EUCLID Spectroscopy

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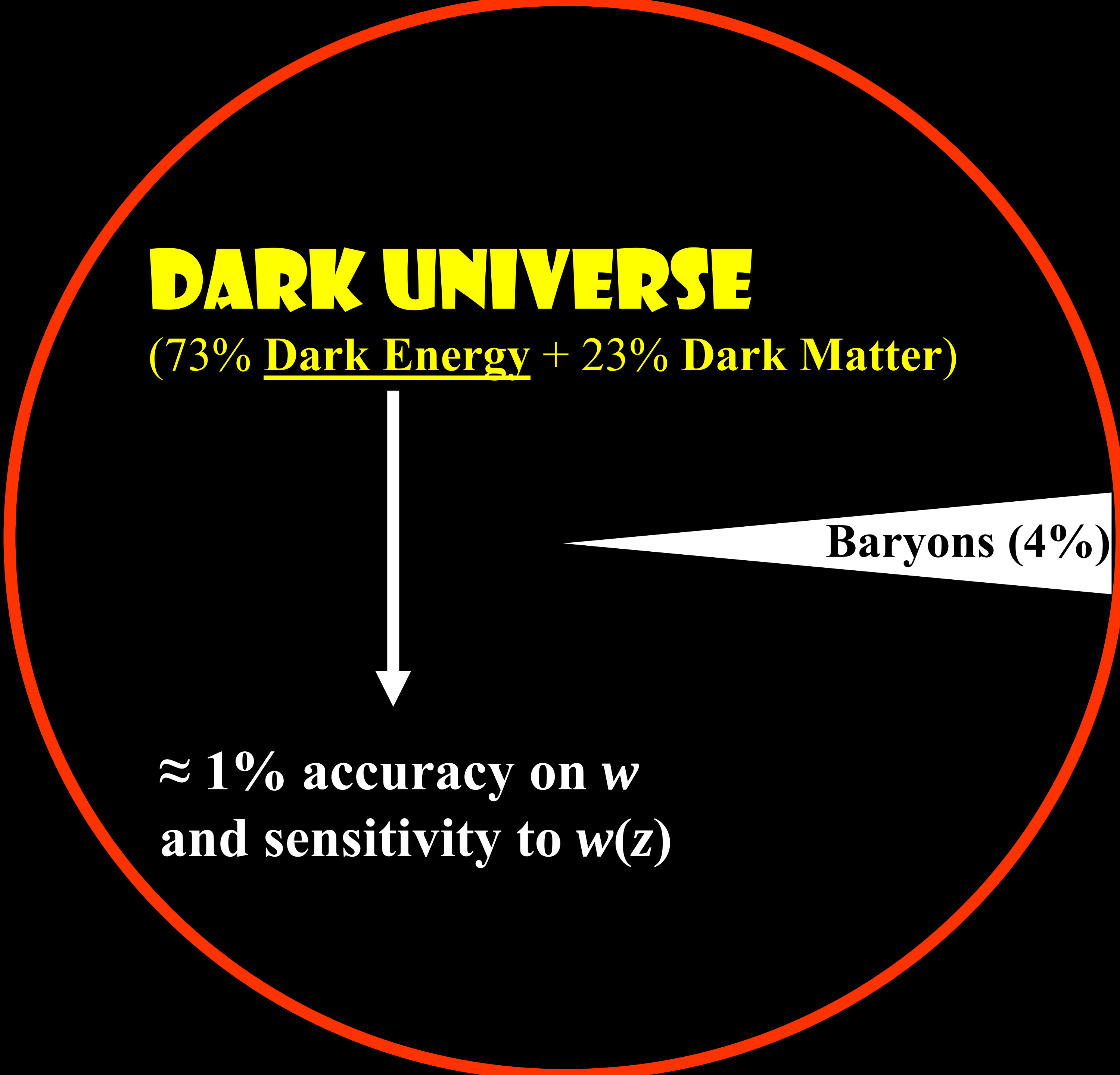
& the EUCLID-NIS Team

"Observing the Dark Universe with EUCLID", ESA – ESTEC, 17 November 2009

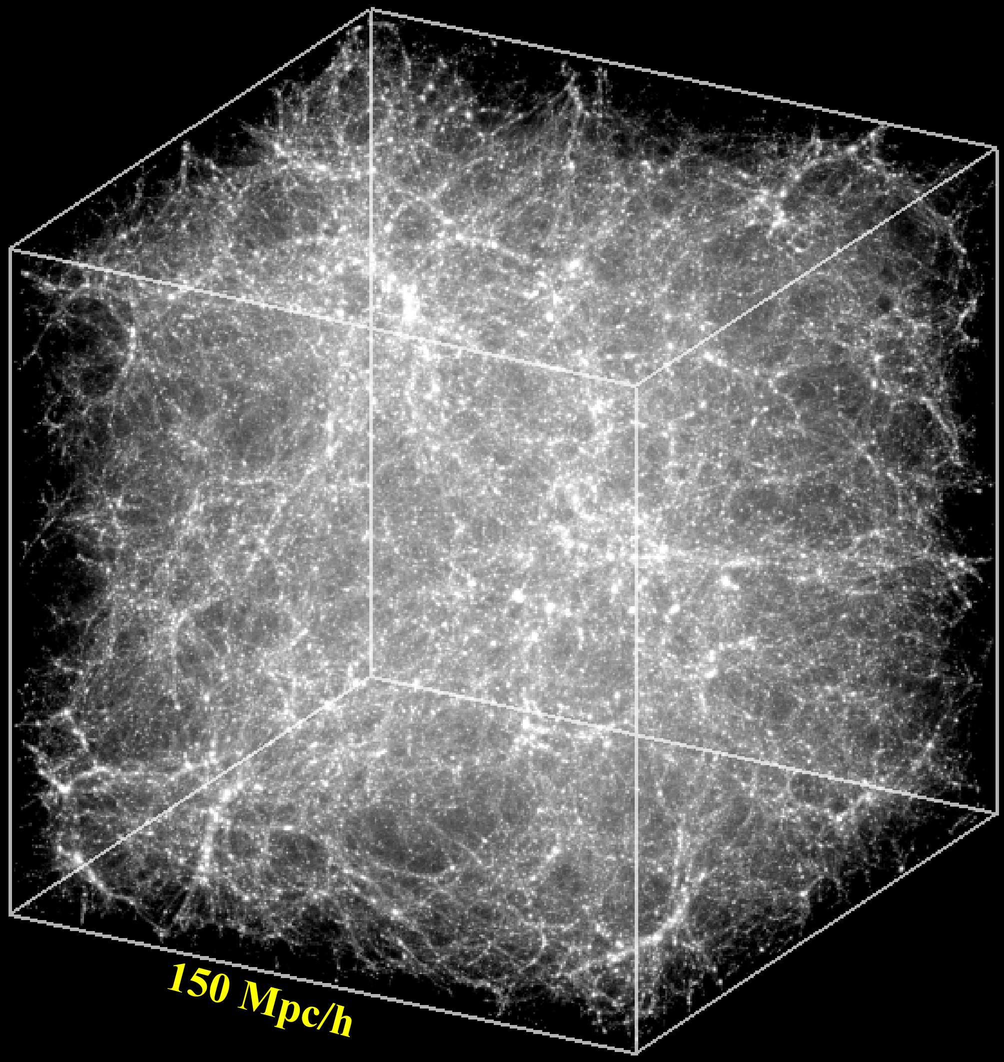


DARK UNIVERSE
(73% Dark Energy + 23% Dark Matter)
Baryons (4%)
≈ 1% accuracy on w
and sensitivity to w(z)

- Weak gravitational lensing
- Type Ia Supernovae
- Baryonic Acoustic Oscillations
- Redshift-space distorsions
- Integrated Sachs-Wolfe effect
- Clusters of galaxies
- Age – redshift relation

MASSIVE SPECTROSCOPIC SURVEY

Large scale distribution of Dark Matter



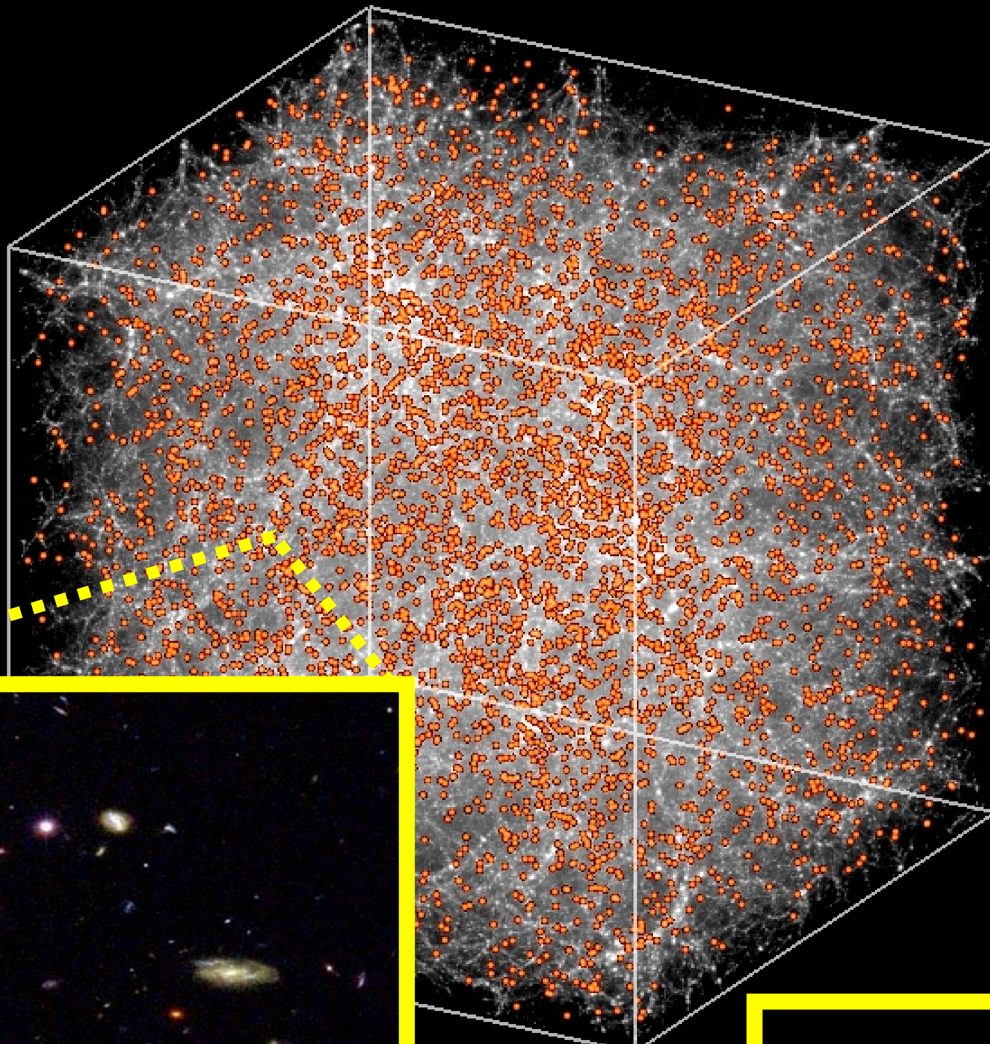
- **Expansion of the box:**
  → Expansion rate *H(z)*

- **Collapse of structures inside the box:**
  → Gravitation

Need to cover Gpc^3 volumes

Simulations by A. Orsi

3-D evolutionary map of the Universe at 0.5<z<2



- ❑ Each galaxy has 3 coordinates: RA, Dec, Redshift
  ➔ **3-D map**
- ❑ Several boxes at different redshifts
  ➔ **evolution**

"For free":
Galaxies, AGN, Galactic stars

Top Level Requirements

- Number of spectroscopic redshifts **$> 5 \times 10^7$**
- Redshift accuracy **$\sigma_z/(1+z) \leq 0.001$**
- Redshift range **$0.5 < z < 2$**
- Sky coverage **$\geq 20{,}000\ deg^2$**
- Deep Survey: **2** magnitudes deeper, **$\geq 40\ deg^2$**

