First Light And Reionization Explorer

FLARE

FLARE — Science Case

First Light and Reionization

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Science Case: First Light and Reionization

Rychard Bouwens, Andy Bunker, Andrea Ferrara

Identification of the Brightest and Most Massive z~12-15 galaxies

Shape of UV LF at high redshift: Schechter vs. Power-Law

Tests of fixed SMHM evolution for predicting LF / MF evolution

Providing Targets for Spectroscopic Study with the EELTs

Look for other sources like GN-z11…

Constrain how fast UV LFs are evolving to z~14

Useful to consider Wider/Shallower Survey than Baseline Plan?

Identifying More Lensed z>12 Galaxies / Galaxy Clusters / Evolved Galaxies

Photometrically Identify Extreme Line Emitting Sources

[OIII], Lyalpha emitters, or pop III-type sources?

Identification of relatively bright quasars at z>8 to probe damping wing in IGM

Discovery of Evolved Galaxies at Very Early Times…

Discovery of the Earliest / Most Massive Clusters

Discover pair instability SNe from earliest stars?

Repeated Regions?

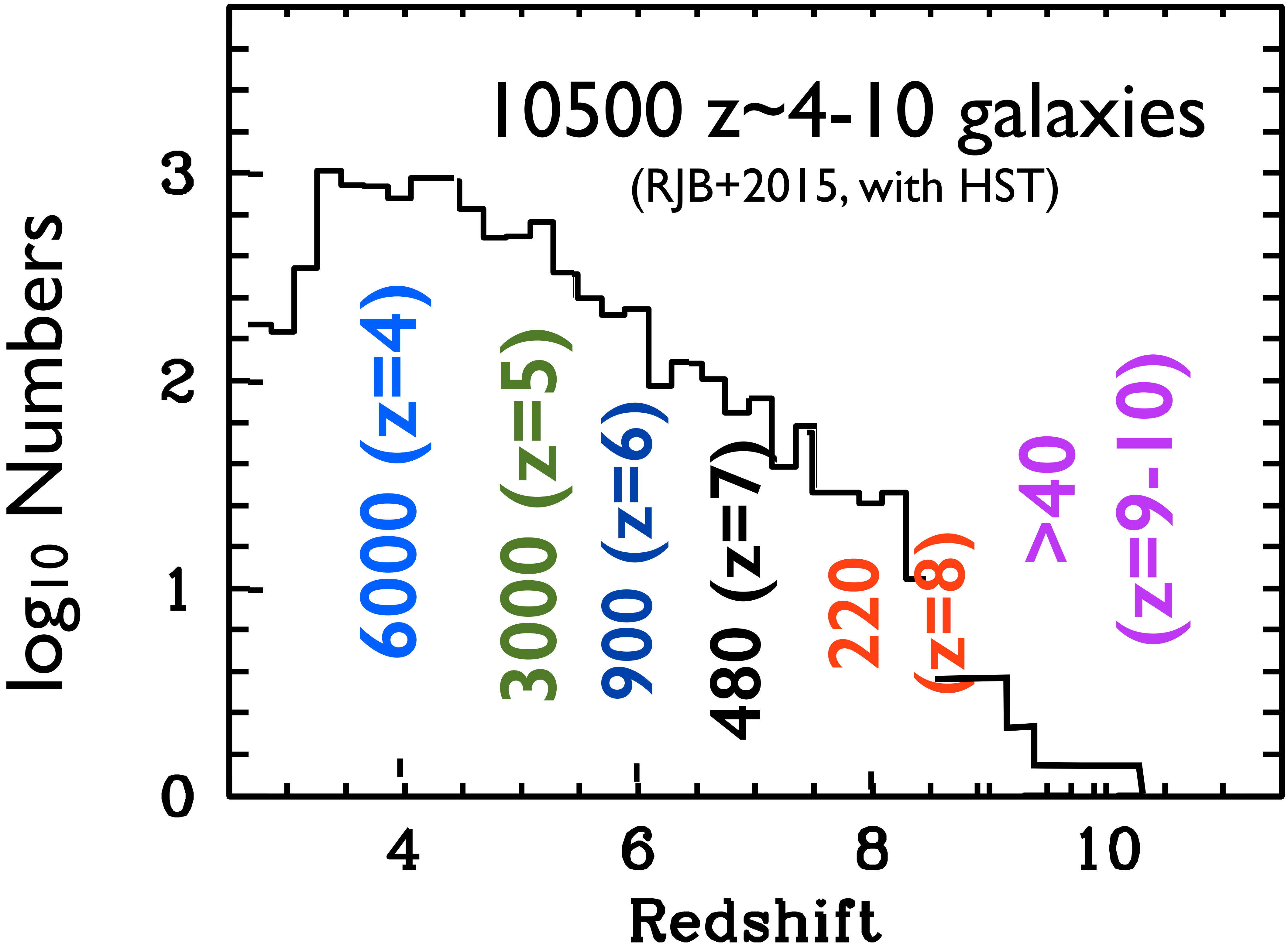
Probe the Power Spectrum from Faintest Early Galaxies to Very Large Scales

Science Case

Characterize Bright Galaxies at the Earliest Times

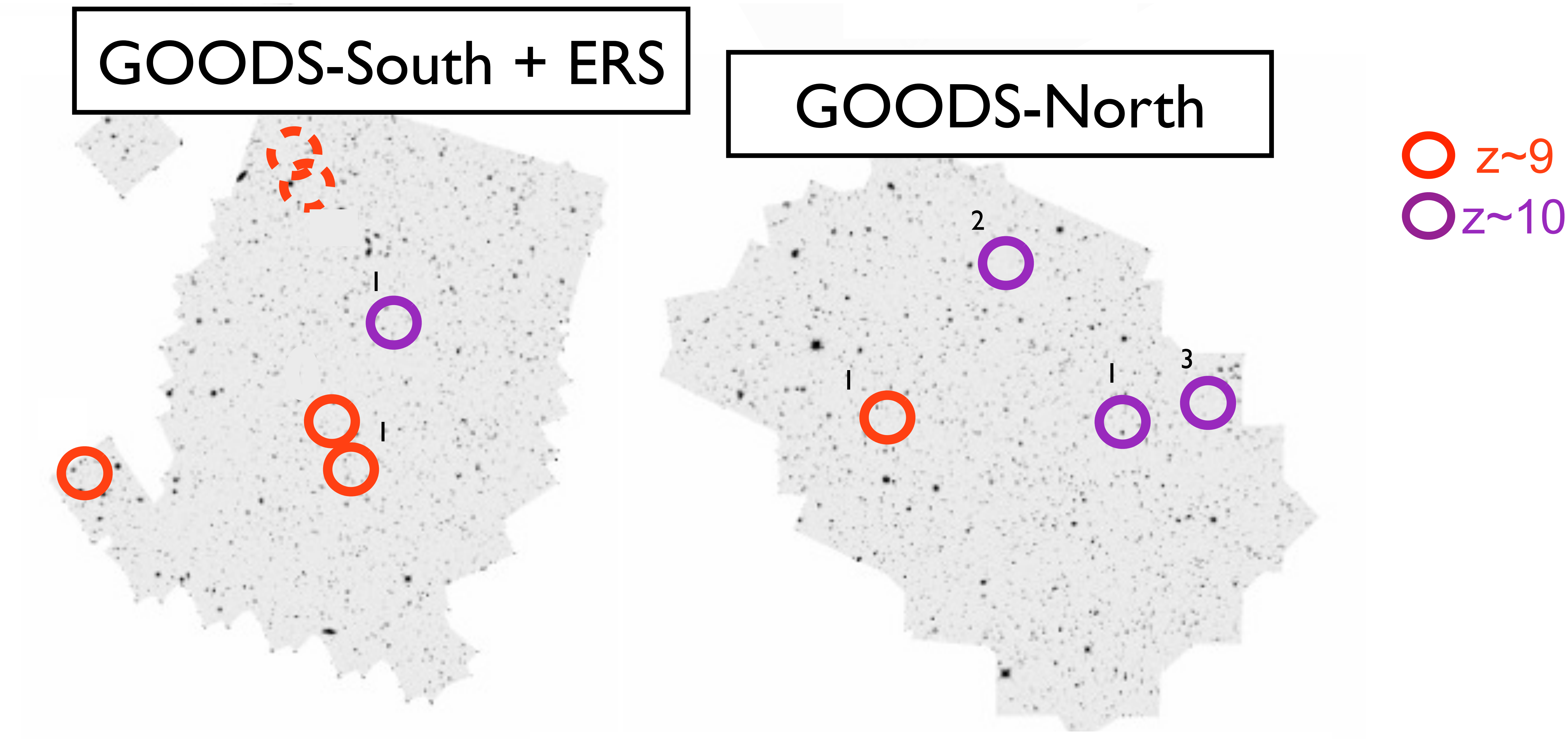
How many galaxies are expected?

How many galaxies can we find at high redshifts?



(wide-area ground-based data adds more!)

z=9-10 Sample over CANDELS



10 z=9-10 galaxies

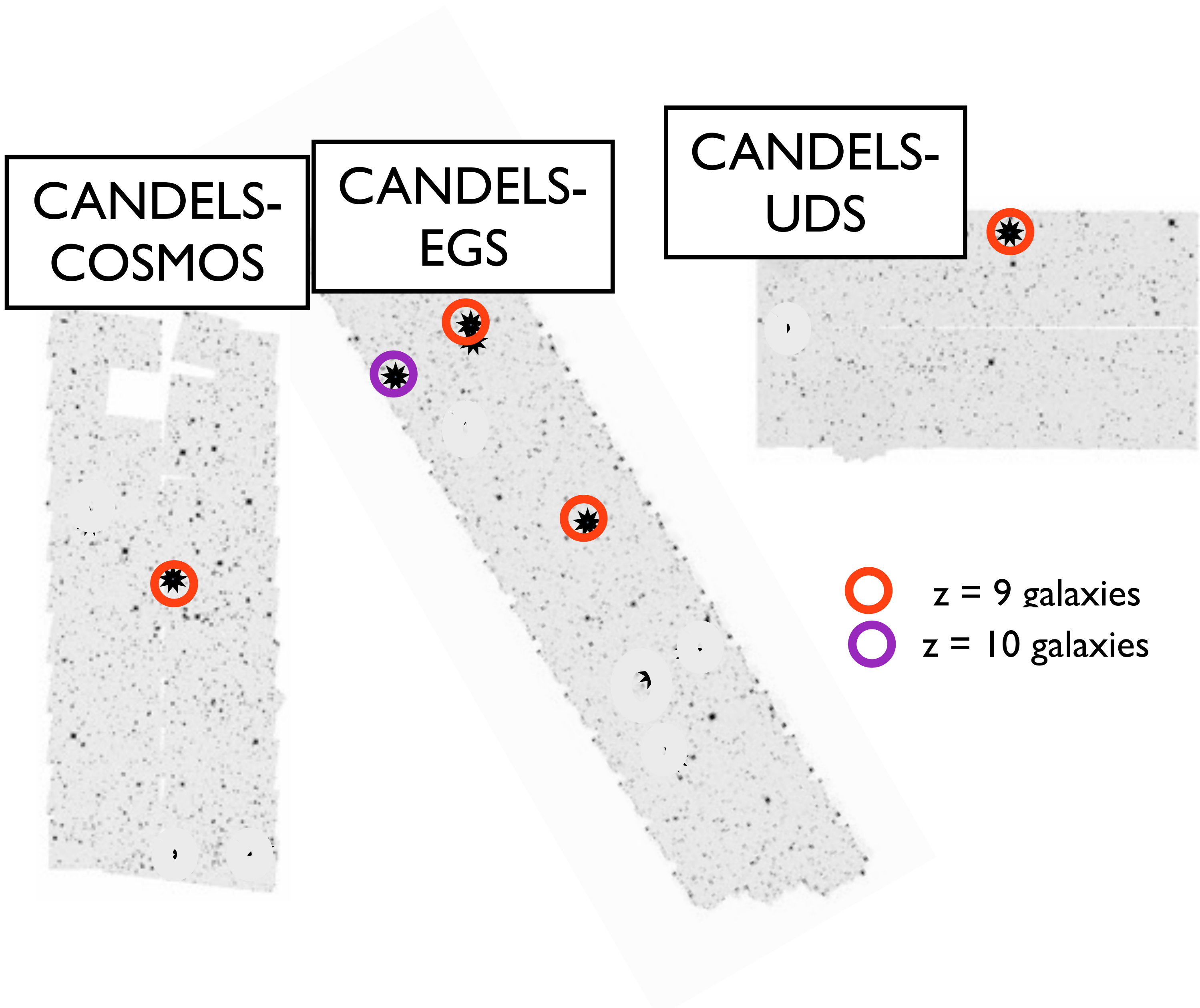
Oesch+2014/Bouwens+2015

z=9-10 Sample over CANDELS

Use Full HST,
Spitzer/IRAC,
Ground-Based Optical
+ Near-Infrared Data
to Identify best z=9-10
candidate galaxies

+

Targeted Follow-Up
Observations with HST
(B9-CANDELS)



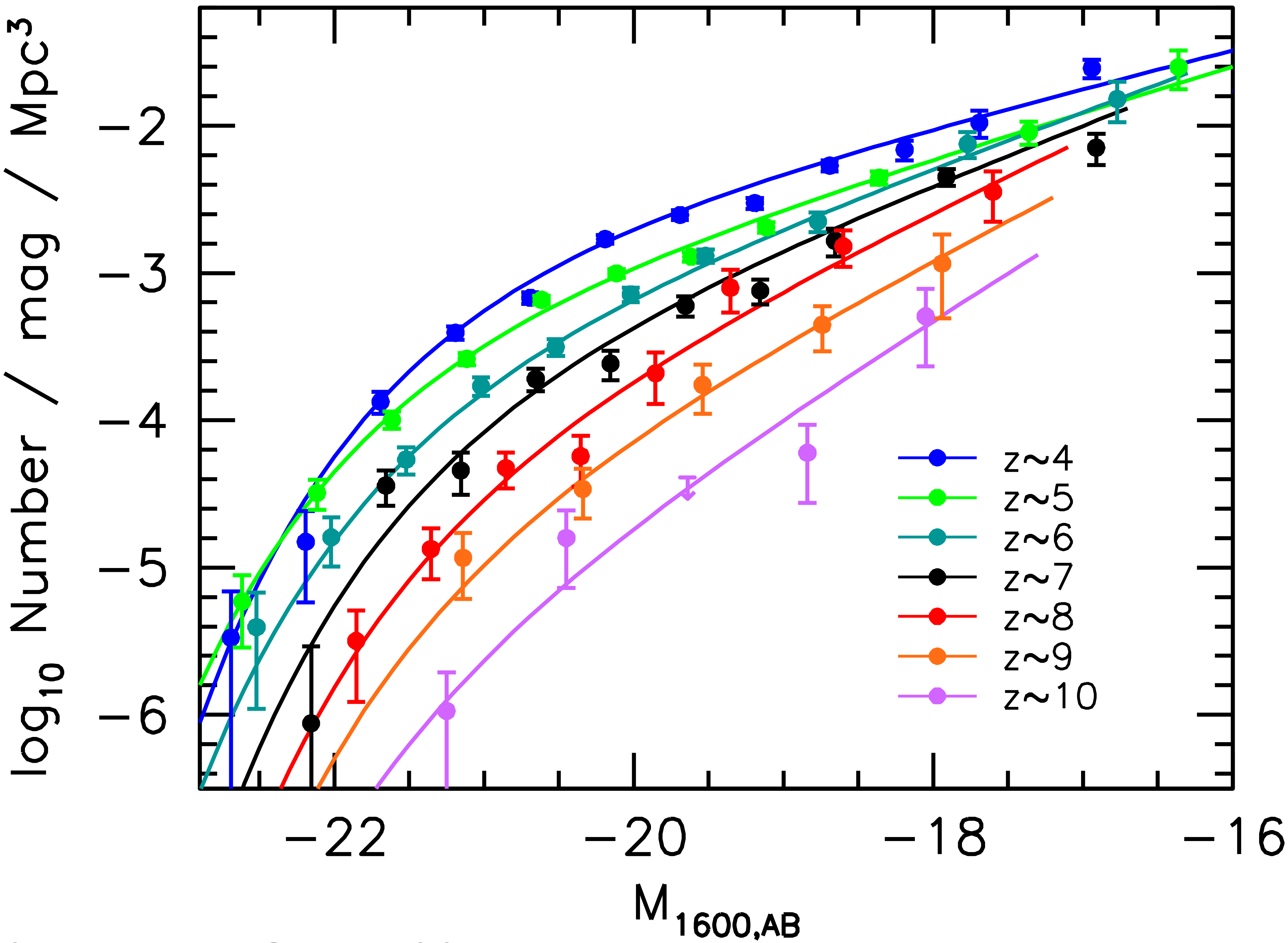
5 more z=9-10 galaxies (after follow-up)

Bouwens+2015

15 z=9-10 galaxies

How does the luminosity function evolve?

