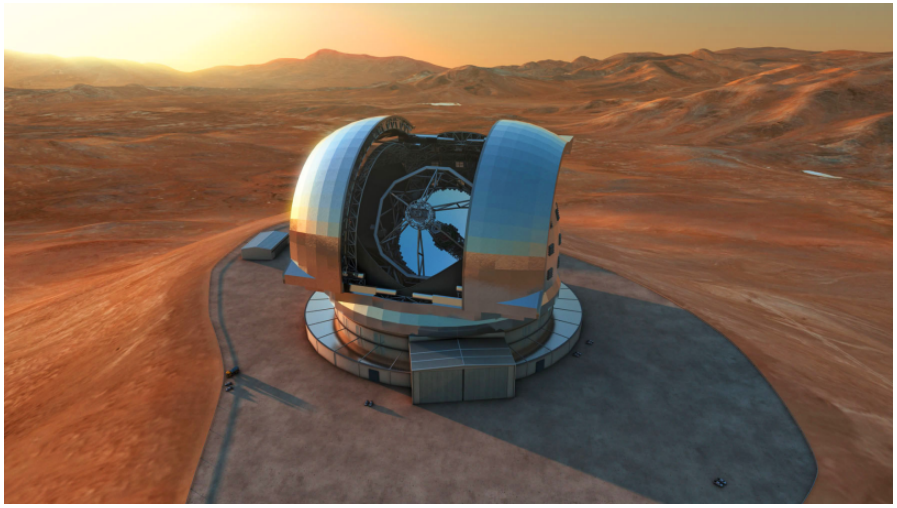


E-ELT: A QUICK REVIEW OF (SOME) PNCG PROGRAMMES (COSMOLOGY, GALAXIES)

J.-G. CUBY
LAM

Source

Instrument Phase A studies : 9 Instruments and 2 AO modules (2 (2007-2009)

E-ELT Design Reference Mission (DRM) (ESO)

- Detailed studies of 'prominent science cases' elaborated by the ESO E-ELT SWG and project office and the community (2010-2011)
- Generic instrumentation
- The absence of a comprehensive instrumentation plan for the E-ELT makes the DRM exercise in large part academic. We don't know if this will be the science carried out in the first 2, 5 or 10 yrs of telescope operations

Usual Disclaimers

- By no means an exhaustive review. Only a few representative examples
- The science that you will do in 2025 (?) will not be the science that we would do today with the facilities of 2025

Stars and Planets

S1 – Solar System Comets
S2 – Extra-Solar-System Comets
S3 – From giant to terrestrial exoplanets:
detection, characterisation and evolution
S4 – Freely-floating planetary mass objects
S5 – Young stellar clusters (incl. Galactic Centre)
S6 – Magnetic fields in star formation and in very low-mass objects
S7 – Origin of massive stars
S8 – LMC and SMC field star population
S9 – Circumstellar Disks
S10 – Stellar remnants: black holes and neutron stars
S11 – Asterosismology

Stars and Galaxies

G1 – The intracluster stellar population

G2 – Planetary Nebulae as traces of the element abundances in early type galaxies and diffuse light in clusters

