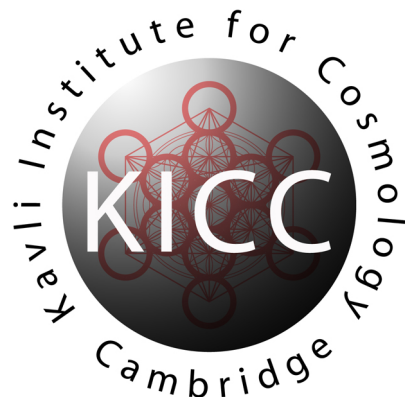


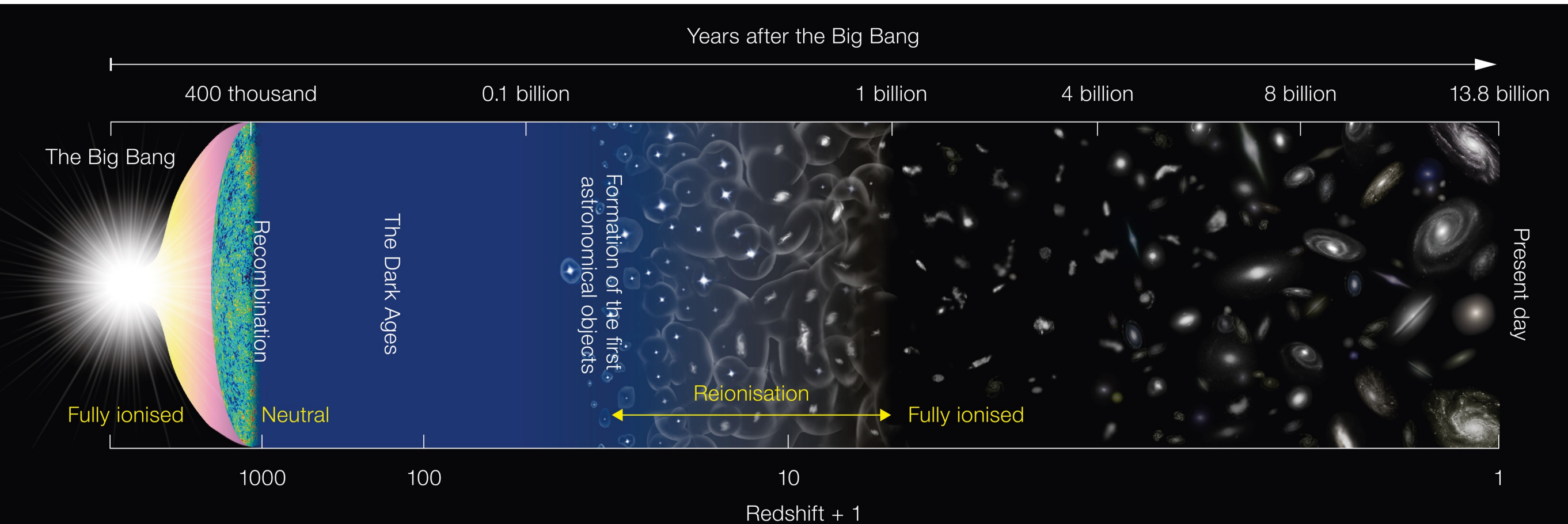
An ALMA view of galaxies in the Epoch of Reionisation

Renske Smit

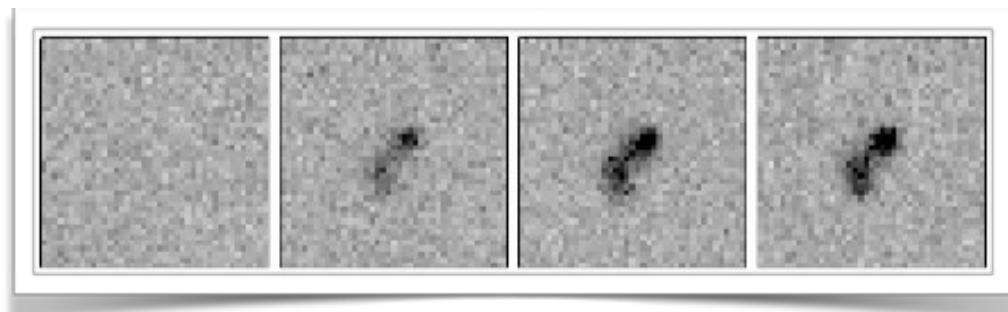
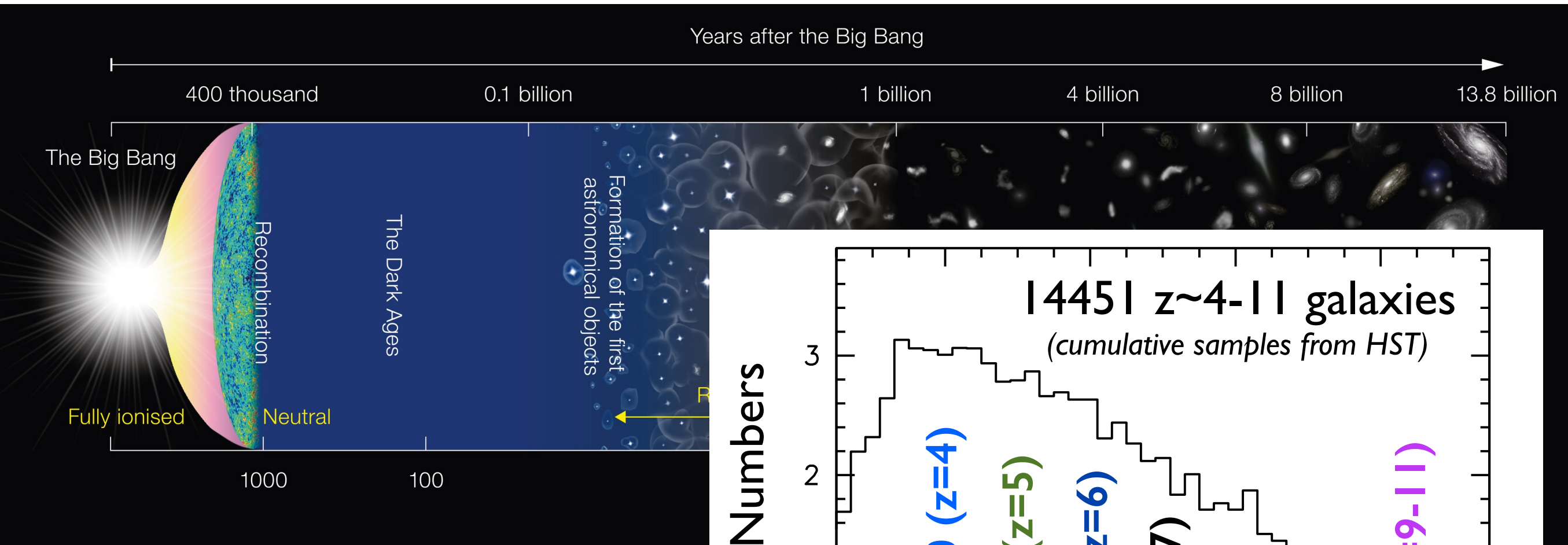
Newton-Kavli fellow — Kavli Institute for Cosmology, Cambridge
(moving to → Liverpool JMU)