(HUDF/XDF, parallels, 5 CANDELS Fields, 4 Frontier Fields)



RJB+2015, in prep; Oesch+2015, in prep

Model Physics

Independent of Halo Mass

Ingredient #1: Higher Redshift Halos Must Be Brighter
(Star Formation More Efficient)

Independent of Redshift / Cosmic Time

Ingredient #2: Faint-Slope Shallower than in Halo-Mass Function,
M_{halo}/L_{UV} higher for fainter galaxies, due to SNe feedback

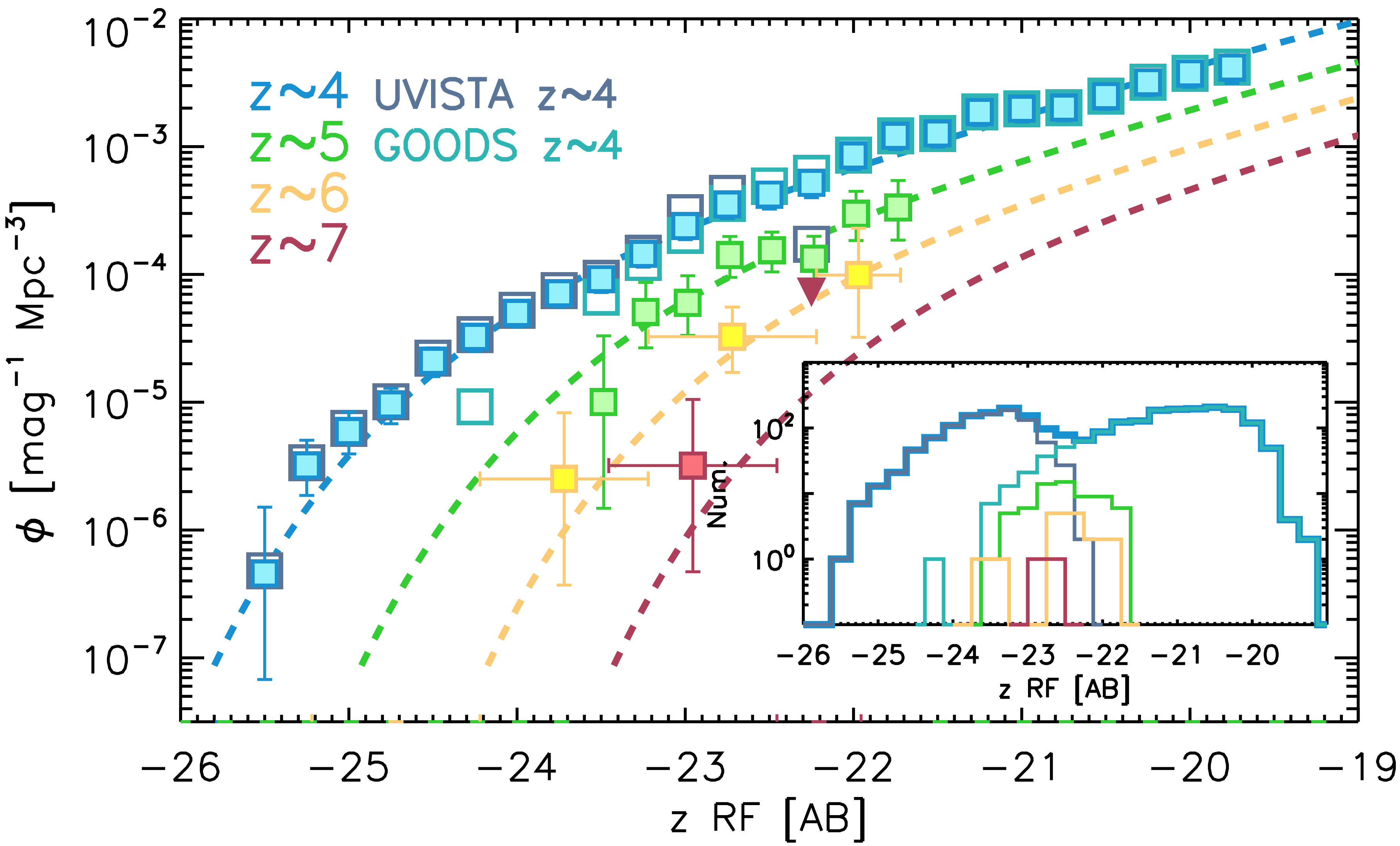
Ingredient #3: Must be a Cut-off at the Bright End of the Luminosity Function above some Fixed Mass (Quenching / Dust Extinction)

Both ingredient #2 and #3 assume no evolution in SMHM relation seen at z~0 to z~3…

Model Physics

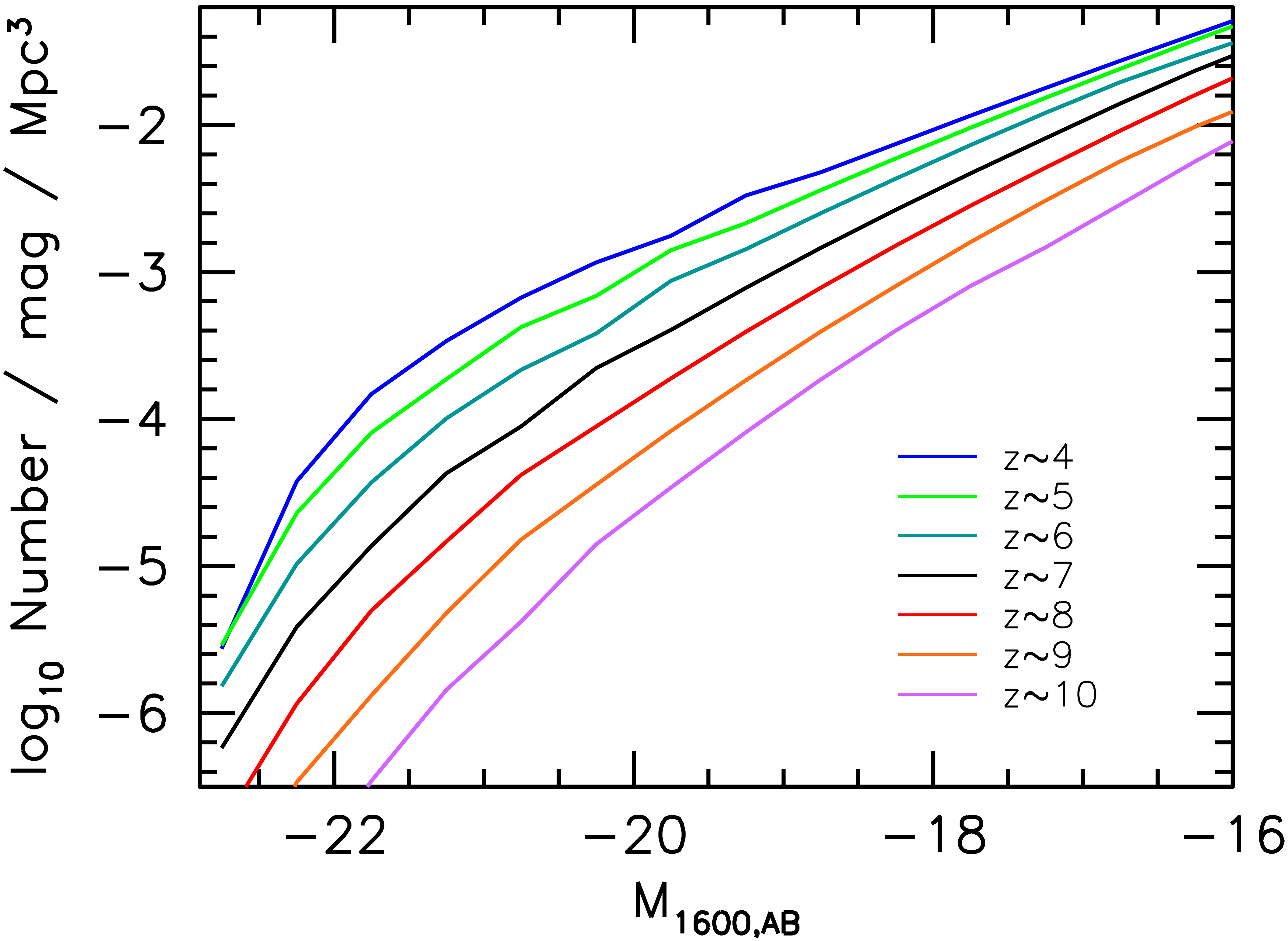
Also no obvious evolution in SMHM relation from z~7 to z~4
(i.e., no evolution in baryon fraction)

Rest-frame optical LF (constructed from IRAC 5.8+8.0 data shows same evolution as expected for halo mass function



Stefanon+2016 (similar results implied by Grazian+2015 galaxy stellar mass function)

Model z=4-10 UV Luminosity Functions



How does the luminosity function evolve?

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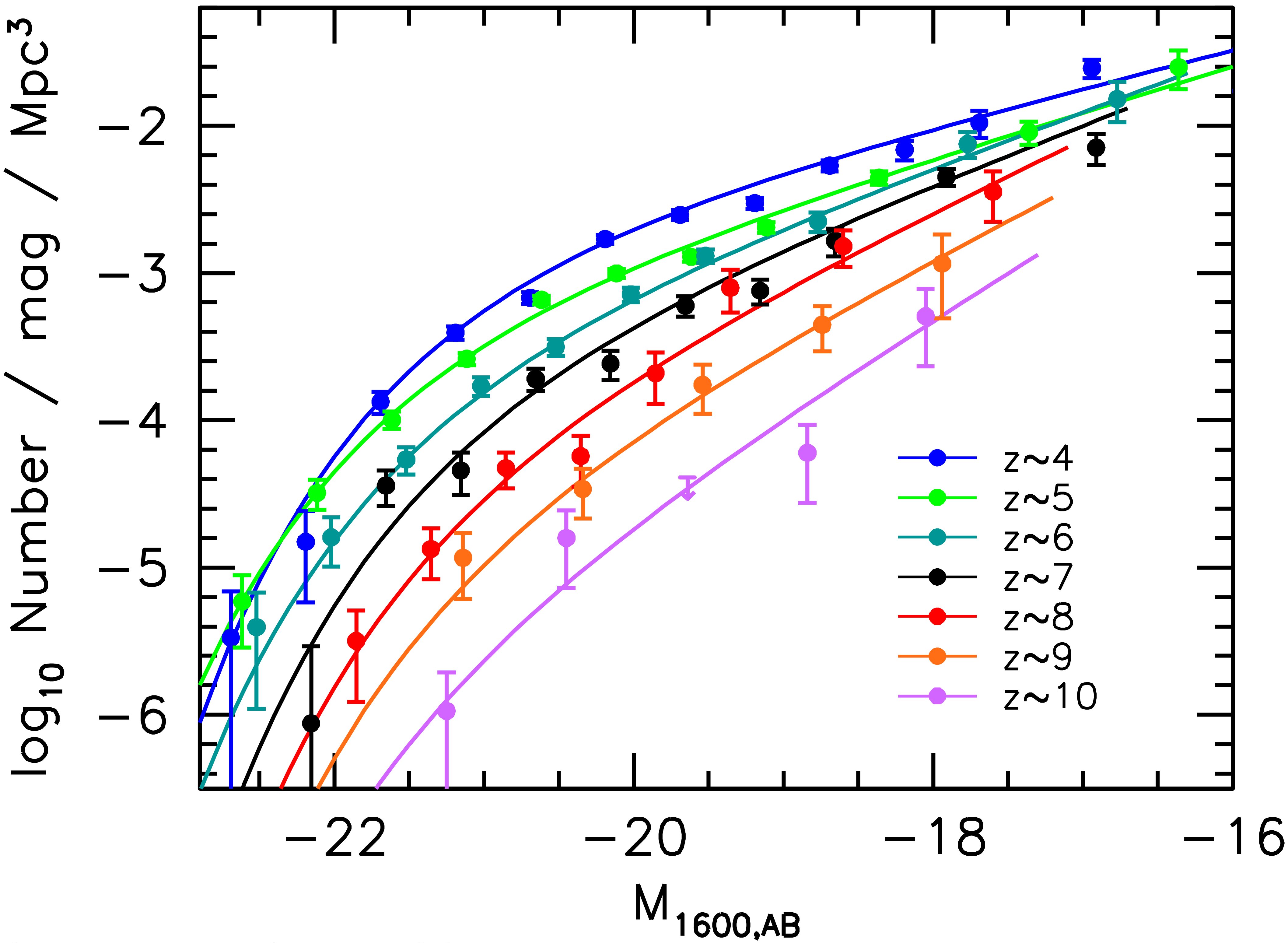

