The Star Formation and Assembly Histories of High Redshift Galaxies

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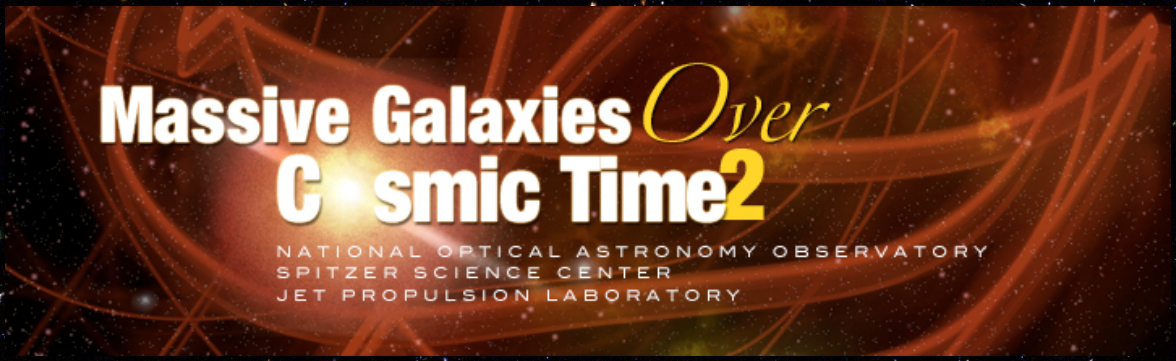

The Star Formation and Assembly Histories of High Redshift Galaxies

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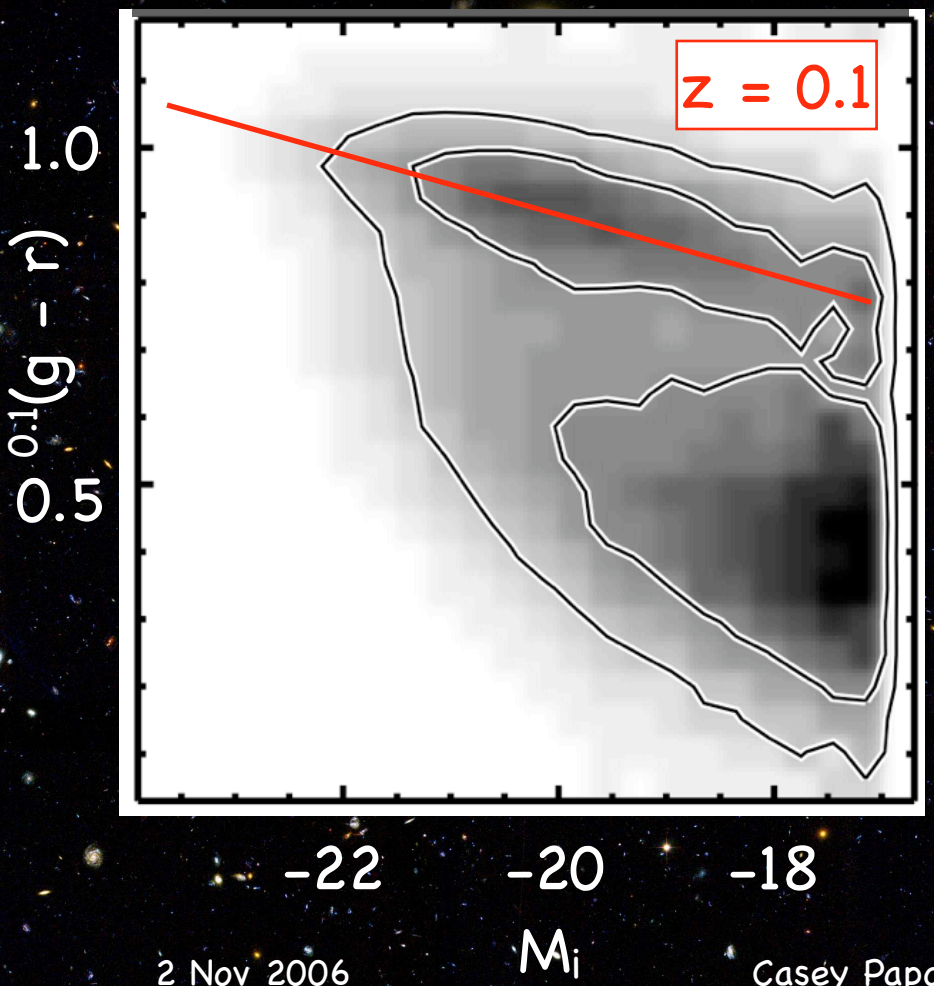
AEGIS: J. Huang, J. Lotz, K. Noeske, M. Ashby, D. Koo, S. Faber; et al.

Key Issues For Massive Galaxy Evolution

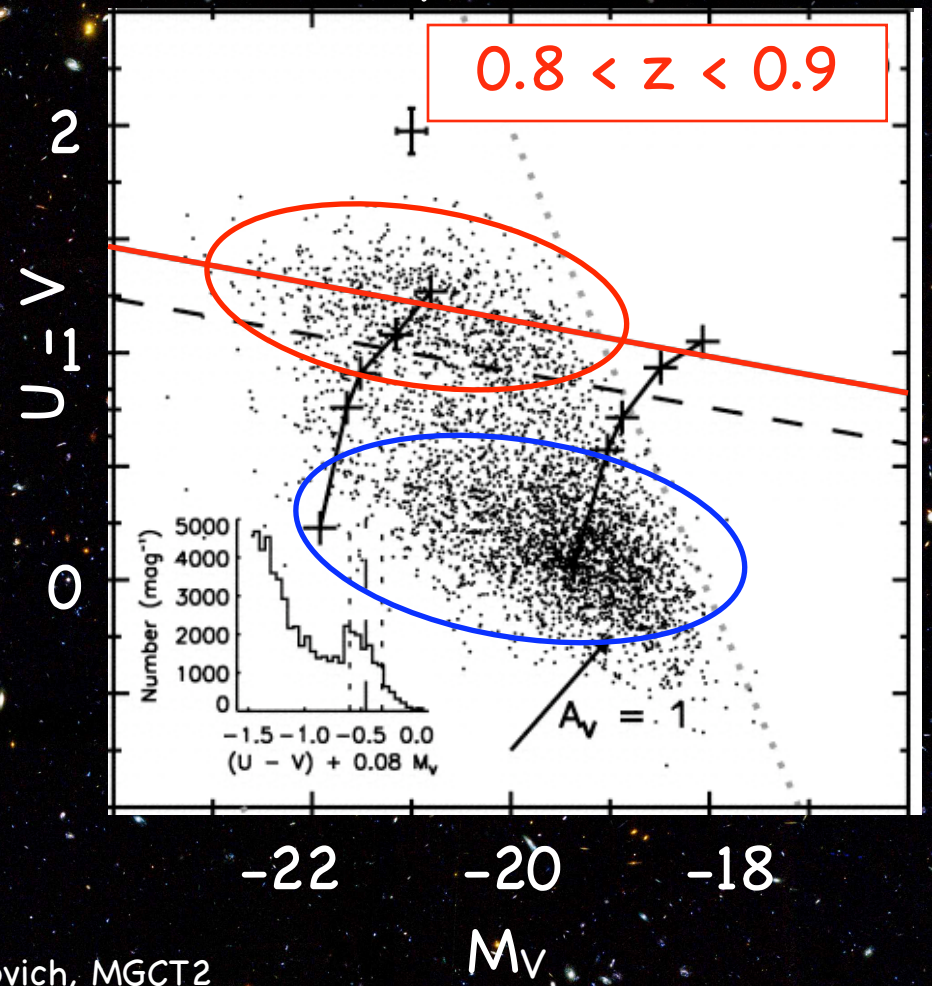
- When did galaxies assemble into their present-day configuration?
- When did the stars in massive galaxies form?
  - What drives the SFR in high-redshift galaxies?
  - What shuts it off?

