ELT SCIENCE CASES: COSMOLOGY

- **Perpectives after NGST and CELT — time-frame 2010-2015**

- **Targets provided for high spatial and spectral resolution by other telescopes: NGST, CELT, SWIFT and successors, ALMA**

- **Synergy with space- and ground-based facilities:**

XEUS	ALMA	SKA
high z AGN	high z QSOs	redshifted HI
$z \leq 2$ normal galaxies	high z starbursts	

Spatial Resolution: Diffraction Limit

at $\lambda = 1\mu$ and adopting $\Omega_{\rm M} = 0.3$, $\Omega_\Lambda = 0.7$, $h = 0.65$

Telescope	**NGST (6m)**	**30m**	**100m**
Resolution (mas)	**35**	**7**	**2.1**
Scale (pc) per Res element at $z = 4$	**270**	**55**	**16**

Typical size (pc)	300	50	10
Object	giant HII region	compact HII region central gas disk in AGN with $M_{BH} \sim 10^8\ M_\odot$	globular cluster

Sensitivity

- **Imaging** point source, diffraction limit, S/N ∼ 5-10, Δt = 1 hr

tel	NGST	30m	100m
mag	$R_{AB} \sim 29.5$	$R_{AB} \sim 31$	$R_{AB} \sim 35$
mag	$J_{AB} \sim 30$		$J_{AB} \sim 32$
FoV	$4.6' \times 4.6'$	$\Phi \sim 2'$ (AO/2μ)	$\Phi \sim 2'$ (AO/2μ) ?

- **Spectroscopy** point source, diffraction limit, S/N ∼ 20, Δt = 2 hr
  Res∼300

tel	NGST	30m	100m
mag	$J_{AB} \sim 25$	$R_{AB} \sim 26.5$	$R_{AB} \sim 30.5$

- **Spectroscopy** point source, diffraction limit, S/N ∼ 20, Δt = 10 hr
  Res∼10000

tel	30m	100m
mag	$R_{AB} \sim 25$	$R_{AB} \sim 28.5$

Typical Magnitudes for various classes of objects

- **SNIa** $\mathbf{I_{AB} \sim 26.5}$ **at** $\boldsymbol{z = 1.7}$
  $\mathbf{I_{AB} \sim 29.0}$ **at** $\boldsymbol{z \sim 4}$

- **LBGs** $\mathbf{R_{AB} \sim 24.5}$ **at** $\boldsymbol{z_{spec} \sim 3}$
  $\mathbf{I_{AB} \sim 25.0}$ **at** $\boldsymbol{z_{spec} \sim 4}$

- $\boldsymbol{L^\star}$ **galaxy** $\mathbf{R_{AB} \sim 26.5}$ **at** $\boldsymbol{z \sim 4}$

- $\boldsymbol{z = 6.56}$ **galaxy** **unlensed flux at JHK′ ∼60nJy or AB=27.2**

- **GRB afterglows** **flux independent of** $\boldsymbol{z}$ **at** $\boldsymbol{2\mu}$

  theoretical expectations at $z = 10$: f(2μ)$\sim$ 30μJ or K_{AB} ∼20.3 at t=1 day
  f(2μ)$\sim$ 1.5μJ or K_{AB} ∼23.6 at t=10 days

  existence of weak (∼20 times fainter) afterglows

  high fraction of dark afterglows: NGST

Number of sources and surface densities

- GRBs **SWIFT is expected to detect ∼100 bursts per yr**
2 yr nominal life-time 2004/5 → successors?

- QSOs **R ∼ 24 at z ∼ 2-4 : 75 deg^{-2}**

- Compact galaxies **R ∼ 24 at z ∼ 2-4 : 5000 deg^{-2}**
at z ∼3-4, half-light radius ∼1-2 kpc → r ∼0.2-0.4 arcsec

- $L^\star$ galaxy **R ∼ 26.5 at z ∼ 2-4 : 15 arcmin^{-2}**

- Probing large-scale structures on small scales
at z ∼ 3-4, 1 Mpc → ∼3 arcmin

Re-ionization epoch

1. First QSOs

high spectral resolution

IGM enrichment : C IV forest $z \leq 13.2$, C II $z \leq 15.5$
Ionized bubbles : some transmitted flux within the Lyα troughs

Targets: J & H dropouts – wide field deep IR surveys (VISTA), NGST, synergy with XEUS

advantage of a 100m

2. GRBs as above plus

physics of GRB hosts: time dependent O I, C II C IV absorptions
GRB rate (SFR)

Targets: opt/near IR robotic telescopes, future γ-ray missions
2004-5 synergy between SWIFT, VLT and Keck
dark GRBs: NGST

Re-ionization epoch (continued)

3. First Starburts

physics of of the first galaxies: M $\sim 10^8$ $M_\odot$, AB $\geq$ 30 at $z \sim 10$
sizes $\sim$ 100 pc, σ_V a few 10 km s^{-1}

low spectral resolution: ct, break and He II1640 emission
Lyα fully quenched
high spectral resolution: stellar absorption features