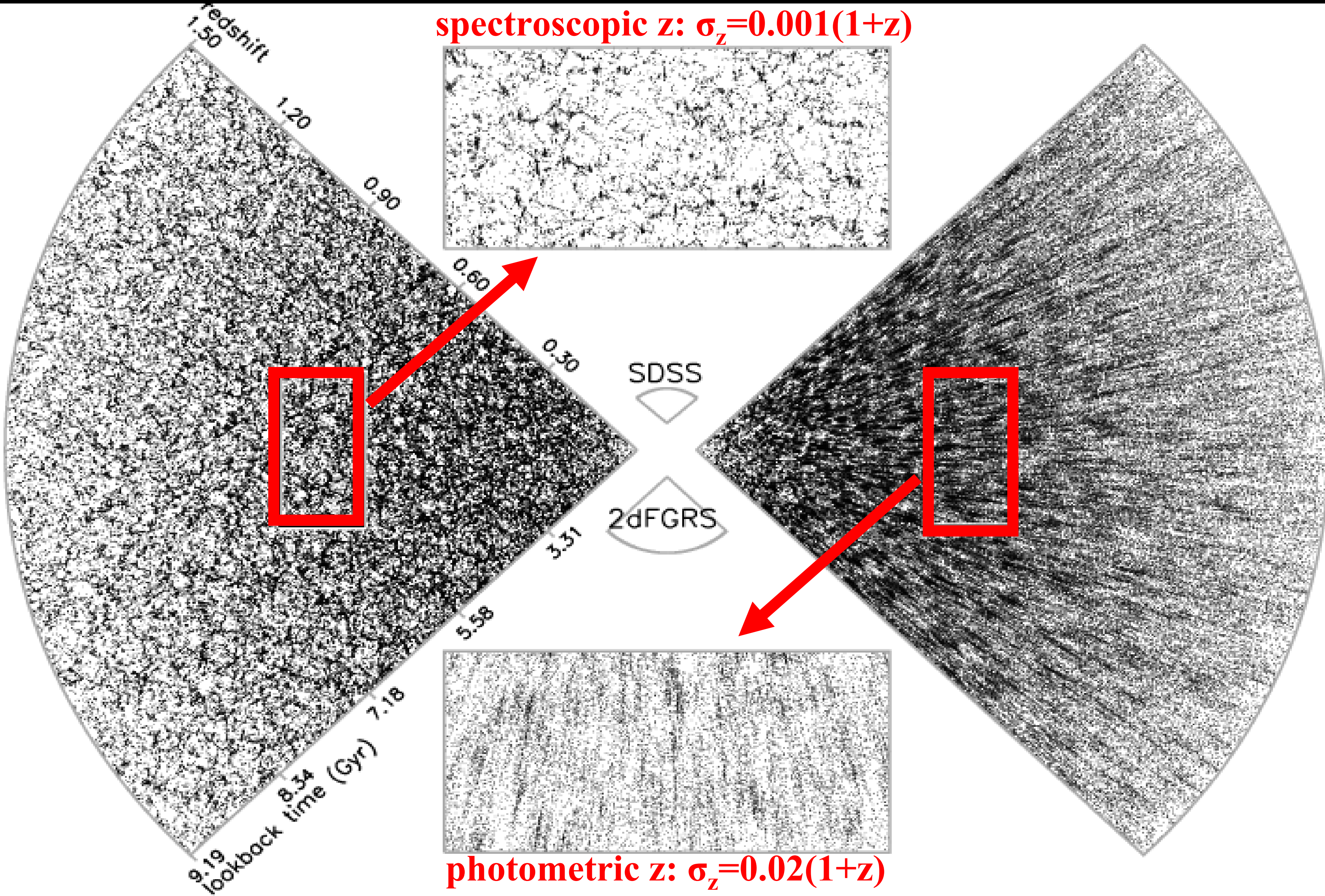
- Mission duration **≤ 5 years**

Why spectroscopy ?

Why from space ?

Why near-infrared ?

Why spectroscopy ?



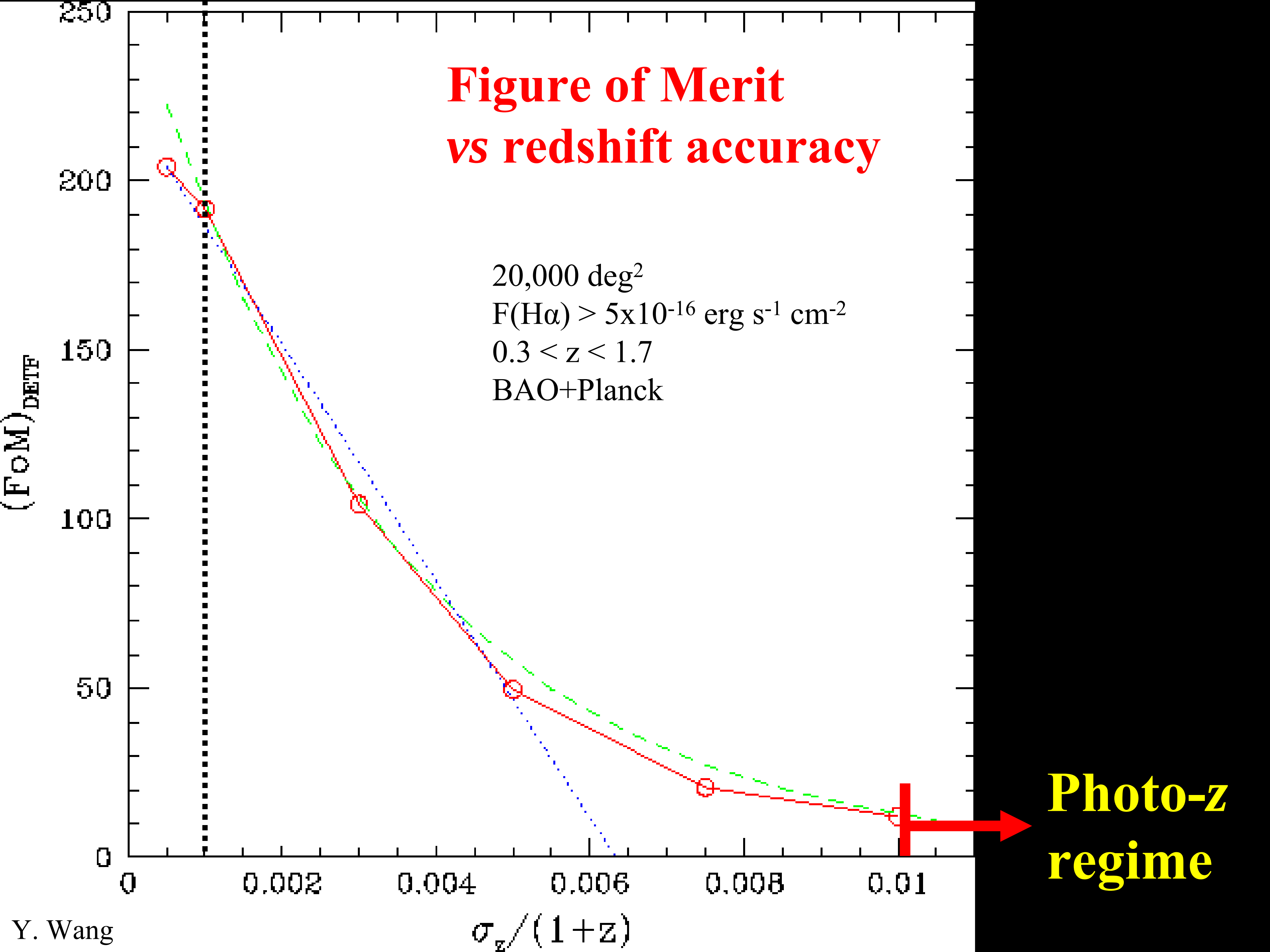


Figure of Merit
vs redshift accuracy
20,000 deg^2
F(Hα) > 5x10^{-16} erg s^{-1} cm^{-2}
0.3 < z < 1.7
BAO+Planck
$(\mathrm{FoM})_{\mathrm{DETF}}$
$\sigma_z/(1+z)$
0
50
100
150
200
250
0
0.002
0.004
0.006
0.008
0.01
Photo-z regime
Y. Wang

Why going to space ?

- Sky background : stable and ≥ 500x lower
- No atmospheric emission and absorption lines
- Homogeneous and uniform data with clean selection function
- Higher redshifts (e.g. $1.5<z<2+$) = higher accuracy on $w(z)$
- Survey speed
- EUCLID multi-probes = control of systematics (same timescale !)

Why in the near-infrared ?

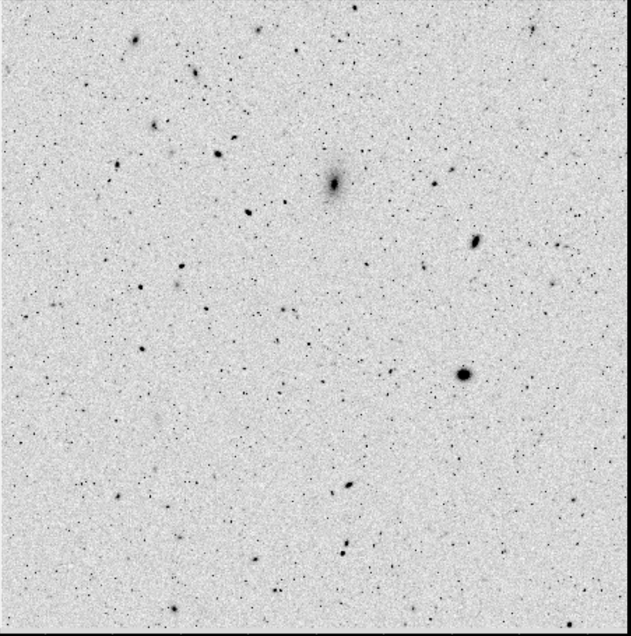
- Instantaneous coverage of $0.5 < z < 2$ with Hα emission (1 – 2 μm)
- Much less affected by dust extinction than optical
- Rest-frame optical spectra ➔ high legacy value

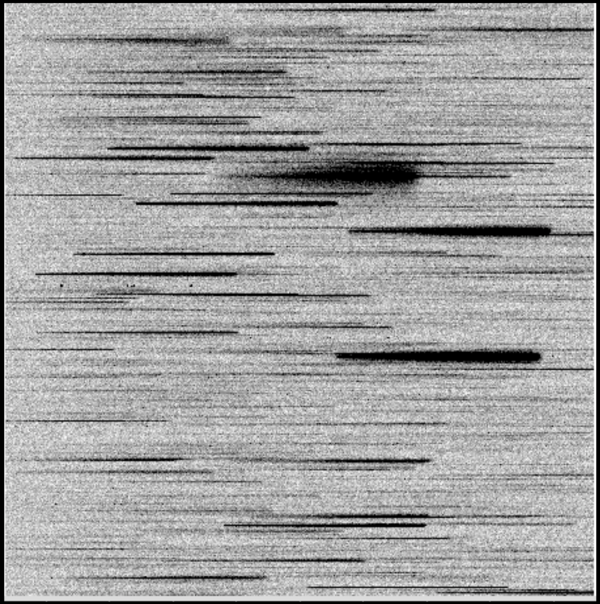
How ?

