

Parallel Observation of FPC-S with Other Instruments

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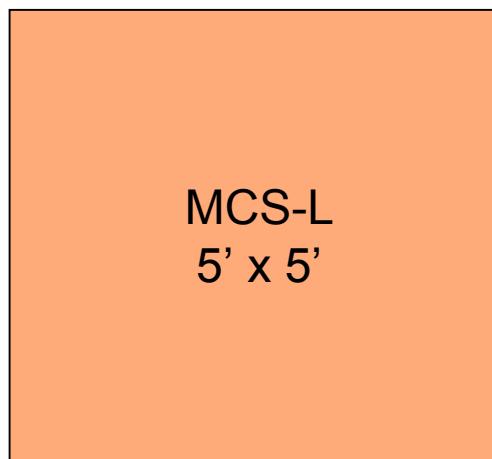
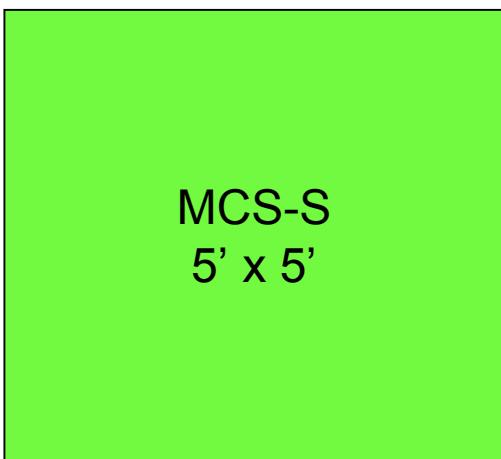
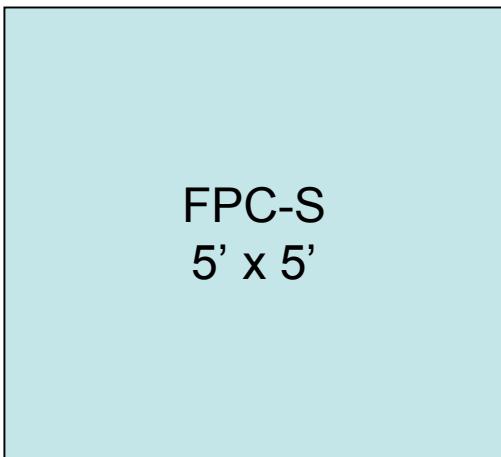
FPC-S

- $5 \times 5 \text{ arcmin}^2$ (3X fov of JWST)
- Pixel: 0.3" (\sim PSF FWHM)
- 0.7-5 μm (R=5 imaging, R=20 spectroscopy)
- 5 wide-band filters + 3 LVFs
- ~26.3 AB mag at 100 sec, 3- σ , imaging
~27.7 AB mag at 1 hr, 5- σ , or
~25 AB mag at 20 sec 5- σ

Why SPICA/FPC-S, not JWST?

- Parallel observation: Use FPC-S while MCS or SAFARI are observing their main targets (e.g., HST)
- Synergy with MIR/FIR instruments
- Wide area coverage from parallel observation (+ post-cryogenic operation)
- Unique filter??

Parallel Observation



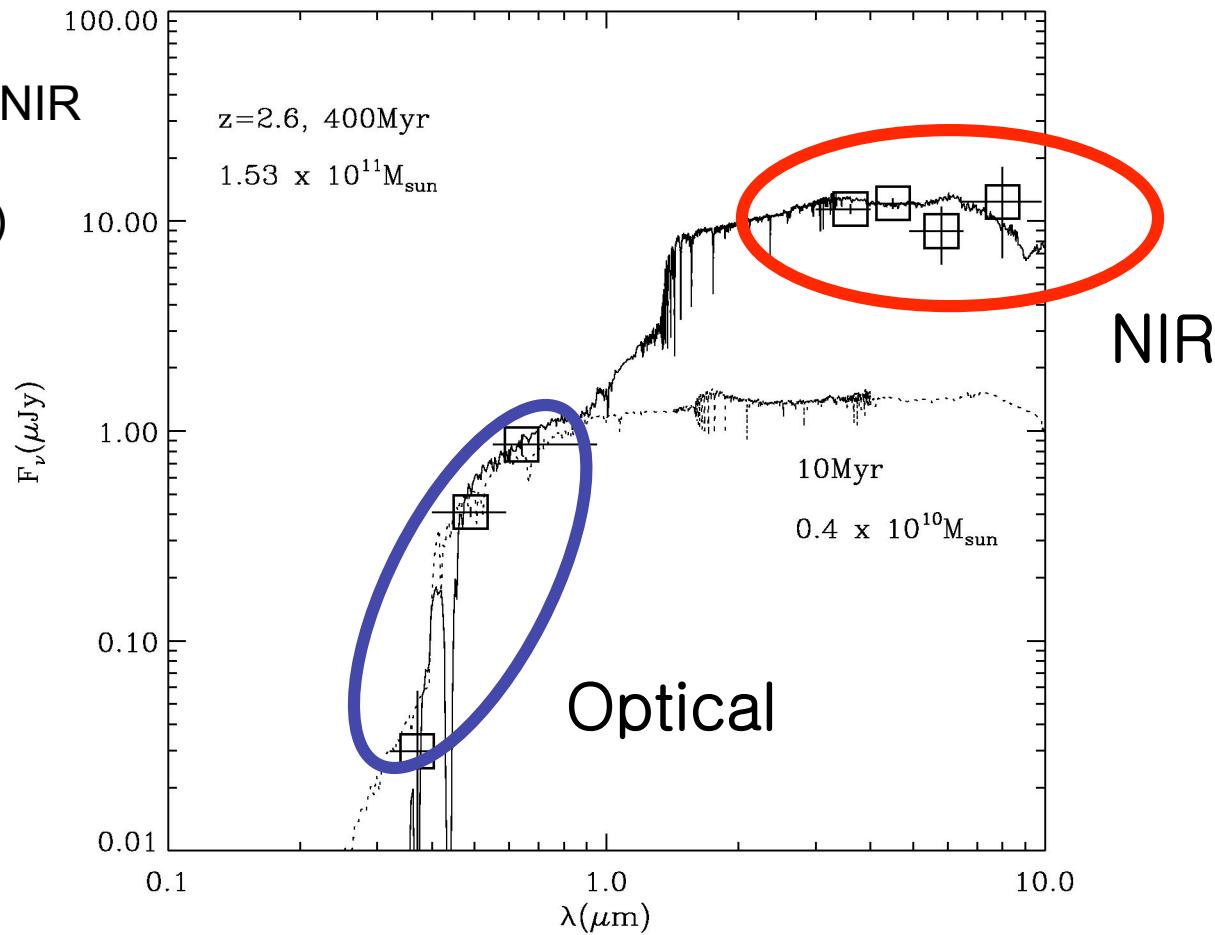
- FOV, good match with other instruments
- Parallel observation with $>> 25 \square'$