G3 – Stellar Clusters and the Evolution of Galaxies

G4 – Imaging & Spectroscopy of Resolved Stellar Populations in Galaxies

G5 – Spectral observations of star clusters

G6 – Young, massive star clusters

G7 – Measuring the stellar IMF in local group galaxies

G8 – Star formation history through supernovae

G9 – AGN Demographics

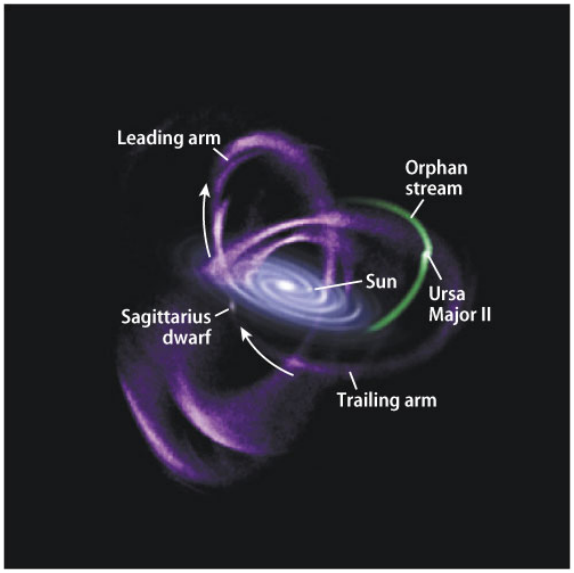
Galaxies and Cosmology

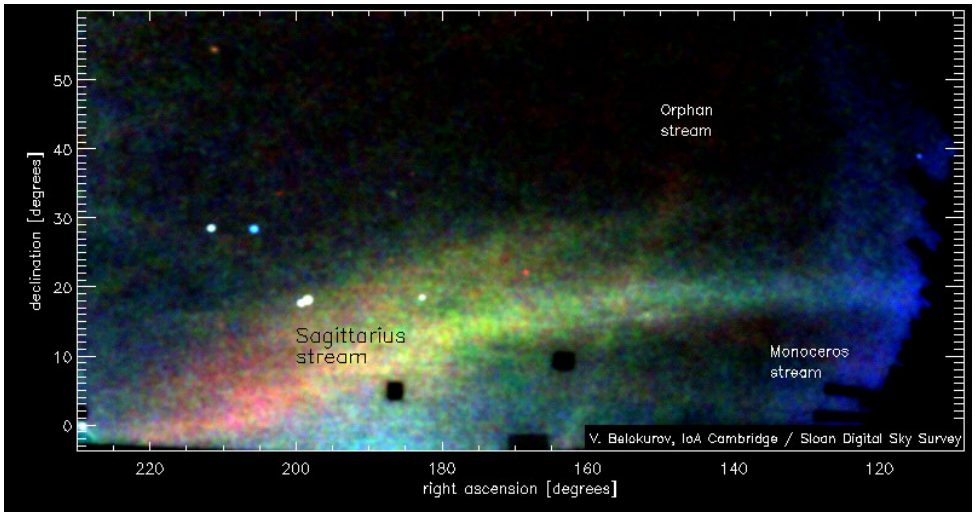
C1 – Dark Energy – Type Ia Supernovae as Distance Indicators
C2 – A dynamical measurement of the expansion history of the Universe
C3 – Testing the variability of fundamental constants with QSO absorption spectra
C4 – First light - The Highest Redshift Galaxies (z>10)
C5 – Galaxies and AGN at end of reionizaion
C6 – Probing reionization with GRBs and quasars
C7 – Is the low density IGM metal-enriched?
C8 – Topology of the IGM at z = 2-3
C9 – Galaxy Formation and Evolution
C10 – Physics of High Redshift Galaxies
C11 – Gravitational Lensing
C12 – Deep Galaxy Studies at z = 2.5

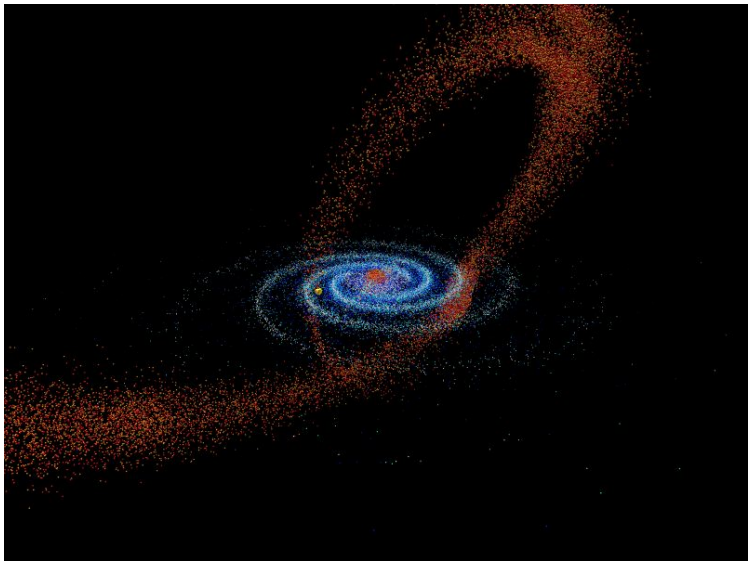
Resolved Stellar Populations in Galaxies

Study of stellar populations in the Local Group and beyond

- Detailed stellar populations
- Reconstruction of the (merging) history
- Constraints on Dark Matter content and distribution (e.g. dSphs)
- Testing ΛCDM structure formation models
- SDSS (SEGUE, APOGEE), VLT (FLAMES), RAVE (AAO), etc.

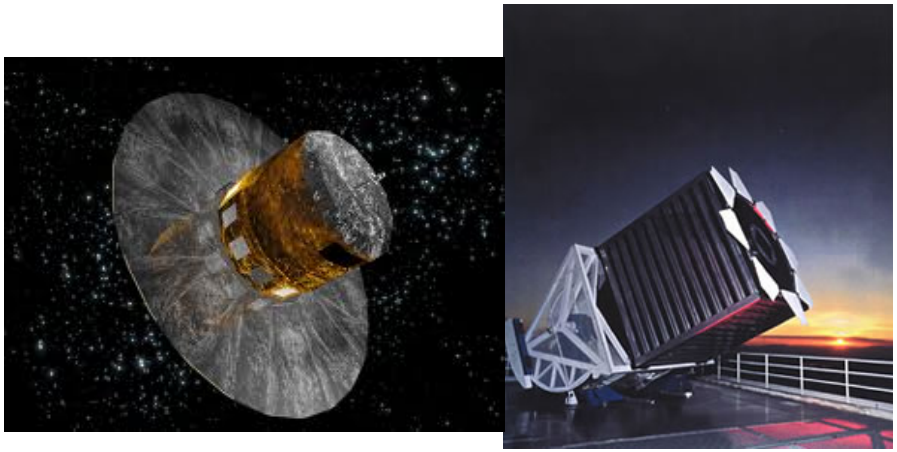






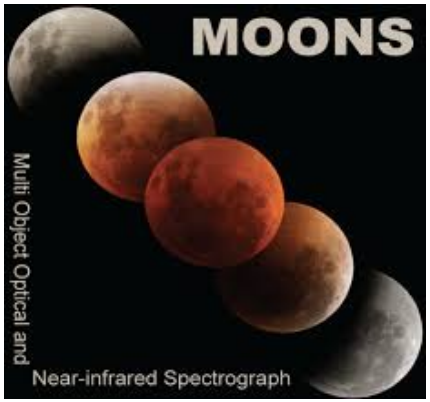
Resolved Stellar Populations in Galaxies