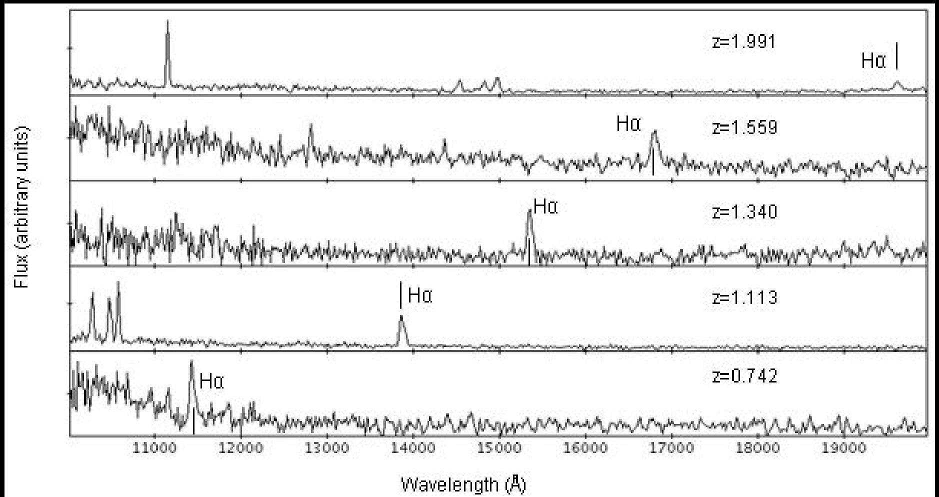
Slitless spectroscopy (baseline)

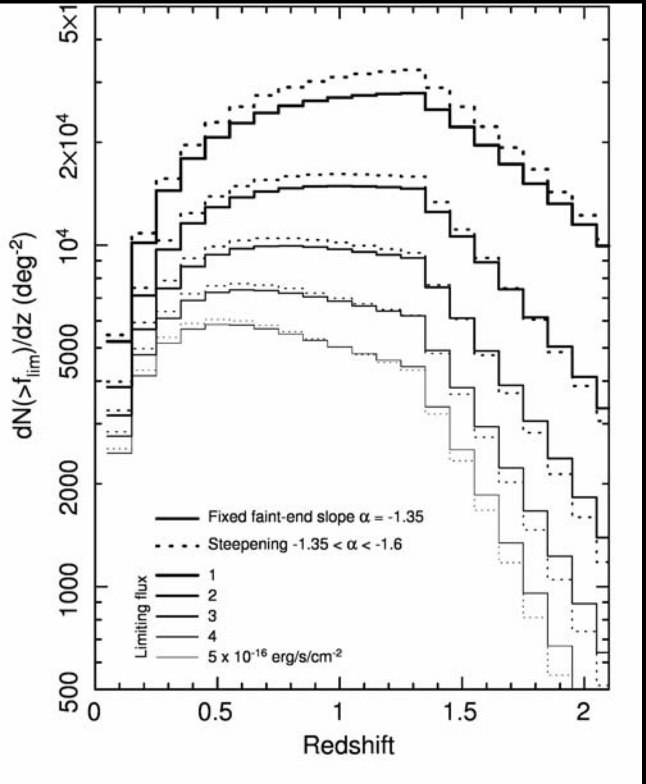
Star-forming galaxies

Hα emission at 0.5<z<2



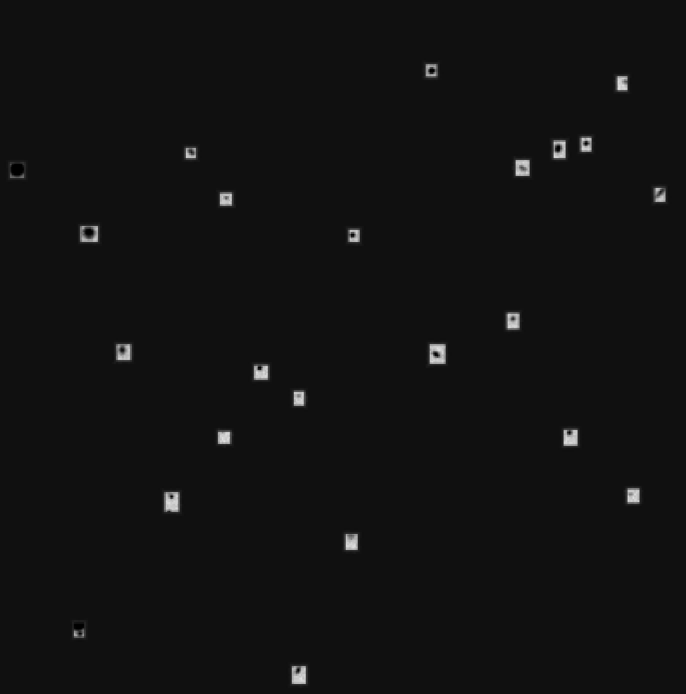


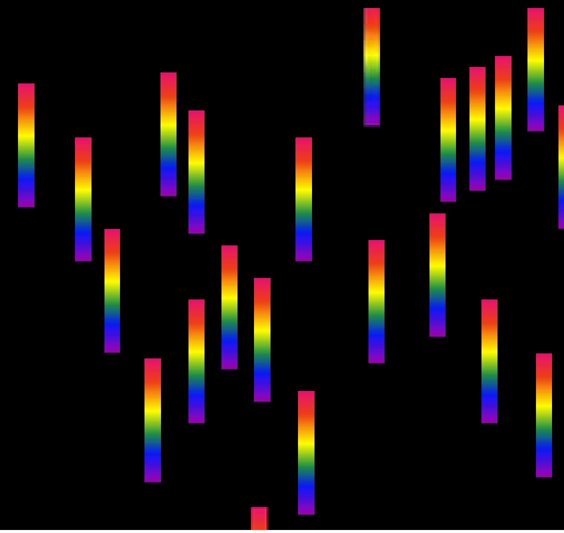


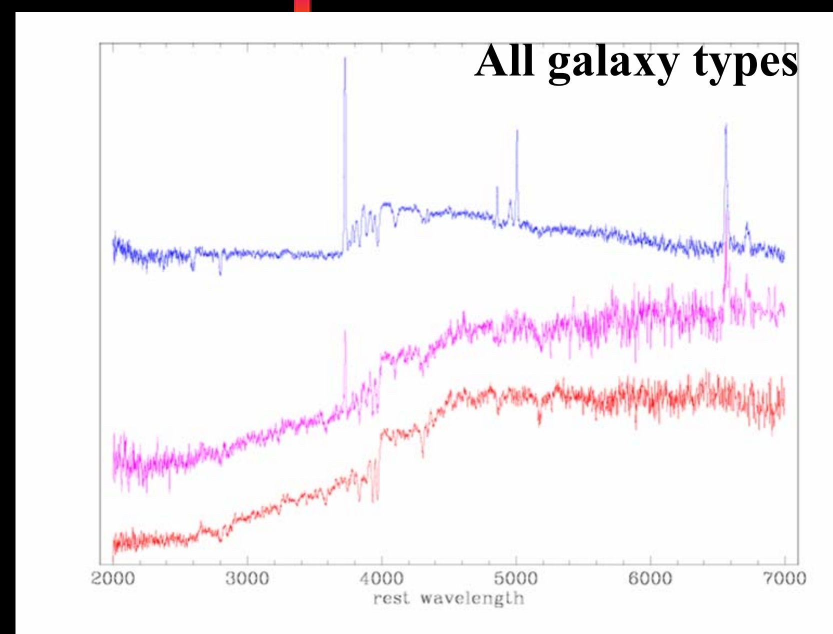


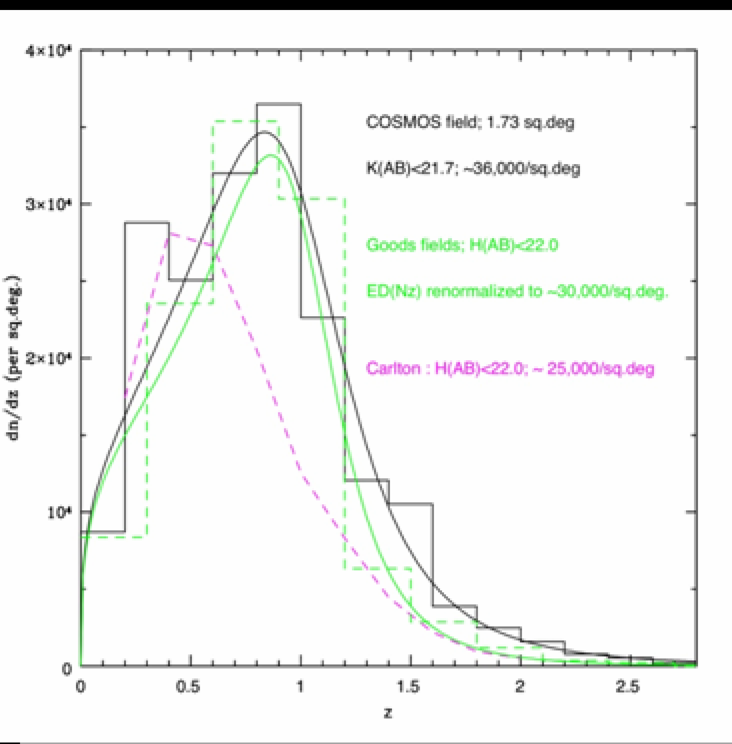
DMD "slit" spectroscopy (option)

All types of galaxies at 0 <z< 2.5 selected in the H-band ($\lambda_{obs} \approx 1.6\ \mu m$) ($H_{AB}$< 22)





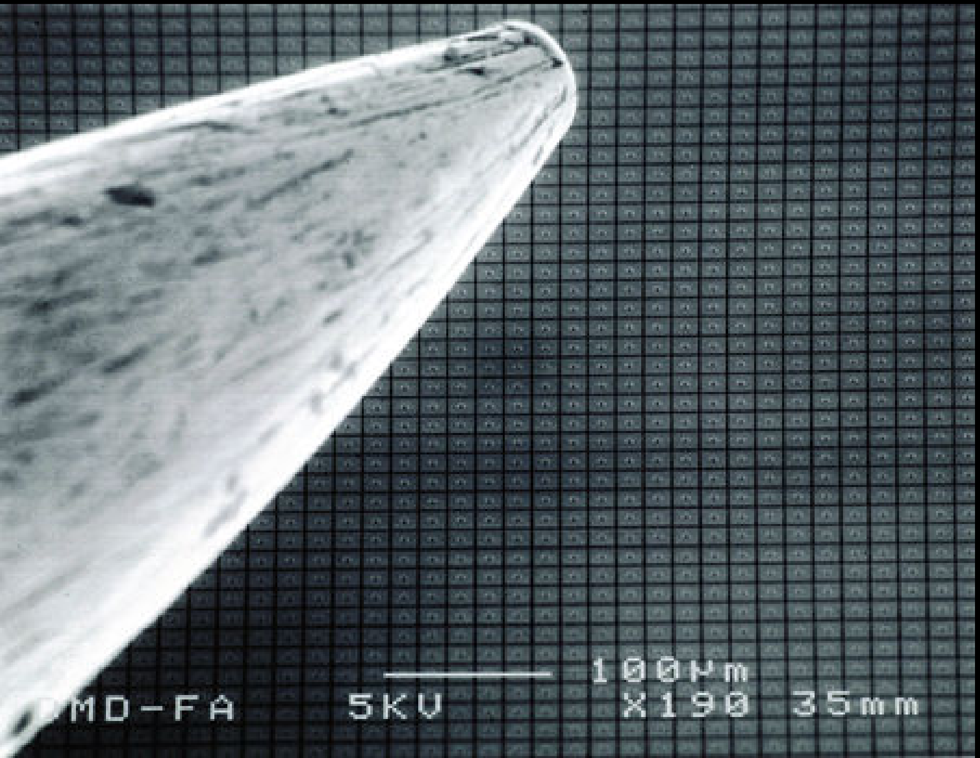




Digital Micromirror Devices (DMDs)