Massive Galaxies and the Red Sequence

SDSS, Blanton et al. 2002

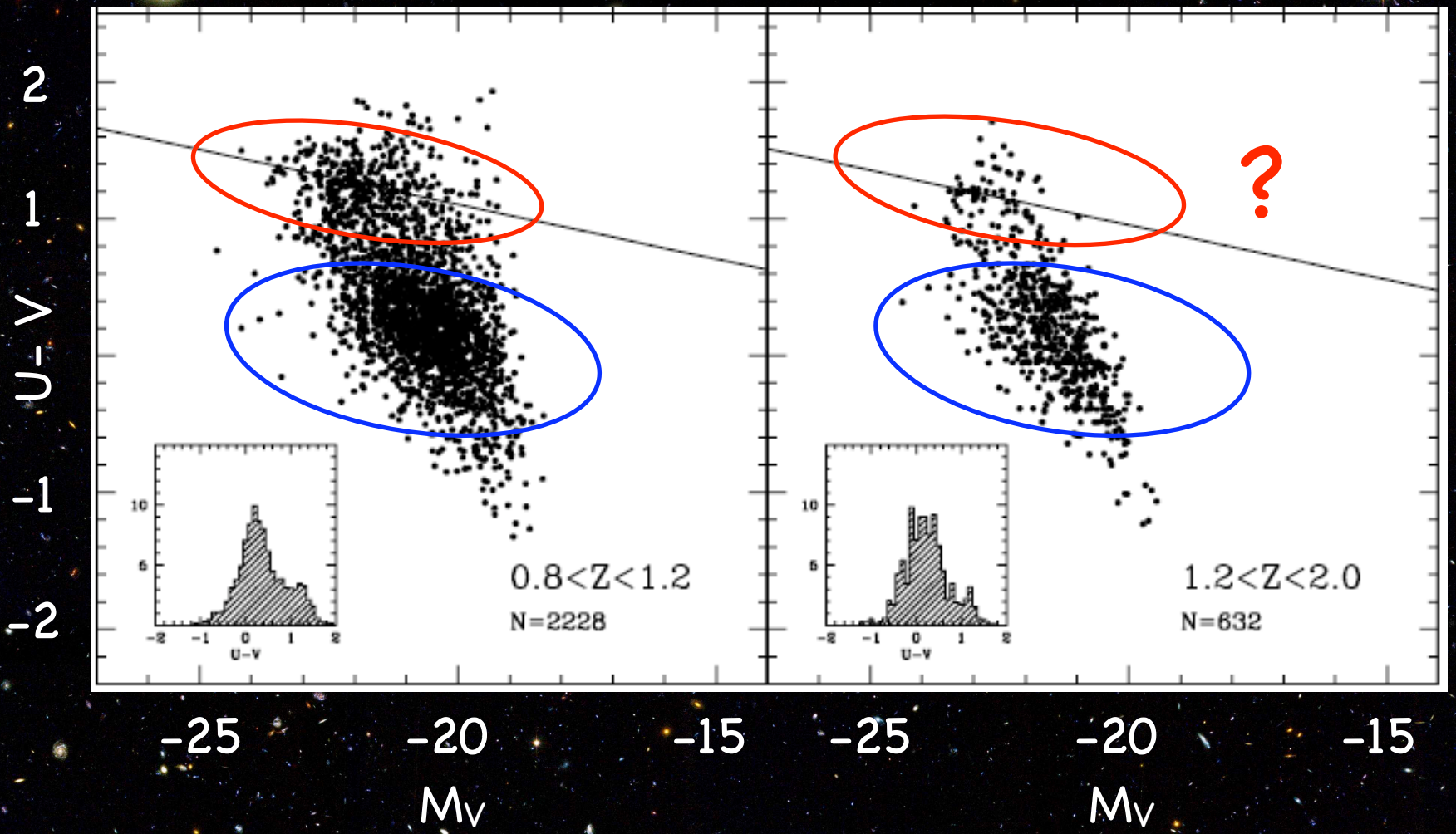


COMBO-17, Bell et al. 2004



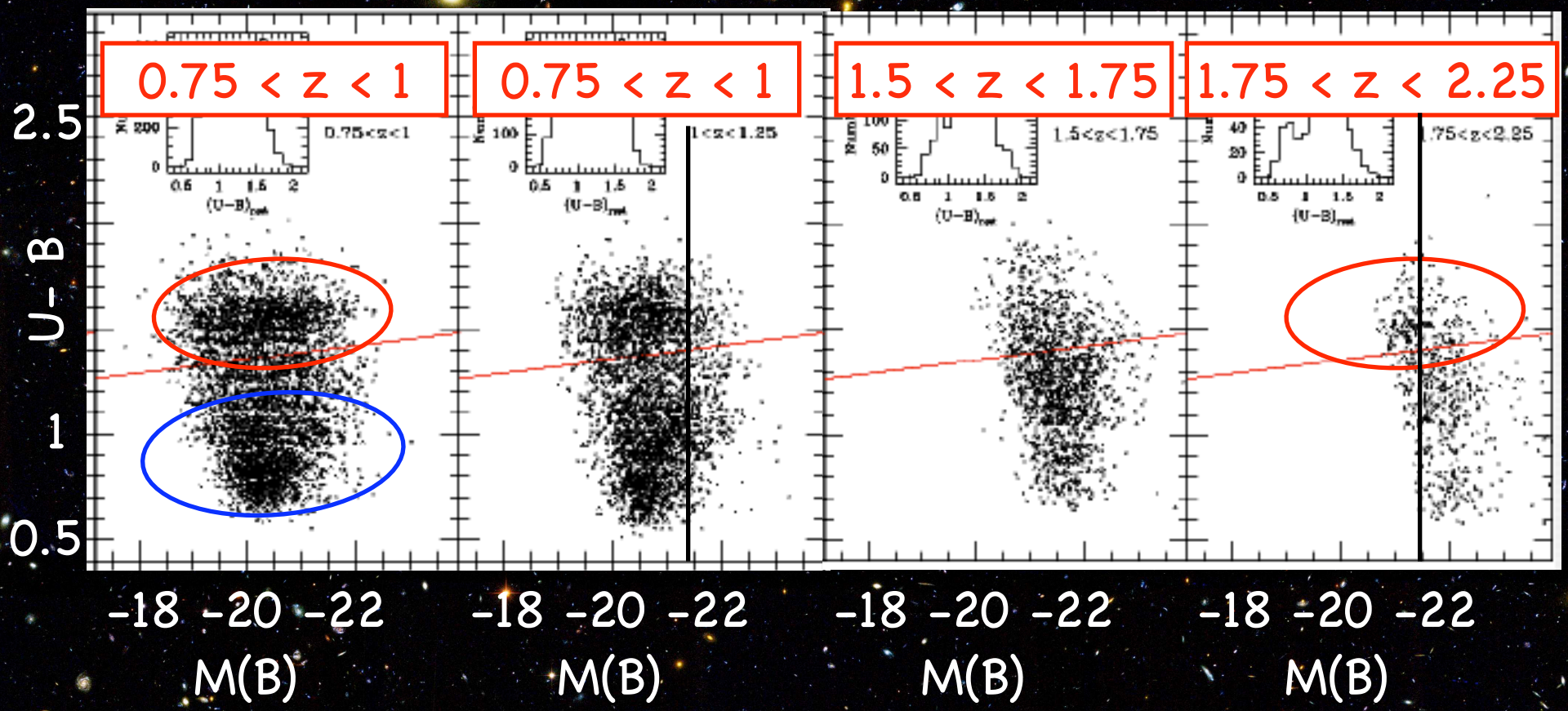
Massive Galaxies and the Red Sequence

VVDS, Franzetti et al. 2006



Massive Galaxies and the Red Sequence

UKIDSS; Cirasuolo et al. 2006, astro-ph./0609287



HST Images of the Most Luminous HDF-N Galaxies

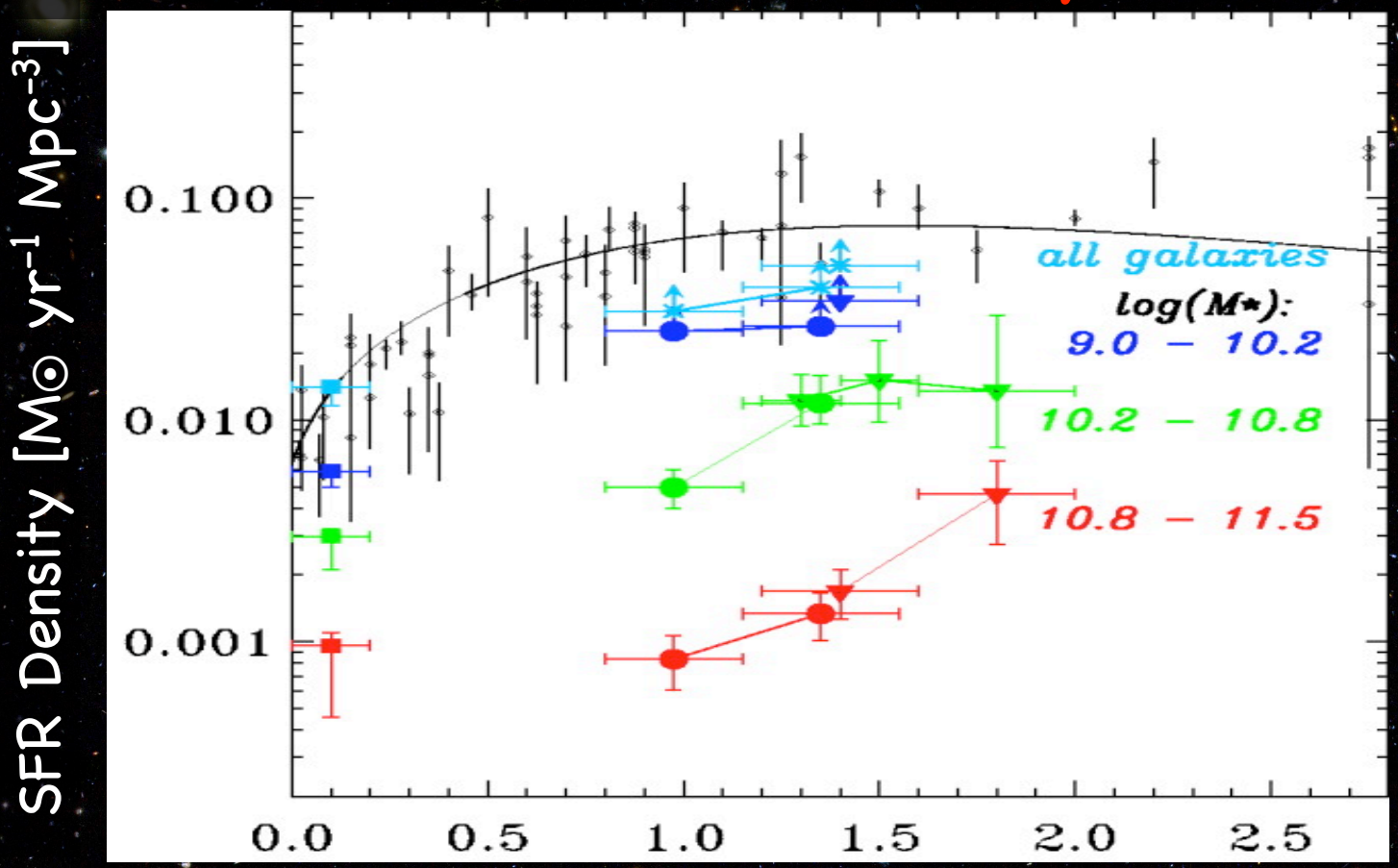
$-23 < M_B < -21$
$0.7 < z < 1.4$

Rest-frame
UV-to-B

$-23 < M_B < -21$
$1.9 < z < 3.0$

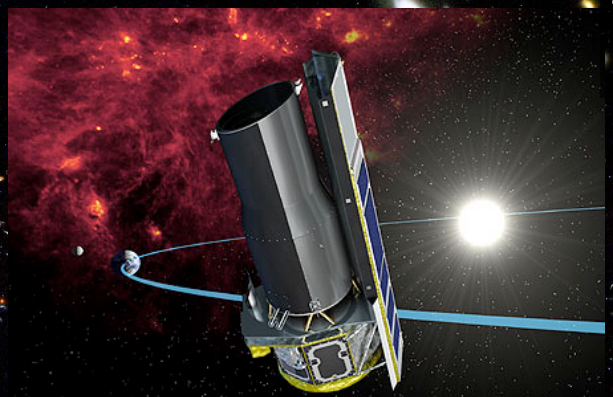
Papovich, Dickinson, Giavalisco, et al. 2005