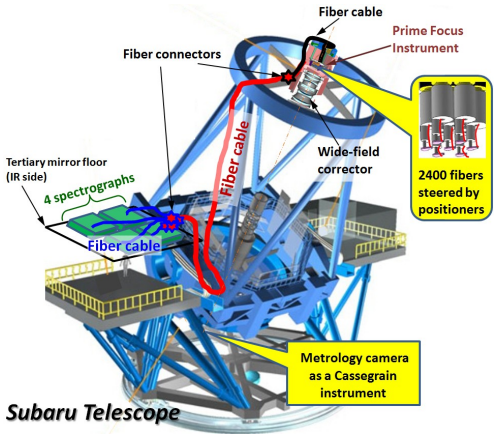
A bright future with SDSS (IV), Gaia, HERMES (AAO), PFS (Subaru), and several proposed instruments motivated by this science case : MOONS (in part), 4MOST (tbc), WEAVE (tbc), MESSIER@CNES, MS-DESI, etc.



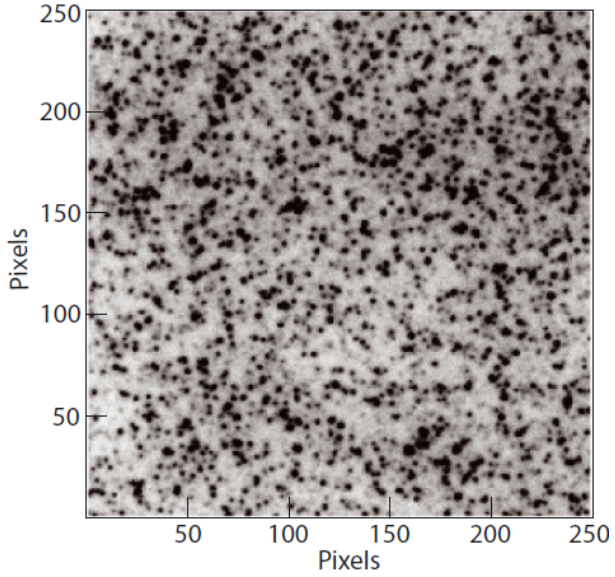
What will the E-ELT do?

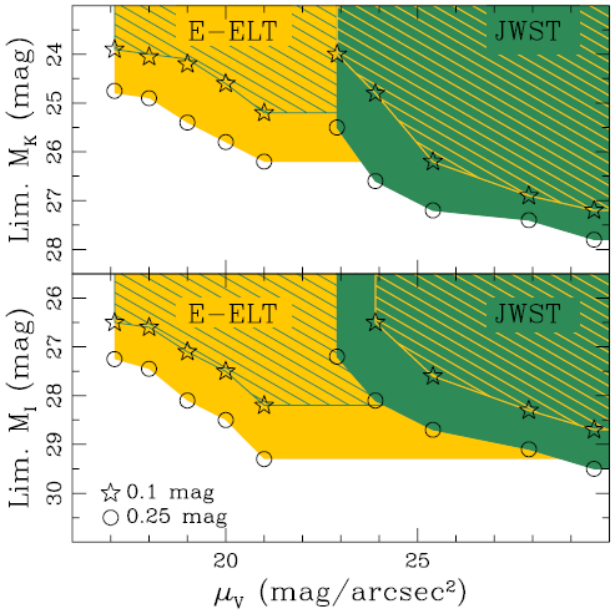
- G4-1: The resolved stellar populations of elliptical galaxies (the holy grail)
  - High resolution imaging, out to the Virgo cluster (M87)
- G4-2: The chemo-dynamical structure of galaxies
- G4-3: First stars relics in the Milky Way and satellites