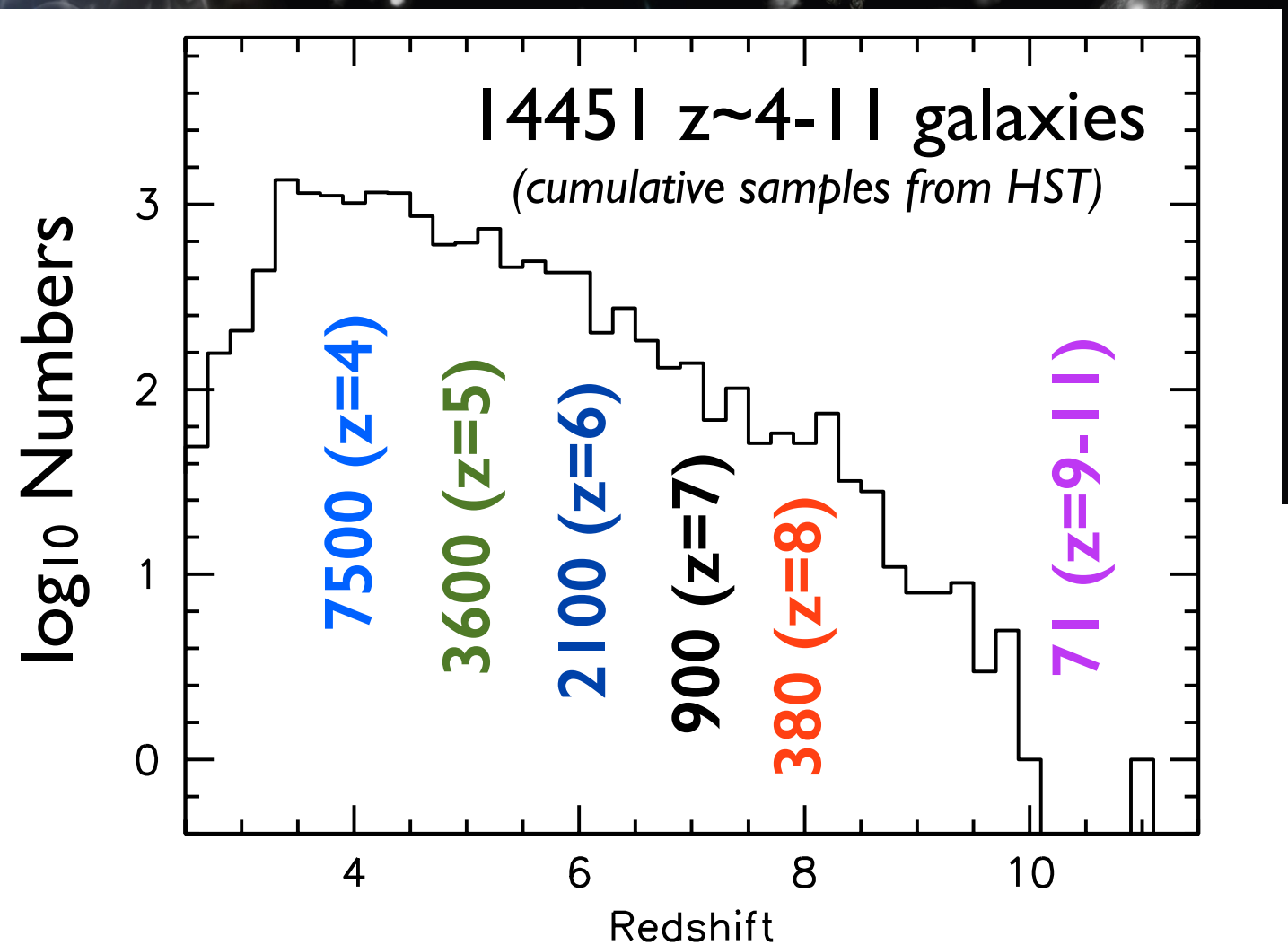
Galaxies in the EoR



Galaxies in the EoR

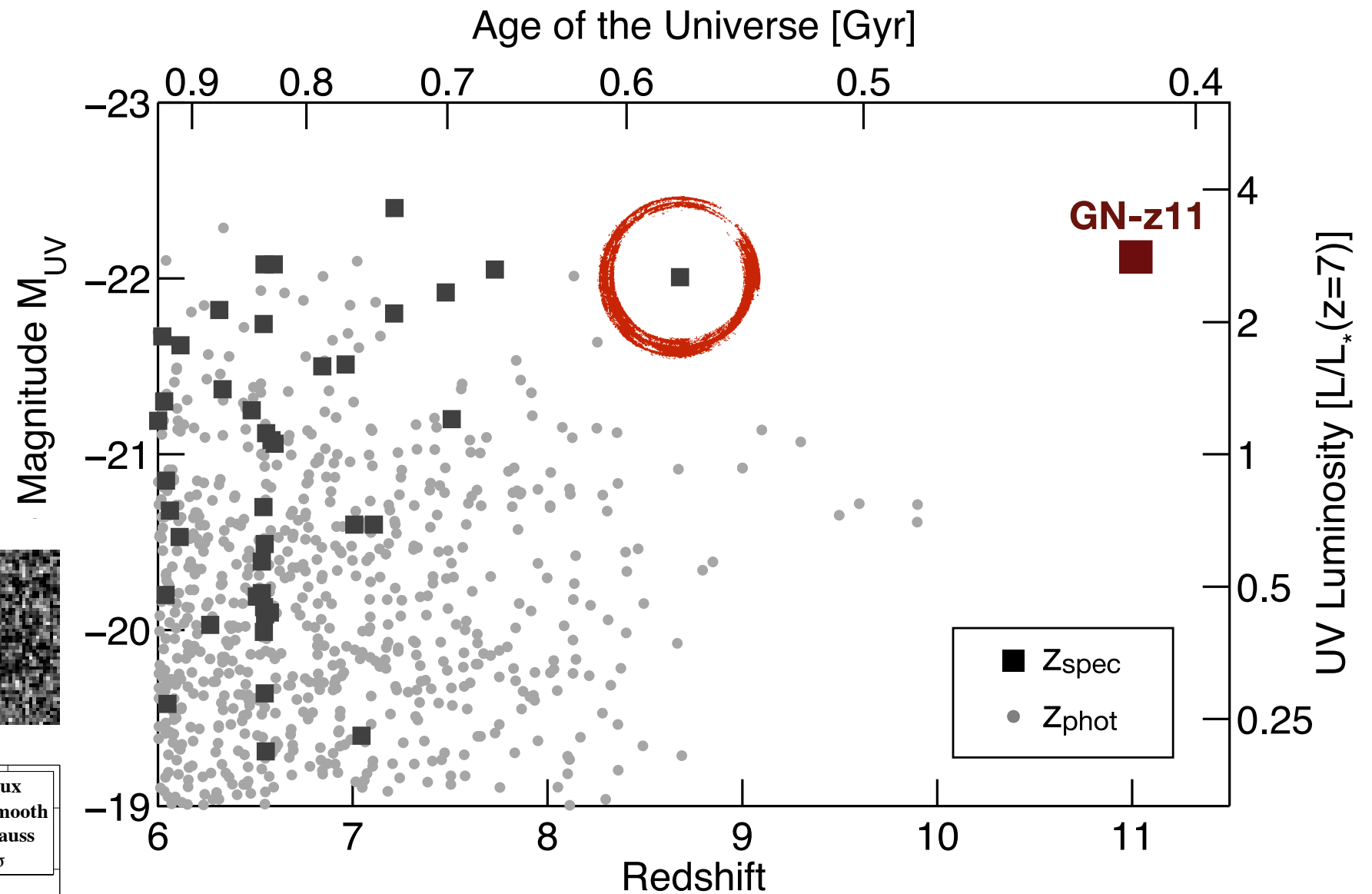
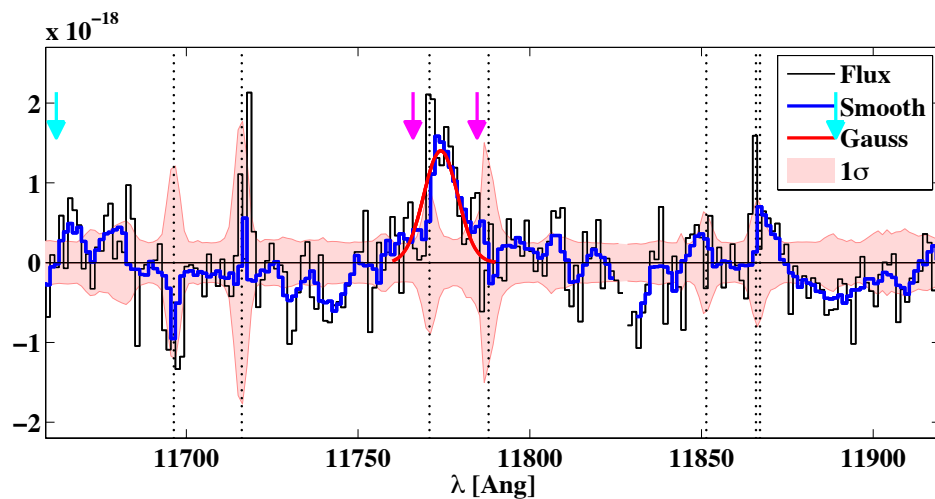
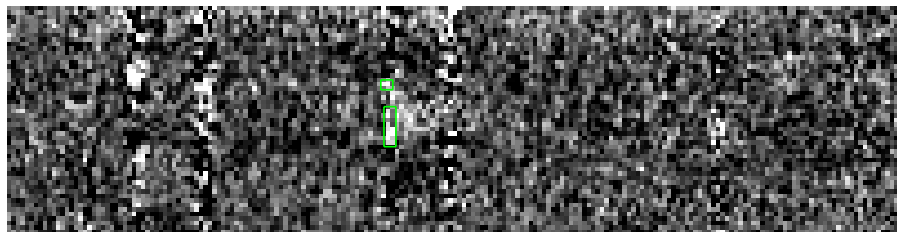


