# *Studying high-redshift galaxies with WIRCAM in Extended GOODS-N*

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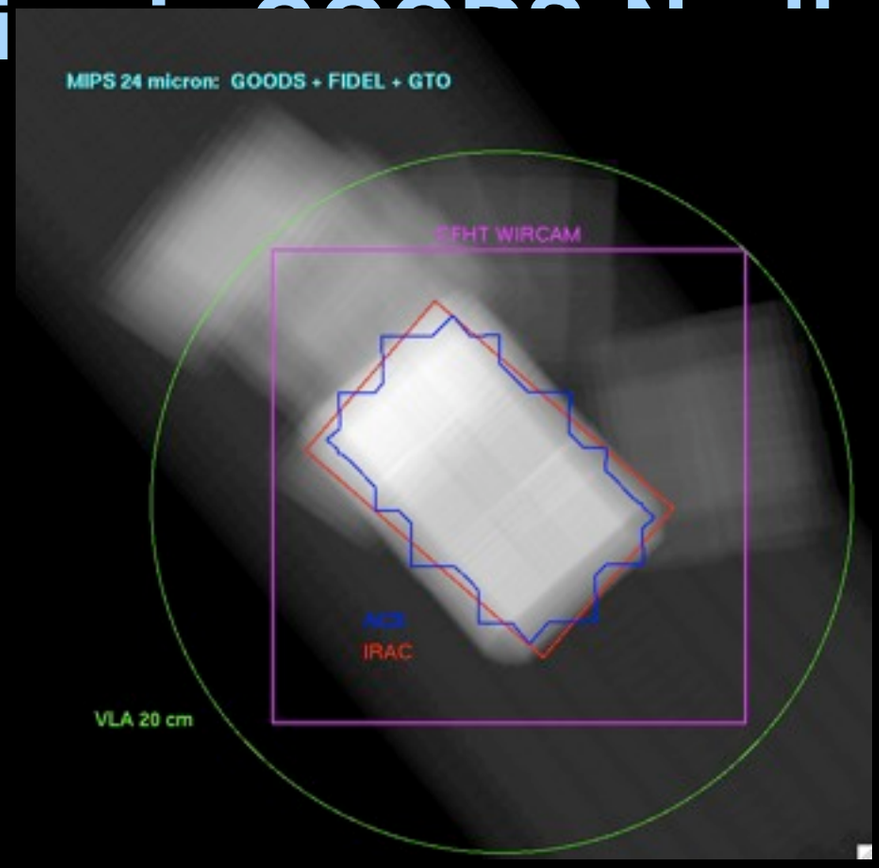
# Deep CFHT/WIRCam J & Ks Imaging in GOODS-N field

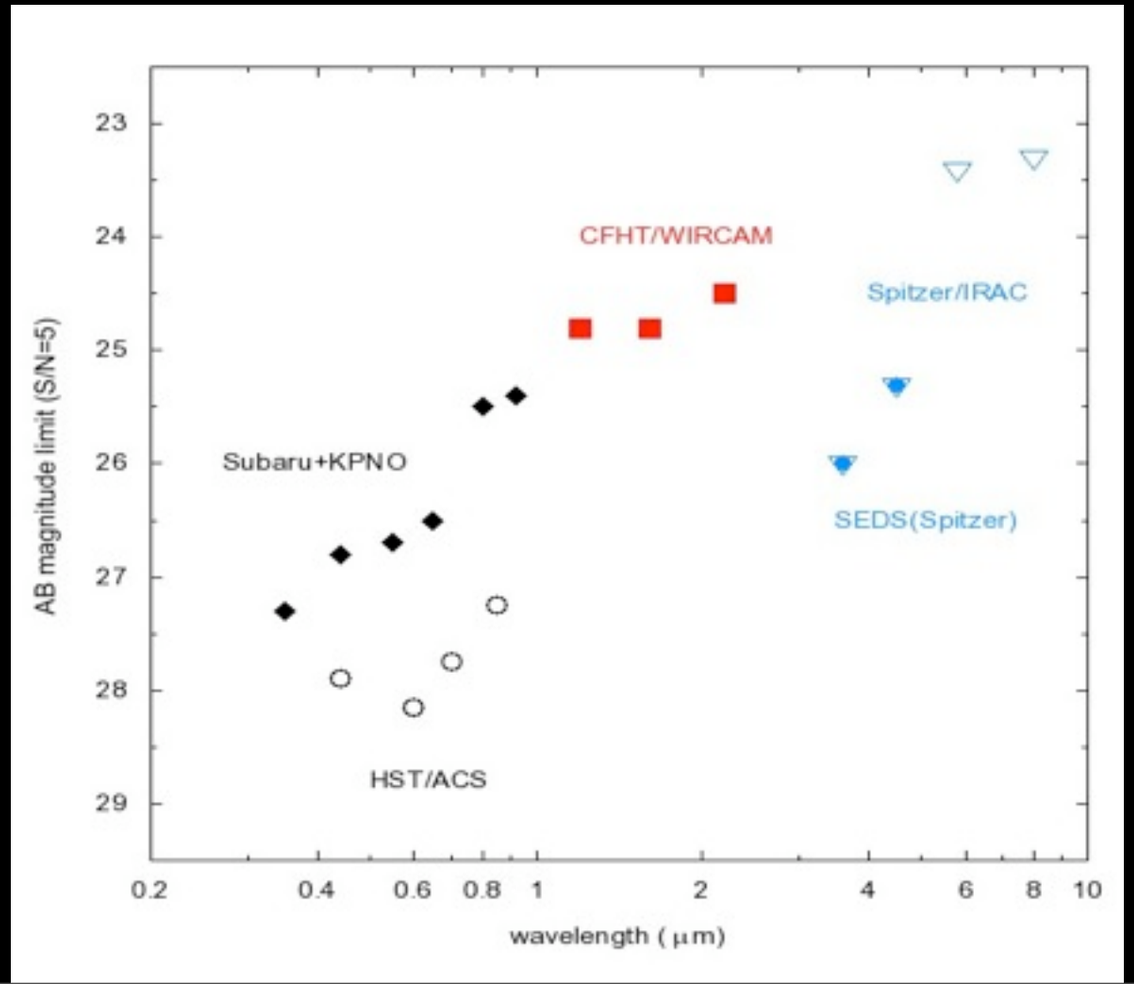
- A Taiwan/Canadian (+ public data taken by Cowie et al.) project carried out over 2006-2010, with 62 hours of WIRCAM