Evolution of the SFR Density as a function of Galaxy Mass



GDDS, Juneau et al. 2005

Spitzer IR 24μm Observations of High-z Massive Galaxies



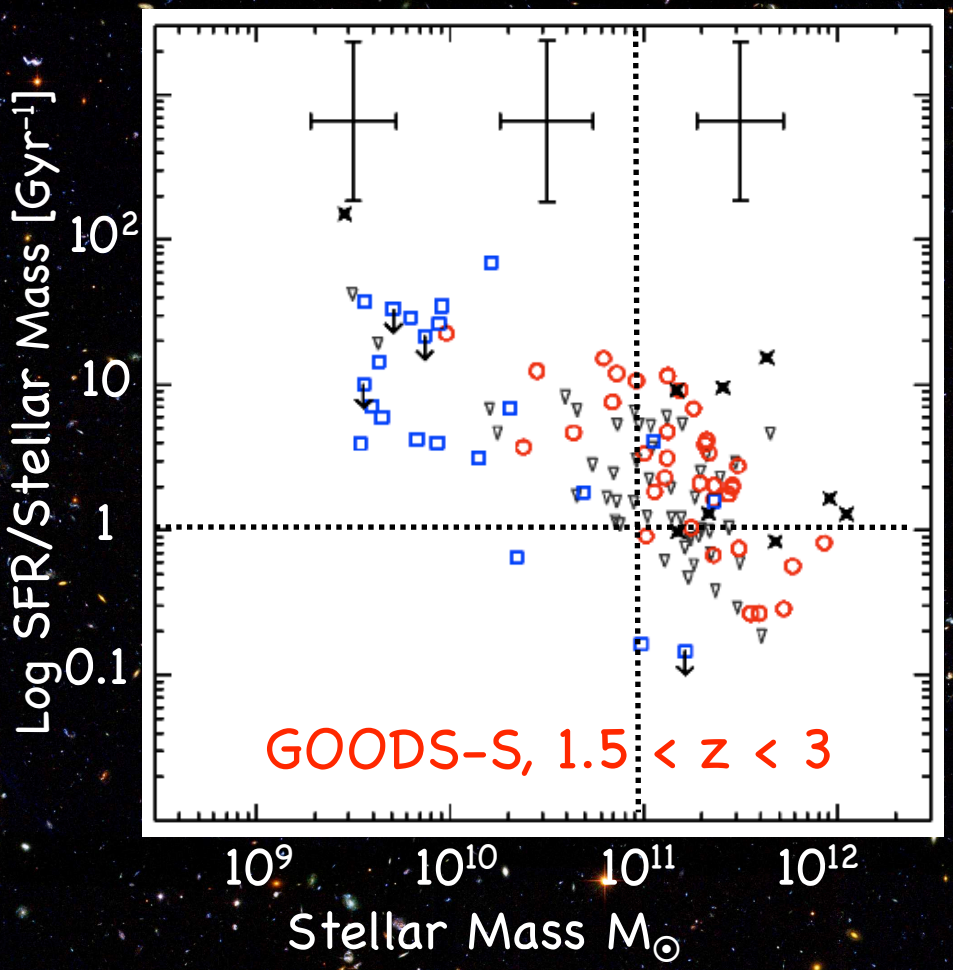
All studies find that high fraction of Massive Galaxies at z~1.5-3 detected at 24μm:

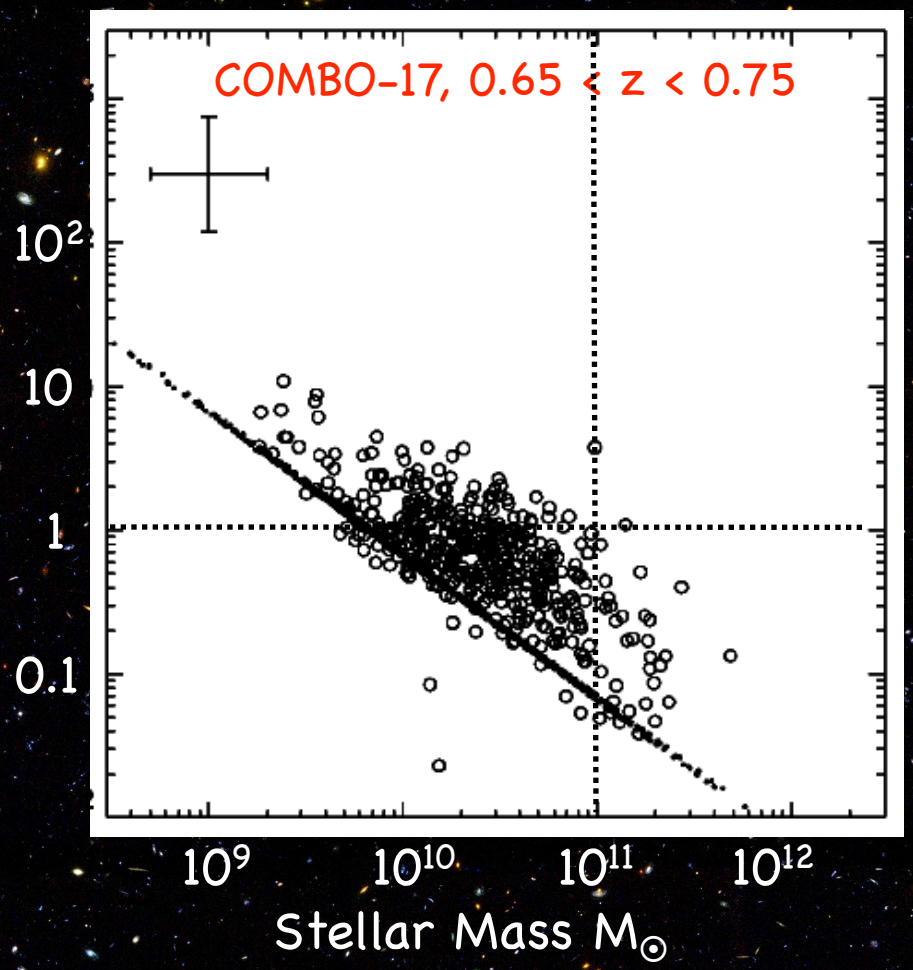
- GOODS-N:
  - Daddi et al. (2005), BzK Galaxies
  - Reddy et al. (2006), LBG, BzK, DRGs
- GOODS-S:
  - Papovich et al. (2006), DRGs
- FIRES/HDF-S:
  - Webb et al. (2006), DRGs

More than 50% detection rates to 80 μJy.

Massive Galaxies, $>10^{11}$ $M_\odot$, at high-z are in IR active evolutionary stages.

Evolution of Specific SFR in Massive Galaxies



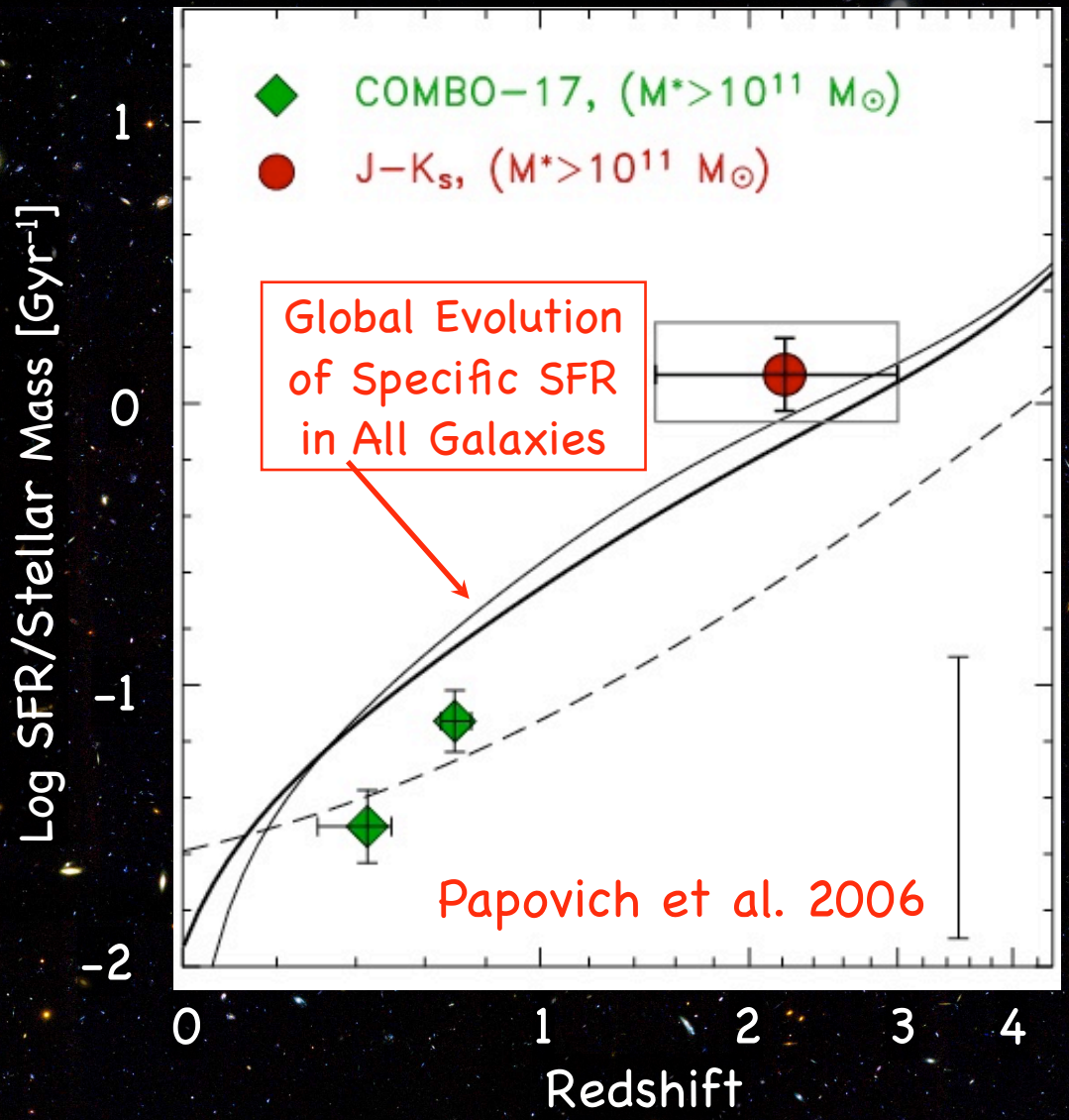


Papovich et al. (2006)
and also Reddy et al. (2006)

