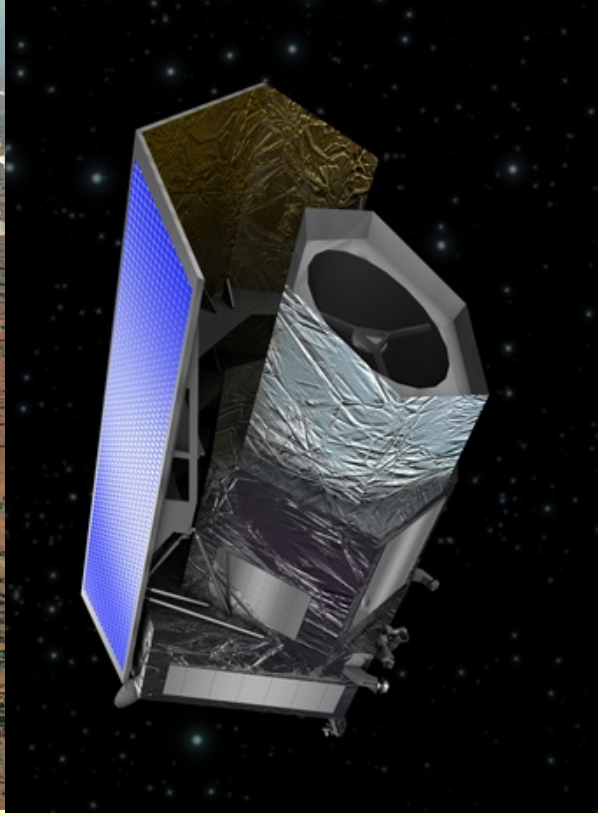
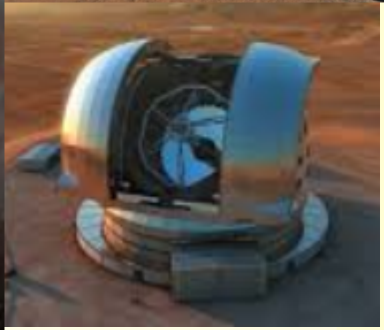




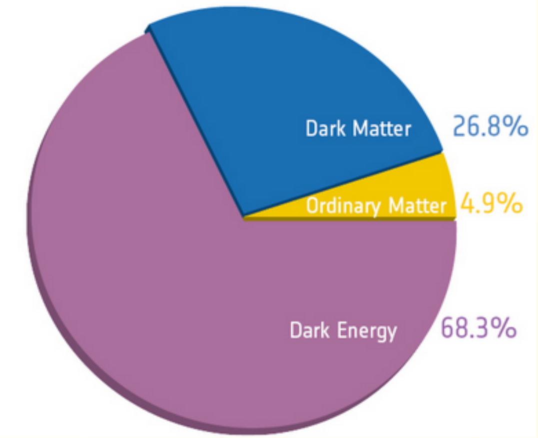
Euclid, JWST, ELT Synergy with SKA

Françoise Combes
Observatoire de Paris

12 February 2014

What do we want to know?

Matter in the Universe
Dark matter/visible matter vs z



Dark energy:
Is it varying with time?

How is the Universe re-ionized?
End of the dark age: cosmic dawn, EoR

How do baryons assemble into the large-scale structures?
Galaxy formation and evolution (mergers, cold accretion)
Star formation history, quenching
Environment: groups and galaxy clusters

Strong-gravity with pulsars and black holes

Related main issues : Euclid

1-What is dark energy: w

Equation of state and nature of DE, through expansion and growth rates, 5 tools: WL, BAO, RSD, CL, ISW

2-Gravity beyond Einstein: γ

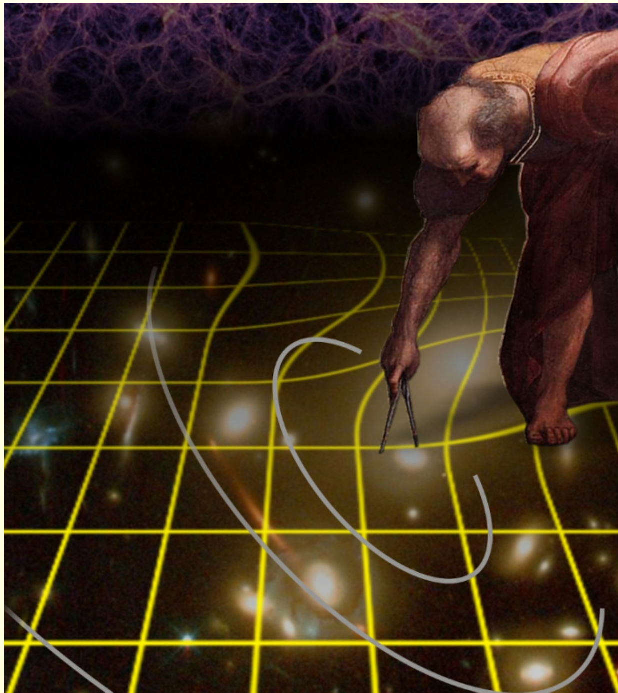
Testing modified gravity, by measuring growth rate exponent γ

3-The nature of dark matter, m_ν

Testing the CDM theory, and measuring neutrino mass

4- The seeds of cosmic structures

Improve by a factor 20, n, σ_8, f_{NL}



EUCLID Legacy

Wide survey 15 000 deg^2
Deep survey 40 deg^2 (+2mag)

12 billion sources (3σ)

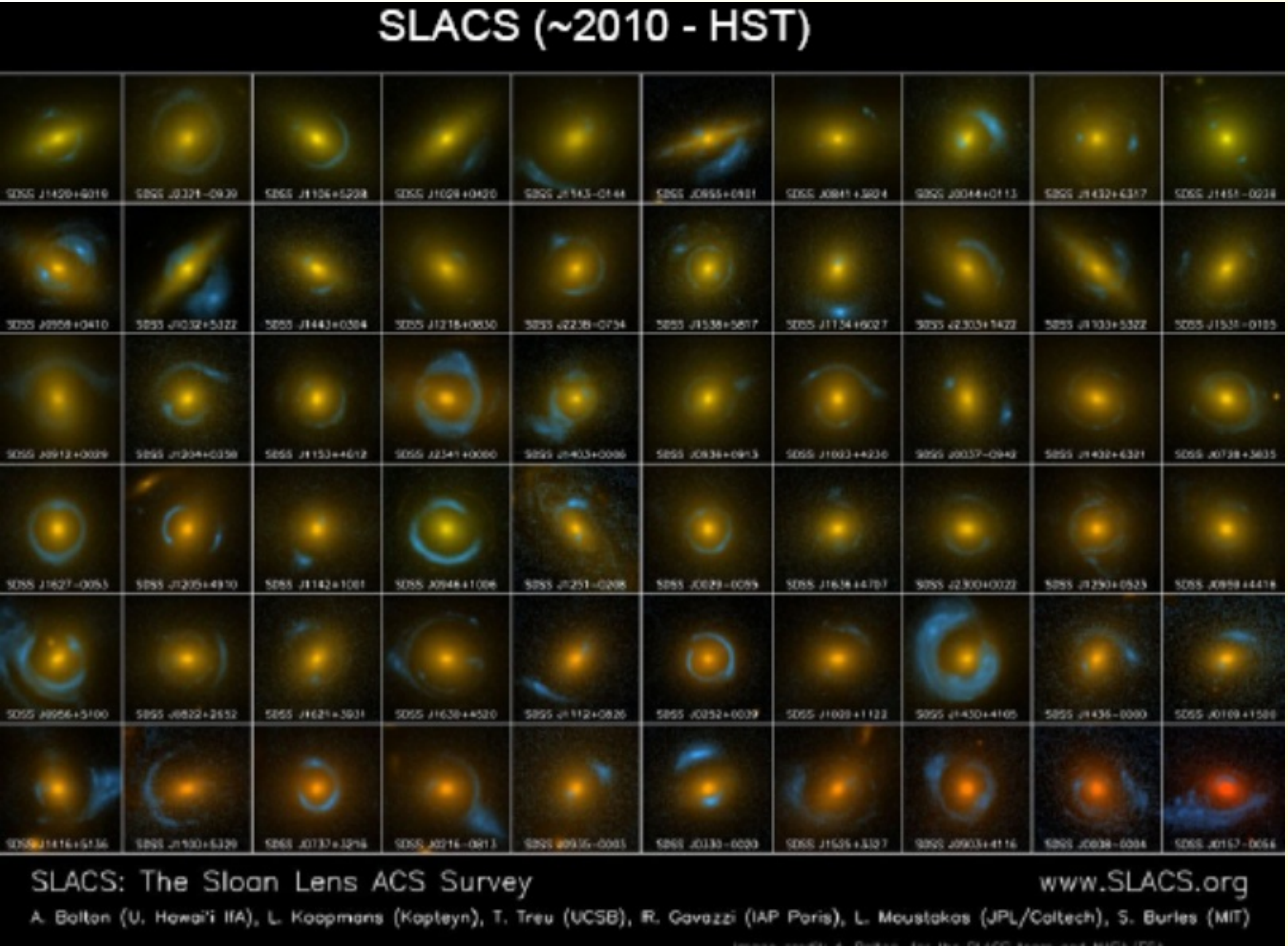
50 million redshifts

A reservoir of targets
for JWST,GAIA, ELT
ALMA, Subaru, VLT, etc

•

Objects	Euclid	Before Euclid
Galaxies at 1<z<3 with precise mass measurement	~2x10^8	~5x10^6
Massive galaxies (1<z<3))	Few hundreds	Few tenss
Hα Emitters with metal abundance measurements at z~2-3	~4x10^7/10^4	~10^4/~10^2 ?
Galaxies in clusters of galaxies at z>1	~2x10^4	~10^3 ?
Active Galactic Nuclei galaxies (0.7<z<2)	~10^4	<10^3
Dwarf galaxies	~10^5	
T_{eff} ~400K Y dwarfs	~few 10^2	<10
Lensing galaxies with arc and rings	~300,000	~10-100
Quasars at z > 8	~30	None

