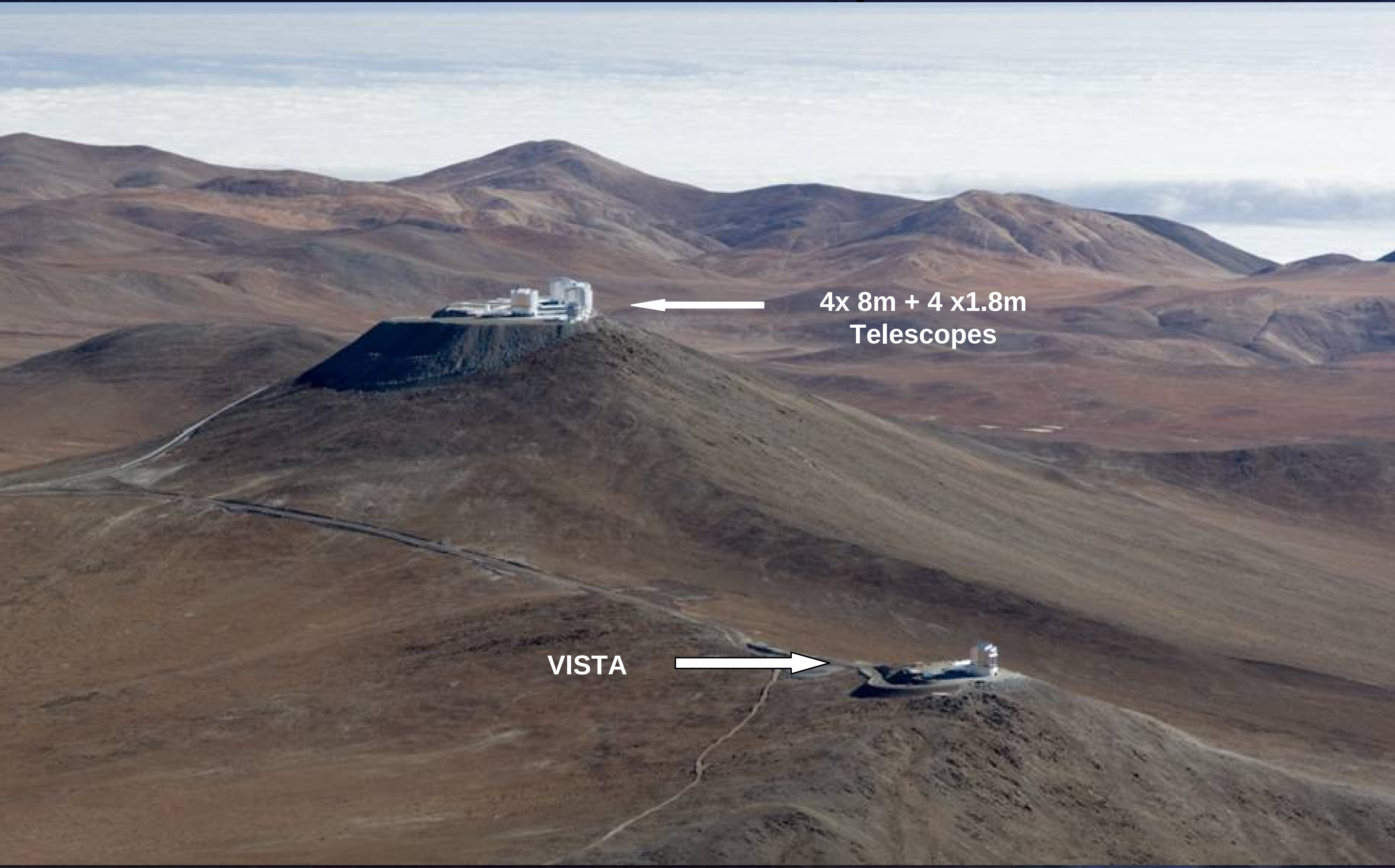
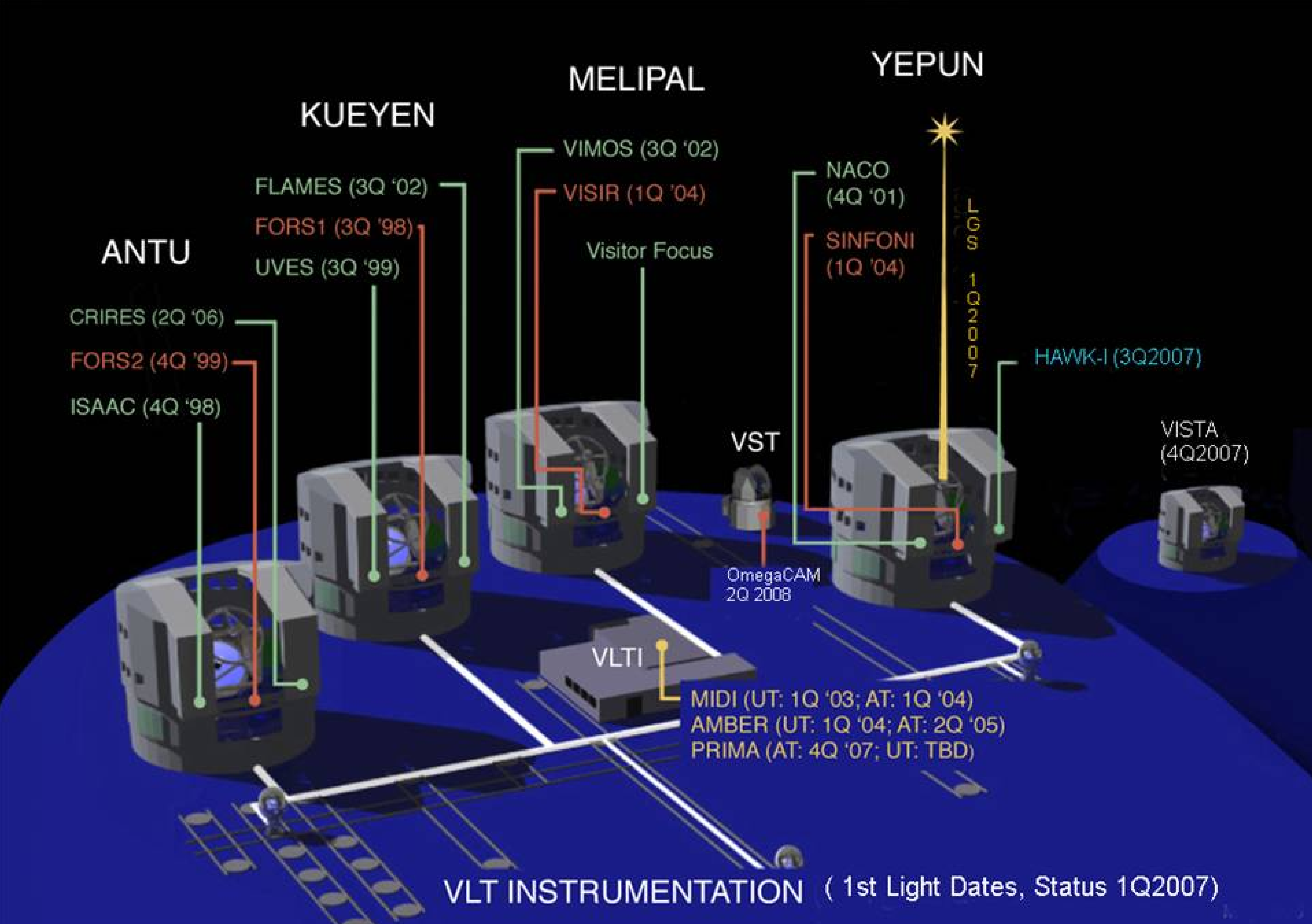
OBSERVATIONS OF AGN WITH FUTURE VLT AND E-ELT INSTRUMENTS ($\lambda\lambda$ 0.3-20 μm)

Sandro D'Odorico
European Southern Observatory

Paranal Observatory, Pacific Ocean and Comet McNaught, Jan 2007 , picture by G. Hudepohl

Mass budget





YEPUN
MELIPAL
KUEYEN
ANTU
VIMOS (3Q '02)
FLAMES (3Q '02)
VISIR (1Q '04)
FORS1 (3Q '98)
UVES (3Q '99)
Visitor Focus
NACO
(4Q '01)
SINFONI
(1Q '04)
LGS 1Q2007
CRIRES (2Q '06)
FORS2 (4Q '99)
ISAAC (4Q '98)
HAWK-I (3Q2007)
VST
VISTA
(4Q2007)
OmegaCAM
2Q 2008
VLTI
MIDI (UT: 1Q '03; AT: 1Q '04)
AMBER (UT: 1Q '04; AT: 2Q '05)
PRIMA (AT: 4Q '07; UT: TBD)
VLT INSTRUMENTATION (1st Light Dates, Status 1Q2007)

ESO Instrument and AO Projects (2007)

Studies

ELT INSTRUMENTS

VLT 2nd Gen, Part 2

VLTI 2nd: VSI
MATISSE
GRAVITY

Design/ Development

HAWK-I(+AO)
X-SHOOTER
KMOS
MUSE(+AO)
SPHERE(+AO)

PRIMA

PA Europe/ Commissioning

VISTA
ΩCam

In Operation (Upgrades)