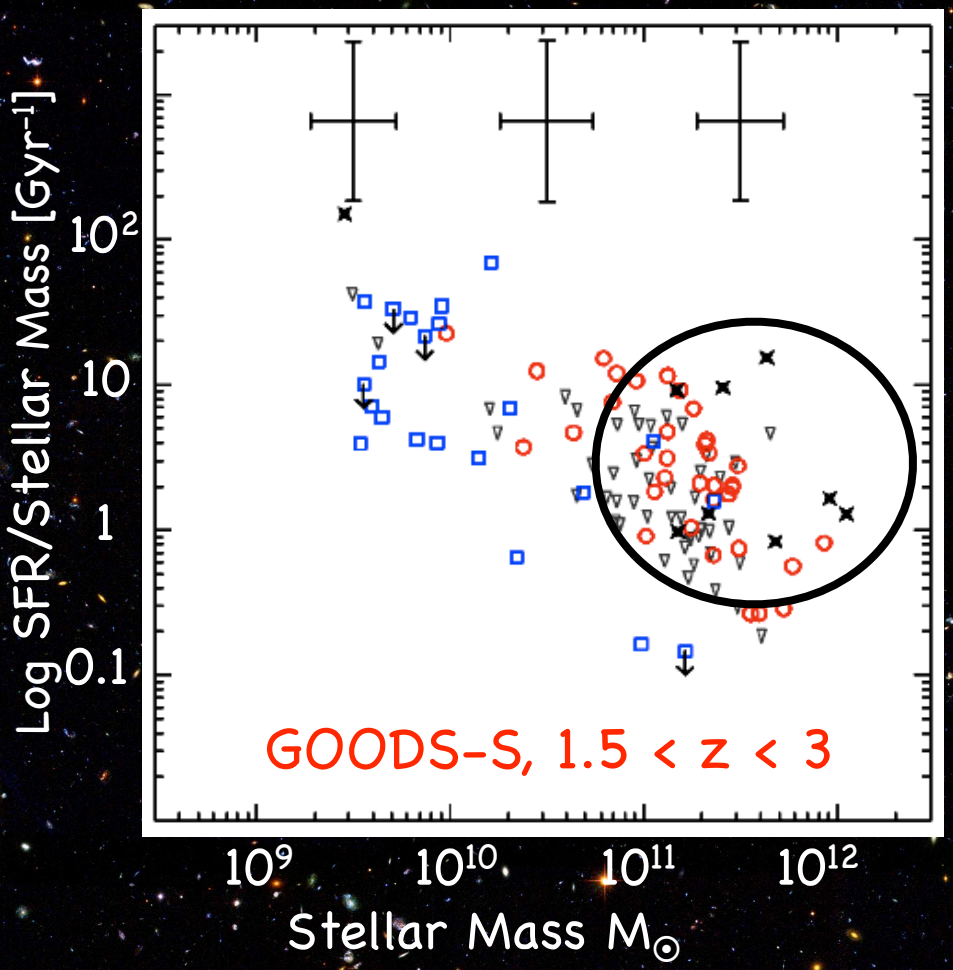
Evolution of Specific SFR in Massive Galaxies

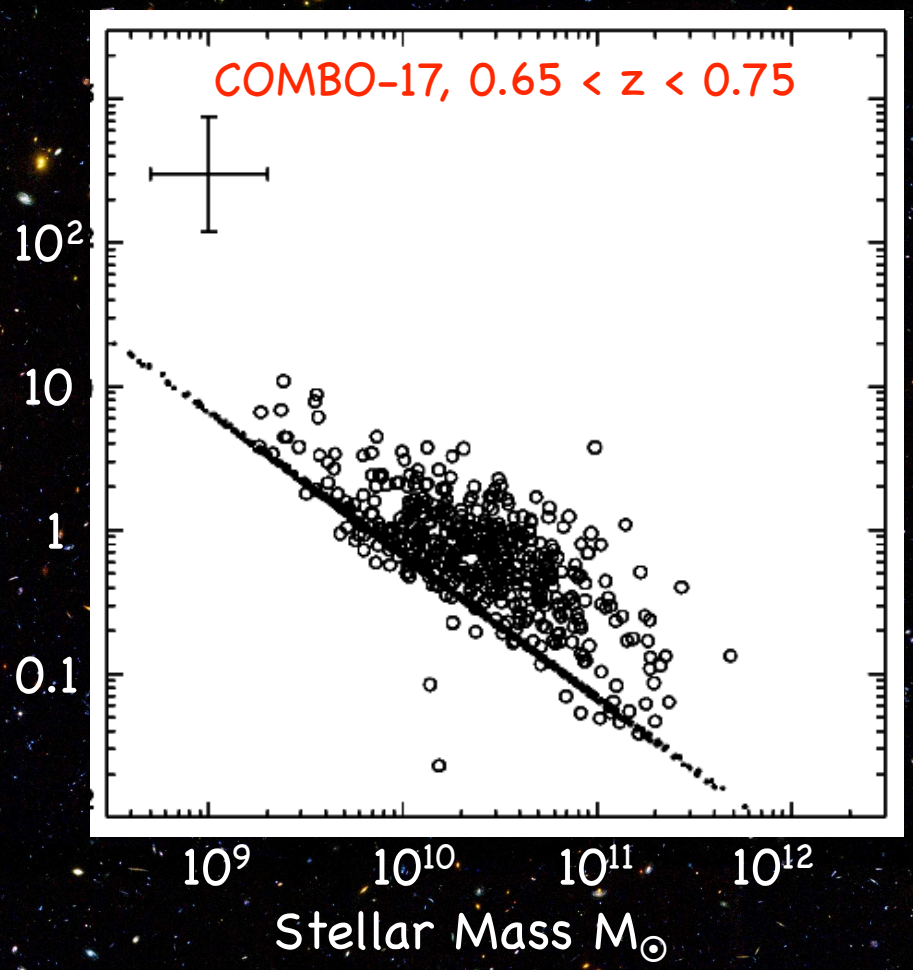
- At z=1.5-3 massive galaxies (>10^{11} M$_\odot$) form stars as fast or faster than cosmic average.

- At z < 1, massive galaxies have formed most of their stellar mass and have lower specific SFRs



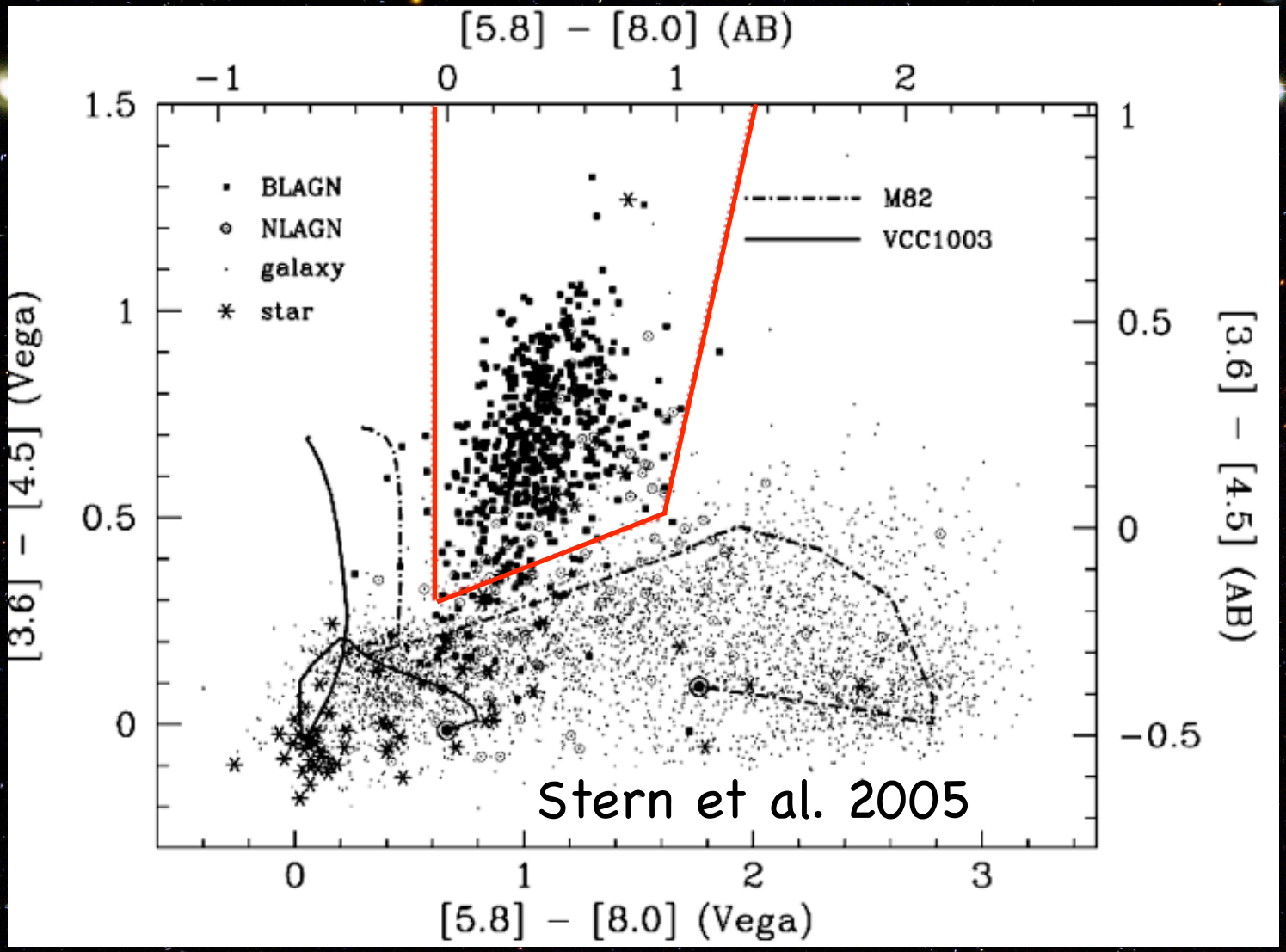
Evolution of Specific SFR in Massive Galaxies





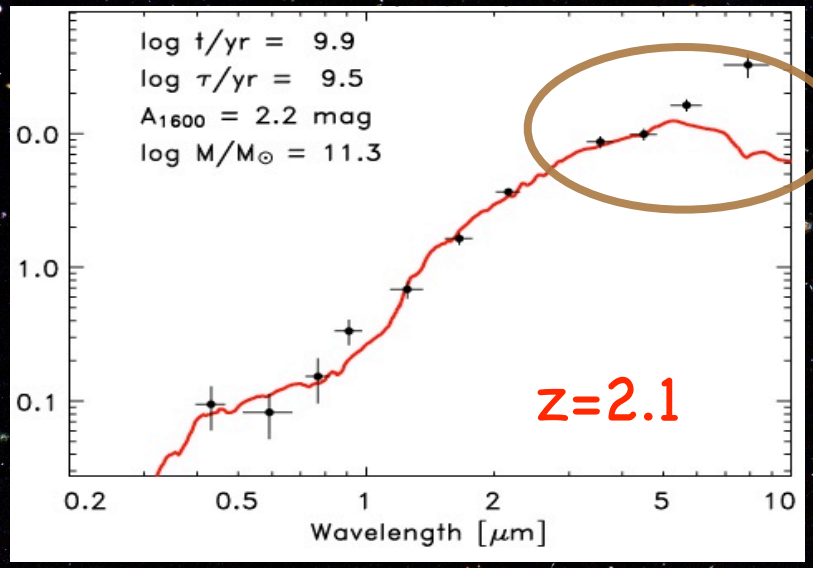
Papovich et al. (2006)
and also Reddy et al. (2006)