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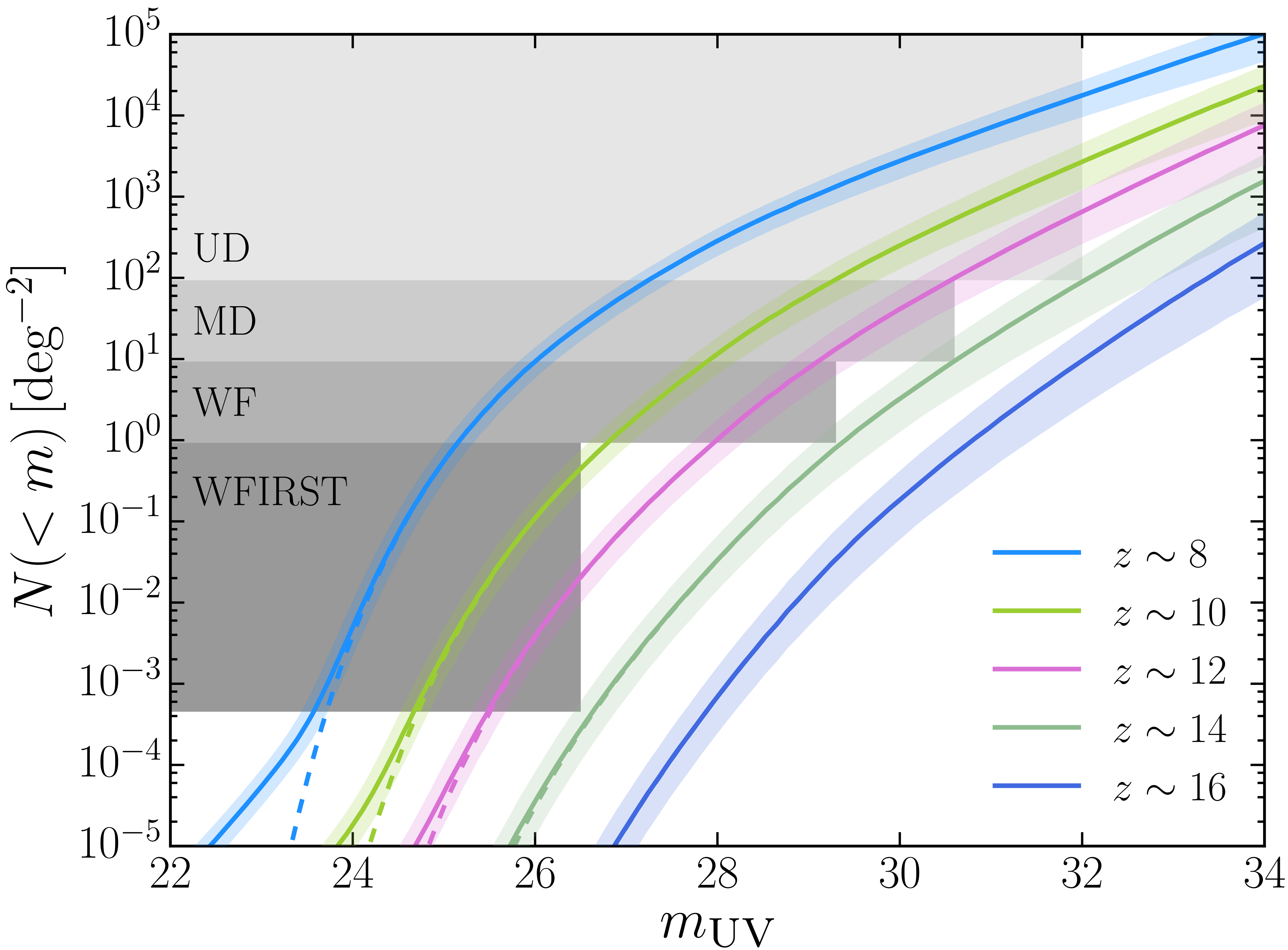
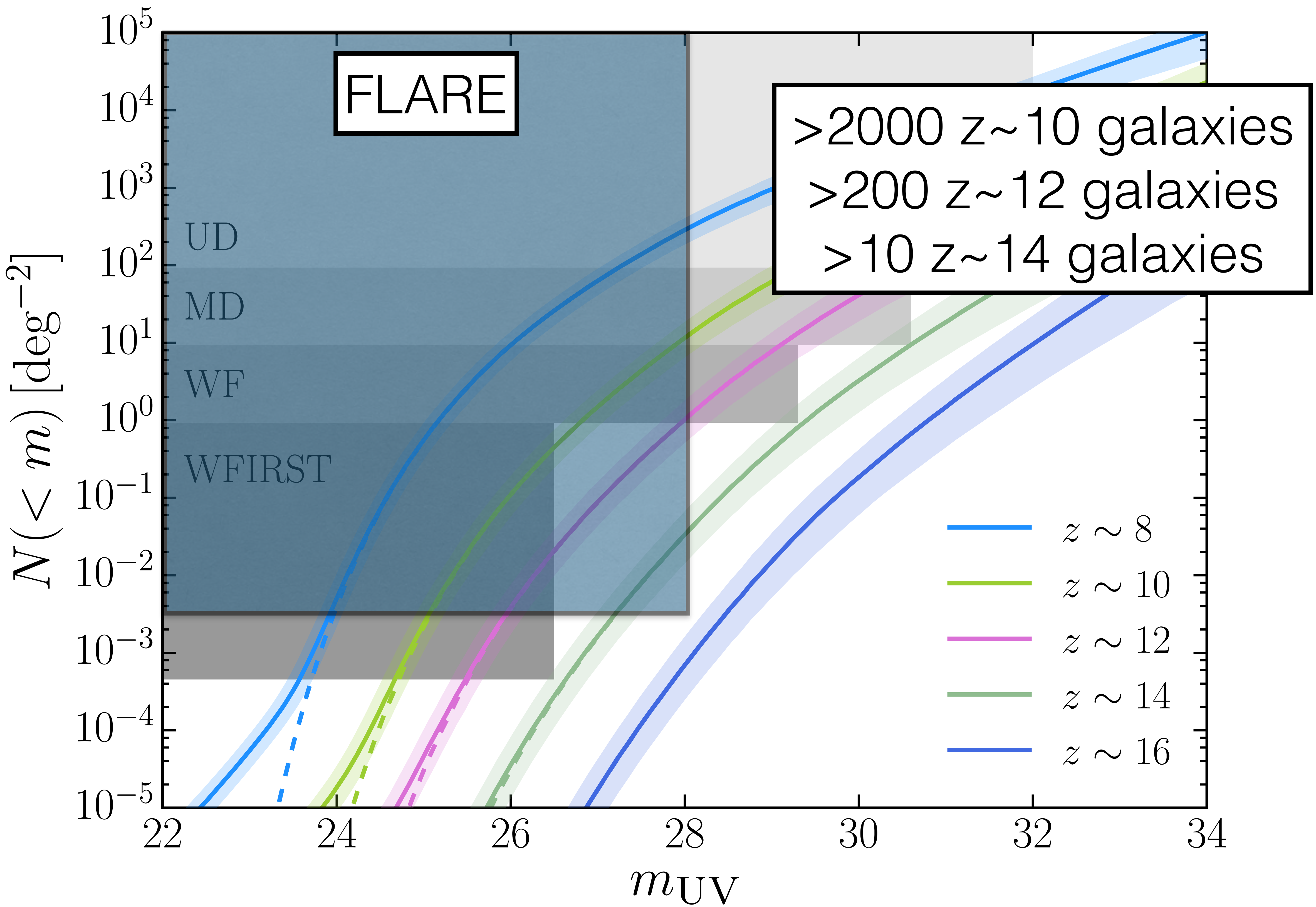
How many galaxies will we find?

JWST…
WFIRST…
FLARE…


UD
MD
WF
WFIRST
$z \sim 8$
$z \sim 10$
$z \sim 12$
$z \sim 14$
$z \sim 16$
$N(<m)\,[\mathrm{deg}^{-2}]$
m_{UV}

Mason+2015



FLARE
>2000 z~10 galaxies
>200 z~12 galaxies
>10 z~14 galaxies
UD
MD
WF
WFIRST
$z \sim 8$
$z \sim 10$
$z \sim 12$
$z \sim 14$
$z \sim 16$
$N(< m)\,[\mathrm{deg}^{-2}]$
m_{UV}

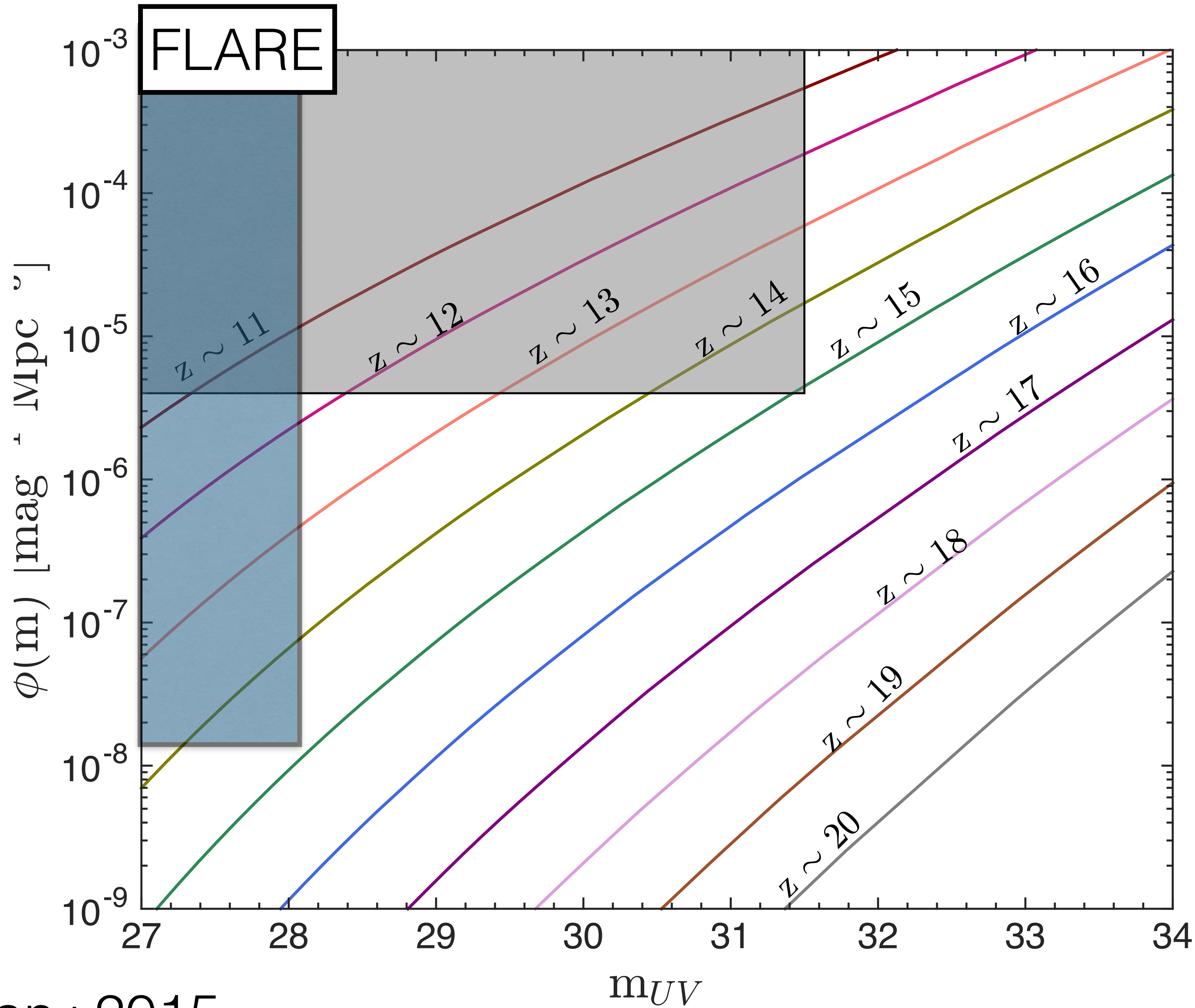
Mason+2015

Gains relative to WFIRST depend a bit on how red WFIRST can probe…

If WFIRST probes to only 2 microns, WFIRST may only efficiently find bright galaxies to z~10-12…

If WFIRST probes to 2.2 microns, WFIRST may allow for the discovery of bright galaxies to z~13+

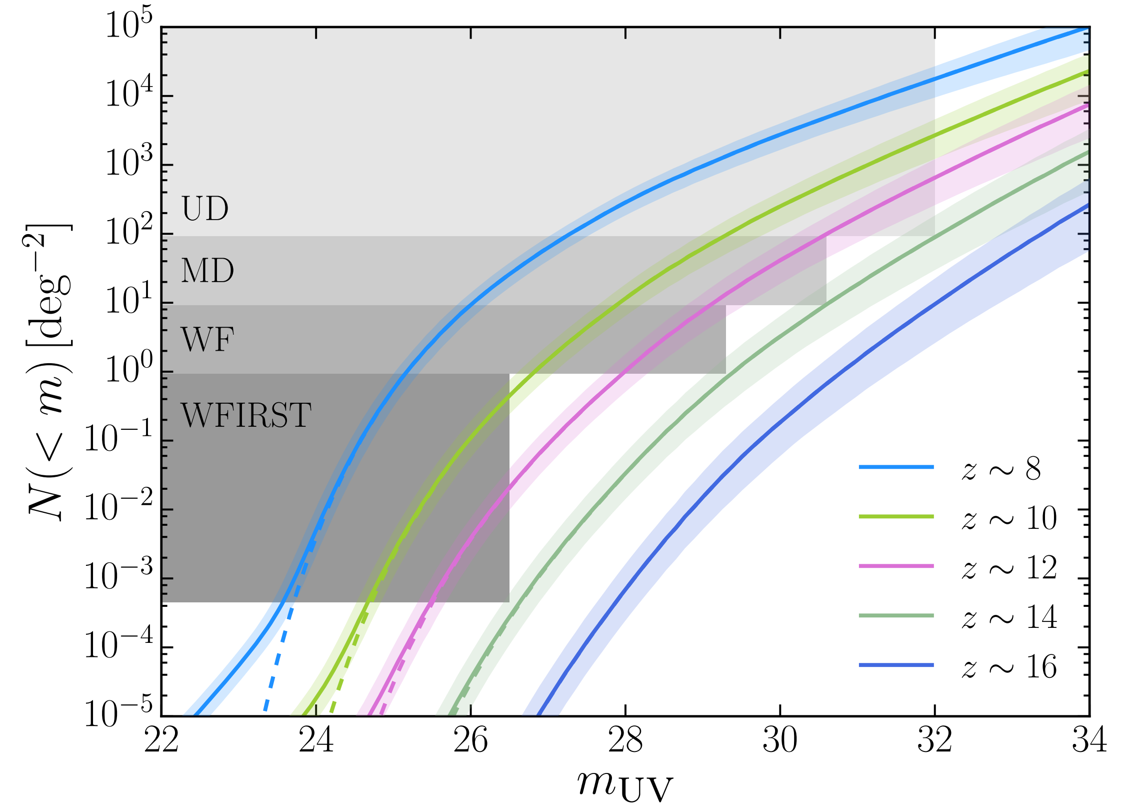
Independent but similar predictions by Mashian +2015 model



Mashian+2015

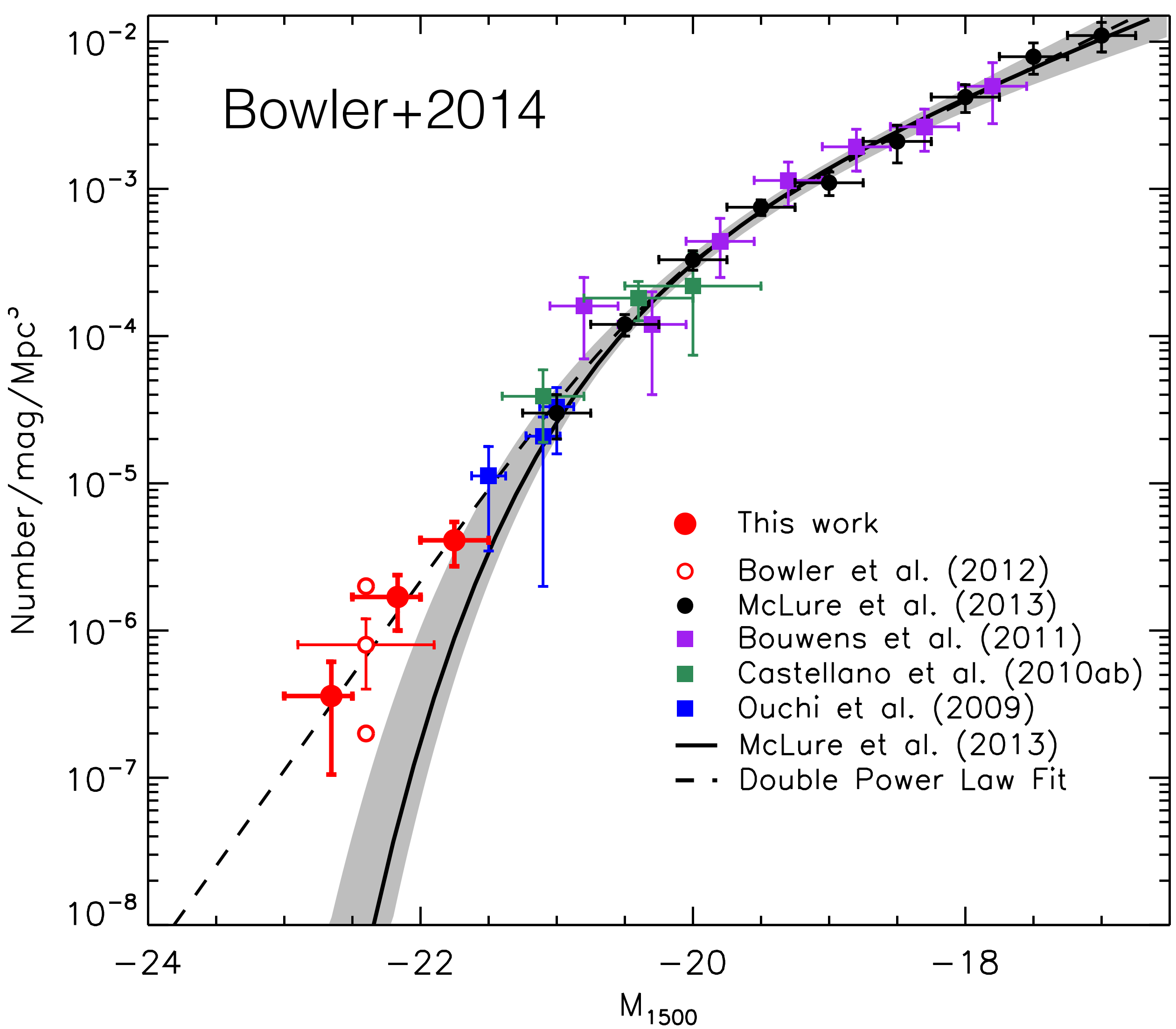
What is the science case?

FLARE will directly determine whether the simple halo model works to z > 10….