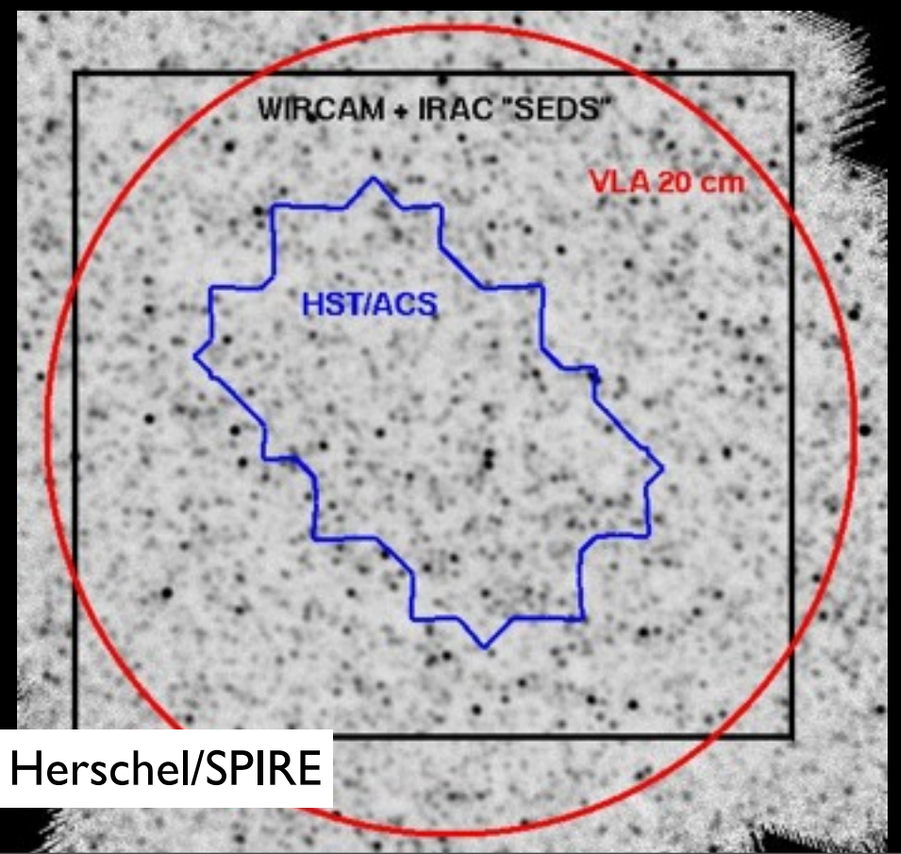
- Survey depth:
  - J ~ 25.0 (AB,5-sigma,2" aperture)
  - K ~ 24.5 (AB,5-sigma,2" aperture)
  - 0.5 × 0.5 deg2 each
  - *H-band imaging is being proposed*

- Overlapped entirely with Spitzer Warm Mission project "SEDs" and GOODS-Herschel SPIRE coverage.

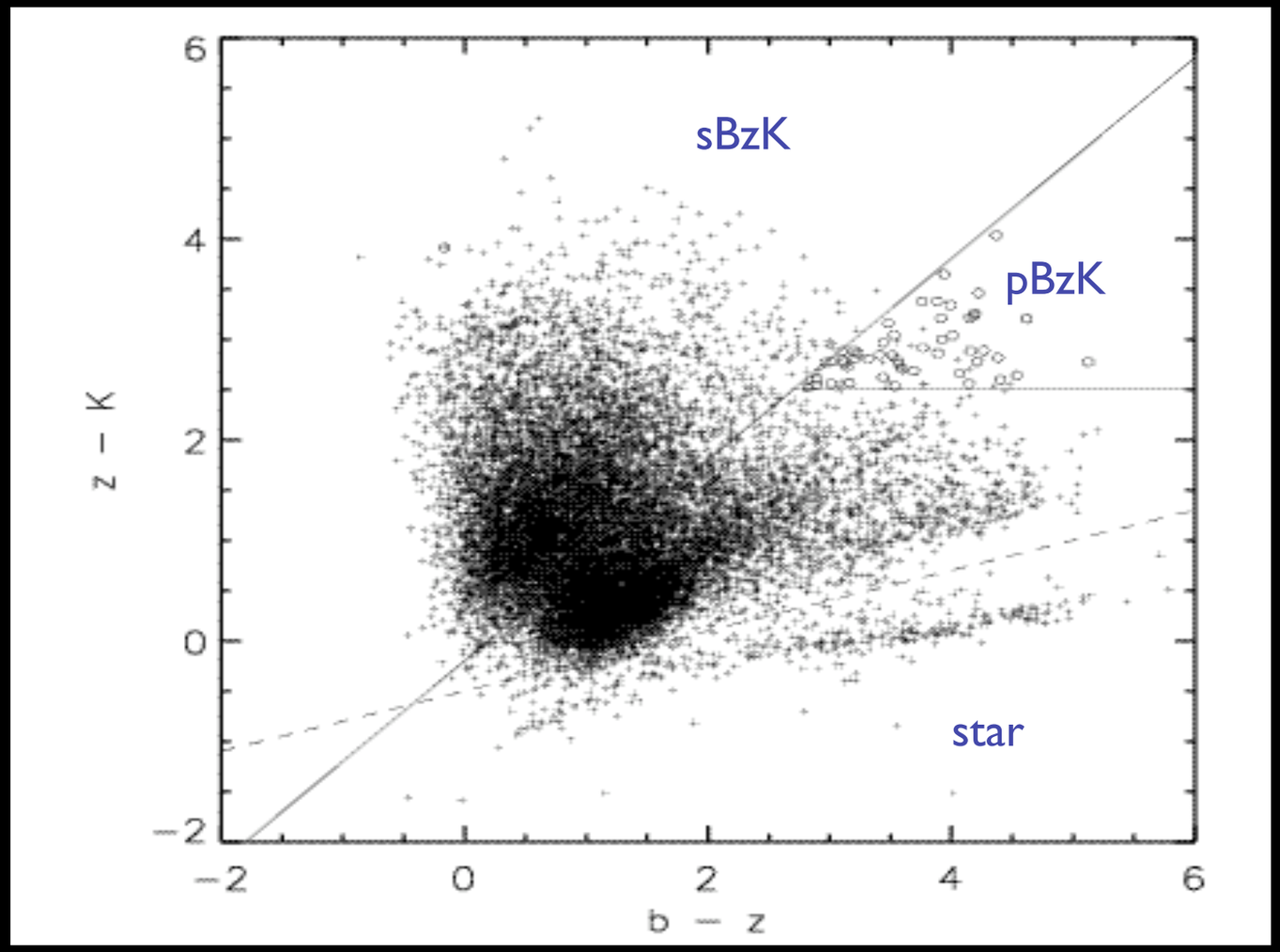
- Sciences:
  - z>7 galaxies (Yan+ in prep; Lin+ in prep)
  - Bzk-selected galaxies (Lin + in prep)
  - Dusty starburst galaxies (Pope et al. 08)
  - LBGs (Younger et al. 07)