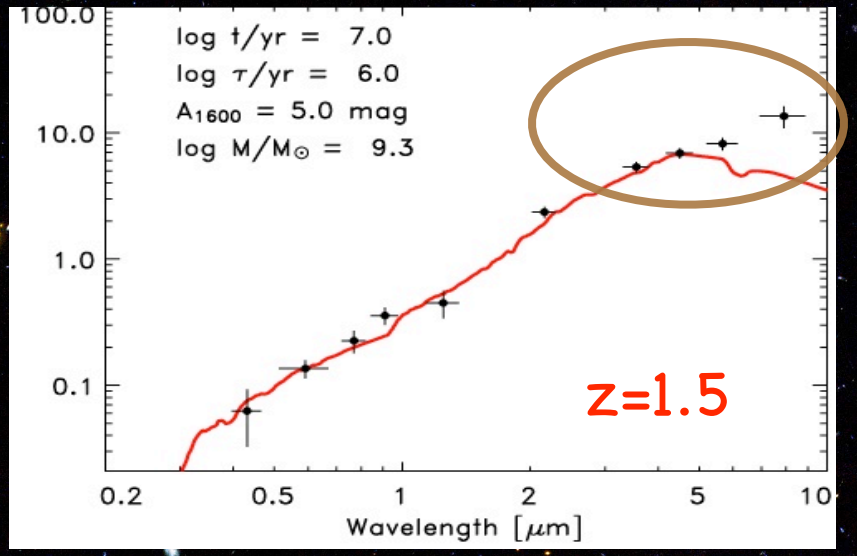
Near-IR Color Selection of AGN

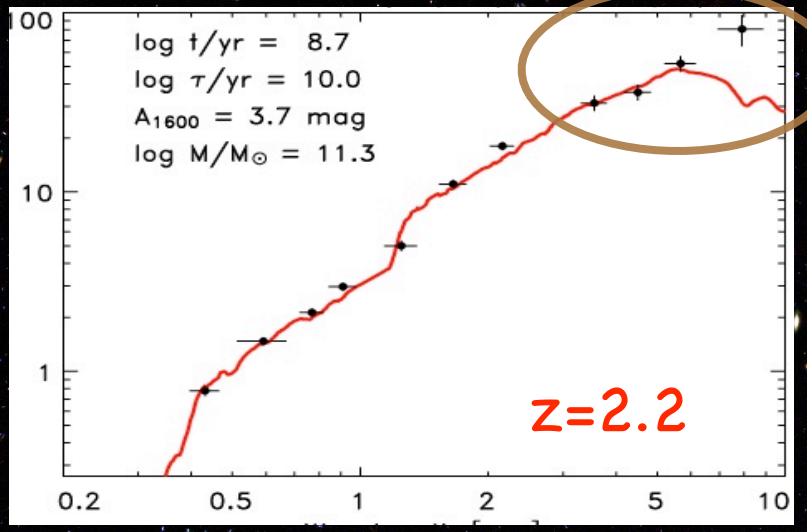


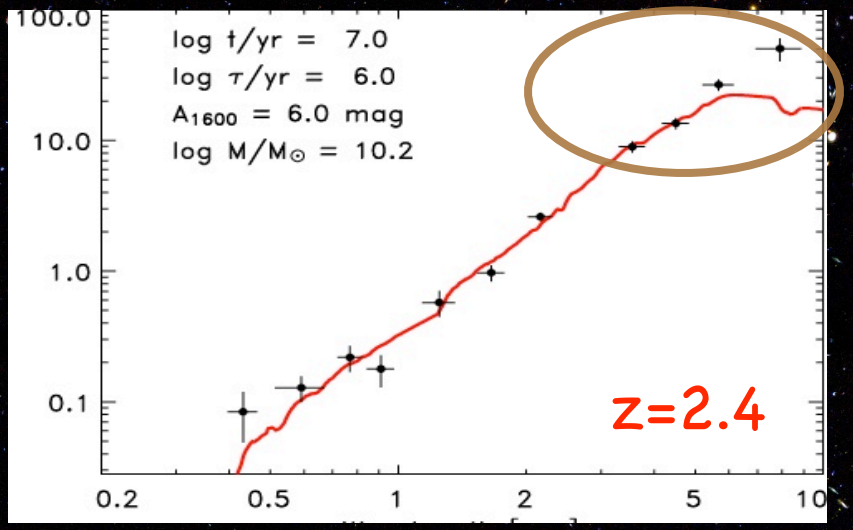
X-ray Sources

Non-X-ray Sources









F_ν [μJy]

Wavelength

2 Nov 2006

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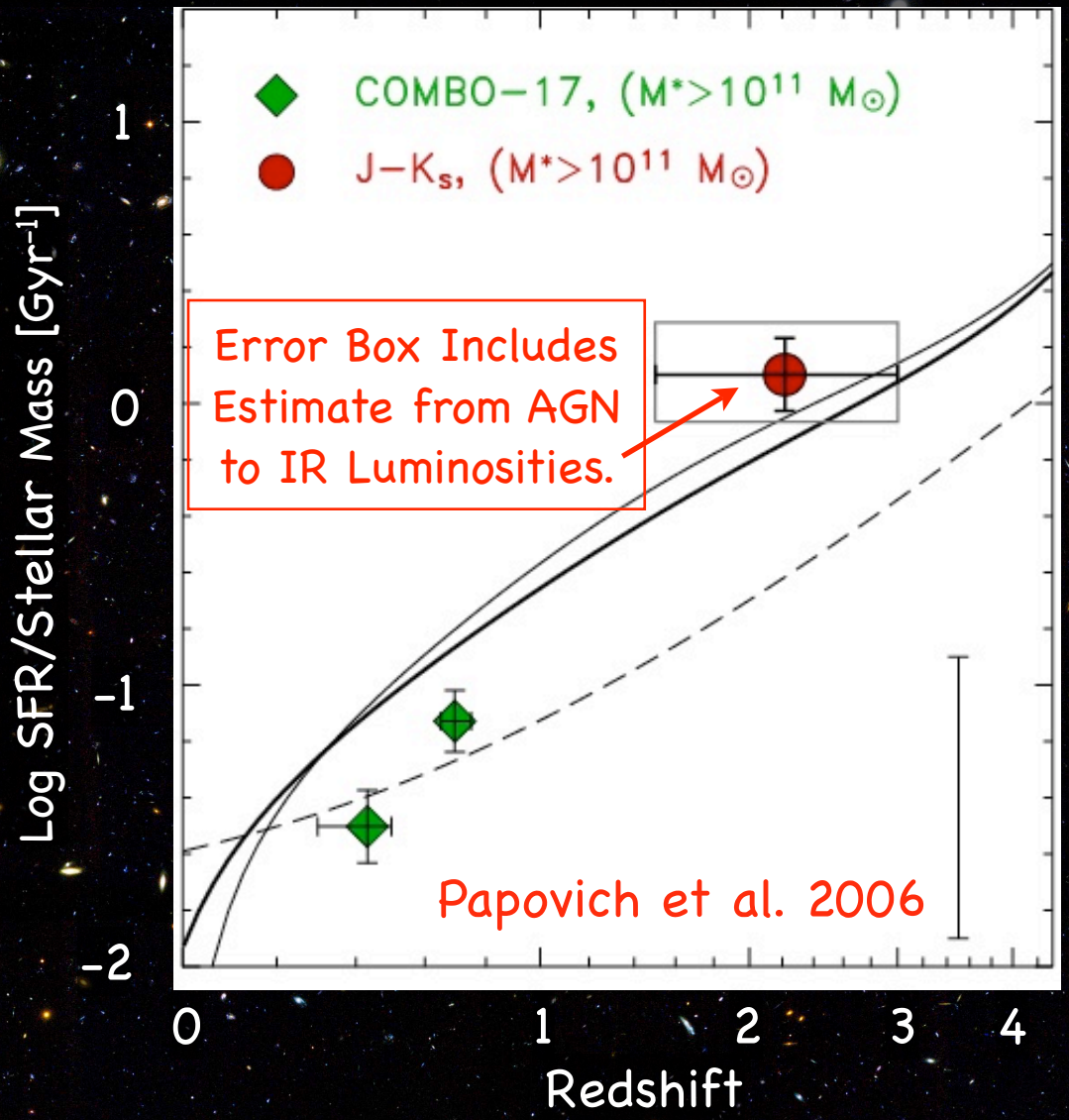
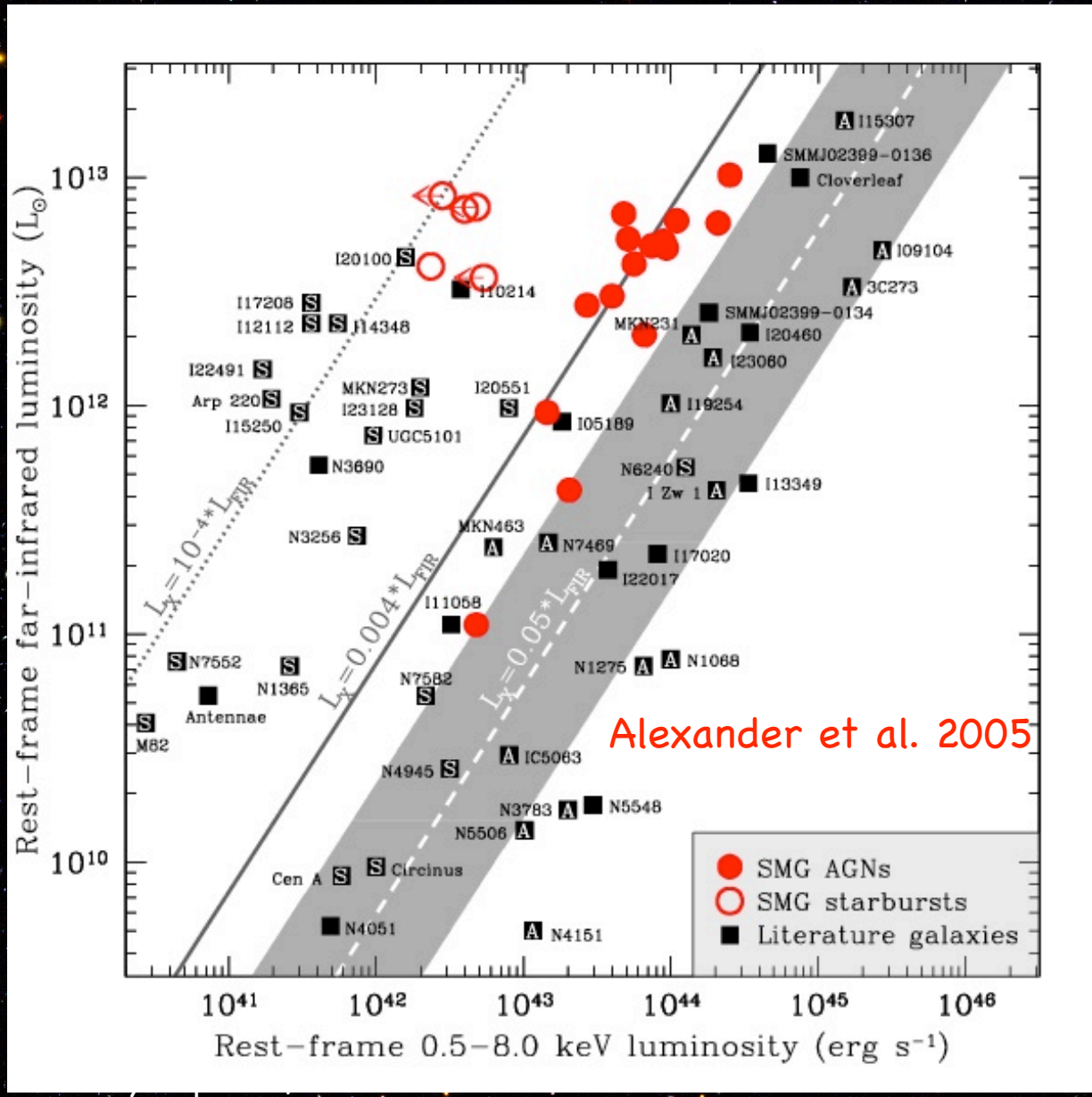