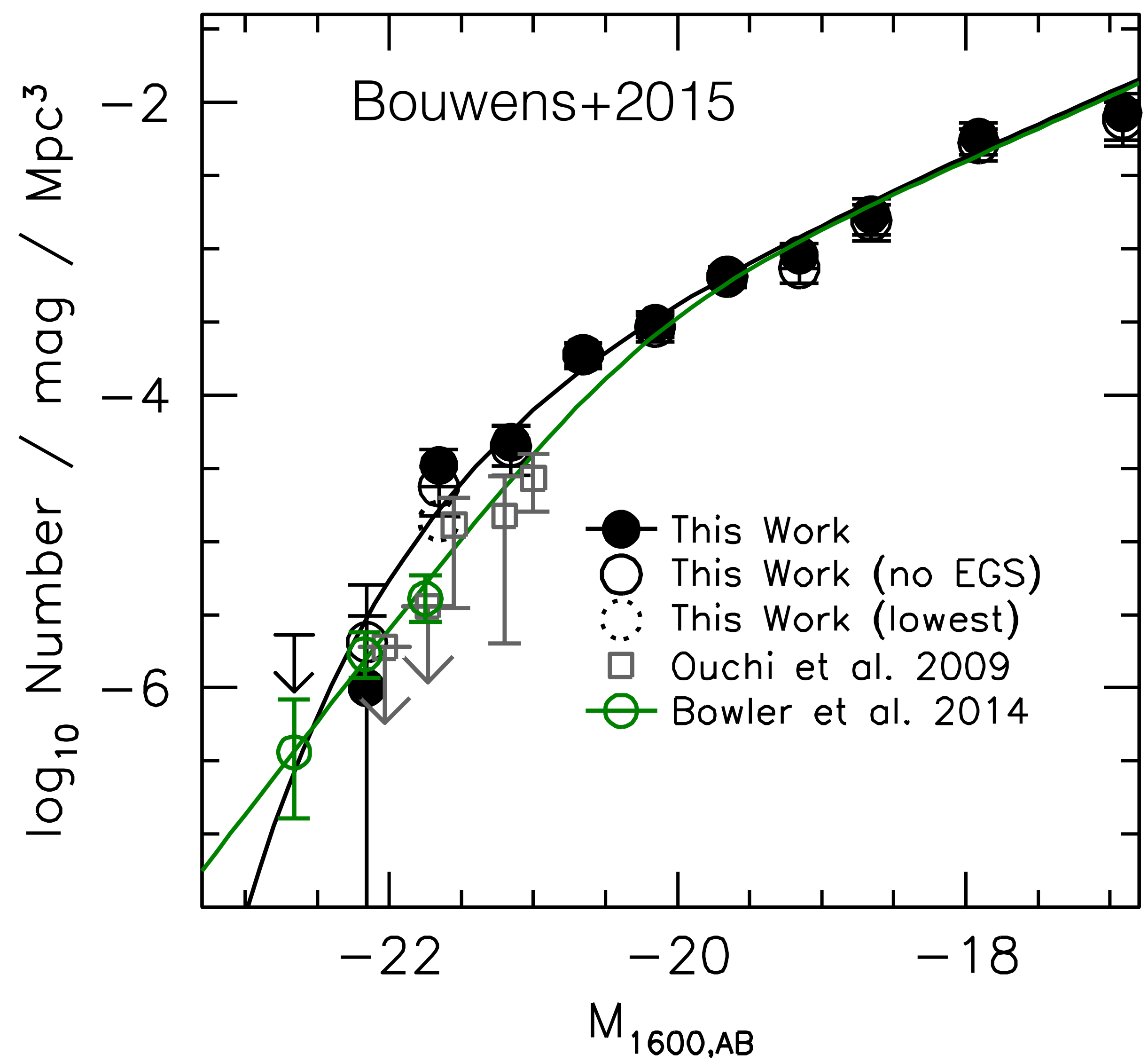


What is the science case for bright z>7 galaxies?

Shape of the UV LF…



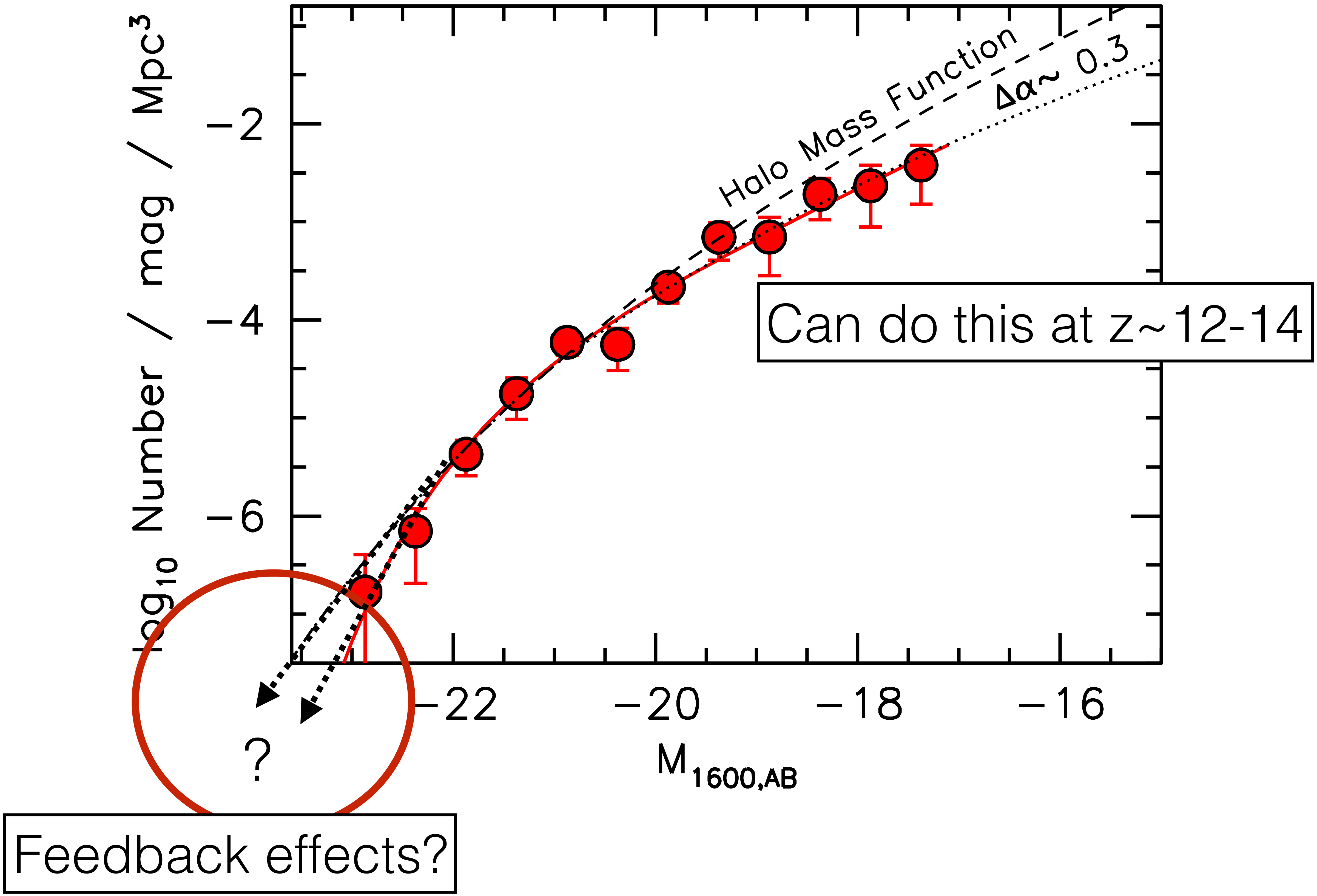
Double Power-Law?



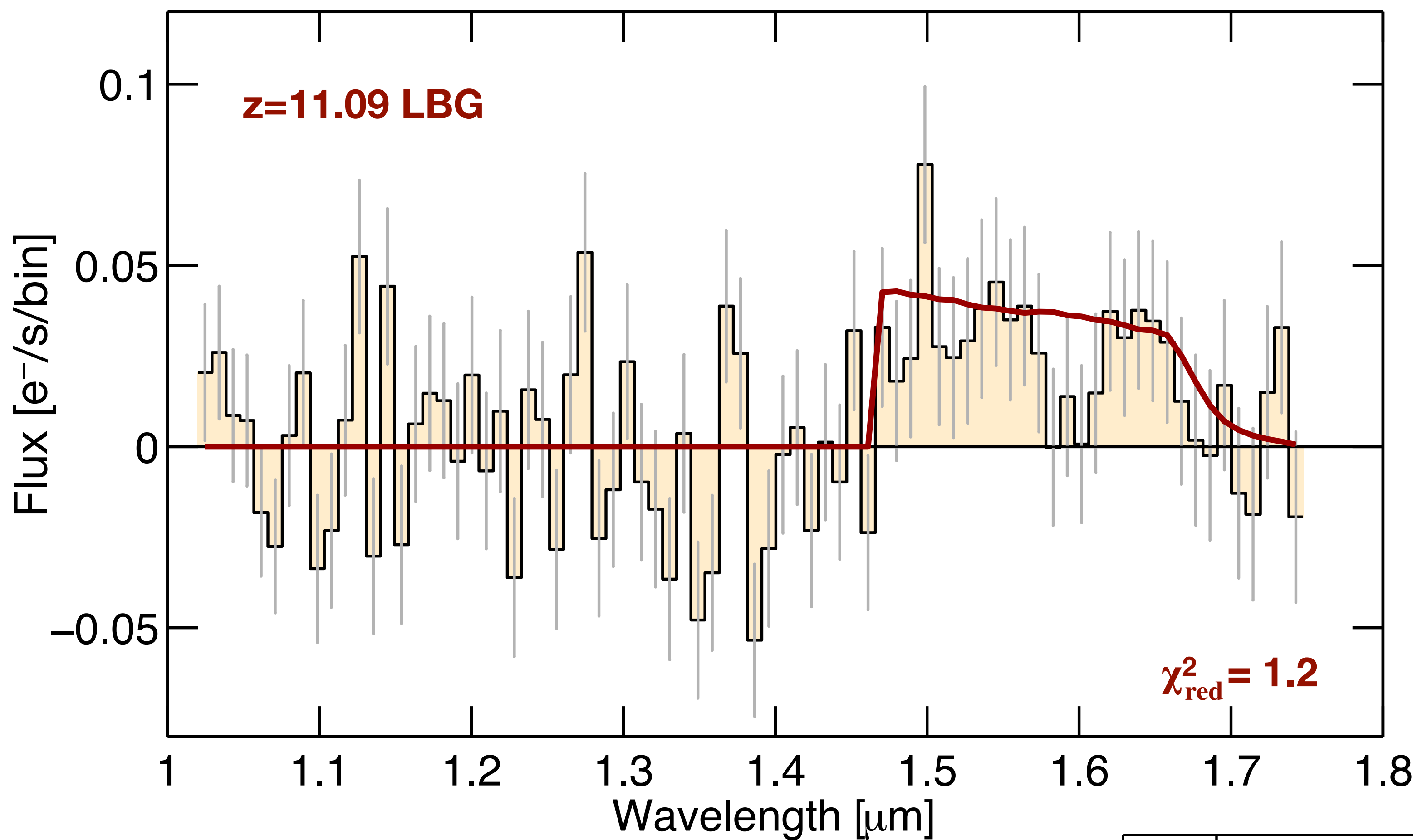
Schechter?

What is the science case for bright z>7 galaxies?

Does the UV LF look like the halo mass function?

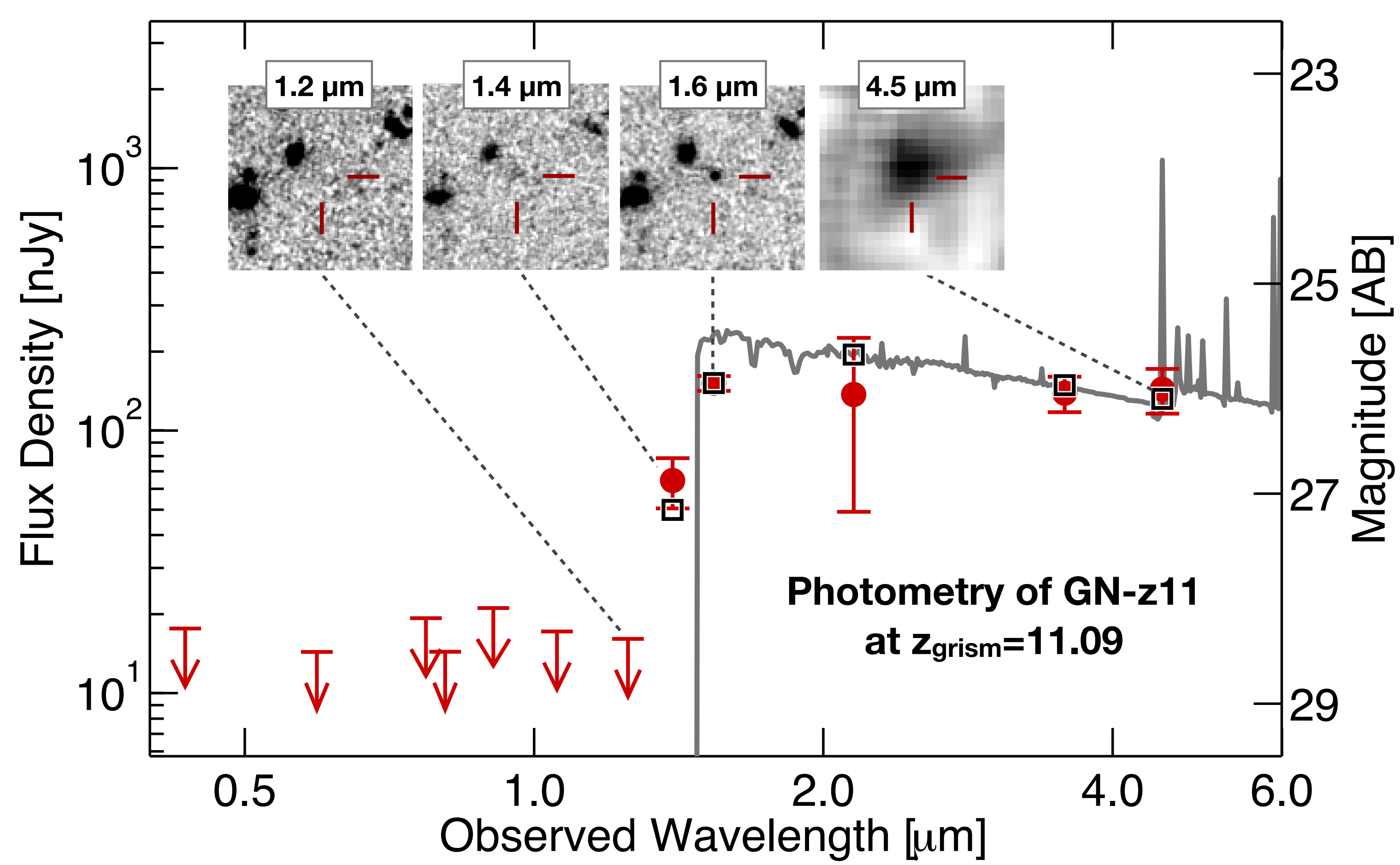


Investigate analogues to one very bright z~11 source



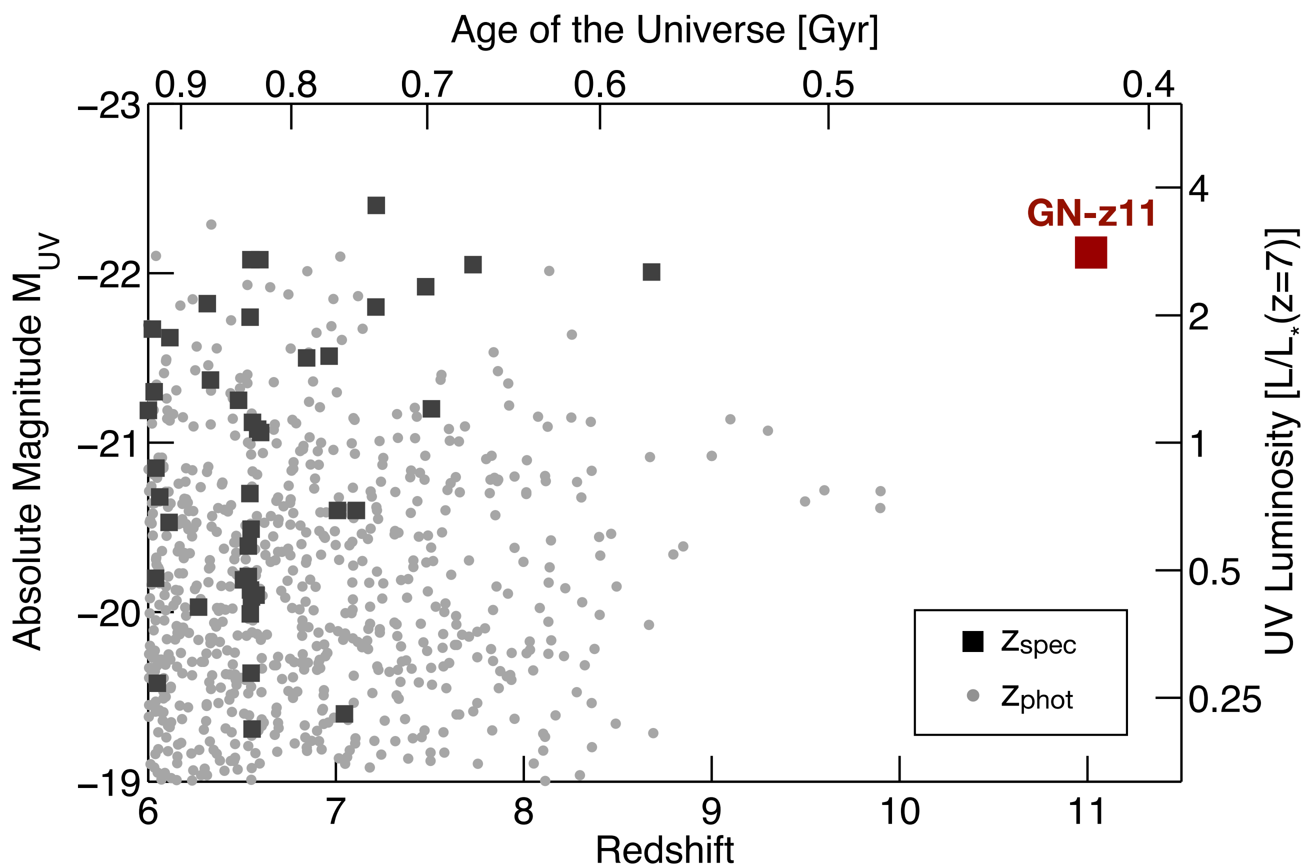
Formally -22 mag,
3 L*(z=3)

Could GN-z11 be typical?