Bouwens et al. 2015,2016



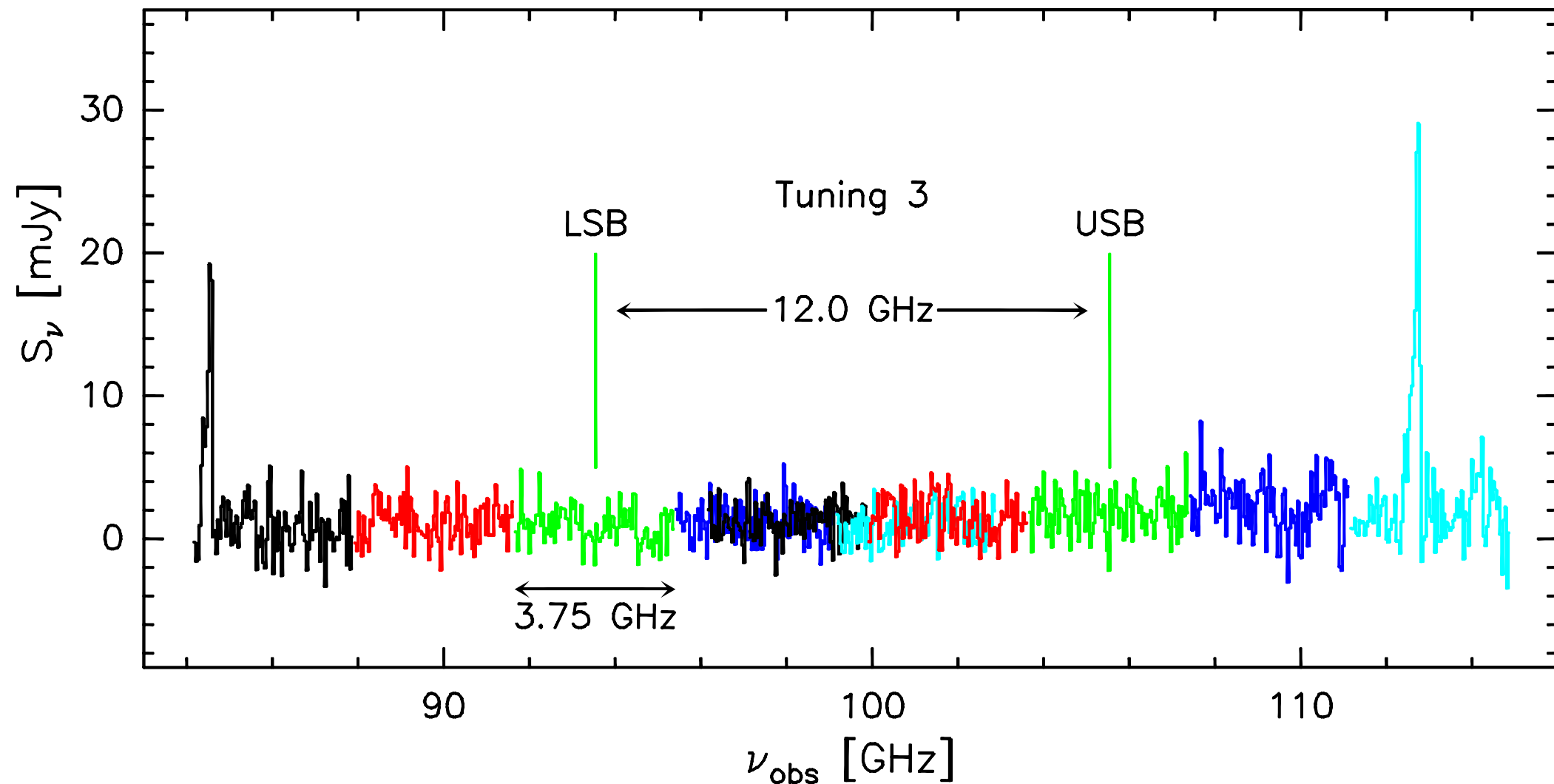
Spectroscopic confirmation of galaxies in the EoR

Ly α @ 8.683
Zitrin et al. 2015

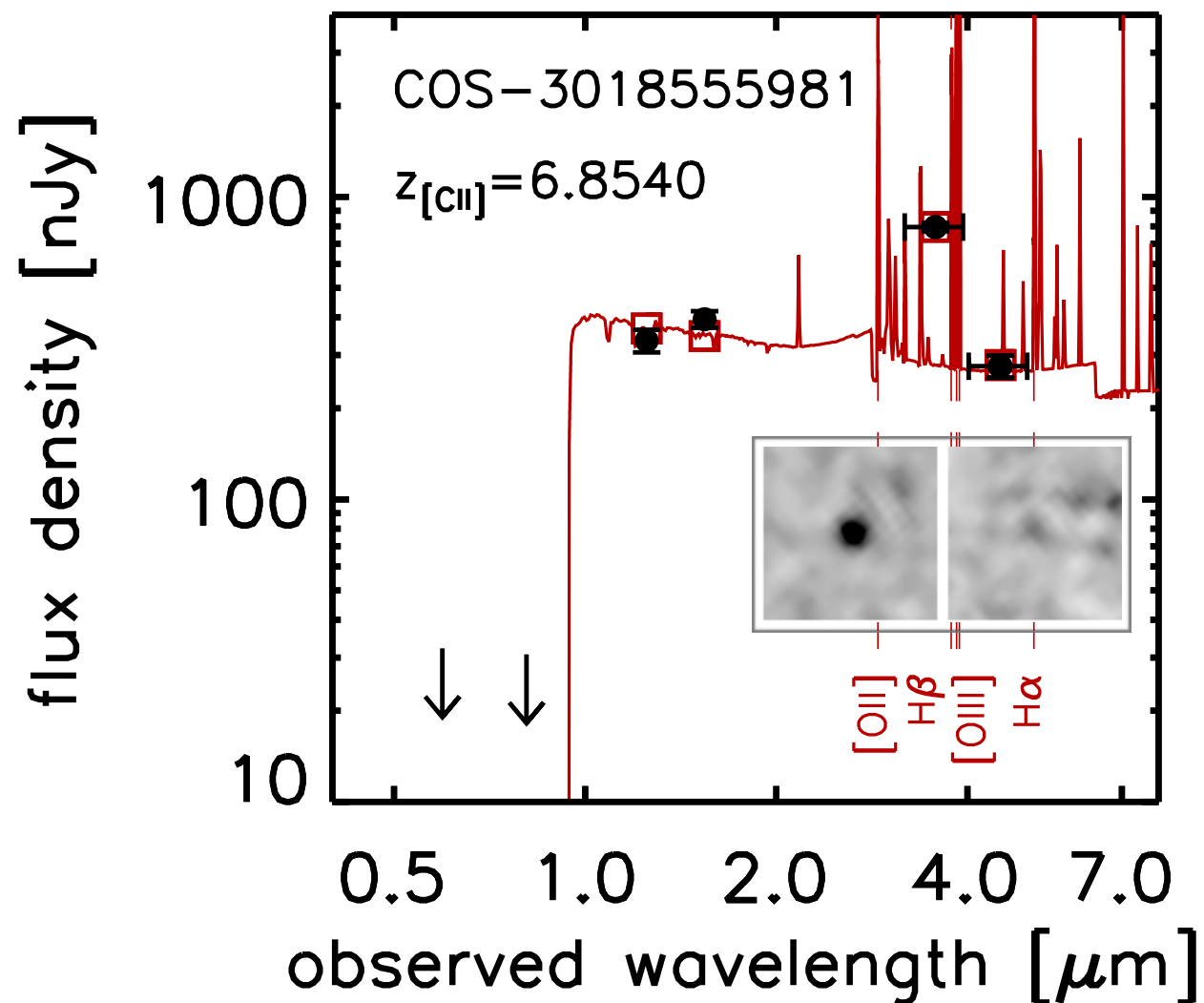


ALMA as a ‘redshift machine’

Uncertainty in photometric redshift requires
a (long) scan of the frequency range



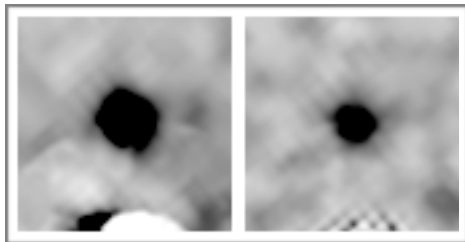
Spitzer: high-equivalent width [OIII] lines



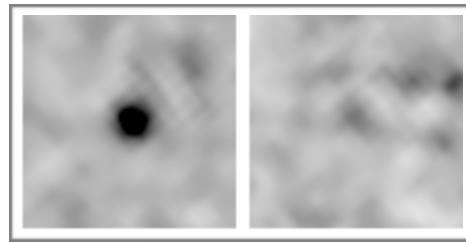
- Large fraction of sources ($\sim 50\%$) show 'extreme' emission lines
- UV-selected galaxies are likely metal poor (hard stellar radiation fields) or high sSFR (recent starburst)

Emission line signatures of H α , [OIII]