Targets: NGST, wide-field near IR with ELTs
narrow-band imaging with ELTs
make use of gravitational amplification

results from WMAP
advantage of a 100m
synergy with ALMA and Herschel

High redshift supernovae

- Cosmological parameters - Ω_Λ need $z(\mathrm{SN}) > 1$
  but WMAP, Planck, SNAP

- Cosmic evolution of SN rate, Comparison with SFR evolution

- Properties of host galaxies compared to those of GRBs

Targets: imaging campaigns with VLT and ELTs
low resolution spectroscopy in the optical and near IR

30m for $z < 2$
100m for $z < 4.5$

Large-scale structures at $z \sim 2$-4.5

Epoch of formation of sheets and proto-clusters
IGM overdensities detected at $z \sim 3$

- 3D mapping of the IGM on scales ≥ 0.5 Mpc

Lyα and C IV forests in close-by sightlines
high resolution spectroscopy of QSOs and bright, compact galaxies
multi-slit/multi-fiber spectrograph

advantage 100m: target surface density at $z > 3.5$
synergy with XEUS: AGN are also tracers of large-scale structures

- Do galaxies trace the same mass concentrations than the IGM

Lyα emitters and LBGs down to $L_\star$ at $z \sim 4$
low resolution, high multiplexing spectroscopy

advantage 100m: target magnitude at $z > 3.5$
synergy with SKA

Dark matter distribution at $z \sim$ 1-2.5

Weak gravitational lensing/cosmic shear on galaxy-halo scales

probing lower DM masses and smaller scales than currently

results compared to halo masses derived from kinematics

foreground objects: high z clusters, groups, galaxy pairs,
massive Es, isolated galaxies with X-ray halos

high spatial resolution: mass reconstruction

background objects: selection by colour and dropout techniques

galaxy density N(z)

imaging at the diffraction limit for large FoVs

$\sim$ 2 Mpc or 6 arcmin at $z \sim$ 1-2

advantage NGST, 30m

Link between AGN activity and galaxy formation

- Black hole masses and AGN accretion disk sizes

$M_{\rm BH} \sim 6 \times 10^{-3} M_{\rm bulge}$

$M_{\rm BH} \propto \sigma_\star^\alpha$ with $\alpha \sim$ 4-4.8

$\sigma_\star$: stellar velocity dispersion at $r > r_{\rm D}$

$r_{\rm D}$: the BH mass starts to dominate the gravitational potential

perturbations measured out to $\sim 10 r_{\rm D}$

Search for and rotation curves of AGN nuclear gas disks

$M_{\rm BH} \sim 3 \times 10^9 M_\odot$, $r_{\rm D} \sim 6$ pc for $\sigma_{\rm V} \sim 300$ km s^{-1}

advantage of a 100m for $z \geq 0.5$

- AGN host galaxy

morphology, gas kinematics, chemical composition
dust content, SFR and environment

synergy with ALMA and Herschel

Physics of galaxies at $z \sim$ 1-5

- **Galaxy evolution** connection to large-scale structure development
  epoch of bulge and spiral disk formation
  mass function
  outflows: ejection of metals in the IGM

- **Physics** kinematics: ordered or chaotic motions (mergers)
  fundamental Plane, Tully-Fisher relation
  mass-luminosity relation
  chemical evolution
  age

- **Diagnostics** emission lines: [O II], Hβ, [O II], Hα
  $z > 4.9,\ 3.5,\ 3.4,\ 2.4$
  stellar absorption lines (age or metallicity indicators)

Physics of galaxies at $z \sim$ 1-5 (continued)

near-IR low and high resolution spectroscopy
multiple IFUs

NGST as efficient as a 30m for low resolution spectroscopy
for galaxies smooth on the 100mas scale
in 2 hrs S/N $\sim$ 20 for $K_{AB} \sim 25$

low resolution spectroscopy limit of a 30m: $K_{AB} \sim 26$
if presence of $\leq$30mas clumps

synergy with ALMA and SKA for molecular gas and galaxies with
very high SFR: f(1.3mm)=20 μJy, S/N $\sim$ 5 in 3.7 hr

Conclusions

science goal	obs. mode	100m	30m	NGST
• reionization epoch				
QSOs & galaxies at z ∼10-15	high res spectra	++	+	
id plus GRS	low res spectra	+	+	+
sub $L^\star$ galaxies at high z	imaging	+		
IGM mapping at z ∼2-3.5	high res spectra	+	+	
at z ∼3.5-4.5	id	++	+	
DM distribution at z ∼1-2.5	imaging		+	+
• SNIa, Ω_Λ, SN rate				
at z <2	low res spectra	+	+	
at z ∼2-4	id	+		
• BH masses at z <0.5	high res spectra	+	+	
at z >0.5	id & spatial res	+		
• galaxies at z ∼1-5	low res spectra	+	+	+
atially resolved spectroscopy	low res IFUs	+	+	
id	high res IFUs	++	+	

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