X-ray Observations of SCUBA Galaxies

80% of SCUBA sources detected in 2 Msec X-ray data; mostly due to AGN.

But, L(X)/L(IR) ratios in X-ray sub-mm galaxies low. What powers IR emission? (see Pope et al. 2006)

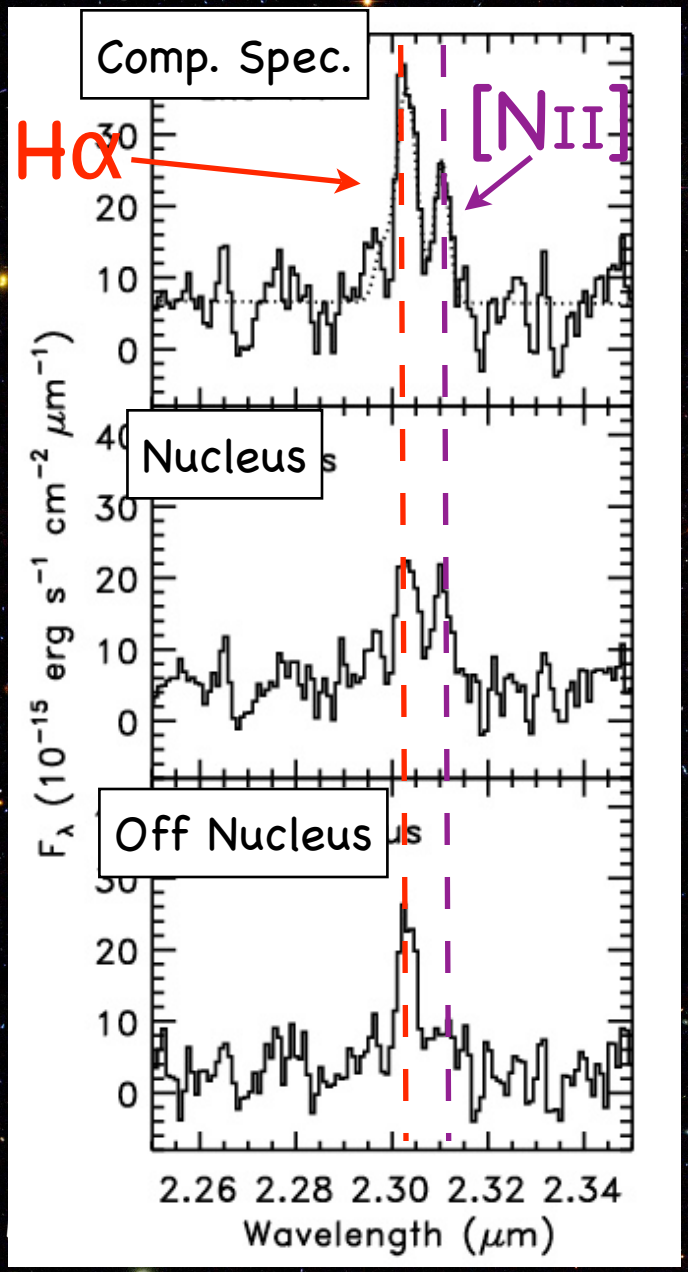


Alexander et al. 2005

2 Nov 2006

Indications of AGN in Sub-MM Galaxies

- Keck NIRSpec Obs. of SCUBA Galaxy SMM J04431+0210 (Frayer et al. 2003)
- Spectrum Shows Hα + [NII], but Hα spatially resolved outside nucleus.
- Very red: J-K = 3.2; Qualifies as DRG.
- But, [NII] may also indicate shocked gas from starbursts... (van Dokkum et al. 2004)

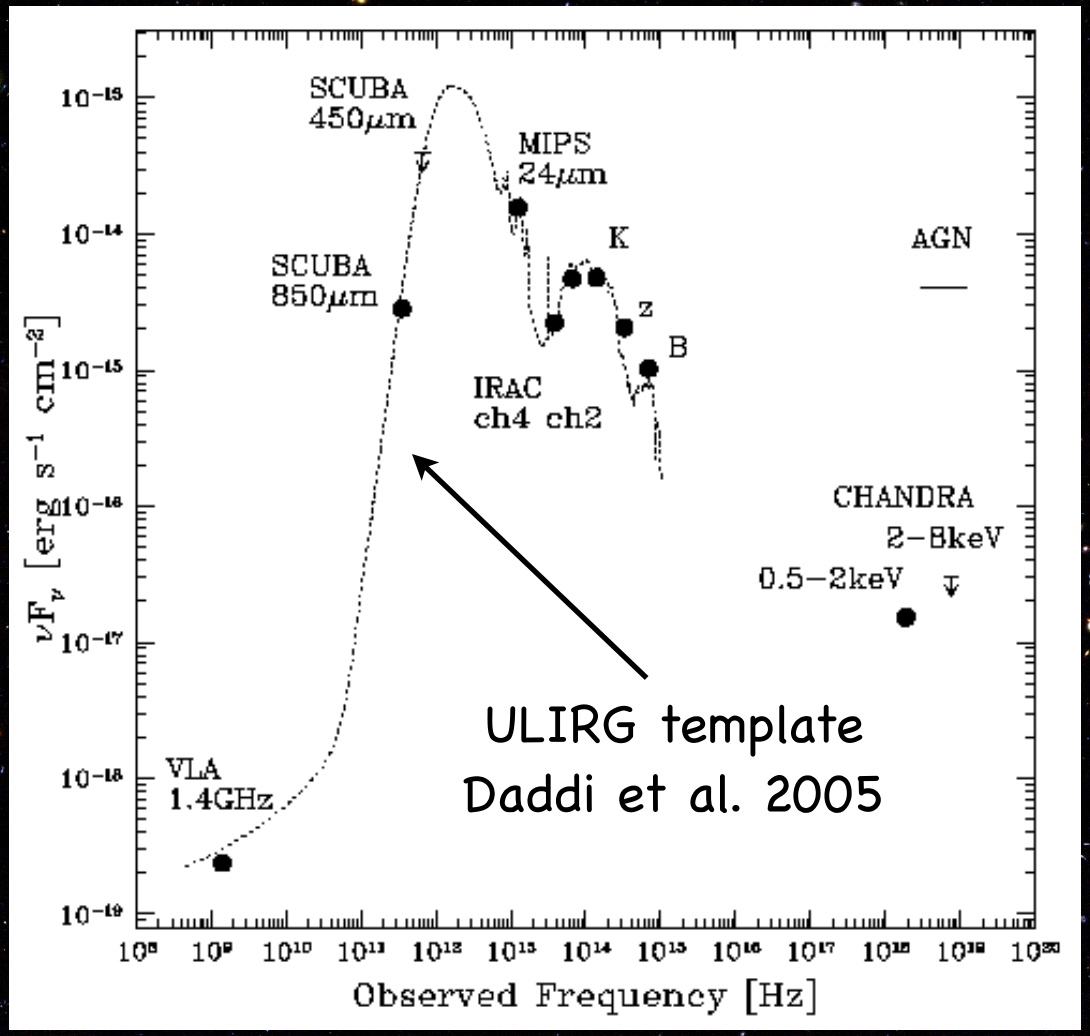


Average X-ray to Radio SED of BzK Galaxies in GOODS-N

- Star-forming BzK galaxies at z=1.9 in GOODS-N have an average SED of a ULIRG with L(IR)=2 x 10^{11} L$_\odot$.

- Agreement between IR, X-ray, radio, sub-mm, and UV SFR indicators within a factor of 2.

