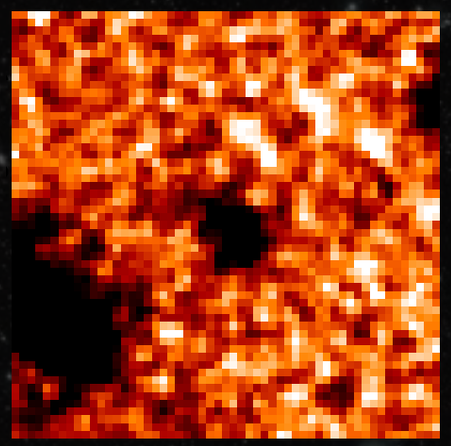
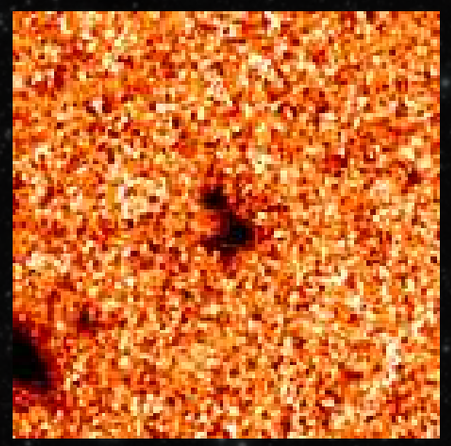
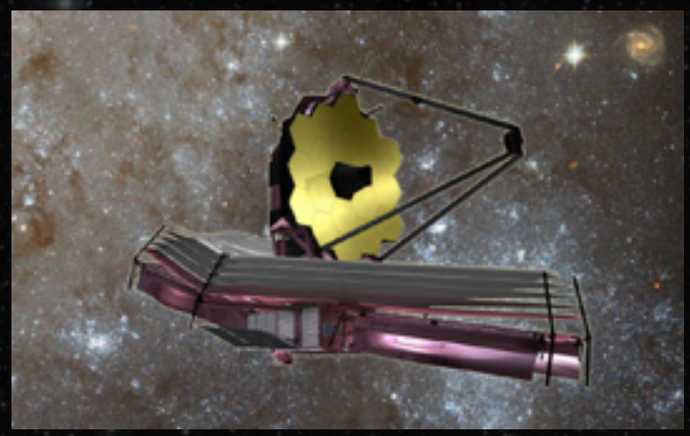
Unveiling the nature of **bright** z ~ 7 galaxies with *HST*, ALMA and *JWST*







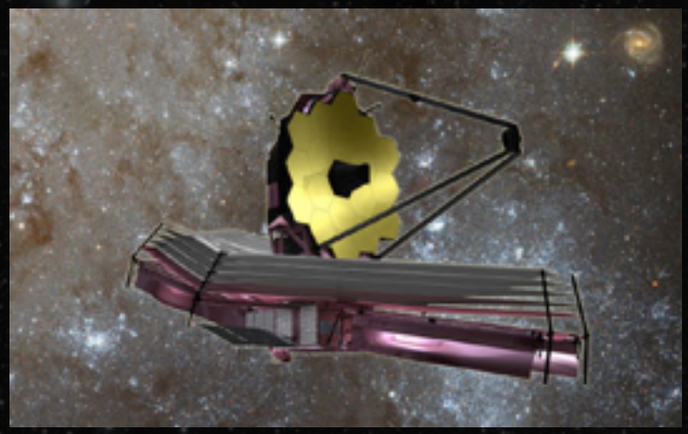
Rebecca Bowler
Hintze Fellow, University of Oxford
Nicholas Kurti Junior Fellow, Brasenose College

with Jim Dunlop, Ross McLure, Derek McLeod, Matt Jarvis

Bright galaxies into the EoR

NIRCam/NIRSpec GTO surveys:

Deep ~ tens sq. arcmin
Wide 400 sq. arcmin (< CANDELS)