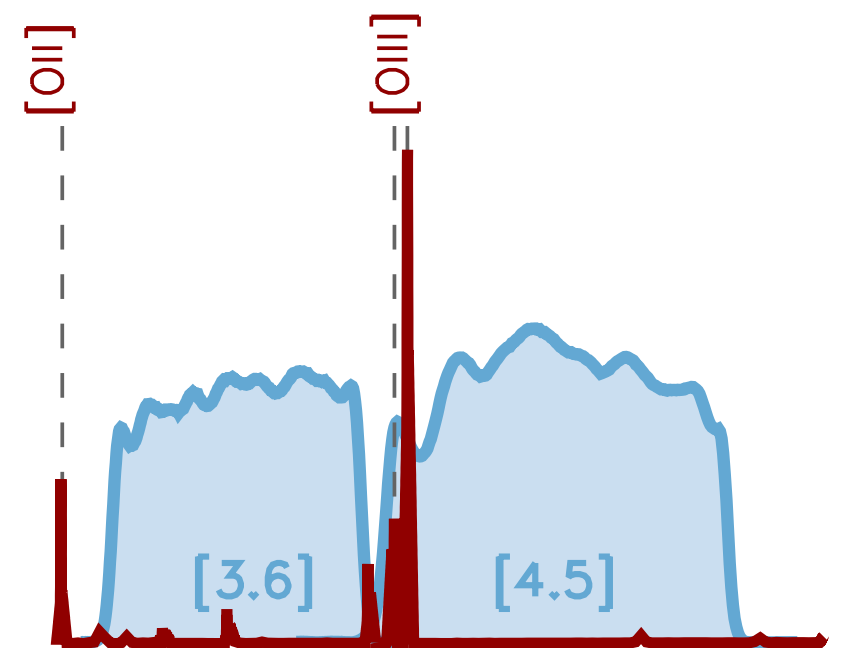
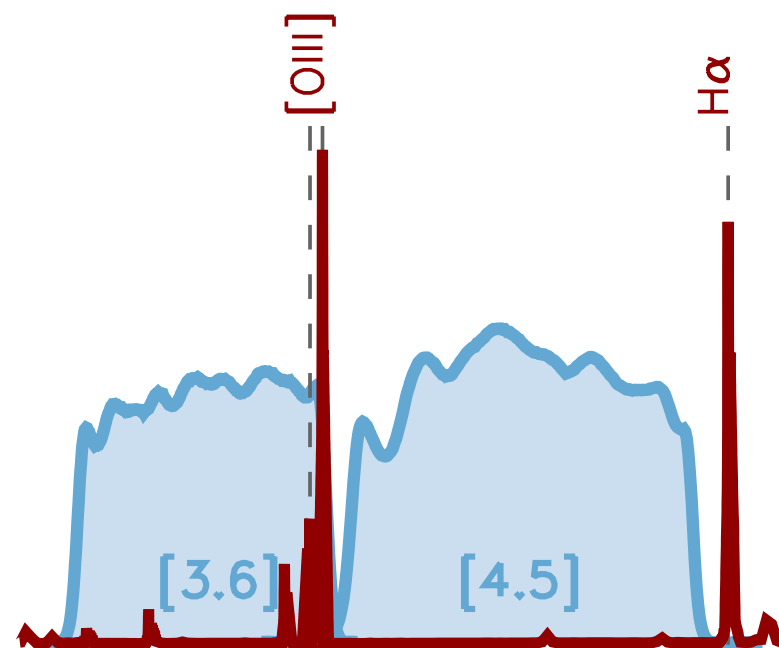
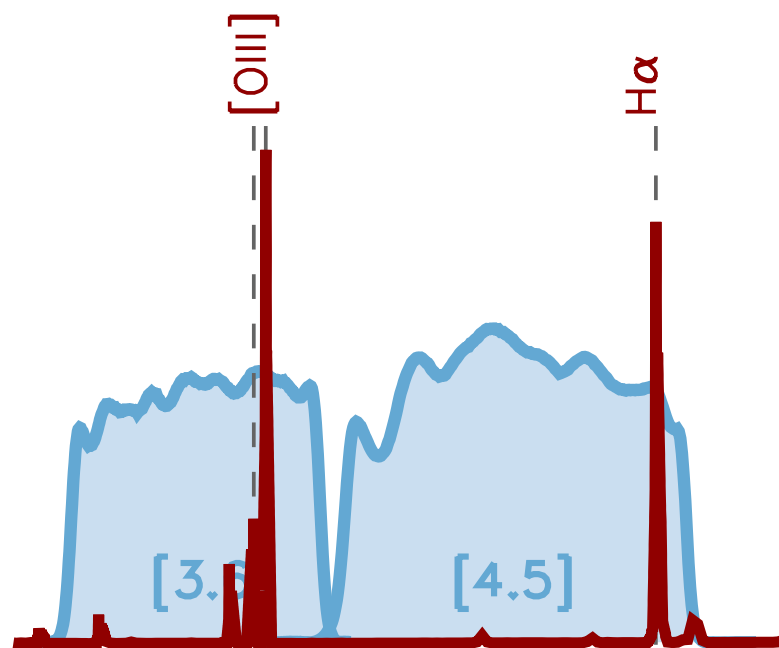
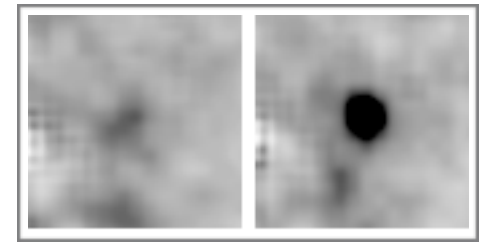
$z \sim 6.5$