Why FPC-S? Mass+Age+SFR of Distant Galaxies

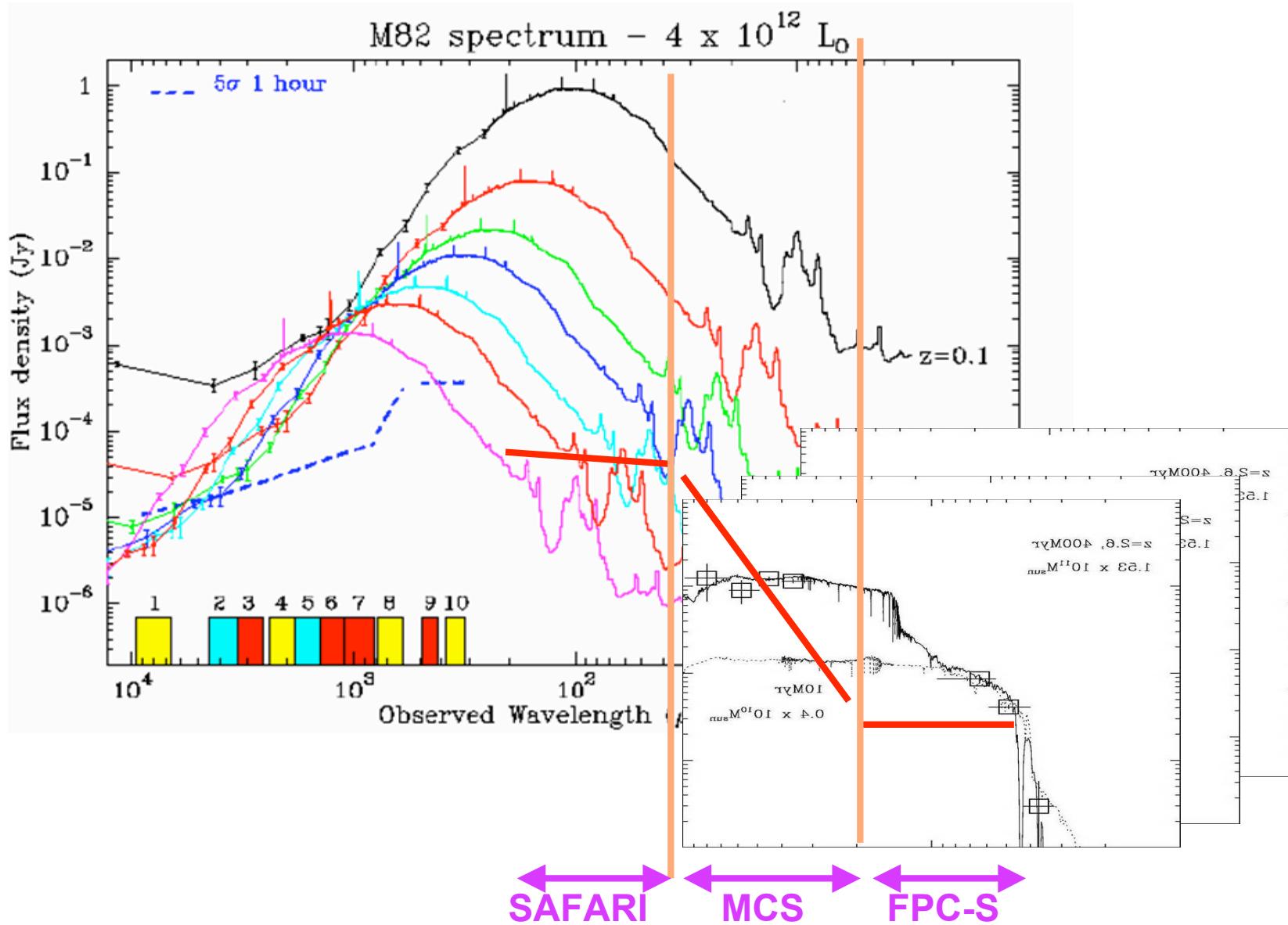
Mass: Optical/NIR

Age: Dn(4000)