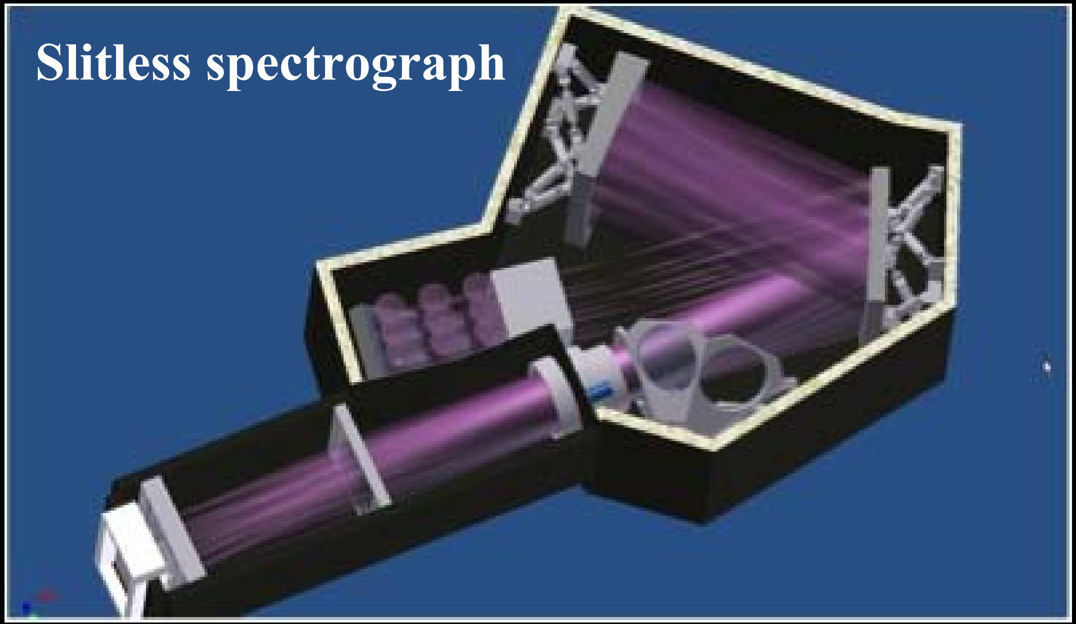
TI "Cinema" DMD arrays of 2048×1080 independent mirrors (14 x 14 µm each)

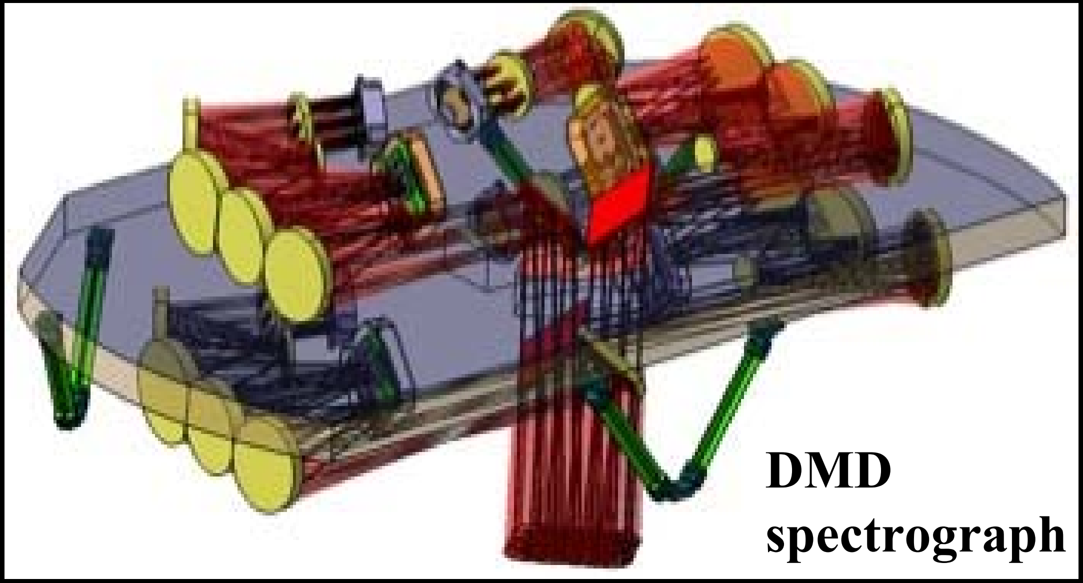
→ Never used in space
→ Lab tests ongoing (Visitech+LAM+ESA)



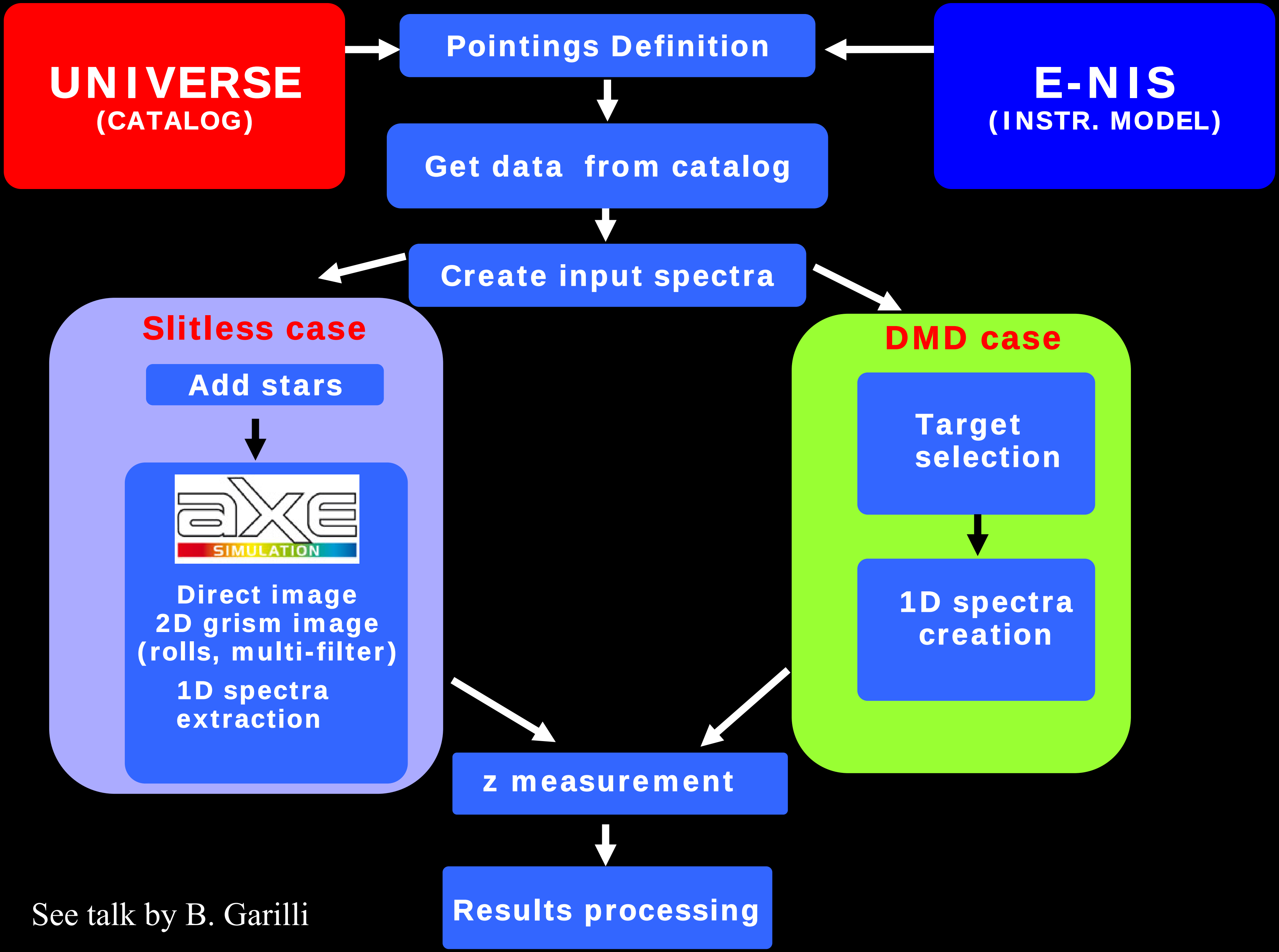
Can E-NIS meet the requirements ?

