ISM and Galaxy Evolution — the ELT View

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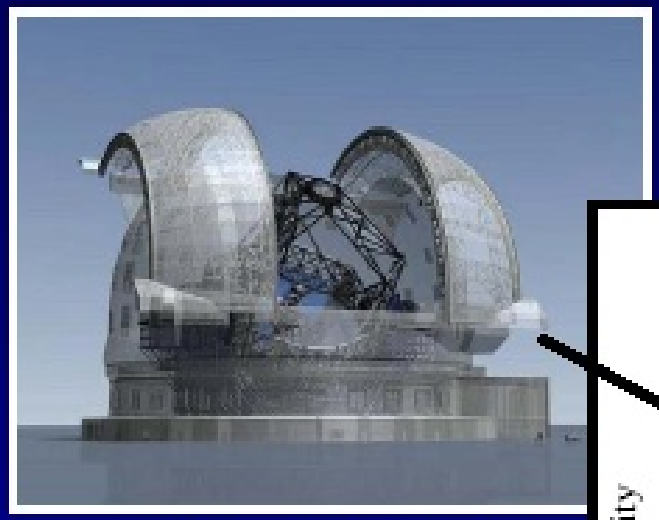
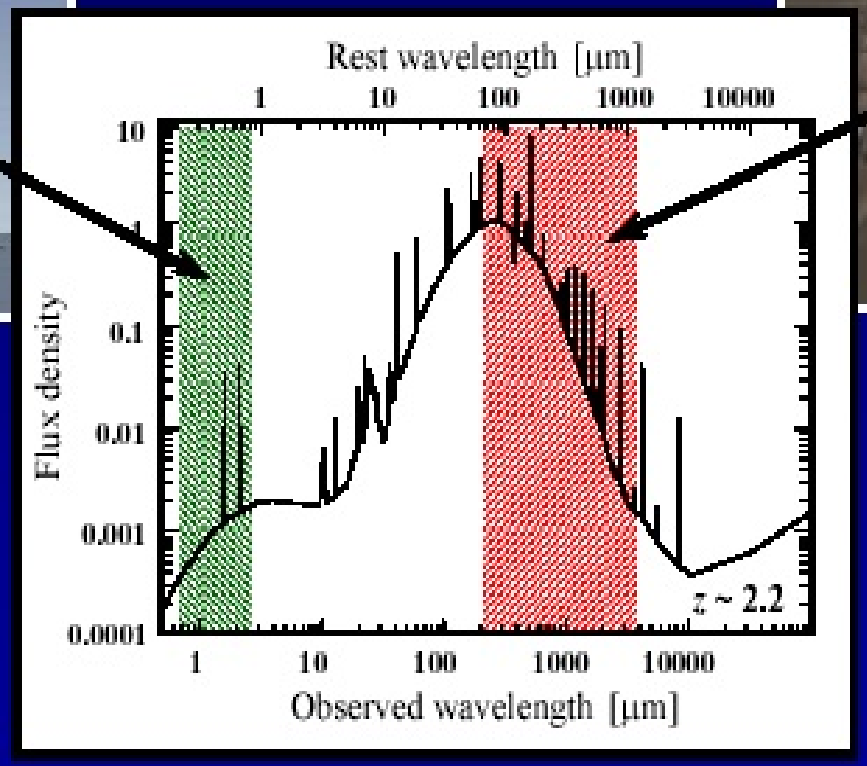
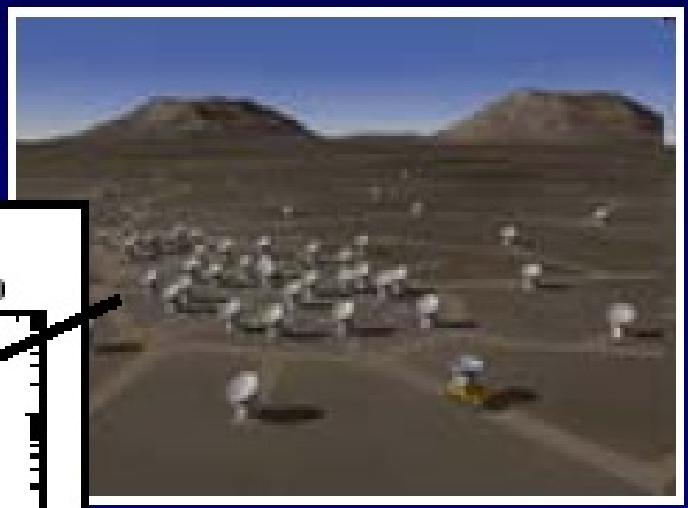


E-ELT, GMT, TMT





ALMA

Starlight, HII & AGN

Dust & Molecules

Where we stand and looking in perspective

- The current generation of ground & space telescopes are producing a plethora of high-redshift targets that are beyond their own capability to properly follow them up (nice to have an ELT now ...)
- i.e. They are producing a more than adequate supply of potential ELT (and ALMA) targets
- What are the problems likely to be still unsolved in 2017 (2018)?

The problems we perceive today

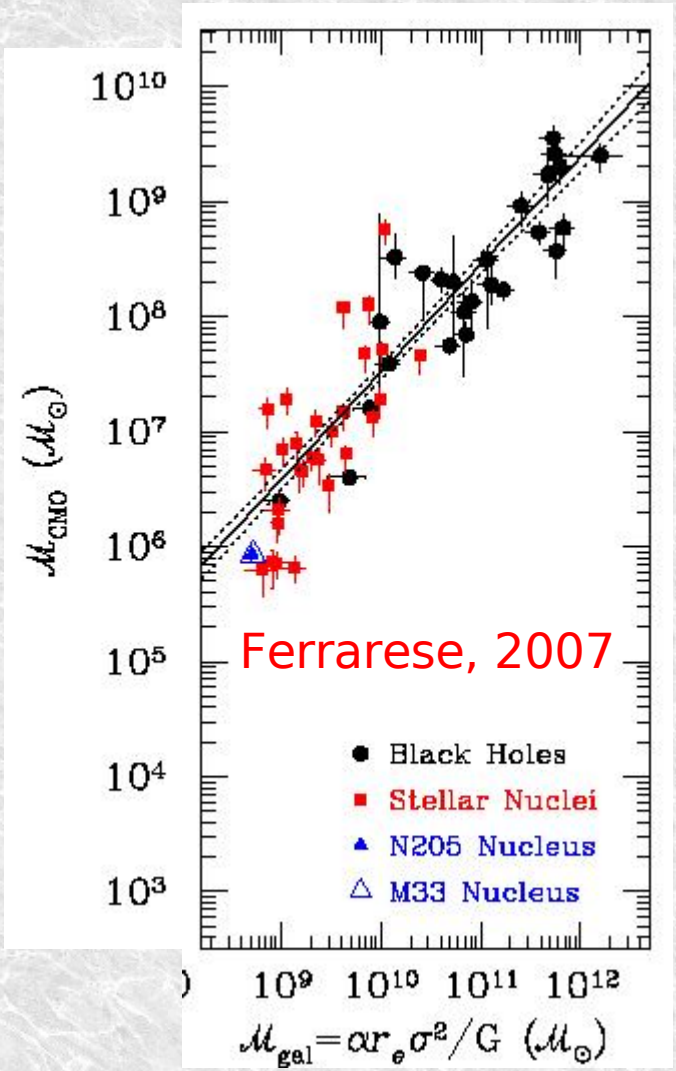
- Find and study the agents of re-ionization
- Galaxy-AGN “co-evolution”
- Mapping the Chemical enrichment of galaxies
- Disk evolution, bulge formation

Much progress expected in the next decade, but what problems will likely need ELT to get (properly) solved????

The Agents of Re-ionization

- The present: no confirmed object @ z>7 is known today, but at z=6.7 the Universe is already almost fully ionized!
- The task appears to be beyond the capability of 8-10m class telescopes.
- A job for the ELT: Get emission-line spectra (redshifts, velocity widths, metallicities, etc.) of candidate z>~7 galaxies that would be identified on VISTA/Hawk-I ultradeep imaging as z-, Y- and J-band dropouts, and may be beyond (?) JWST spectroscopic capabilities.

Galaxy-SMBH Co-Evolution



The co-evolution Paradigm rests on two main arguments:

1) $M_{SMBH}/M_{Bulge} \approx 10^{-3}$
   (the "Magorrian" ratio)

2) We may need "AGN Feedback" to switch-off star formation and start making the passively evolving galaxies at z~2

The Punchline in Galaxy-AGN Co-evolution:

