Project T-REX

OU5: E-ELT MOS

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Participants: IASF-MI, OA Roma

Why MOS? Why surveys?

- Galaxies are complex objects: different morphologies, sizes, colors, irregularly distributed in space. What are the relationships between galaxy properties? What is the role of the environment?
- Galaxy properties evolve: evolution of the LF and MF, SFRD peaks at z~2, merging, LSS evolution, biased galaxy evolution. What is the exact shape of evolution?

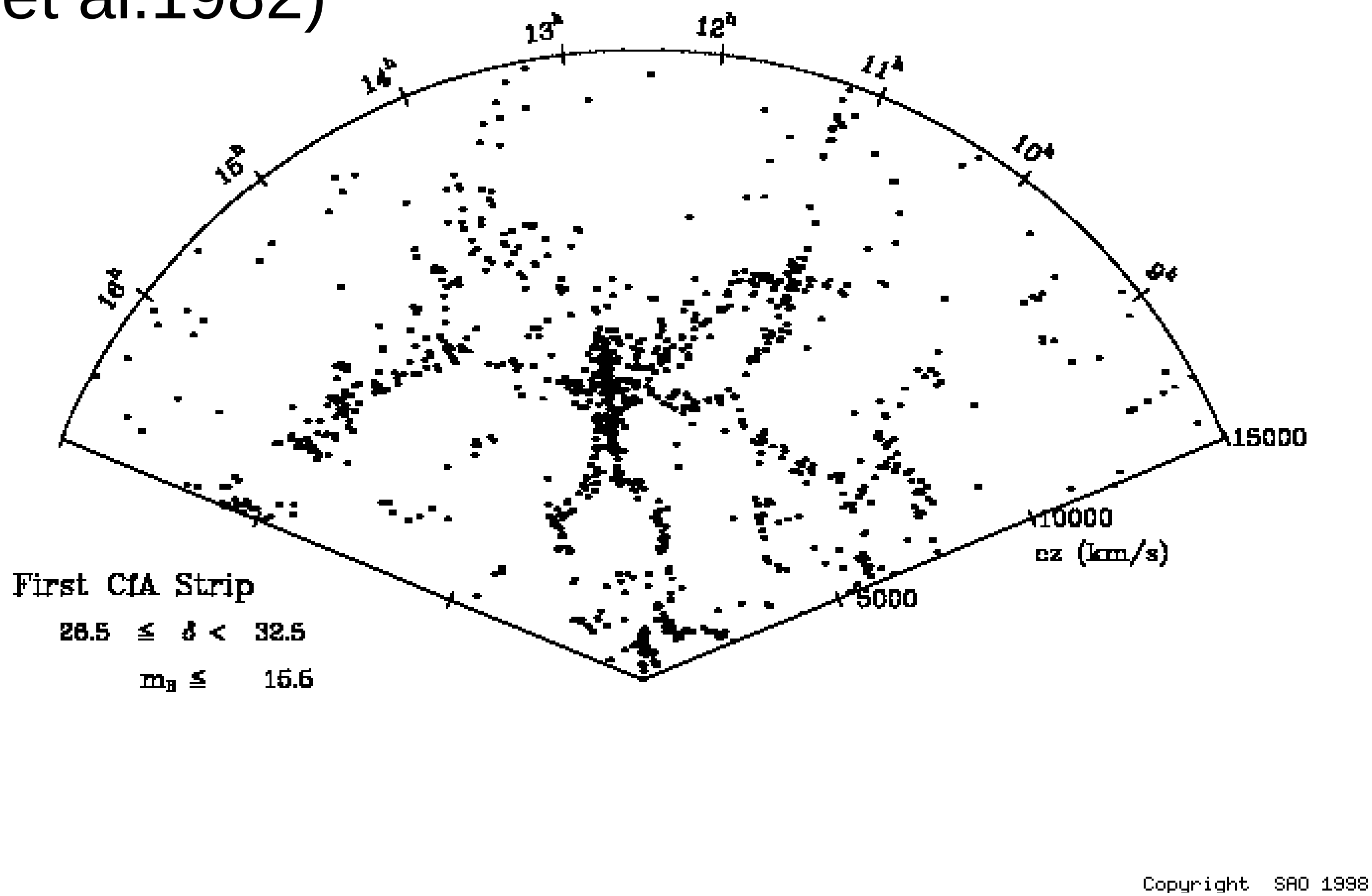
Need MANY objects at each of several epochs

- Spectroscopic surveys made possible by MOS spectrographs
- Multi-Object Spectrograph have long since been the work-horse of (extragalactic) astronomy

The ancestors

'nos esse quasi nanos gigantium humeris insidentes' Bernardo di Chartres, XII cent.