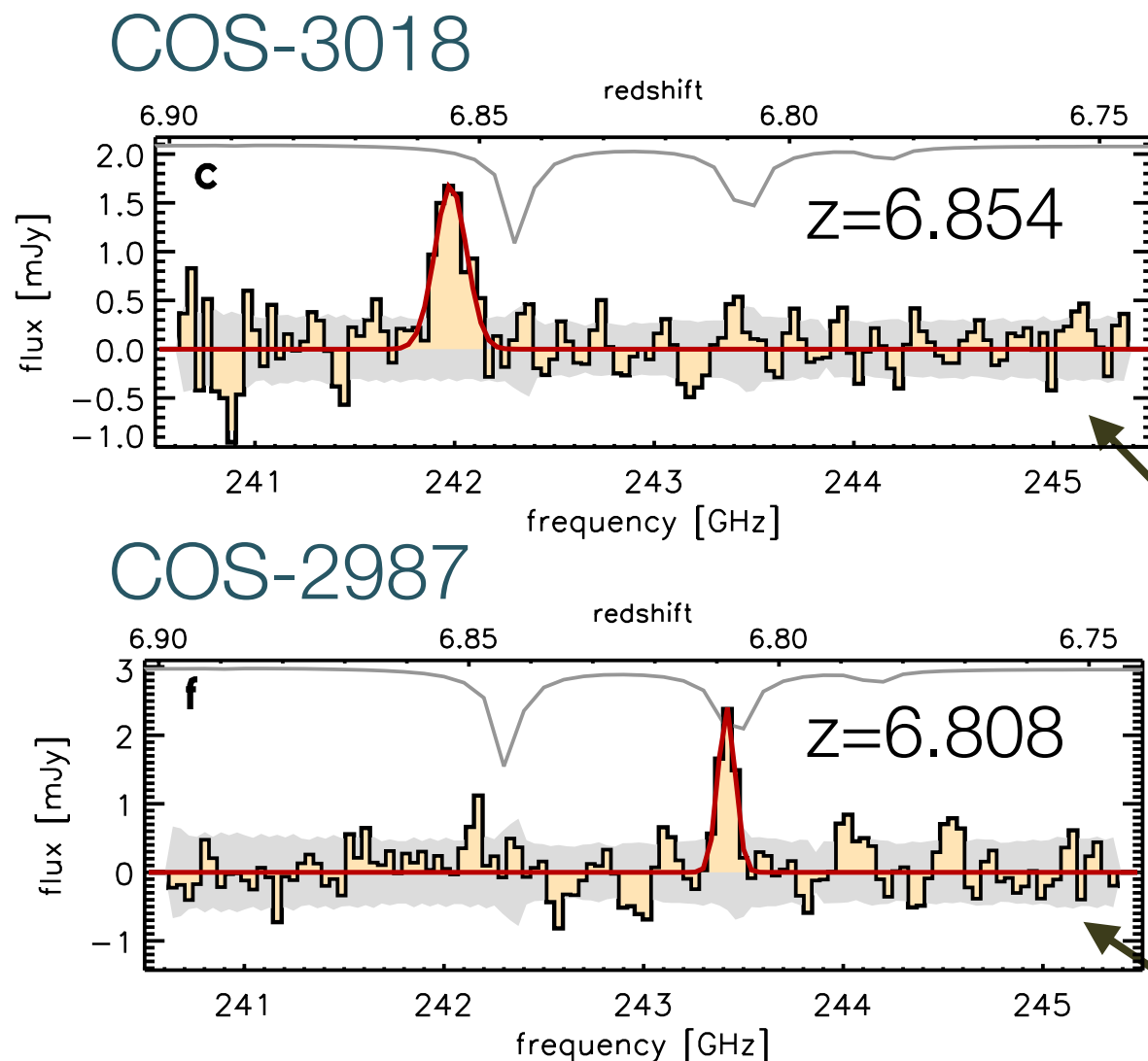
$z \sim 6.8$



$z \sim 7.1$

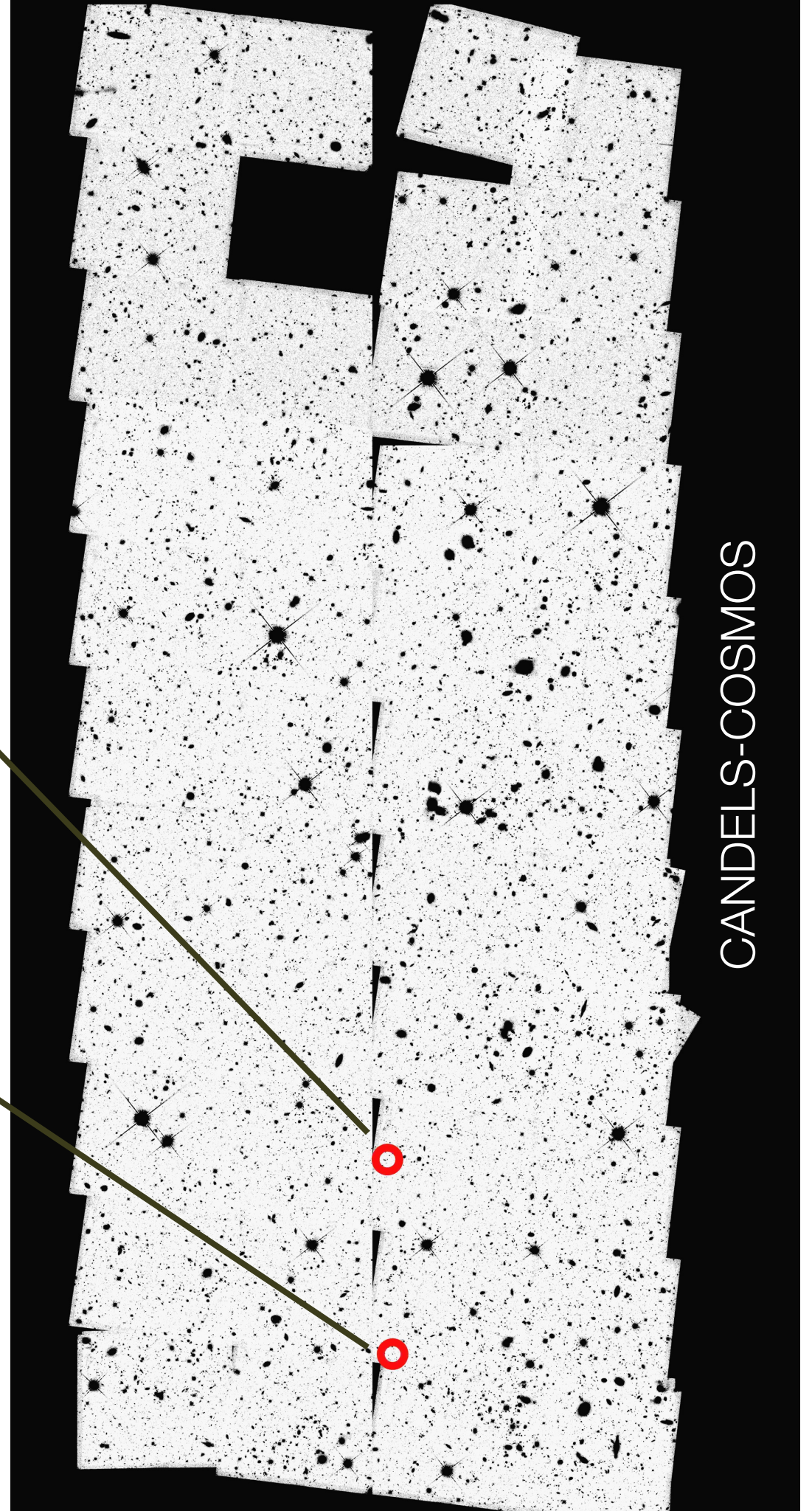


Spectroscopic redshifts with ALMA

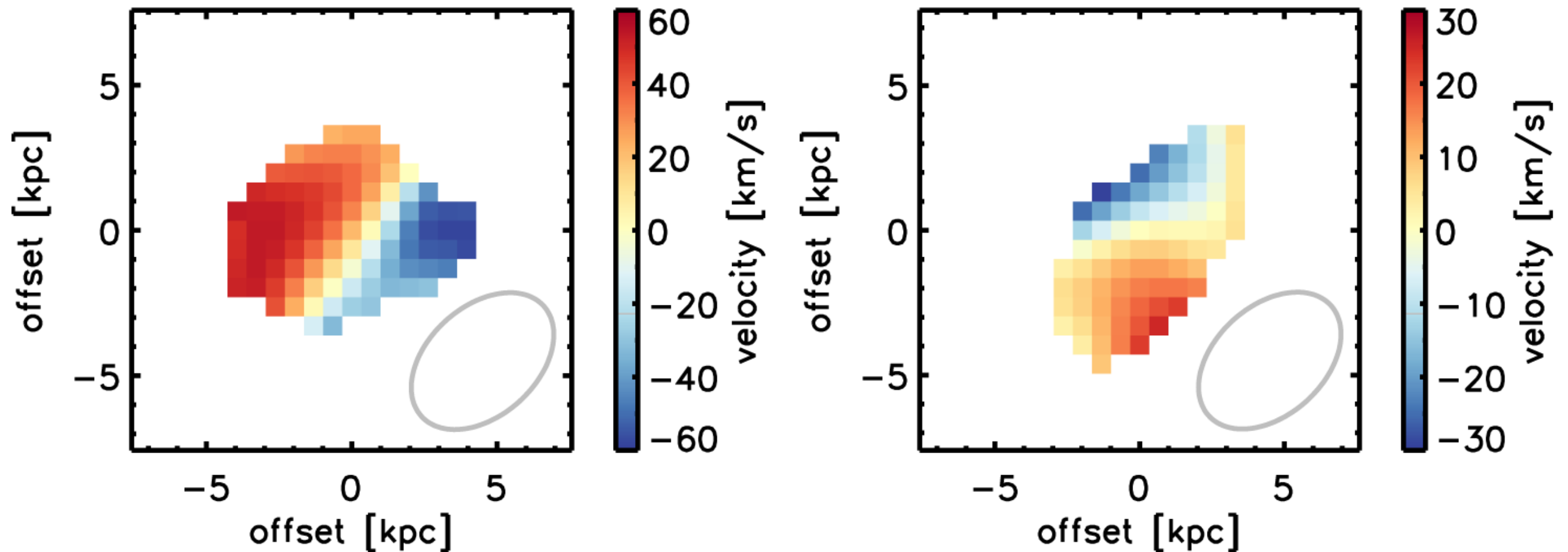


First UV-selected galaxies
to be confirmed in the EoR
with ALMA

Smit et al., 2018, Nature

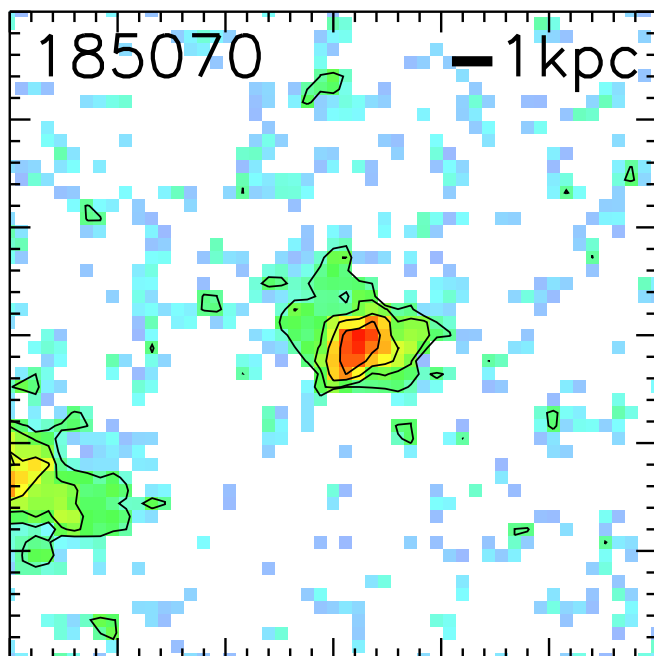


First low-resolution kinematic measurements