Daddi et al. (2005); see also Pope et al. (2006)



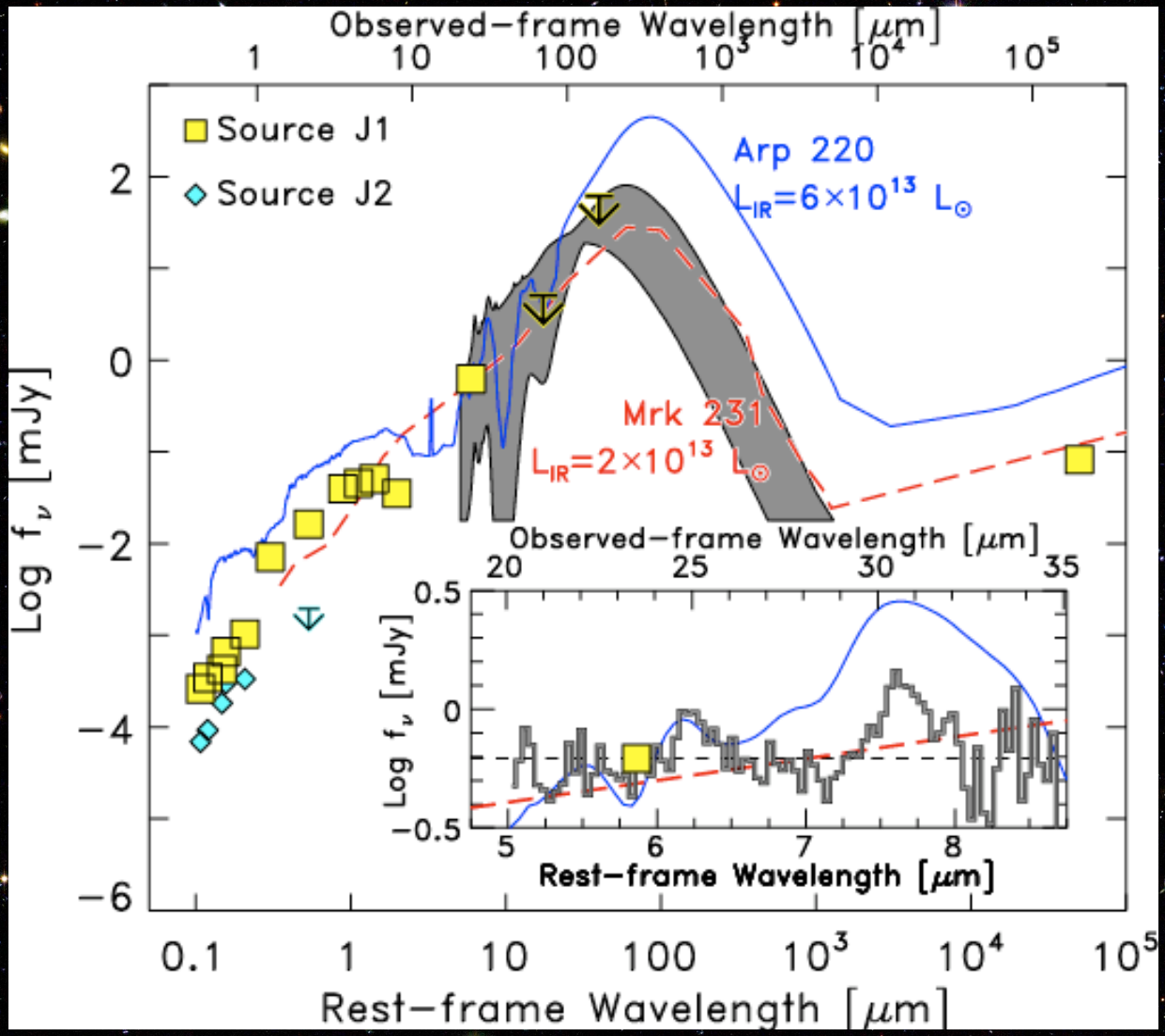
Spitzer 20-160μm Observations of a Galaxy at z=3.01

U-dropout in EGS

24μm-bright, f(24μm) = 0.75 mJy.

24μm-derived L(IR) is 3x larger compared to IRS+MIPS+radio

Huang et al. (2006, astro-ph/0608456)



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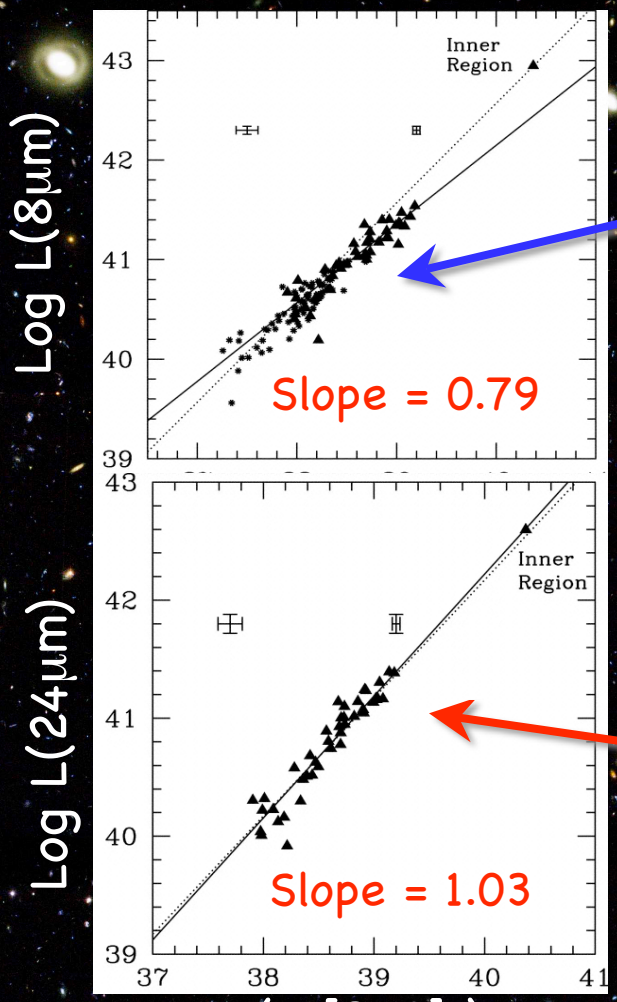
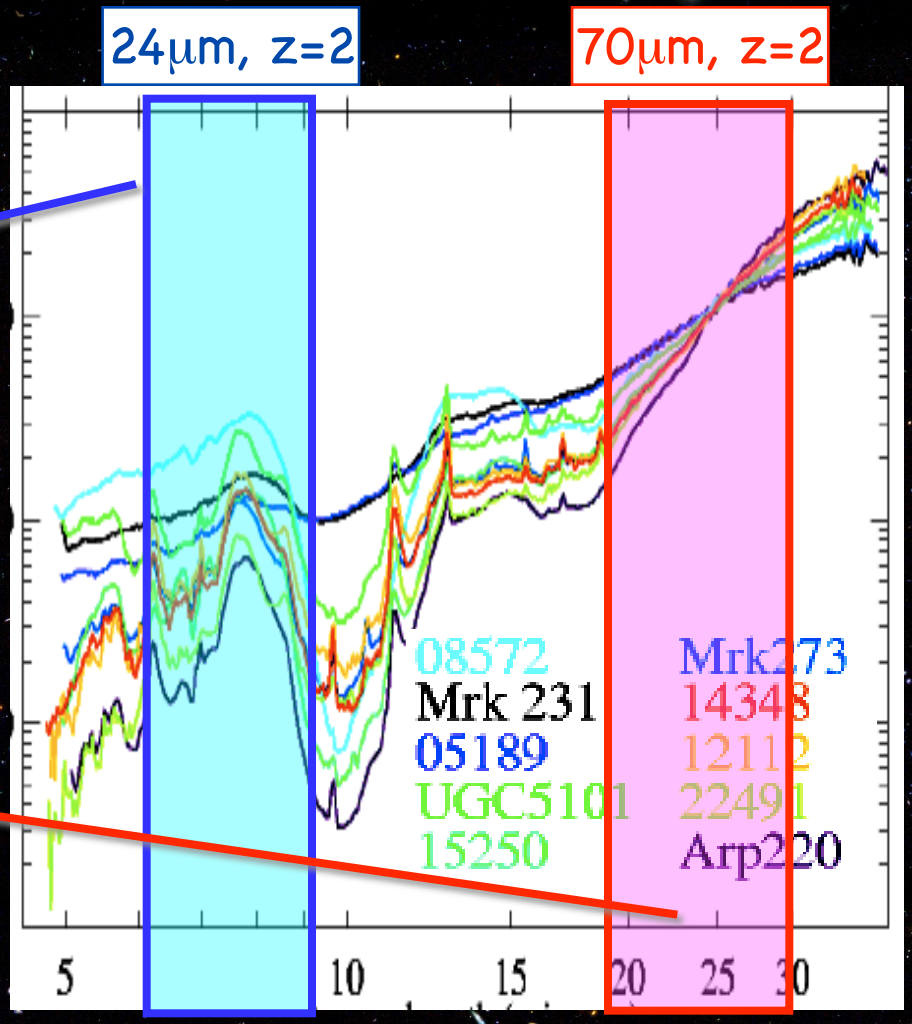
Spitzer 24μm is Rest-frame mid-IR at z~2