- CfA redshift survey:m<14.5, 3000 galaxies, z<0.05 (Huchra et al.1982)

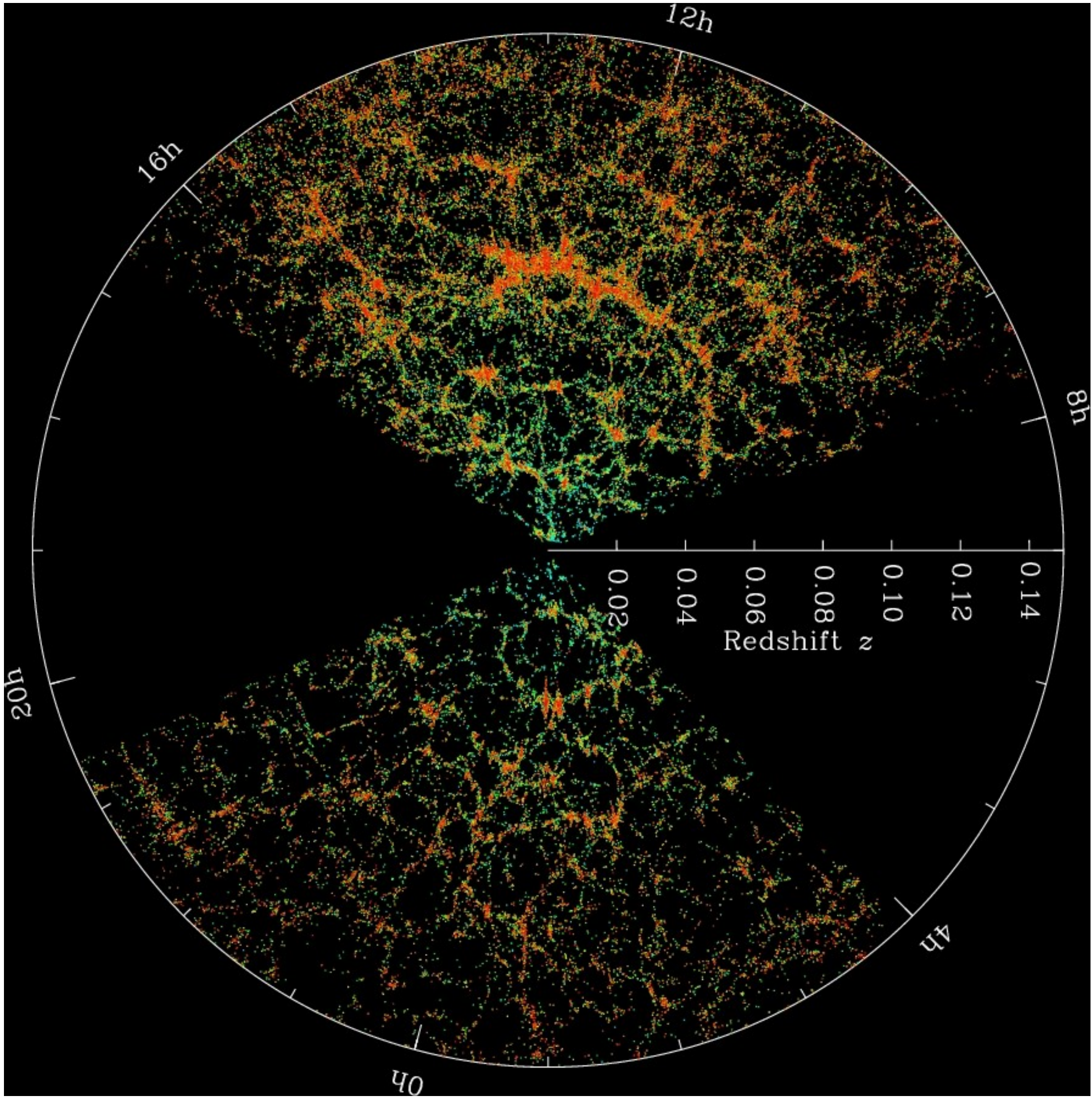


The ancestors

- ESP: ~3000 redshifts z<0.3 ~30 sq.deg. Bj<19.4 Optopus@3.6m (Vettolani et al., 1991)
- Las Campanas redshift survey: ~26500 galaxies, z<0.2 (Shectman et al., 1996) 700sq.deg. MOS@LAS Campanas
- CFRS ~ 1000 redshifts, <z>=0.6 MOS@CFHT (Lilly et al. 1991)
- 2DF ~230000 galaxies, <z>~0.1, 1500 sq. deg. 2DF@AAO (Colless et al. 2001)

Yesterday

- SDSS <z>~0.1, 14,555 sq. deg., $3*10^6$ objects, dedicated instrument and telescope (Abazajian et al. 2003) still on-going with eBOSS, APOGEE-2, MaNGA



Yesterday

- DEEP2: ~1sq.deg. I_{AB} <24 0.7<z<1.55 ~50000 gals (Davis et al. 2003)

VLT

- GOODS/ESO 5000 spectra 1.8<z<3.5 (Balestra et al.2010)
- VVDS (UD, Deep+Wide):35000 gals, 8.7sq.deg. m<24.75, z<6.7 (LeFevre et al 2014)
- ZCOSMOS: 20000 galaxies, m<22.5,0.5<z<0.8, 1 sq.deg. (Lilly et al. 2009)
- VIPERS: ~80000 galaxies, m<22.5 0.5<z<1.5, 24 sq.seg. (Guzzo et al. 2014)
- VUDS: ~ 10000 galaxies , m<25.5 2 < z < 6 1 sq.deg. (LeFevre et al. 2015)

TODAY

VLT Public Surveys

- I-F **Gaia-ESO Survey:** Milky Way, from halo to star forming regions. homogeneous overview of the distributions of kinematics and elemental abundances. Coupled with GAIA astrometry to quantify formation history and evolution of galactic populations.