CANDELS GOODS
North and South

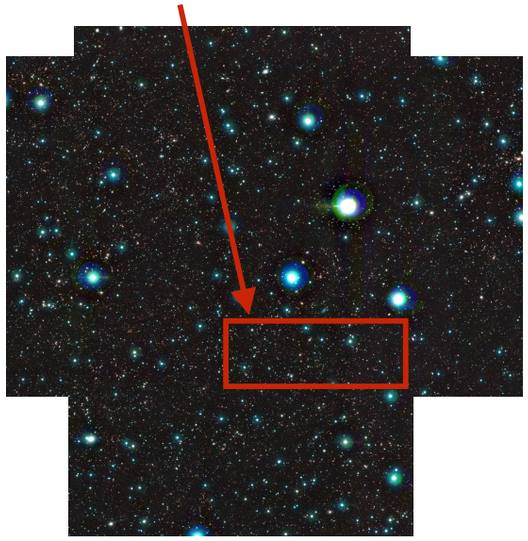
Hubble Ultra Deep Field

CANDELS EGS

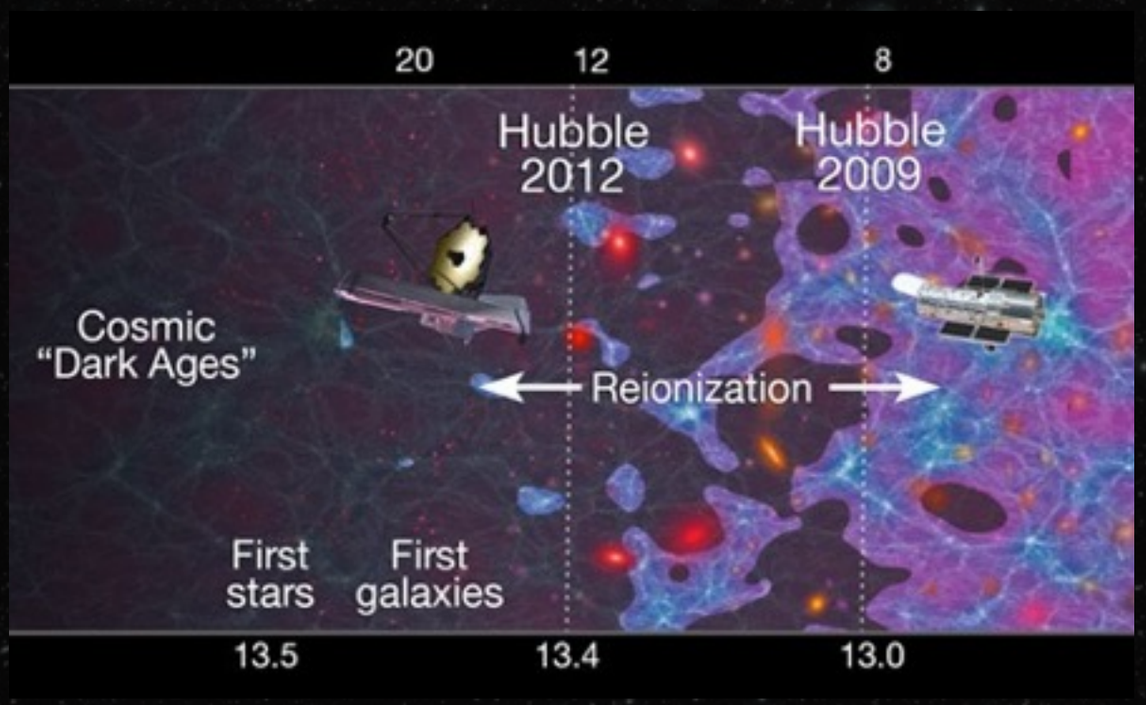
CANDELS COSMOS

CANDELS UDS

UltraVISTA Survey / COSMOS field



UKIDSS Ultra Deep Survey /
Subaru XMM-Newton Deep Survey

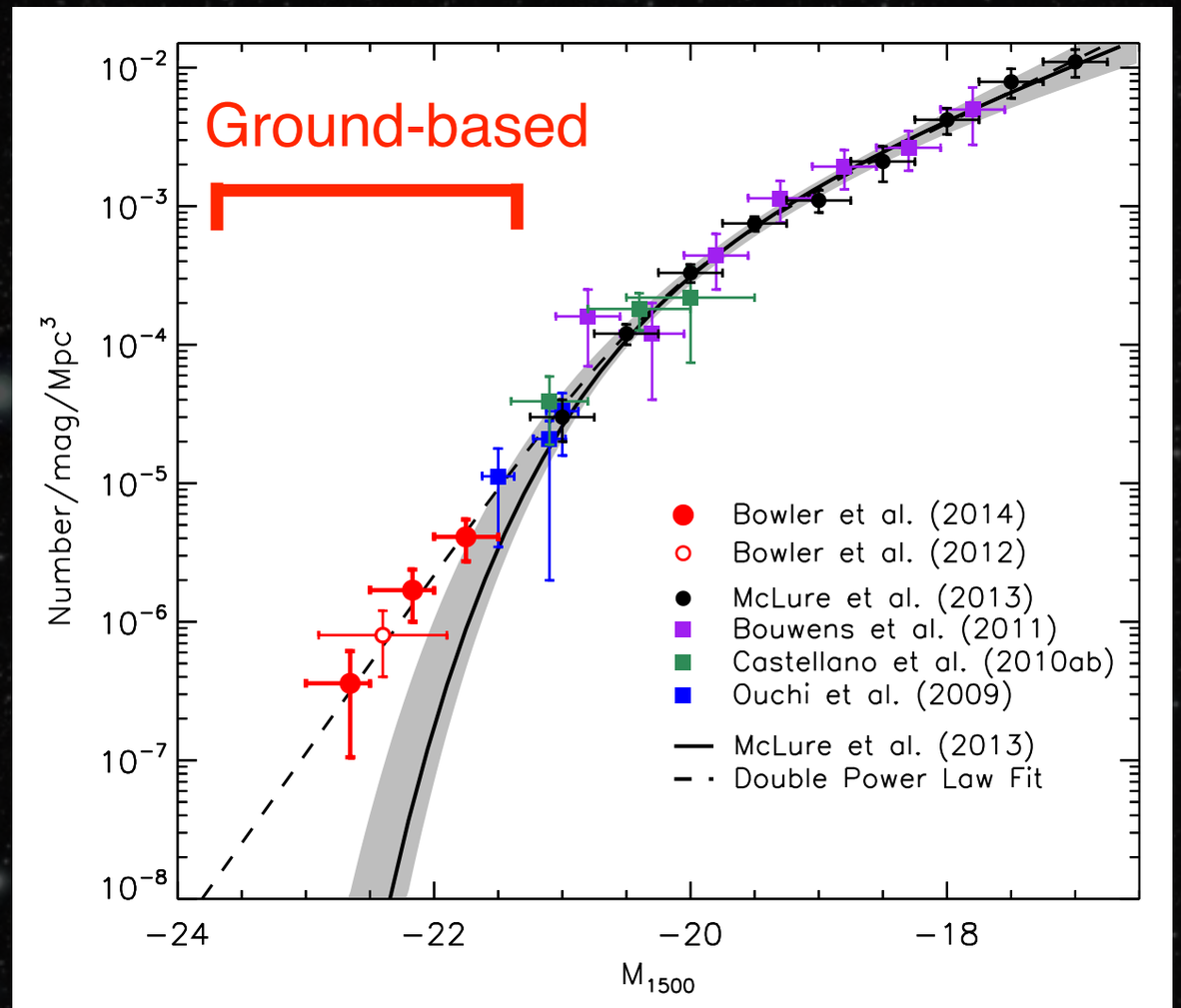


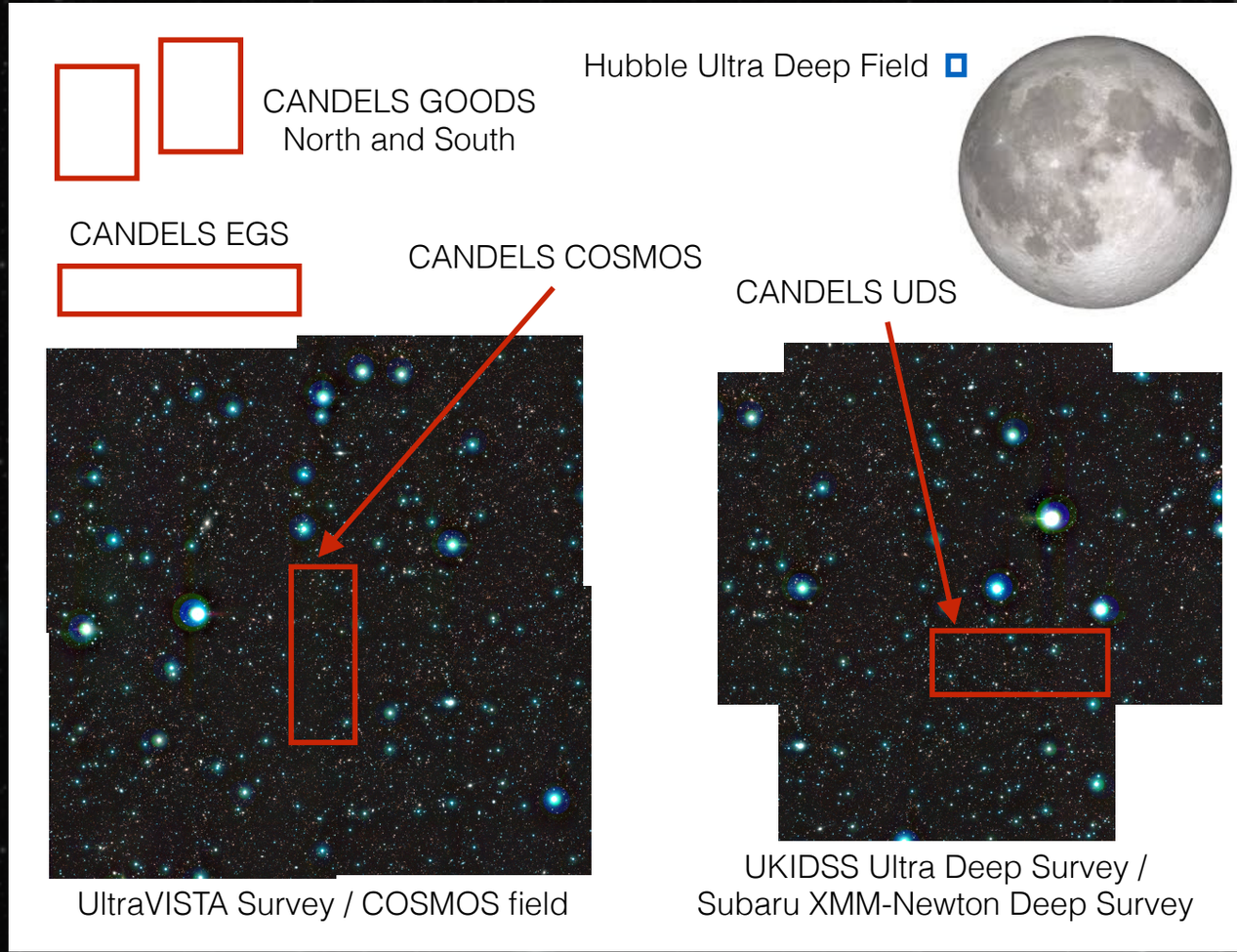