# BzK –selected galaxies at 1.4<z<2.5



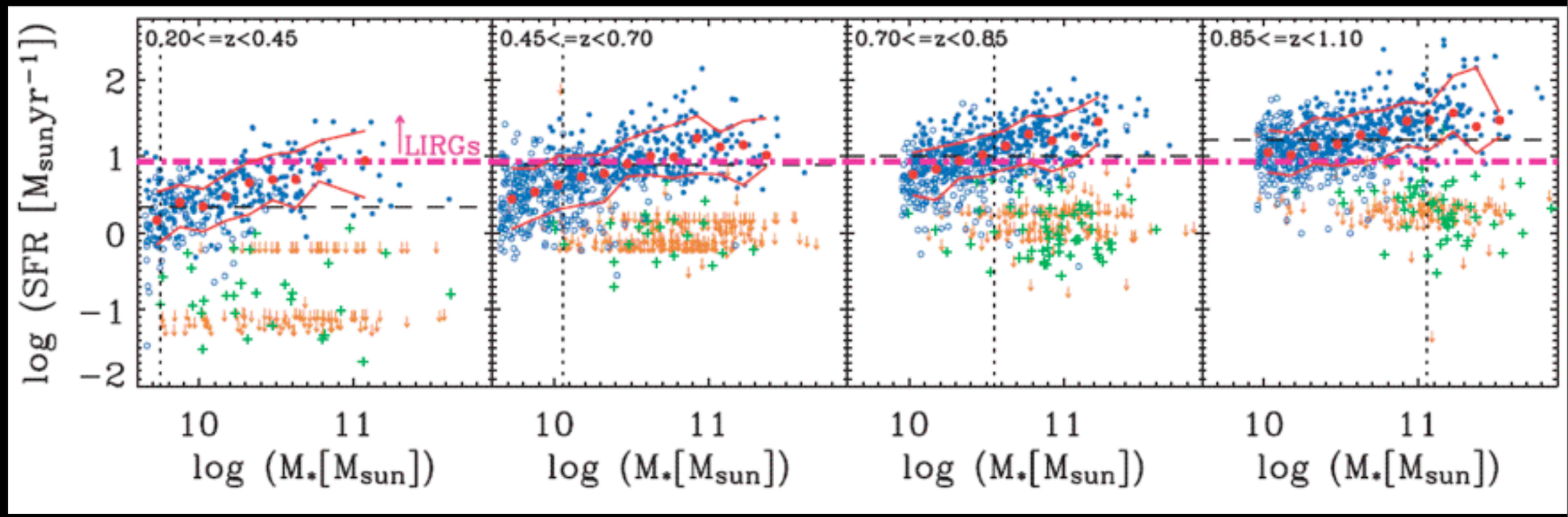

- Filter used: ACS/F435 (b), ACS/F850 (z), WIRCAM (K)
- Sample Size down to Ks ~ 24.0 (AB):
  - -7339 (star-forming bzKs)
  - -70 (passive bzKs)
  - -703 (un-classified bzKs)
  - -7348 (non-bzks)
  - -448 (stars)

- Deep IRAC: robust measurement of stellar masses using rest-frame 1.6 micron fluxes
- Multi-wavelength data: photometric redshift
- Deep b, z and K data: allow for selection of faint BzK samples and estimates of UV extinction-corrected SFR

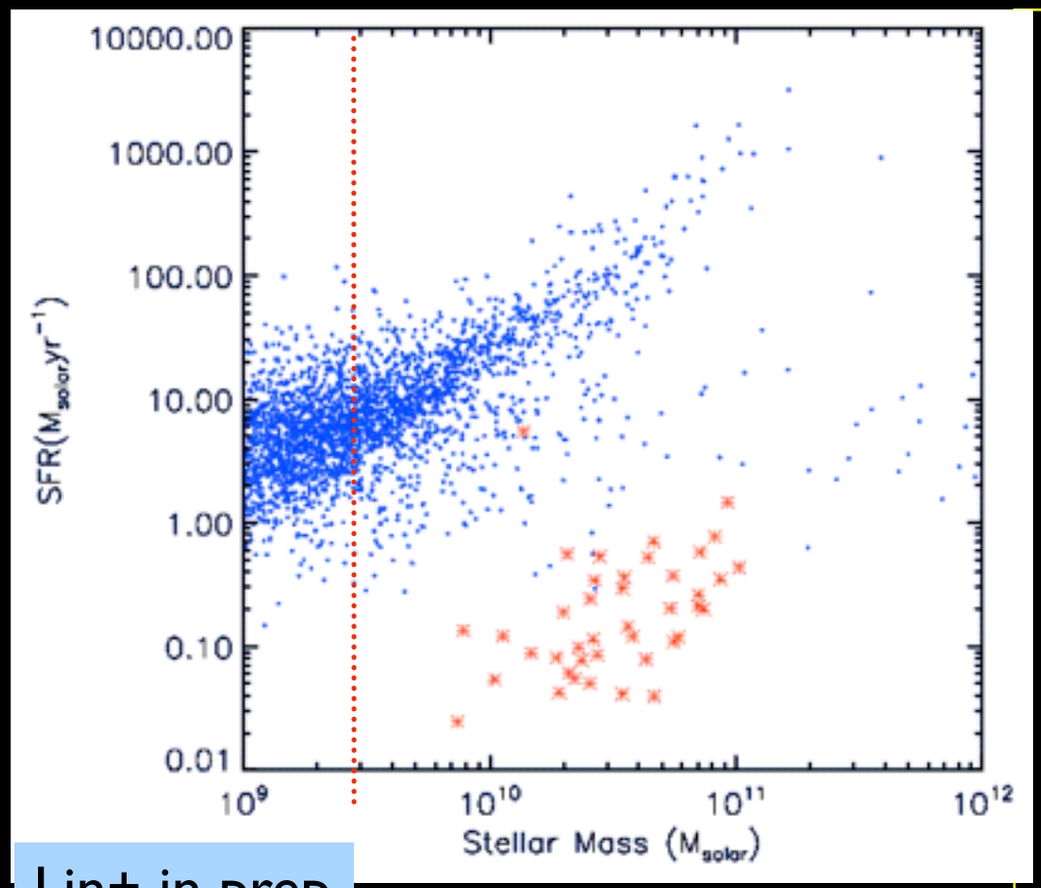
# Star formation rates of star-forming BzKs

0<z<1

Noeske+07a; Elbaz+07; Daddi+07




z~2

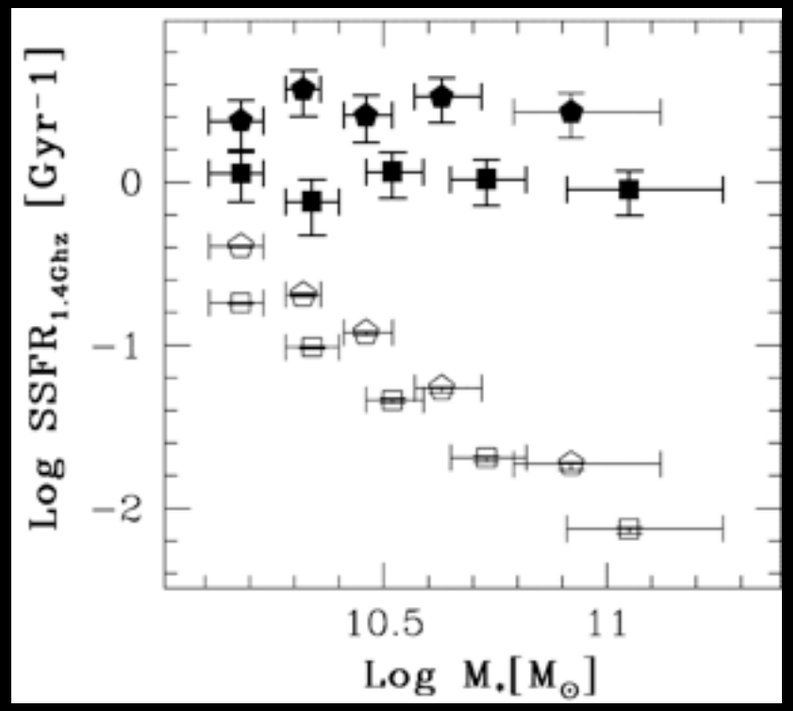



Lin+ in prep.