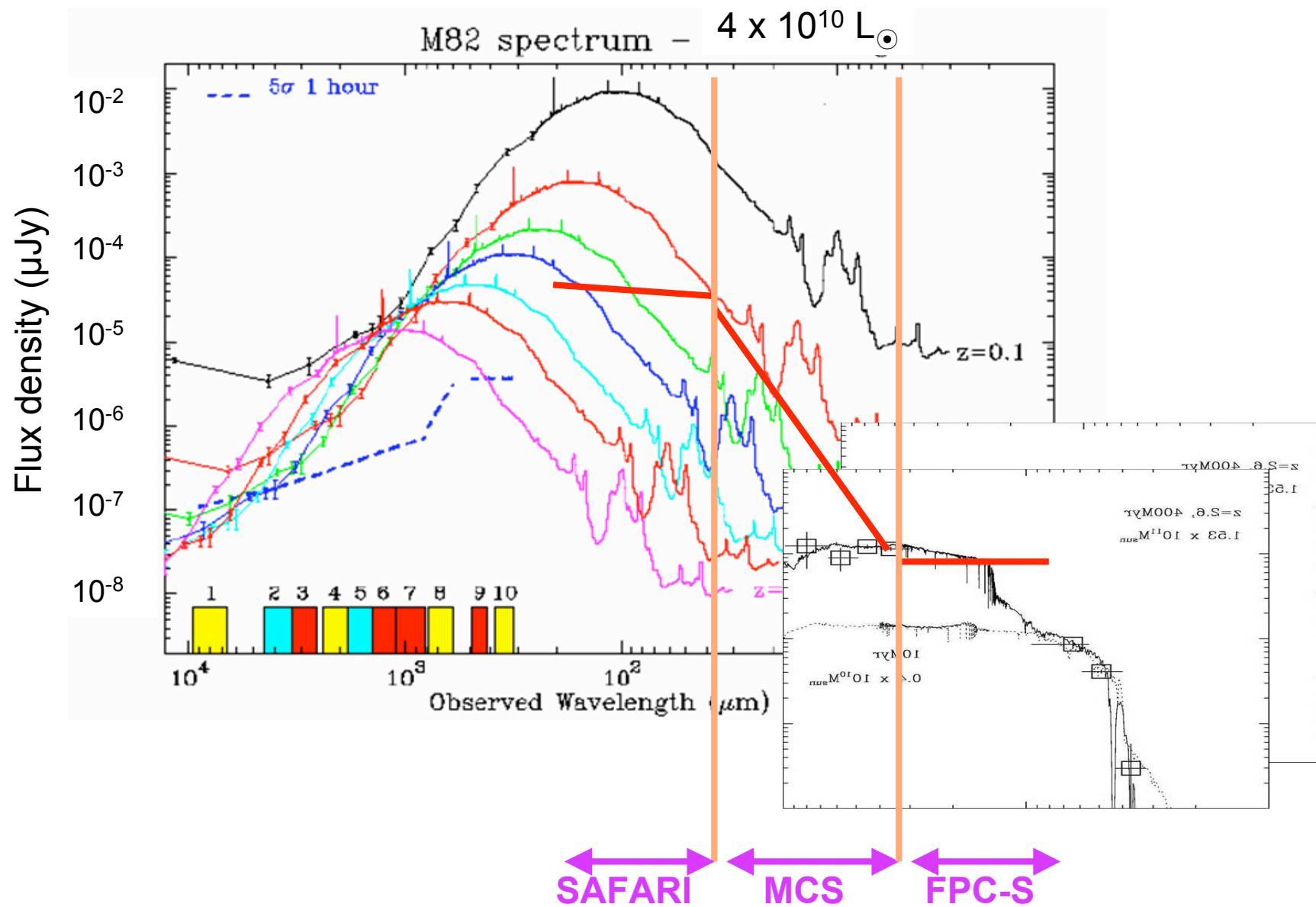
SFR: UV

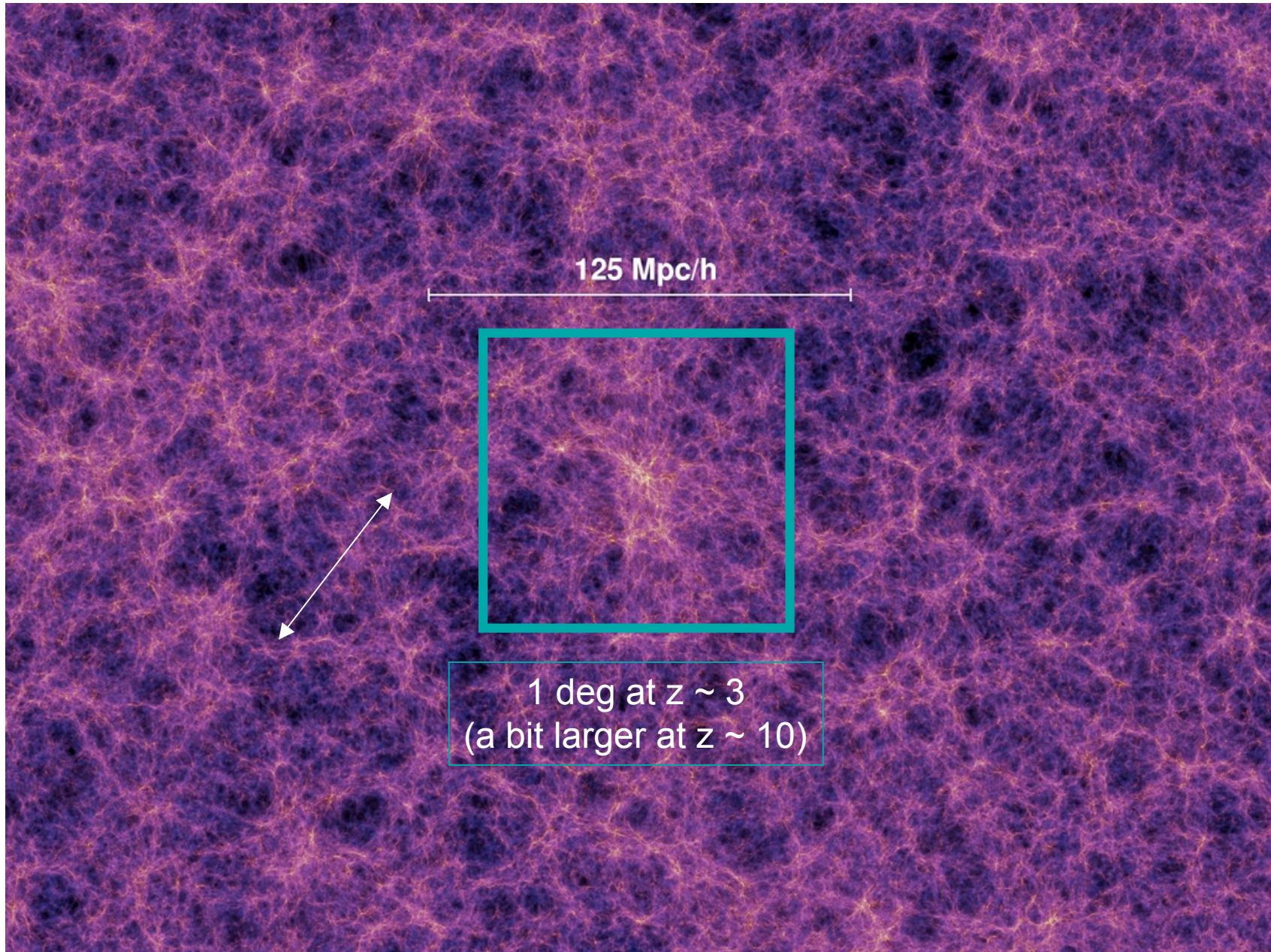


SFR(FIR) + SFR(MIR) + Mass/Age(FPC-S)