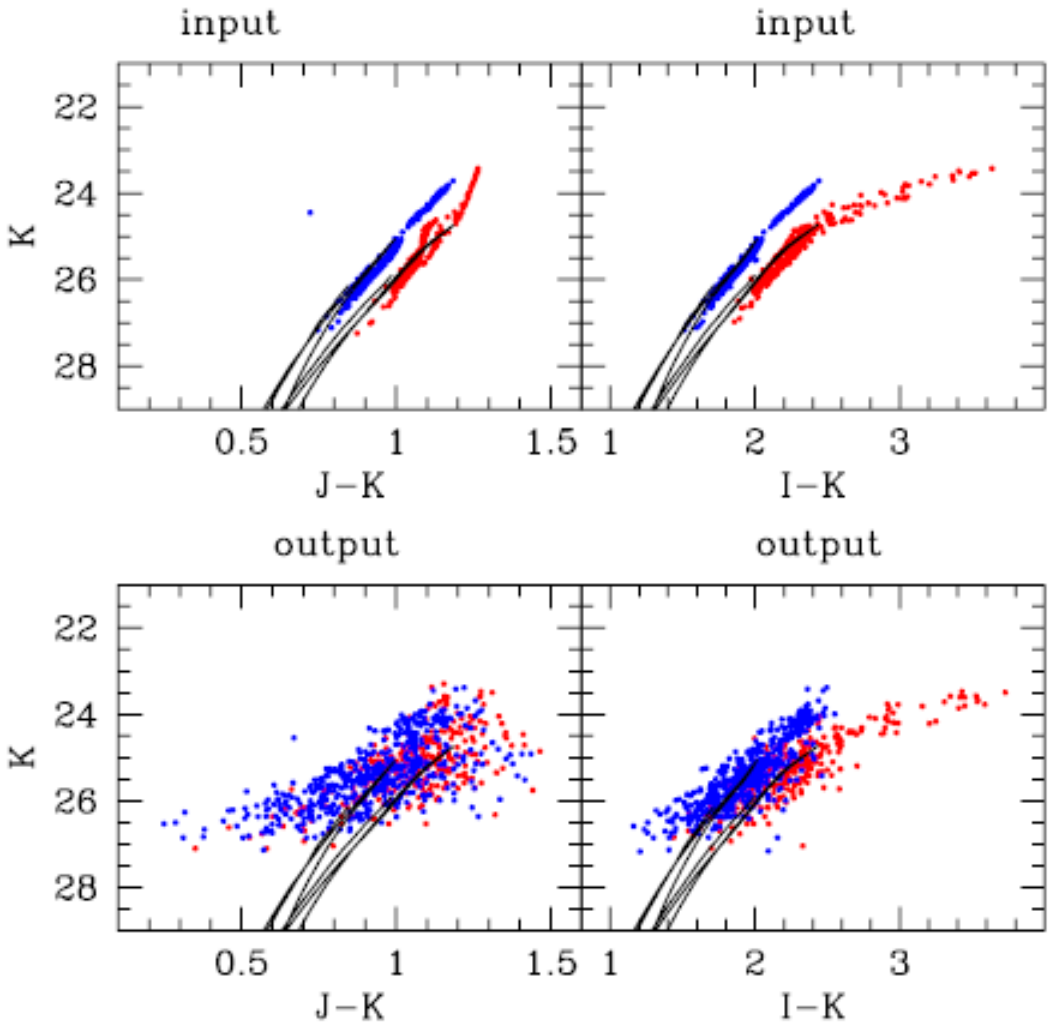


The resolved stellar populations of elliptical galaxies



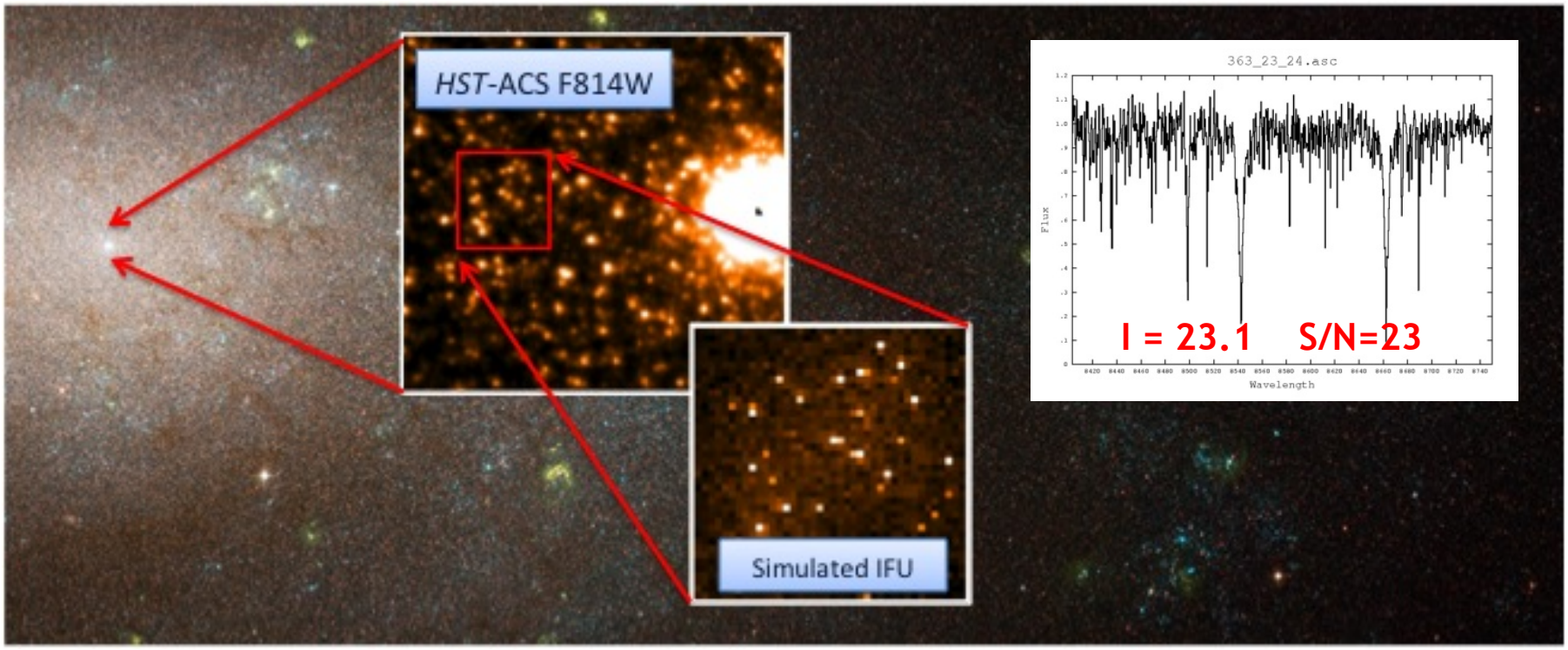


VIRGO (M87)



Deep et al., 2011

Imaging & Spectroscopy of Resolved Stellar Populations in Galaxies



Simulations of stellar spectra in a nearby galaxy at 2 Mpc

Resolved Stellar Populations in Galaxies: Main findings

Imaging (ELT-CAM)

- Accurate colour-magnitude diagrams will be best constructed in the I and H bands