Strong Lensing



Will become an industry

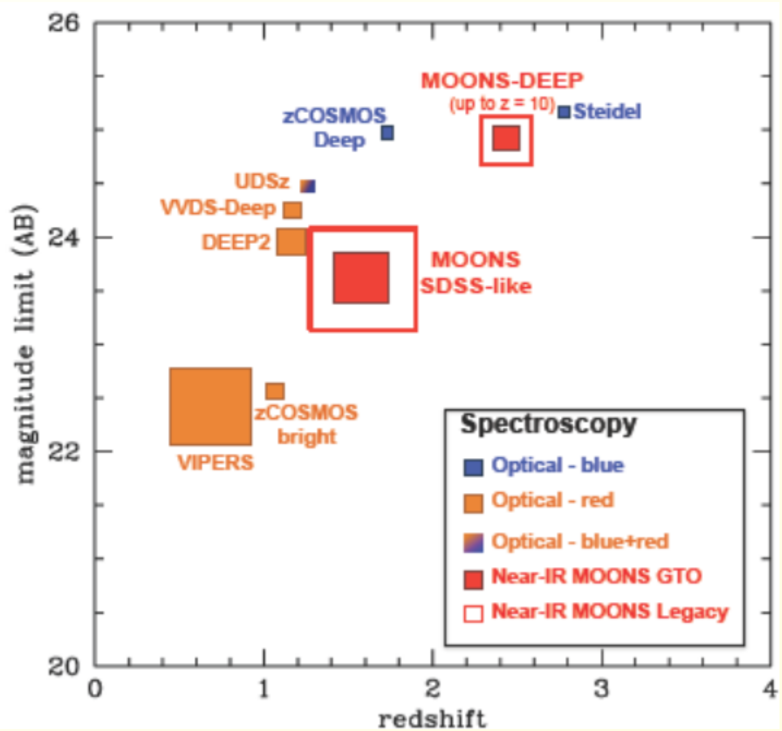
Substructure study; high-z normal galaxies… **Dark matter studies**

➔ Similar number per unit surface with SKA 100 000

Ground spectroscopy in synergy

HI spectroscopy will provide spectro-z catalogs for Euclid
Ultimately 1 billion HI spectro-z (SKA2)
With SKA-1 ~ 10% of SKA2

MOONS is ideal to provide the control sample for Euclid
Euclid is ideal to provide deep near-IR photometry for MOONS



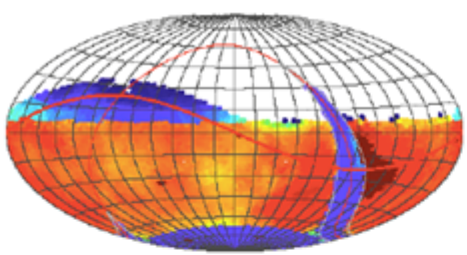
In addition to the ground photo-z Survey, with CFHT in the North DES, LSST in the South

E-ELT: very small FOV
Will make follow-up of SKA and Euclid sources, with high resolution
Complementary in science goals

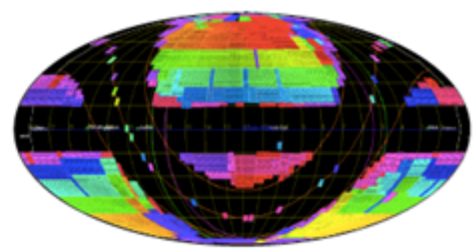
Overlap in space, redshift

SKA-Euclid projects: (mainly <z>=1-2)

–Euclid + SKA photometry + emission line galaxy analyses,
–Euclid + SKA redshifts,
–Euclid + SKA morphometry and astrometry



LSST, Equatorial



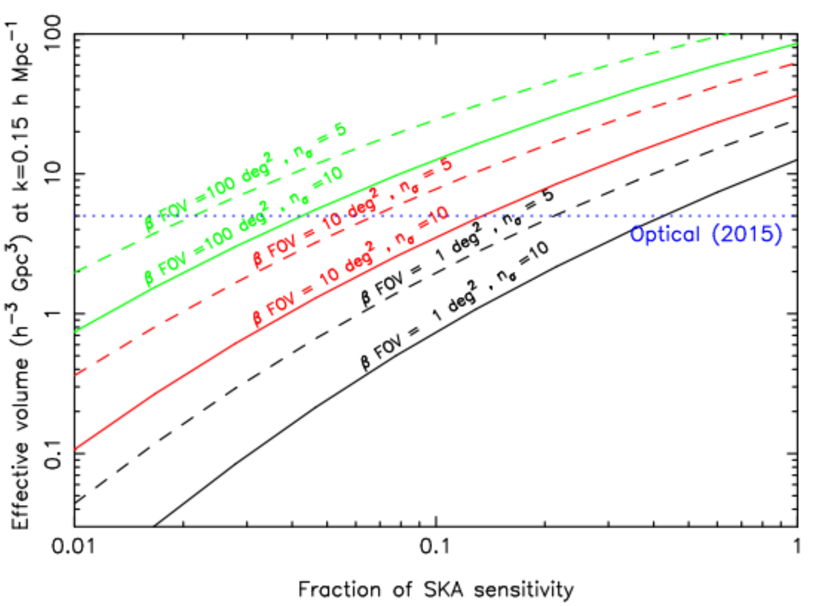
Euclid, Ecliptic

SKA

	LSST	Euclid	Overlap
Area (sqdeg)	18,000	15,000	5,000

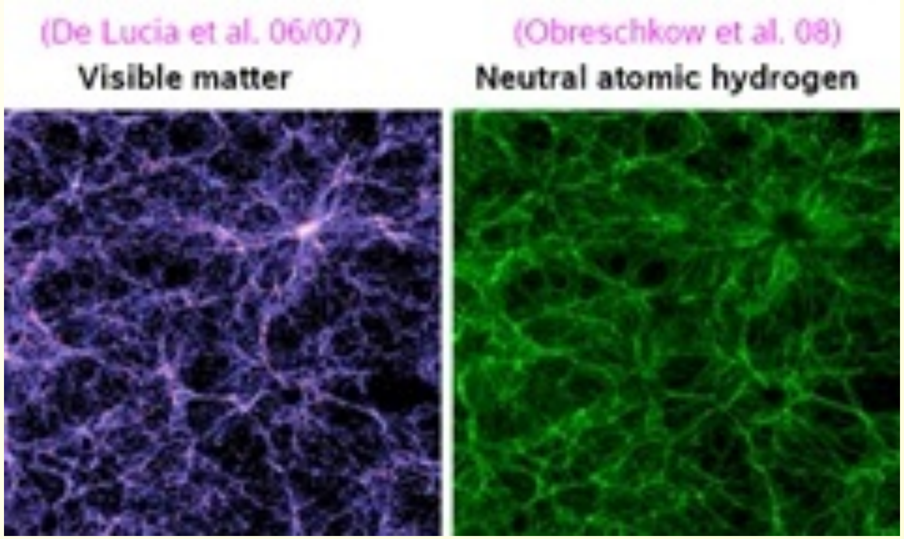
Zmedian~1

BAO: comparable galaxy numbers ?