Twofold study

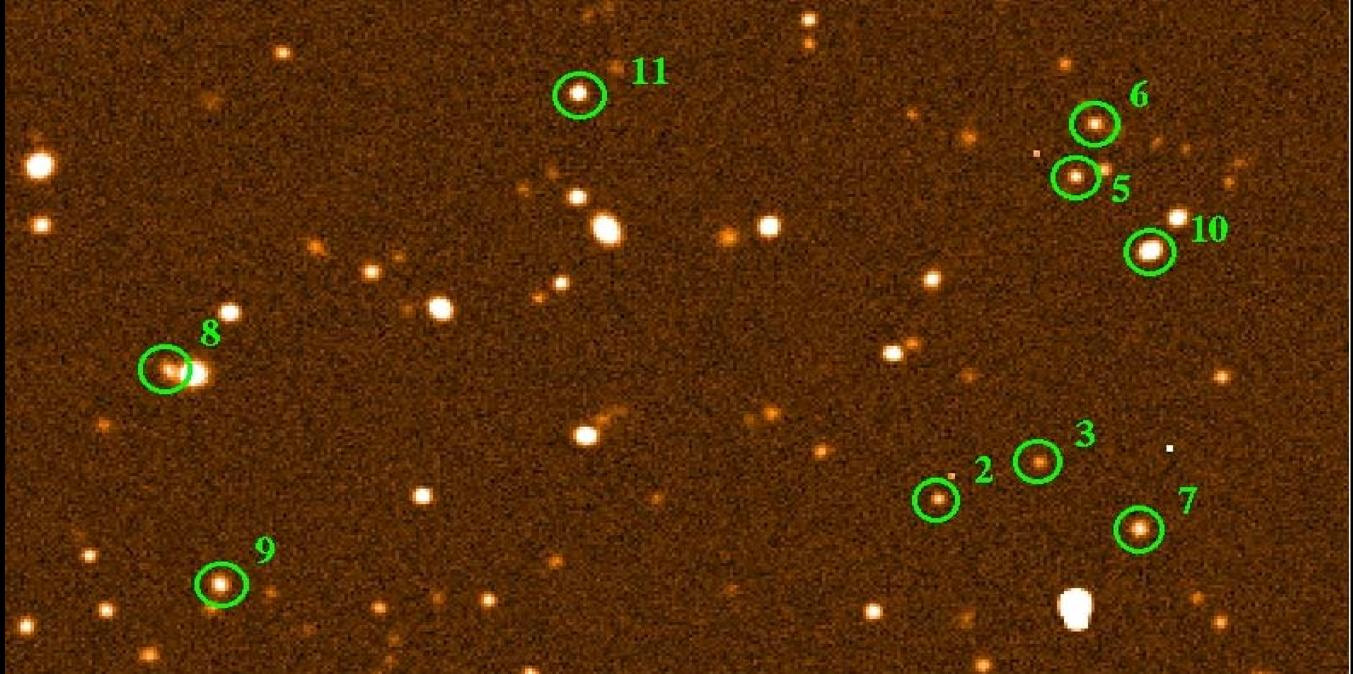




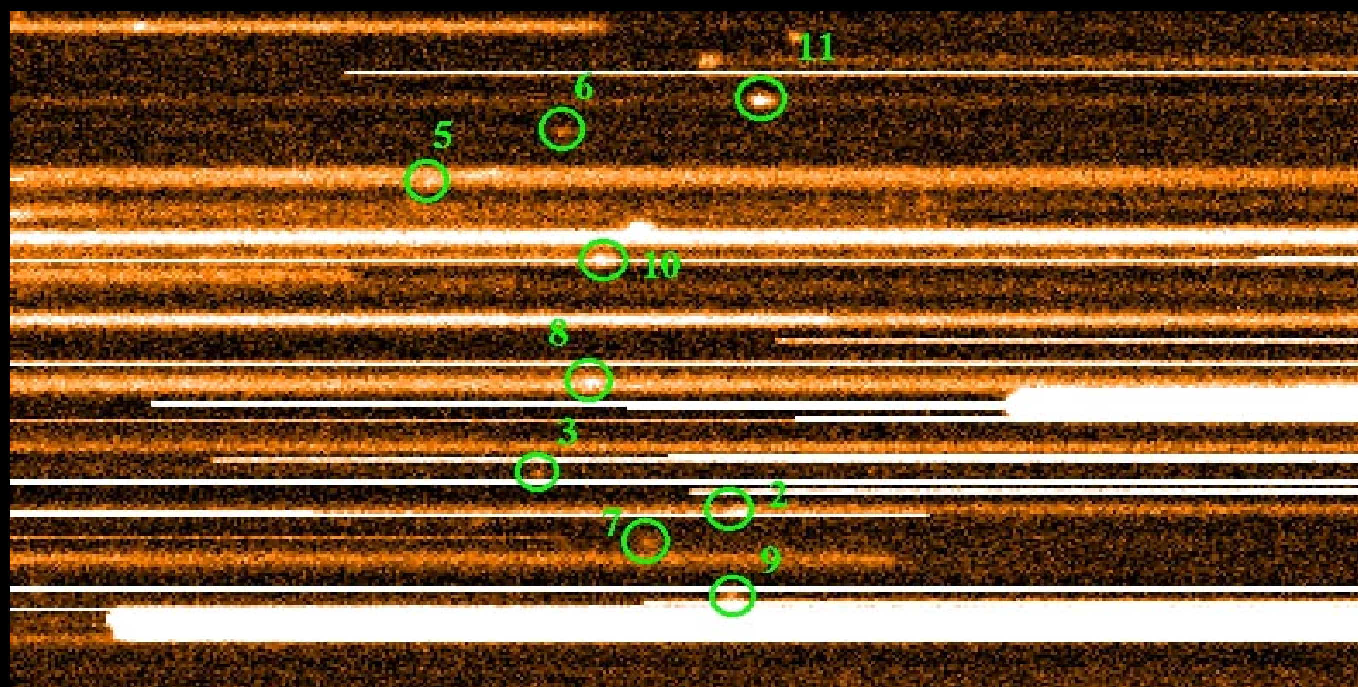
See talk by F. Zerbi



See talk by B. Garilli

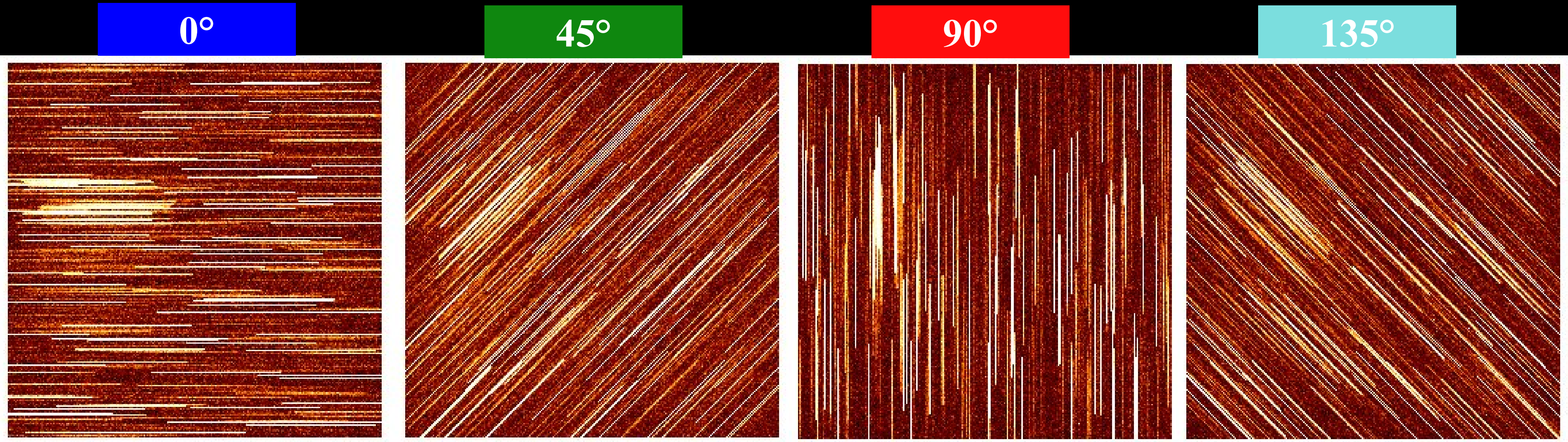


Direct Image

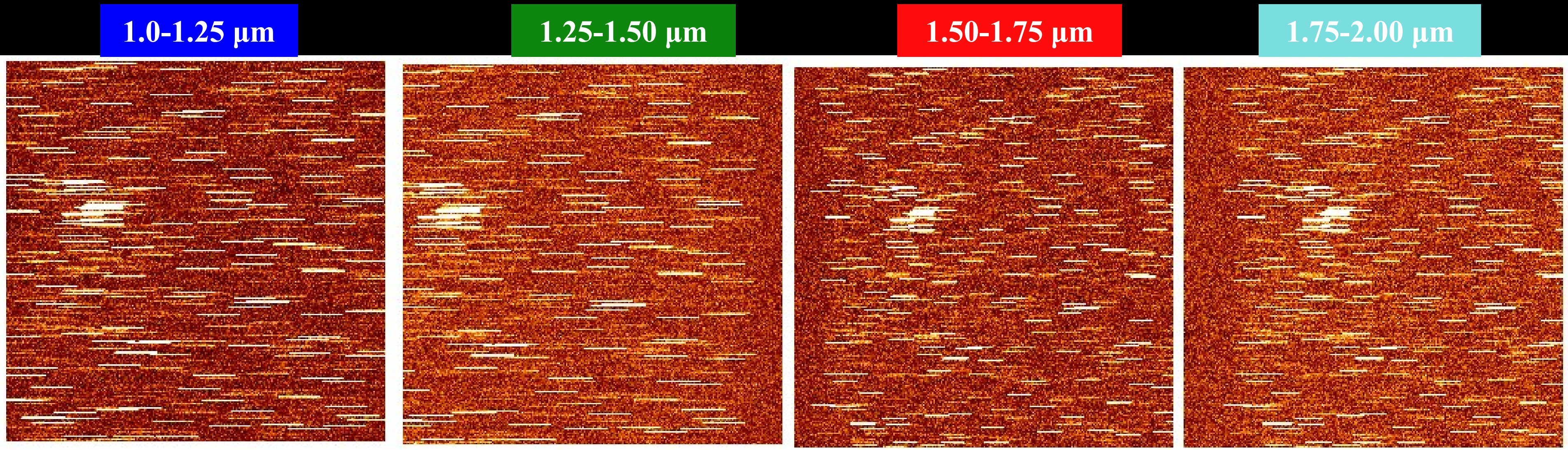


Slitless Dispersed Image

Mitigation of “confusion” (1): Multiple roll-angles

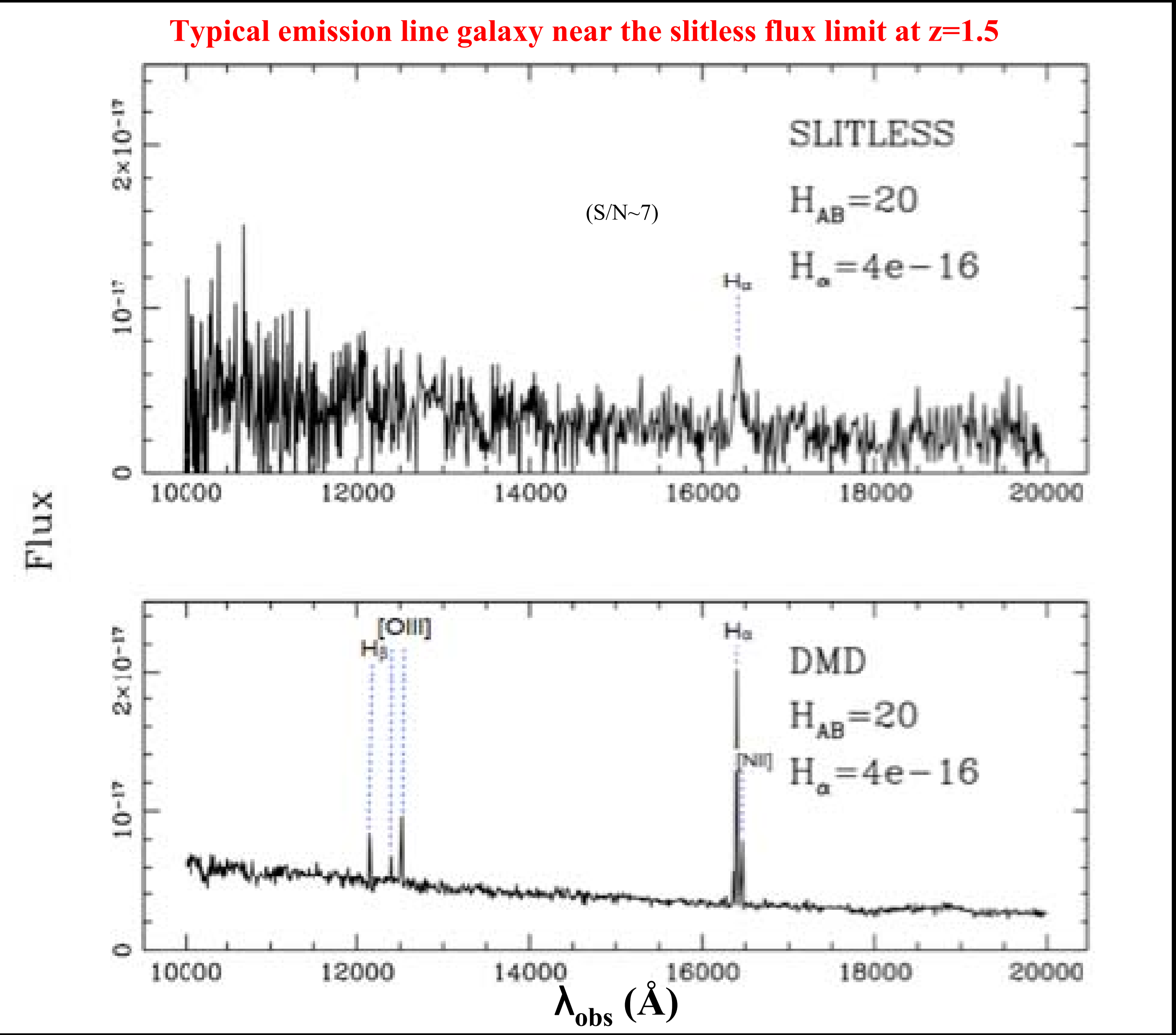


Mitigation of “confusion” (2): Multiple filters



Spectral "confusion" does not exist with DMD spectroscopy

Simulated spectra and limiting fluxes



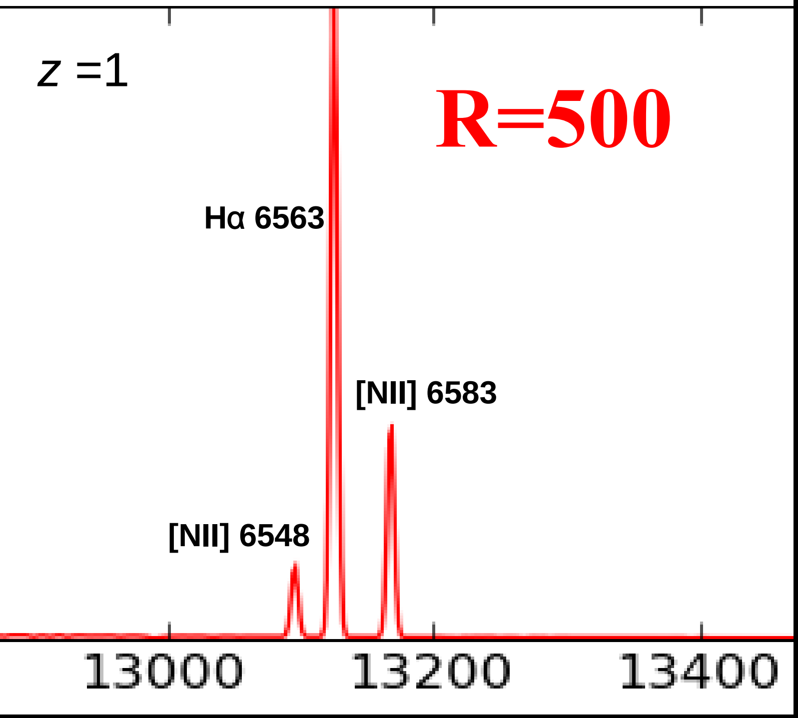
Stronger background in slitless spectroscopy