Bright galaxies into the EoR

Lyman-break galaxies as bright as $m_{AB} = 24$, without lensing

~ few per sq. degree for the brightest LBGs

HST surveys
e.g. CANDELS, UDF+





Bright galaxies into the EoR

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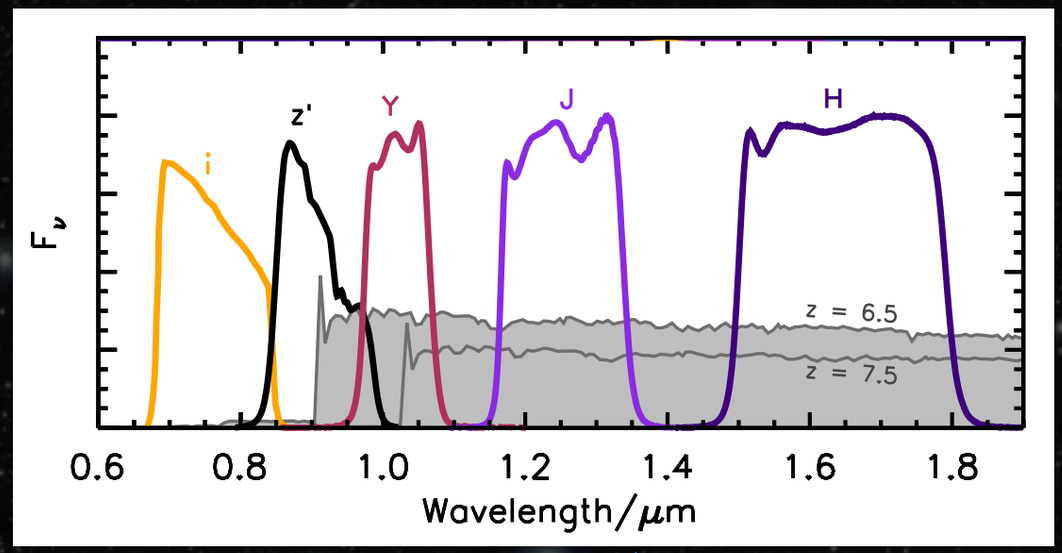
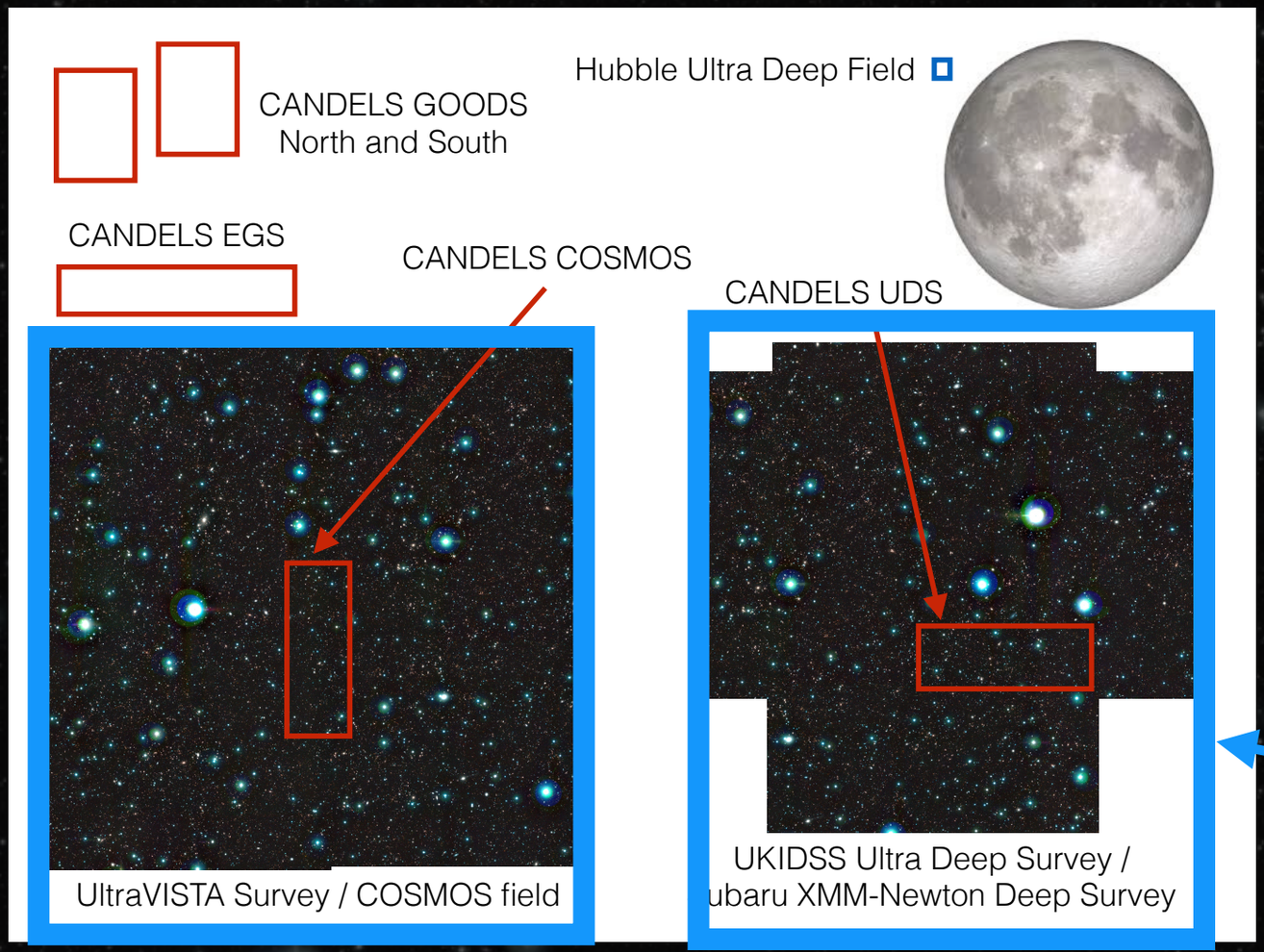