VLT/I
2xFORS
ISAAC
UVES
NACO+AO
FLAMES
VIMOS
VISIR
SINFONI+AO
CRIRES+AO

MIDI
AMBER

La Silla
HARPS
EFOSC2
EMMI
SOFI
SUSI2
FEROS
WFI

New Systems, components development

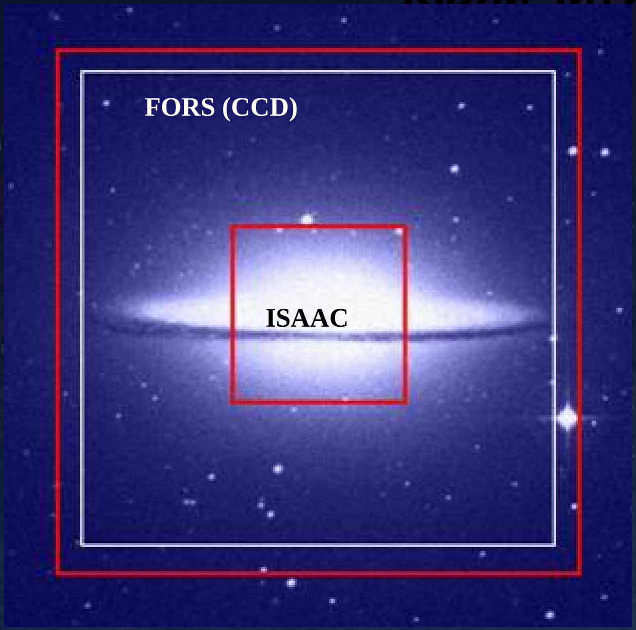
Detectors (incl WFS)
Array Controllers (NGC)
New optics (VPH)
AO components
Cryogenic systems
Control Electronics
Laser Comb

Special Projects

MAD
APE

HAWK-I IR Imager - built by ESO

Near infrared imager, built by ESO

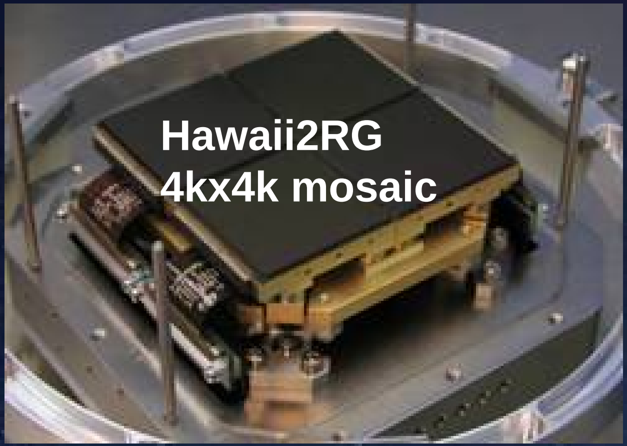


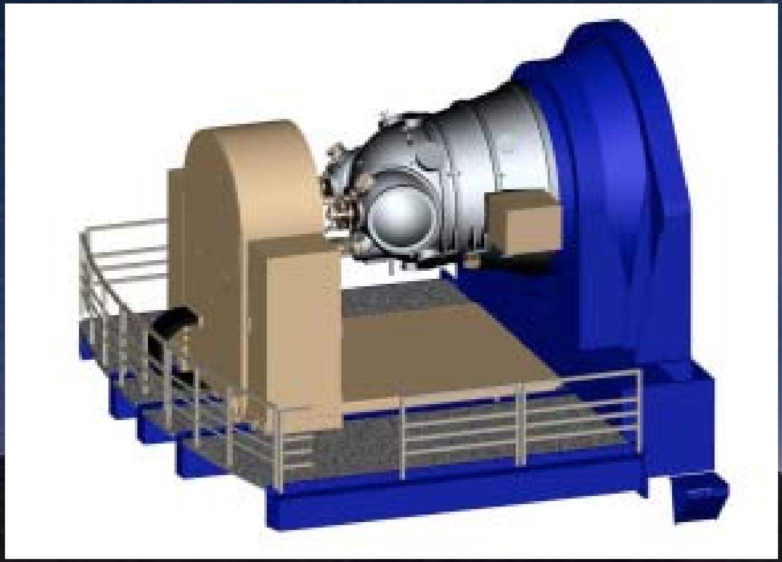
HAWK-I, NIR ARRAY MOSAIC

- Photometry, Morphology of galaxies up to z=2
- Survey for z>2, red galaxies
- High z clusters
- Star and planetary disk formation
- Brown dwarf surveys

- 1-2.5µm
- All cryogenic mirror optics (F/11→F/4.4)
- Optics at 120 K, detector 60-80 K
- 4kx4k mosaic detector (2.7mm gap)
- 0.1” pixels;7.5x7.5’ field
- 2 x 6 position filter wheels
- Designed for use with deformable M2 and LGS

HAWK-I IR Imager: *Installation at telescope 3Q2007*



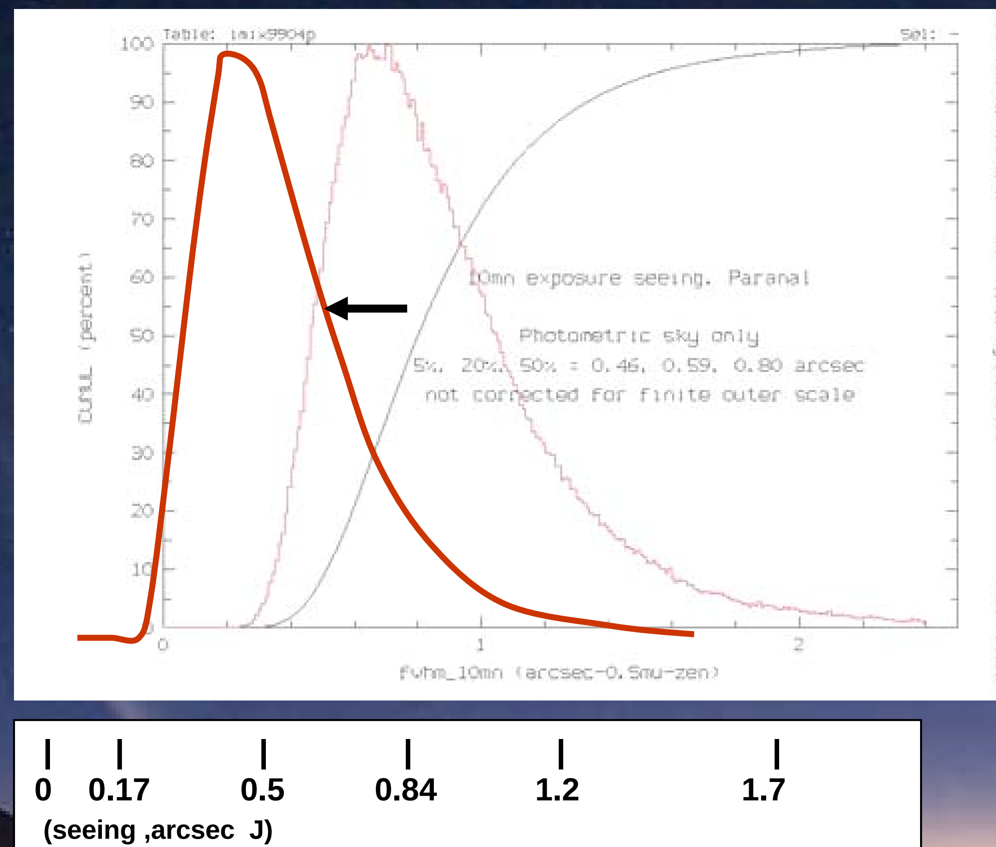


Garching lab , February2007

Expected Gain from AO in NIR Imaging at UT4

In J Band for median seeing the expected gain is 30% in FWHM and 50% in EE.

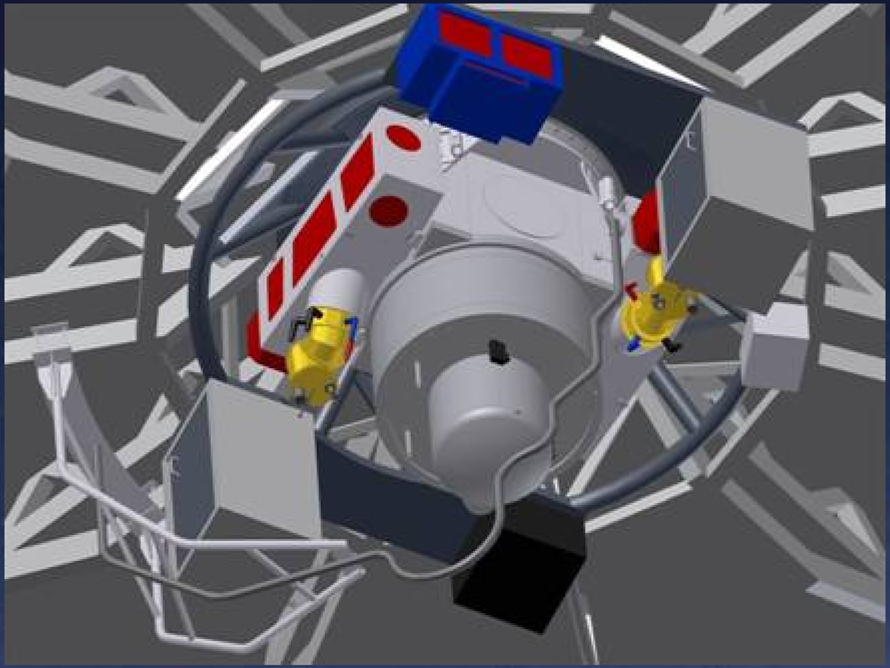
Significant shift in seeing distribution (~ 50% percentile of nights with seeing ≤ 0.5")



X- Shooter : Intermediate Resolution, High Efficiency Spectrograph; UV to K' bands in one shot