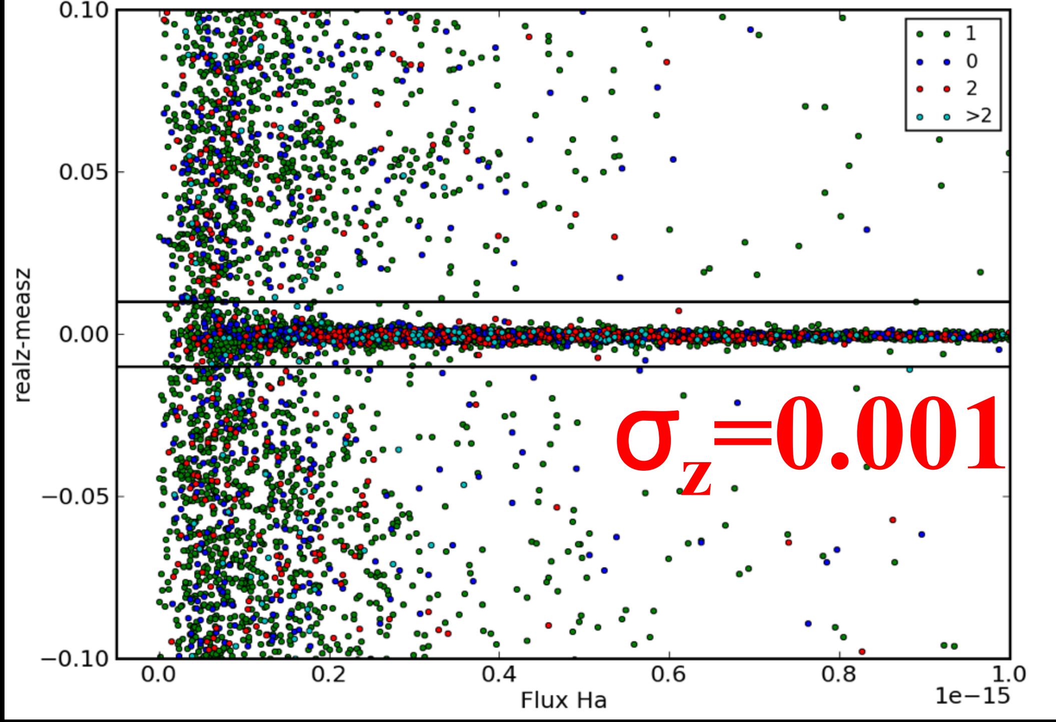
H_{lim}≈19.5 (vs 22, DMD)

<u>Slitless</u> limiting line flux (unresolved source):

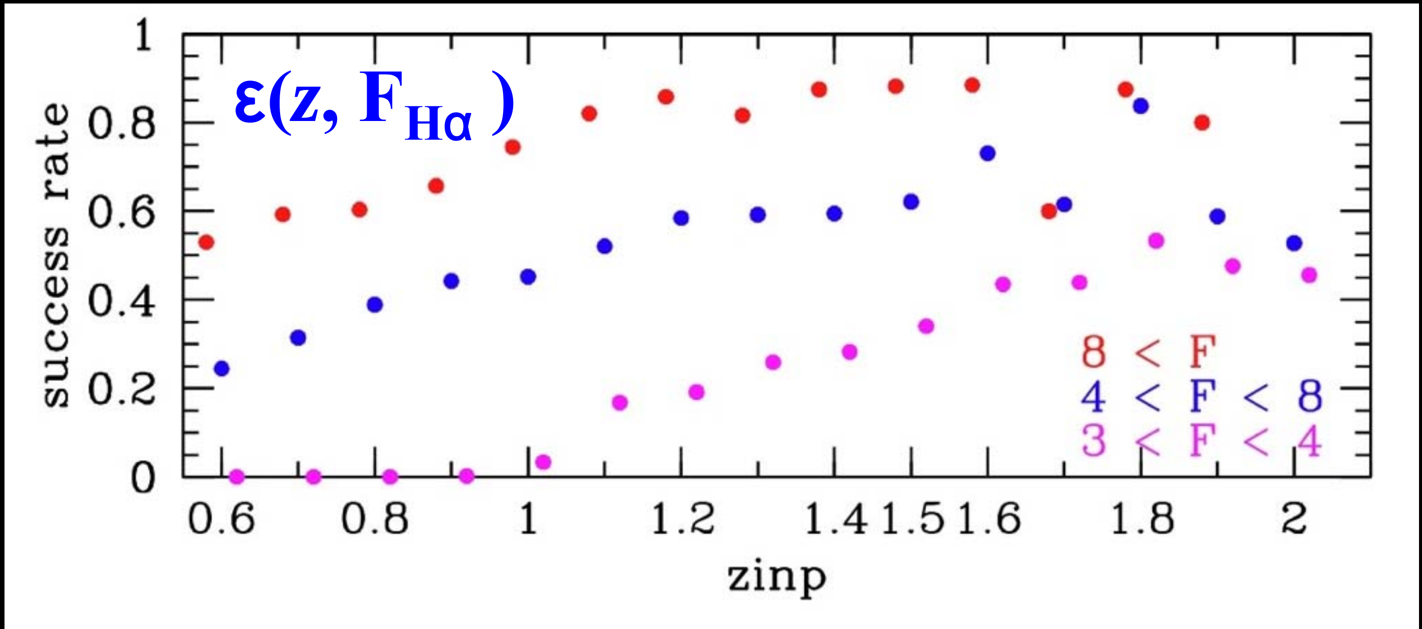
F>4x10^{-16} erg/cm^2/s

S/N=7 at 1.6 μm





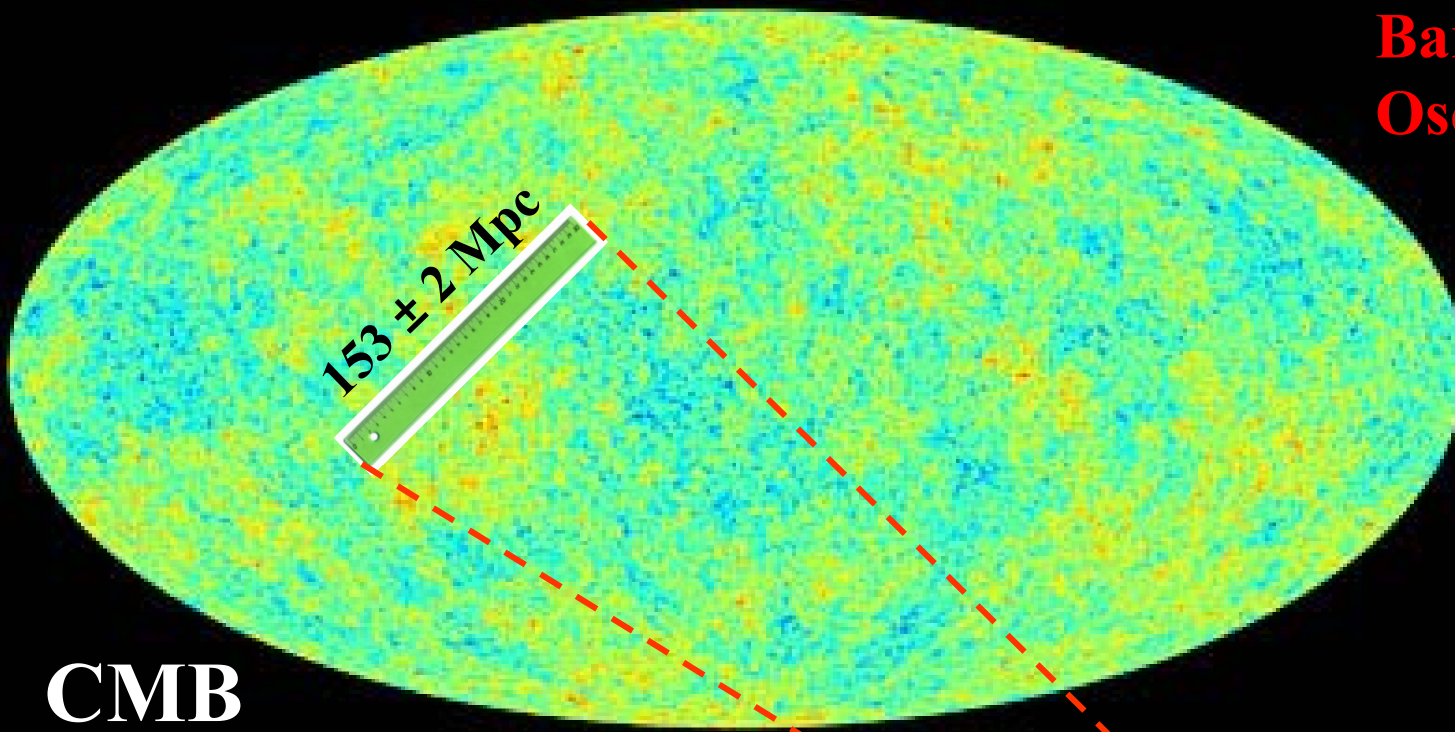
Slitless main results



Science

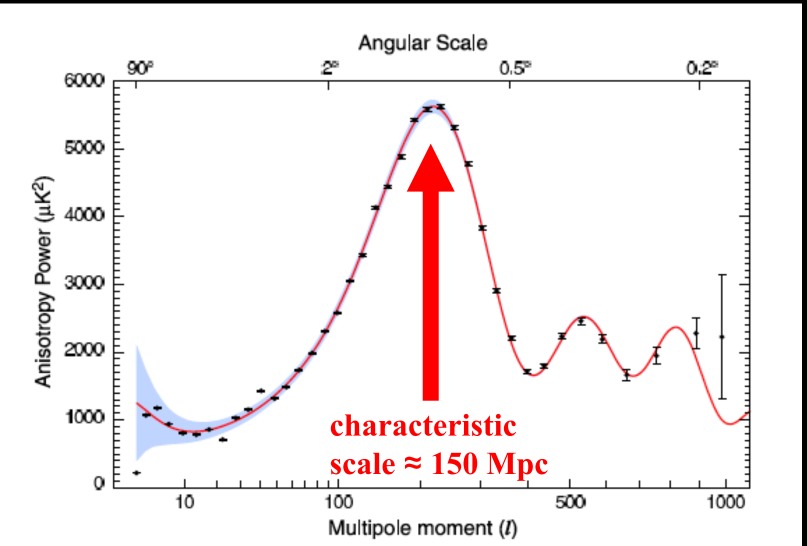
Baryonic Acoustic Oscillations (BAO)

