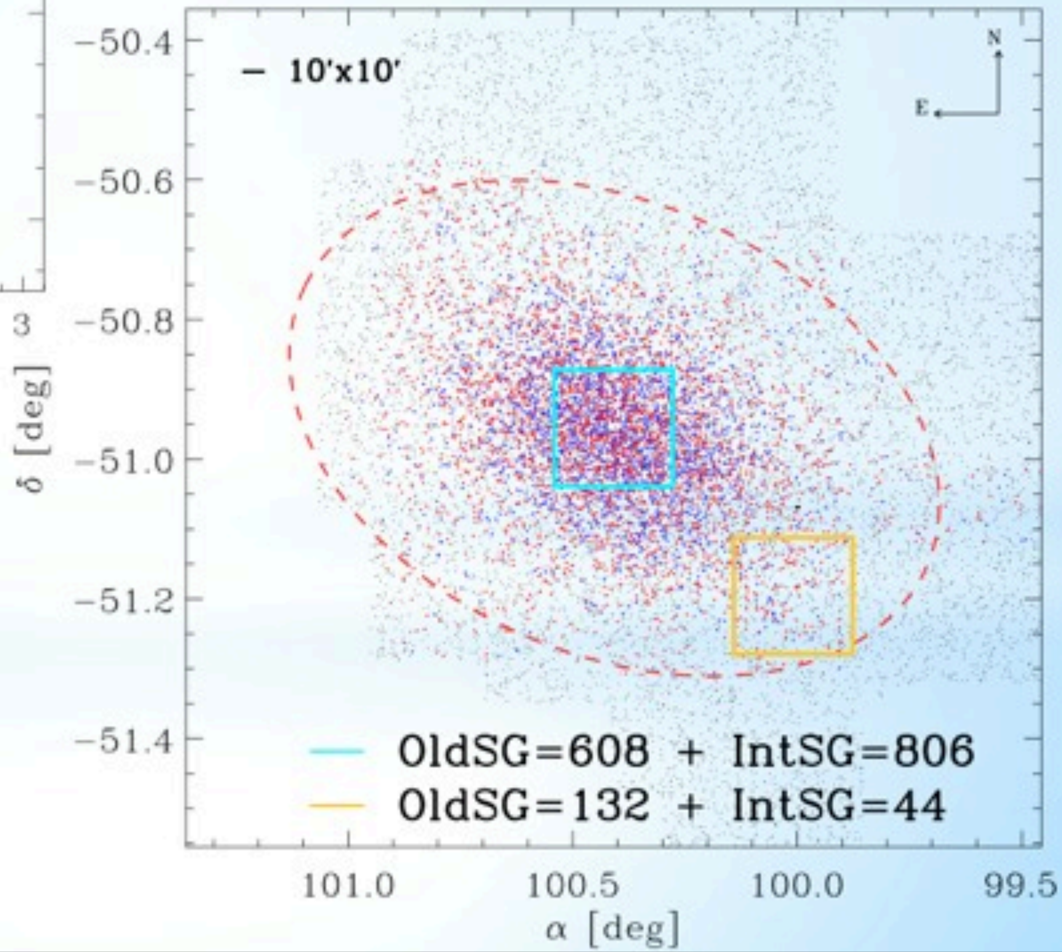


Smecker-Hane et al. 1996
Mateo 1998


FORS2
GMR
GHR
W07
0.5 dex
1 dex
V [mag]
16
18
20
22
24
0
1
2
3
B−I [mag]
0.0
0.5
1.0
1.5
V−I [mag]
The spread in color of RGB, due to a metallicity spread, is significantly smaller than suggested by spectroscopic measurements

Carina in MOS@E-ELT





Requirements:

- FoV
- Multiplex
- Limiting magn.

Requirements for MOS@E-ELT in the NIR

Large FoV > 7'x7' (goal 10'X10')

High multiplex > 200

Spatial res. < 0.3—0.9 arcsec

Kinematics (+met. Ind.)