-to be installed at the VLT in 3Q 2008-

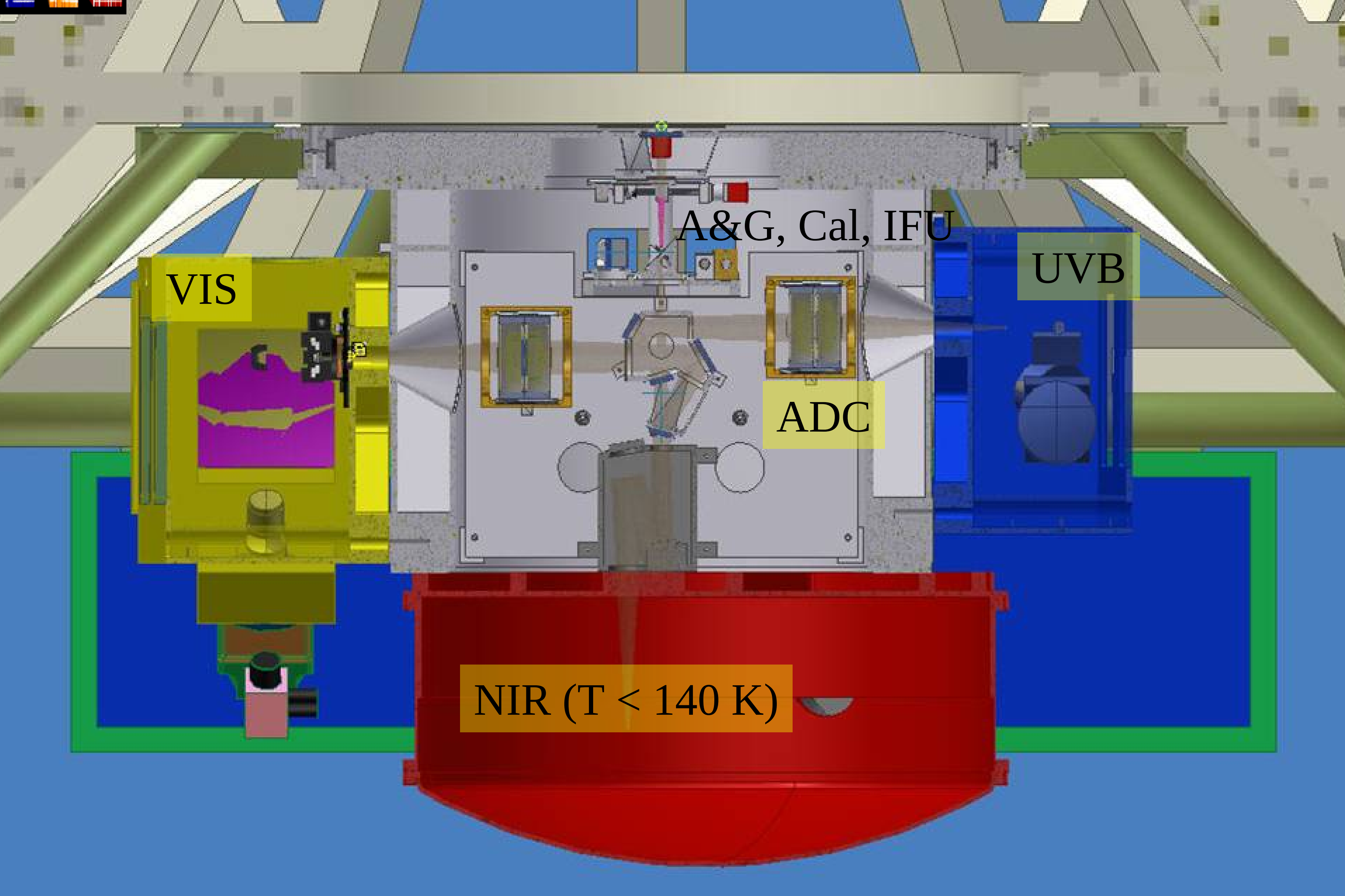
- 'Point and shoot'
- Spectrograph at Cass
- 300-2400nm spectral coverage
- 3 arms, fixed echelle format
- R ~ 4000-7000 (1" slit)
- Slits(12") + small IFU (1.8x4")
- Full Science DR pipeline



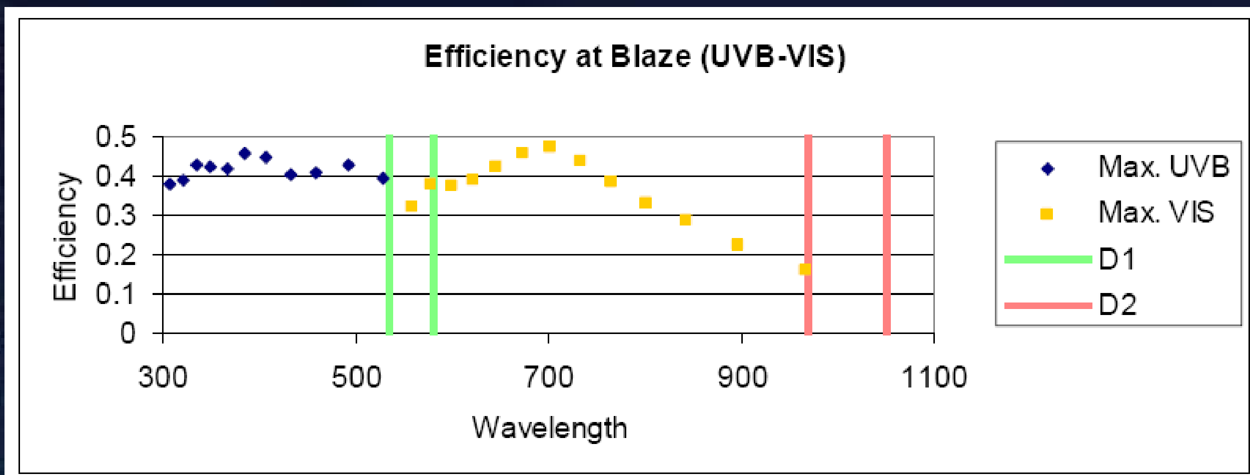
- High-redshift emission-line galaxies
- AGNs at intermediate and high z
- Absorption systems in QSO spectra
- Tomography of intergalactic medium
- Supernovae
- GRB afterglows
- Brown dwarfs and T-Tauri stars
- Stellar remnants and compact binaries

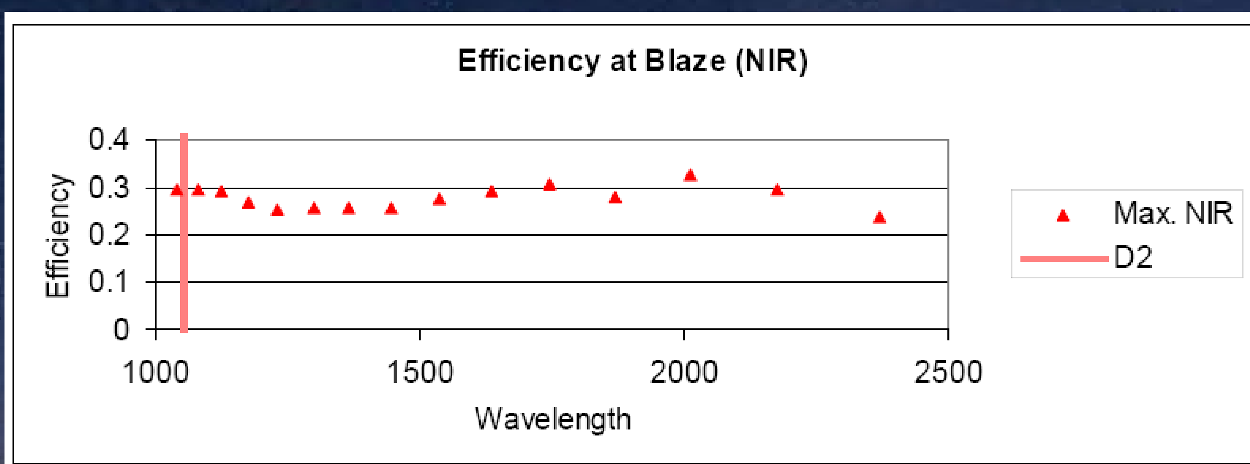
Built by Consortium: ESO, Amsterdam,ASTRON, Copenhagen, Nijmegen,Paris, INAF Brera and Trieste,

X-SHOOTER LAYOUT



Predicted overall efficiency

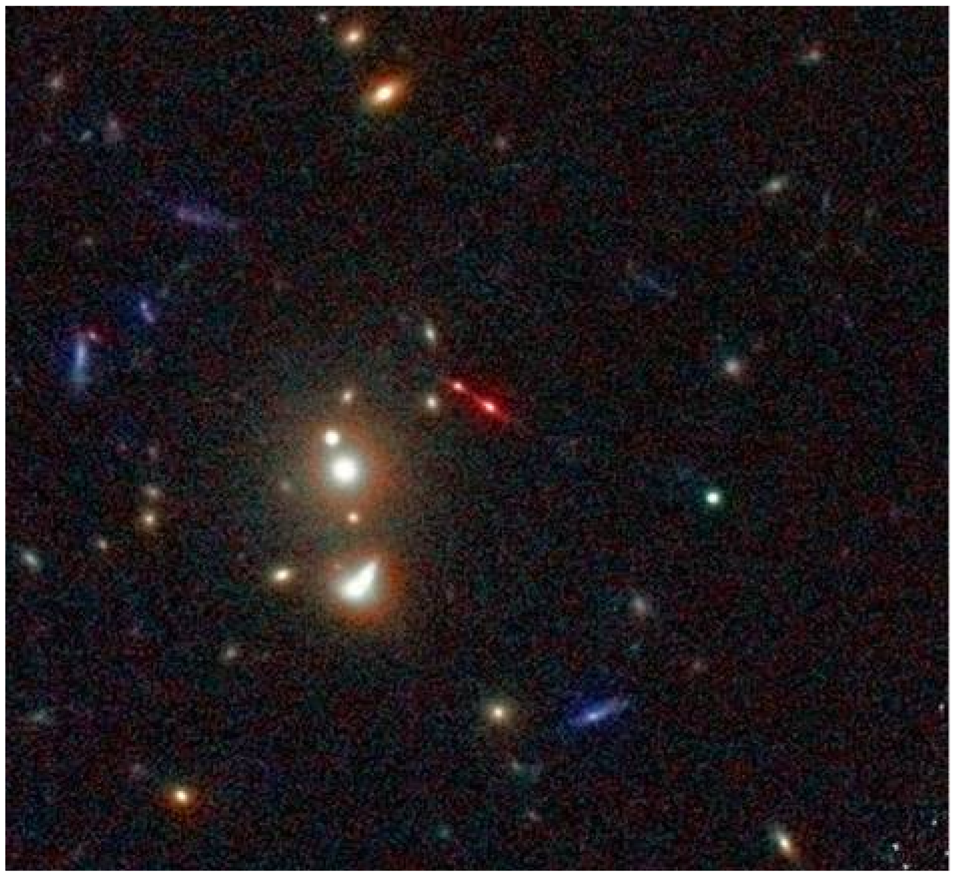




Limiting Magnitudes (S/N=10 in 1 Hr)