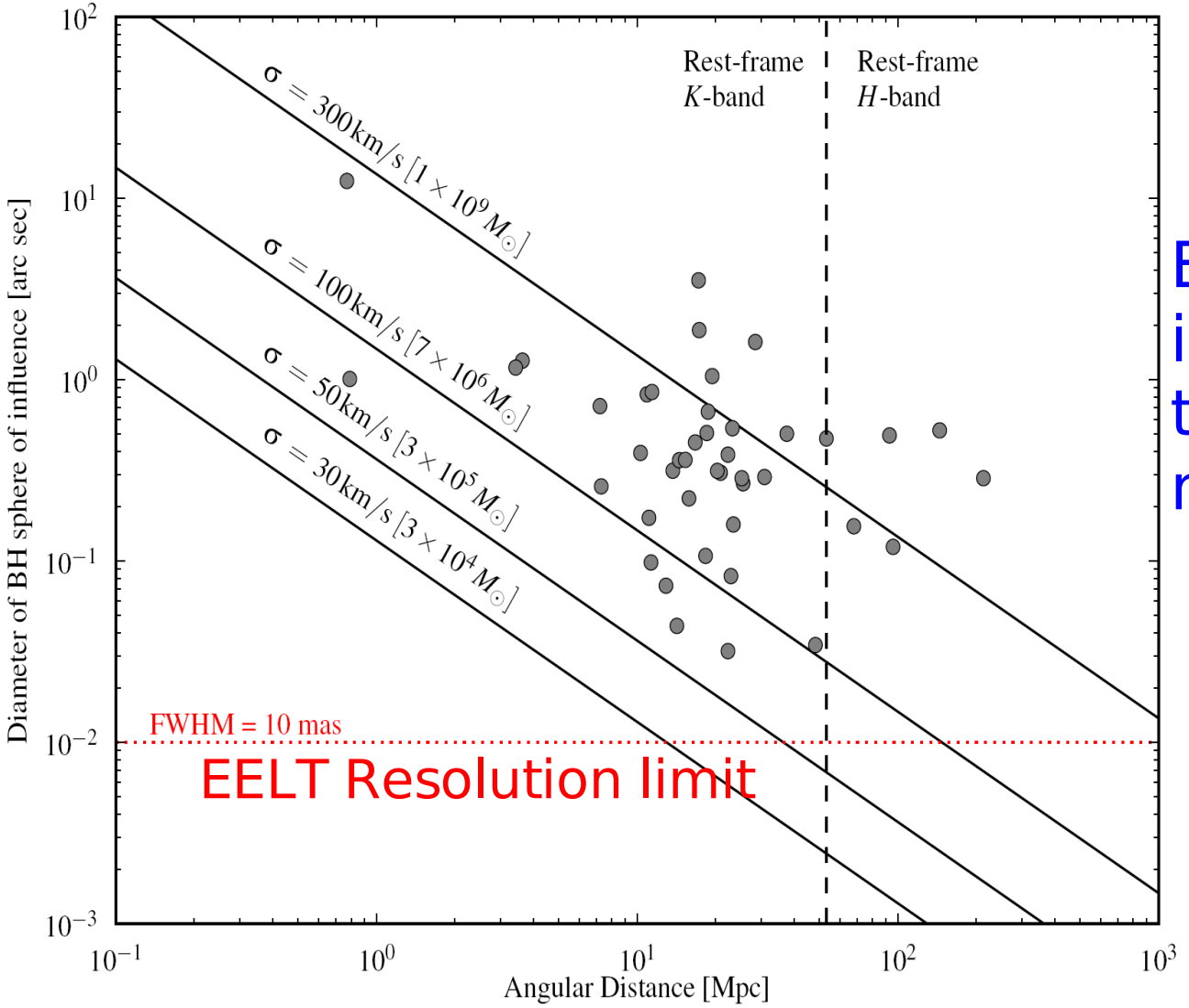
- Mapping the evolution of the M_{BH}-M_{bulge} relation to (very) high redshifts

- Role of AGN feedback in quenching star formation and leading to passive ellipticals: seeing feedback in action

A Chicken and Egg Problem (?)

- Do SMBHs precede galaxy assembly? Or do they follow it? Or do SMBHs and Galactic spheroids grow together?
- Does M_{BH}/M_{nulge} increase, decrease or stay the same with increasing redshift?
- One needs to measure M_{BH} and M_{bulge} in both active and inactive galaxies at the highest possible redshift

SMBH masses from stellar kinematics in the BH vicinity

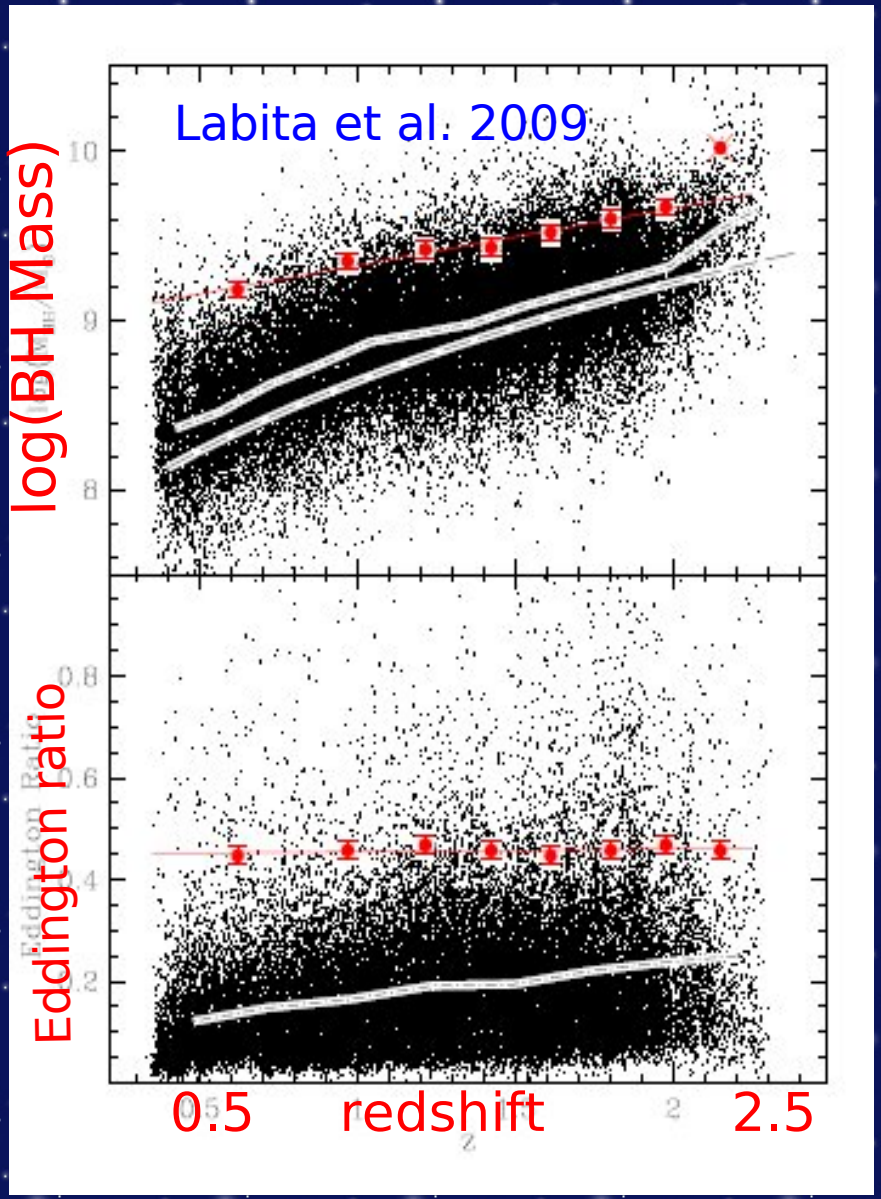


Even with EELT it is usable only up to relatively modest redshifts

z~0.35

0.1 Distance (Mpc) 1000

At higher redshift one has to rely on the BLR of AGN/QSOs

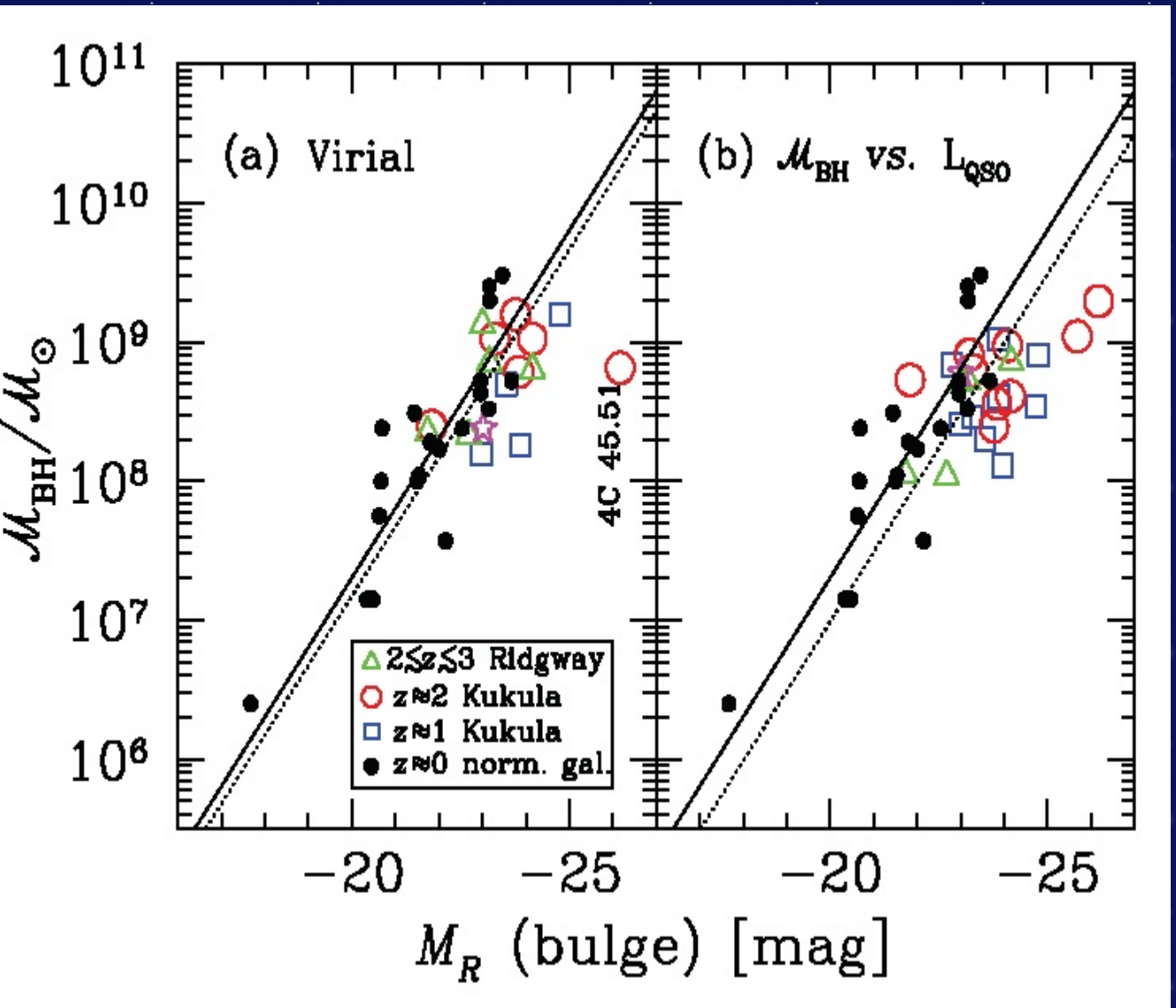


$M_{BH} \sim R_{BLR}\sigma^2_{BLR}/G$ or from $M_{BH} \propto \sigma^2_{BLR} L_{QSO}$

To get the mass of the host spheroid we need to deblend host and QSO light, hence the superior resolution of the ELT is critical!

i.e. Much less affected by several biases than current efforts.