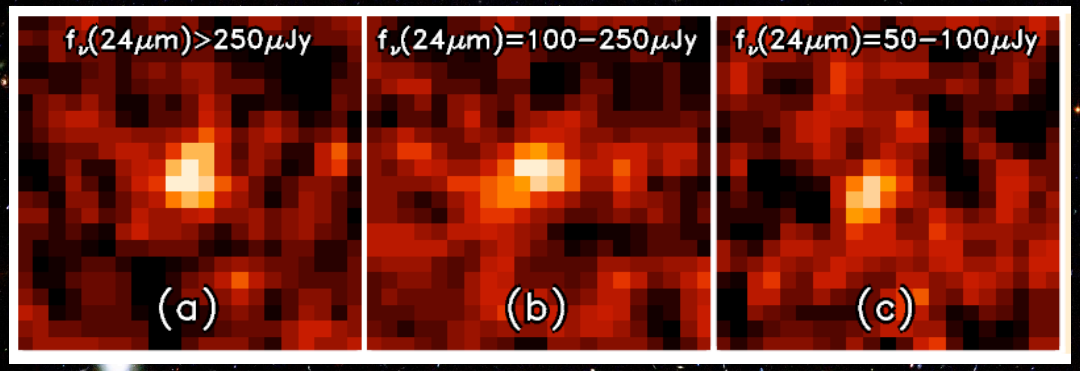


Calzetti et al 2005

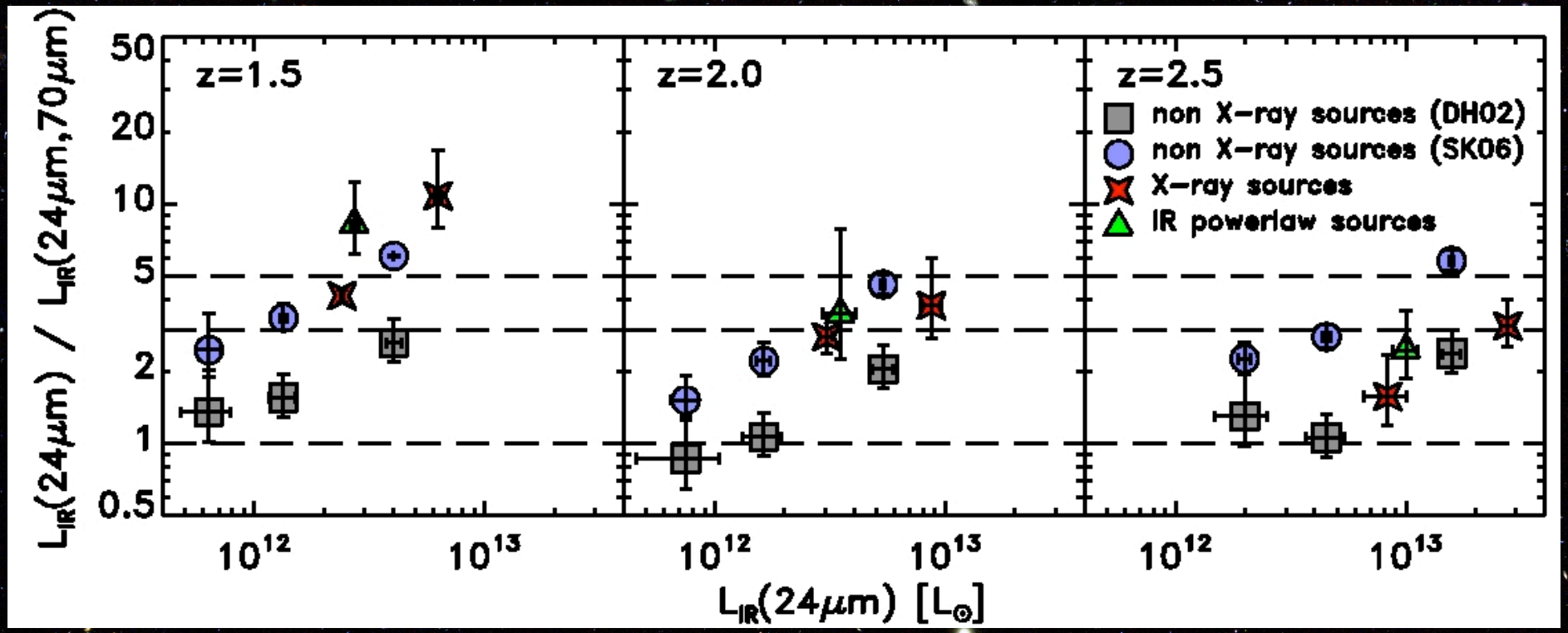


Armus et al 2006

Stacked 70μm Images of 1.5 < z < 2.5 galaxies

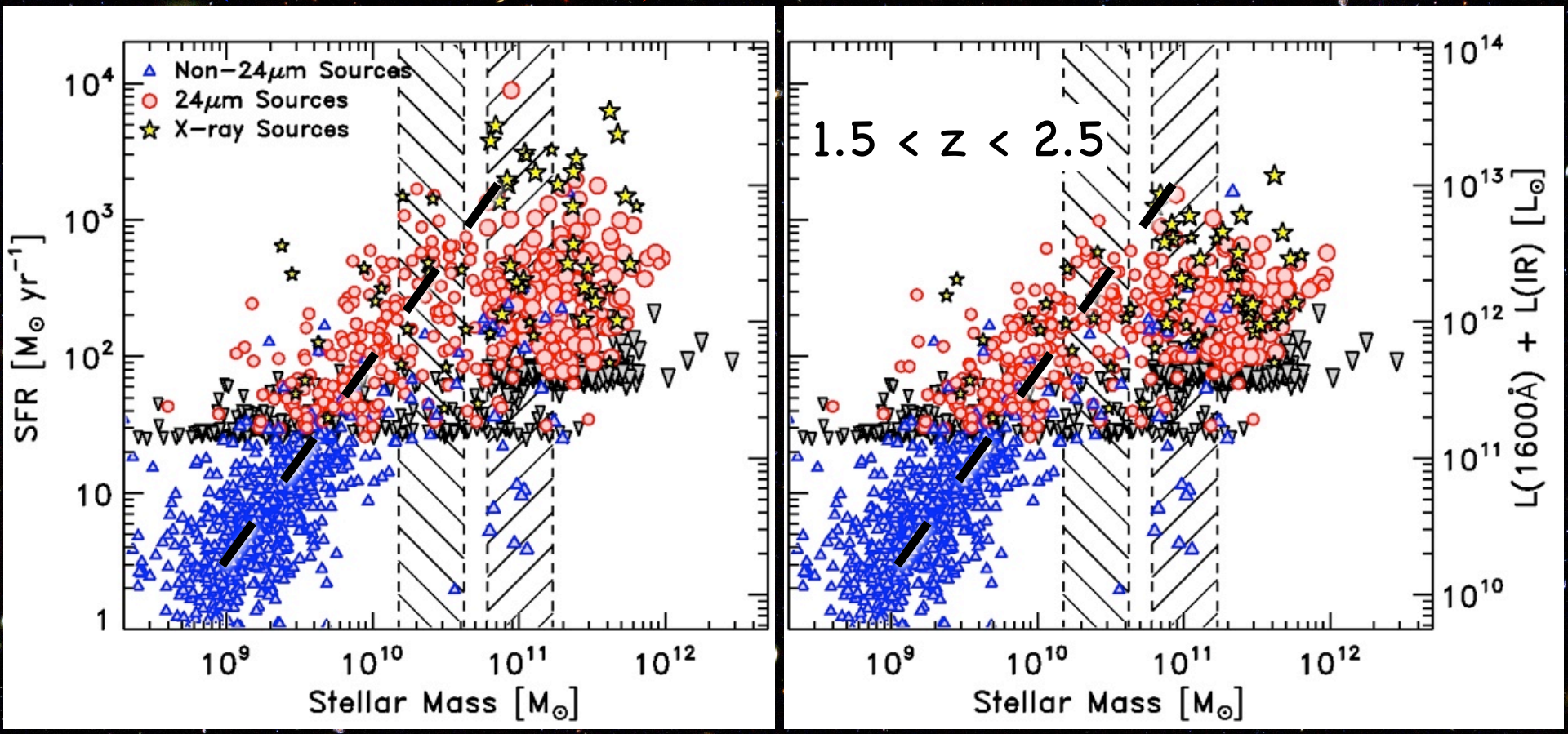


F(24μm)>250 μJy 100-250 μJy 50-100 μJy



Implications for SFR vs Mass

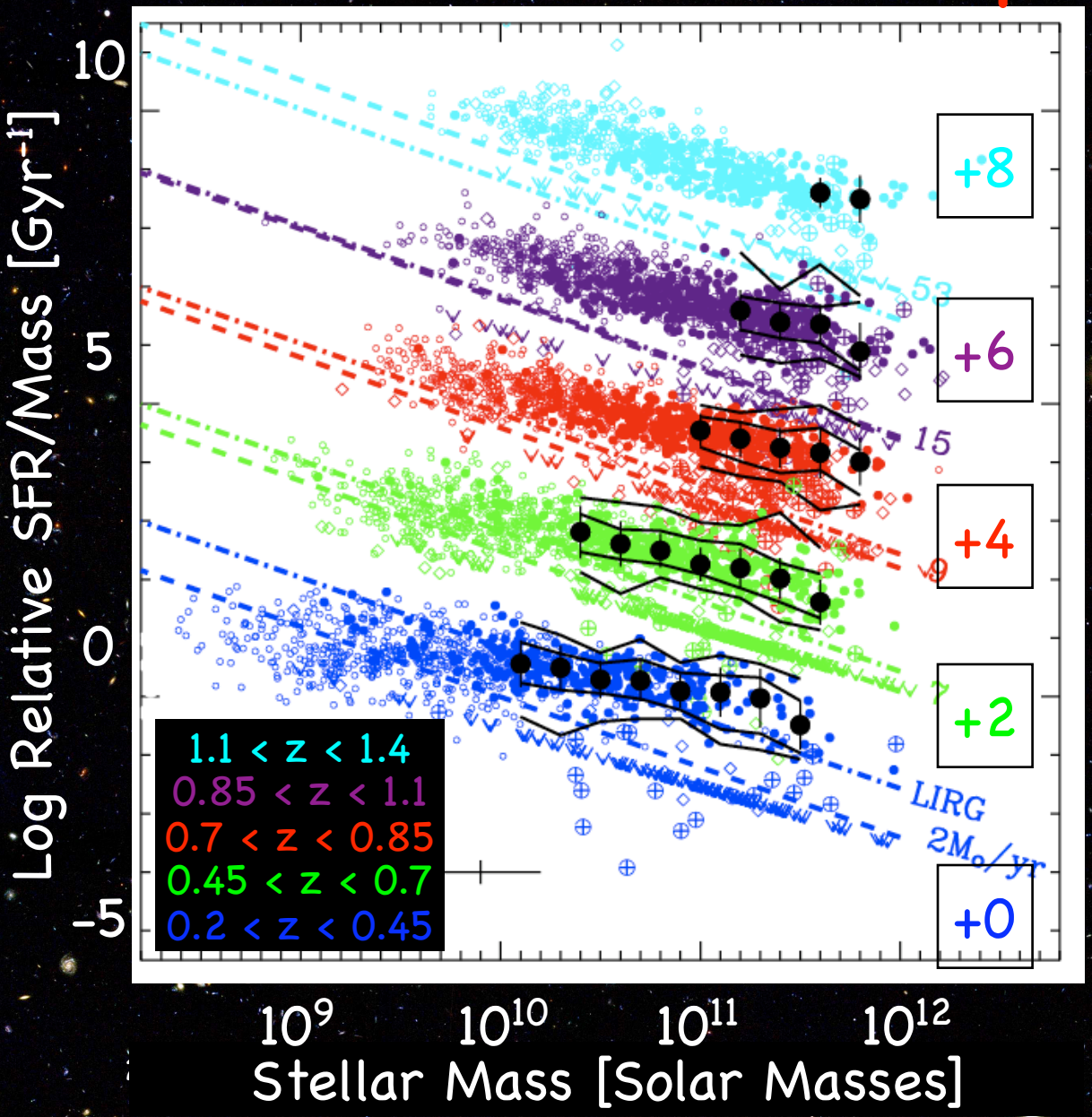
GOODS ← → MUSYC



SFR from UV + 24μm

corrected with $\langle f_\nu(70\mu m)\rangle$

Evolution of the Specific SFR



- Noeske et al. 2006
- Scatter in SF sequence is 0.3 dex.
- <68% of lifetime has a SFR within 2x the average rate.

Paraphrased from R. Somerville, August 2005 …

THE ASTROPHYSICAL JOURNAL, 523:L109–L112, 1999 October 1

YOUNG GALAXIES: WHAT TURNS THEM ON?

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Received 1999 June 8; accepted 1999 July 22; published 1999 August 27

R. Somerville: Old Galaxies: What Turns them Off?

Summary and Questions:

- o When did Galaxies Form their Stars?
  - Most Massive Galaxies at $1.5 < z < 2.5$ are IR luminous.
  - Active epoch for star formation.
  - Indications for AGN in high-mass high-z galaxies.
- o Still need to fill in shape of Galaxies' IR SEDs to understand bolometric emission.
- o Is SFR proportional to Stellar Mass?
- o What is the Fraction of Galaxies Falling off SFR/Mass Sequence as a function of (1) Mass and (2) Redshift?
- o MGCT3 ? Yes !