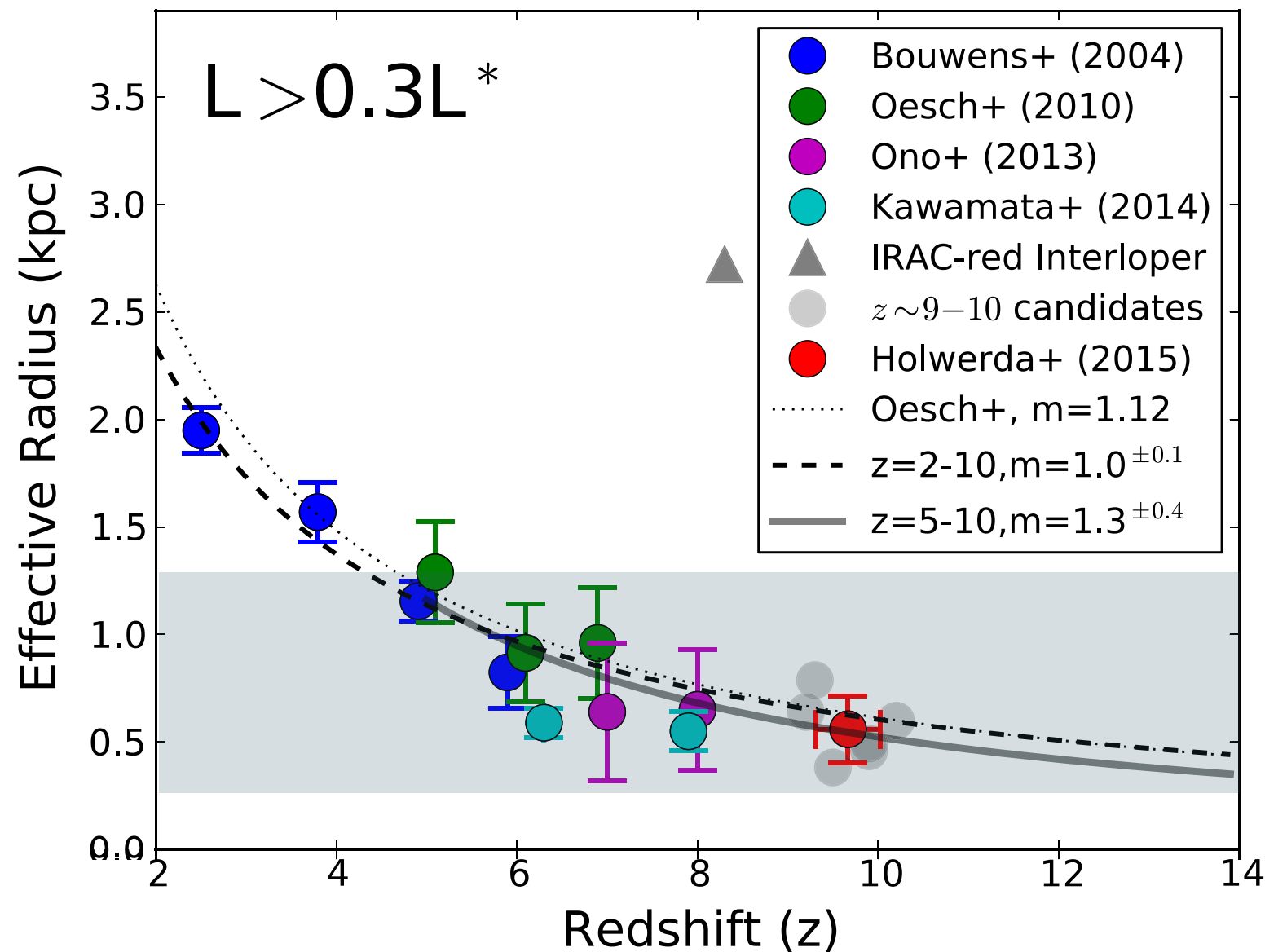


UV sizes of LBGs

Even for bright LBGs the sizes of $z > 6$ are typically < 1 kpc

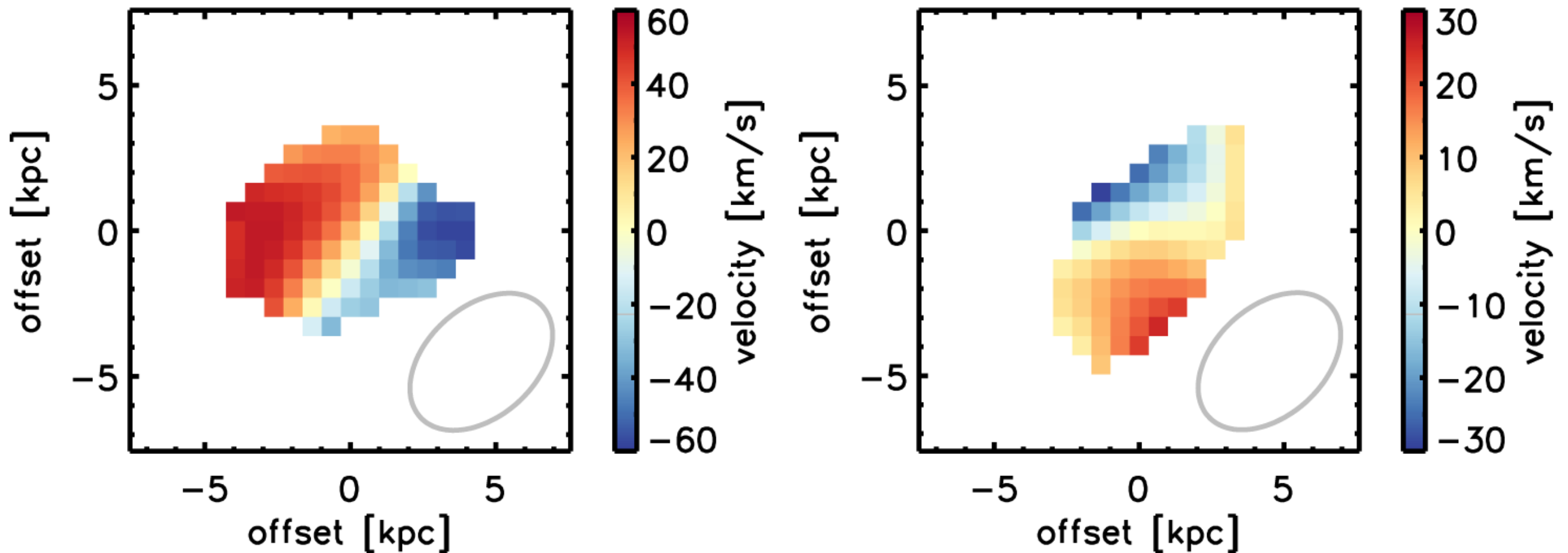


Bowler et al., 2017



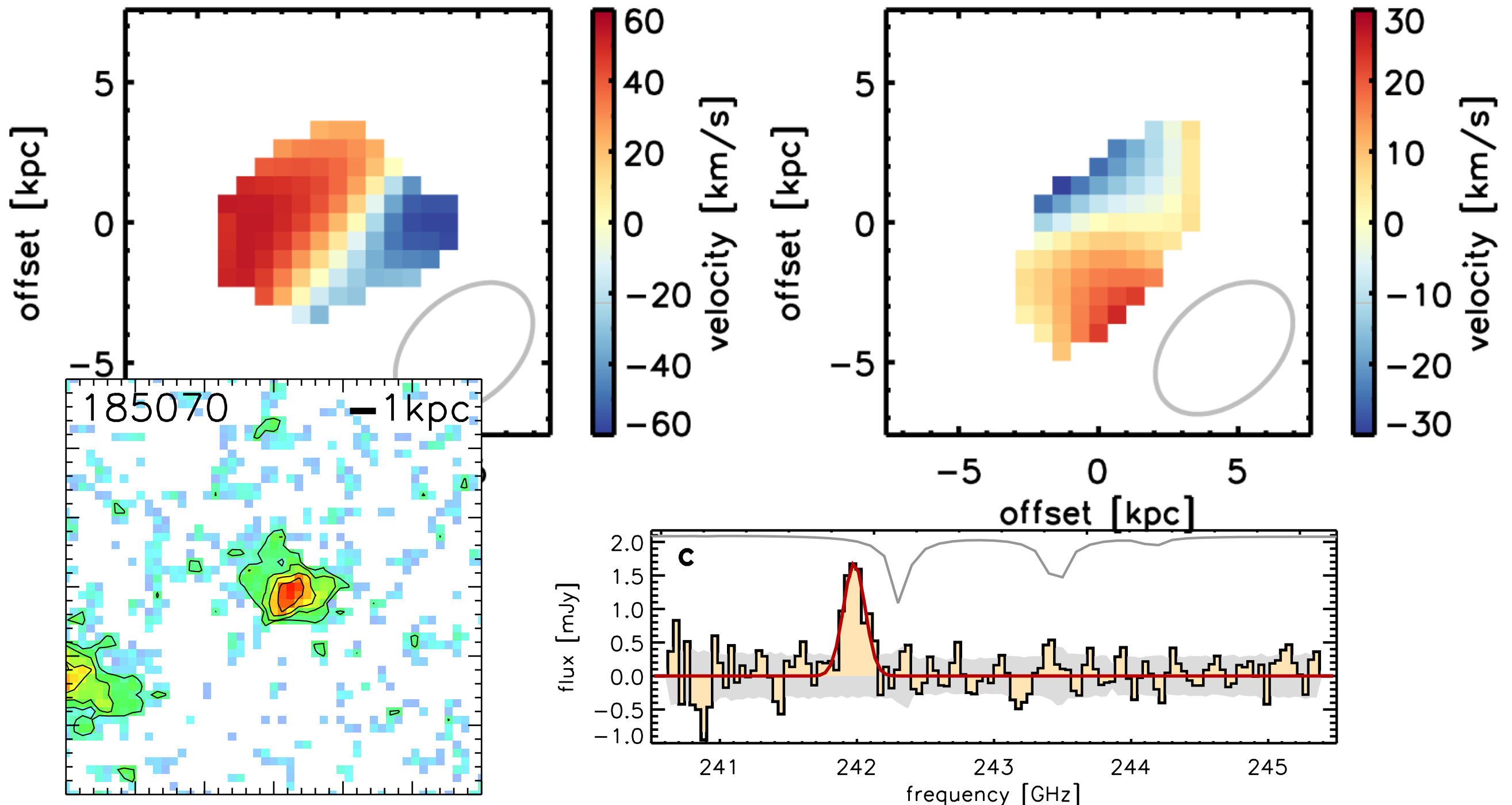
Holwerda et al. 2015

First low-resolution kinematic measurements



Smooth accretion from the cosmic web as an important mechanism for galaxy growth at $z \sim 7$?