- S **Lega-C**: deep spectroscopy of 3100 $z = 0.6 - 1.0$ Stellar velocity dispersion, stellar ages and abundances. Link between the present day galaxies and the population that existed during the first few billion years after the BigBang.
- S **VANDELS:** 2500 high signal-to-noise spectra within an area of 0.2 deg2. $1.5<z<7$ up to 80 hours integration time: metallicities and velocity offsets from absorption and emission lines, allowing a detailed investigation of the physics of galaxies in the early Universe.

Tomorrow

- **KMOS:** 24 2.8”x2.8” IFU modules,FoV , NIR
- **MUSE:** 24 IFU modules, 1 arcmin FoV, VIS
- **MOONS**: 500 sq.arcmin, 1000 fibres/pt, NIR
- **4MOST** : 4 sq.deg. >1500 fibres/pt, NIR

EUCLID: slitless, 0.5 sq.deg FoV, R~300, NIR

But also: MOSFIRE, WFMOS, JWST, TMT, GMT

Multi-various MOS

MOS come in many 'forms'

- Fiber-fed or slit based
- Aperture spectroscopy, more recently multi-IFU
- Optical domain, more recently NIR
- Common denominator: MULTIPLEXING

Statistics is (still) a fundamental requirement to understand the global properties of (not only) galaxies and derive the history of the Universe

Scientific cases summarized in ELT-MOS white paper (Evans et al. 2013, Hammer et al. 2015)

Distant galaxies

- Still a scarcely known domain: small samples, limited to z~7, few spectroscopic confirmations
- LF evolution unconstrained
- Very little (if any) knowledge of physical properties (SFR, metallicity)
- JWST, Euclid and MICADO will provide candidates down to m_{AB}~29 for ELT spectroscopic follow-up