Peng et al. (2006) argue that M_{BH}/M_{bulge} increases with increasing redshifts

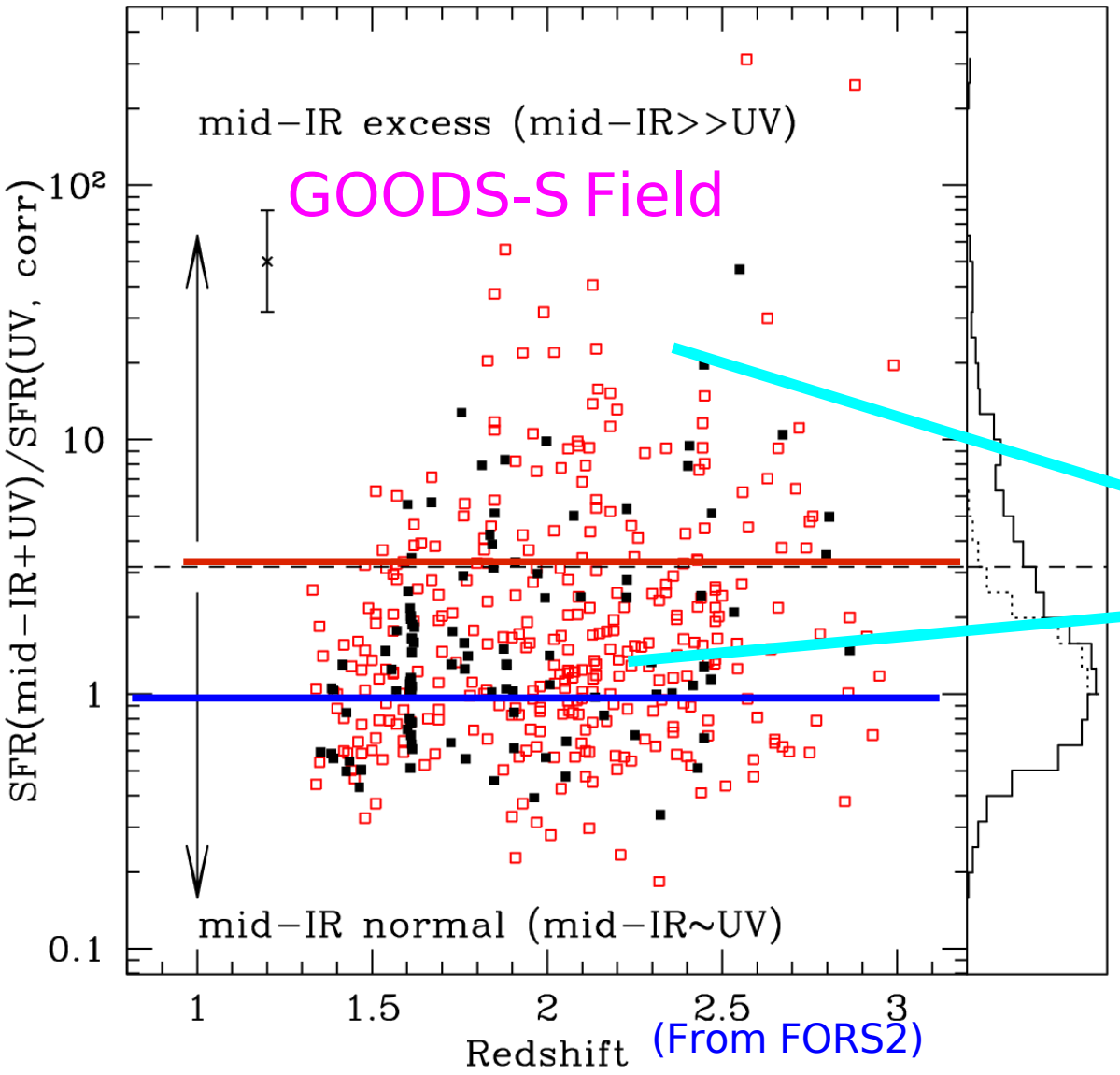


Do Black Holes reach completion before spheroids?

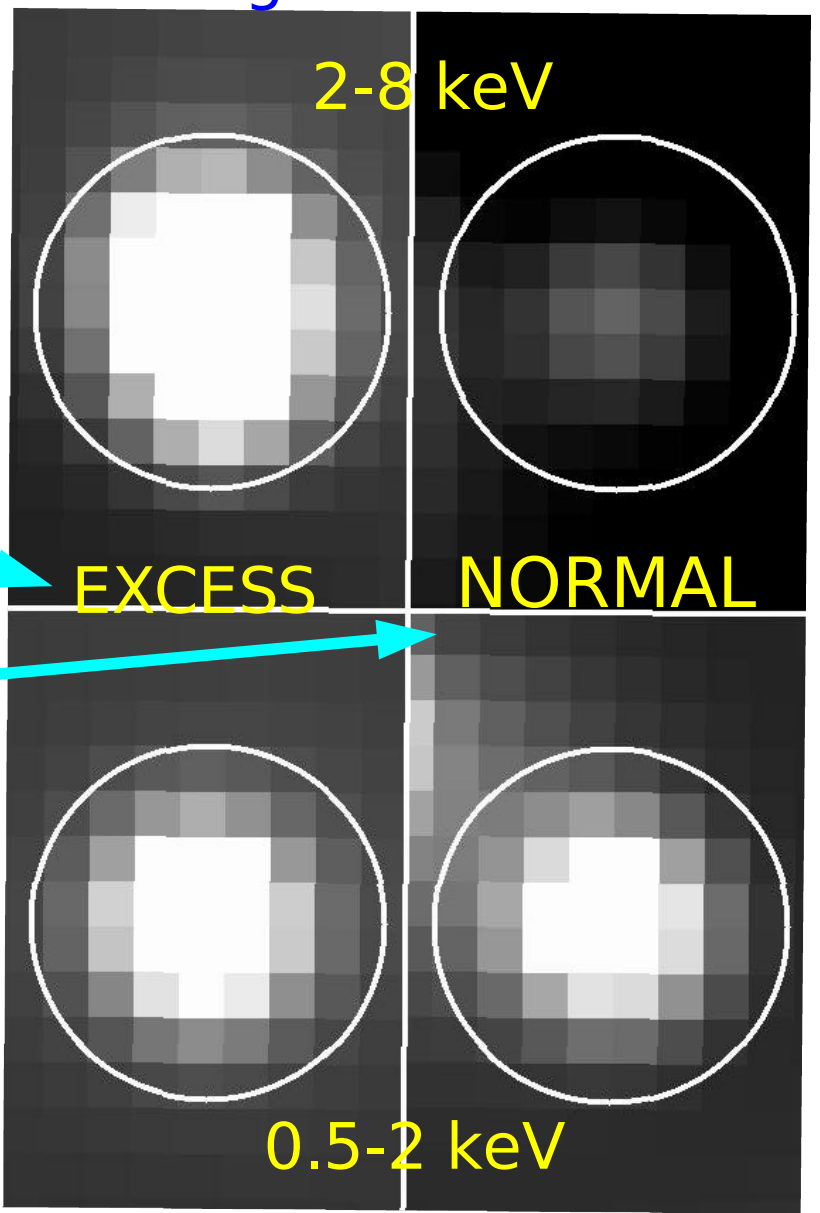
Humm ... maybe, but beware of the many systematic biases!!

Combining Optical/IR, Spitzer/MIPS & Chandra data ....