Band	AB mag
U	22.0
B	22.1
V	22.1
R	21.8
I	21.5
z	20.8
J	20.6
H	20.7
K	18.7

X-shooter Science Goals: Star Formation and gas properties at Early Epochs from Emission Lines



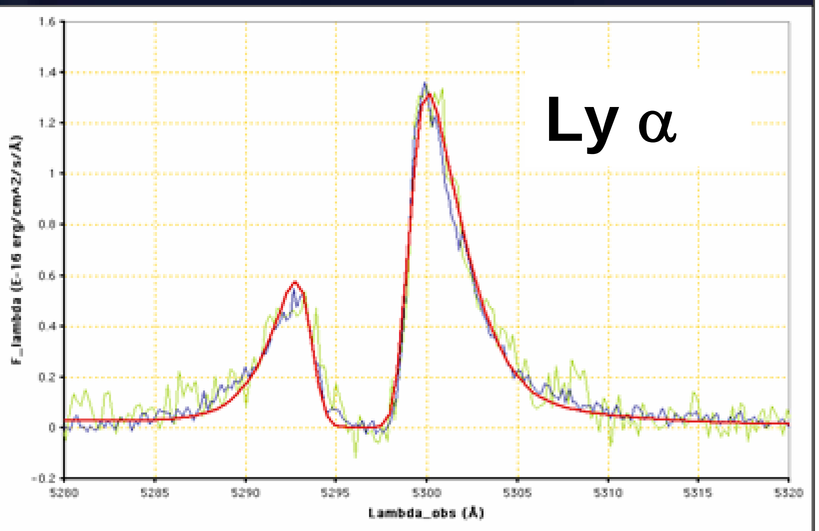
Lynx lensed galaxy z=3.4

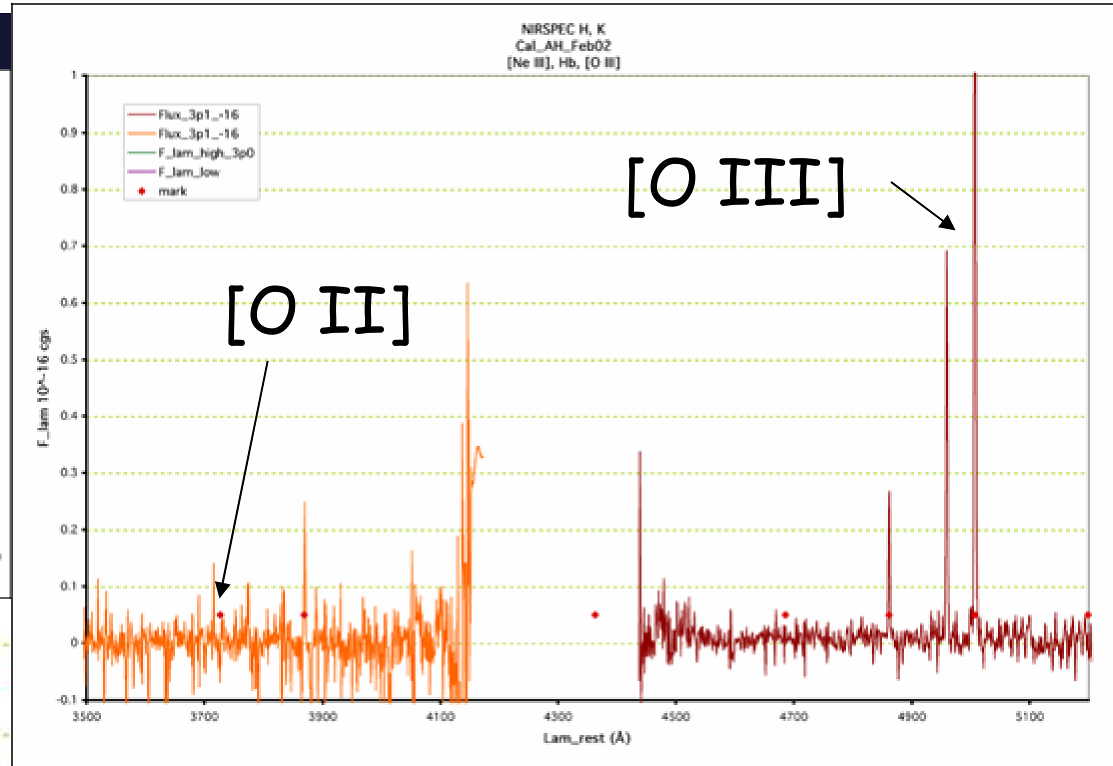
Case of the Lynx galaxy studied at Keck with ESI and NIRSPEC (Fosbury et al 2006)

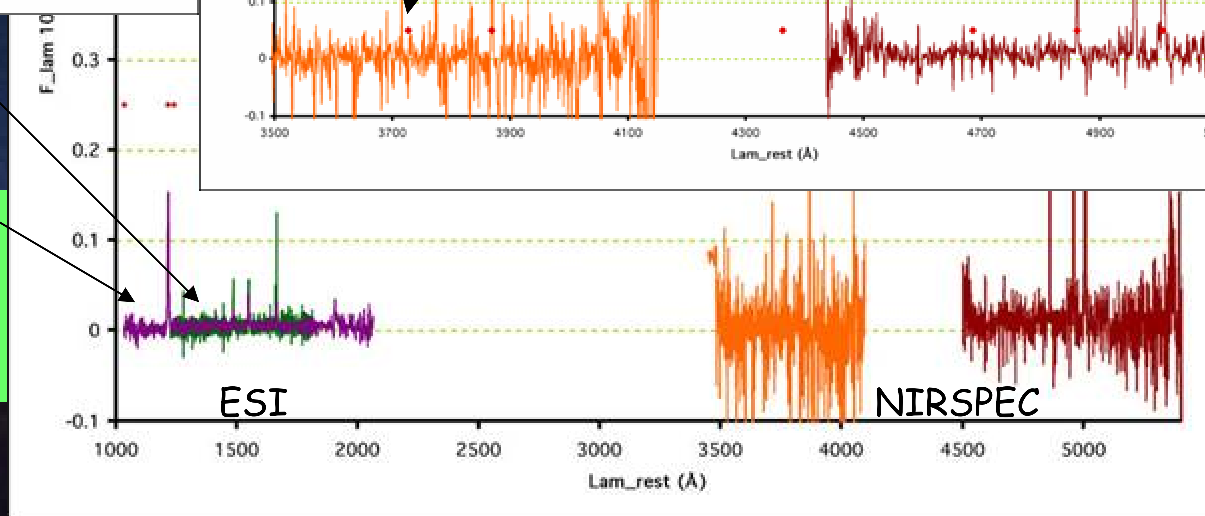
Emission line galaxies magnified by an intervening cluster provide unique information on star formation history at early epochs.

Intermediate resolution spectroscopy has provided line intensities and kinematics. Used to infer the properties of the ionizing sources and abundances

Abundances in ionized gas in a galaxy at high z: X-shooter to provide the full spectrum in a single exposure with high photometric accuracy to a fainter magnitude limit







Lynx lensed galaxy z= 3.4; Fosbury et al., 2004

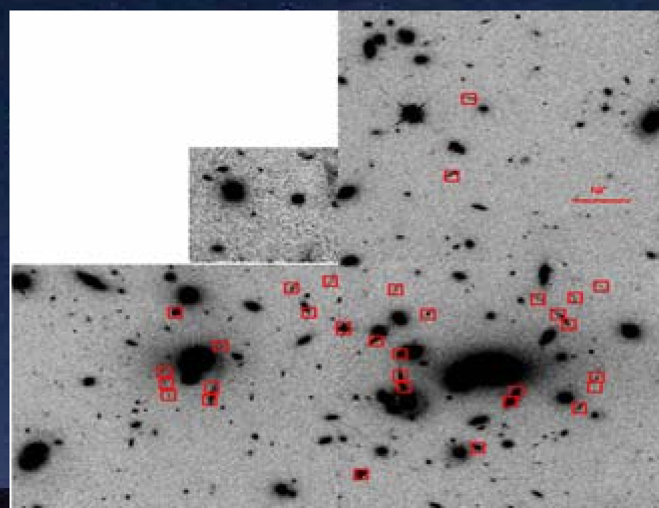
KMOS- Nasmyth of UT1
Near Infrared (1-2.5μm) multi-object spectrograph

Consortium by PPARC† (Oxford, Durham , Edinburgh ATC); MPE and Obs. Munich; ESO

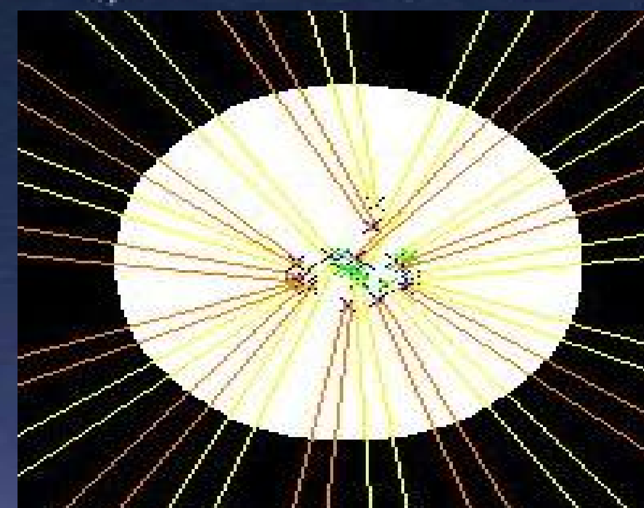
Led by R. Sharples and R. Bender

- *Mass assembly of galaxies at z~2*
- *Galaxies at z>7*
- *Age dating of galaxies*
- *Star formation*