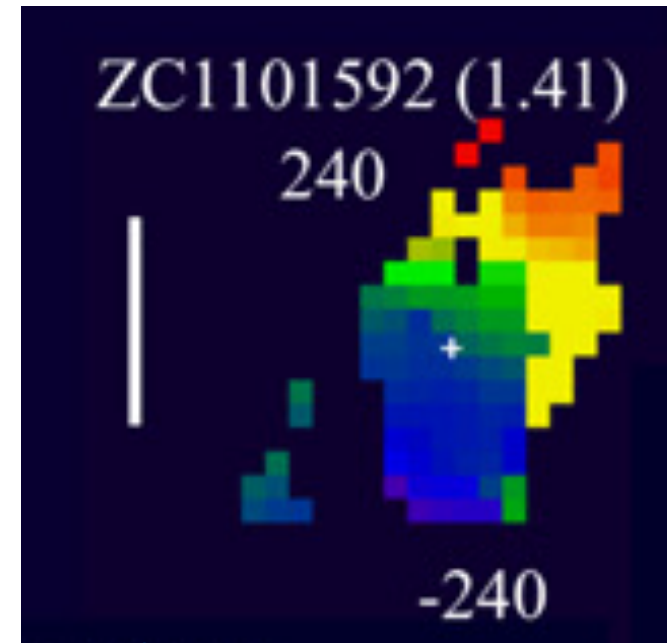
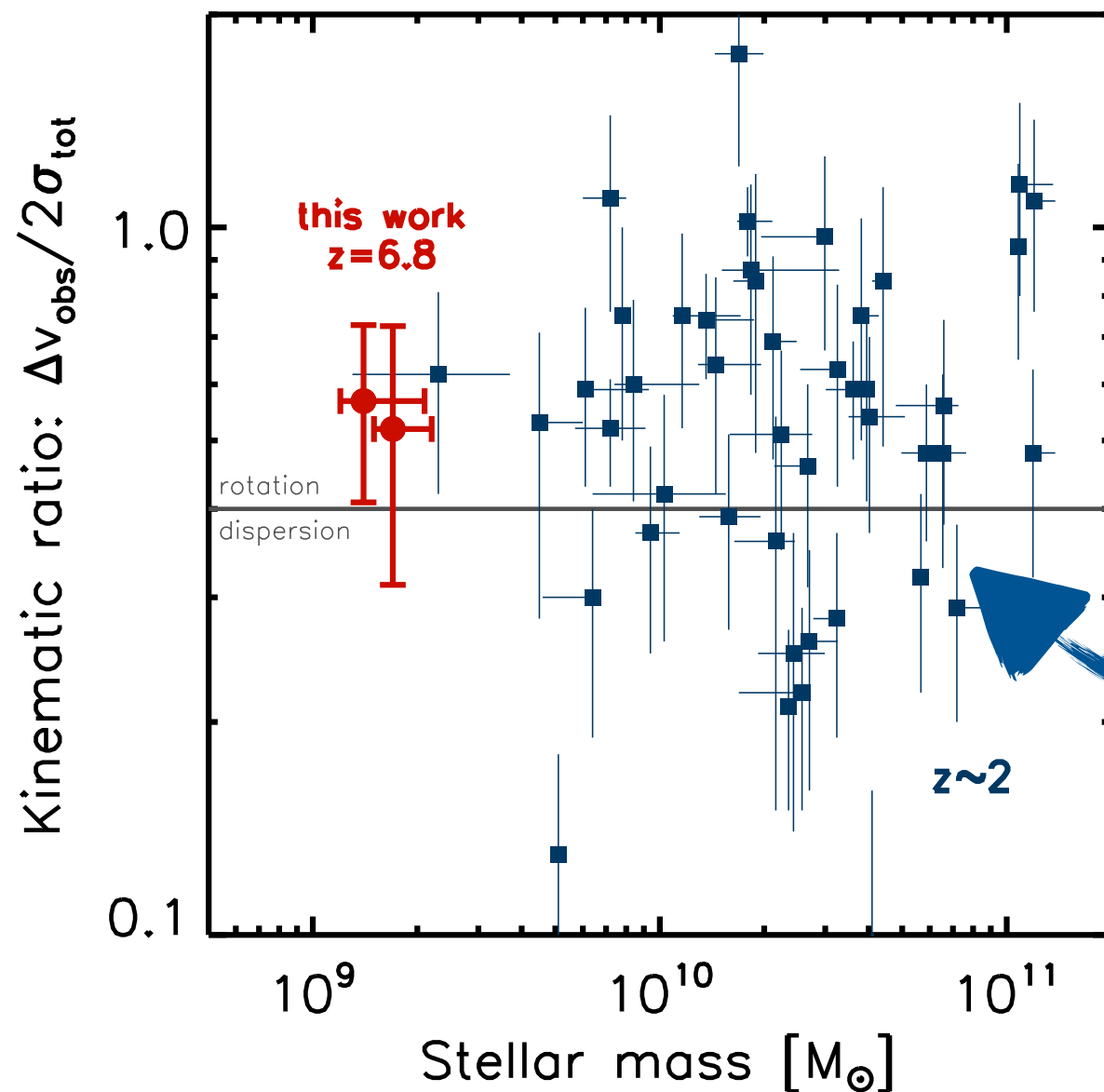
First low-resolution kinematic measurements



Bowler et al., 2017

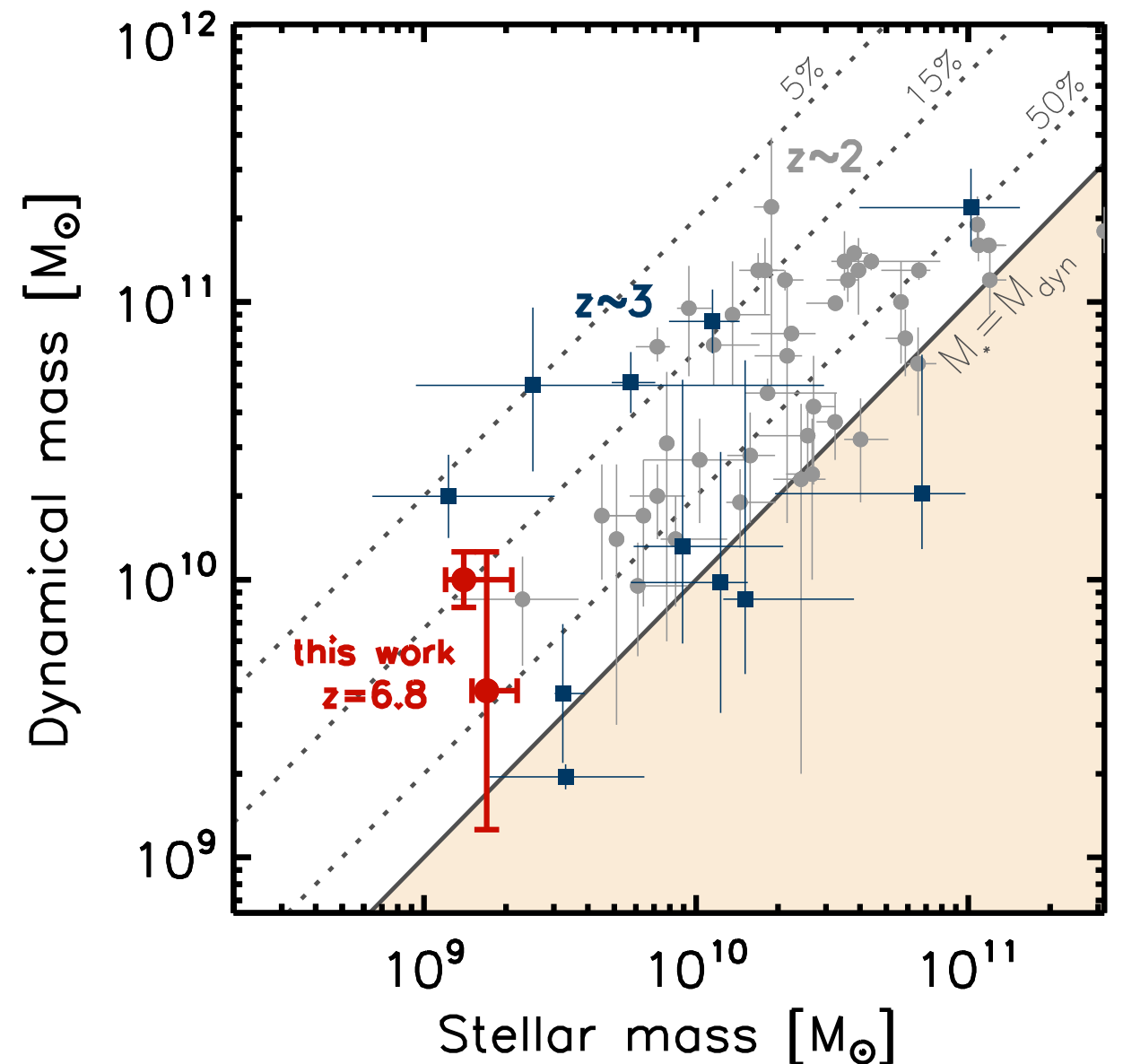
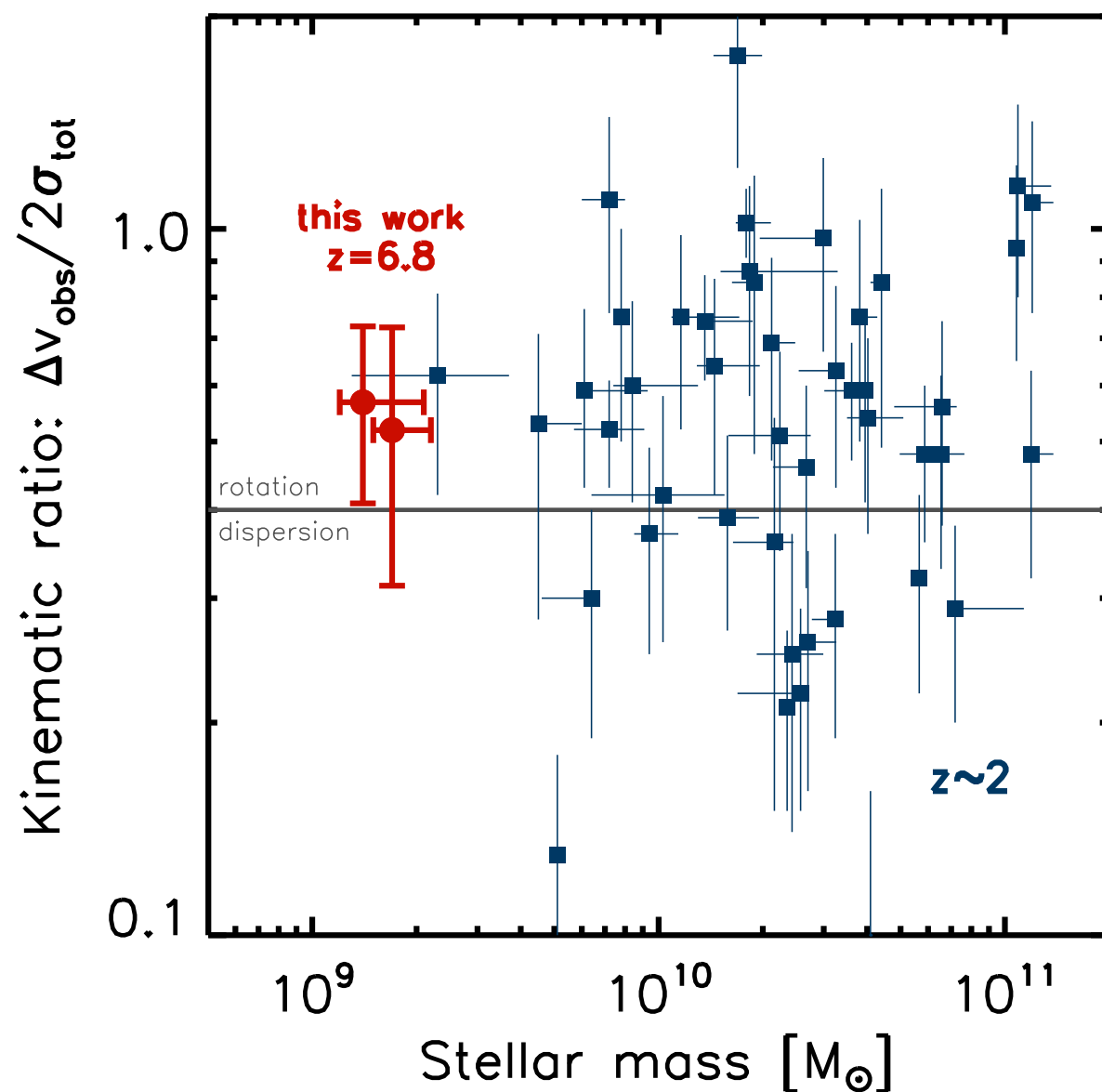
Smit et al., 2018, Nature