VLT+HST+Spitzer+Chandra

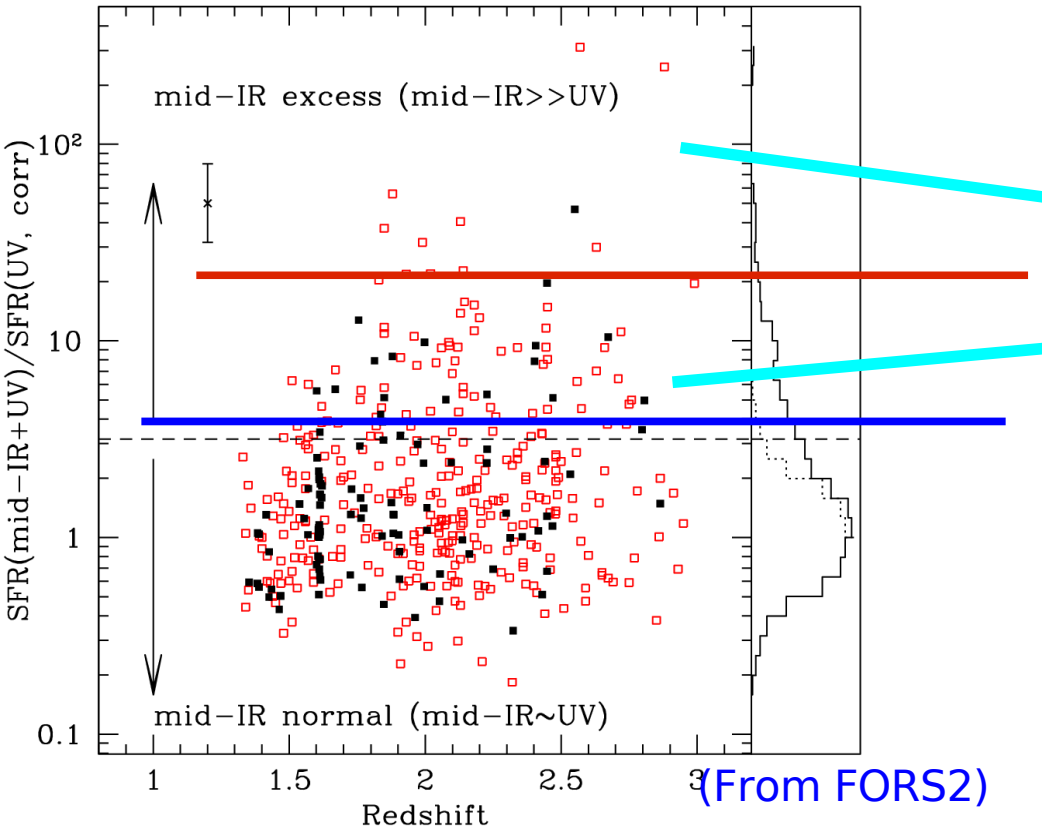


Stacking Chandra data

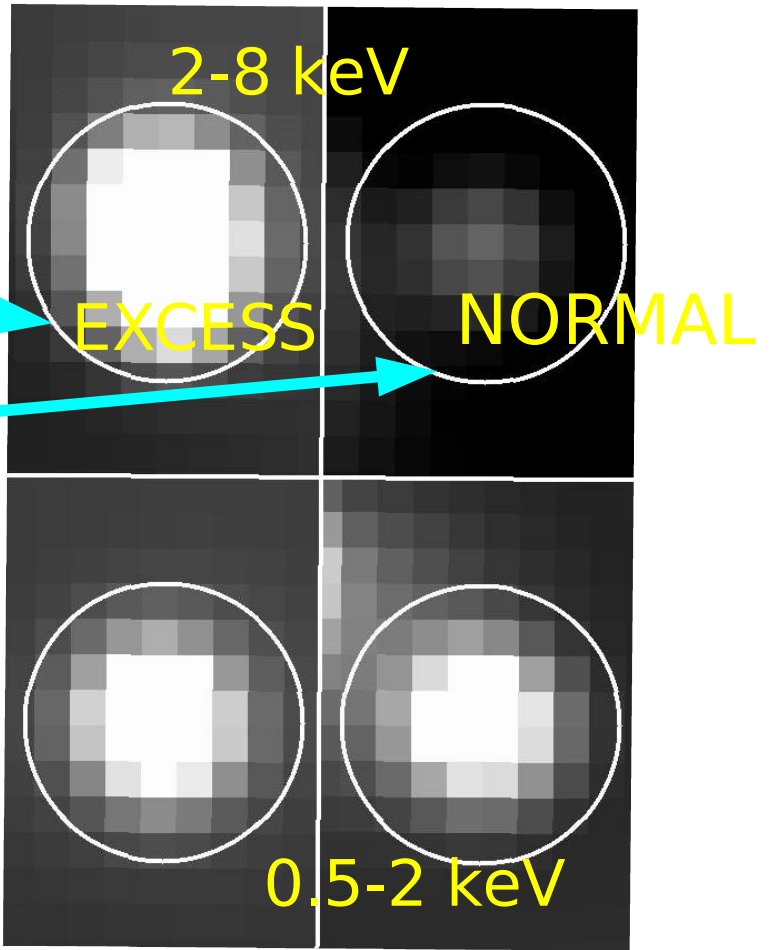


… Suggests that up of ~40% of massive SF galaxies @ z~2 may contain a Compton-thick AGN: How to *see* it with ELT and ALMA?

Daddi et al. 2007; Fiore et al. 2008

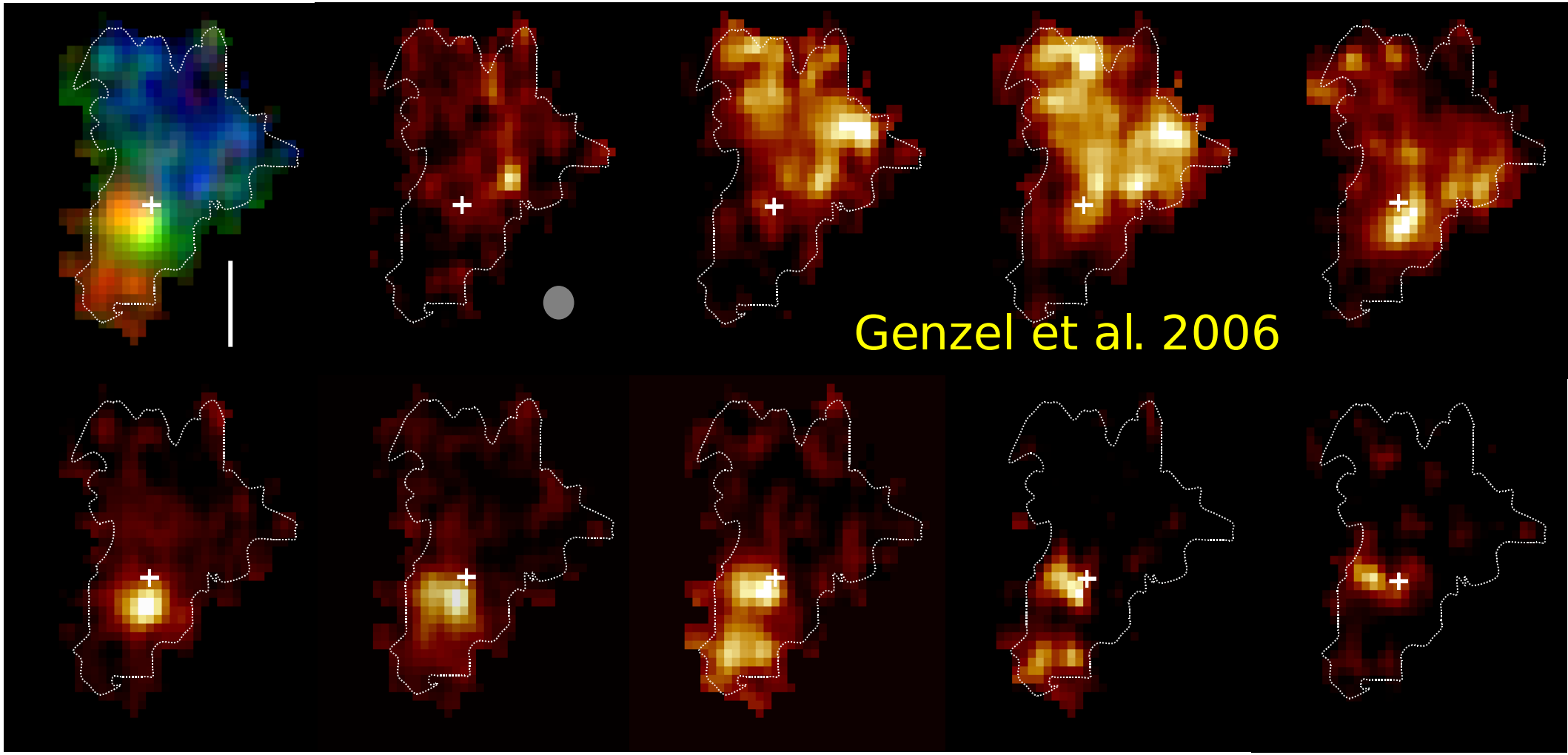


(From FORS2)