- For Cen A it will be possible to probe the horizontal branch with an accuracy of 0.05 mag all the way into the central parts of the galaxy
- For M87 in the Virgo cluster the E-ELT will be able to probe the tip of the red giant branch with 0.05 mag accuracy all the way into the very dense central parts of the galaxy

Spectroscopy (ELT-IFU, ELT-MOS)

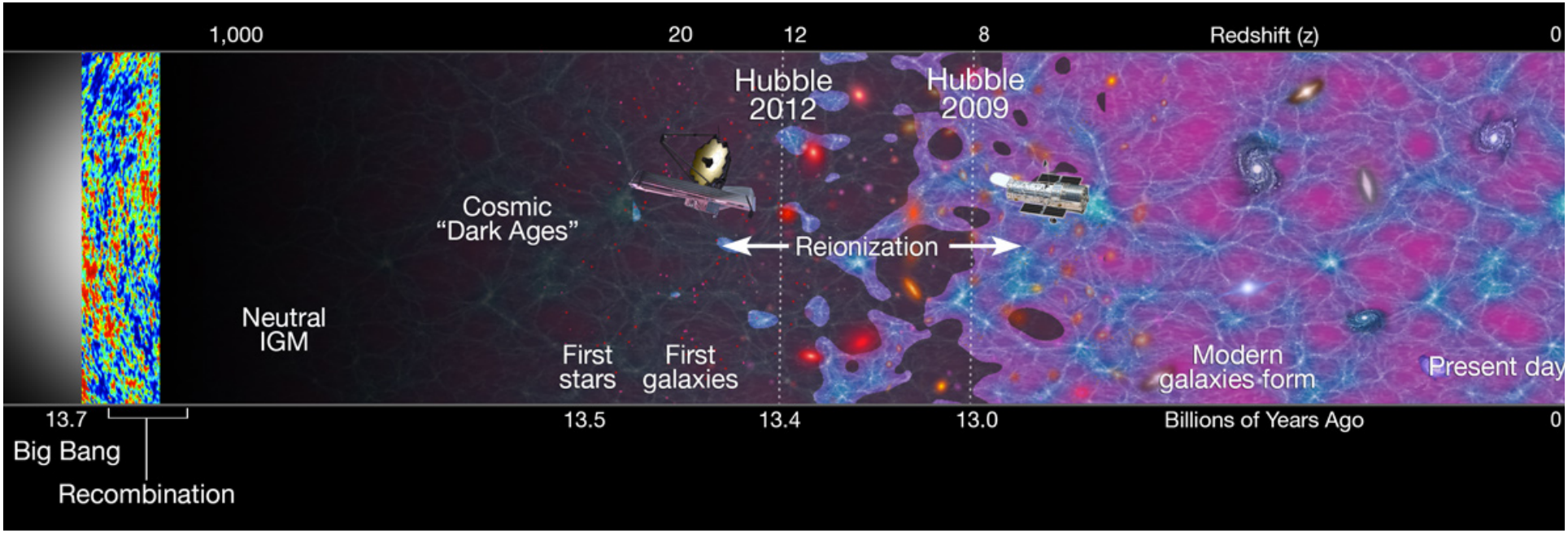
- Out to 4 Mpc (Cen A) accurate velocities (5 $km.s^{-1}$) can be derived for stars 0.5 mag below the tip of the RGB in 2 h at just 1 effective radius from the galaxy's centre.