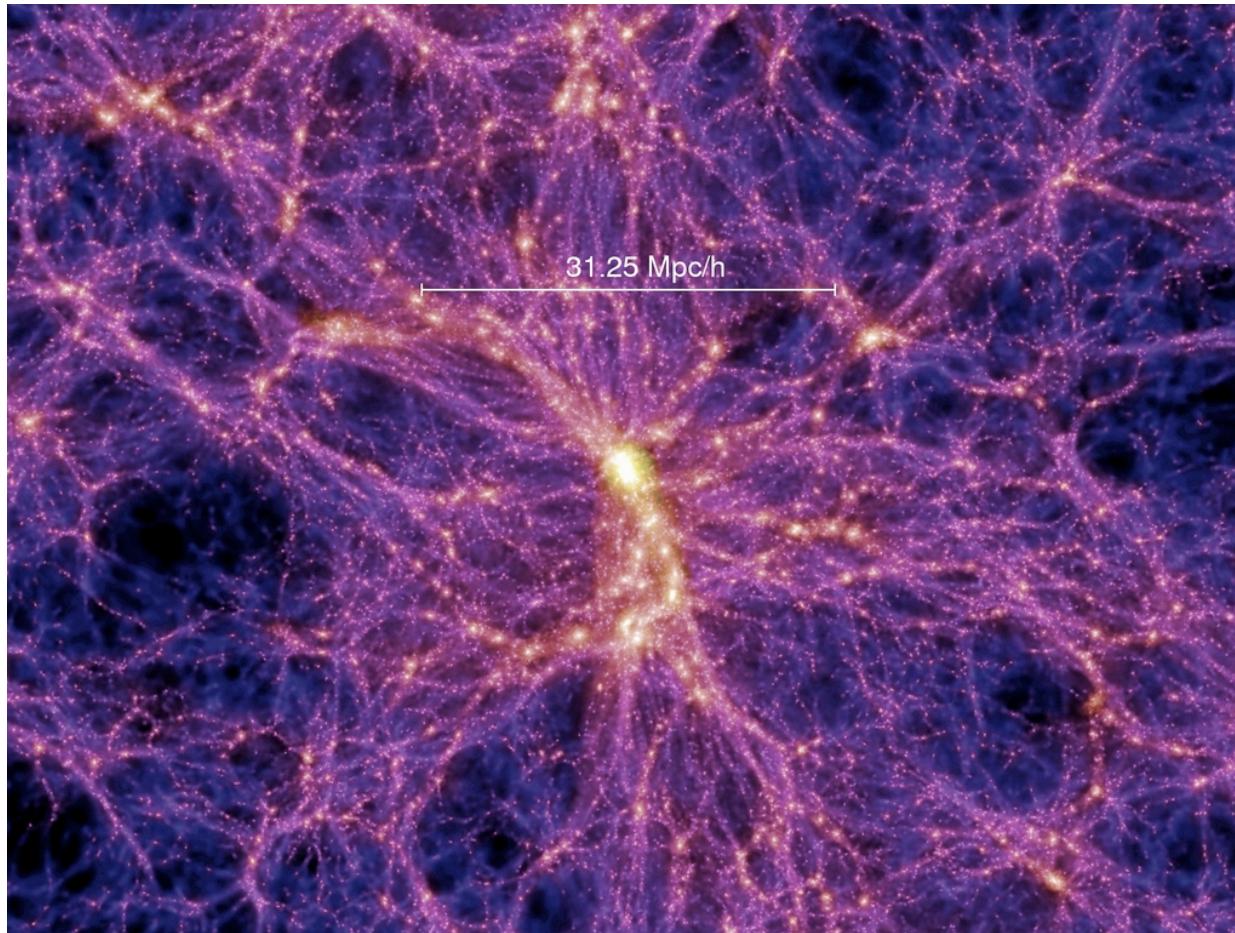


SFR(FIR) + SFR(MIR) + Mass/Age(FPC-S)





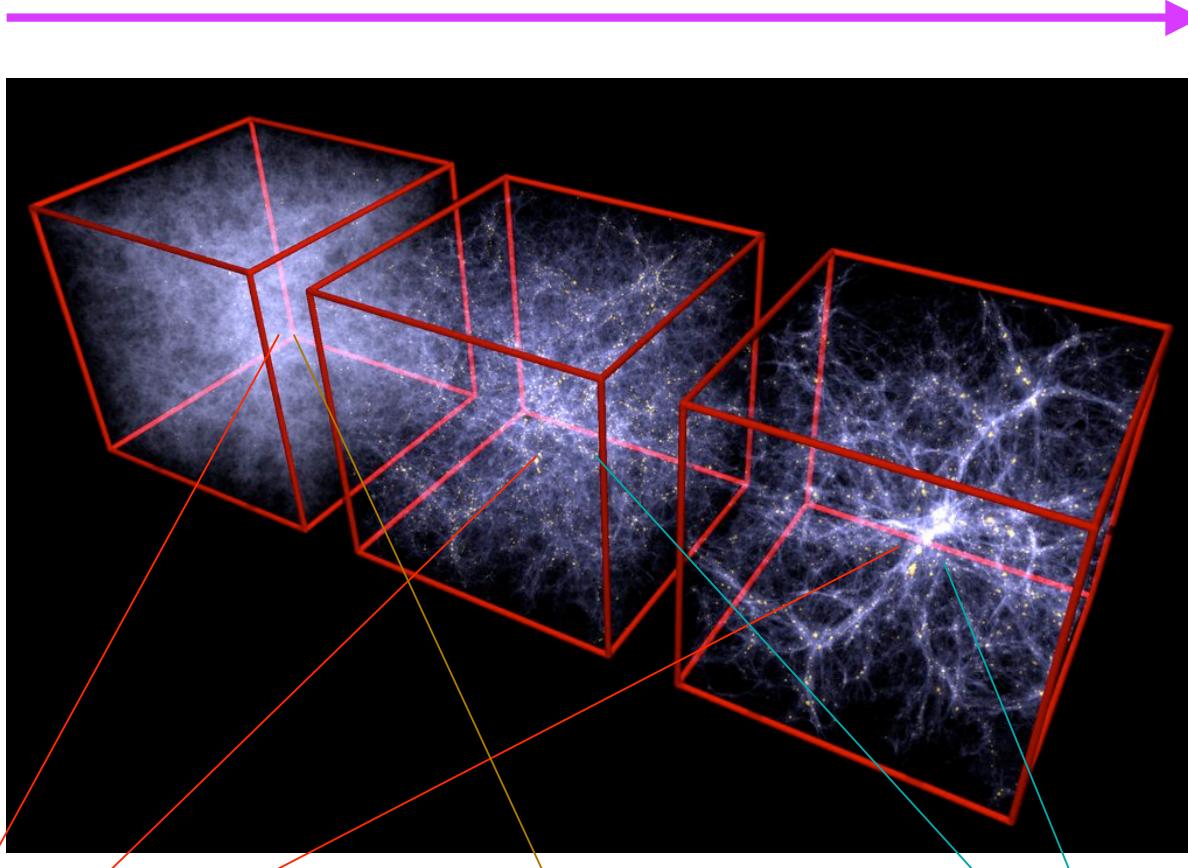
Millennium Simulation



- Galaxy formation, tens – hundreds of LBGs $\sim 1\text{-}2 \text{ deg}^2$, deep survey
- Proto-clusters, massive galaxies, quasars \sim a few tens to hundreds deg^2