SKA-1 SKA-2

Between SKA and Euclid



Different biases: HI surveys are not cluster biased
SKA: no bias from dust, stars..
Larger area covered in the sky (but less spatial resolution)

HI surveys for BAO with SKA-1

All sky survey: 4 10^6 gal z=0.2 3π sr

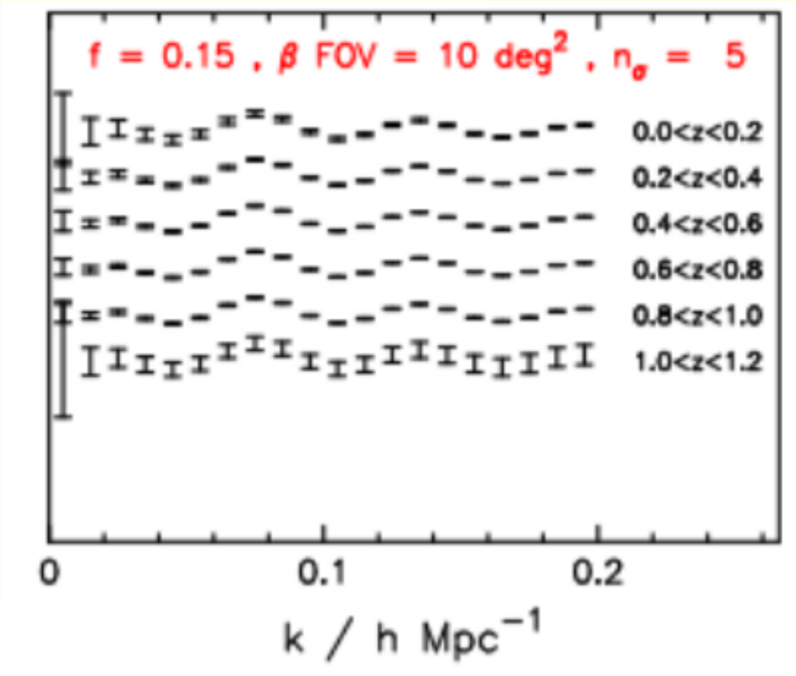
Wide-field survey 2 10^6 gal z=0.6 5000 deg^2

Deep-field survey 4 10^5 gal z=0.8 50 deg^2

Euclid 10^8 gal at z~1

But photo-z, with 2 10^5 spectro-z
Pure sample, deep field

SKA will help to provide pure sample

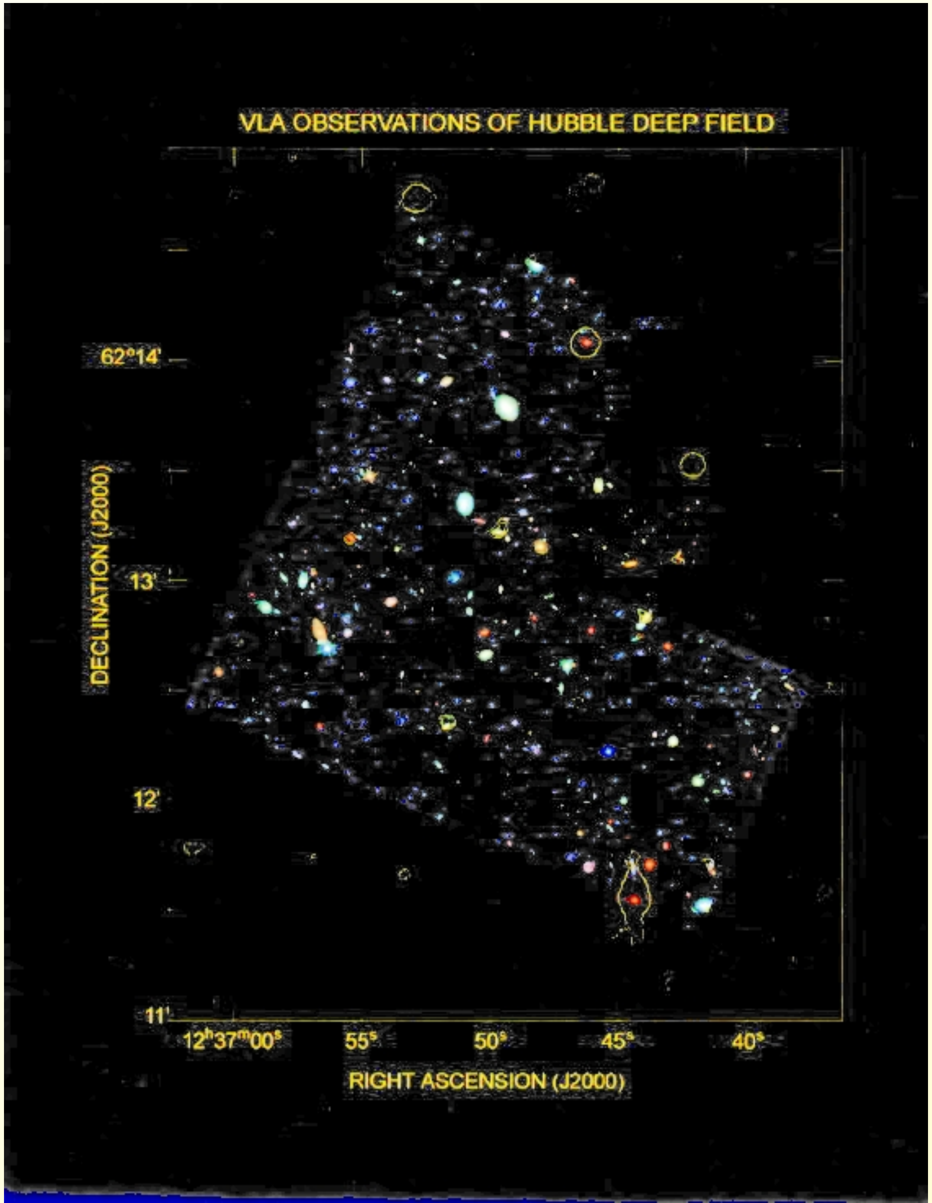


WL, AGN -- Present status of radio surveys

HDF-N 5 x 5 arcmin area to I ~29th magnitude

Fomalont et al., ApJ 475, L5 (1997)

6 sources detected by VLA with $S_{8.4} > 12$ μJy (50 hour observation)