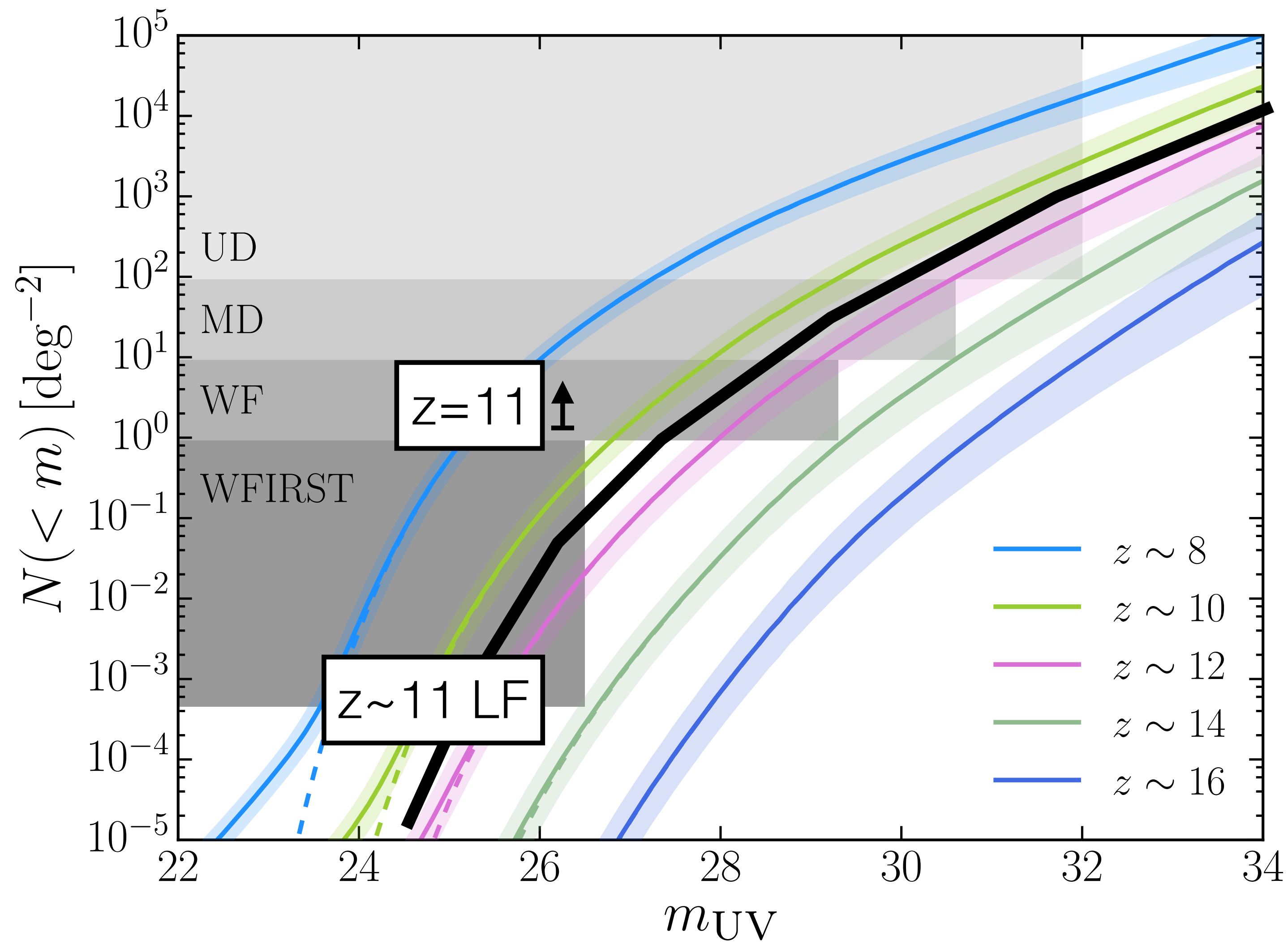


Oesch+2016

Investigate analogues to one very bright z~11 source

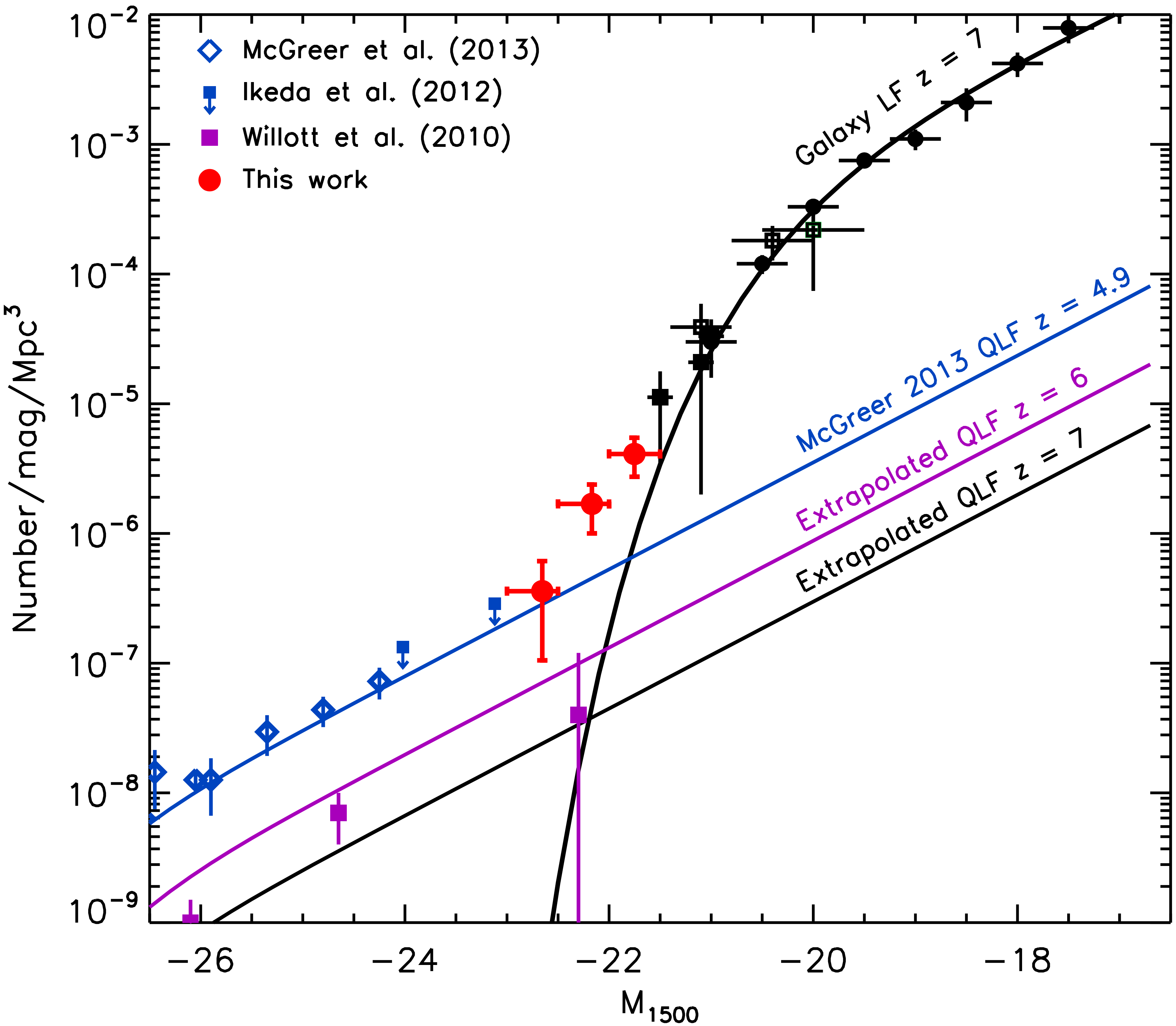


Mason+2015



Oesch+2016

Probe Interface between Galaxy and Quasar LF at very high redshifts



Different Functional Form for Quasar LF and Galaxy LF

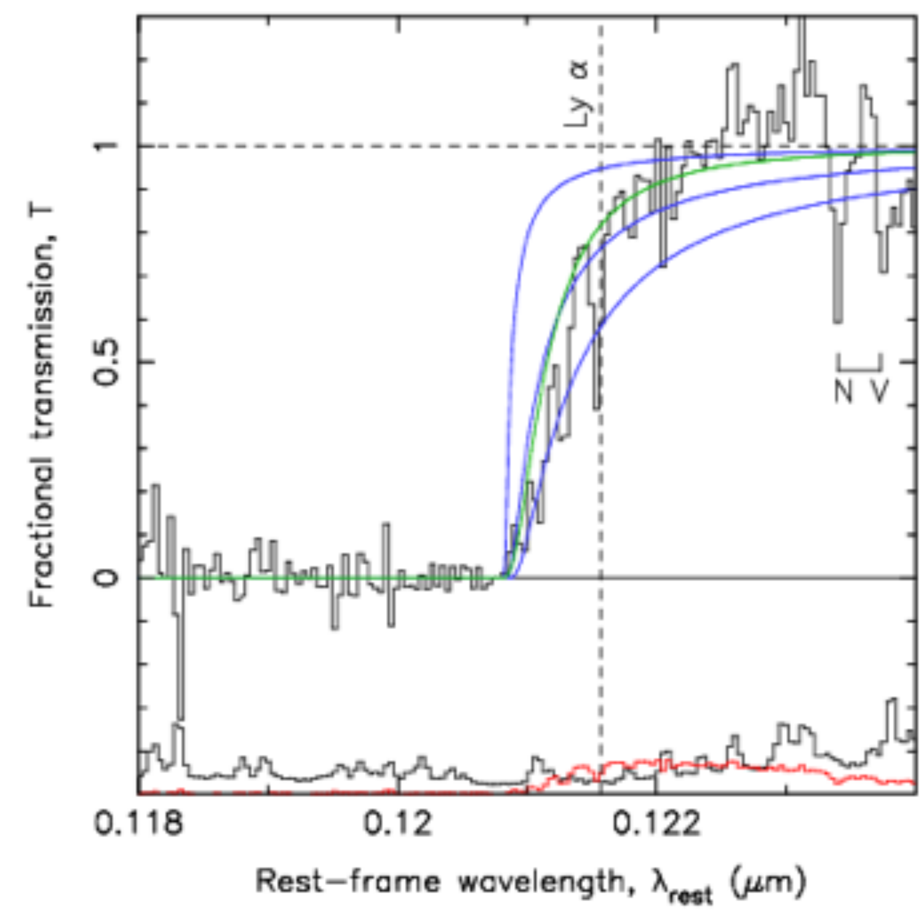
Would be scientifically very interesting to probe the interface

Bowler+2014

How can FLARE improve our constraints on reionization?

Faint galaxies dominate the UV luminosity density… but these are best probed by JWST… so it may not help significantly there

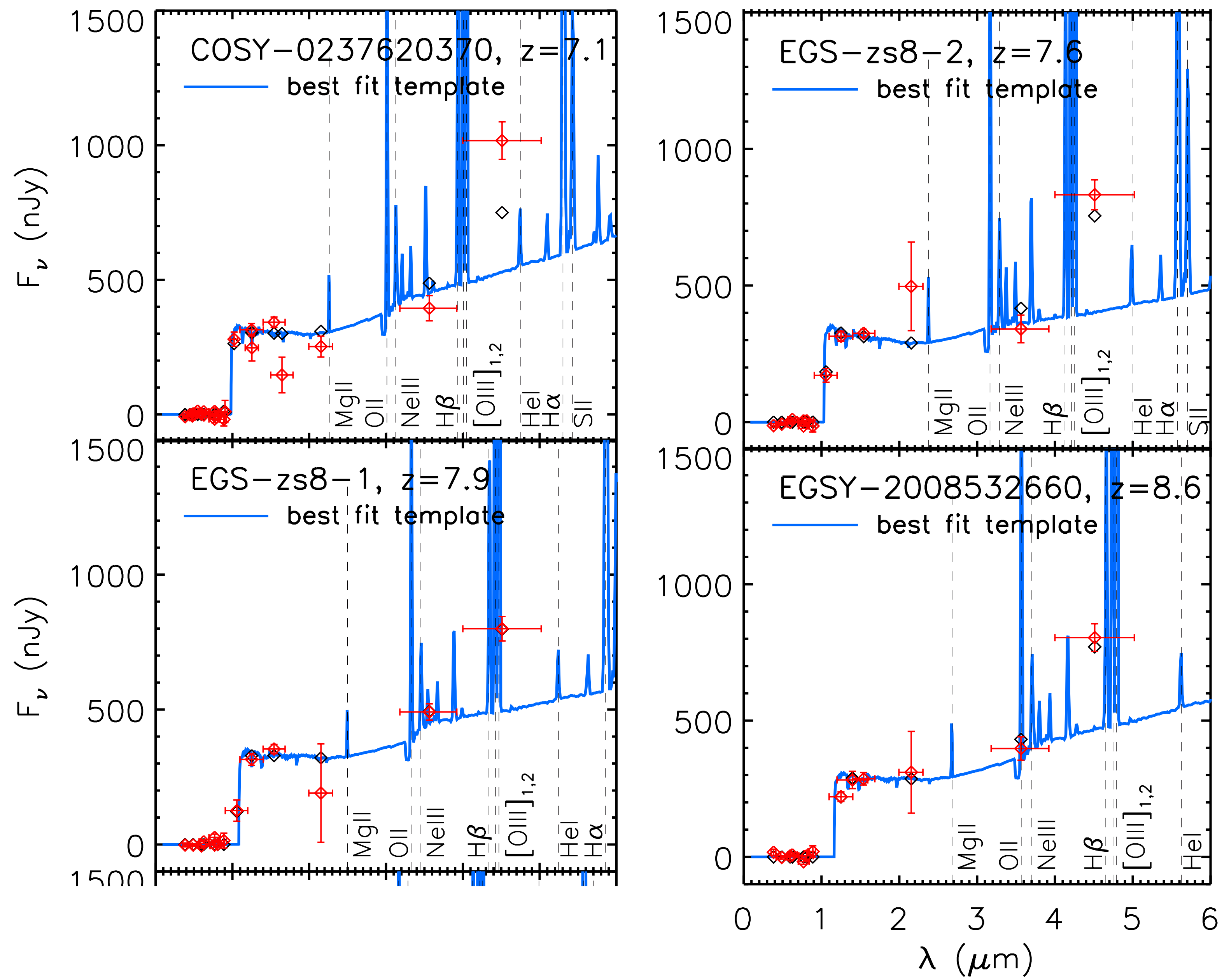
FLARE, however, could be useful in finding bright z~8-10 quasars that could probe the Gunn Peterson damping wing of Lyman-alpha