Key Science Topics (Extragalactic)

Time

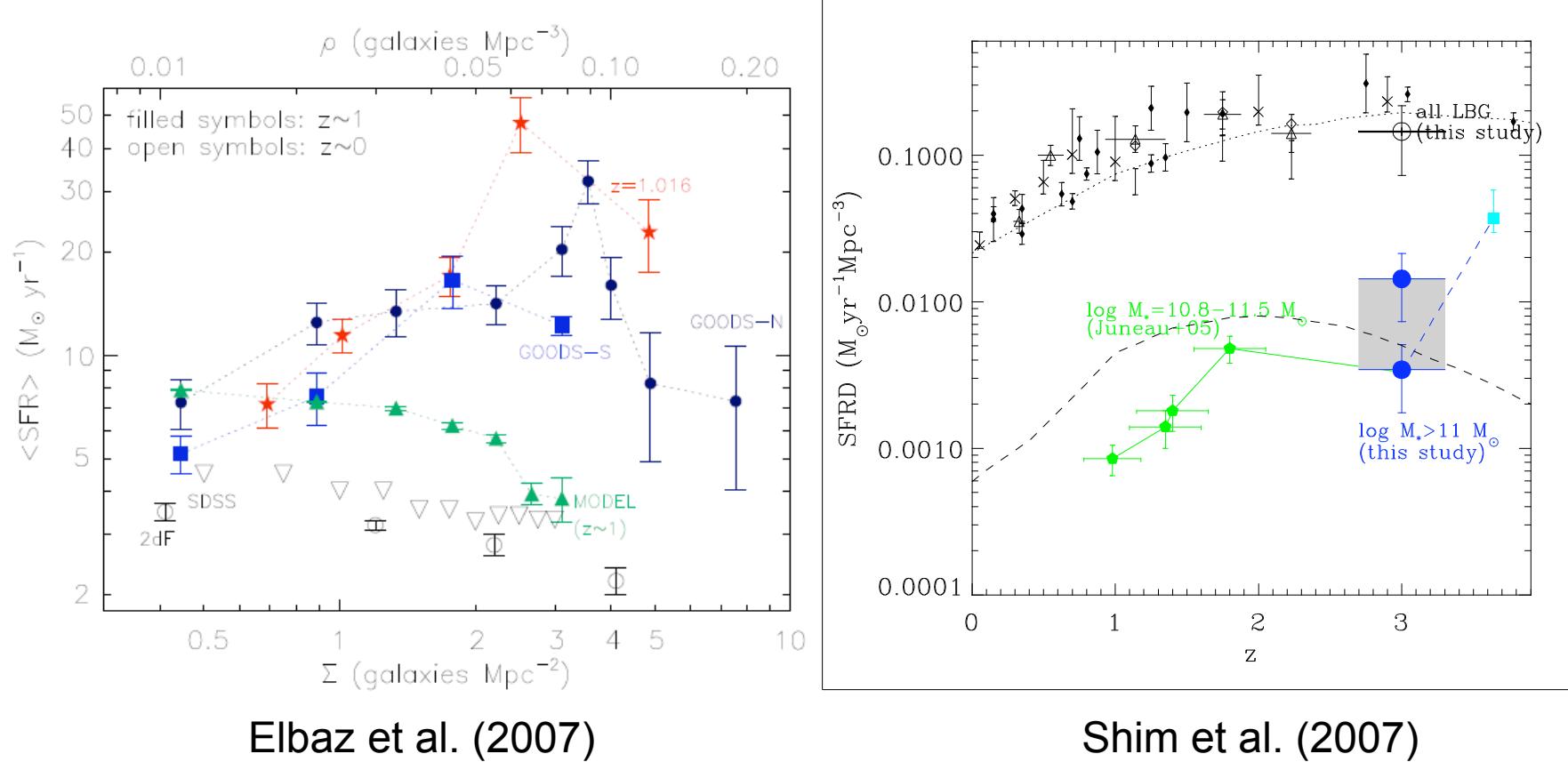


Galaxy formation/evolution:
mass/SFR/environment
($z=1-6$)

First SMBHs (Quasars),
& First galaxies ($z > 6$)

Proto-clusters
& cluster of galaxies
($z=1-4$)

Galaxy Evolution at Intermediate Redshift



Elbaz et al. (2007)

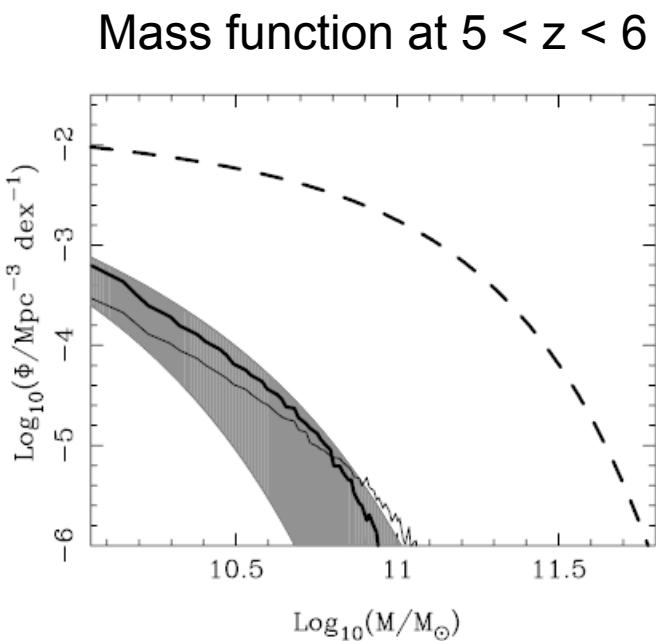
Shim et al. (2007)

- Interplay between mass/local density is important for galaxy evolution ($z > 1$??)