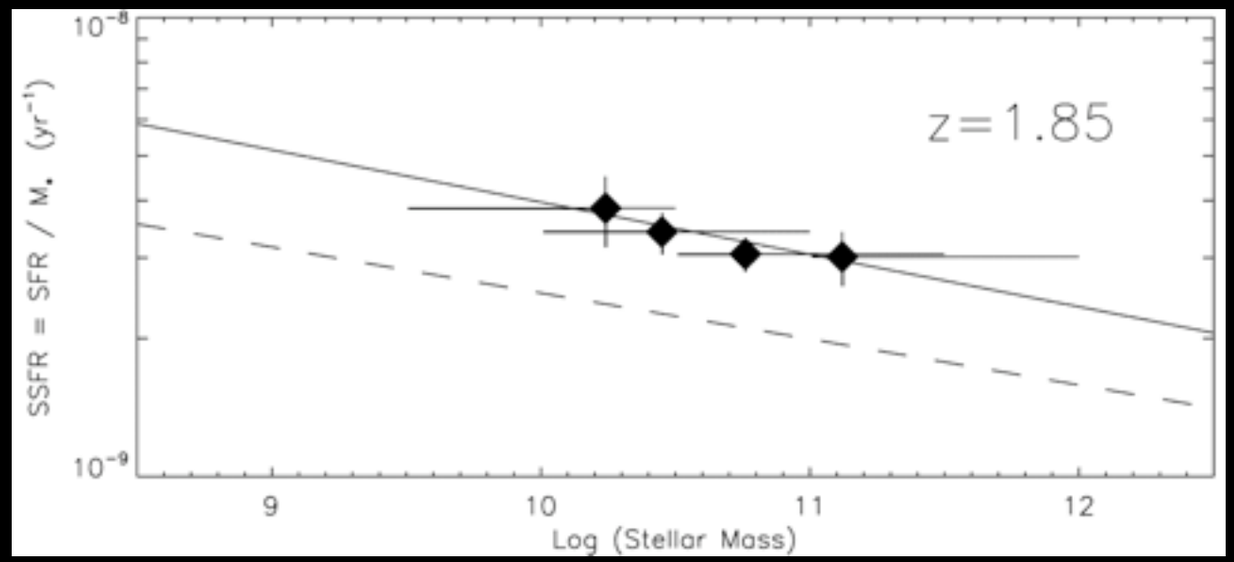
- The star forming Main Sequence (MS) exists at z~2 as well.
- ~40% of star-forming BzK galaxies brighter than K>24.0(AB) have SFR > 10 $M_\odot$/yr
- At a given stellar mass, the SFR at z~2 is and 3x-10x that at z~1, and 15x-30x that at z~0
- Low stellar mass system has a broader range of SFR compared to more massive galaxies.

# Specific-SFR vs Stellar Mass for BzKs

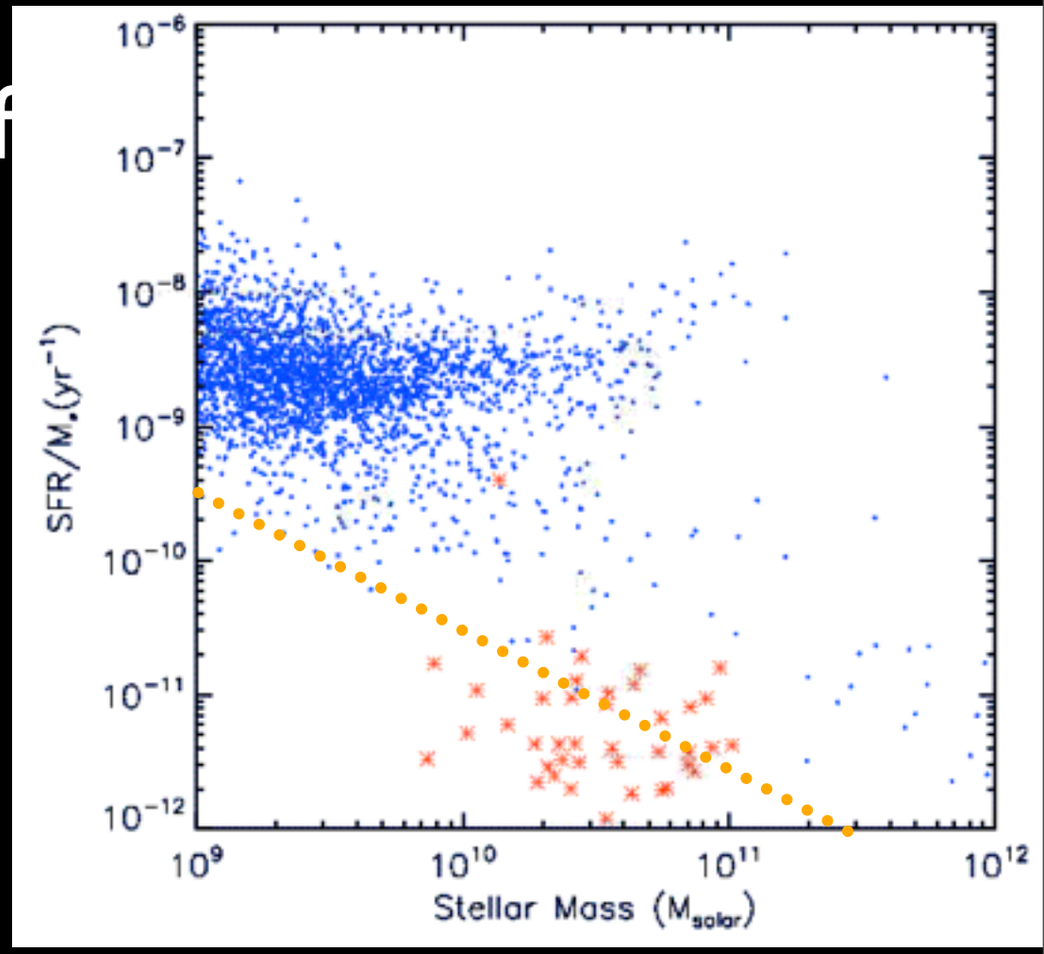
Pannalle+09




Dunne+09

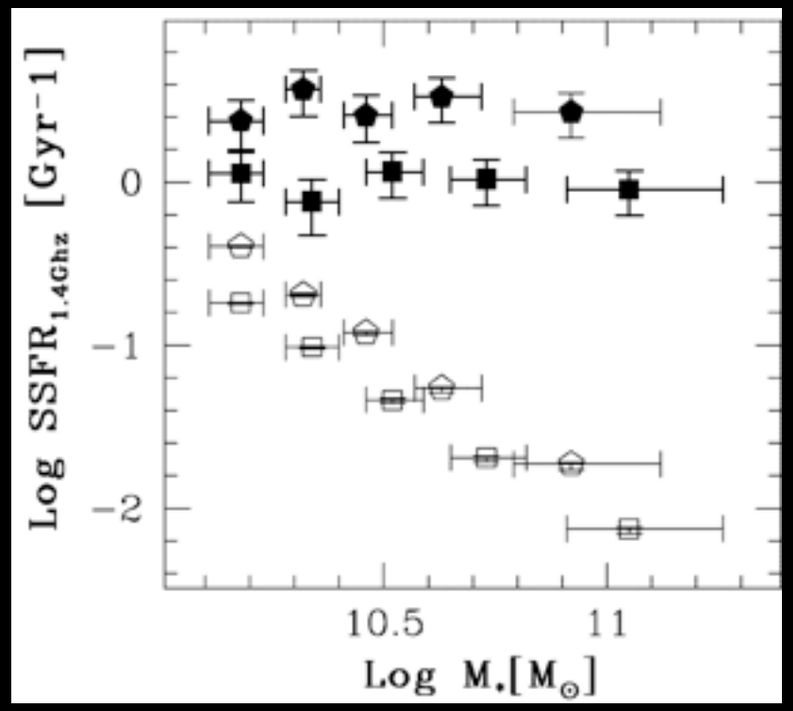



Have we really seen the dawn of downsizing at z~2 ?