Simulation of a KMOS cluster observations →



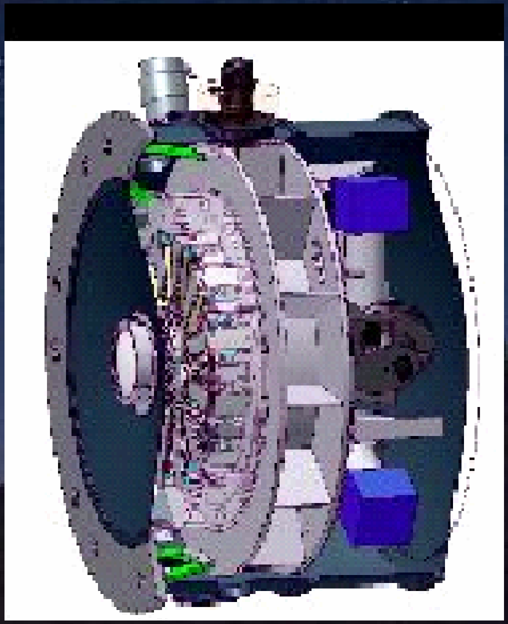
WFPC-2 image of A2218 with arclets marked



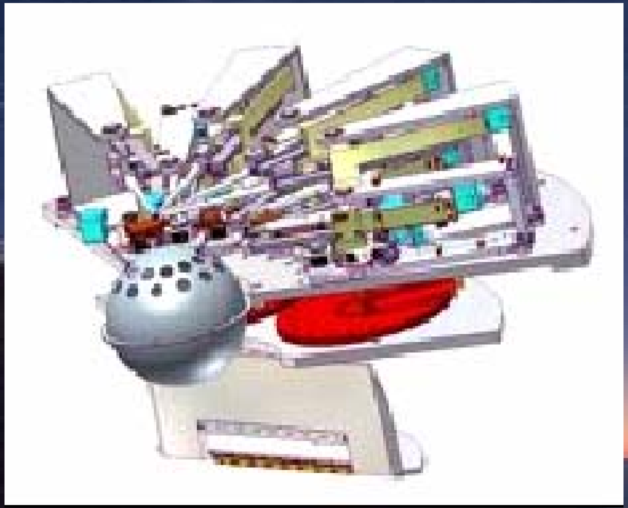
21 of 24 KMOS arms allocated

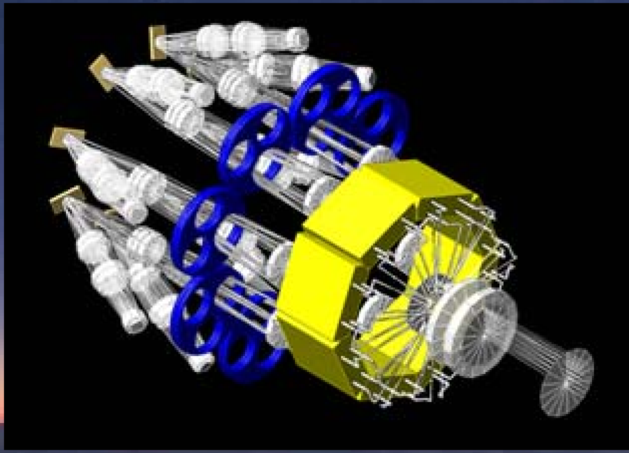
KMOS

- 24 Fully cryogenic IFUs
- Deployable over a 7.2’ field with pick-off arms
- Each IFU 2.8 x 2.8”, sliced to 0.2 “ (14 x 14 resolution elements)
- Packed configuration possible
- Distributed over 3 identical spectrographs (3 2kx2k arrays)
- Wavelength range: 1-2.45μm
- R~3500



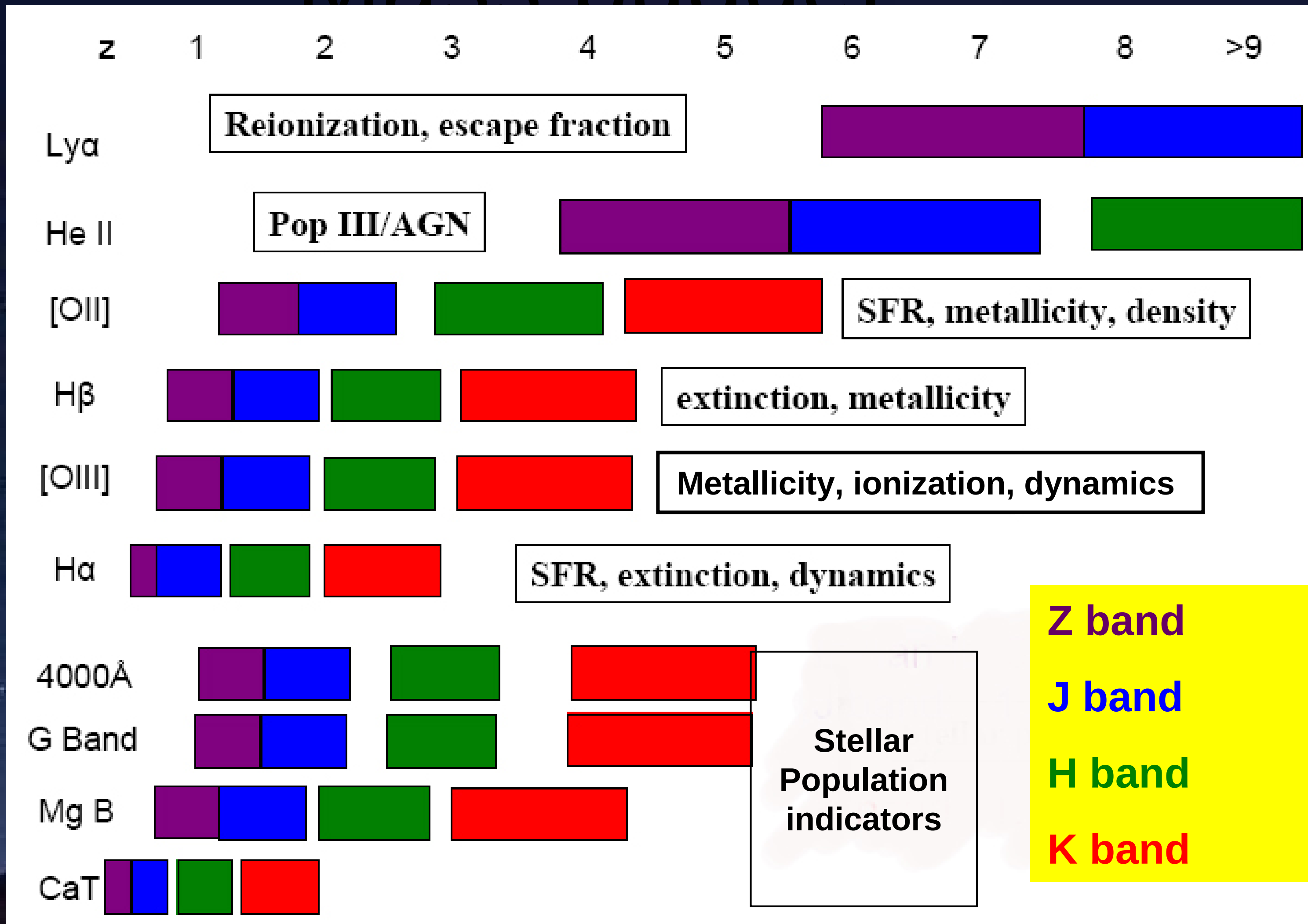
FDR July 2007, Installation 2011





KMOS: VISIBILITY OF DIFFERENT DIAGNOSTIC LINES

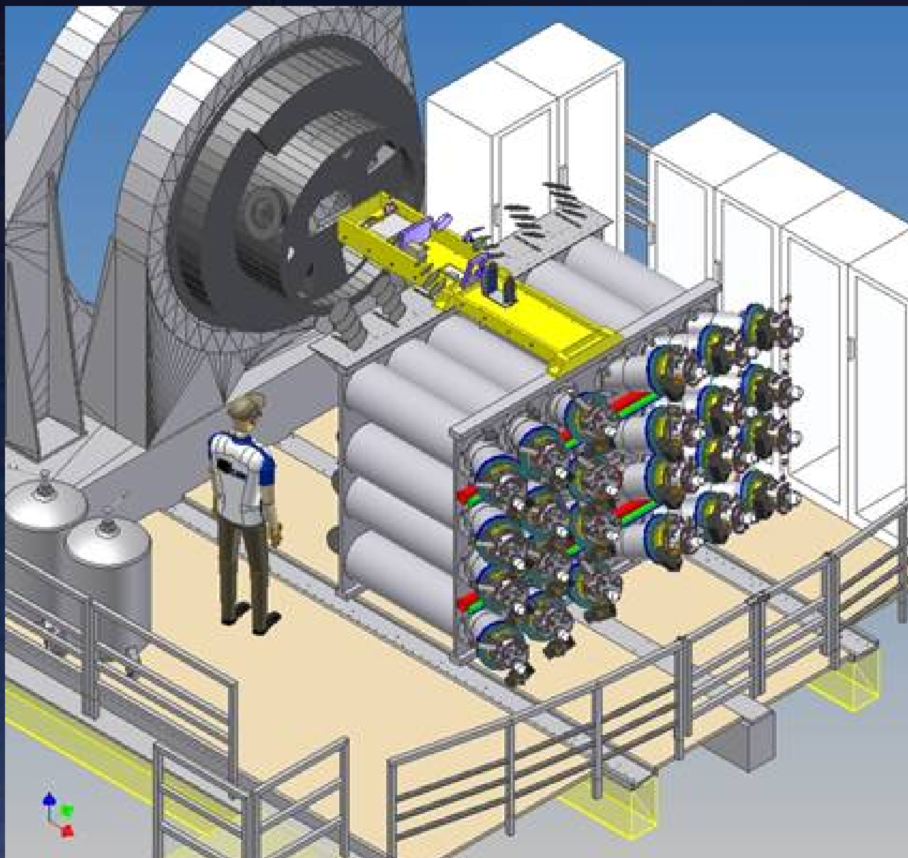
Mass budget



Adapted from M. Lehnert (2006)

MUSE-AO fed visible IFU spectrograph

CRAL, Lyon; Leiden; Göttingen;
Potsdam; Toulouse; Zurich; ESO (detectors, AO), P.I. R. Bacon