Galaxy Formation at $1 < z < 6$

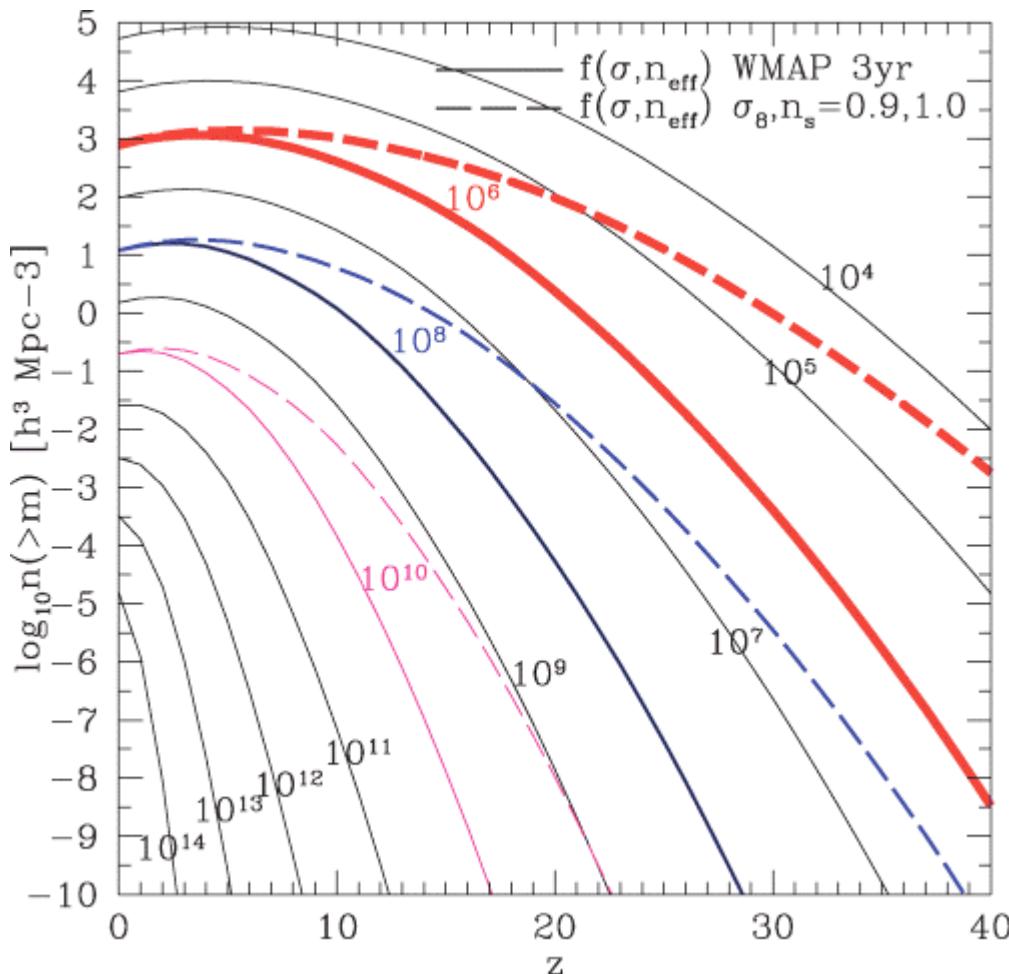
- At $AB < 27.7$ (25.2) AB mag,
- $\sim 10^8$ (10^9) M_\odot galaxies
- 1 deg ~ 110 Mpc comoving length at $z=3$

→ Parallel observation allows investigation SFR versus stellar mass/environment, synergy with FIR/MIR observation (also coordinate observation with ground-based facilities)



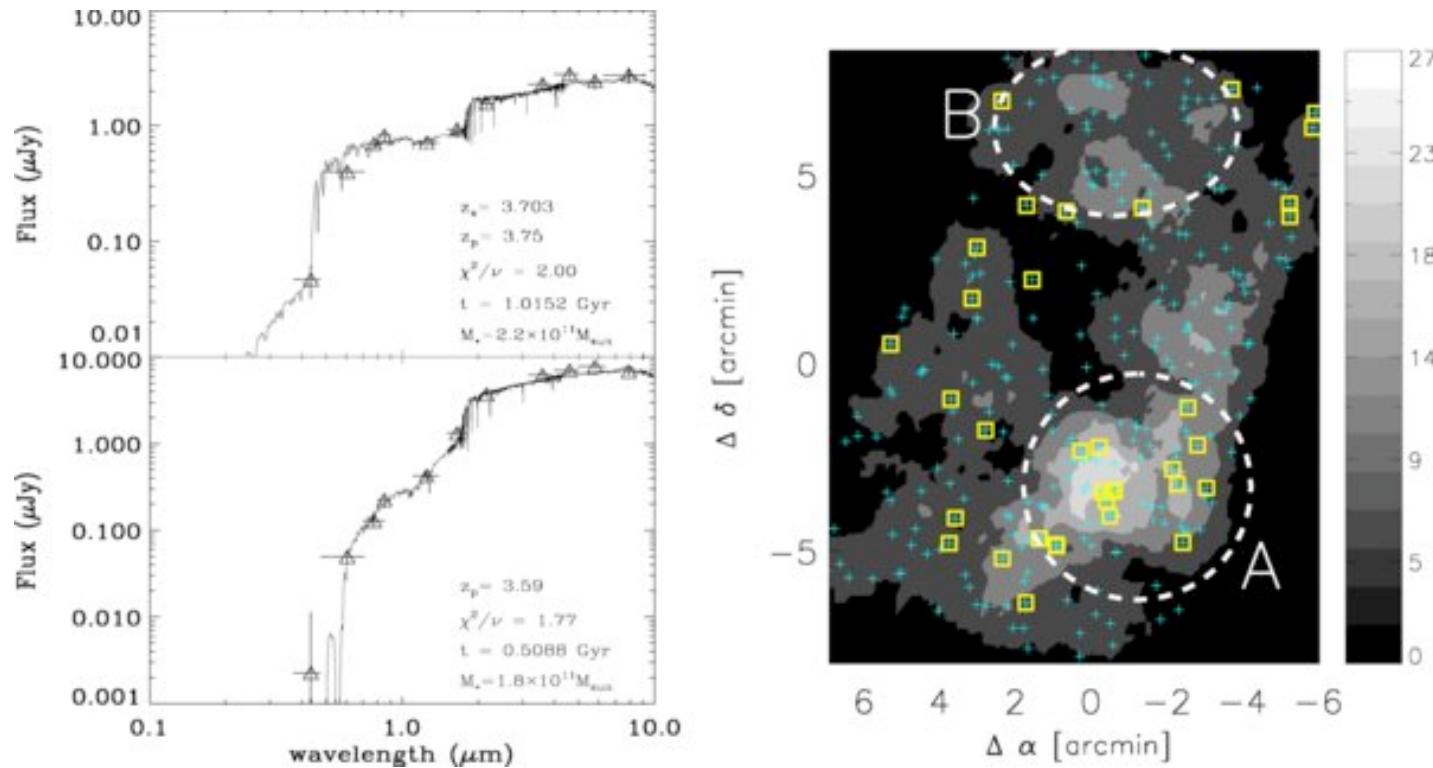
McLure et al. (2009)