High Resolution Spectroscopy (ELT-HIRES / CODEX)

- The E-ELT will be able to provide a comprehensive survey of extremely metal poor candidate stars in the halo of the Milky Way and in nearby dwarf galaxies

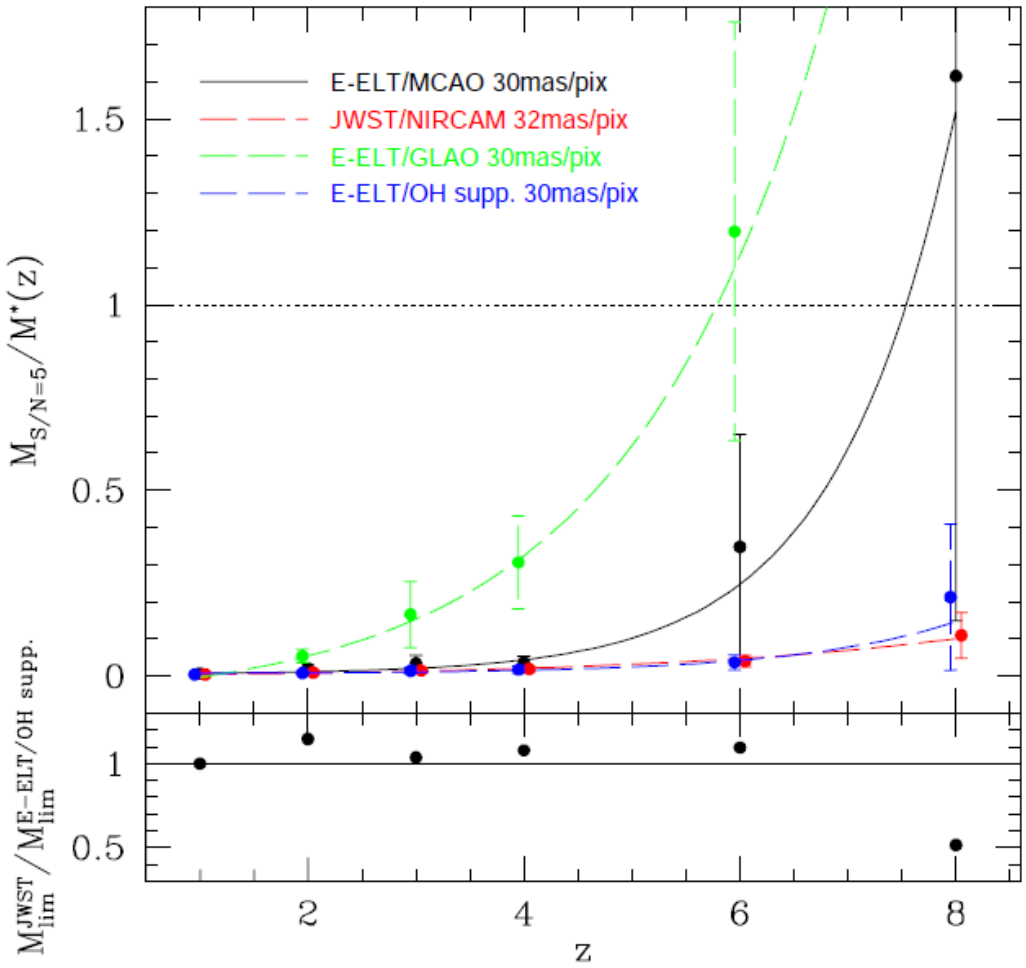
Physics of High Redshift Galaxies
First light - The Highest Redshift Galaxies

Galaxy evolution out to z ~ 6 and study of the highest redshift galaxies into the reionization epoch



Physics of High Redshift Galaxies

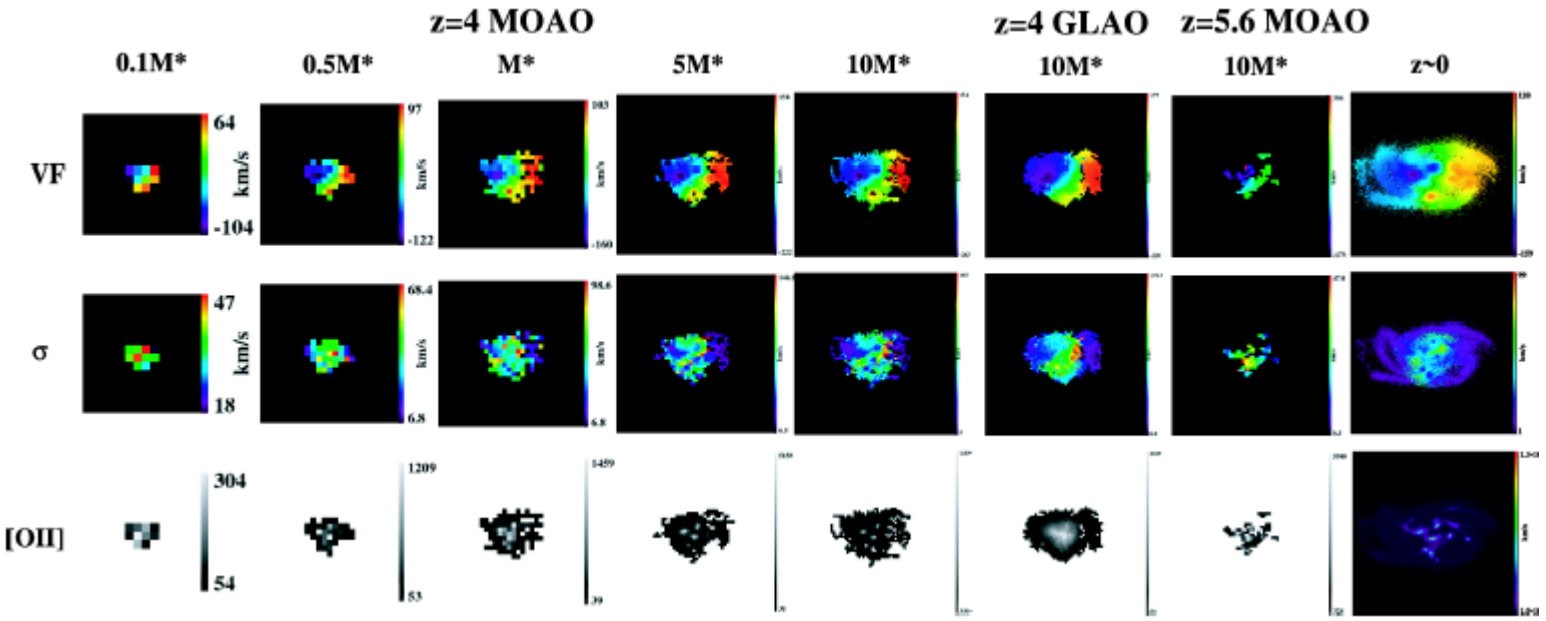
Mass limit (relative to M*) vs. z at SNR = 5