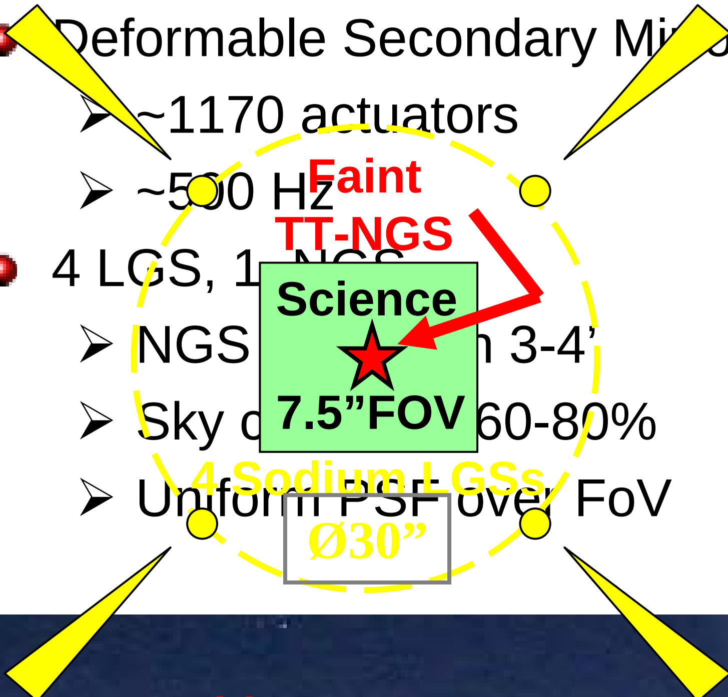
- Nasmyth UT4 + AO unit
- 1' x 1' field IFU
- 7x7" Narrow Field Mode
- 24 Spectrometers
- 4k x 4k CCD detector
- R ~ 3000
- 0.48-0.95 μm

- Deep (Lyα) surveys
- Physics of galaxies
- Black holes in AGN
- Young stellar jets

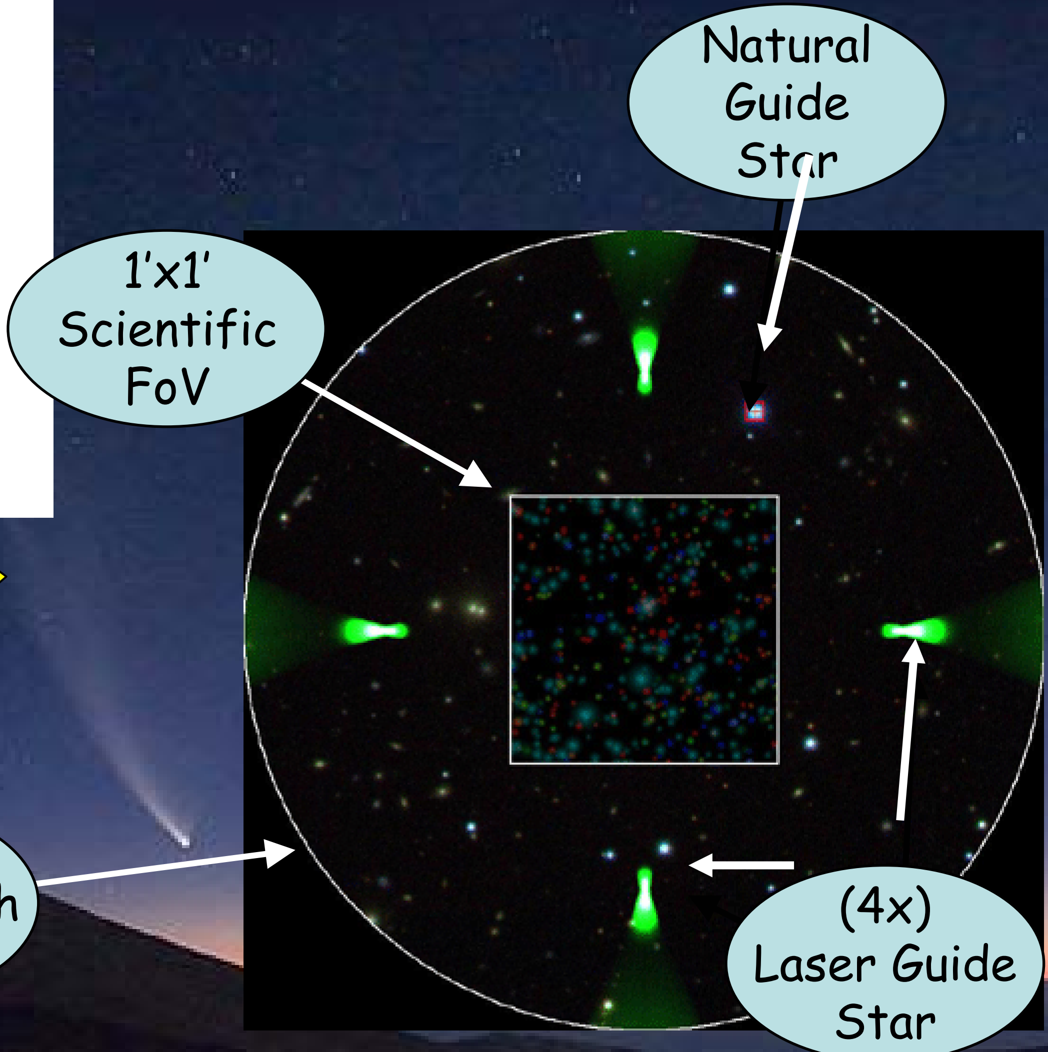
PDR June 2007, Installation 2012

GALACSI: AO system for MUSE (2013)

- Deformable Secondary Mirror
  - ~1170 actuators
  - ~500 Hz
- 4 LGS, 1 NGS
  - NGS … n 3-4'
  - Sky c… 60-80%
  - Uniform PSF over FoV

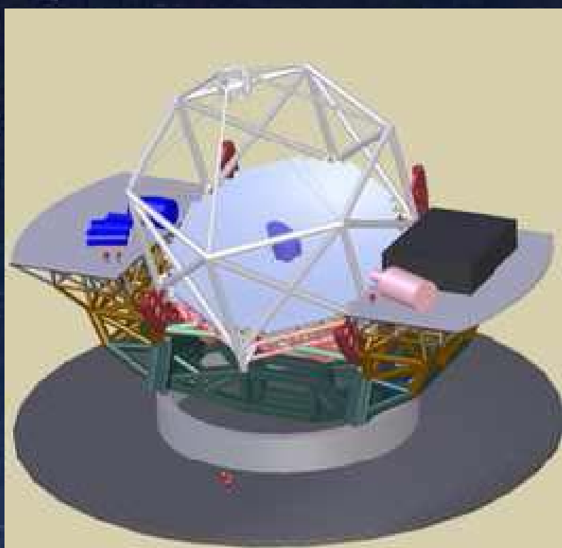


Strehl 10% at 650nm

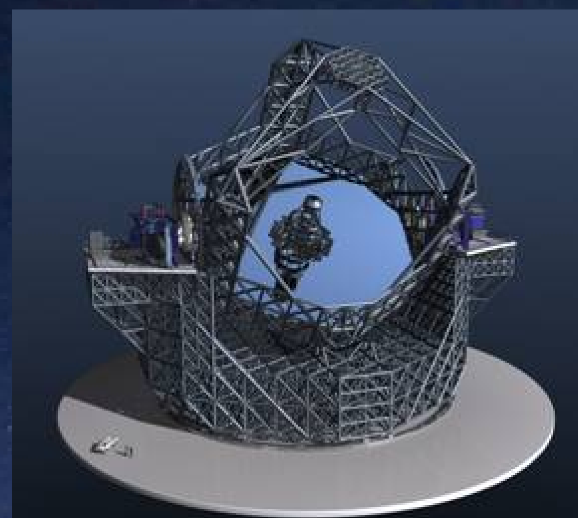


OPTICAL-INFRARED TELESCOPES PROJECTS WITH D> 20m

- TMT (Caltech, Univ. California, Canada)   30m
- European ELT   42m (formerly OWL 60-100m)
- Giant Magellan Telescope (Carnegie+ USA Univ.+Australia) 7x8m



TMT



European ELT

GMT

Start of operation: 2015-2020

GAINS FROM AN ELT

- **More photons from the larger collecting area (→ fainter sources within reach, less time to reach a given magnitude limit)**

  →*For **photon-noise dominated** observations, the faintness limit (at fixed time and S/N) and the speed (1/ time required to reach given S/N) are proportional to D^2 .*

  →*For **sky/background limited** observations at natural seeing, the faintness limit proportional to D , the speed to D^2.*

  →*For **detector noise dominated** observations, faintness limit proportional to D^2, the speed to D^4.*

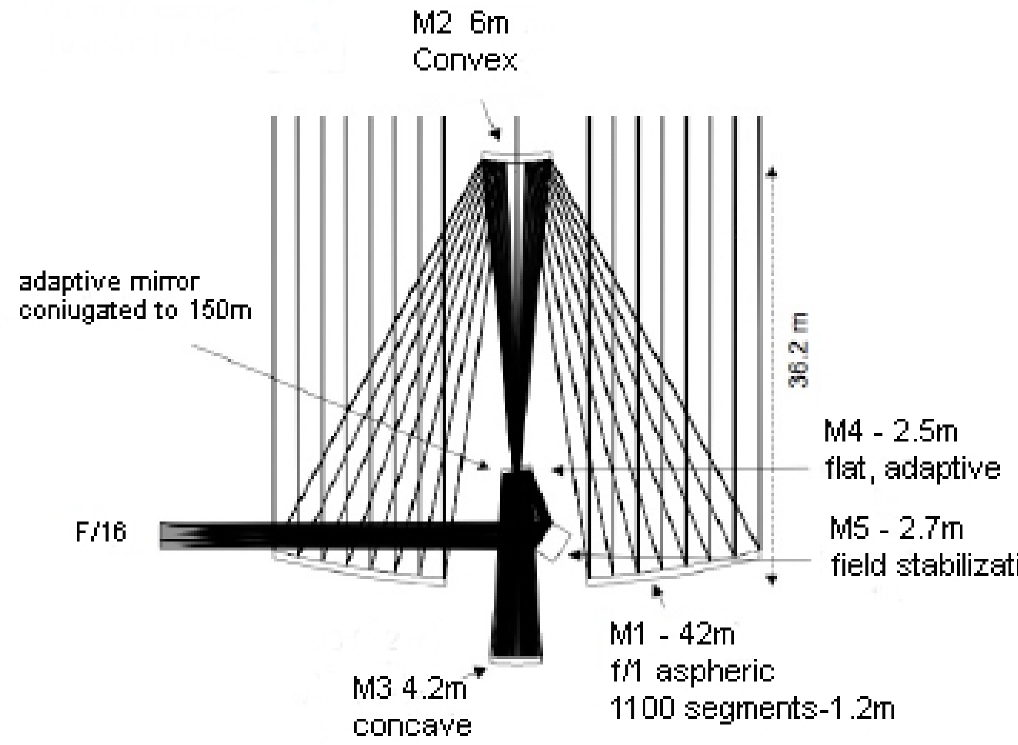
- **Higher angular resolution ($\theta = 1.22\lambda / D$) if atmospheric turbulence can be properly corrected with Adaptive Optics** (significant fraction of the flux of point-like sources within the Airy disk)