Proto-clusters



- Number of massive halo s
 - ~ Initial density fluctuation n,
 - non-Gaussianity, etc
 - Test of galaxy formation process (SF of massive galaxies started in overden sity?)
- Reed et al. (2008)

Proto-cluster at $z \sim 3.7$ in GOODS-South



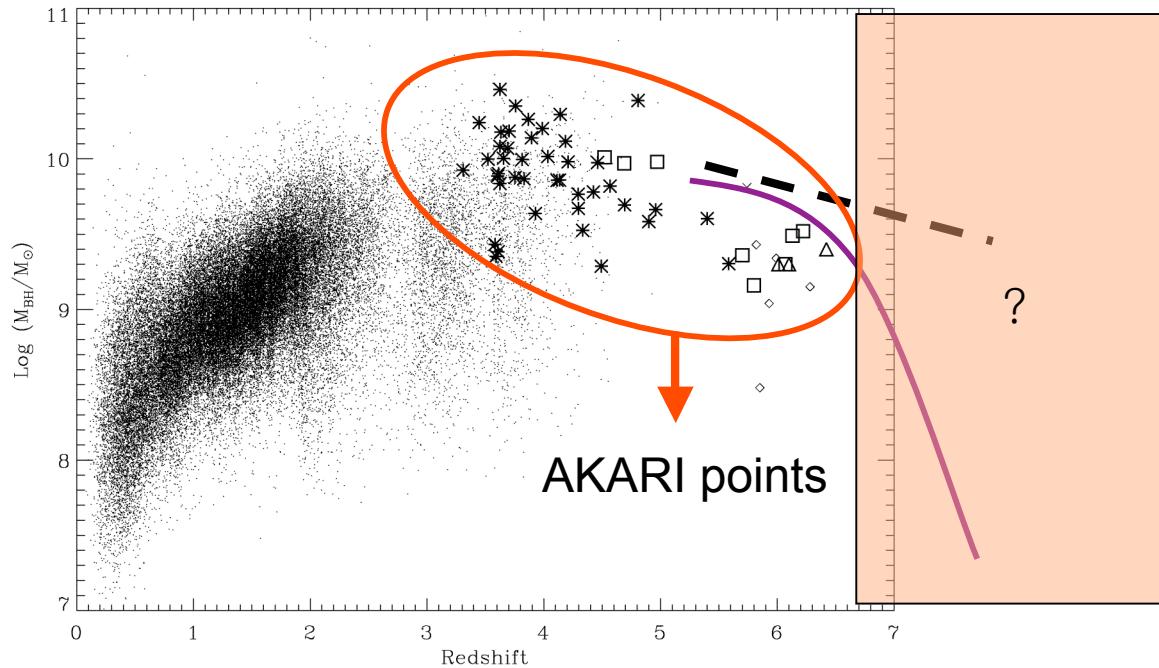
$M \sim 10^{15} M_{\odot}$ proto-cluster at $z \sim 3.7$ (Kang & Im 2009)

Yellow squares: $> 10^{11} M_{\odot}$ galaxies with ages $\sim 0.5 - 1$ Gyr

Proto-clusters ($z > 1$)

- ~ 1 per deg² to ~ 100 per deg² for $10^{14} M_{\odot}$ clusters
- Large scale structure is important (> 100 Mpc scale) – filaments, outskirts of clusters
- Star formation in high density environment?

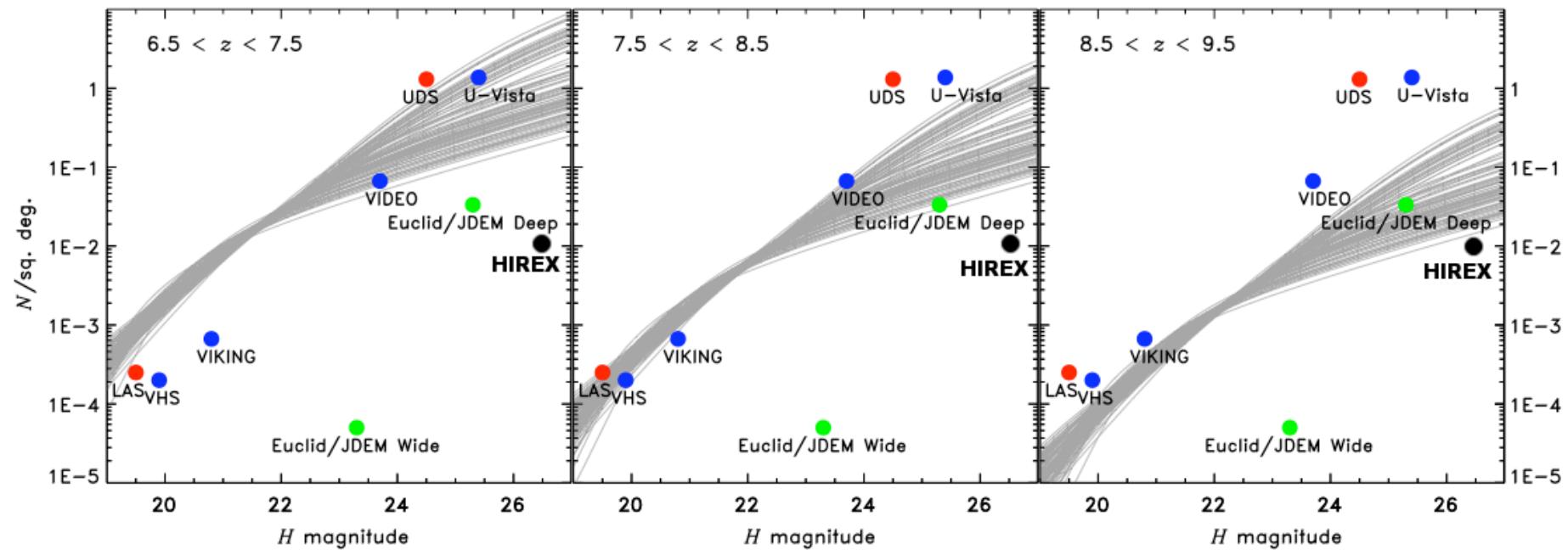
Quasars and SMBHs at High Redshift



No $M \sim 10^{10} M_{\odot}$ SMBHs at $z > \sim 6$ ($t_{\text{univ}} \sim 0.9$ Gyr):
they are growing!