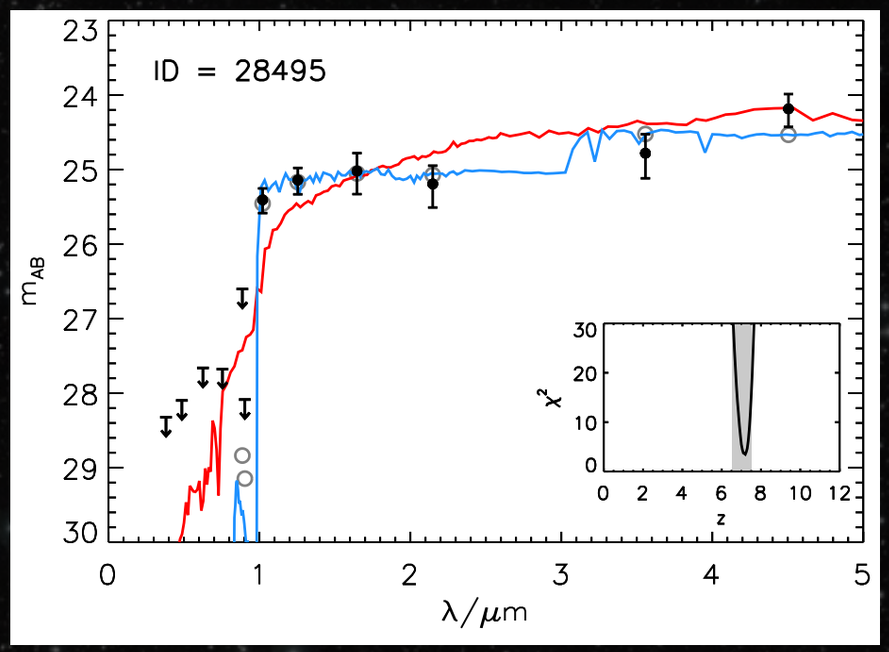


Near-infrared data from: UltraVISTA* in COSMOS, UKIDSS and VIDEO* in the UDS

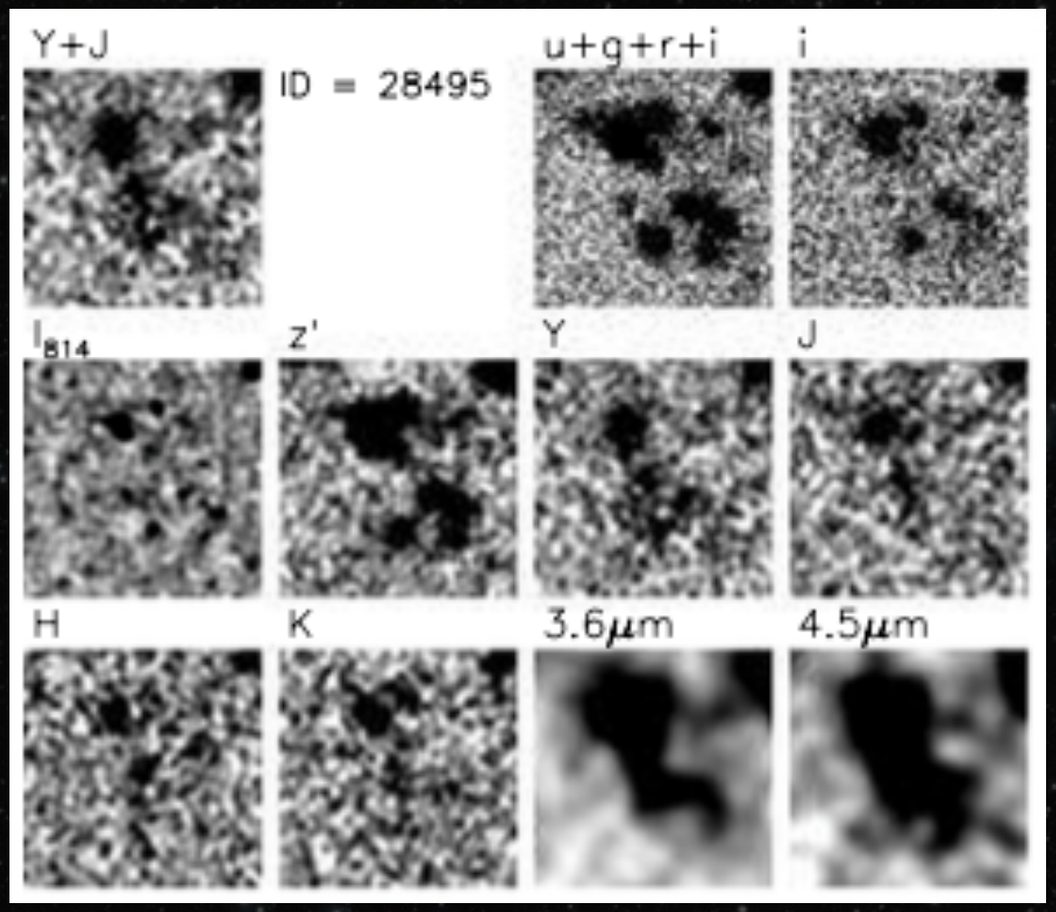
Total area = 1.65 sq. deg

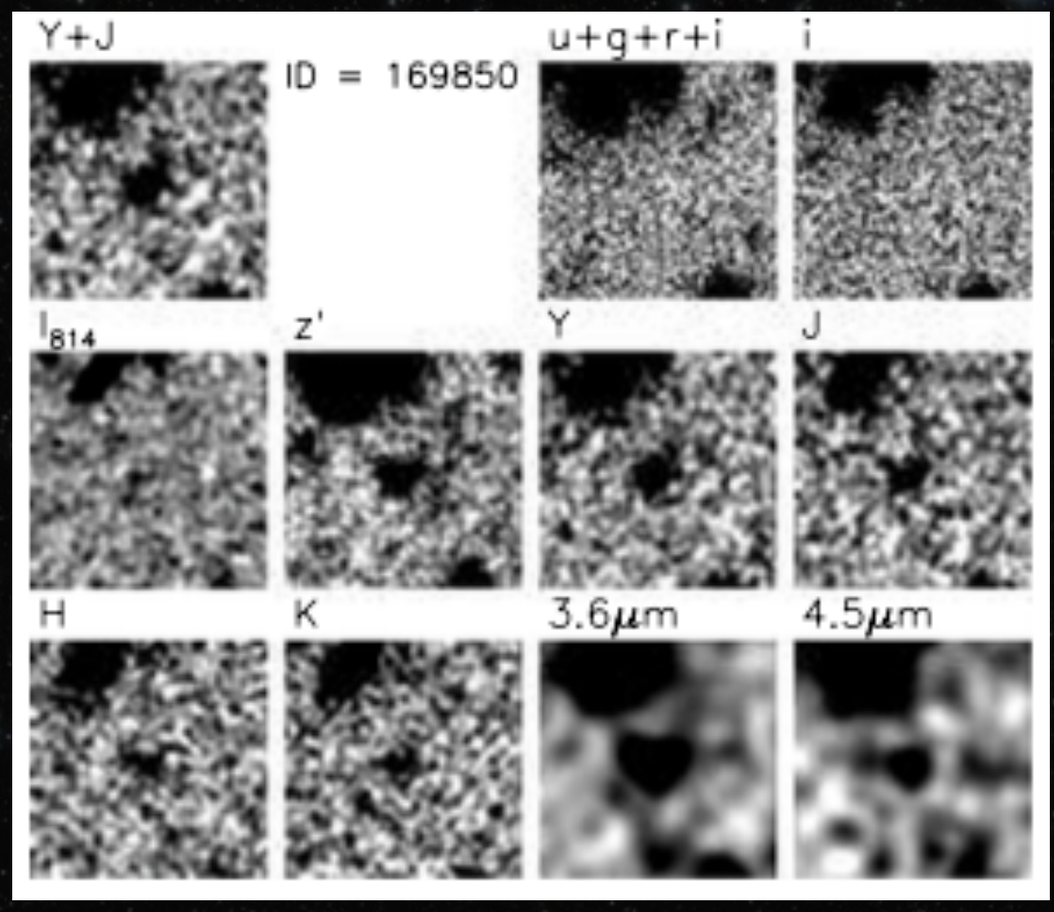
*ESO Public Surveys

The sample of bright z ~ 7 LBGs

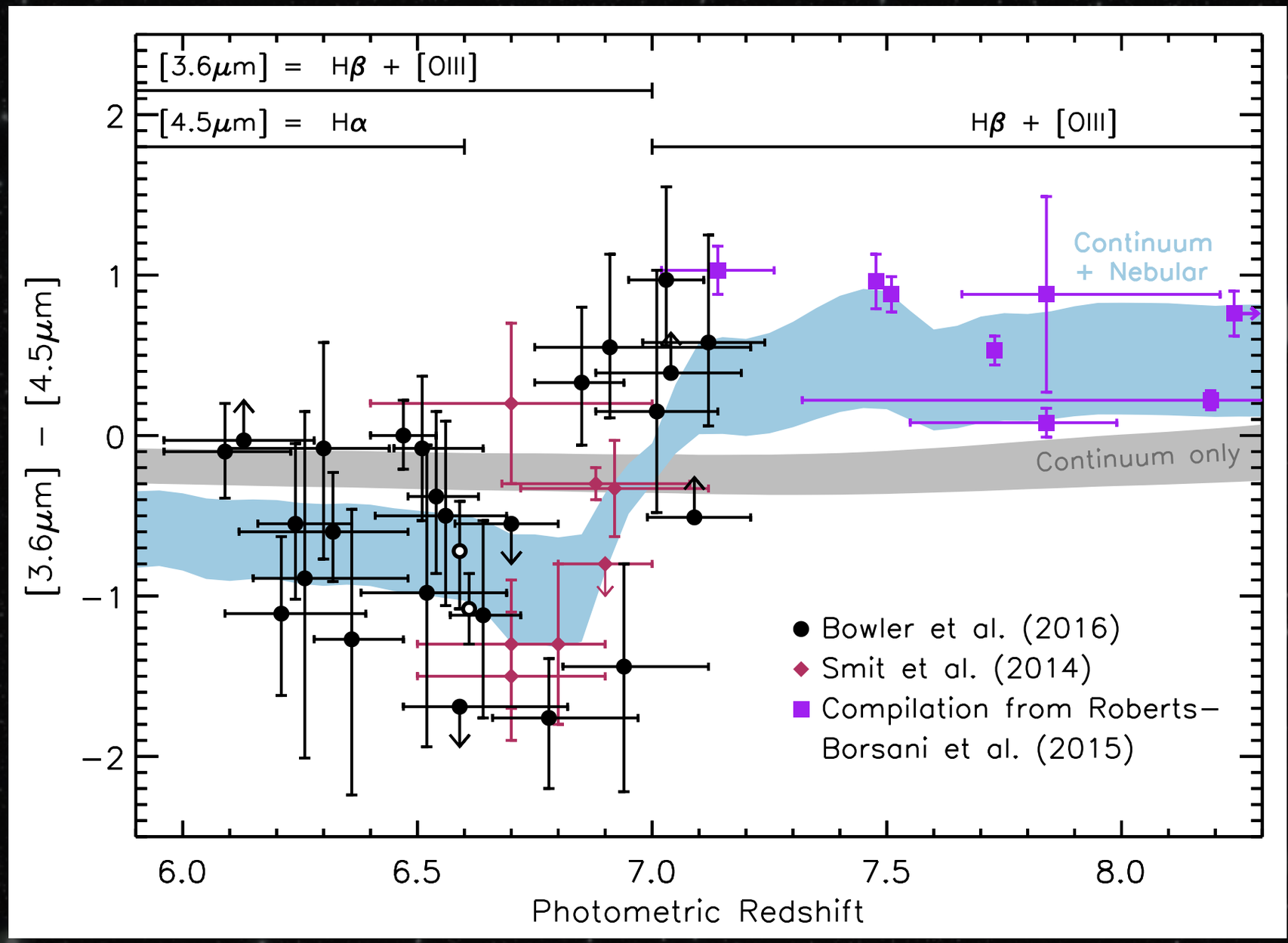


- ~30 Lyman-break galaxies at z ~ 7 (11 brighter than mAB = 25.0)