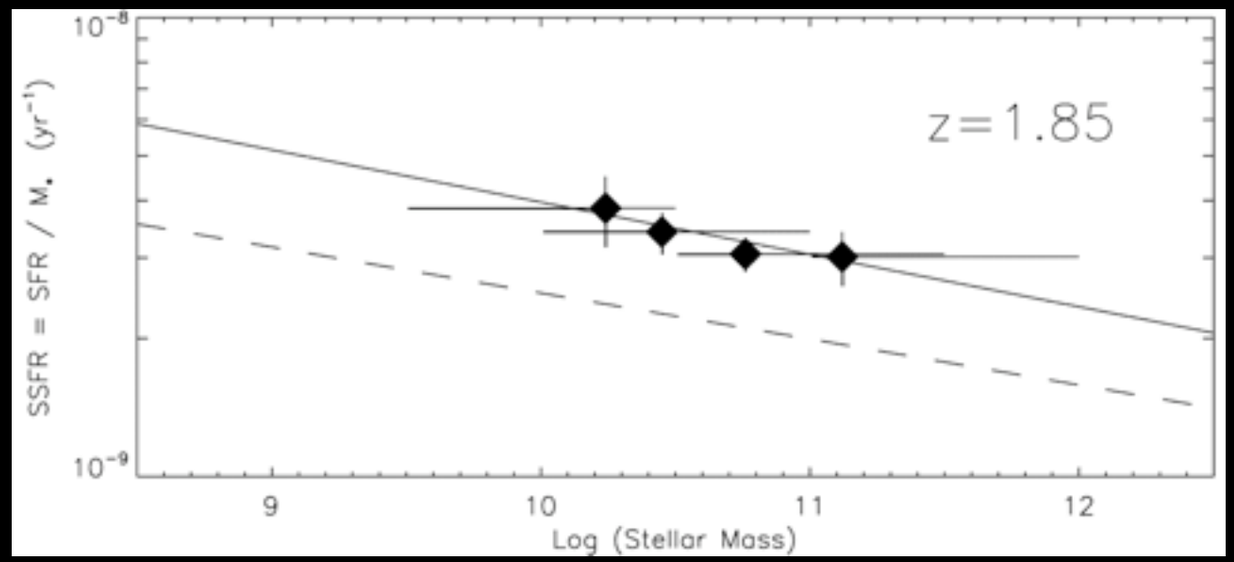


# Specific-SFR vs Stellar Mass for BzKs

Pannalle+09

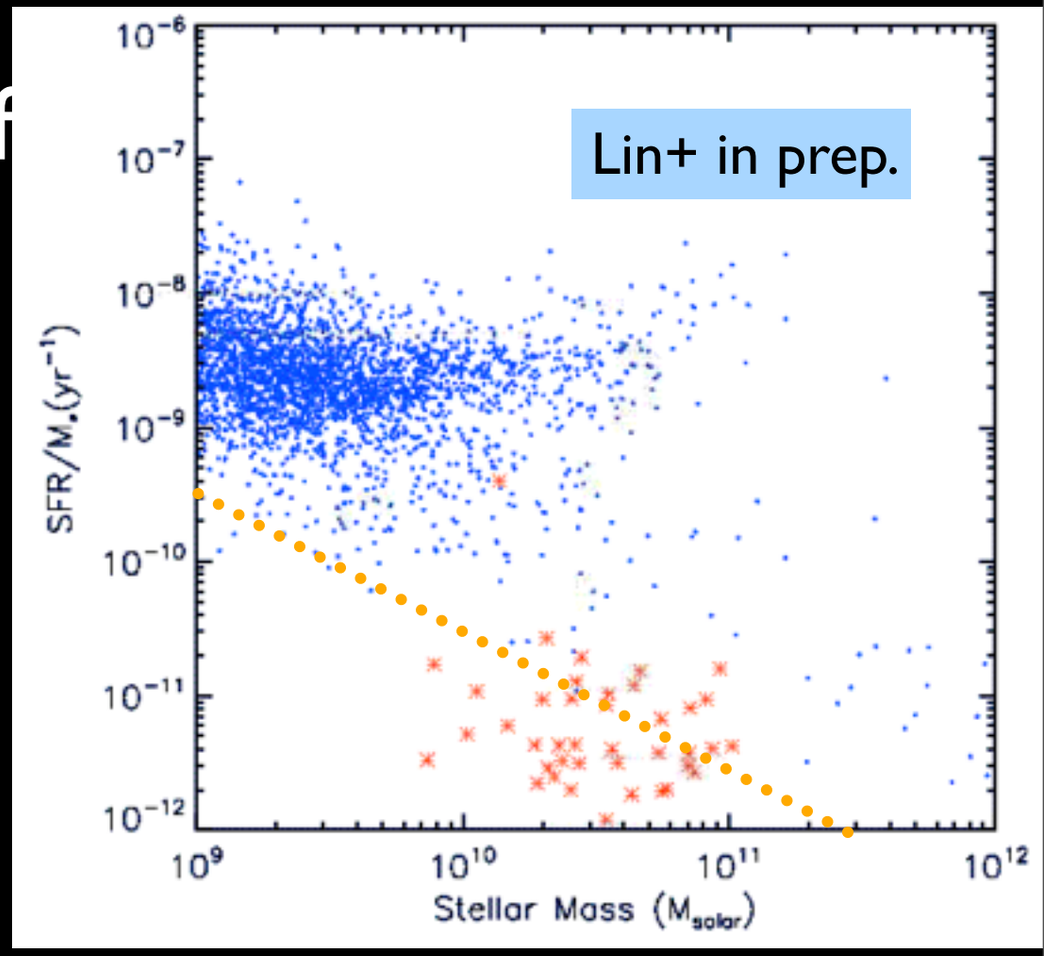



Dunne+09



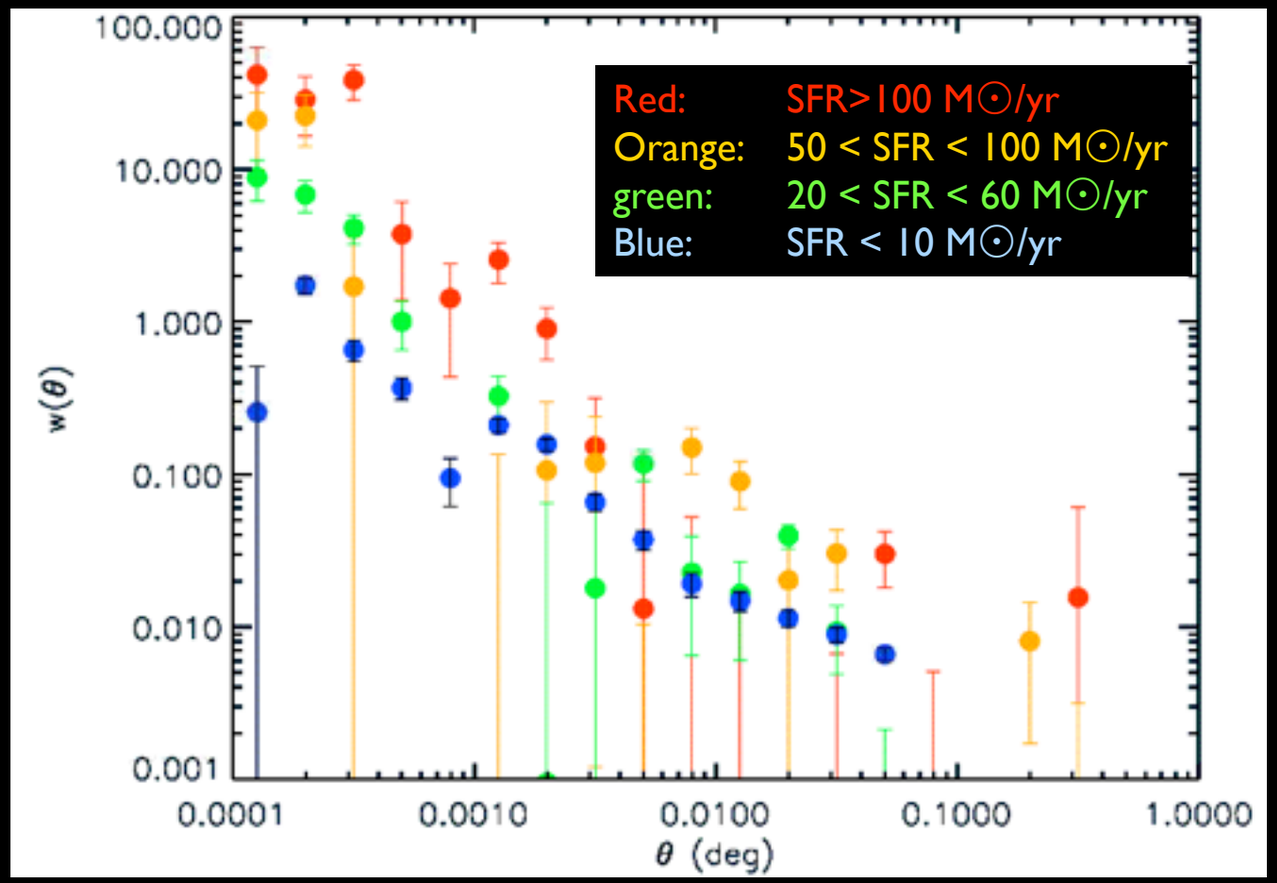

## Have we really seen the dawn of downsizing at z~2 ?

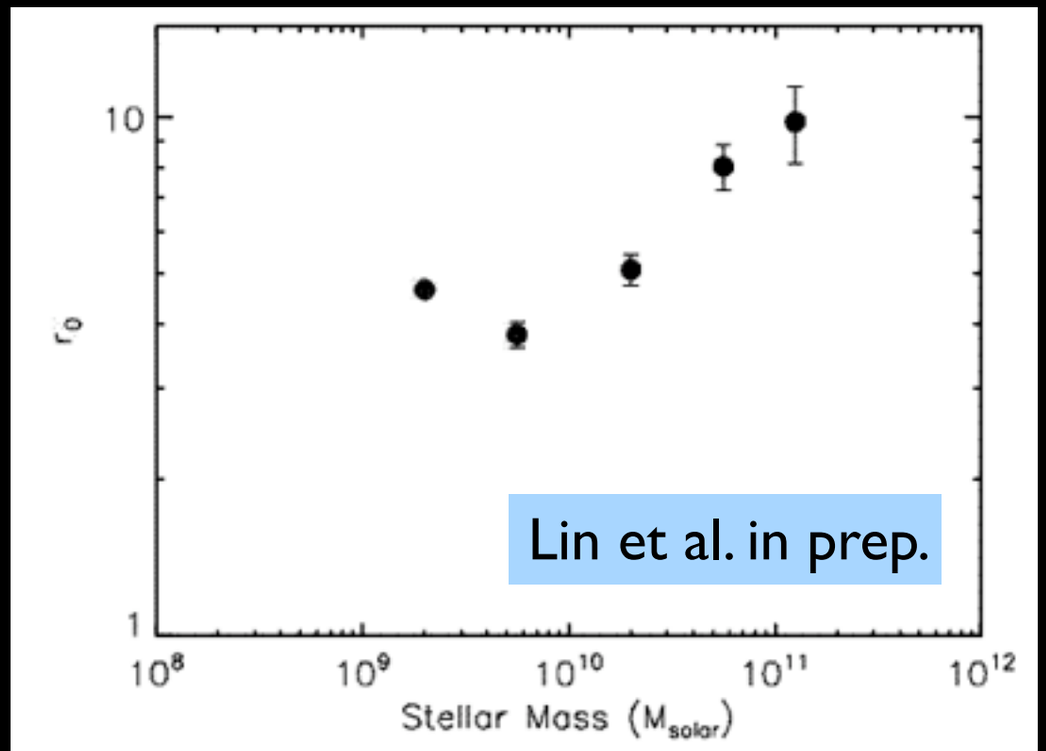
- *The SSFRs are roughly constant over ~ 1.6 dex in stellar mass, unlike the