see talks by
Y. Wang &
W. Percival

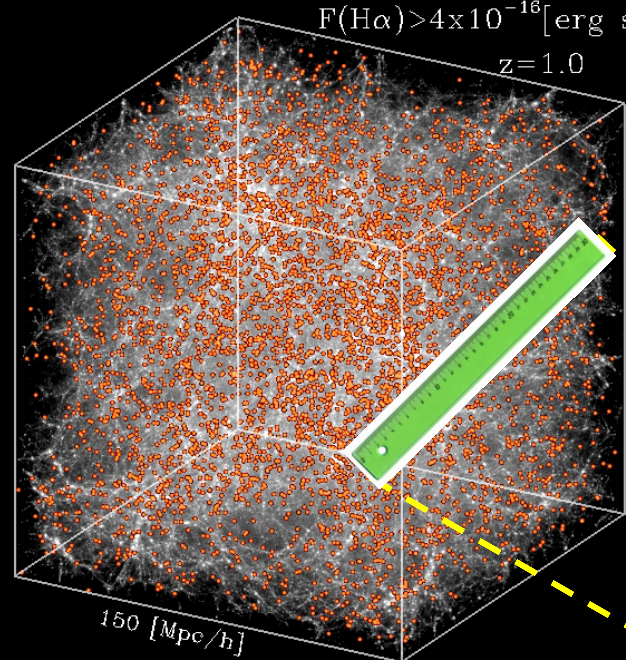


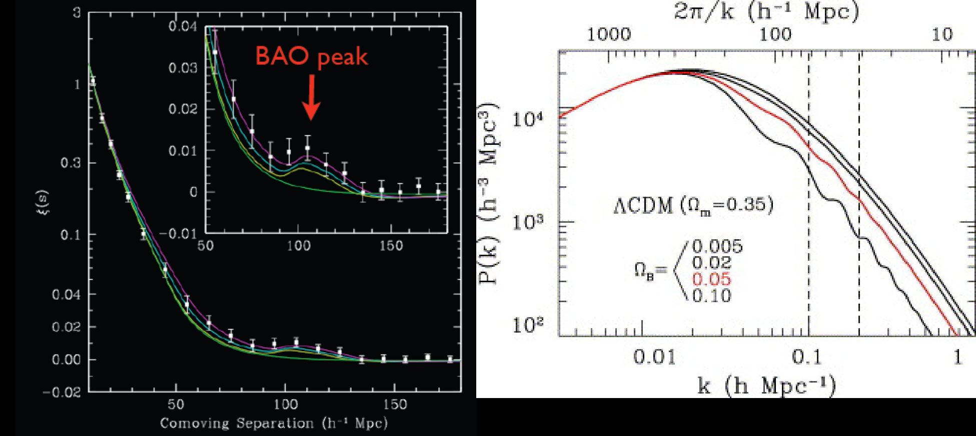
CMB
z ≈ 1090

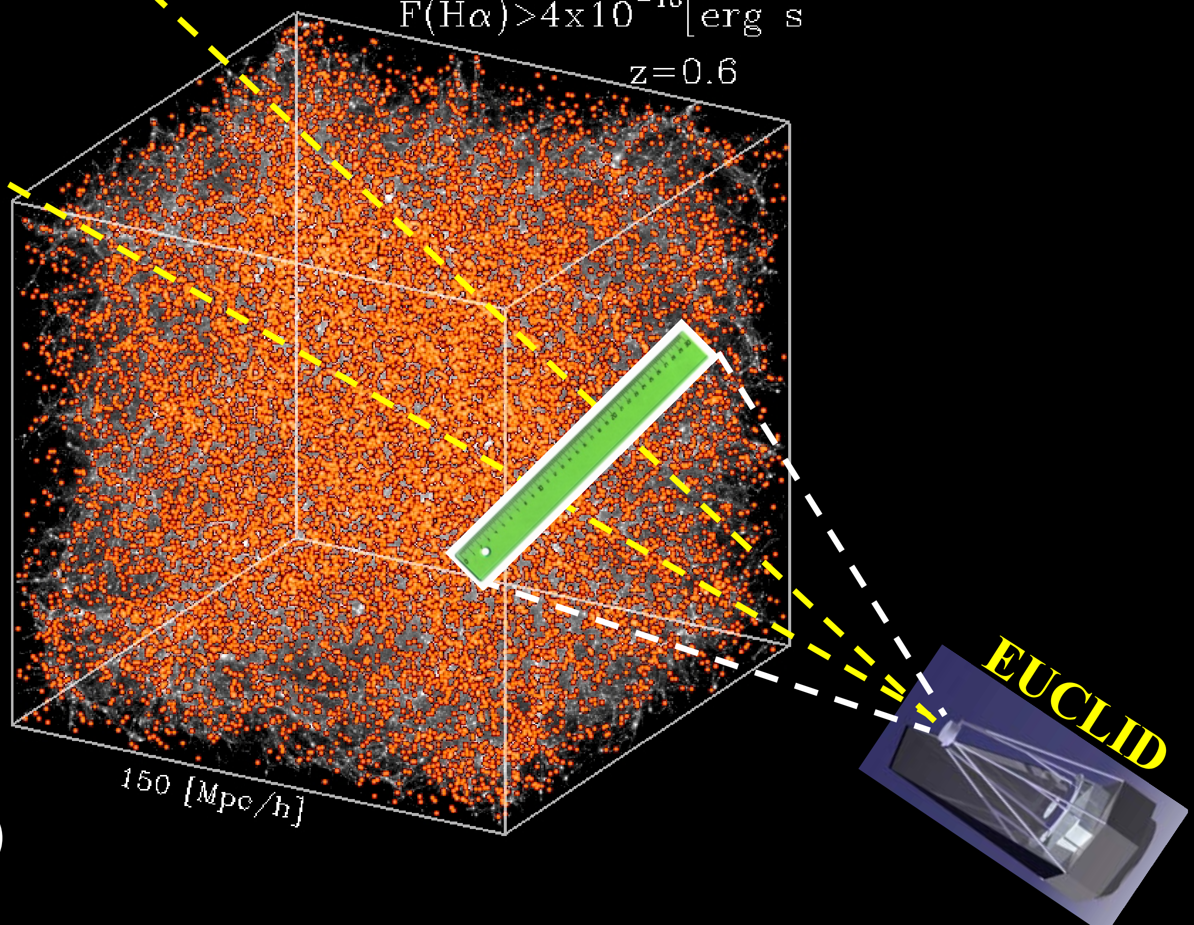
standard ruler



Planck

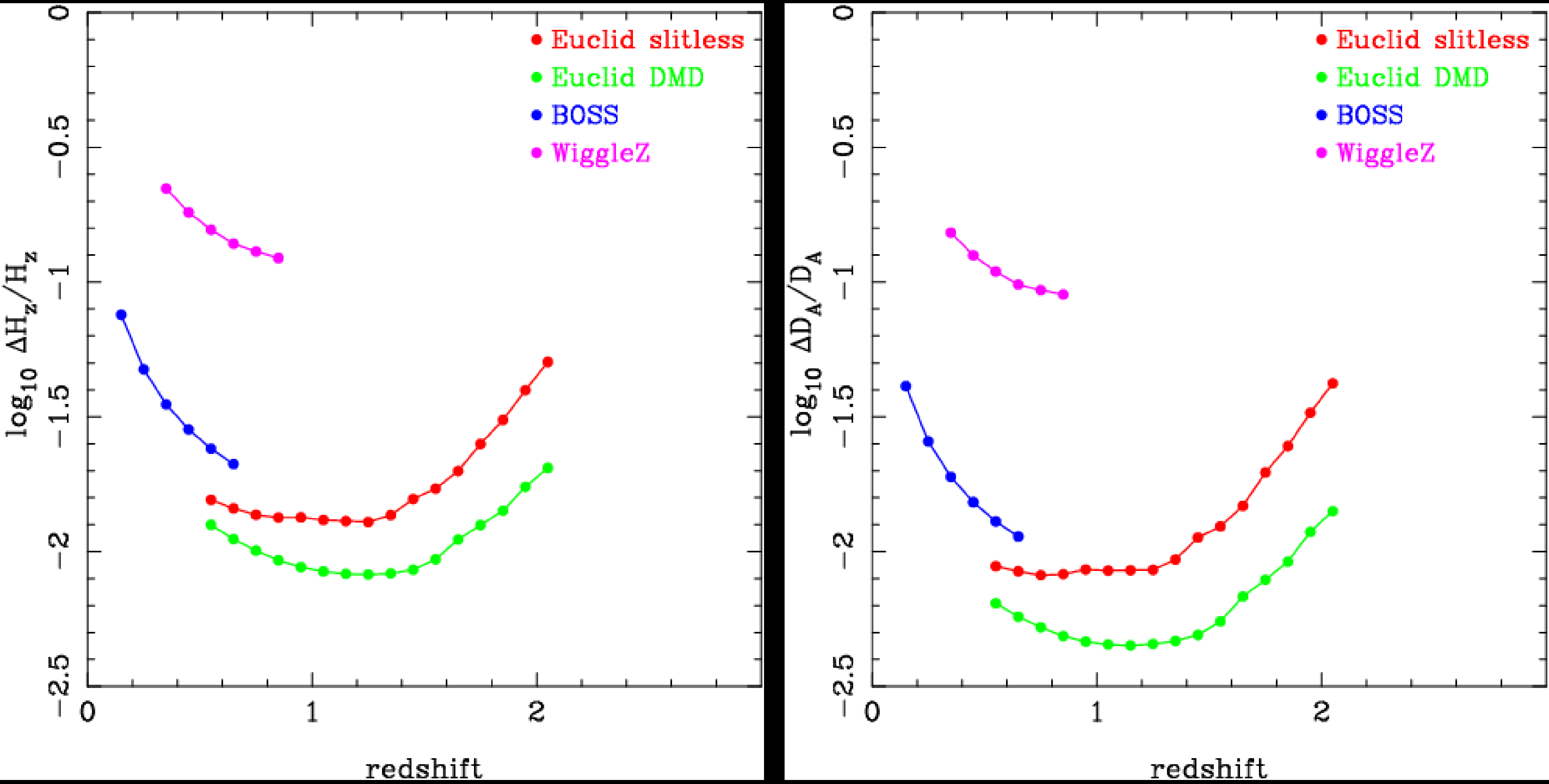




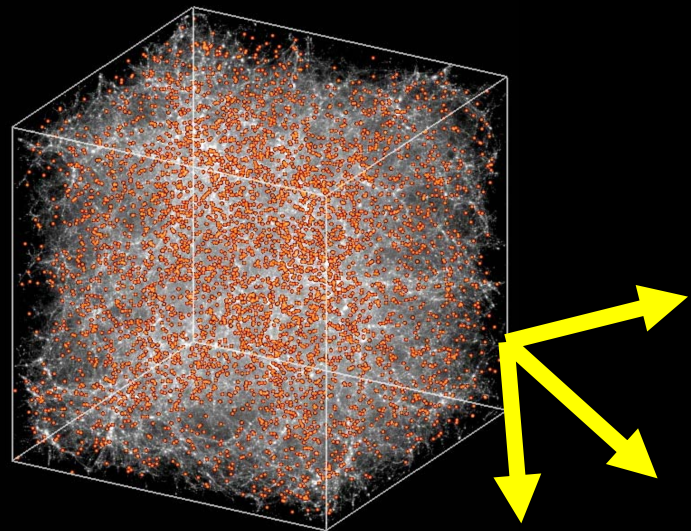


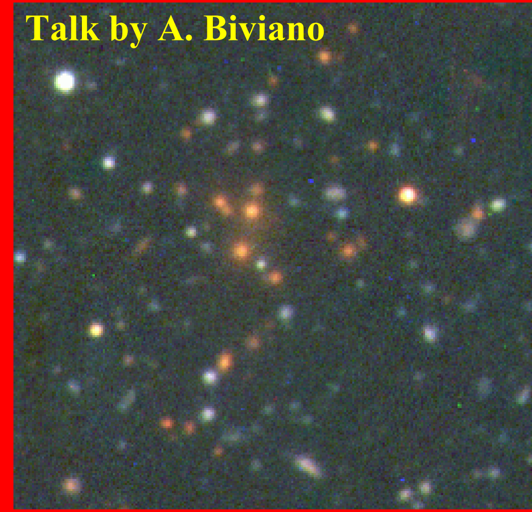
- *H(z)* (radial)
- $D_A(z)$ (tangential)
- *H(z)* & $D_A(z) = f(w)$

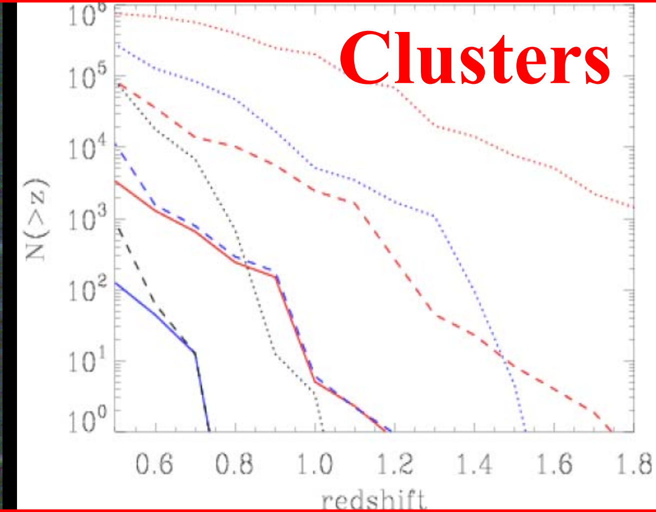
The power of E-NIS to constrain *w*(*z*)