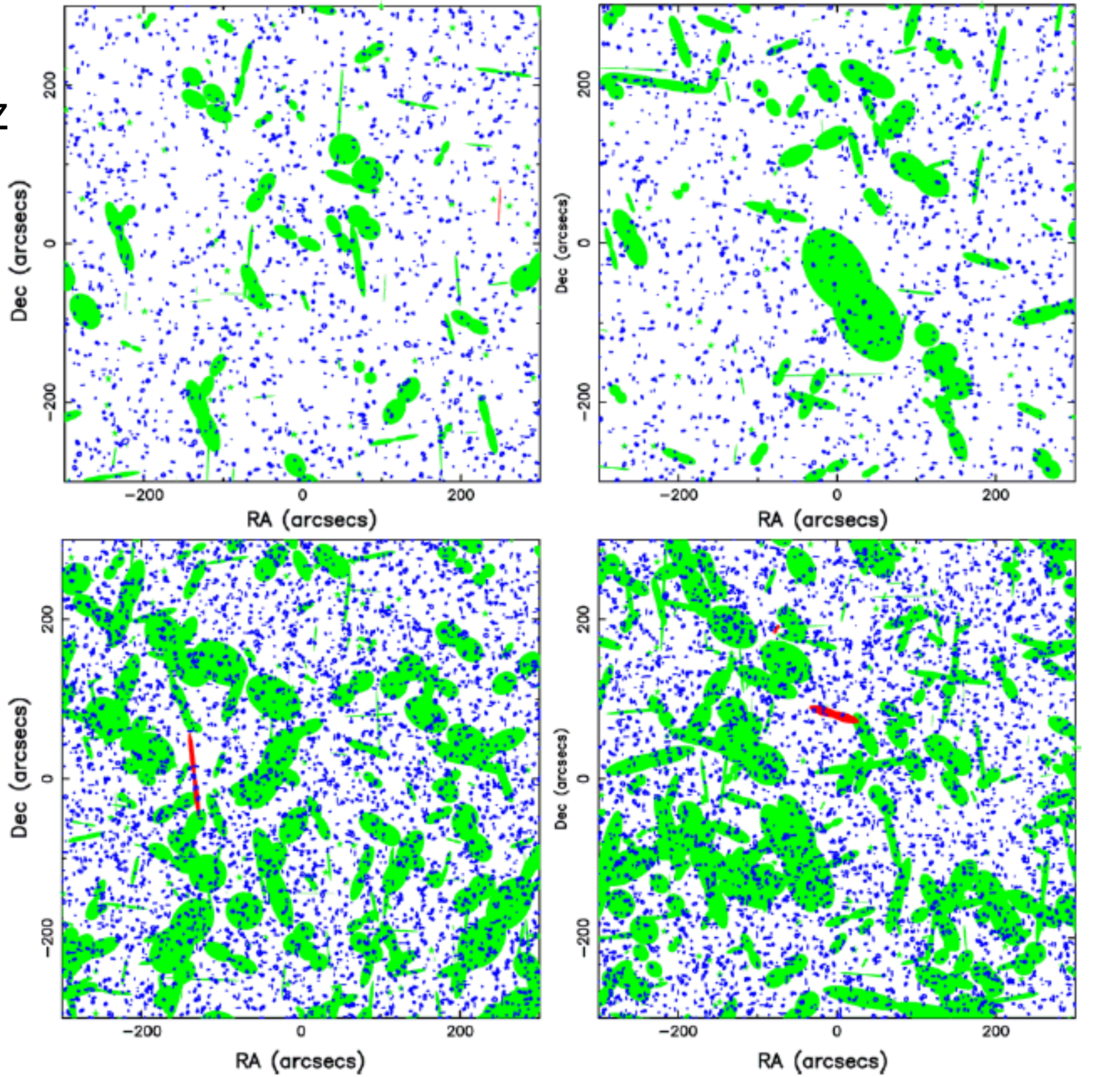
Deep radio sky
10' size, @ 1.4GHz

1μJy top
100nJy bottom
Left and Right
Cosmic variance

FRI: green, double
FRII: red, double

Beamed FRI:
green dot
Beamed FRII:
red dot
Star-forming: disk

Jackson 2004



Continuum surveys with SKA1

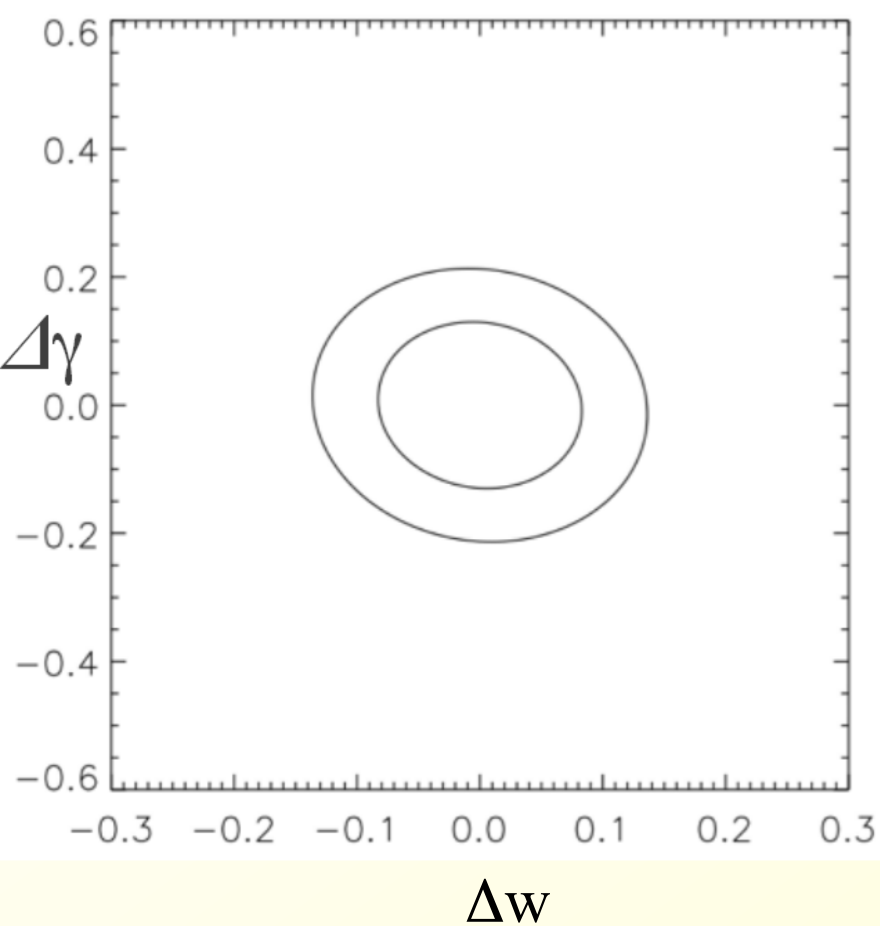
In 2yrs achieve 2 μJy rms would provide ≈4 galaxies arcmin^2 (>10σ)

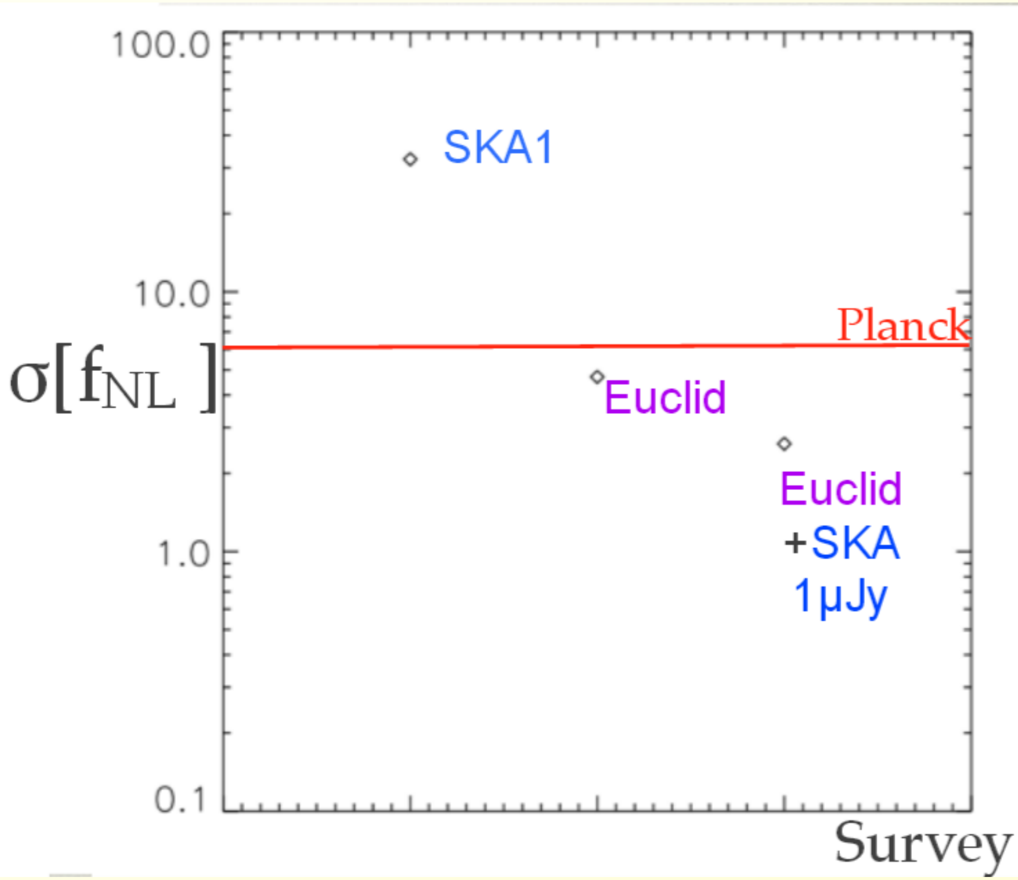
PSF is excellent quality circular Gaussian from about 0.6 – 100"
With almost uniform sky coverage of 3π sr

➔Total of **0.5 billion radio sources, for All sky survey**
for weak lensing and Integrated Sachs Wolfe

For wide-field (5000 deg2) **2 μJy rms** ≈6 galaxies arcmin^2 (>10σ)
For deep-field (50deg2) **0.1 μJy rms**, ≈20 galaxies arcmin^2 (>10σ)