Mortlock+2014

Identify z>7 Sources with Extreme Line Emission Dominating Individual Bands

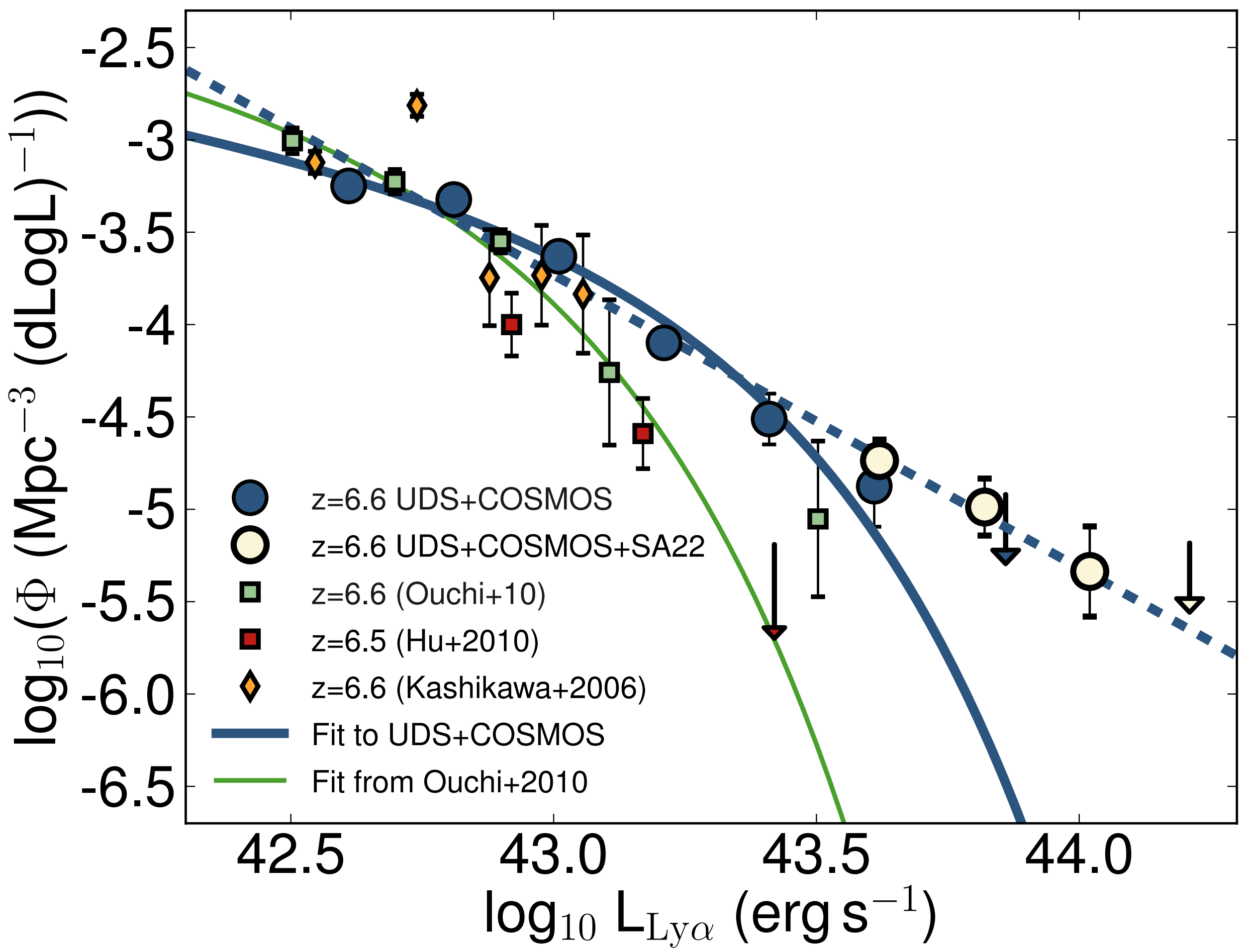
Should be able to identify loads of bright systems significantly more extreme than these…

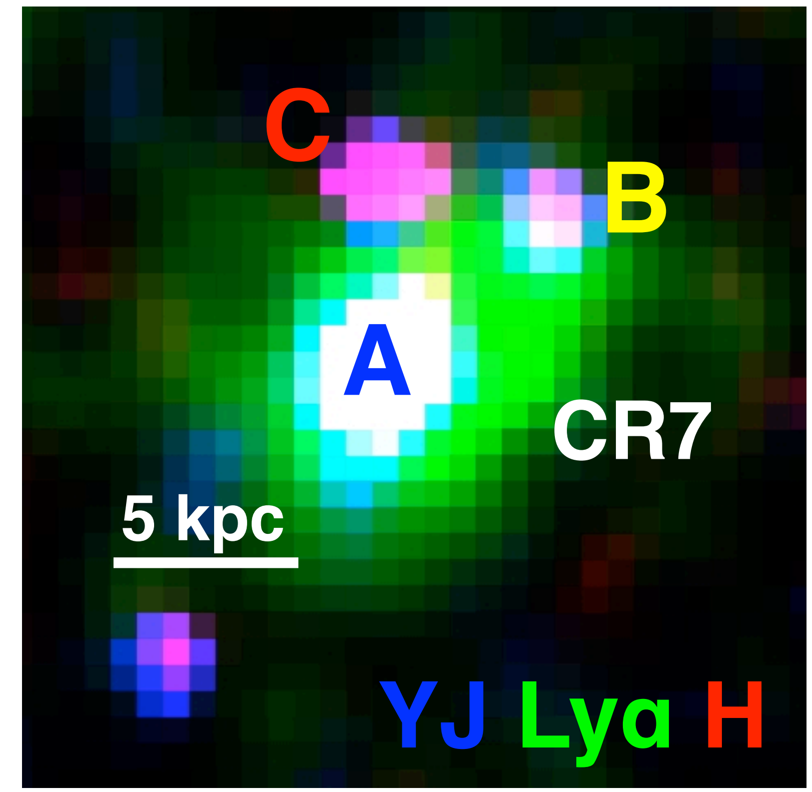


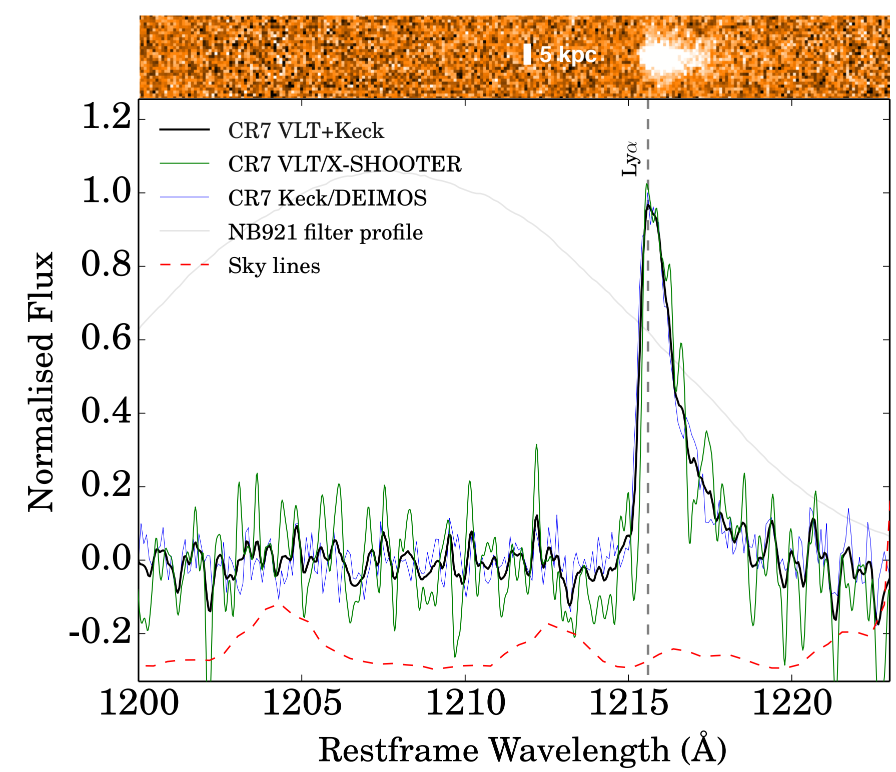
e.g. Roberts-Borsani+2015

Identify z>7 Sources with Extreme Line Emission Dominating Individual Bands

Extremely Bright Lyalpha emitters

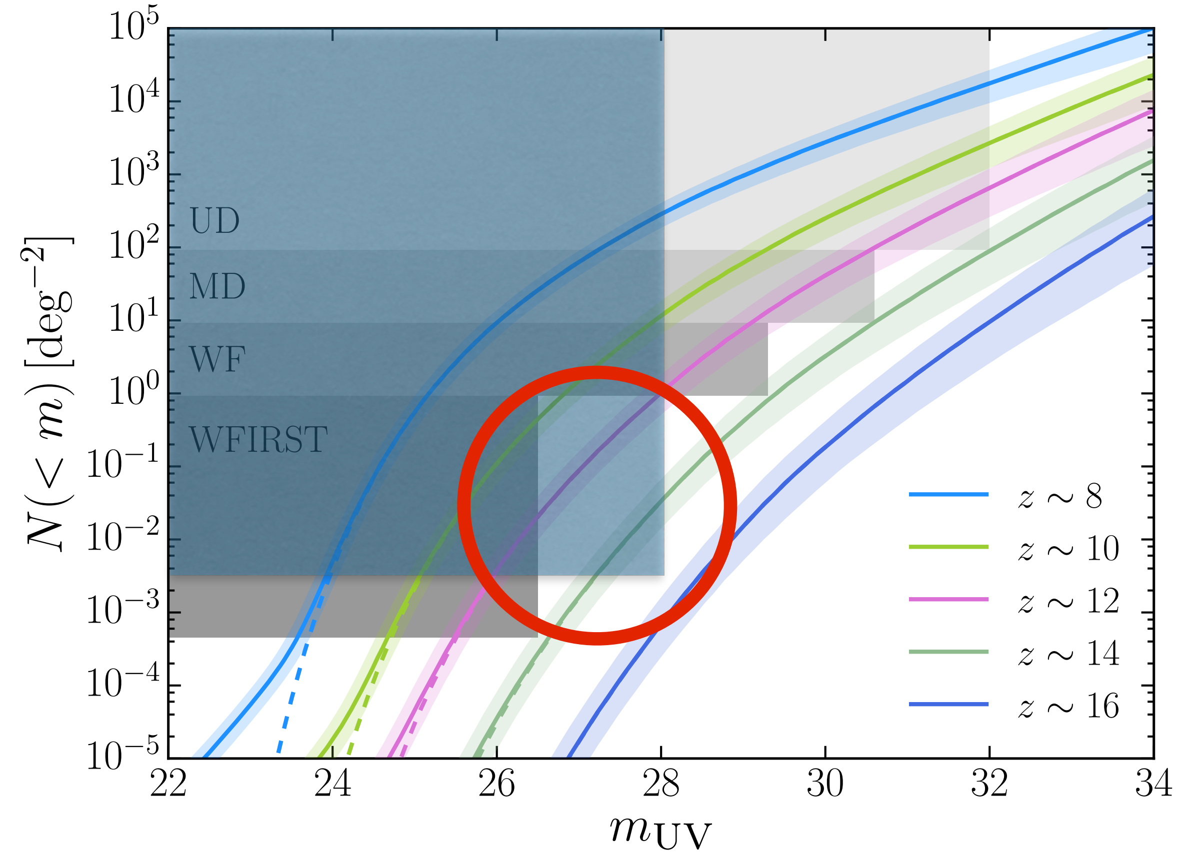




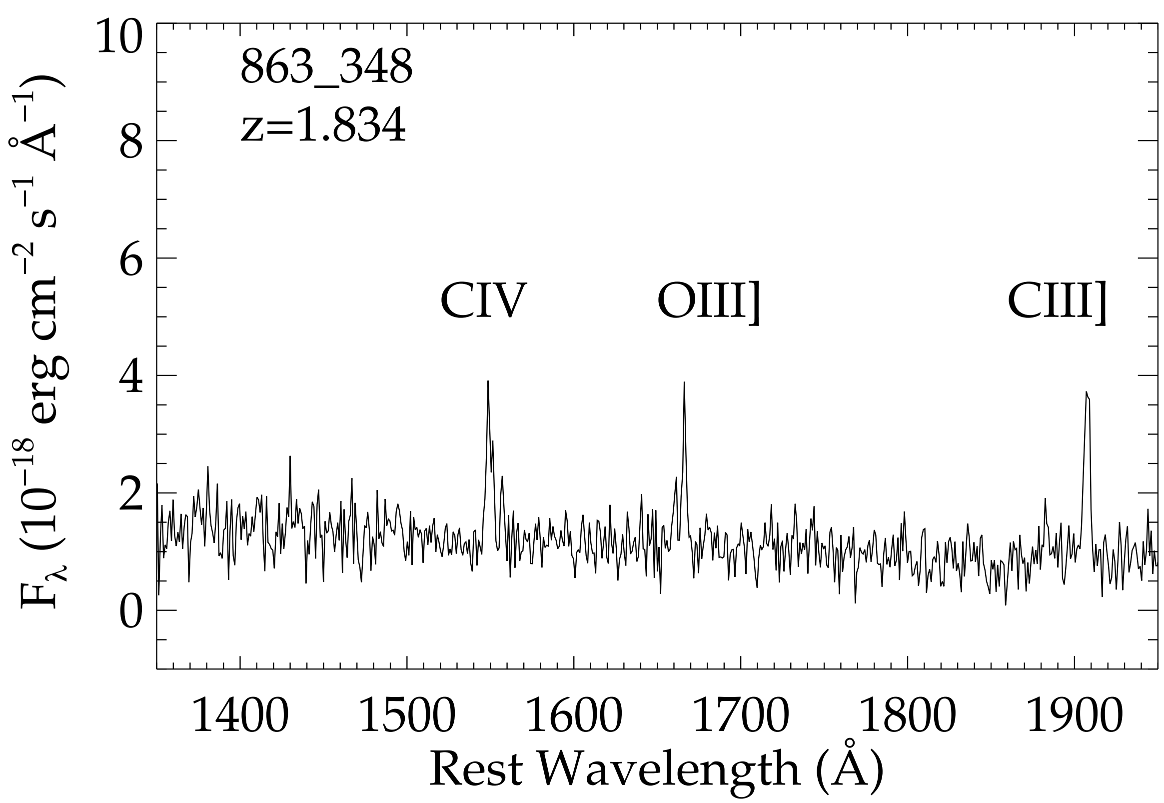


Matthee+2015; Sobral+2015

Identification of very bright high-redshift sources allows us to pursue spectroscopy on select number of very bright z~14 galaxies



Mason+2015



Enables detailed follow-up studies of high-ionization UV lines in rare sources to z~14… metallicity, density of nebulae with various EELTs…

Stark+2014

Build-up of Quenched Galaxies?

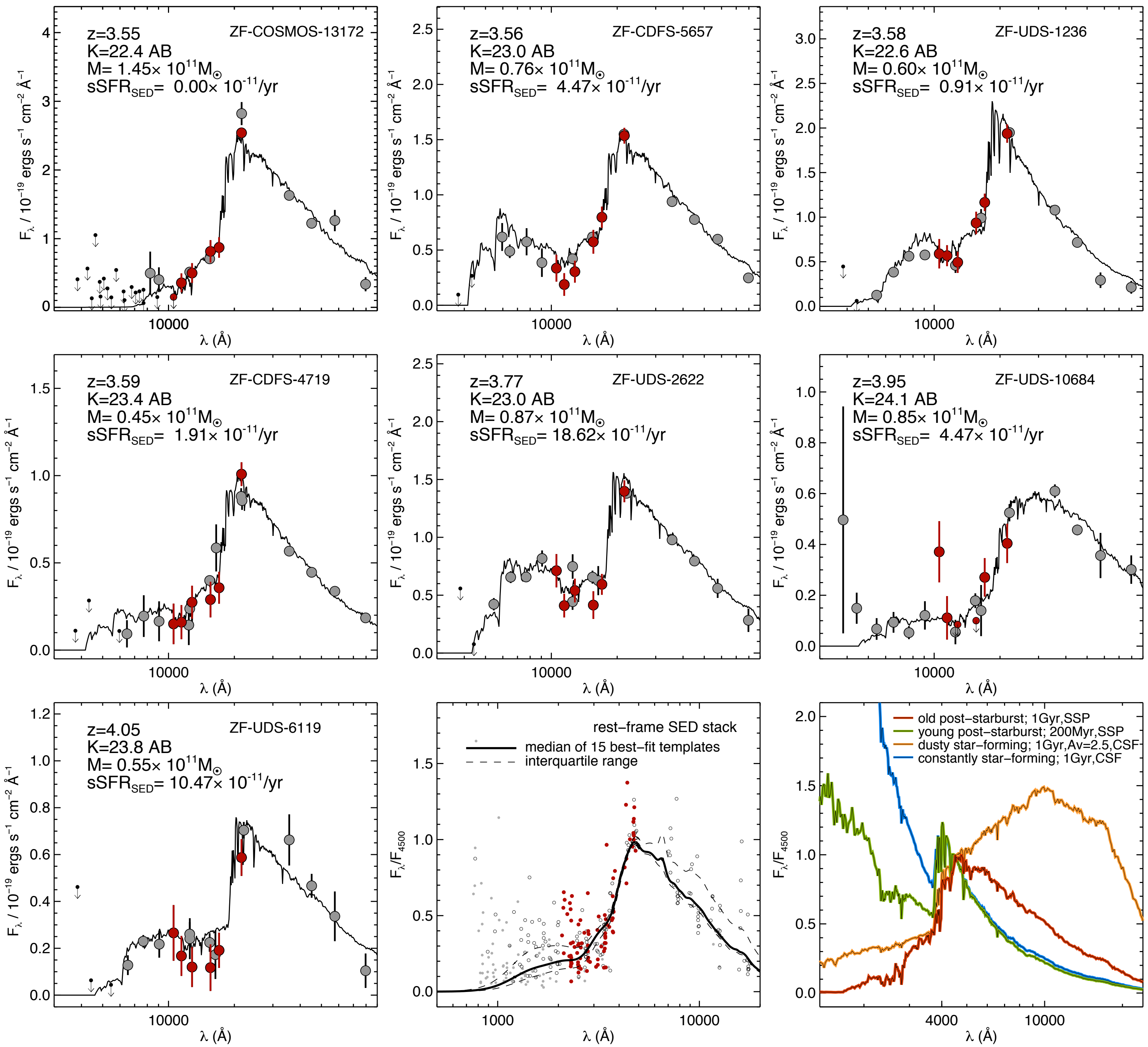


FIG. 2.— Observed SEDs of UVJ selected quiescent galaxies. Red datapoints correspond to the FourStar medium-bandwidth filters. The solid curve is the fitted model from FAST. Downward pointing arrows are 1σ upper limits. Bottom-middle: Rest-frame SED of the 15 far-IR undetected galaxies (open symbols), normalized at rest-frame 4500Å, with gray symbols corresponding to 1σ upper limits. The solid curve is the median of the best-fit template SEDs. Dashed lines mark the interquartile range. Bottom-right: Four model SEDs with constant star formation or a single stellar population (SSP) and ages from 200Myr to 1Gyr. The observed SEDs are characterized by pronounced Balmer/4000Å breaks, similar to the old post-starburst model.