Low-res R~3,000—4000

Limiting mag. J,H~25 mag

S/N ~10-15 (50h)

Abundances

High-res R~20,000—30,000

Limiting mag. J,H~23 mag

S/N~60-80 (30h)

Simultaneous multiplexity between medium and high resolution

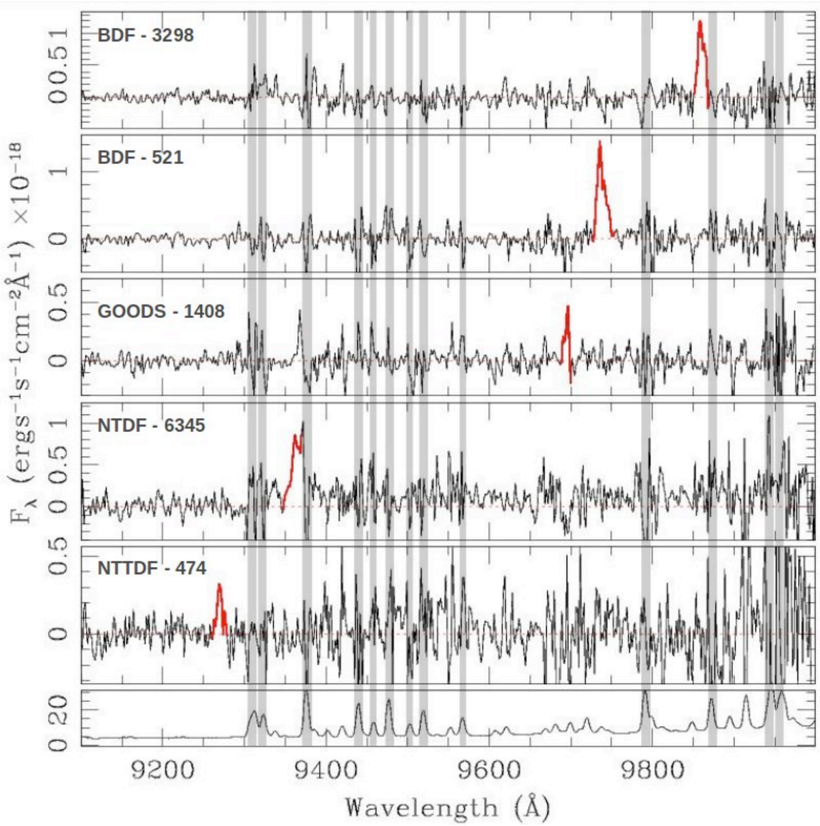
I The first galaxies: exploring the end of the dark ages; (Pentericci, Fontana, Grazian..)

2. Faint high redshift AGN: synergies with future X-ray facilities (Fiore, Comastri ...)

3. Quiescent old galaxies in the early Universe (Longhetti, Zibetti, Fontana..)

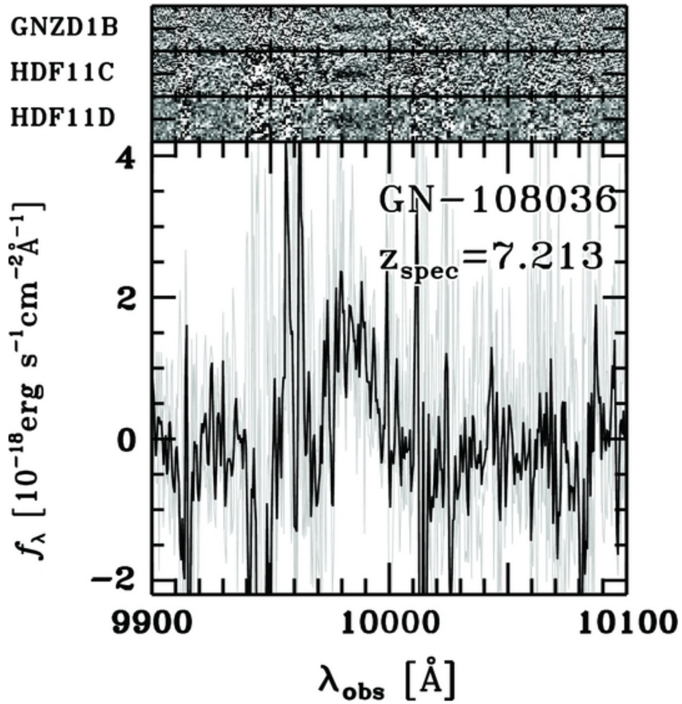
4.Stellar populations ant high z: Metallicity and kinematics of high redshift "normal" galaxies (Zibetti, Longhetti, Mannucci etc..)