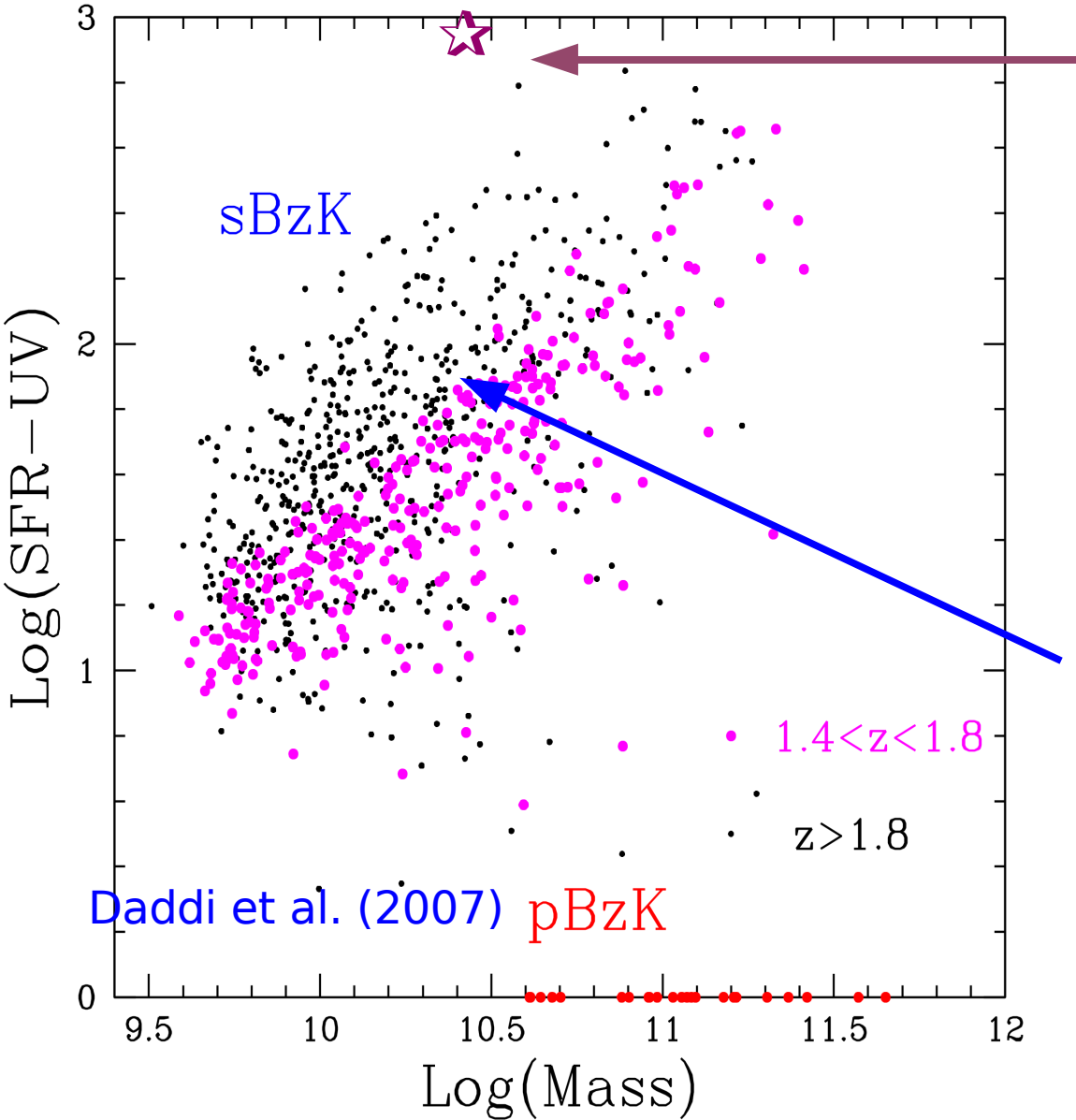
A paradigm shift in galaxy evolution: from major-merger dominated, to (quasi) continous accretion via

cold streams



SF rates correlate tightly with Mass

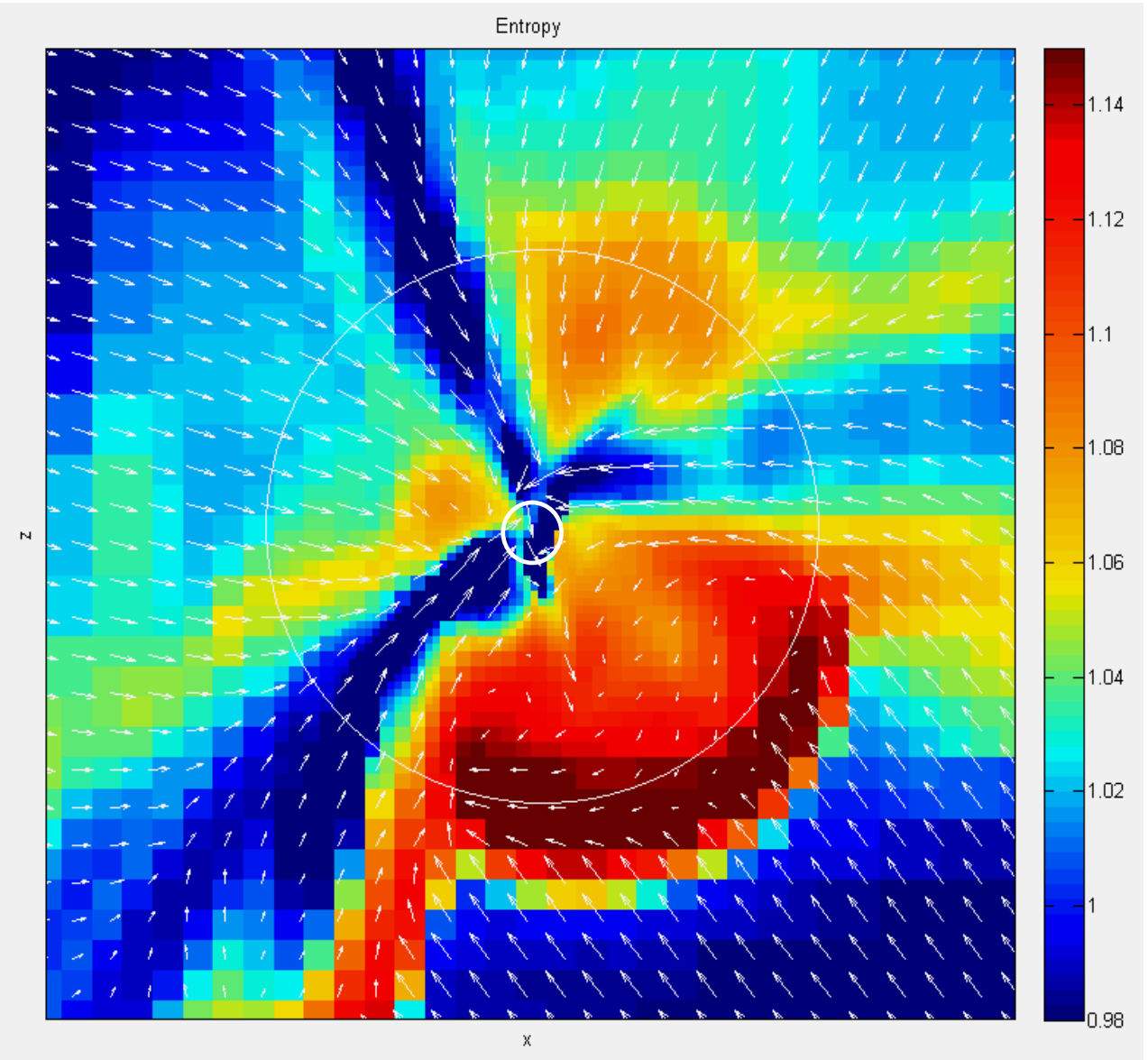
$\langle SFR(M,t) \rangle \simeq 270\ (M/10^{11})\ (t/3.4 \times 10^{9})^{-2.5} = dM/dt$



SMGs may be the real, major-merger driven, starburst galaxies

No starbursting galaxies! just galaxies with high SFR, continuously fed by cold-stream accretion!!!

Feeding high rates of SF by cold streams in hydro-simulations

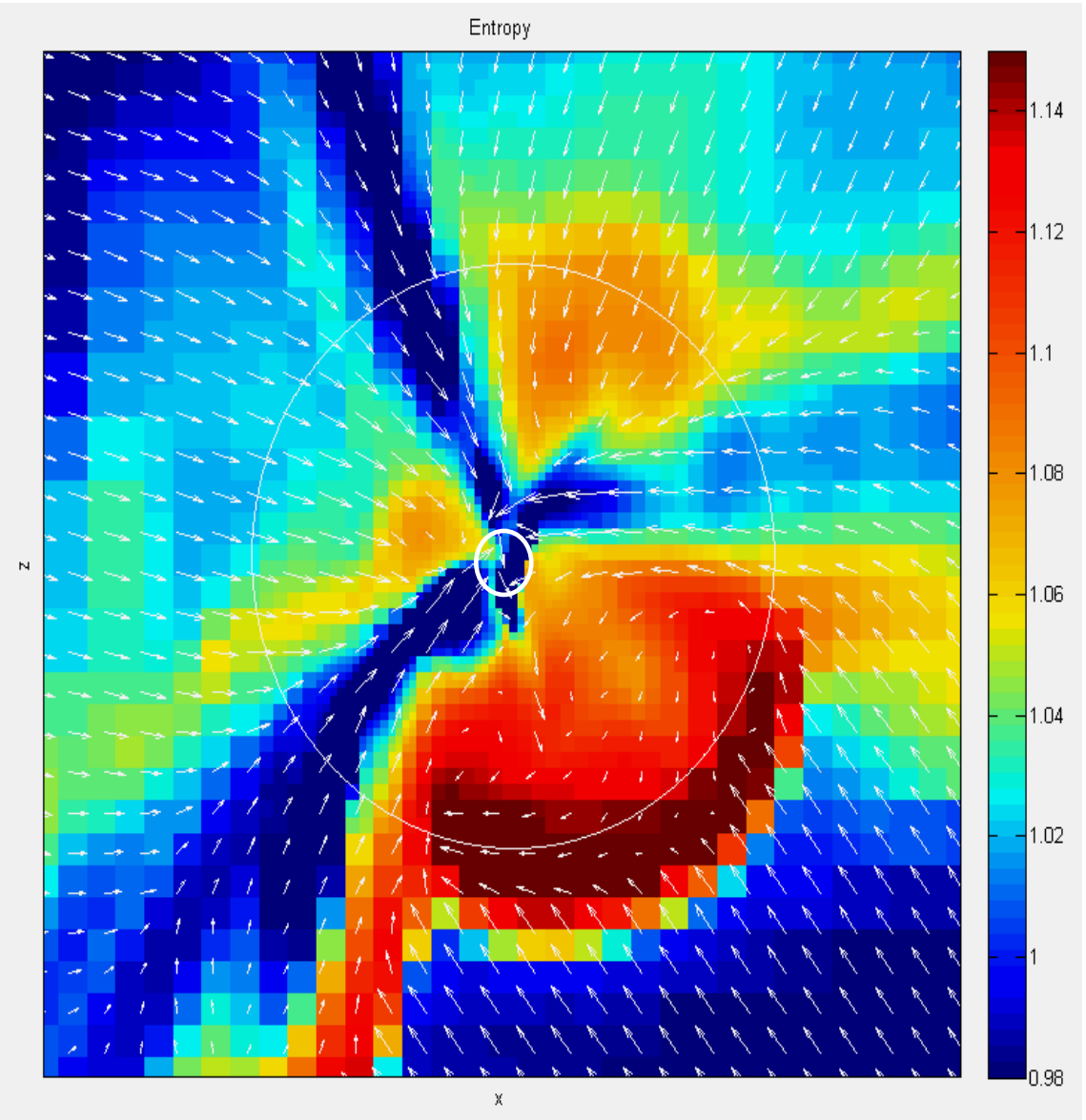


Not all gas is shock-heated to virial temperature (Binney 1977, PhD Thesis!! + 2004).