Could Search for Evolved, Massive Galaxies to z~7-8

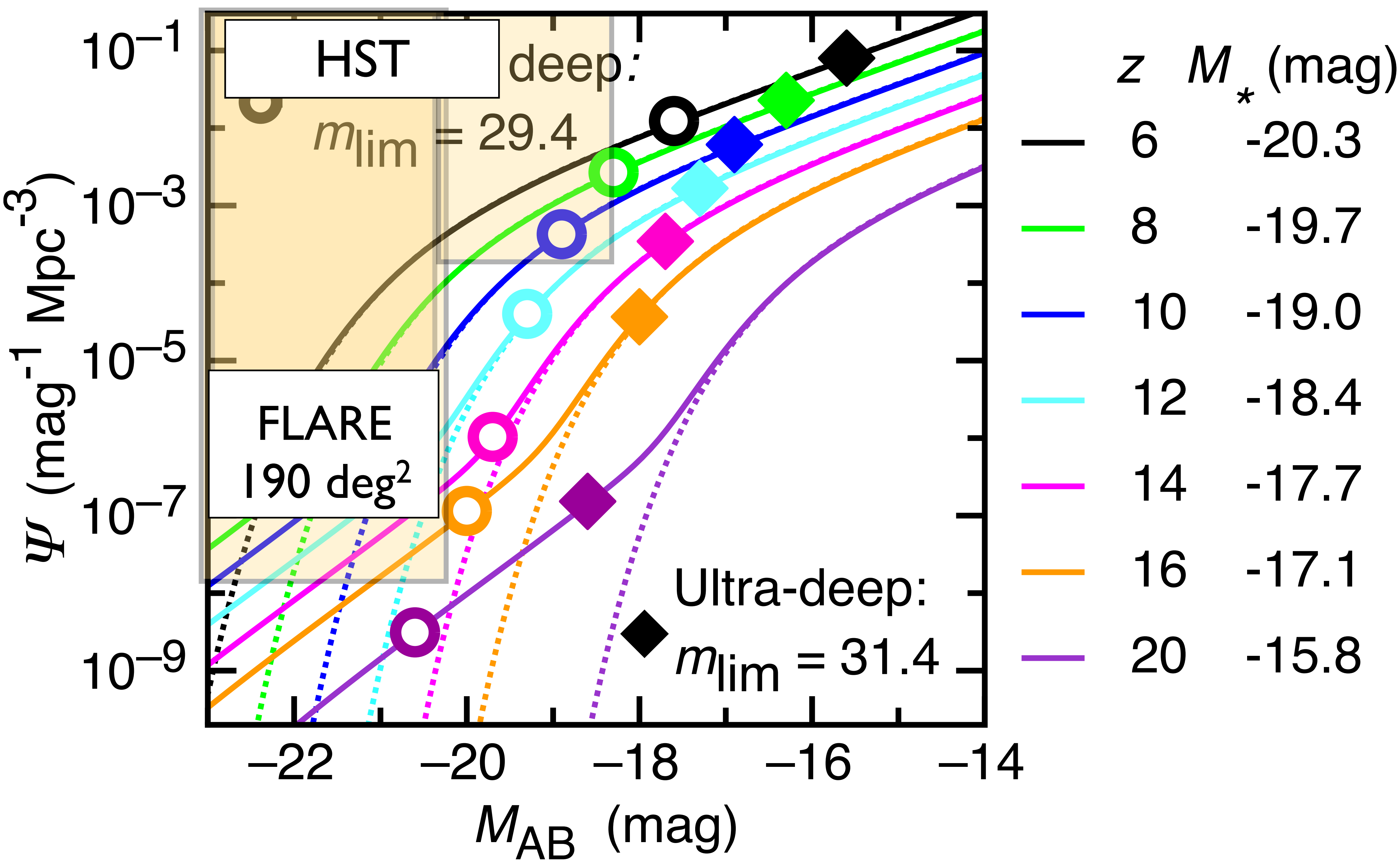
Evolved Galaxies would show significant F277W - F356W breaks

Straatman+2014 (early galaxies at z~4)

Discovery of Galaxy Clusters

FLARE could be very useful for discovering galaxy clusters should they exist at very high redshifts

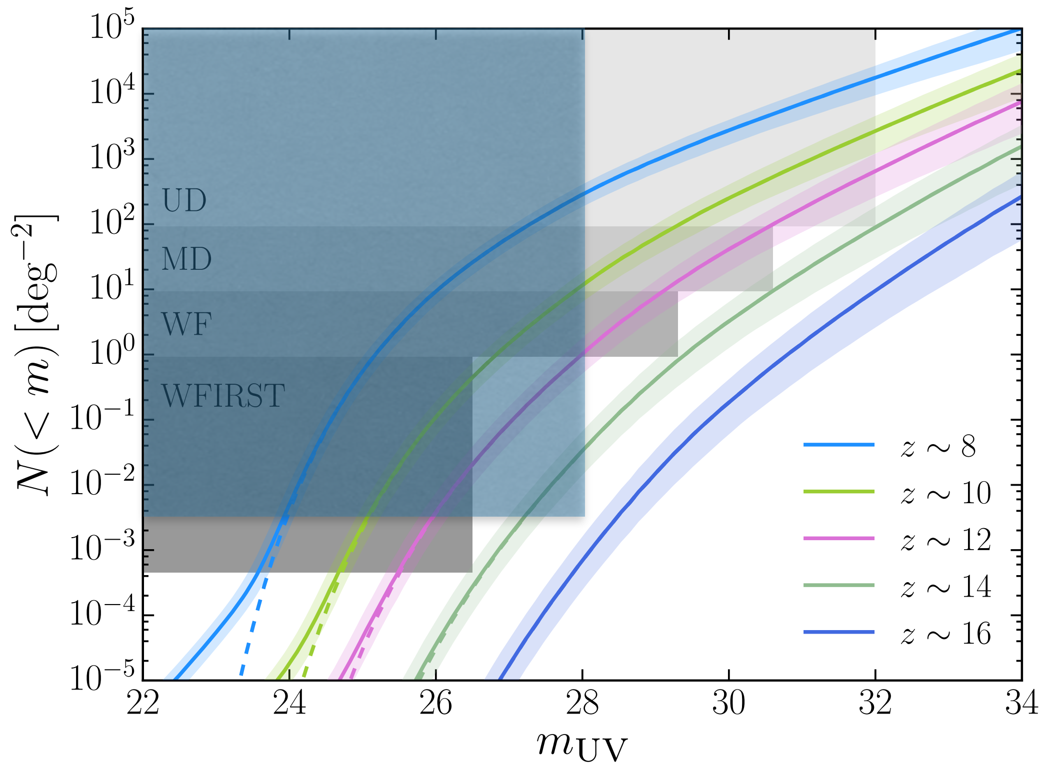
Lensing magnification of z~8-20 galaxies by foreground galaxies will allow us to examine more typical galaxies with our searches and push to even higher redshifts, i.e., z~16



Wyithe+2011

Case for Wider / Shallow Component?

Baseline Plan



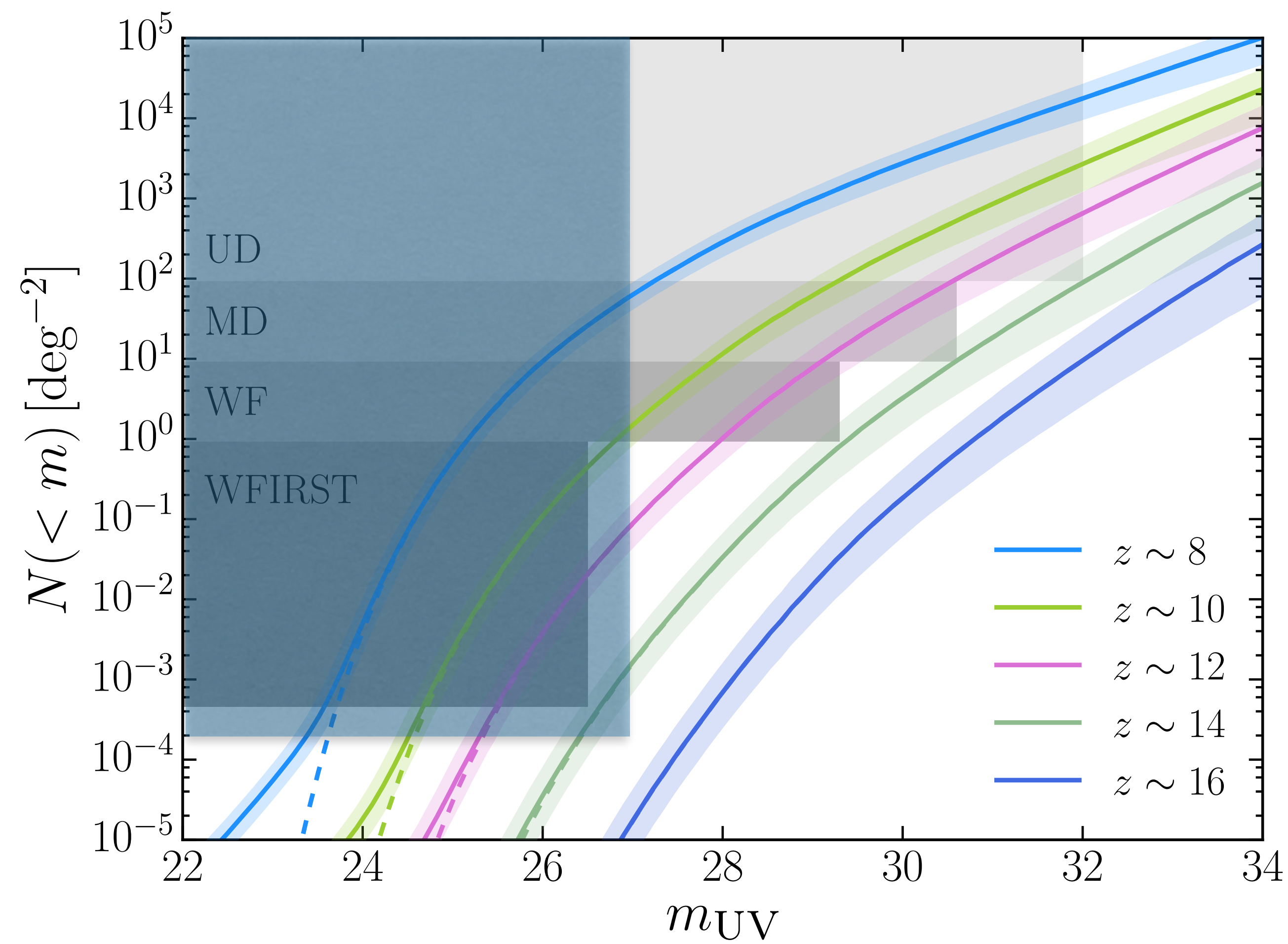
Discovery of Lensed z>12 Galaxies

Evolved Galaxies

Better for Early Quasars

Discovery of Many More Galaxy Clusters

Useful to Consider 10x Wider / Shallow Component?



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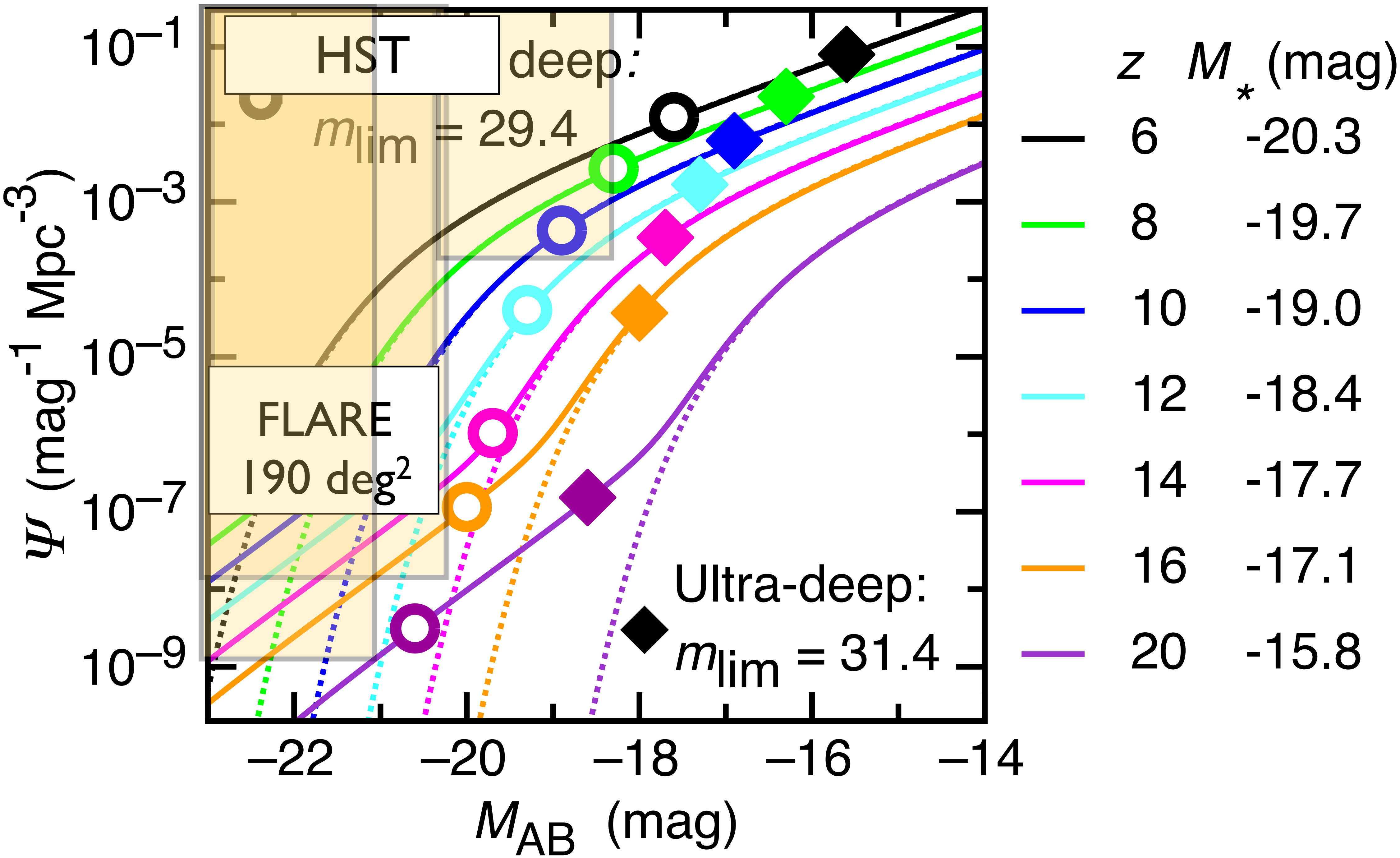
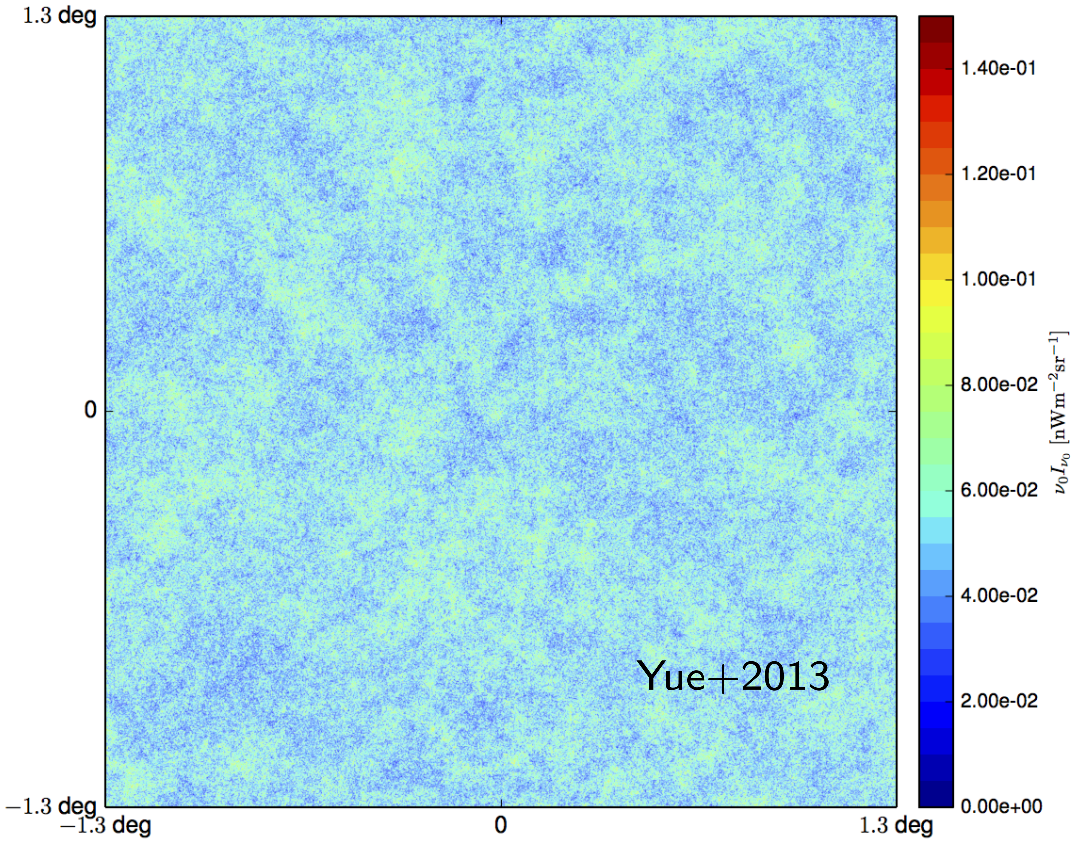