Combining SKA1 (cont) & Euclid



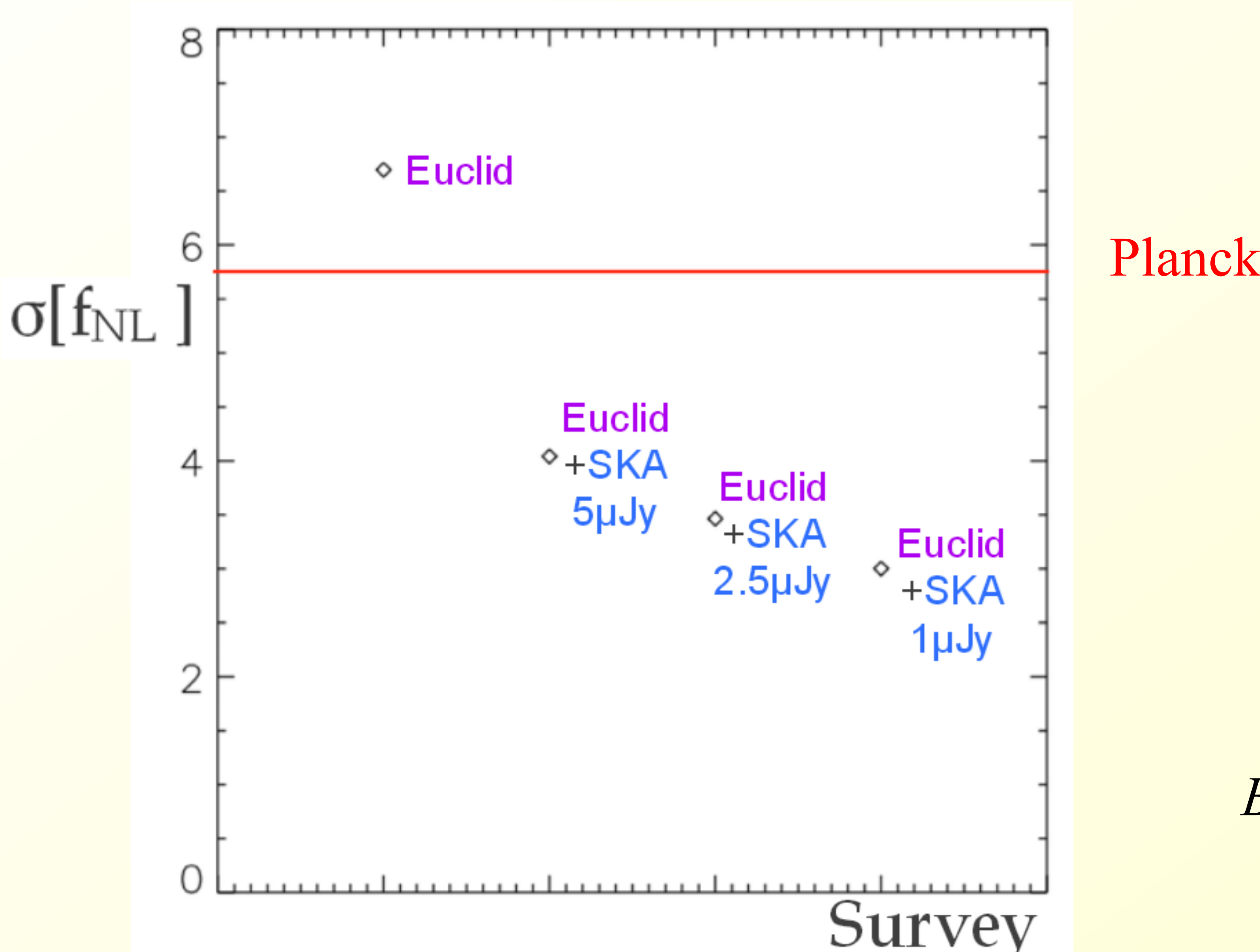


f_{NL} indicator of non-gaussian fluctuations

Bacon 2013

From ISW studies

f_{NL} indicator of early-universe physics



Bacon 2013

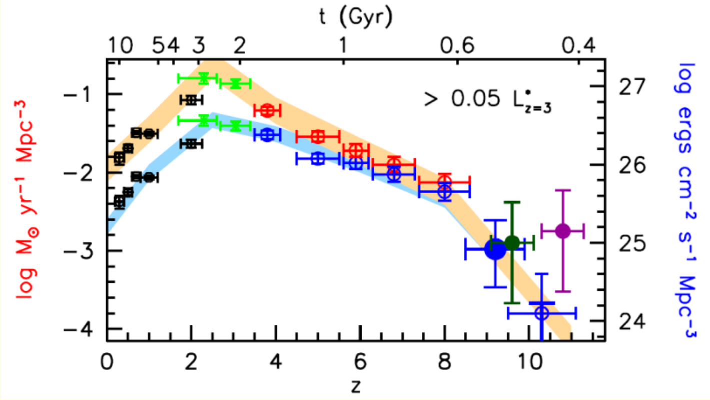
Related main issues : JWST & ELT

Galaxy formation and evolution, physics and dynamics

Surveys of galaxies at high and intermediate redshifts

Mass assembly and star formation, mergers, cold accretion

Quenching: supernovae and AGN feedback



Epoch of reionization

Early galaxies and black holes z=10-6

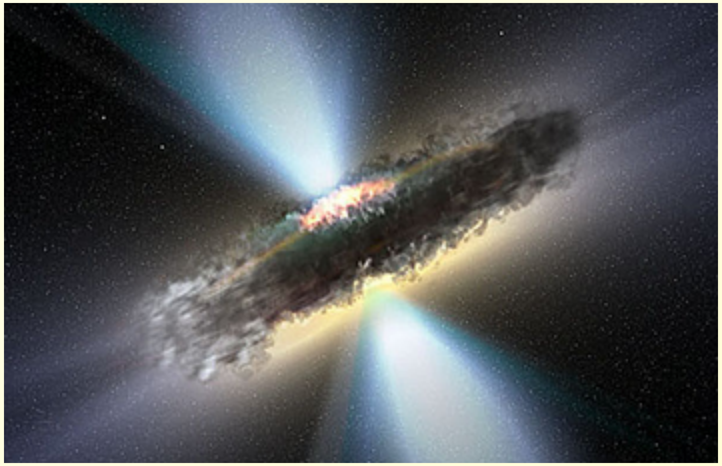
Absorption in front of QSO, GRB

IGM

AGN and super-massive BH

Symbiotic growth with galaxies

Physics of accretion



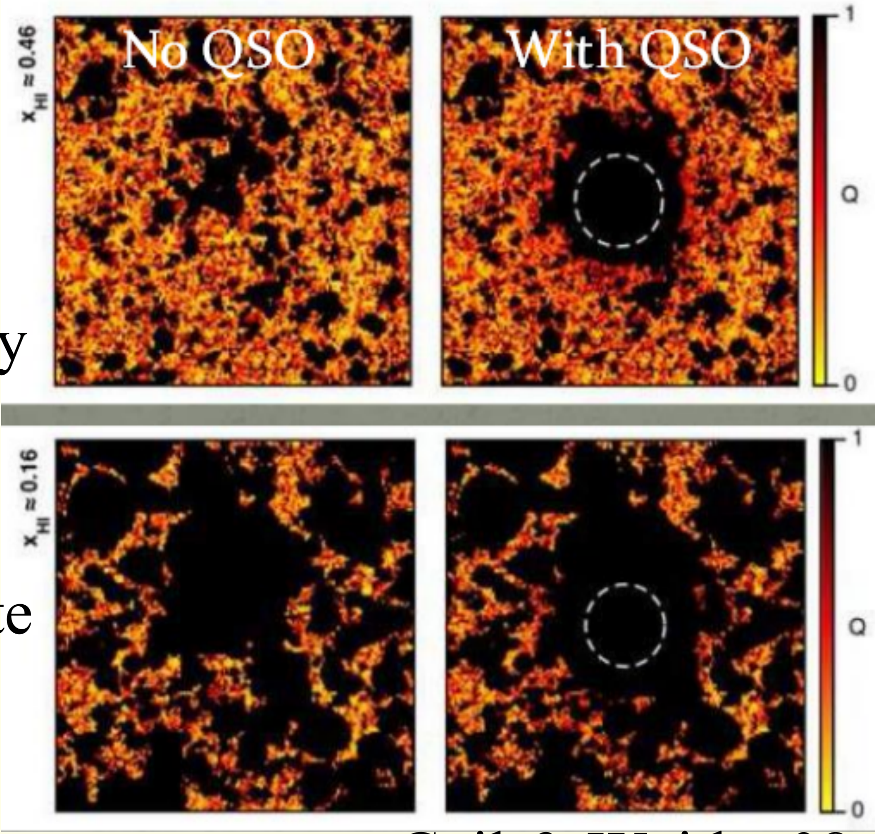
E-ELT, Euclid and SKA parameter space

Parameter	E-ELT	Euclid	SKA
FOV	Single object to 10' diameter patrol field	0.5 sq deg FOV ~full sky survey	1 deg^2 or larger @ 1 GHz 100 deg^2 @ 0.1 GHz
λ range	Optical to mid-IR	Optical and NIR	Radio 2cm–4 m (0.07 – 10+ GHz)
Spatial resolution	~Few mas (with AO) to seeing limited	0.2"(VIS) to 0.3" (NIR)	30 arcmin (0.5 km, 4m) to 1 mas (3000 km, 2cm)
Spectral resolution	Broadband imaging to R~100,000 (TBD)	Broadband imaging R=250 slitless spectroscopy	
Location	Dec ~ - 29 Fully steerable mount	Orbit around L2 – restricted pointing at any time	Australia + S. Africa, Beam formation anywhere in sky

Simulations of EoR

Early

Late



Geil & Wyithe 08

Only simulations for now!