I Exploring the dark ages: the highest redshift galaxies



z=7.109

Z=7.008



Pentericci+11
Vanzella+11
Fontana+10

O. Ouchi+12

The spectroscopic confirmation of high-z galaxies is hitting a "ceiling" at z≈7.2.

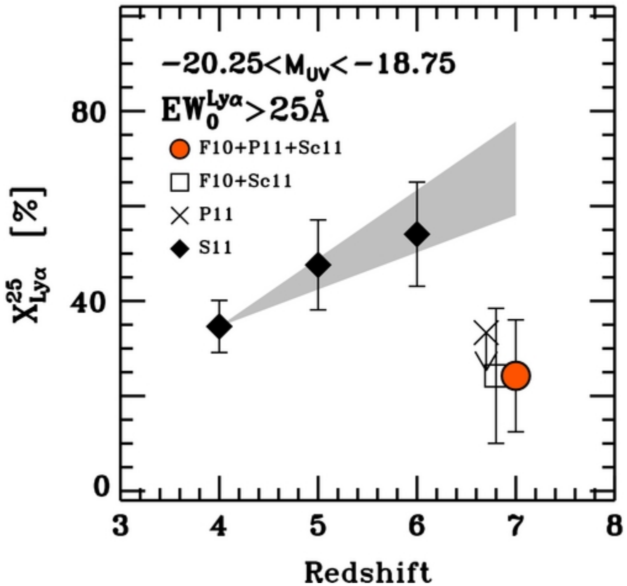
It is likely he combination of :

- a technology barrier (end of optical MOS, need for IR MOS)
- a sudden change in the properties of galaxies: **the first trace of reionization?**

We will need to detect the continuum of very faint galaxies (m27-28) with a low number density (<1/arcmin2)

Candidates will be accumulating slowly, we need to be able to observe them also after JWST era

We need follow up studies (kinematics) of the brightest confirmed galaxies.



@z=8
H=29 ~1 galaxy/arcmin^2
H=28 ~ 0.5 galaxies/arcmin^2
H =27-27.5 ~ 0.12 galaxies/ arcmin

Ono+12
Pentericci+11

2 . Detecting faint AGN at high redshifts: synergies with future X-ray facilities

Studying faint AGN at high redshift is essential to

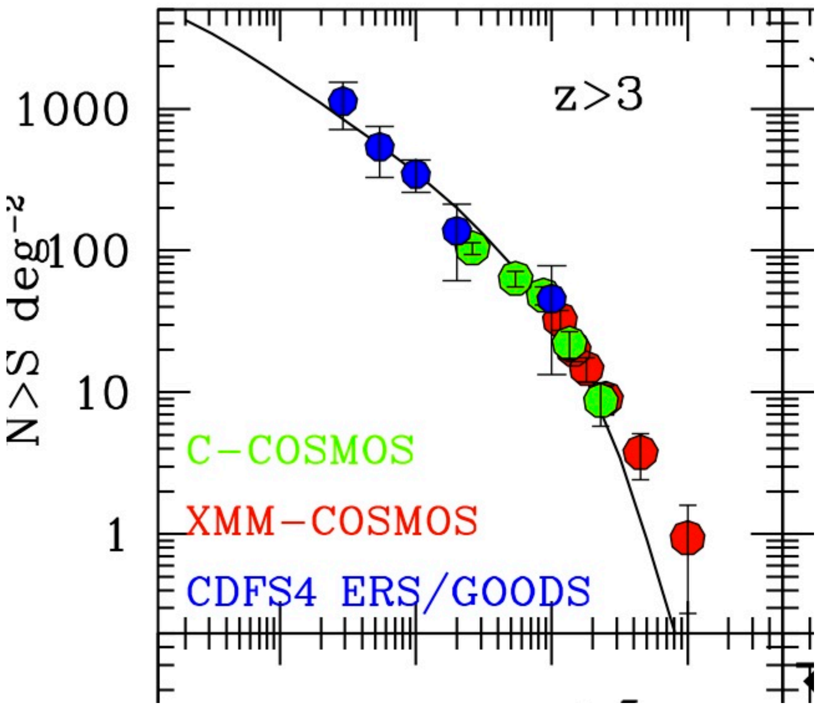
1. Understand the evolution of the correlation between black hole masses and galaxies properties