How did the SMBHs grow when the universe was less than 1 Gyr?

Quasars Number Density



> 10-100 deg² survey at > 25 mag necessary
→ Difficult with JWST

Willott et al. (2009)

LBGs

- At AB < 28 mag,
- 0.2/arcmin² at z ~ 8, or 0.01/arcmin² at z ~ 10 (Bouwens et al. 2010; Ouchi et al. 2009)
- Over 1-2 deg², 36-72 LBGs at z ~10
- Sensitive to a few $\times 10^9 M_{\odot}$ galaxies at z ~ 10 → IGM, SFR, etc
- 1 deg ~ 170 Mpc comoving length at z=10
- Will JWST do this?

Previous Surveys

- Spitzer – GOODS (260 arcmin², 25 AB mag), SWIRE (50 deg², 22 AB mag), COSMOS (2 deg², 24 AB mag), SED S (0.9 deg², 25-26 AB mag)
- AKARI – NEP (5 deg²)
- Herschel – ATLAS (550 deg²@600hrs), HERMES (0.04-100 deg²@900hrs)
- JWST - ?
- SPICA - ?

Possible Surveys

- Deep survey: 1-2 deg² (cf. COSMOS), deeper survey
- Wide survey: ~ 50 deg² (cf. SWIRE/HERMES) – AGN/Galaxy clusters
- Shallow, very wide survey: a few 100 deg² (ATLAS/HERMES)
- Pure parallel survey (HST)
- **1 deg² = ~150 FPC-S pointings**
~27.7 AB mag at 1 hr, 5- σ , or
~25 AB mag at 20 sec 5- σ

Deep survey ($\sim 1 \text{ deg}^2$)

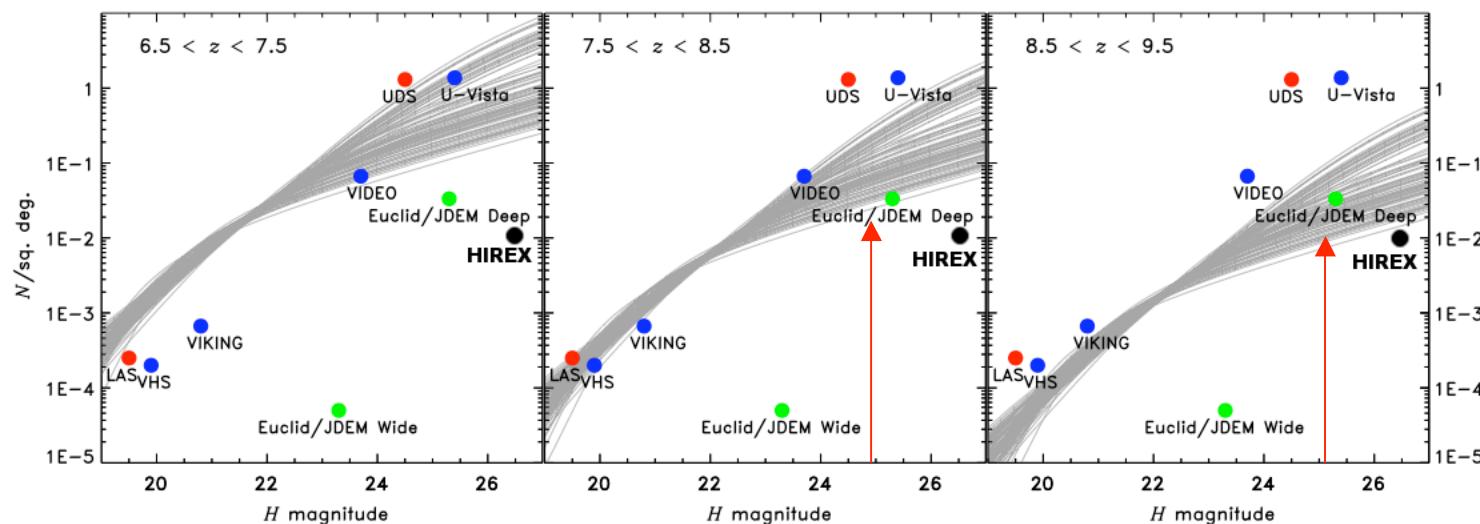
- Parallel with MCS/SAFARI
- $T = 1 \text{ deg}^2 \times 750 \text{ ptng/deg}^2 \times 3600 \text{ sec} \times 5 \text{ filters} = 750 \text{ hrs}$
- 5- σ at 27.7 AB mag
- Good for SF and mass assembly history of galaxies, LBG study

Wide survey (\sim 50 deg 2)

- $T = 50 \text{ deg}^2 \times 150 \text{ ptng/deg}^2 \times 100 \text{ sec} \times 5 \text{ filters} = 1000 \text{ hrs}$
- 5- σ at 25.7 AB mag
- Good for proto-cluster/cluster study, galaxy evolution in clusters, high-z quasars (10-50)

Shallow, wide survey ($\sim 400 \text{ deg}^2$)

- Parallel with SAFARI/MCS?
- $T = 400 \text{ deg}^2 \times 150 \text{ ptng/deg}^2 \times 20 \text{ sec} \times 3 \text{ filters} = 1000 \text{ hrs}$
- 5- σ at 25 AB mag
- 20-100 QSOs at $7.5 < z < 8.5$, 4-40 QSOs at $8.5 < z < 9.5$
- At $z = 3$, $> 2.5 \times 10^9 M_{\odot}$, $> 10^{10} L_{\odot}$
- > 400 clusters/proto-clusters, low- z , SDSS-type science



Willott et al. (2009)

Summary

- MCS (MIR) + SAFARI (FIR) + FPC-S (Optical/NIR) → mass, age, SFR of distant galaxies! (1-100 deg²)
- Target of opportunity: GRBs at high redshift
- Post-cryogenic mission?