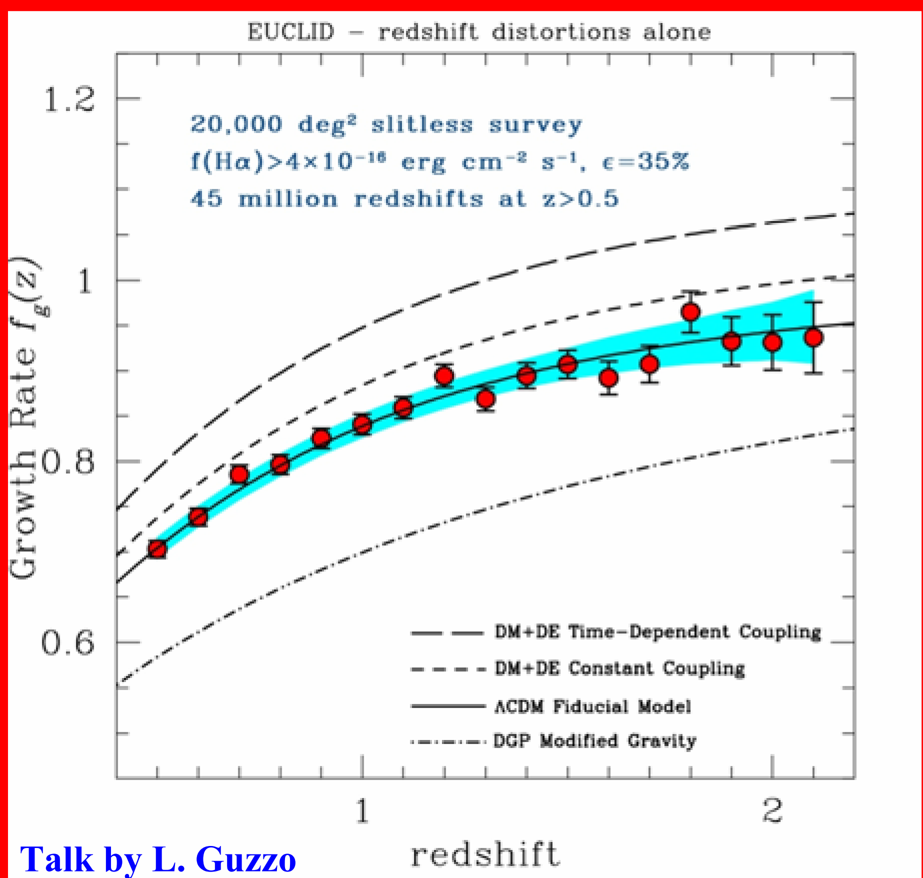


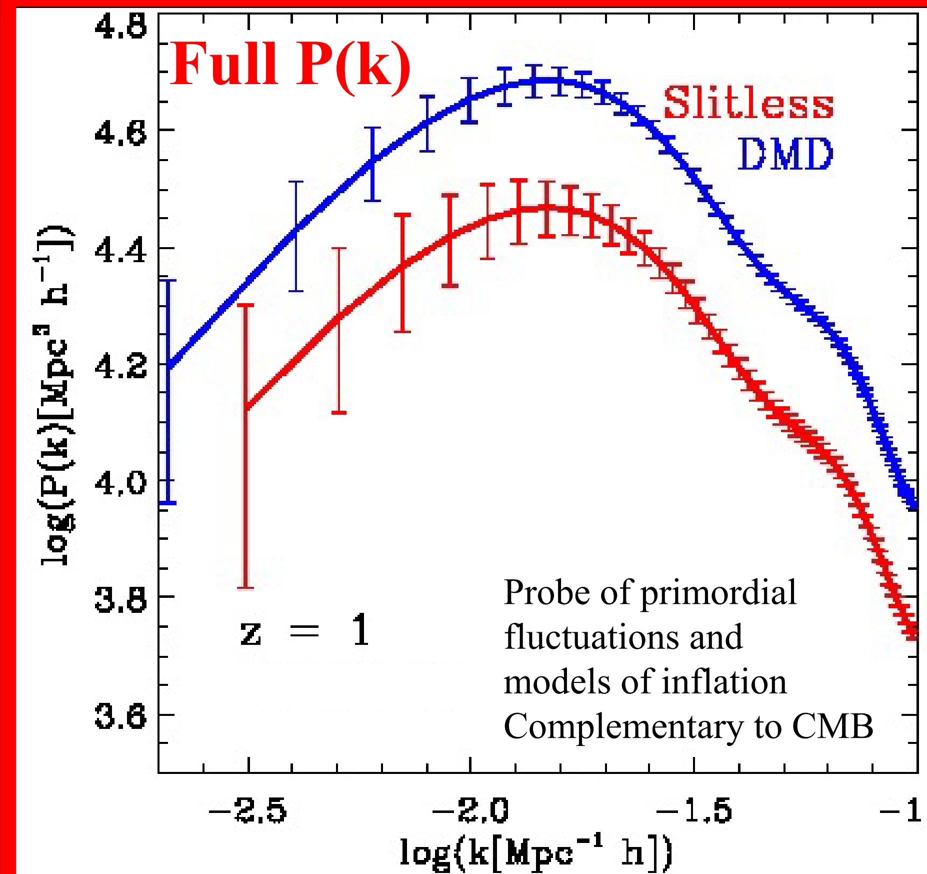
- FoM(E-NIS+Planck) ≈ 310
- FoM(WL+Planck) ≈ 480
- FoM(ENIS+EIC+Planck) ≈ **1500** (150x better than now !)
- E-NIS = DETF Stage IV experiment

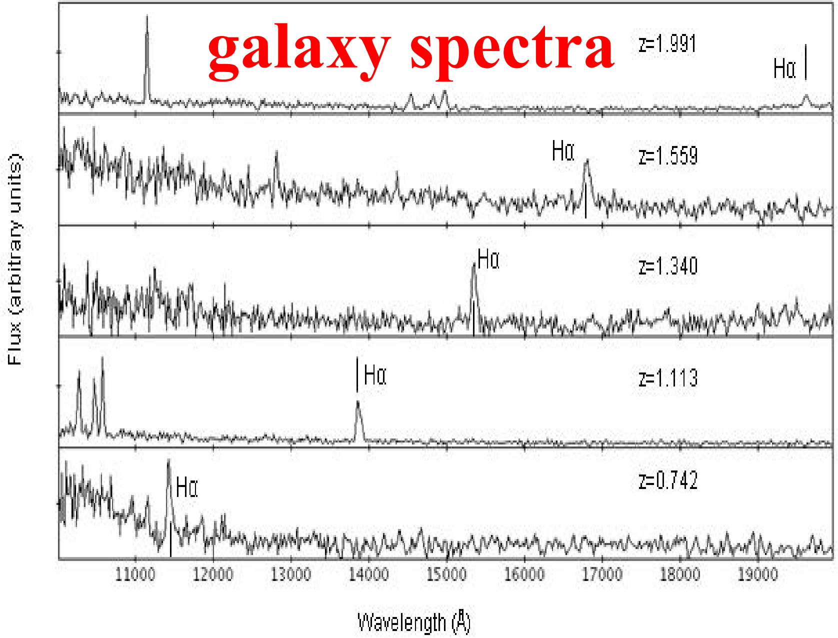



Talk by A. Biviano

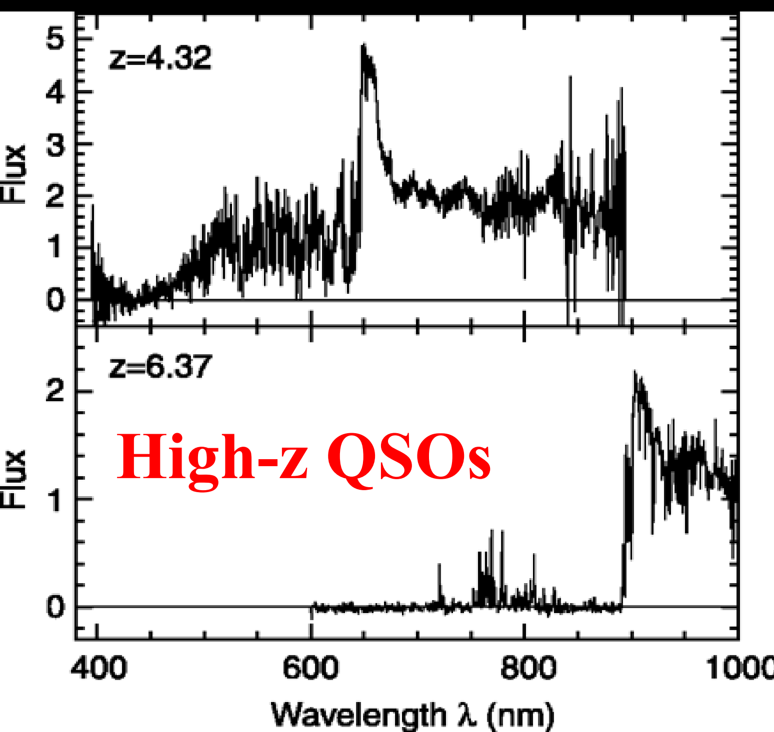

Clusters
N(>z)
redshift
0.6
0.8
1.0
1.2
1.4
1.6
1.8


EUCLID – redshift distortions alone
20,000 deg² slitless survey
f(Hα)>4×10⁻¹⁶ erg cm⁻² s⁻¹, ϵ=35%
45 million redshifts at z>0.5
Growth Rate $f_g(z)$
redshift
DM+DE Time-Dependent Coupling
DM+DE Constant Coupling
ΛCDM Fiducial Model
DGP Modified Gravity
Talk by L. Guzzo


Full P(k)
Slitless
DMD
z = 1
Probe of primordial
fluctuations and
models of inflation
Complementary to CMB
log(P(k)[Mpc³ h⁻¹])
log(k[Mpc⁻¹ h])



Talk by G. Zamorani



Additional Science (slitless)

- $\geq 65 \times 10^6$ galaxies & AGNs: star formation, co-evolution of distribution functions, environment…
- Clusters of galaxies (mostly at $z < 1$)
- Clustering and halo statistics
- The largest unbiased survey for high-z QSOs
- Most luminous objects at $z > 7$ (*Deep Survey*)
- Our Galaxy (ultracool dwarfs, IMF…), +GAIA
- SNe (*Deep Survey*)
- **Synergy with VIS/NIP, multi-λ surveys, JWST, ALMA..**

High legacy value !

Additional Science: the extra gain with DMD spectroscopy

	DMD		Slitless	
Science Case	Wide	Deep	Wide	Deep
→ Physics of galaxies	● (green)	● (green)	● (red)	● (red)
Galaxy evolution	● (green)	● (green)	● (orange)	● (orange)
High-z galaxies	● (red)	● (green)	● (red)	● (yellow)
High-z QSOs	● (green)	● (green)	● (green)	● (red)
Galaxy clusters z<1	● (green)	● (green)	● (green)	● (green)
→ Galaxy clusters z>1	● (green)	● (green)	● (red)	● (red)
→ Early type galaxies	● (green)	● (green)	● (red)	● (yellow)
Our Galaxy	● (green)	● (green)	● (orange)	● (orange)

- ● (red) Unfeasible
- ● (yellow) Limited to most luminous objects
- ● (orange) Biased towards some class(es) of objects
- ● (green) Feasible

E-NIS can cover 2π sr and 0.5<z<2 in < 5 years

	Requirements are met !
Feature	Slitless
Survey Type	Redshift
Limiting flux	4×10^{-16} erg/cm^2/s (line) H ≈ 19.5 (AB)
N(galaxies)	≥ 6.5×10^{7}
Effective Volume	19 h^{-3} Gpc^3
Galaxy type	Star-forming
Redshift range	0.5 < z < 2
Redshift success rate	≥ 40%
FoM (BAO)	1
Legacy value	High

E-NIS can cover 2π sr and 0.5<z<2 in < 5 years

	Requirements are met !	High gain
Feature	Slitless	DMD
Survey Type	Redshift	Spectroscopic
Limiting flux	4×10^{-16} erg/cm^2/s (line) H ≈ 19.5 (AB)	H ≈ 22.0 (AB)
N(galaxies)	$\geq 6.5\times10^{7}$	$\geq 2\times10^{8}$
Effective Volume	19 h^{-3} Gpc^3	50 h^{-3} Gpc^3
Galaxy type	Star-forming	All
Redshift range	$0.5 < z < 2$	$0 < z < 2.5$
Redshift success rate	≥ 40%	> 80%
FoM (BAO)	1	≈ 2 – 3x
Legacy value	High	SDSS-like !

Thanks

to the

E-NIS team
ESST + WGs
National Agencies