2. Determining the contribution of AGN to cosmic reionization (as opposed to galaxies) and to the heating of the IGM and its effect on structure formation

3. Understand the formation of black hole seeds that eventually grow to form supermassive BH seen in bulges.

4. Investigate the physics of accretion at high redshifts

Predicted number densities at flux =10^-17

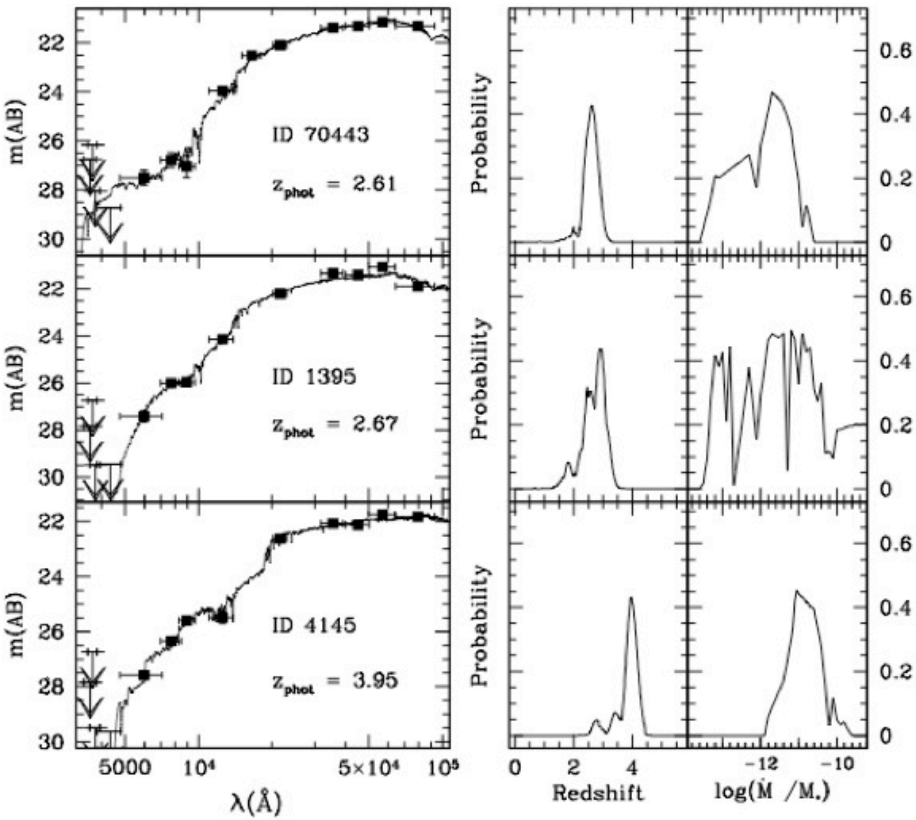


At a flux of 10^{-17} erg/s/cm^2 we expect ≈2000 AGN deg^{-2} at redshift > 3 i.e. 0.5 arcmin^{-2}

AGN with flux 10^{-17} erg/s/cm^2 have predicted magnitudes fainter than H= 27
E-ELT MOS is needed for Spectroscopic observations!