Synergy Euclid /SKA

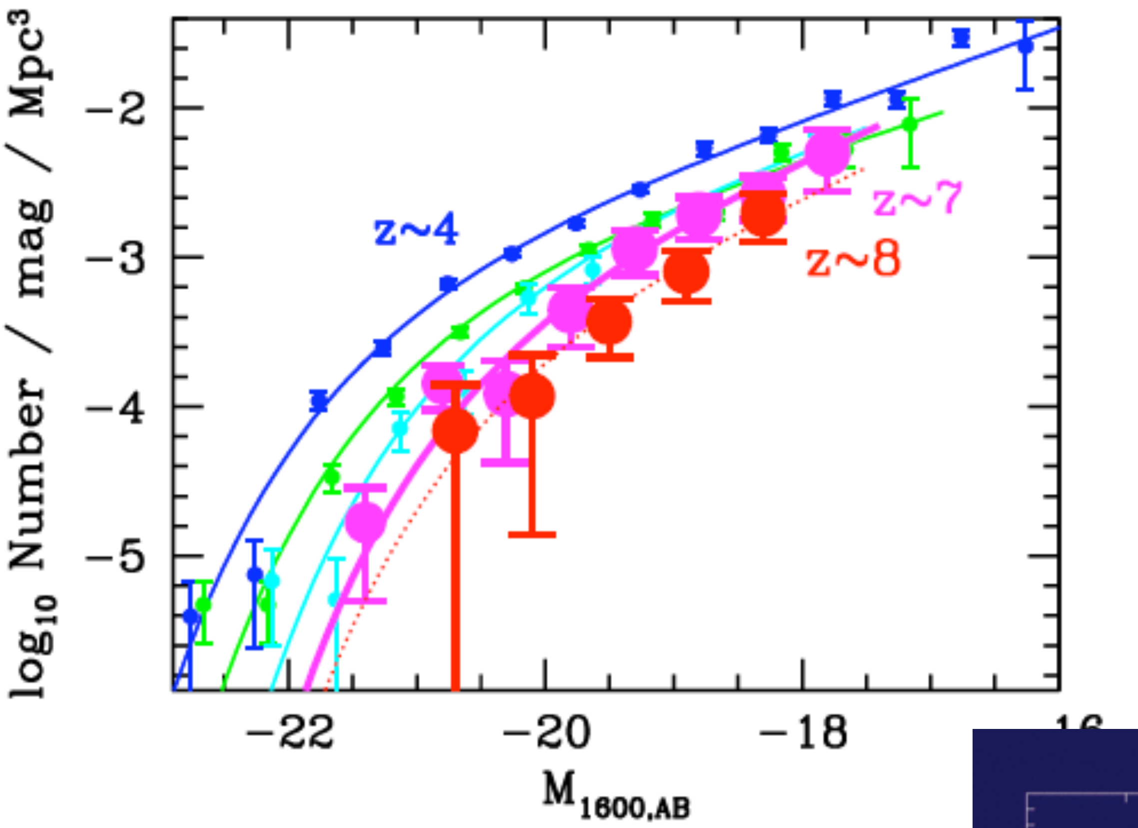
Discovery of the QSO in the EoR

Detection of the HII region around the QSO, at high redshift

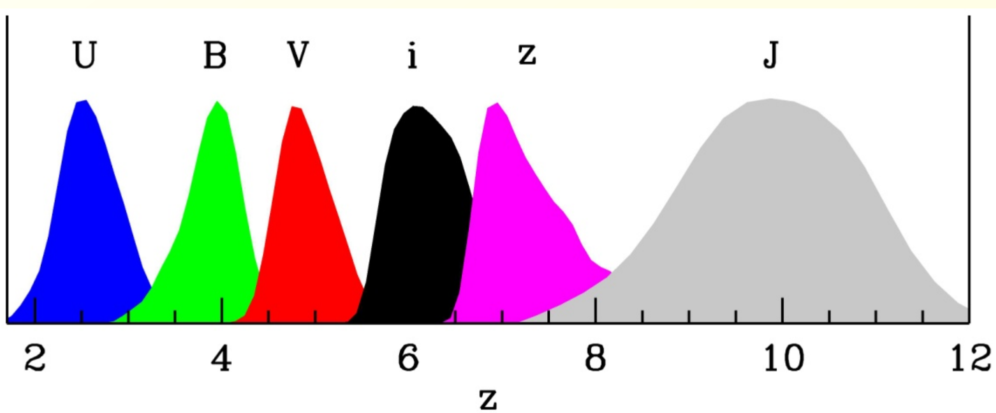
Will be studied in detail and depth by **JWST and ELT**

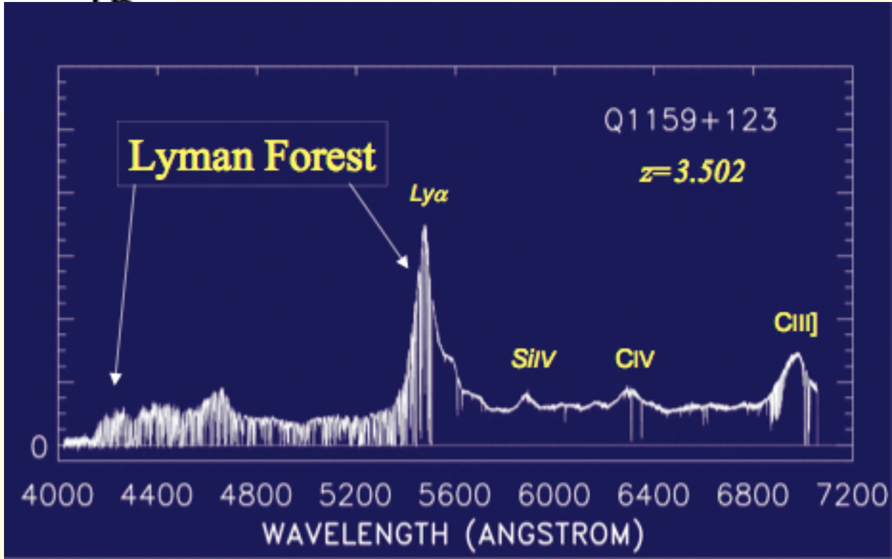
Also absorption studies

Are galaxies at z=7-10 able to re-ionize?



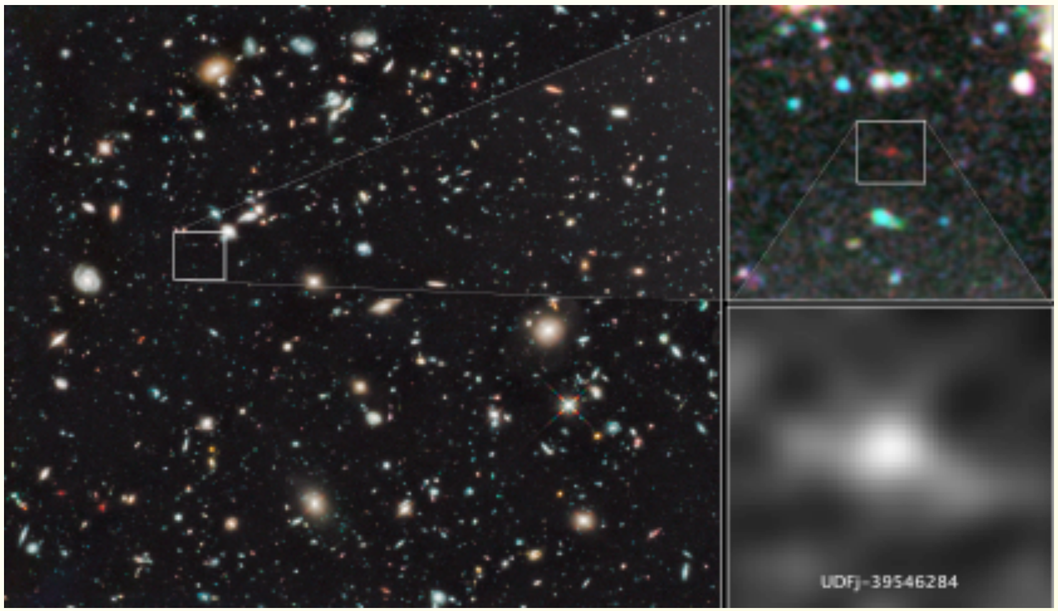
Nbre of galaxies
mag^{-1} Mpc^{-3}

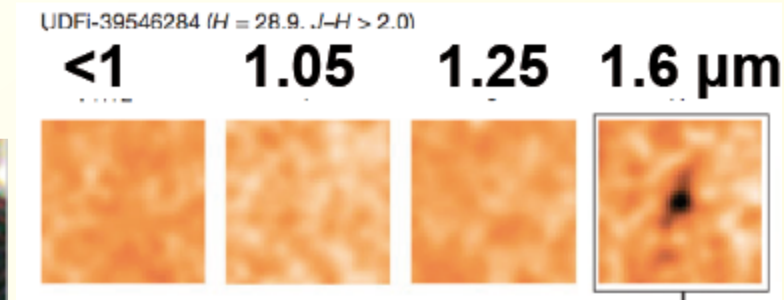




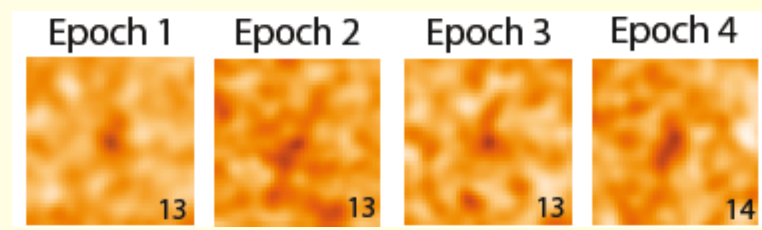
What is the first galaxy?

Candidates at z=10

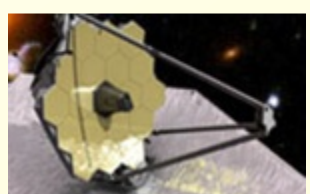




Disappears at λ=1.4 microns



Difficult observations, at the limit
Of present telescscopes
➔JWST
6.5m, 2018



Detected in each sub-group
of observations

Galaxy formation and evolution

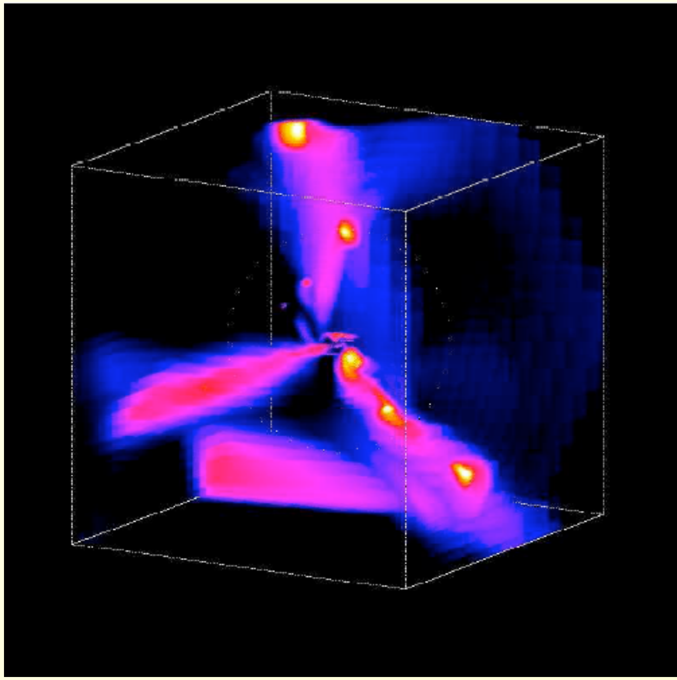
How galaxies assemble their mass?