steady decrease of SSFR with M* seen at z<1. However, this strongly depends on how the outliers are rejuected.*

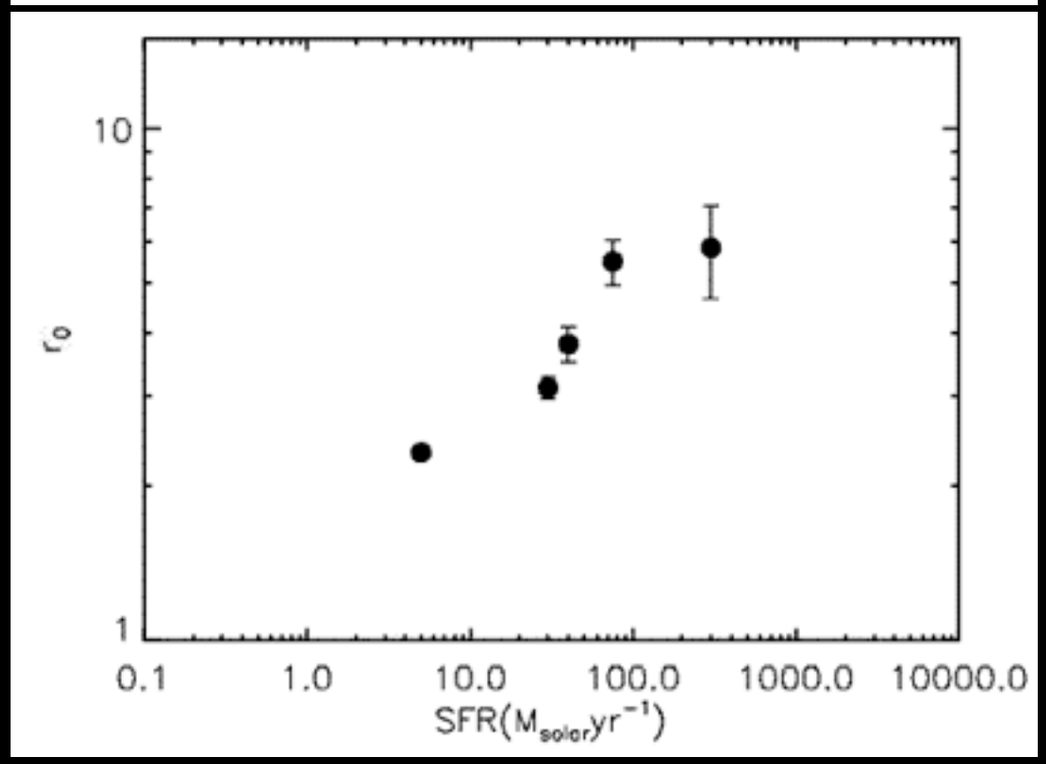


# Clustering properties of z~2 galaxies

Measuring the clustering strength of BzKs provides information about the masses of their hosting dark matter halos (Hayashi+07;Hartley+08; McCracken+10; Foucaud+10).