- 10 < SFR < 40 Msun/yr
- median rest-frame UV slope β = -2.0
- half-light radii from 0.5-3kpc





Nebular emission in bright LBGs



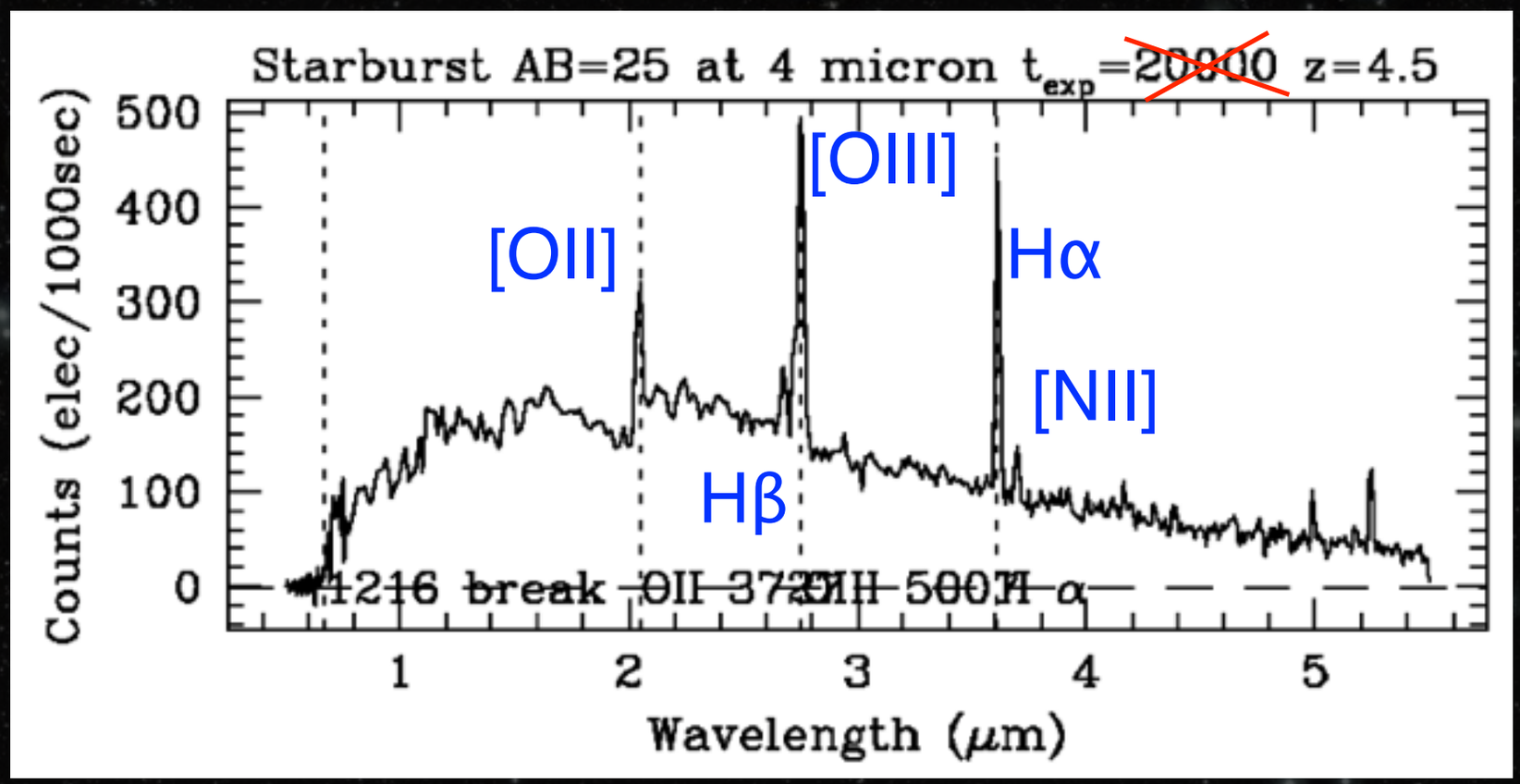
- Deconfused Spitzer SPLASH data at 3.6 and 4.5 microns
- Hints at extremely strong rest-frame optical emission lines
- rest-frame EW (Hβ + [OIII]) = 600-1800A