z = 1 M* galaxy at the E-ELT DL – H band

Physics of High Redshift Galaxies

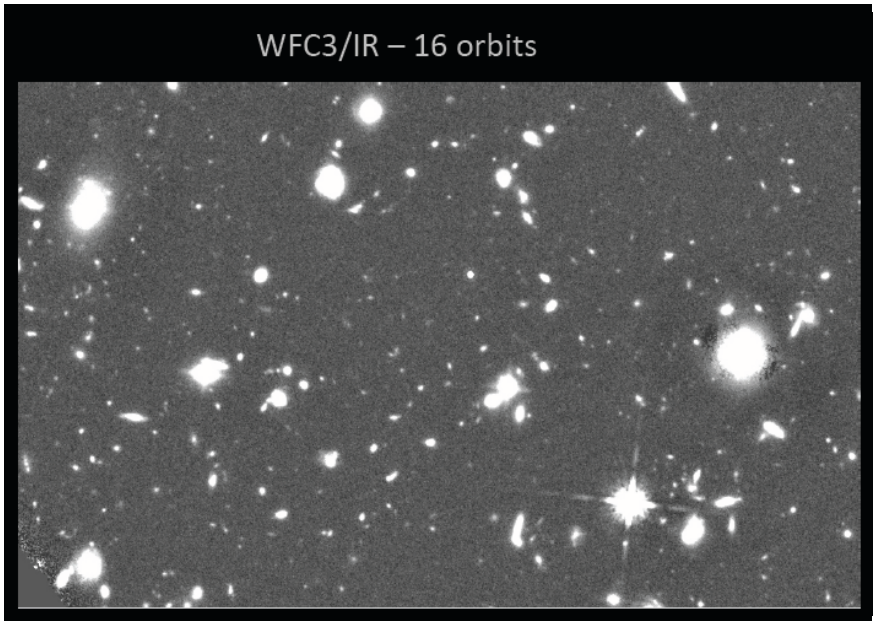
Simulations of clumpy discs at z = 4 using MOAO

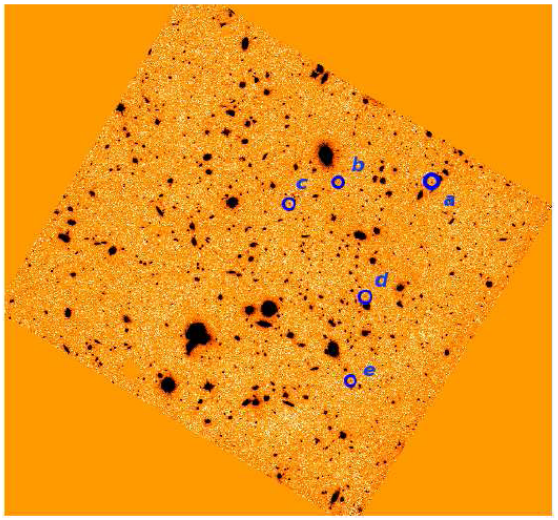


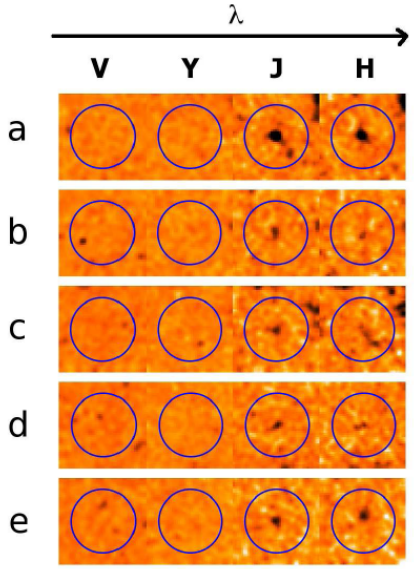
Puech et al., 2011

First light - The Highest Redshift Galaxies

Major progress since the installation of WFC3 on board HST in 2009. Basic information (LFs, sizes, etc.) available for simulating the E-ELT performance