Cold Streams feed galaxies and sustain their SFR

Dekel et al. 2009

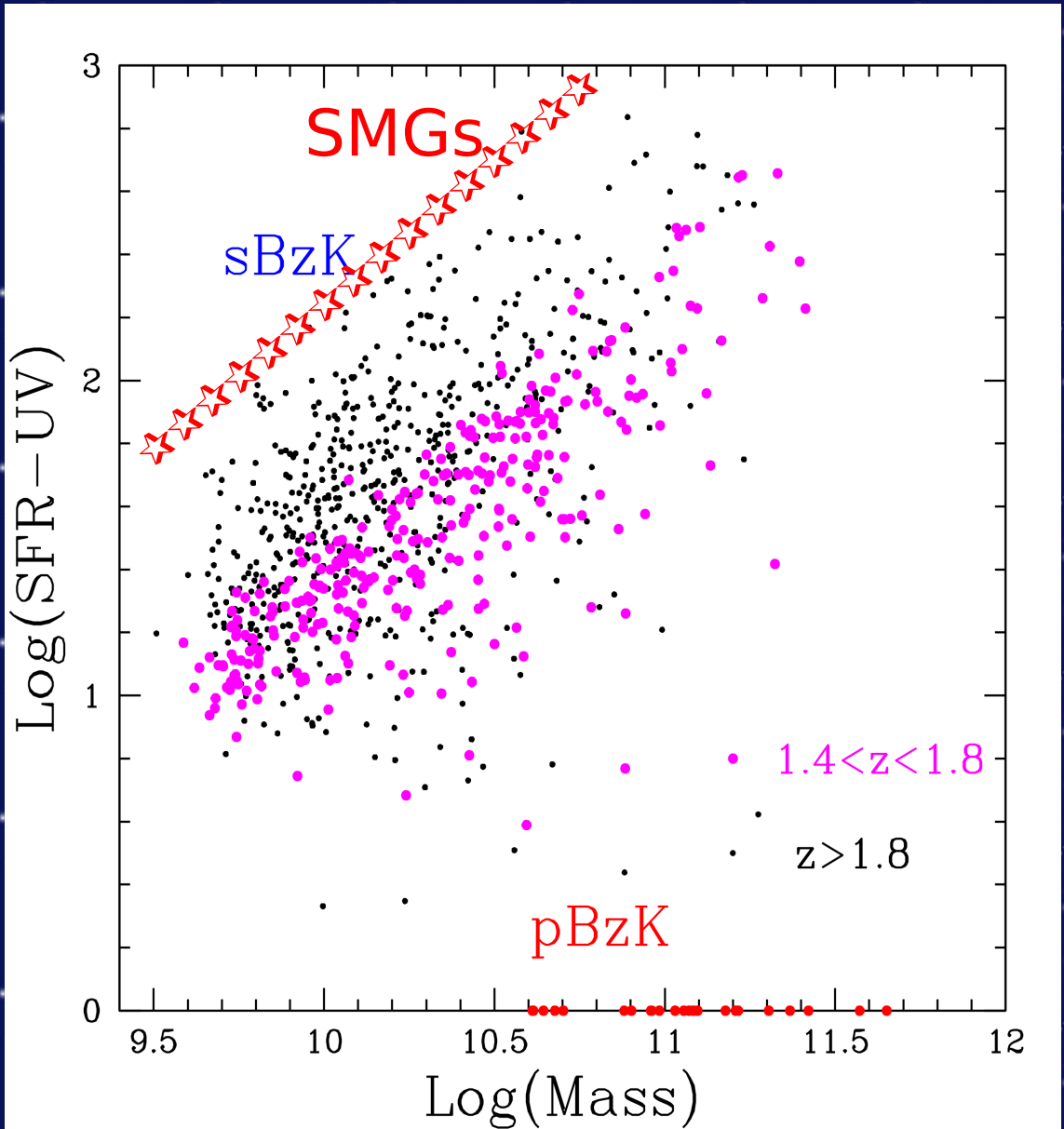
How to *see* the cold streams?



Cold streams feeding galaxies are not so cold ... They cool from ~10^5K down to molecular cloud temperatures, hence emitting recombination lines of H and He: low surface brightness emissions would be best seen by an ELT, e.g. as "Ly-α streams" (or blobs?)

An ALMA/ELT Synergy:

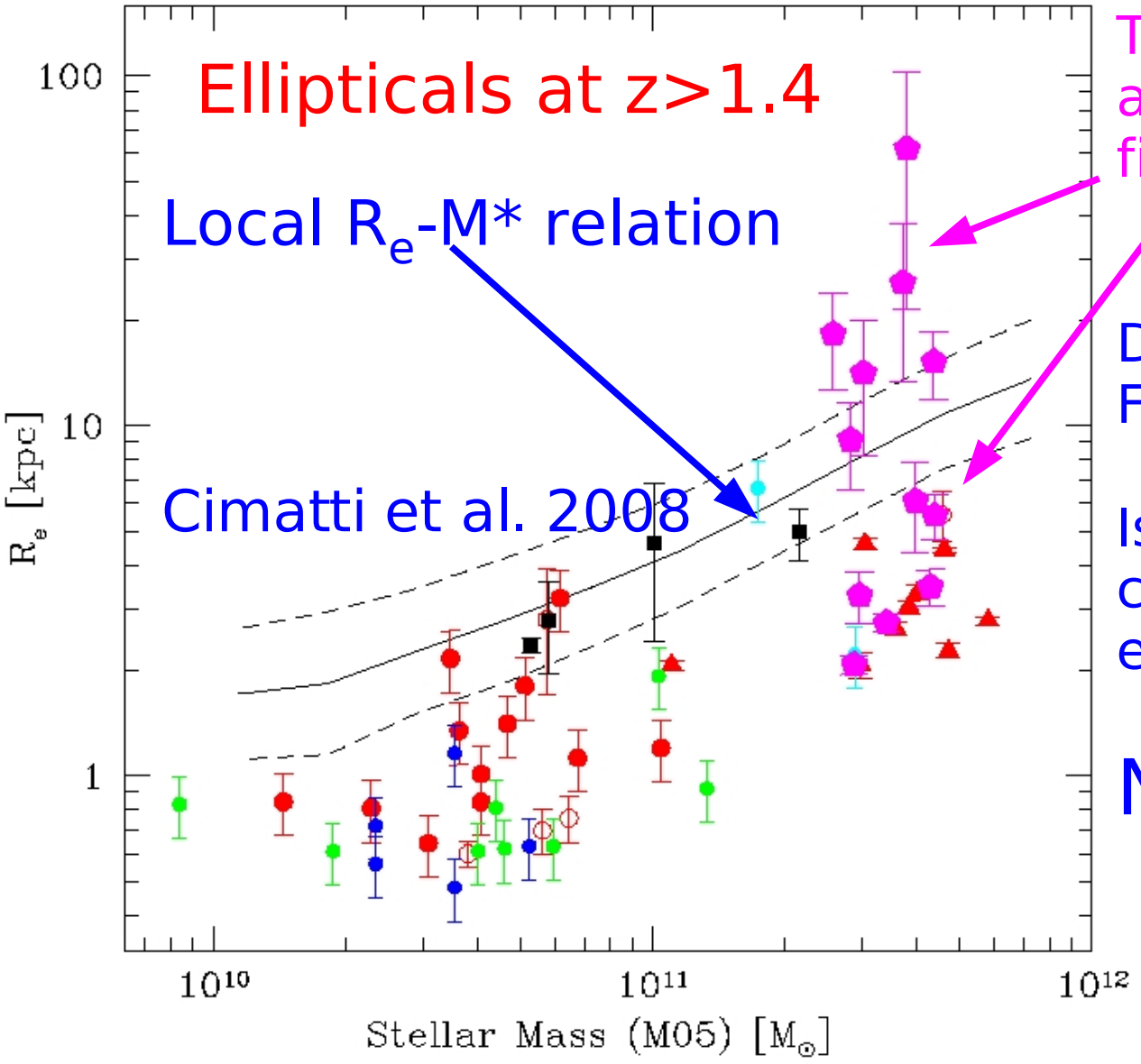
What fraction of total stellar mass is made by cold-stream fed SF, and what fraction is made in major (wet) mergers? (SMGs)



SCUBA2 & Herschel will find them, and ALMA will get redshifts, SFRs, etc.

ELT will finish the job on cold-sream fed galaxies.

The Structure of High-redshift Ellipticals: are they really superdense?