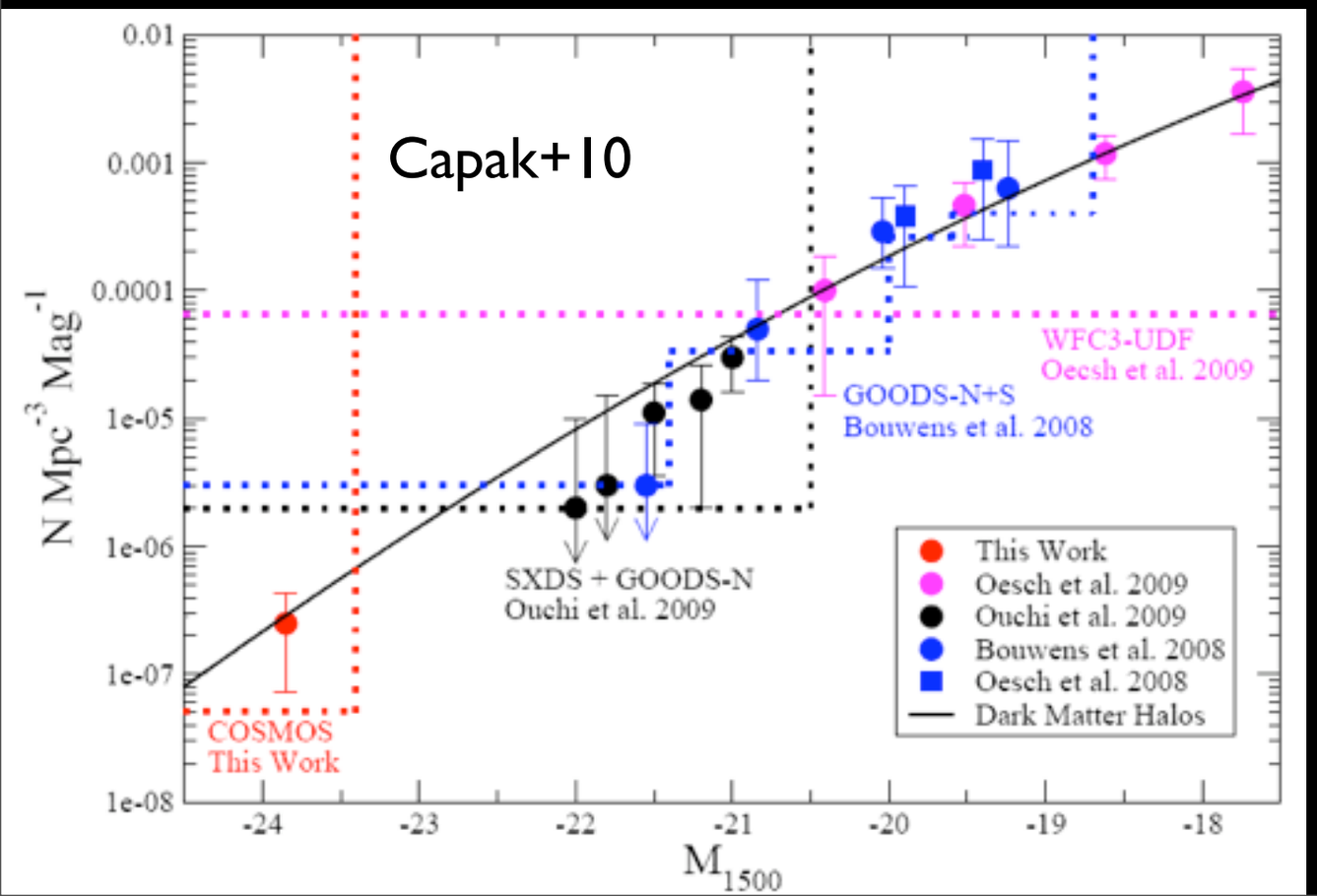



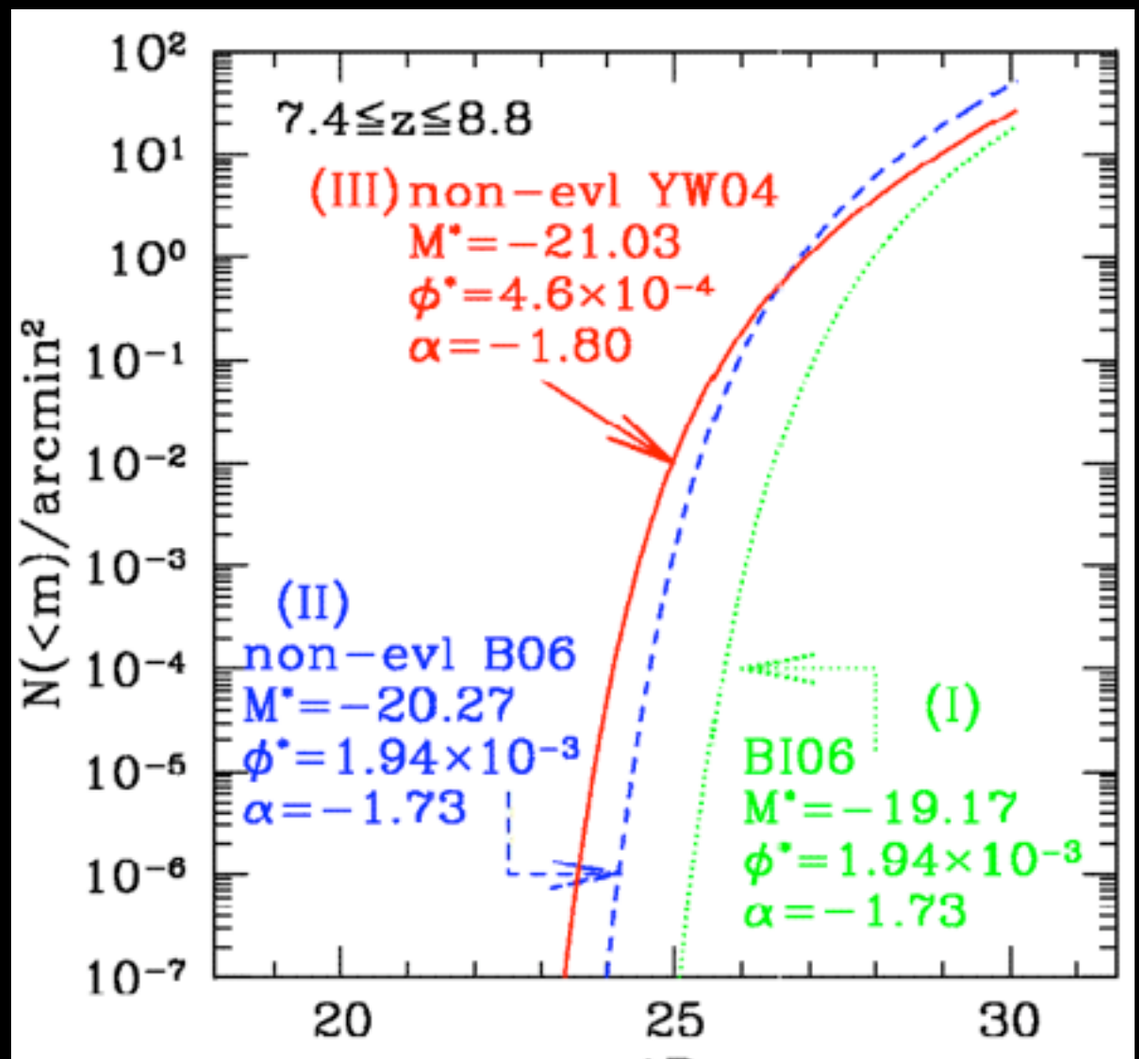

- The clustering amplitude increases with SFR and stellar mass
- The correlation lengths of BzK galaxies with SFR >100 (ULIRG), 10-100 (LIRGS), and <10 $M_\odot$/yr are 5.8, 4.1, and 2.33 $h^{-1}$Mpc, which translate to minimum masses of ~$5\times10^{12}$, $10^{12}$, and $10^{10}$ $M_\odot$ for their hosting dark matter halos respectively.
- ULIRGs at z~2 are likely to be the projectors of the most massive galaxies in present-day's rich clusters.