arXiv:1605.05325

Nebular emission in bright LBGs

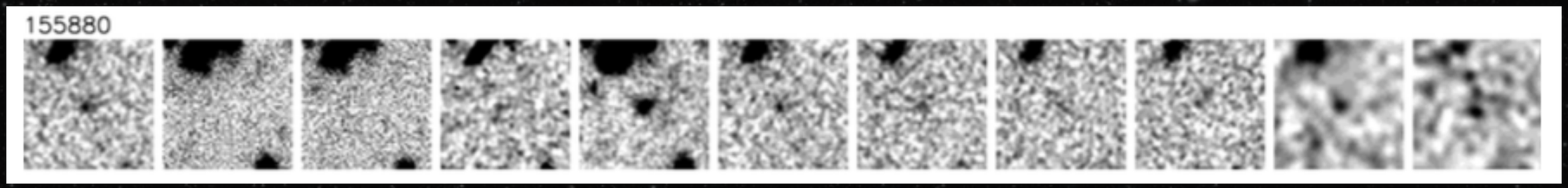
- NIRSpec will clearly detect these lines + the continuum
- Metallicity, Ionisation parameter, temperature indicators
- Balmer break measured directly
- Also access to rest-frame UV lines

e.g. with R =100, t ~ 8 min; R=1000, t < 1hr



c/o Peter Jacobsen

Revealing the nature of bright LBGs



The sample includes the **brightest** known z ~ 7 galaxies, which are ideal targets for detailed follow-up:

… in relatively modest integration times:

- few hours with near-IR spectrographs (e.g. Oesch+2015, Roberts-Borsani+2015…)
- modest integrations with ALMA (e.g. Capak+2015, Maolino+2015…)

Revealing the nature of bright LBGs

HST can reveal sizes/
morphologies that are elusive
in ground-based data

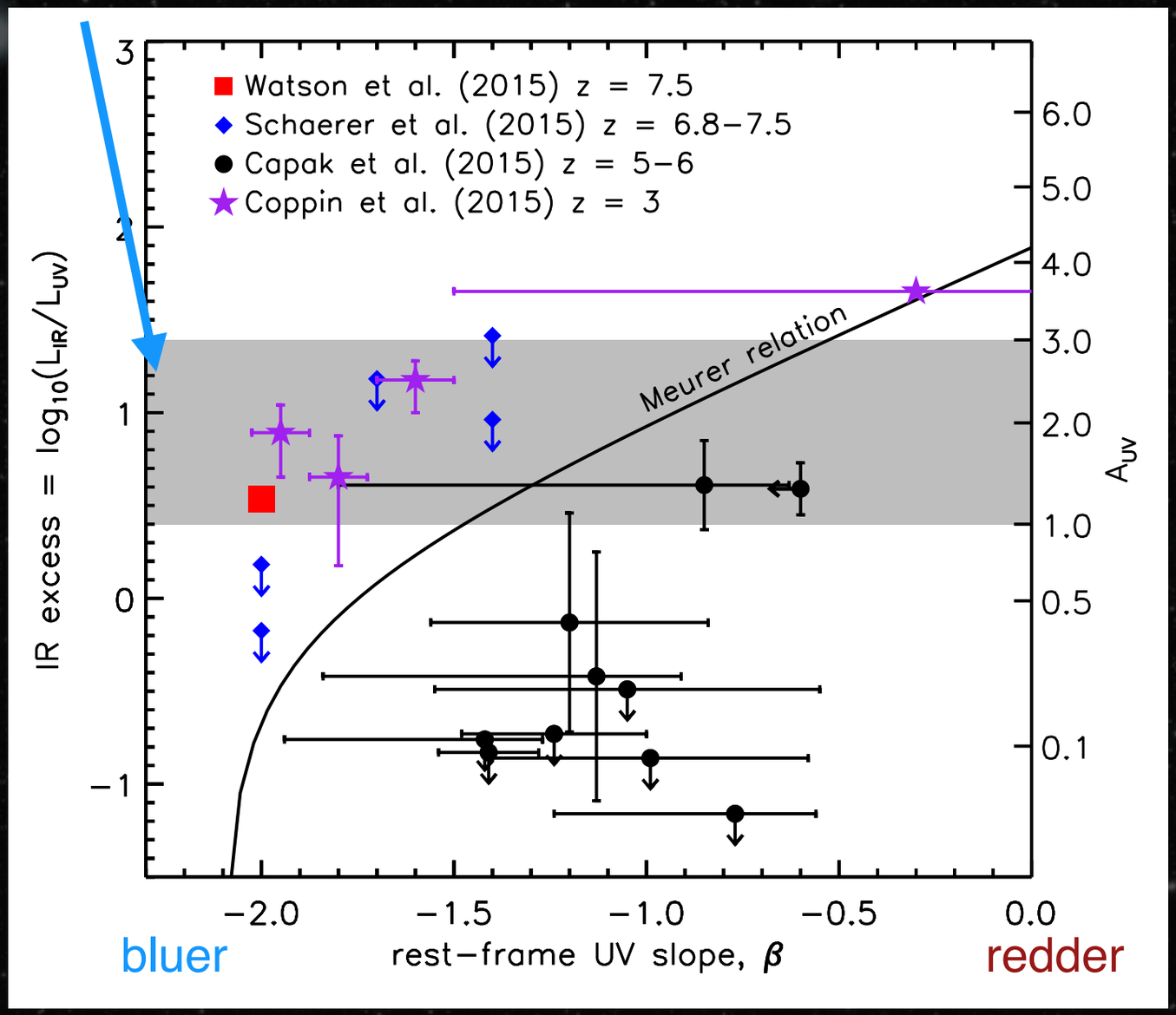
Optical and near-infrared
spectroscopy can reveal
rest-UV emission lines

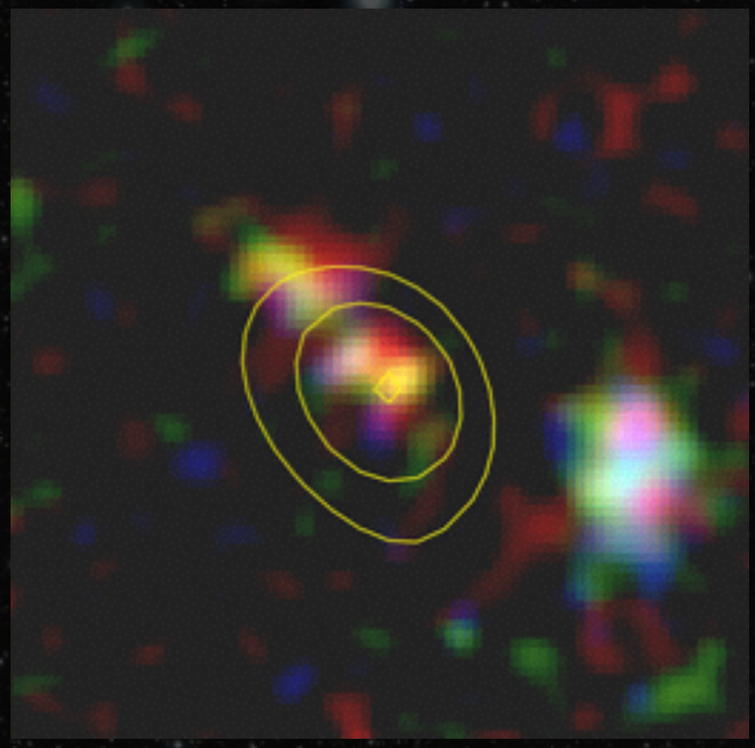
ALMA provides unique view
of dust emission