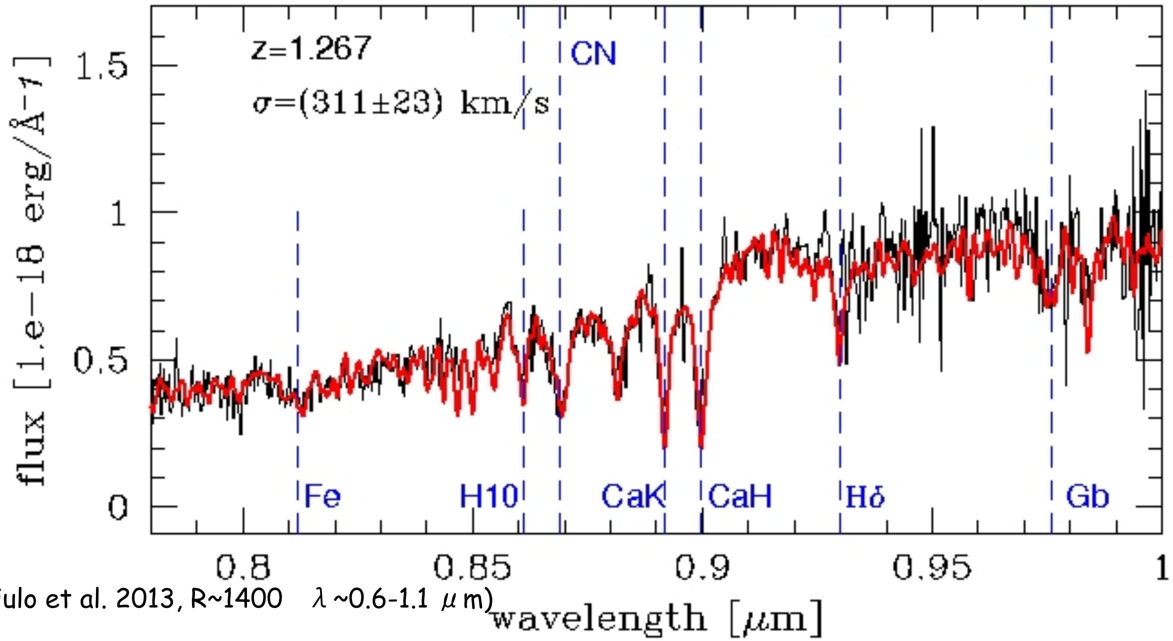
3. Massive quiescent galaxies at high redshift

- Contain the oldest stellar populations at high redshift
- Provide the most stringent constraints to galaxy formation models
- GMASS@VLT provided first exciting results at z≤ 2 with ultra deep VLT observations (Cimatti et al. 2008)
- Studies at 2<z<4 are so far only based on photometric data



Examples of **red and dead galaxies at photo-z > 2.5 in GOODS-South**
(Fontana et al. 2009)
<u>Despite the excellent deep multi-wavelength data the basic properties of many galaxies remain uncertain</u>

TODAY



(Gargiulo et al. 2013, R~1400 λ ~0.6-1.1 μ m)

σ_V = 311 ± 23 km/s

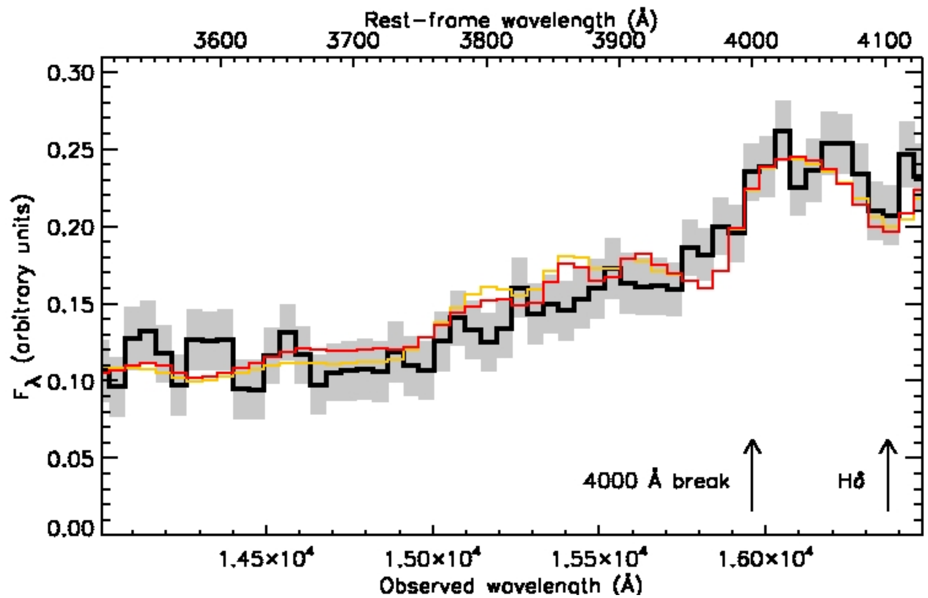
R_e = 2.07 kpc
M_* = 2.2 x 10^{11} M_{sol}