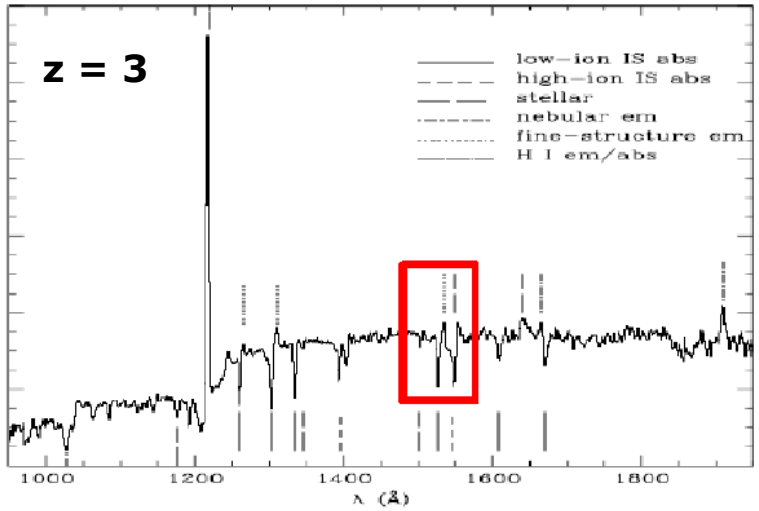


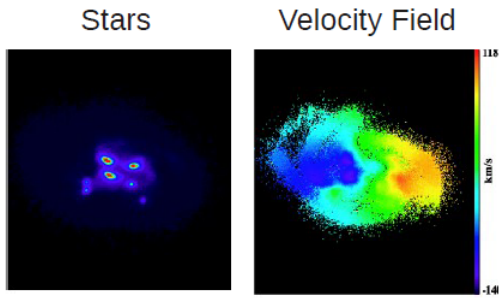


First light - The Highest Redshift Galaxies

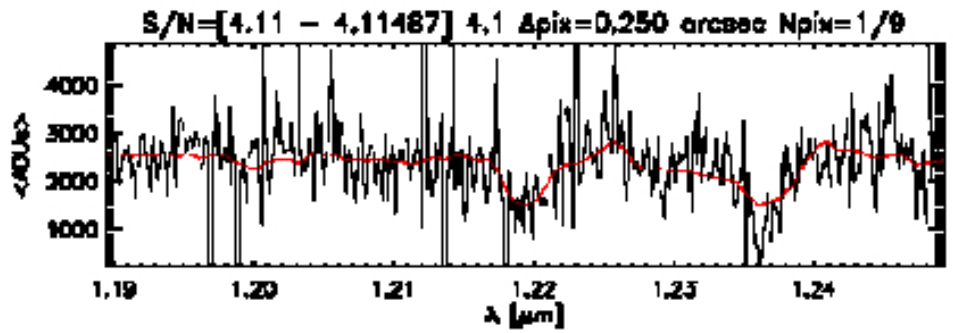
UV interstellar lines

Simulation for an AB=27 galaxy at z ~ 7





z = 0



High Redshift Galaxies: Main Findings

Imaging (ELT-CAM)

- The E-ELT will be able to provide useful diffraction limited images of M* galaxies up to a redshift of 2.5, resolving them into clumps.
- At higher redshifts it will be necessary to give up diffraction limited resolution.
- Highest redshifts: the realm of JWST

Spectroscopy (ELT-IFU, ELT-MOS)

- Measure [O II] emission line from M¤ galaxies up to a redshift of ~ 5 in ~25 hrs.
- It will be possible to distinguish between rotating disks and major mergers down to a limiting stellar mass of 0.5 M¤ out to z = 4.
- Full rotation curves of M¤ galaxies out to z = 2
- The E-ELT will be able to measure UV instellar lines on HAB > 27 galaxies at redshifts > 7 in ~ 40 hrs (a few tens of such galaxies in any single E-ELT field)

High Resolution Spectroscopy (ELT-HIRES)

- IGM Tomography
- Probing reionization with GRBs and quasars

Conclusions and final remarks

Resolved stellar populations and high-redshift galaxies have been highlight science cases for the ELTs since their inception. An ELT-MOS will be a key instrument for these studies

Resolved stellar populations

- Major advances expected in the next decade from Gaia and planned surveys
- E-ELT will extend these studies to beyond the Local Group and out to Virgo

High Redshift Galaxies

- ALMA, LOFAR, SKA precursors and later Euclid will considerably change the landscape on high redshift galaxies and reionization
- The main science case for JWST
- Presumaly, the same paradigm as for HST and 8-m telescopes will apply: imaging from space, spectroscopy from the ground (between OH lines)
- Strong competition from TMT : the two first light E-ELT instruments (ELT-CAM and ELT-IFU) represent less than ½ the scientific capabilities provided by the TMT first generation instruments

A comprehensive E-ELT instrumentation plan is urgently needed including specifications and schedules for ELT-MOS and ELT-HIRES