How much mass assembled in mergers?

How much through gas accretion and secular evolution?

Star formation modes; main sequence,

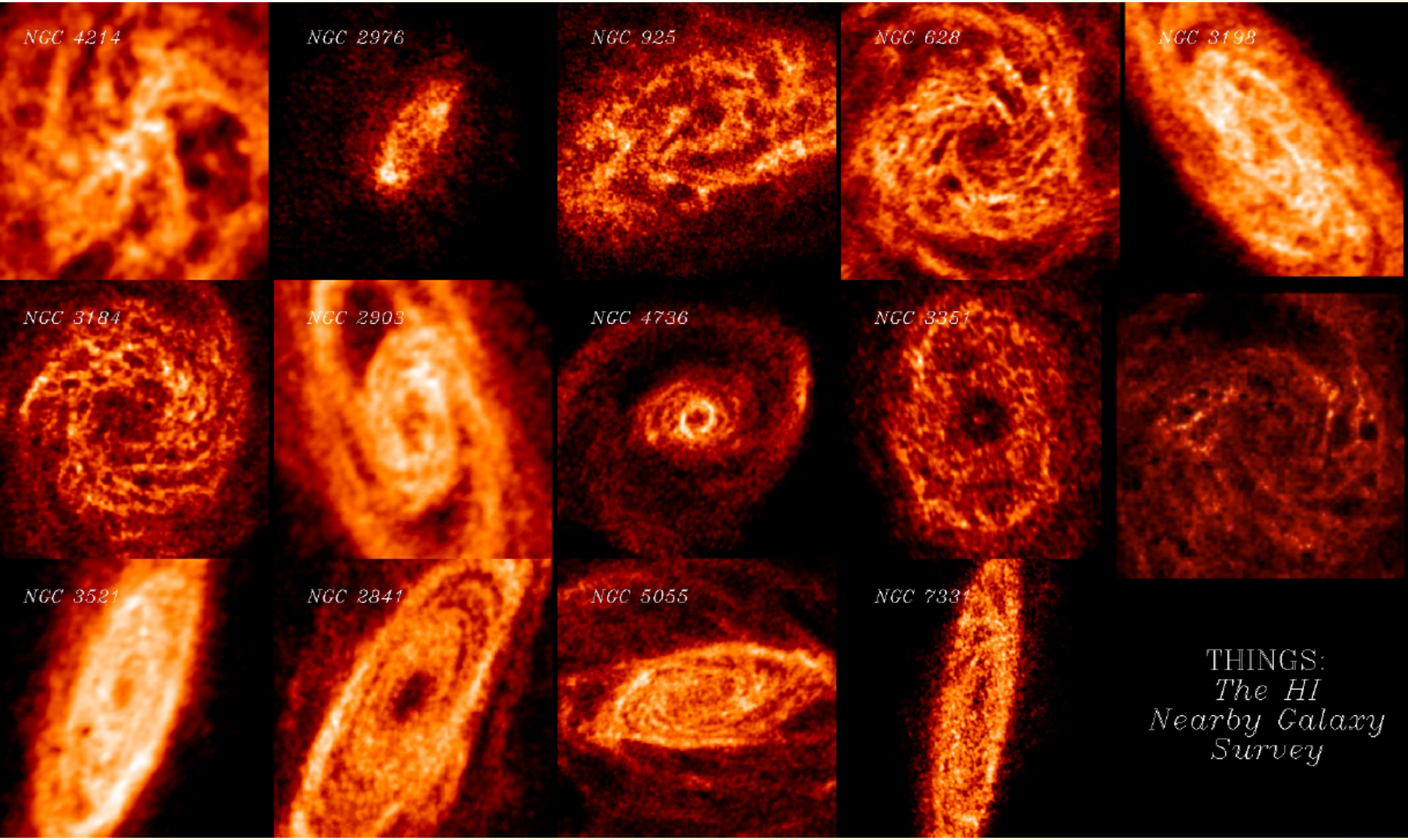
Starburst, mergers?



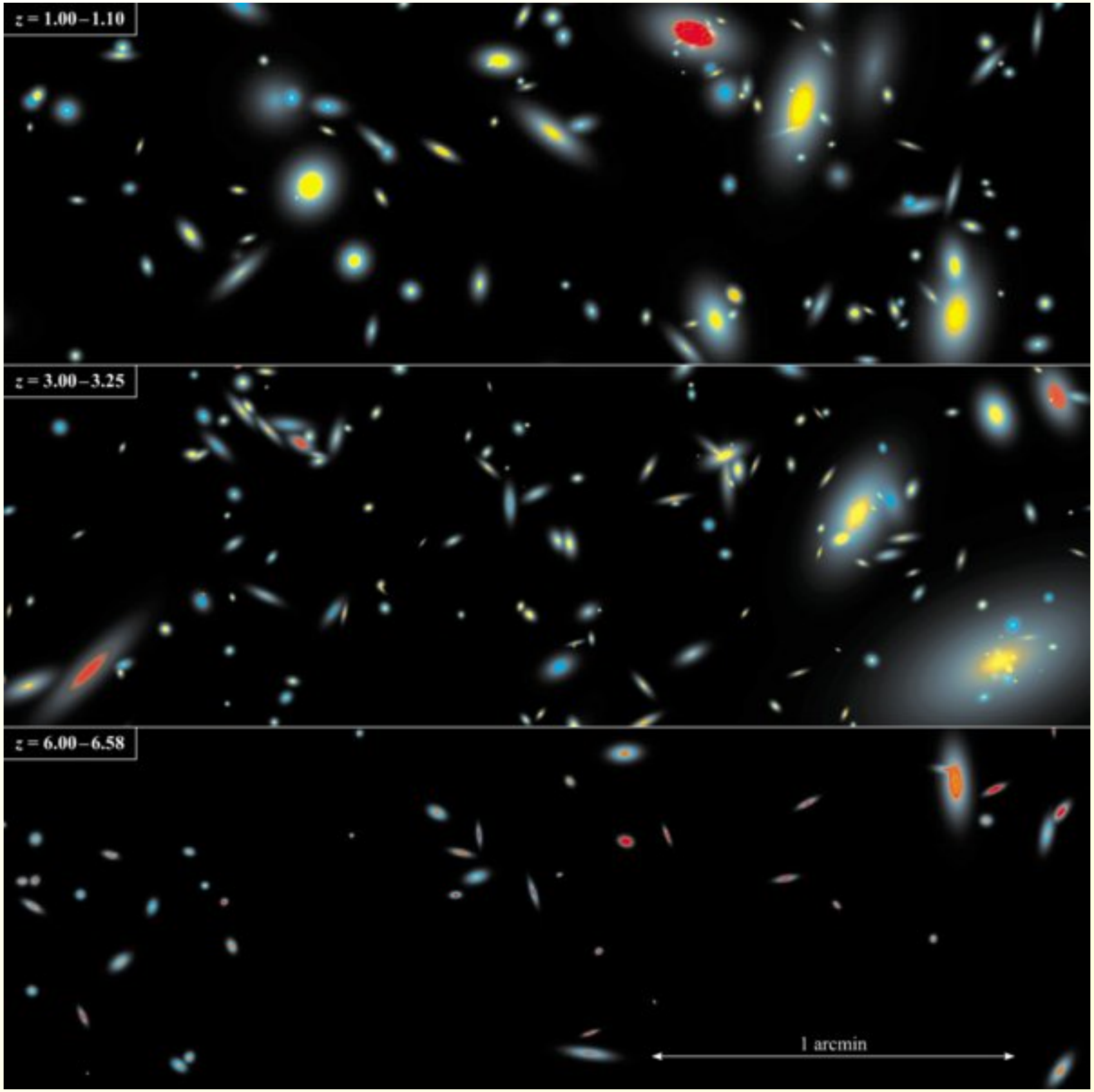
Modes of Quenching

SF and AGN feedback

Atomic hydrogen HI-21cm



Simulated sky, z=1, 3, 6



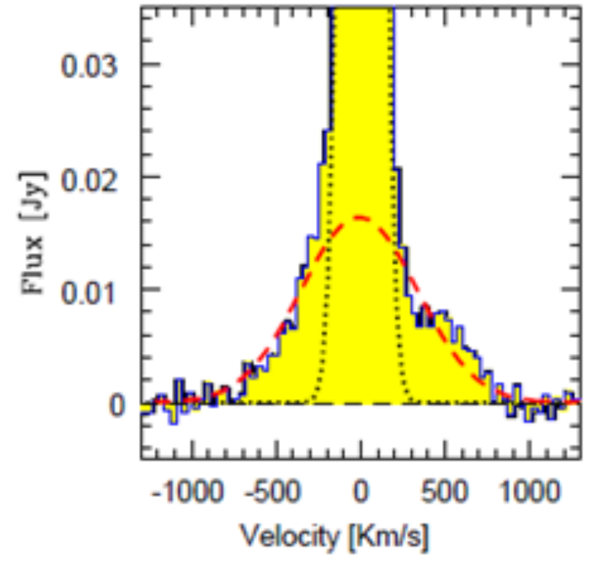
Obreschkow et al 09

z=3 scale x10
z=6 scale x100

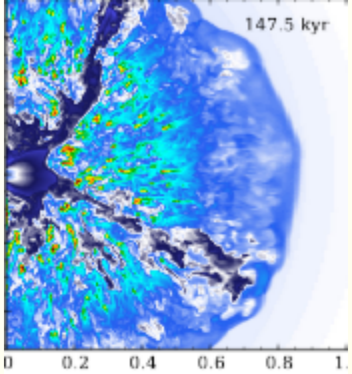
240 Mpc comoving depth
3 x 1 arcmin surface