# z>7 candidates

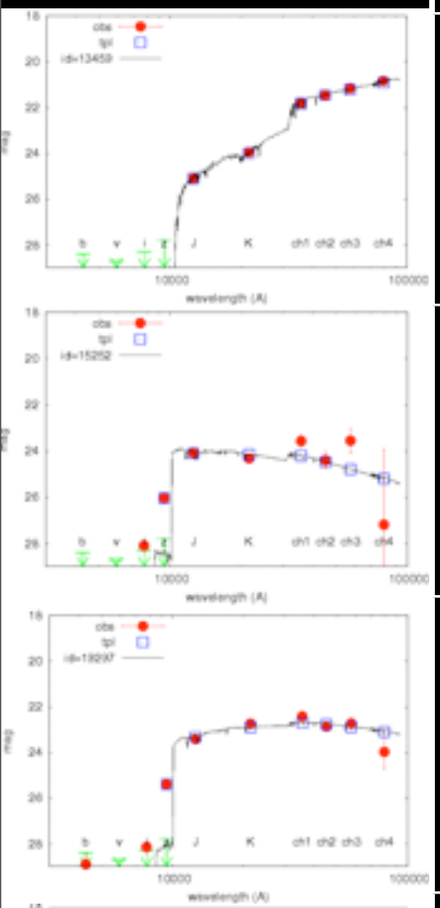
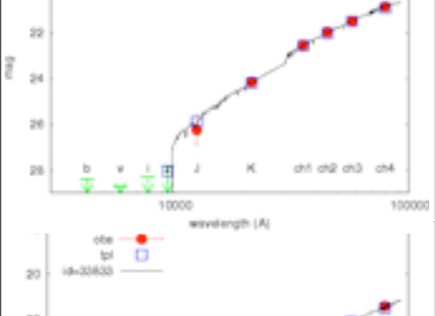
- Pushing the redshift limits of high-redshift galaxies are essential in:
  - quantifying the contribution of early star formation to cosmic reionization
  - characterizing the history of cosmic star formation rates
  - probing the formation mechanism and evolutionary path of early galaxies

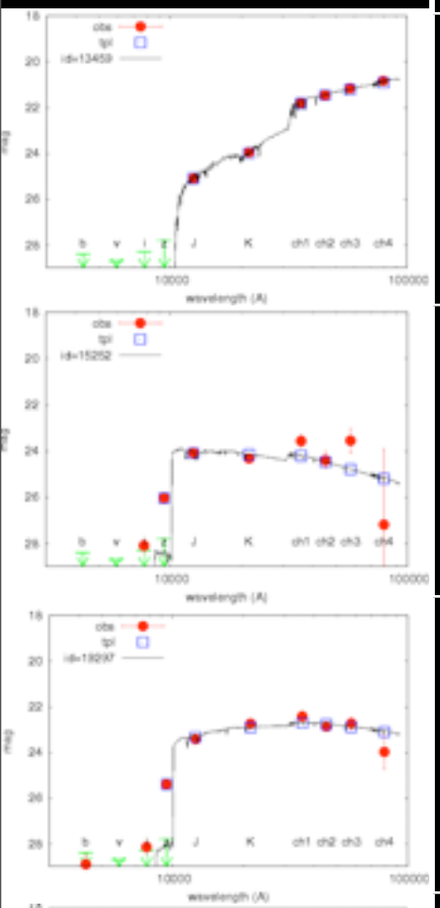
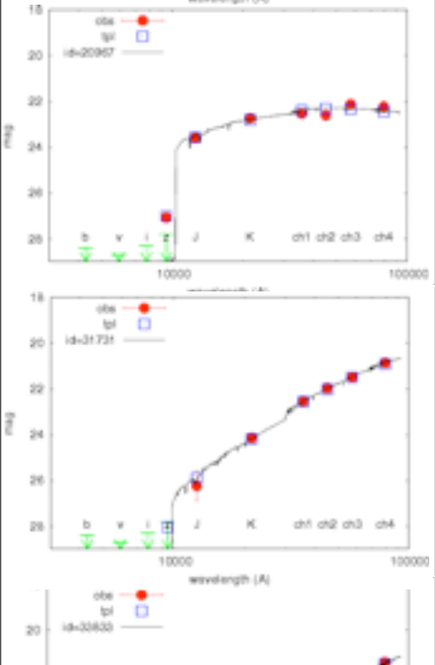



- To date most candidates at z>7 are selected in extremely deep pencil beam surveys with very small areas. Median-size but deep NIR surveys provide constrains in the part of LF 1-2 mag brighter than L*




**Courtesy of Haojing Yan**

| | z | chisq | 24um | X-ray | comment |
|---|---|---|---|---|---|
|  | 7.49 | 0.05 | 44.2 | no | z=6.5? |
|  | 7.33 | 2.99 | no | no | |
|  | 7.26 | 4.61 | no | no | z = 1.95? |
|  | 7.49 | 1.17 | 20.5 | no | z = 2.63? |
|  | 7.05 | 0.11 | 5.38 | 1.69E-15 | Has IRS 16 um detection; a z~4.35 AGN? |
|  | 8.15 | 0.29 | 20.9 | no | z = 3.85? |

| | z | chisq | 24um | X-ray | comment |
|---|---|---|---|---|---|
|  | 7.49 | 0.05 | 44.2 | no | z~6.5? |
|  | 7.33 | 2.99 | no | no | |
|  | 7.26 | 1.61 | no | no | z = 1.95? |
|  | 7.49 | 1.17 | 20.5 | no | z = 2.63? |
|  | 7.05 | 0.11 | 5.38 | 1.69E-15 | Has IRS 16 um detection; a z~4.35 AGN? |
|  | 8.15 | 0.29 | 20.9 | no | z = 3.85? |

# Summary

- Deep NIR data in GOODS-N allows for the studies of high-z dropout galaxies , and the star formation and clustering properties for BzK galaxies down to Ks~24 mag.

- There exist main sequence for star-forming galaxies at z~2. The star formation rate scales with the stellar mass. Preliminary analysis suggests that the specific star-formation rate does not depend on the stellar mass, as seen in z<1.

- The clustering amplitude depends on the K-band mag, stellar masses, and star formation rate, being stronger for brighter, more massive, and greater star formation rate systems.

- We found 6 candidates with NIR + photoz selection of z>7 galaxies, among which only one candidate is left after removing ones with 24 micron detection and unrealistic stellar masses.

*On-going Spitzer Warm Mission "SEDs" will yield 4 x larger samples. Stay Tuned!*

# Thanks !