VLT-FORS2 obs, **8 hrs exposure**, 4 ETGs

(Gobat et al. 2012)

z~3 passive galaxy

HST WFC 3 spectrum
16 orbits



Quiescent (passively evolving) galaxies at z>2

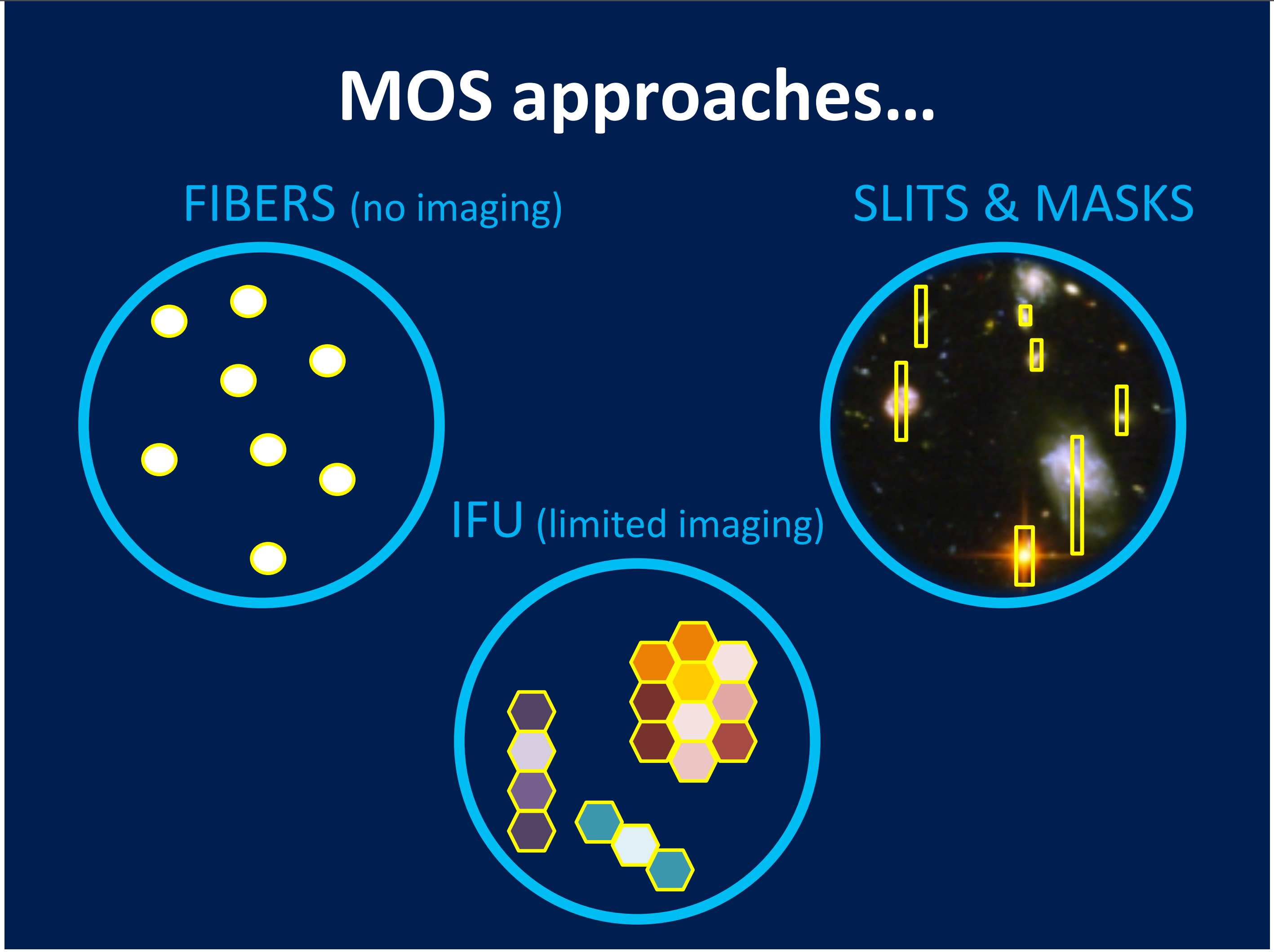
GOODS ($K \leq 25$)

8587 galaxies

	1392 @ z > 2.5	(763 @ z > 3)
passive gal	43@ z > 2.5	(14 @ z > 3)

Expected in a 5'X5' field

	250 @ z > 2.5	(150 @ z > 3)
passive gal	8 @ z > 2.5	(3 @ z > 3)



Crucially, the T-rex team combines wide experience with slits (VIMOS) and is actively involved in the proposal of a fiber-fed spectrograph for VLT (MOONS).