HI line, and CO lines

AGN NLR, BLR

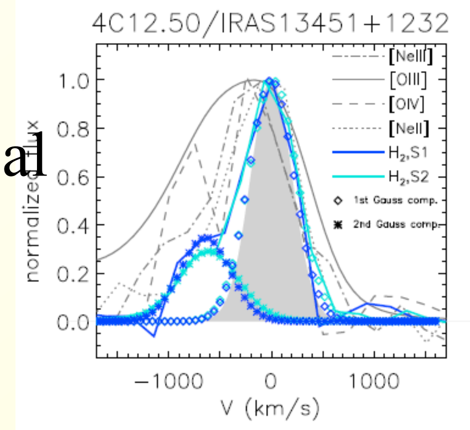


IRAM *Ferruglio et al 2010*



UFO
Wagner et al
2012

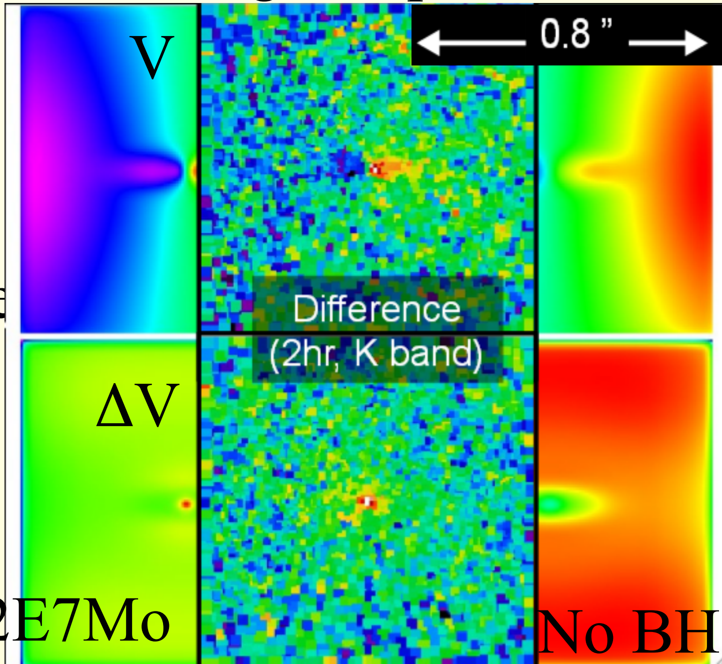
Dasyra & Combes 2012



AGN-driven outflow in Mrk 231

AGN and starburst,
Outflow 700Mo/yr

In Virgo Kupcu-Yoldas



BH 1.2E7Mo

No BH

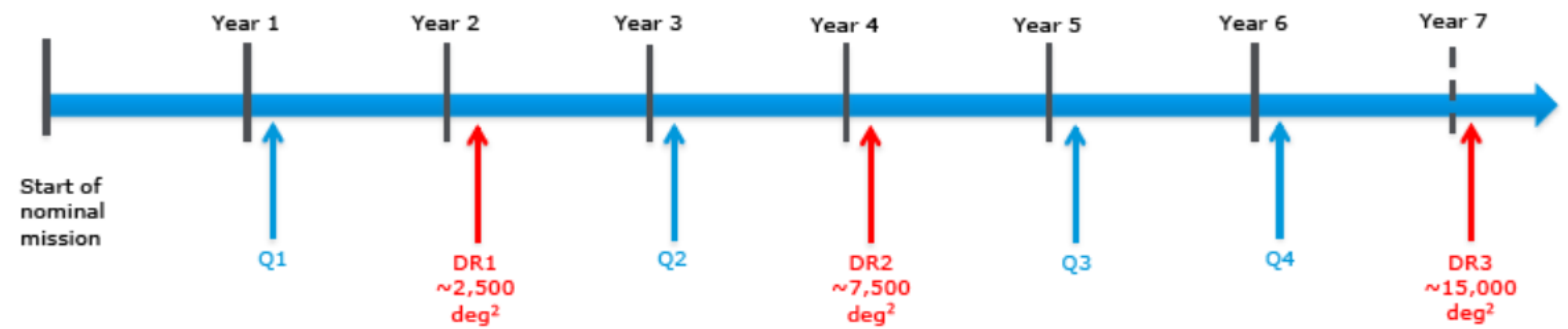
JWST-ELT Census of black-holes

Spatial resolution (5mas)= sphere of influence
10^6 Mo BH at Virgo distance
10^9 Mo BH at z~0.2

Corresponding Time-scales

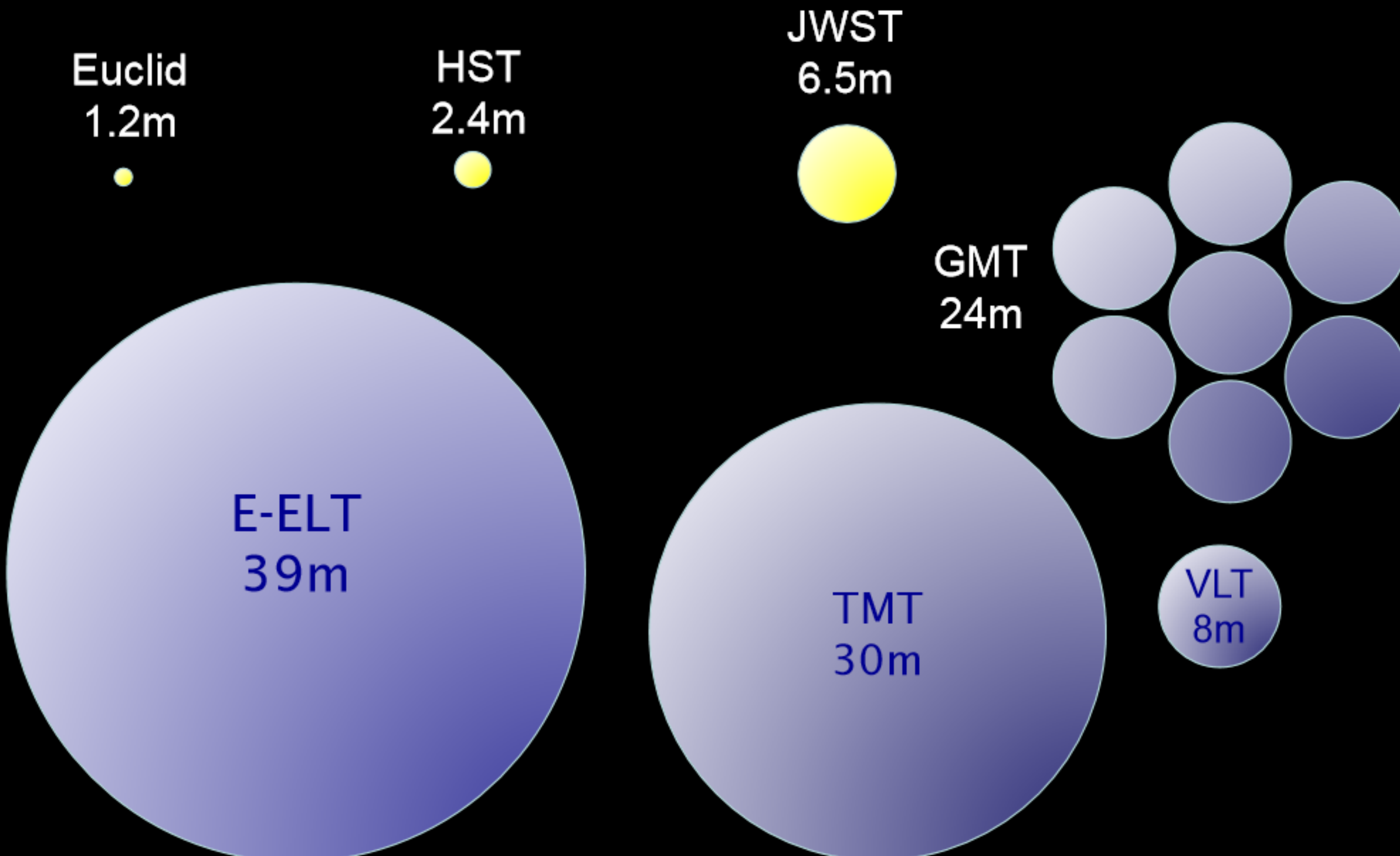
- **2018 – 2021:** construction of **SKA1**
- **2019/20:** early science begins
- **2022 – 2025:** construction of **SKA2**
- **SKA** operational for 50 years.

Euclid: 2020 - 2027



LSST: 2020-2022 Commissioning: 2022- Science!
E-ELT: 2023.. JWST: 2018.. 2028

Telescope primary mirrors



Collecting area = sensitivity
Diameter = resolution
Field of view = mapping speed

SKA footprint to scale /100,000