Wyithe+2011

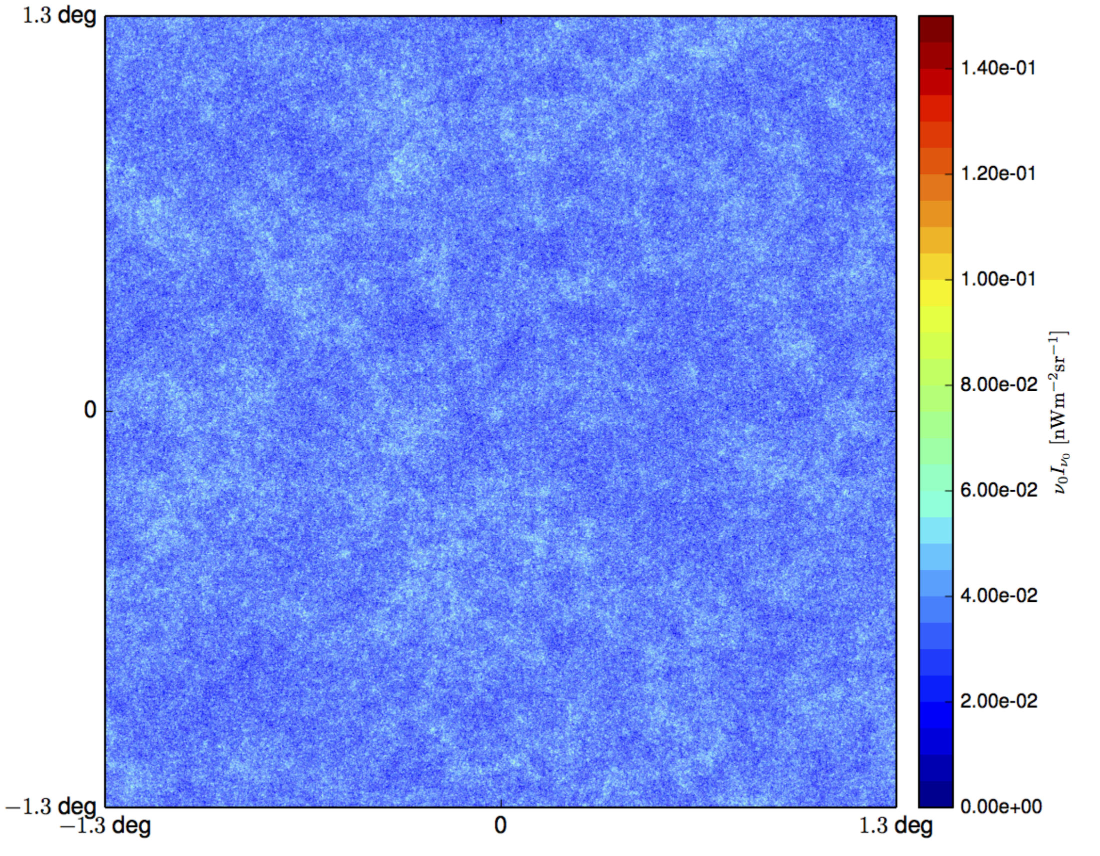
Mock maps for NIRB from **normal star-forming galaxies** with $m > 28$

("power excess" is not shown here):

3.6μm



4.5μm

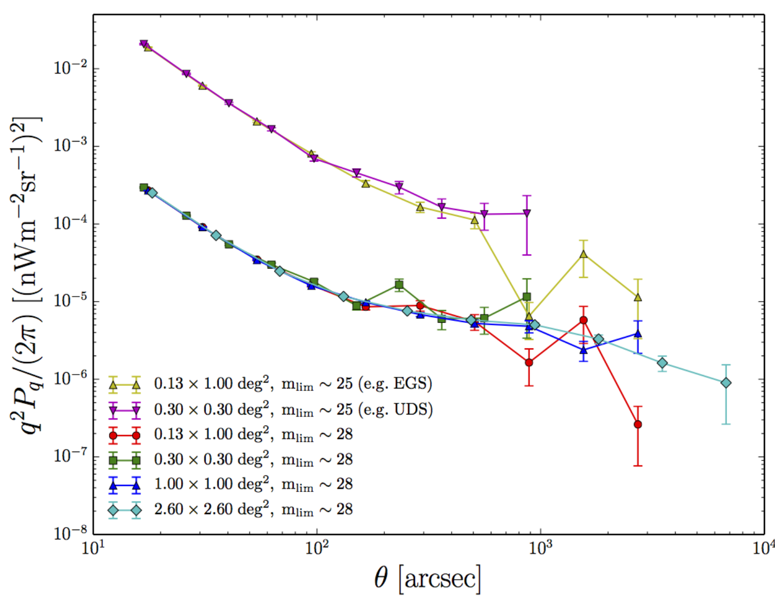


From Andrea Ferrara

Angular PS vs. survey setups

(EGS & UDS: deep & large Spitzer fields)

3.6μm



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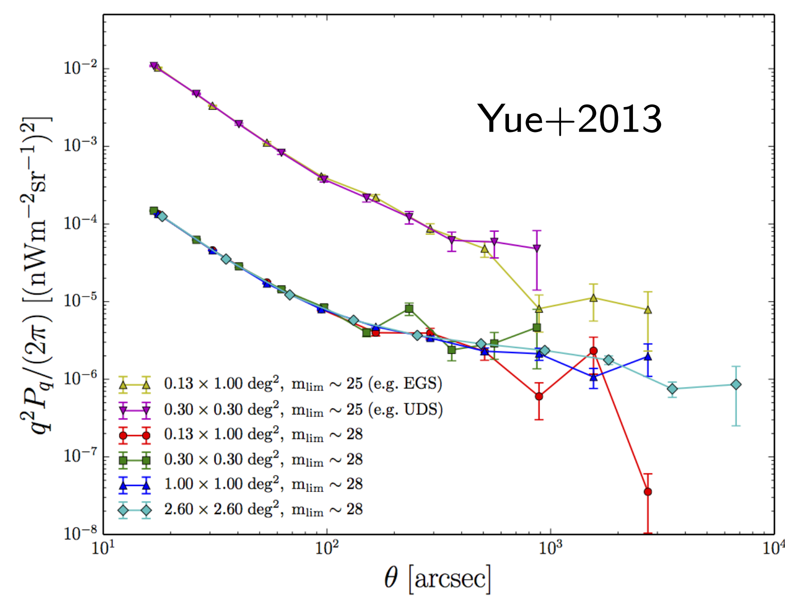


FLARE larger area & deeper detection limit will allow to:

- extend PS measurements to larger scales (crucial to determine natures of NIRB sources);
- reduce the errors on measured PS;
- reduce the shot noise level, favoring the detecion of the clustering term.

From Andrea Ferrara

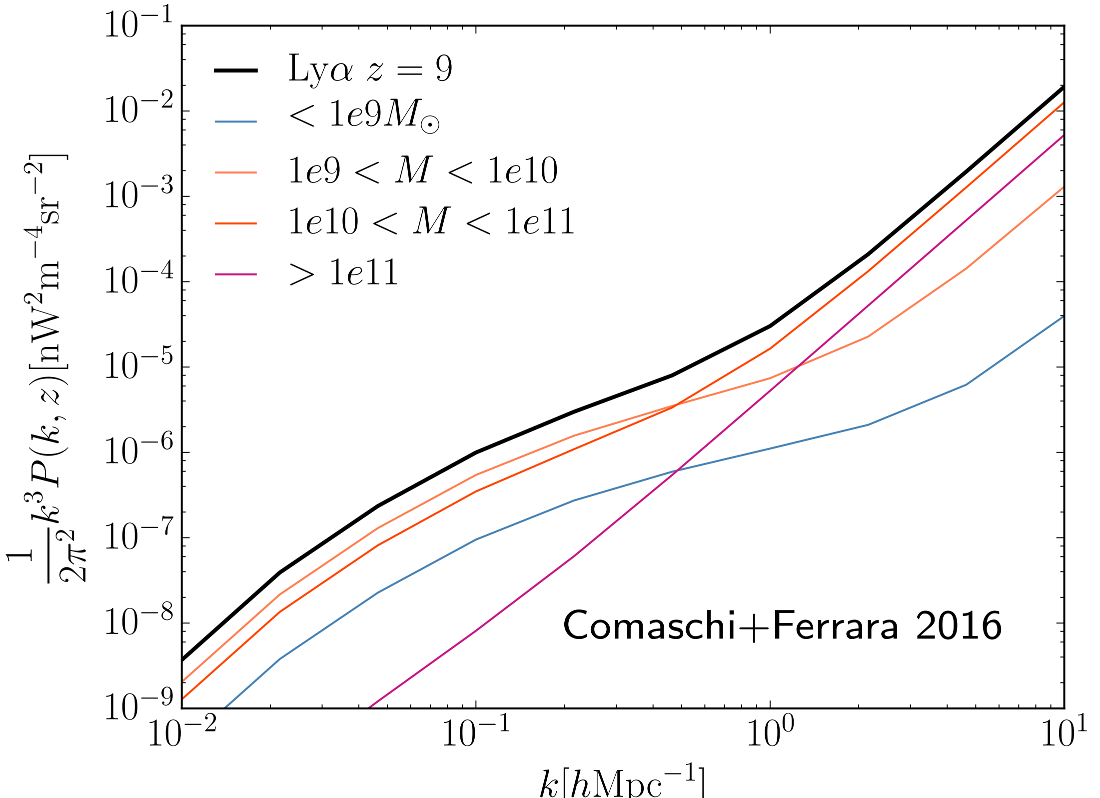
Intensity Mapping (1)

Method: Observe 3D fluctuations in cumulative line emission with integral field spectroscopy.

Goal: Probe galaxies that host most of the star formation, expecially during EoR.

Possible lines (e.g.):

Lyα $(z > 9)$
HeII 1640$\AA$ $(z > 6.6)$
H_α $(1 < z < 6.5)$
[OII] 3727$\AA$ $(3 < z < 12)$
[OIII] 5007$\AA$ $(2.5 < z < 9)$



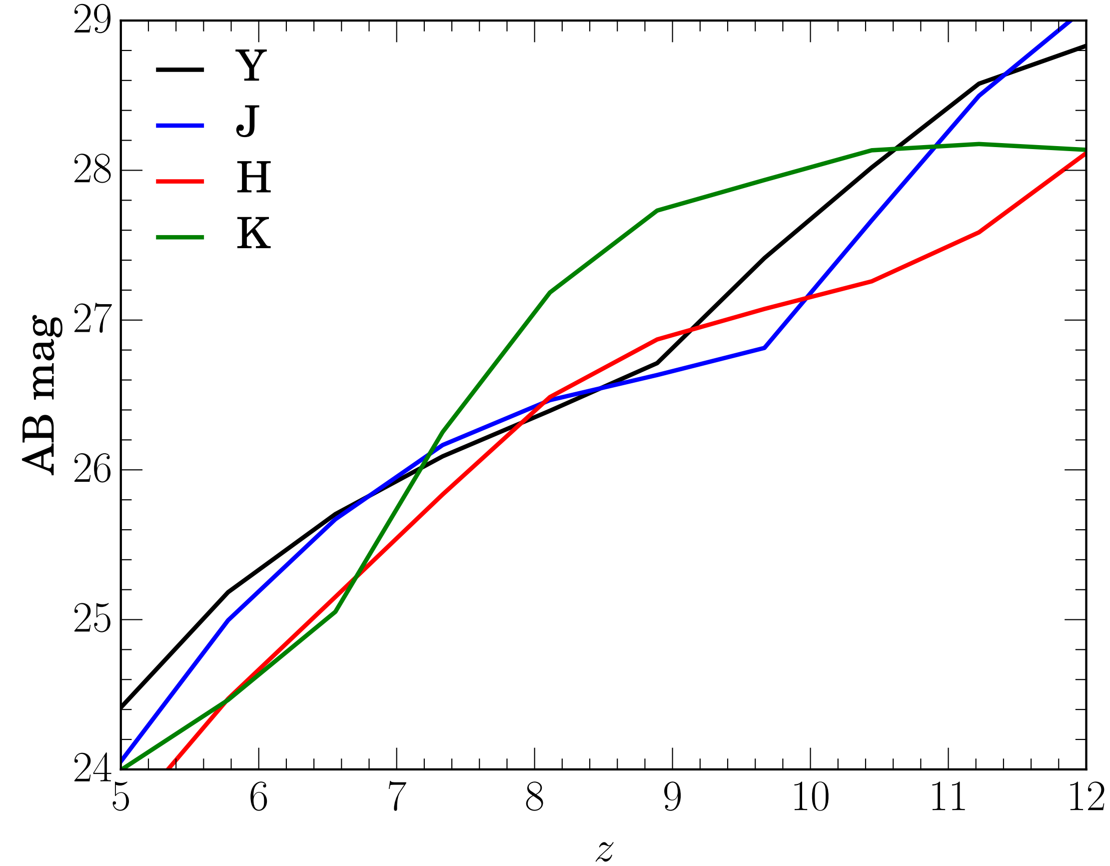
From Andrea Ferrara

Intensity Mapping (2)

Identification of interlopers: line confusion precludes the observation of EoR emission (e.g. H_α from $z = 2$ covers $z = 9$ $\mathrm{Ly}\alpha$ emission).

$\Longrightarrow$ with deep photometric surveys we can remove interlopers.

$\mathrm{Ly}\alpha$ intensity mapping requires $m_{\mathrm{AB}} > 26$ to clean EoR observations (Comaschi, Yue, Ferrara in prep.).



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