ALMA observations of the dust continuum

Cycle 3 imaging of 6 bright LBGs at z ~ 7

Measured with ALMA





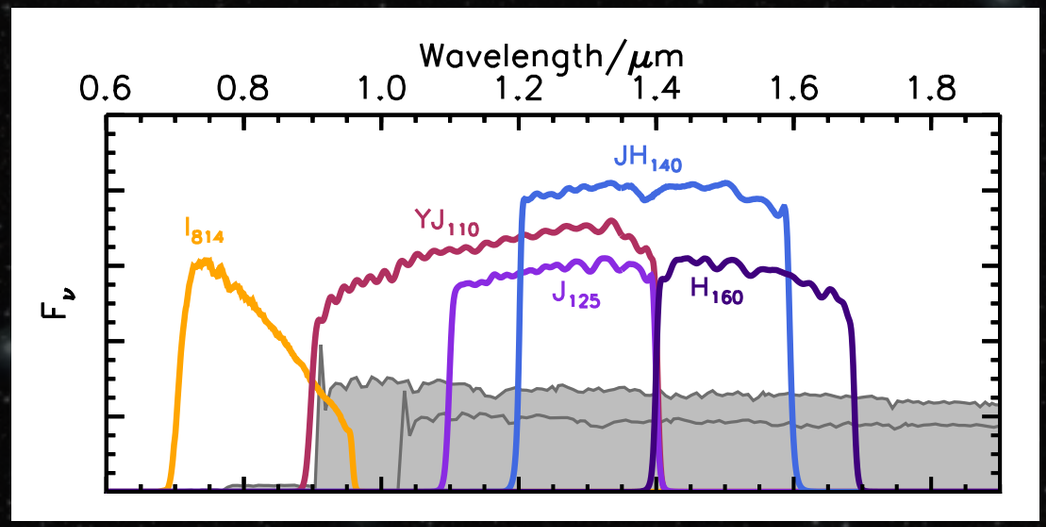
e.g. the ‘dusty normal galaxy’ at z = 7.5 from Watson et al. (2015)

- Balmer decrement and β measured by NIRSpec can be directly compared to ALMA results

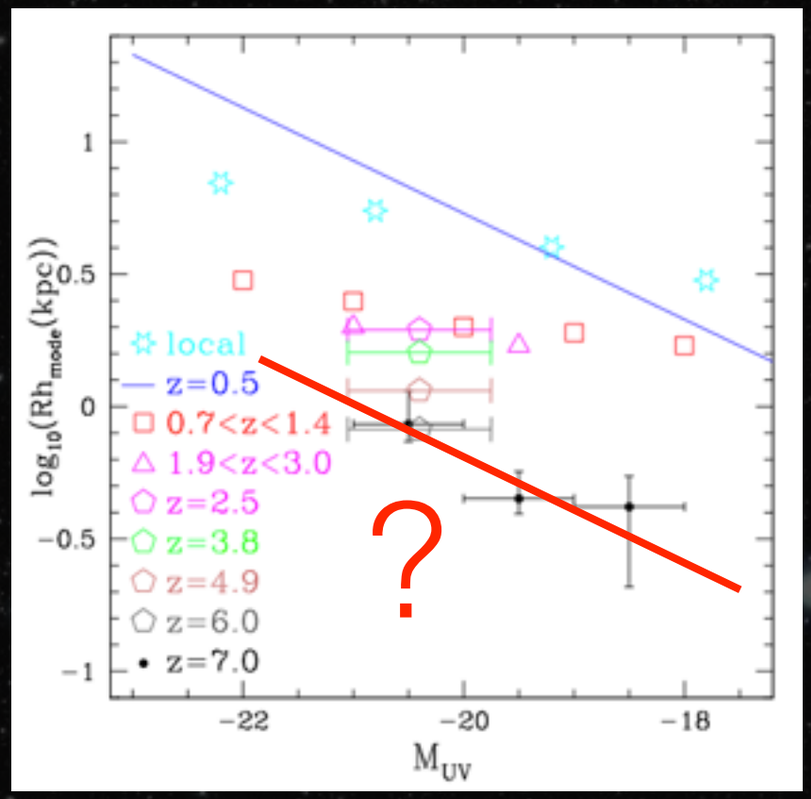
HST/WFC3 follow-up of bright LBGs

17 orbits of HST/WFC3 using the wide JH140 filter

Targeting 17 of the Bowler et al. (2014) sample with $6.5 < z < 7.2$, $M_{UV} < -21.5$

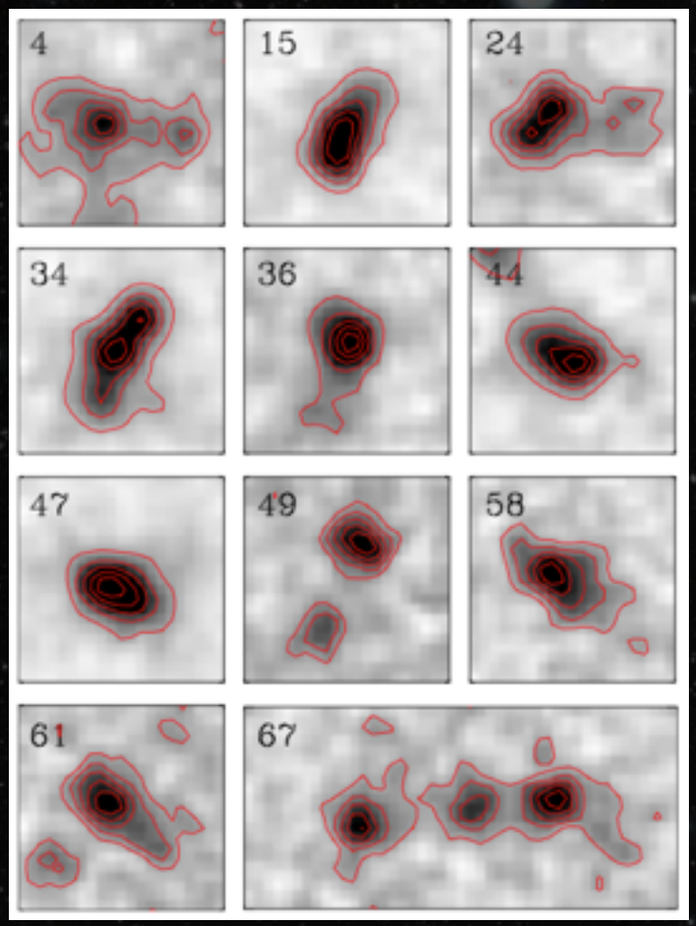


Size-luminosity relation?



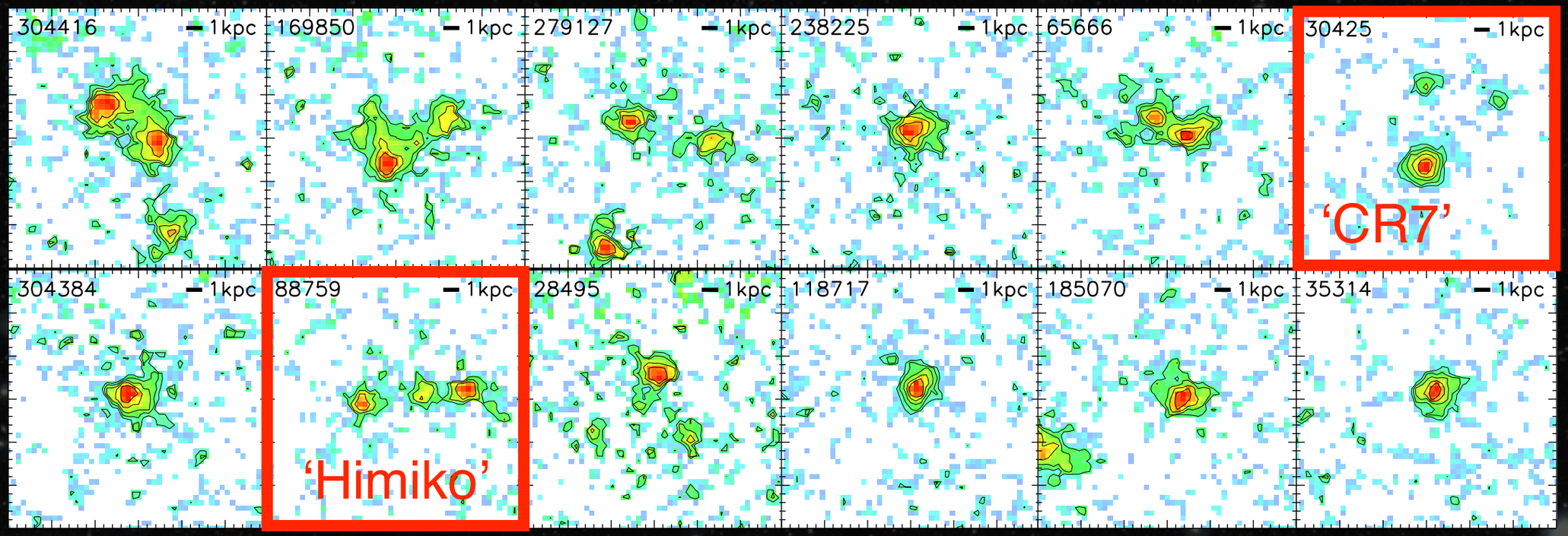
Grazian et al. (2012)