→*For sky limited observations of point-like (**stars, GRB, SN, QSO**), unresolved at DL sources the faintness limit is proportional to D^2, the speed to D^4 .*

*NB **High z galaxies intermediate case, below seeing size but not DL***

E-ELT: 42m ,5 mirror AO telescope

10’ Nasmyth field with very high image quality, 9% vignetting

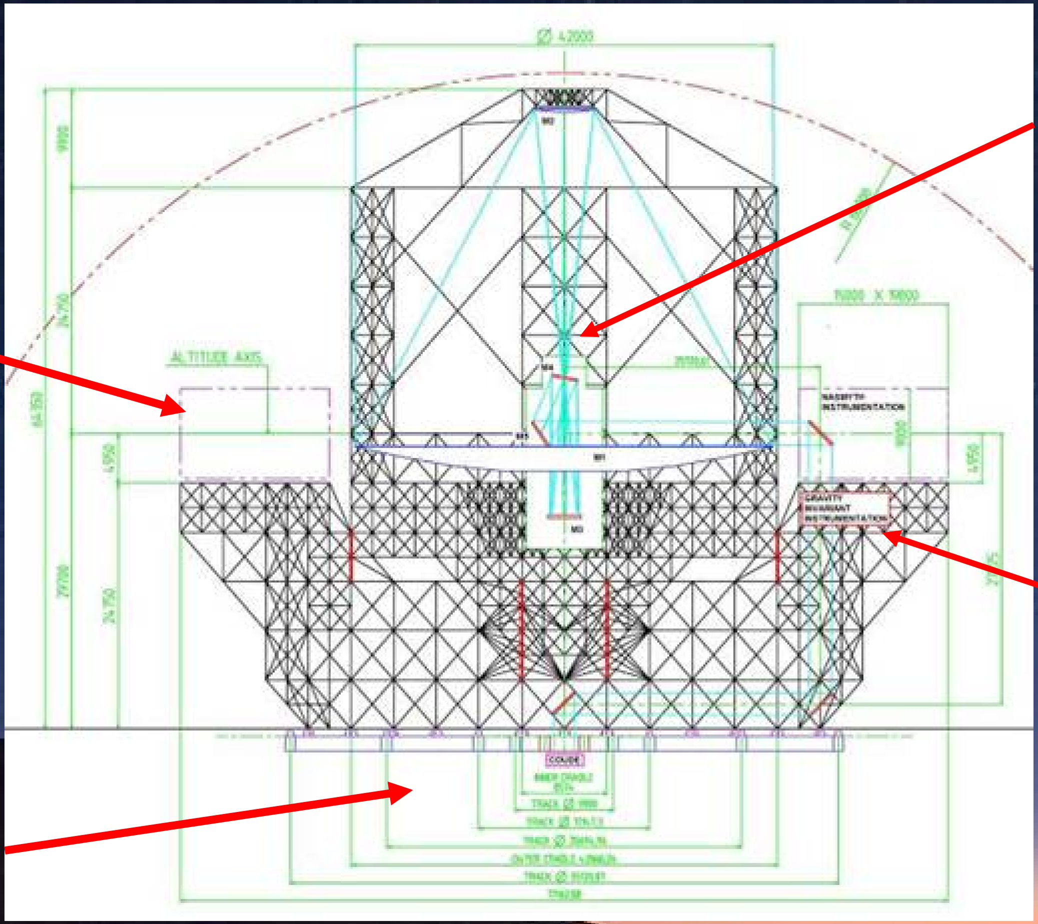


The basic telescope parameters

	λλ	Diffraction limit
I	0.80	4.8 mas
J	1.2	7.1 mas
H	1.6	9.6 mas
K	2.1	12.6 mas
L	3.6	21.5 mas
M	4.5	27.0 mas
N	10	60.0 mas
Q	18	108 mas

F/34.6

Instrument Focii at the 42m AO Telescope



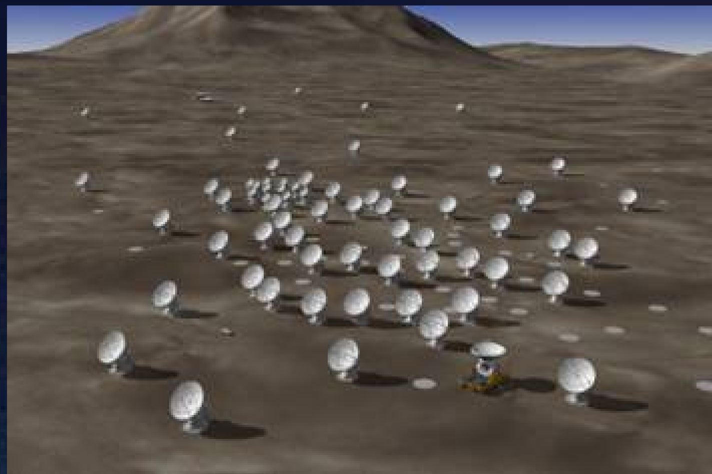
Intermediate F/4.6

Nasmyth F/15

Nasmyth F/16 Gravity invariant

Coudè F/34

ELT CONTEXT IN THE 2ND DECADEof the 3RD MILLENNIUM

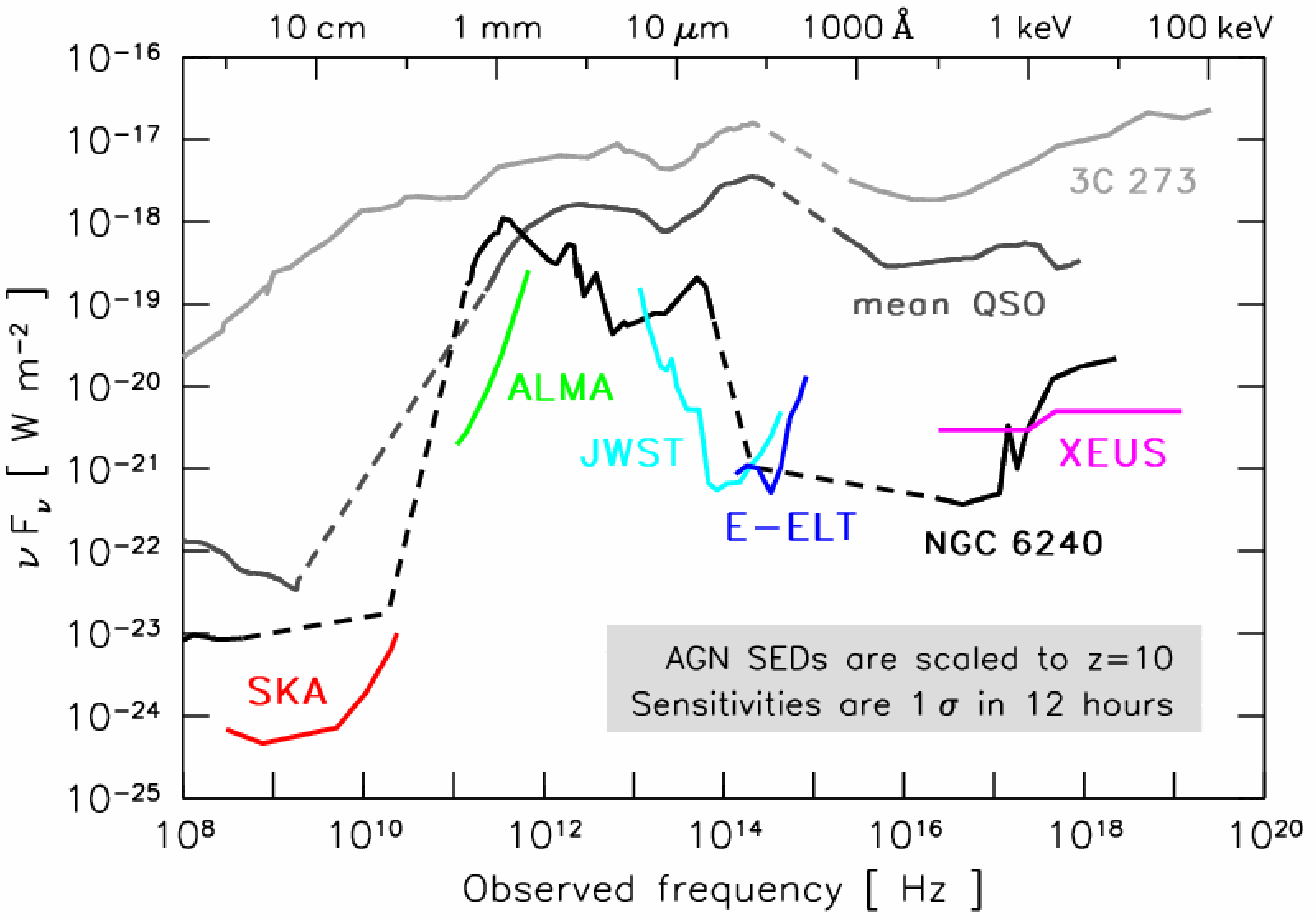


ALMA : antenna array for high angular resolution submillimeter observations (2012)

JWST: NIR and Thermal IR cameras and spectrographs (2014)

SKA, square km radio array(2018?)