The 12 K-brightest ellipticals at <z>=1.6 in the COSMOS field (Mancini et al. 2009)

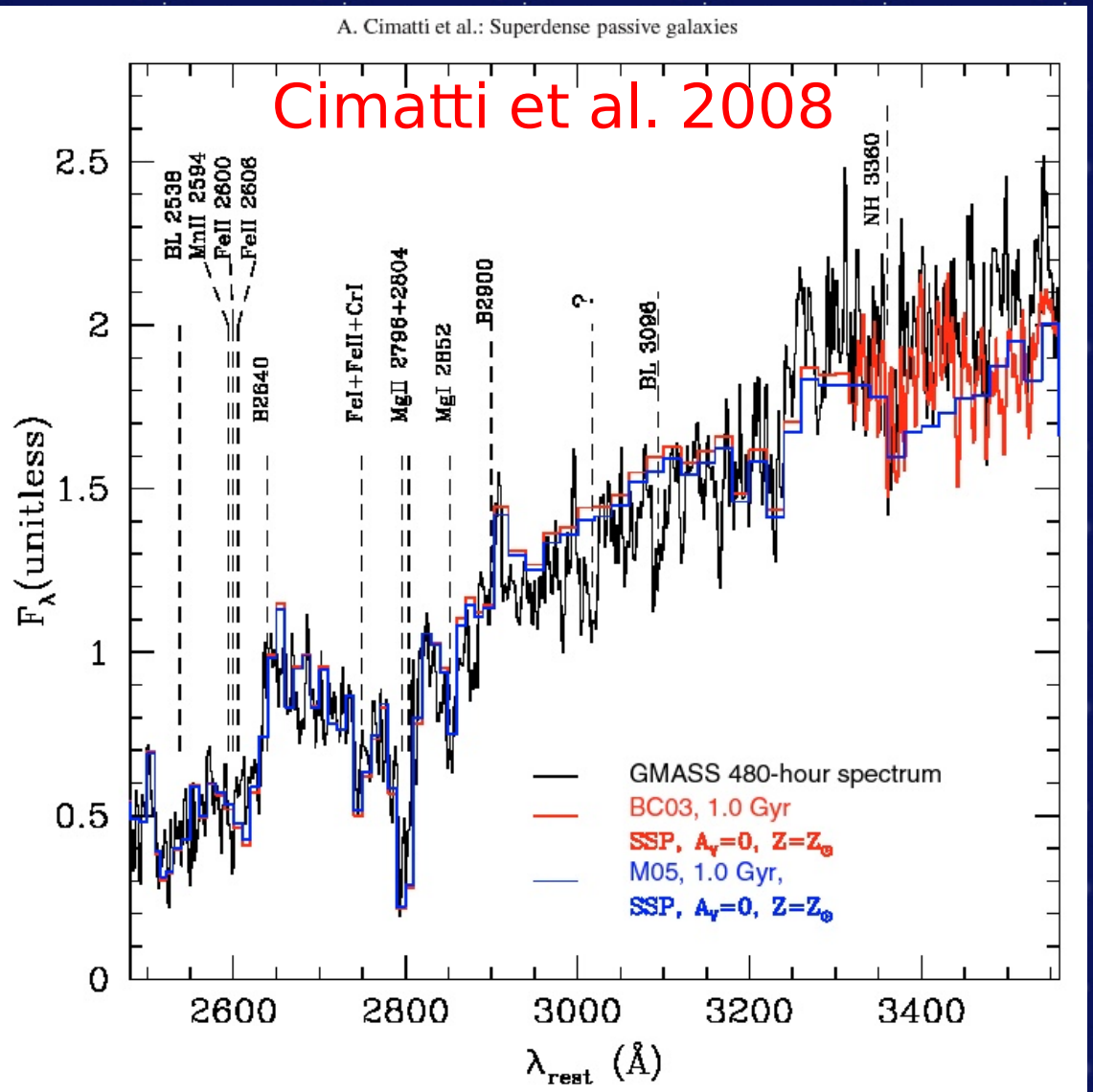
Do they lie on the Fundamental Plane?

Is their velocity dispersion consistent with their estimated mass and radii?

Needs to measure

---> σ <---

Getting redshifts and σ's of red galaxies by looking in the ultraviolet (!)



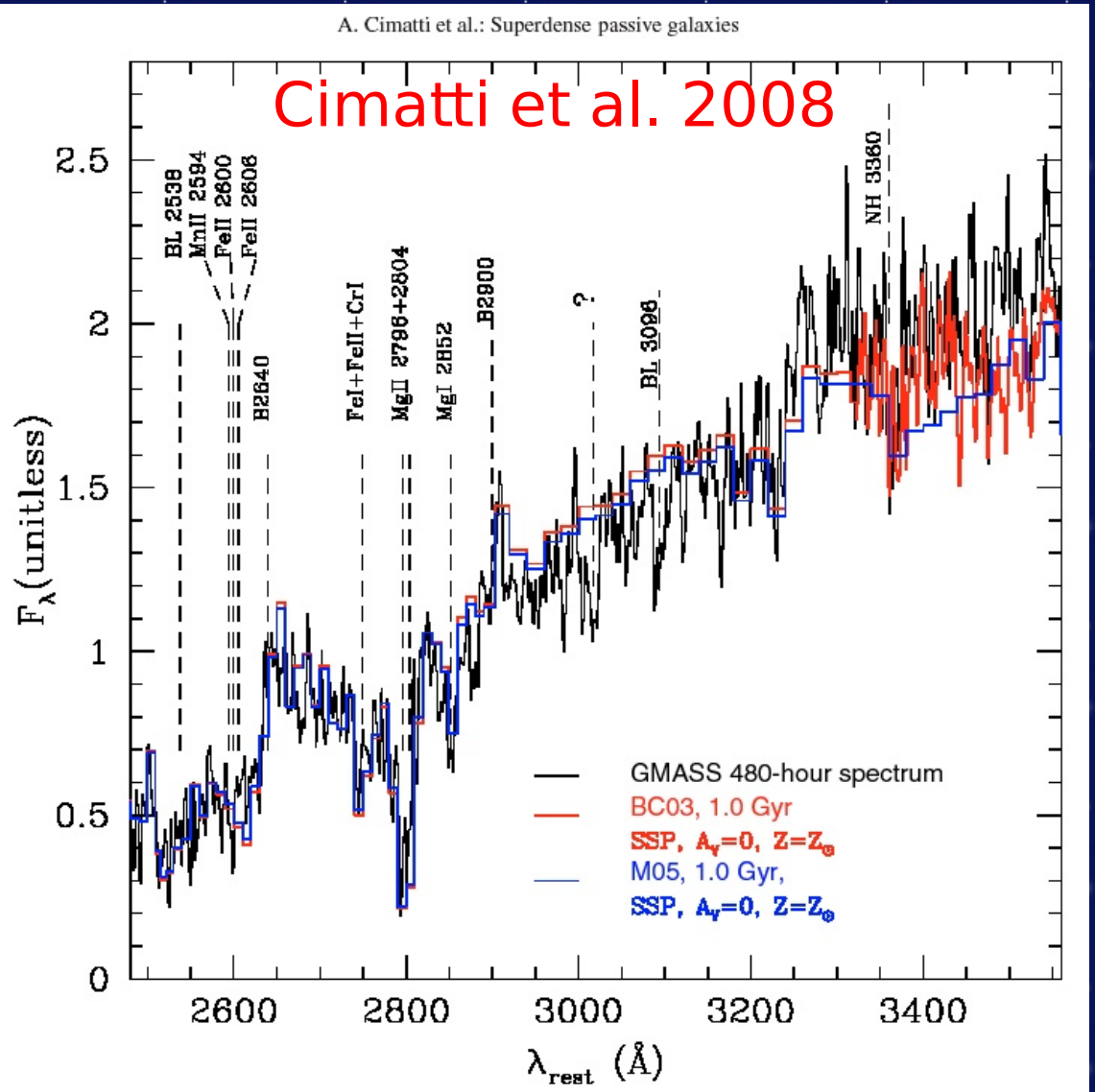
13 GMASS Passive galaxies at <z>=1.6

30 to 60 hours per galaxy

Total integration time for this stacked FORS2 spectrum: 480h (!)

Getting σ from this stacked spectrum:

$\sigma \sim 267$ km/s
(Cenarro & Trujillo '09)



$\sigma \sim 287$ km/s

down to

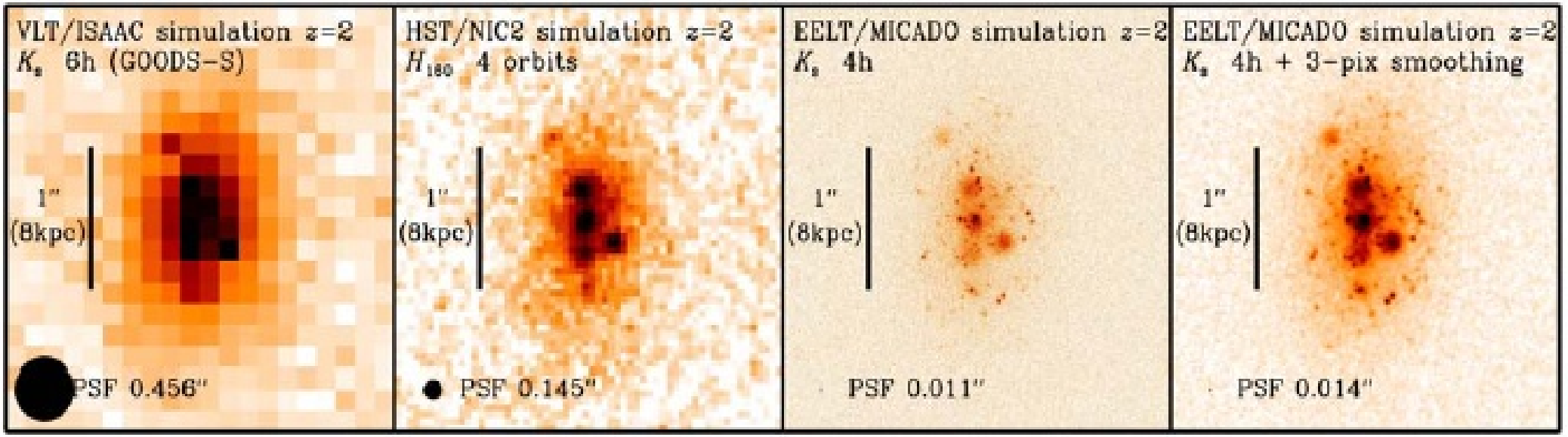
$<\sim 163$ km/s

when considering a $\sigma(z) \sim 0.0007$ error in the individual redshifts of the 13 stacked galaxies.
(Cappellari et al. '09)

Thus, ELT will be critical to

- Measure the velocity dispersion of individual galaxies, thanks to its wider collecting area
- Get more accurate effective radii, thanks to its angular resolution
- Map also the outer low surface brightness regions of these galaxies, thanks to its sensitivity, that we suspect may be lost in the noise in HST images.