Optical vs IR?

IR is scientifically preferred for:

- high redshift galaxies,
- kinematics and abundances of stellar populations,
- “easily” delivers diffraction limited resolution...

but optical is important for

- intermediate-z galaxies,
- strong metal lines in red giants
- hot stars (blue supergiant of external galaxies)
- beats JWST competition..

Bottom line: pushing toward a continuous coverage 0.37-1.6μm

Spectral Resolution:

- Abundances in nearby stellar systems calls for high resolution (>20.000)
- Kinematics of nearby stellar systems and extragalactic cases need R=4000-5000

Spatial Resolution:

- Most stellar and all extragalactic cases are doable with moderate AO (seeing 0.3”)
- Some stellar cases would benefit from extreme AO (30mas scale)

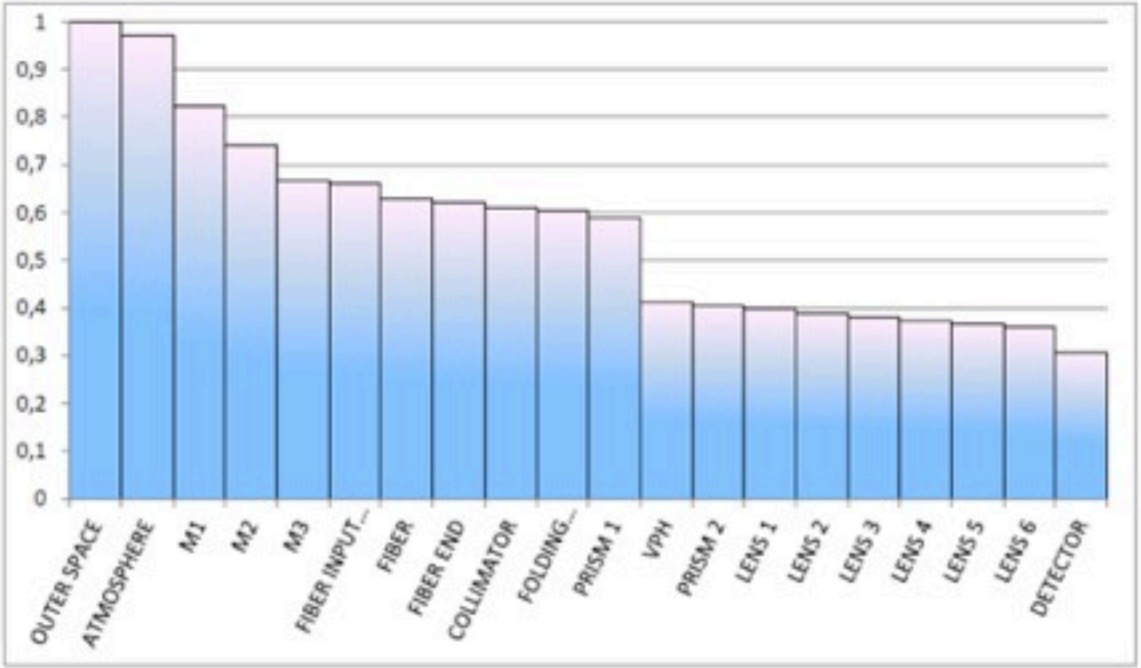
Contribution to technical developments and studies:

- Overall design and construction (IASF-Mi, OAR, OAB)
- Positioners (OAR, IASF-Mi, OAPD)
- End2end simulations (OAR, OArcetri)

Second Stage: physical simulation of the optics

Optical budget

	Full Path	Throughput
OUTER SPACE	1	1
ATMOSPHERE	0,97	0,97
M1	0,85	0,82
M2	0,90	0,74
M3	0,90	0,67
FIBER INPUT LENS	0,99	0,66
FIBER	0,95	0,63
FIBER END	0,99	0,62
COLLIMATOR	0,98	0,61
FOLDING MIRROR	0,99	0,60
PRISM 1	0,98	0,59
VPH	0,70	0,41
PRISM 2	0,98	0,41
LENS 1	0,98	0,40
LENS 2	0,98	0,39
LENS 3	0,98	0,38
LENS 4	0,98	0,37
LENS 5	0,98	0,37
LENS 6	0,98	0,36
DETECTOR	0,85	0,31
Throughput %	0,31	



Output focal plane images