XEUS, X ray imager-spectrometer (2020?)



Plot cortesy of V.Mainieri

"Prominent" Science Cases for the E-ELT

1) Planets and Stars:
    Extrasolar Planets (S3)
    Circumstellar disks (S8)
    IMF in Stellar Clusters (S5)

2)Stars and Galaxies:
    Resolved Stellar Populations (G4) **(To the distance of Virgo)**
    Black Holes/AGN (G9) **(Including Galactic Centre science)**

3)Galaxies and Cosmology
    First light-the highest redshift galaxies (C4)
    Studies of Absorption lines: Dynamical measurement of universal expansion,
        IGM studies (C2, C7)
    Physics of high redshift galaxies (C10)

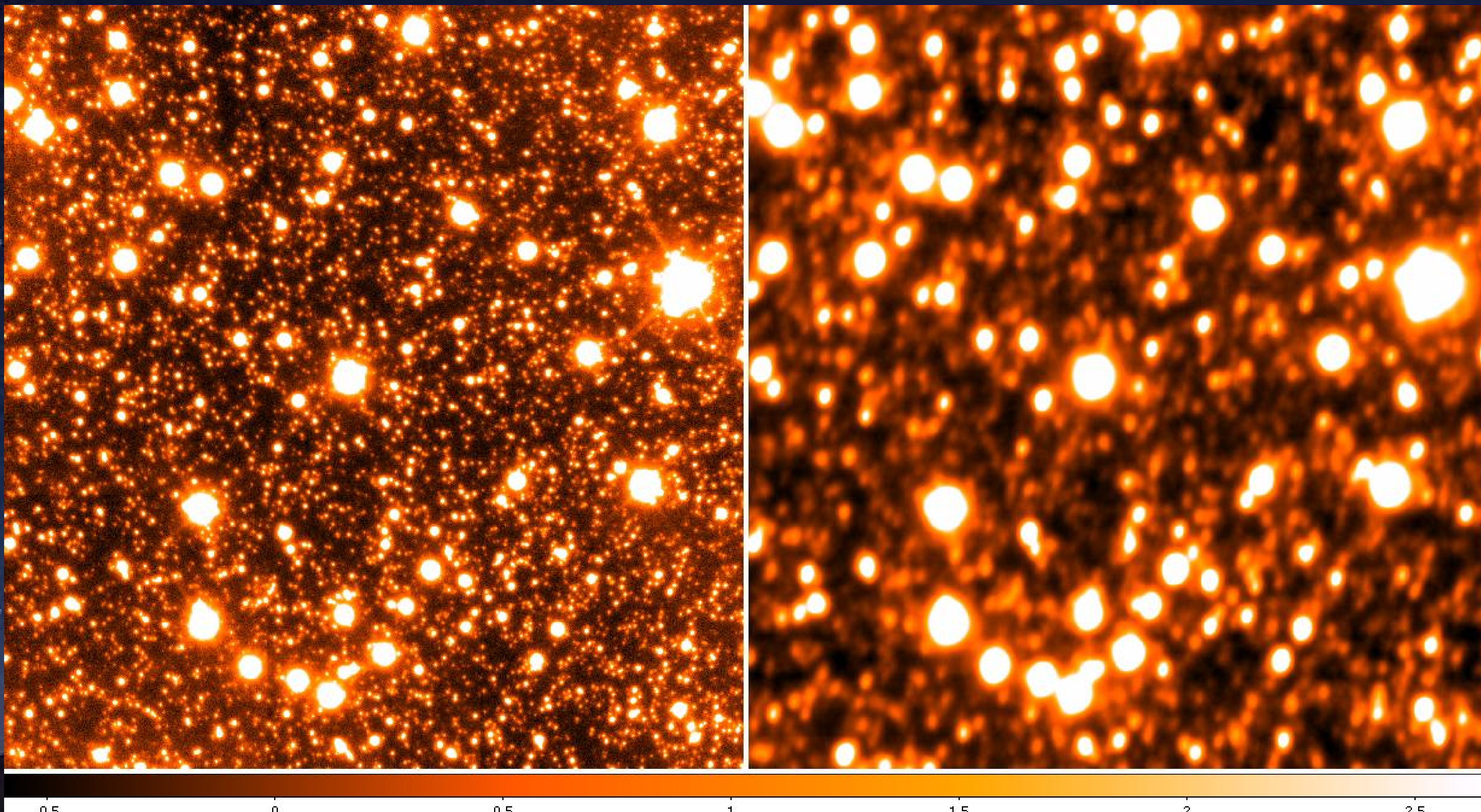
European ELT Instrumentation Studies (2007-2009)

- EPICS + Extreme AO- planet identification and characterization
- CODEX (0.4-0.7 μm) – high R spectroscopy with unique stability: Earth-mass planets detection, expansion of the universe, physical constants over time
- Diffraction Limited Imaging Camera (Z-J-H-K)- field 30"-60"
- Diffraction Limited Camera+Spectrograph (L, M, N, Q); field 30"
- Single Integral Field, Wide Band Spectrograph (0.4 -2.4 μm)- close to diffraction limit,
- Multi IFU NIR Spectrograph ; low order AO, field ~5', 20 arms
- 2 new instrument concepts (tbd in 4Q 2007)

STUDY TEAMS NOW BEING SELECTED

Multi Conjugate AO at VLT –
MAD run in April 2007

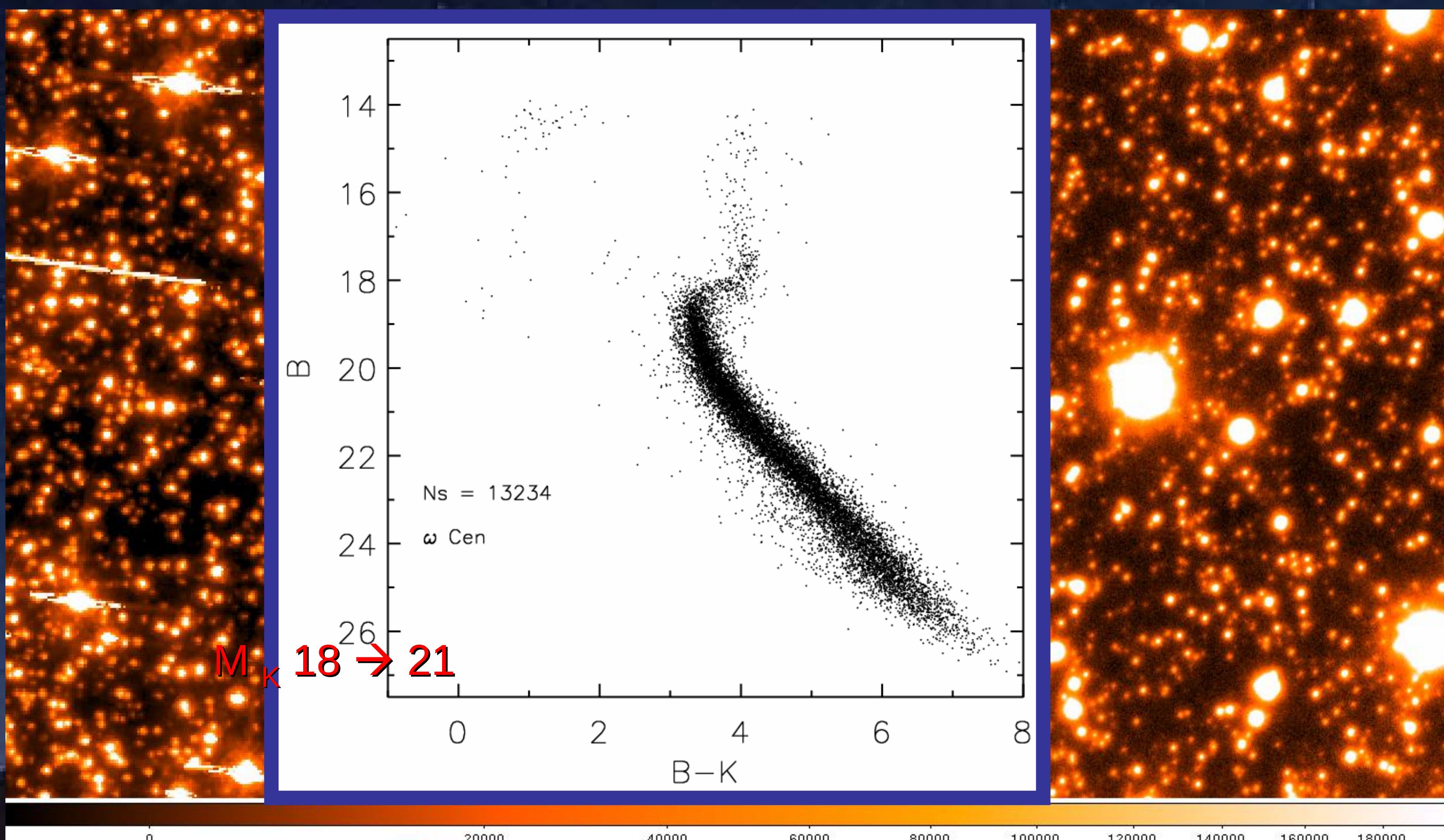
MAD FWHM=0.18”   versus ISAAC FWHM=0.55”



Preliminary assessment of MAD test data by S.D’Odorico & M.Nonino

Omega Cen Globular Cluster

Advanced Camera of HST (B band) and MCAO at UT3(K band)
(Field of view ~ 1’, FWHM(K)= 0.18 “, (B) 0.12”)



Preliminary assessment of MAD test data by S.D’Odorico & M.Nonino

Mid IR Observations of AGNs at low z

A Mid IR instrument at the E-ELT will have ~5x the resolution of VISIR at the VLTand ~6x of MIRI at the JWST (7 pc at the distance of NGC 1068)