Requires: NIR domain, R>3000, multiplex~200 to match surface density (a 7' FoV)

Large Scale Structures

- Reconstruct galaxy density field on 1Mpc scales at z>3
- Relate assembly of stellar mass to the build-up of dark matter halos
- Distribution of galaxies at high z to measure halo mass and number of satellites per halo
- Limited information on clustering at z~3-5: small samples, small sky coverage
- Big uncertainties between available data and models
- Clusters: z~2 well-defined red sequence, SF already quenched. SF progenitors up to z~5

Requires high multiplex (hundreds), moderate resolution, large areas

Galaxy evolution

- What drives galaxy evolution? Role of mergers? Inflows? Outflows? How do the fundamental relations evolve?
- What is the role of sub L* galaxies? Does LF steepens as expected?
- What is the role of AGN-driven outflows? Observed only in the most luminous sources.
- Positive feedback?
- In which phase of the galaxy evolution? And in which galaxies?

Requires aperture and IFU, moderate multiplex, NIR

Table 7: Summary of top-level requirements from each Science Case (with desirable reqs. in italics).

Case	Multiplex	FoV/target	Spatial sampling	λ-coverage (μm)	*R*
SC1 First light	20-40	2"x2" *	40-90 mas	1.0-1.8 *1.0-2.45*	5,000
	≥150	-	(GLAO: 0.6"Ø)	1.0-1.8 *1.0-2.45*	>3,000
SC2 Large-scale structures	≥10-15	2"x2"	(GLAO: IFU)	0.4-0.6 *0.37-0.6*	>3,000
	50-100	-	(GLAO)	0.6-1.8 *0.6-2.45*	>3,000
	>400	-	(GLAO)	0.4-1.4 *0.37-1.4*	>3,000
SC3 Gal. evolution	≥10	2"x2"	50-80 mas	1.0-1.8 *1.0-2.45*	5,000
	≥100	-	(GLAO: 0.6"Ø)	1.0-1.7 *0.8-2.45*	≥5,000 *~10,000*
	≥10	2"x2"	(GLAA: IFU)	0.385-0.7 *0.37-0.7*	5,000
SC4 AGN	~10	-	< 100 mas	1.0-1.8	>3,000
SC5 Extragal. stellar pops.	Dense	1"x1" *1.5"x1.5"*	< 75 mas *20-40 mas*	1.0-1.8 *0.8-1.8*	5,000
	10s arcmin^{-2}	-	(GLAO)	0.4-1.0	≥5,000 *≥10,000*
SC6 Gal. archaeol.	10s arcmin^{-2}	-	(GLAO)	0.41-0.46 & 0.60-0.68 *0.38-0.46 & 0.60-0.68*	≥15,000 *≥20,000*
SC7 GC science	Dense	> 2"x2"	~100 mas	1.5-2.45	≥5,000 *≥10,000*
SC 8 Planet form.	10s	-	(GLAO)	0.5-0.6	≥20,000

* Minimum size is 1"x1" if on/off sky subtraction is used.

MOS@E-ELT

- 3 phase-A studies in 2010
  1) EAGLE
  2) OPTIMOS-EVE
  3) OPTIMOS-DIORAMAS
- ESO-2020, January 2015
- Science with MOS: towards the E-ELT era, Cefalu' 7-11Sept 2015
- LoI next week
- On sky ……. >2025?

Preparing for MOS

1) Science: Laura Pentericci OA-Roma

- Selection techniques (A. Bongiorno)
- Trade-off between limiting magnitude and number of objects
- Scientific requirements for E-ELT MOS (L. Pentericci)
- galaxy formation epoch and mass building: which is the attainable precision?

2) Software: Bianca Garilli IASF-MI

- Exploit multiplexing by maximizing number of sources (S.Rota)
- Design and implement algorithm
- general purpose utility
- Application of prototype to a real case

3) Hardware: Fernando Pedichini OA-Roma

- Detectors for wave front sensors for ELT (F. Pedichini)
- metrology of the opto-mechanical components and of the fiber positioners.
- micro-actuators and micro-encoders in a cryogenic environment,
- Study of the local correction for seeing through MEMS actuators