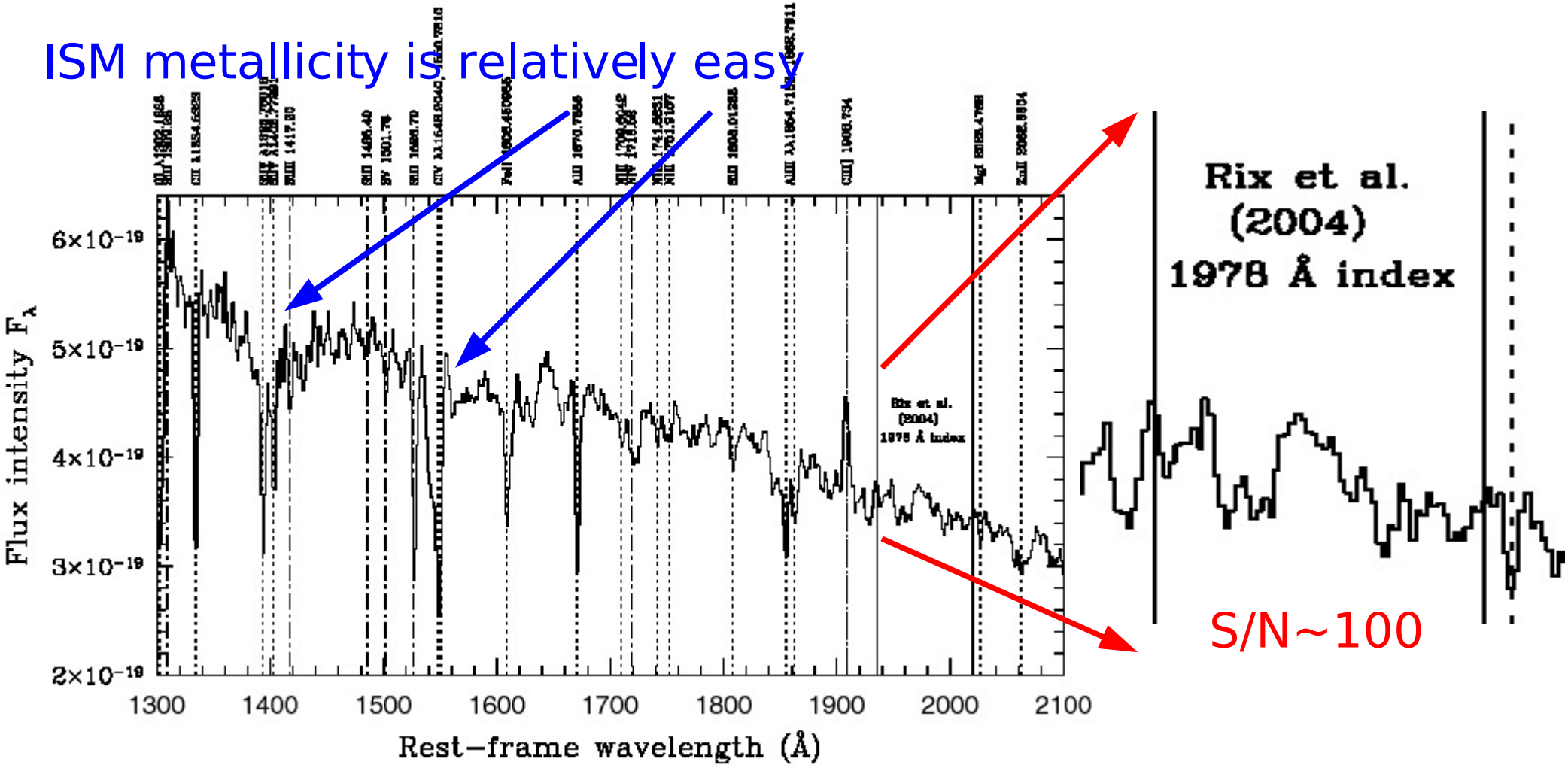
High reolution imaging & 3D spectroscopy of high-z galaxies



The Aim: get panchromatic (almost) megapixel images of z>~2 galaxies, to make next generation of galaxy posters, resolution ~100-200 pc, looking at blobby unstable disks, bulge growth, AGN feedback, galactic winds, in full display. Wait for N. Förster-Schreiber talk for more about this.

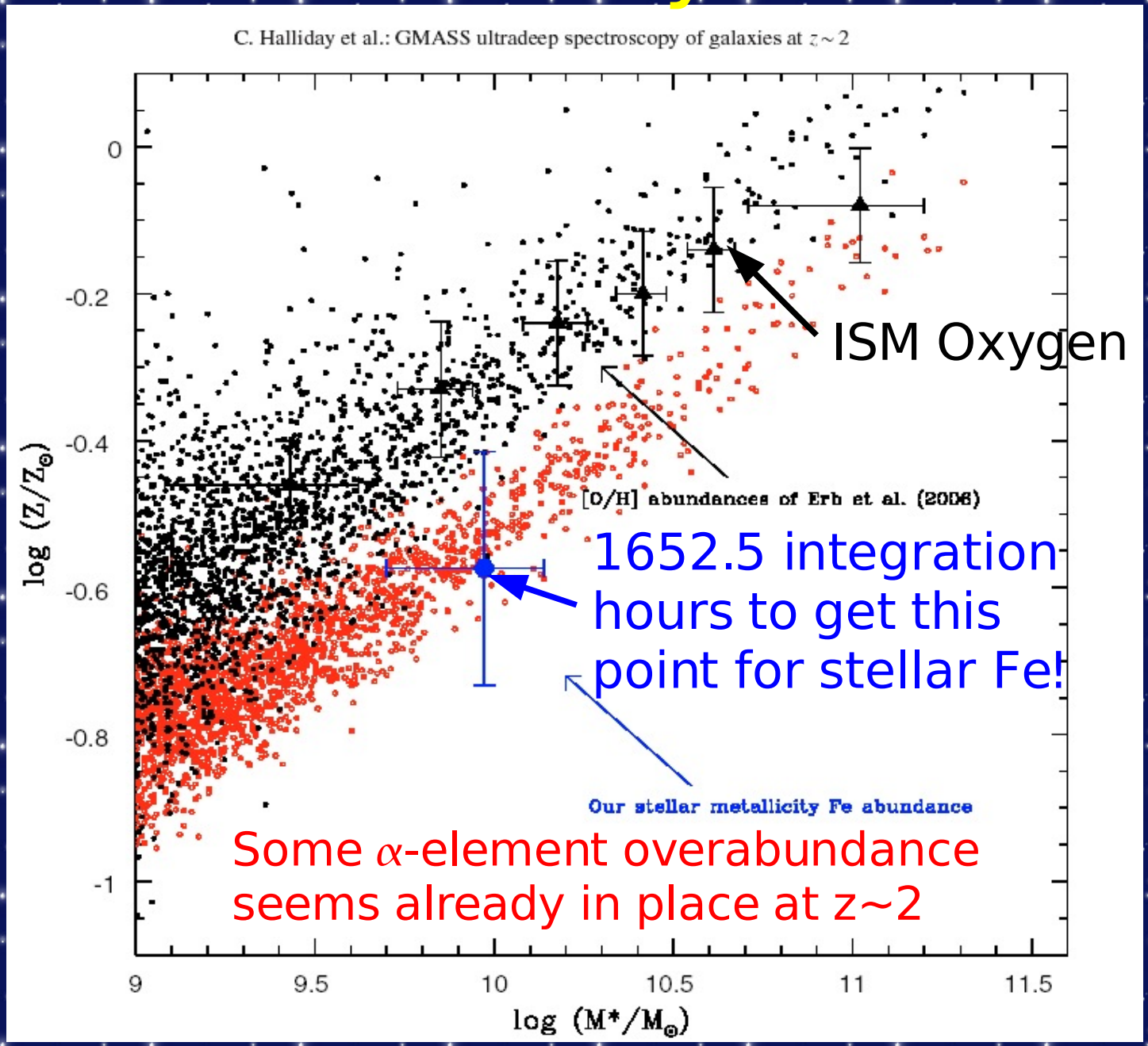
Stellar & ISM Metallicities @ z~2: the stacked spectrum of 75 GMASS SF Galaxies (1652.5 hours !!)

ISM metallicity is relatively easy



Halliday et al. 2008

The Mass-Metallicity relation at z~2



A Summary ....

- Both ALMA and ELT will be essential to "finish the job" on Galaxy (and AGN co-) Evolution
- ELTs compete with JWST on may areas, but will do better in angular resolution and low surface brighness features
- E.g. Size of high-z ellipticals
- E.g. Separating QSO and Host light
- E.g. Seeing "cold streams"
- E.g. Making better "posters" of high-z Galaxies .....