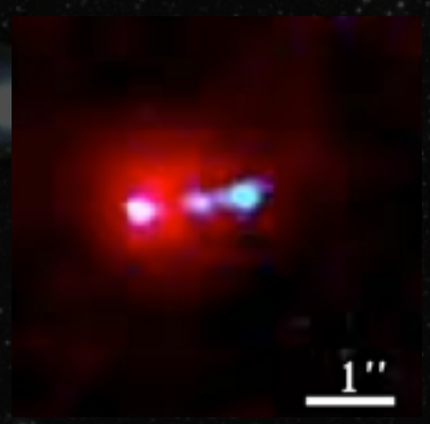
Multiple-components?



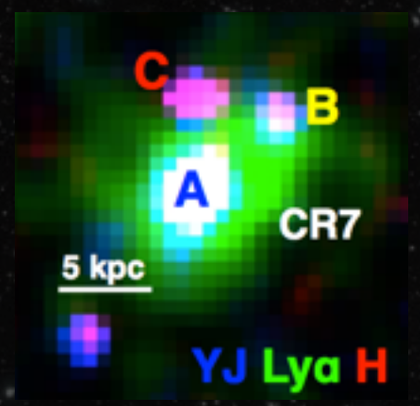
Jiang et al. (2013)

HST/WFC3 imaging of M < -21.5 LBGs





Ouchi et al. 2009, 2013



Sobral et al. 2015

- The brightest Lyman-break galaxies at z ~ 7 are composed of multiple clumps under HST resolution
- Magnitude limited sample, not selected for line emission

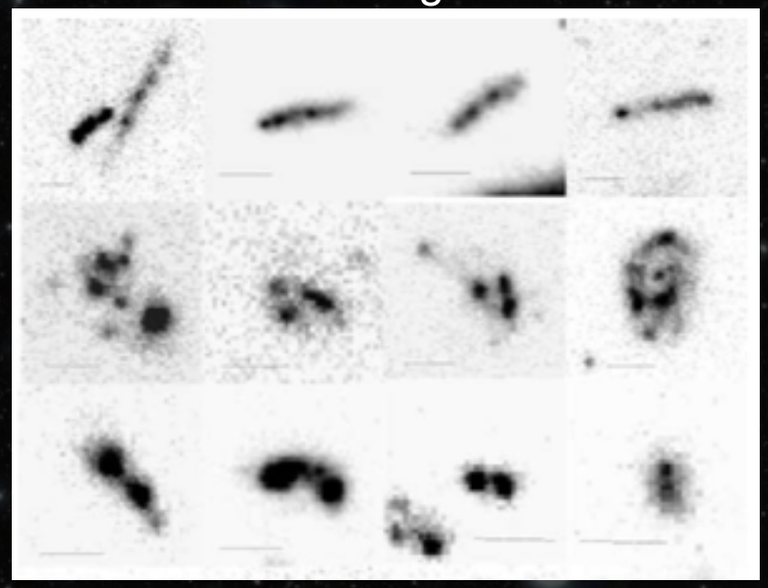
arXiv:1605.05325

Clumpy galaxies at high redshift

z = 2-3 SF galaxies

Guo et al. (2015)

Elmegreen et al. 2005

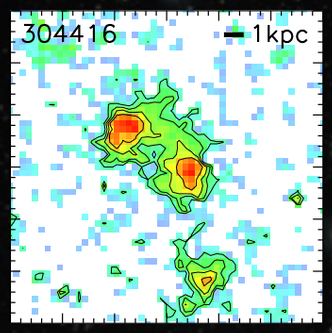


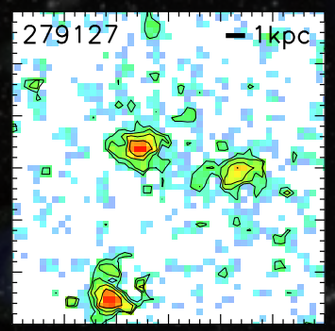
`chain'

`clump-cluster'

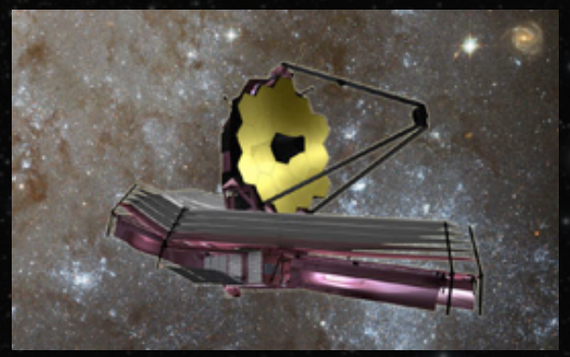
double-core galaxies

Rest-frame UV





Rest-frame optical



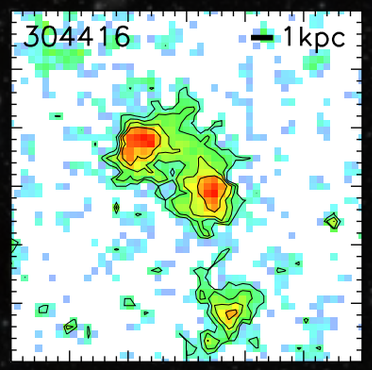
- NIRCam will reveal the underlying stellar mass distribution
- WFC3 FWHM ~ 0.2", NIRCam <~ 0.1"
- S/N ~ 50 for < 10 min

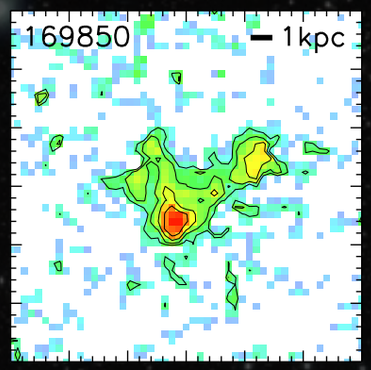
Summary

★ Using **ground-based data** from the UltraVISTA + UDS we now have samples of extremely **bright** star-forming galaxies at z = 7

★ The sample is ideal for detailed follow-up to study galaxy properties into the EoR

★ Observations with HST reveal a clumpy morphology at Muv < -22





With **JWST**:

★ Rest-frame optical emission lines (hence Z, U, T)
★ Underly morphology of the rest-frame optical
★ The presence of dust at z ~ 7