Dynamical properties



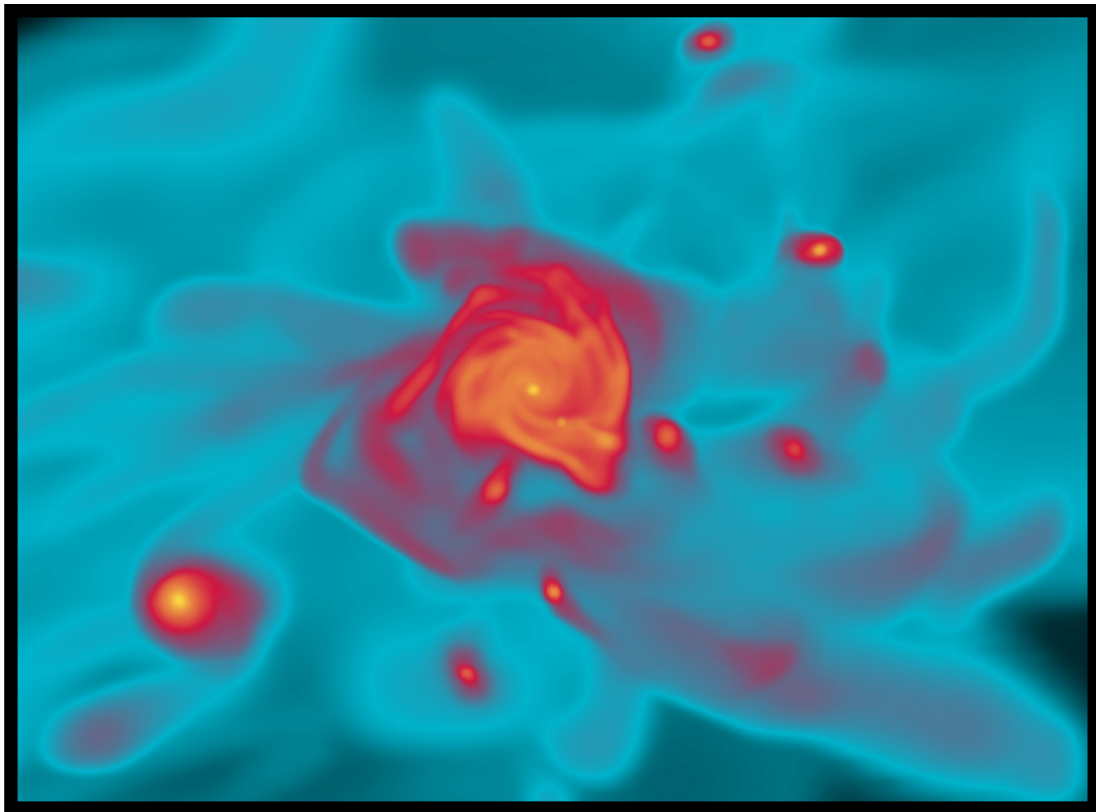
SINS survey before AO -
Forster-Schreiber et al. 2009

Dynamical properties



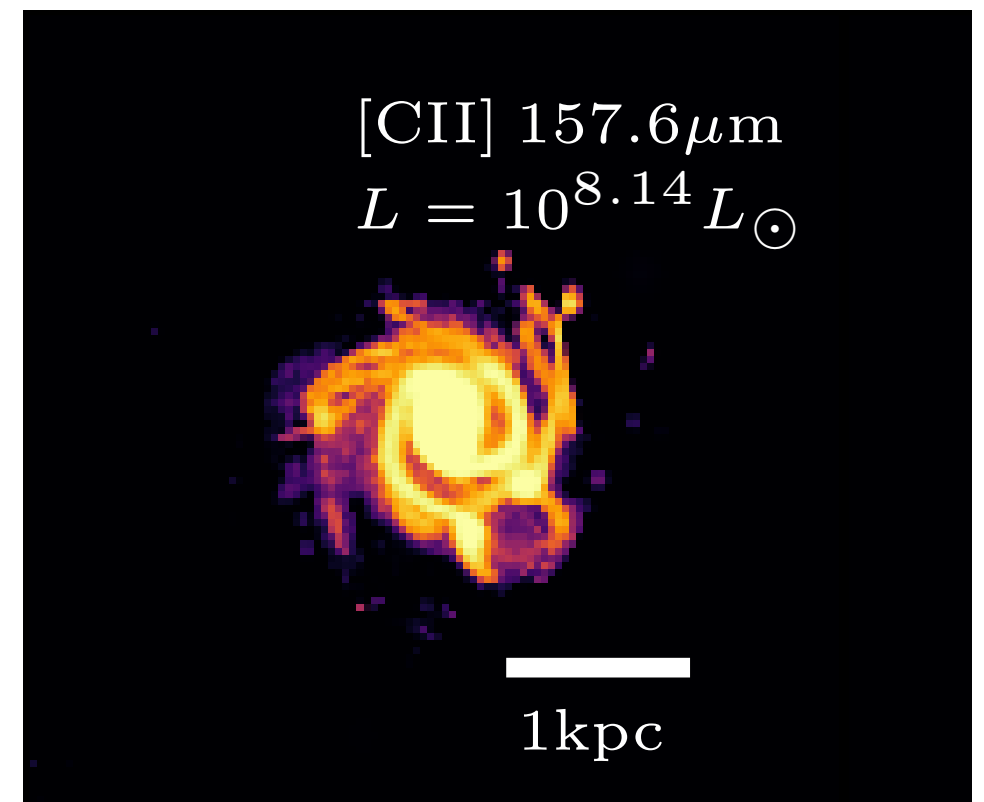
$z \sim 7$ [CII] emitters appear to have similar kinematics to $z \sim 2$ H α emitting galaxies

Simulation predictions for [CII]



Pallottini, et al., 2017;2019

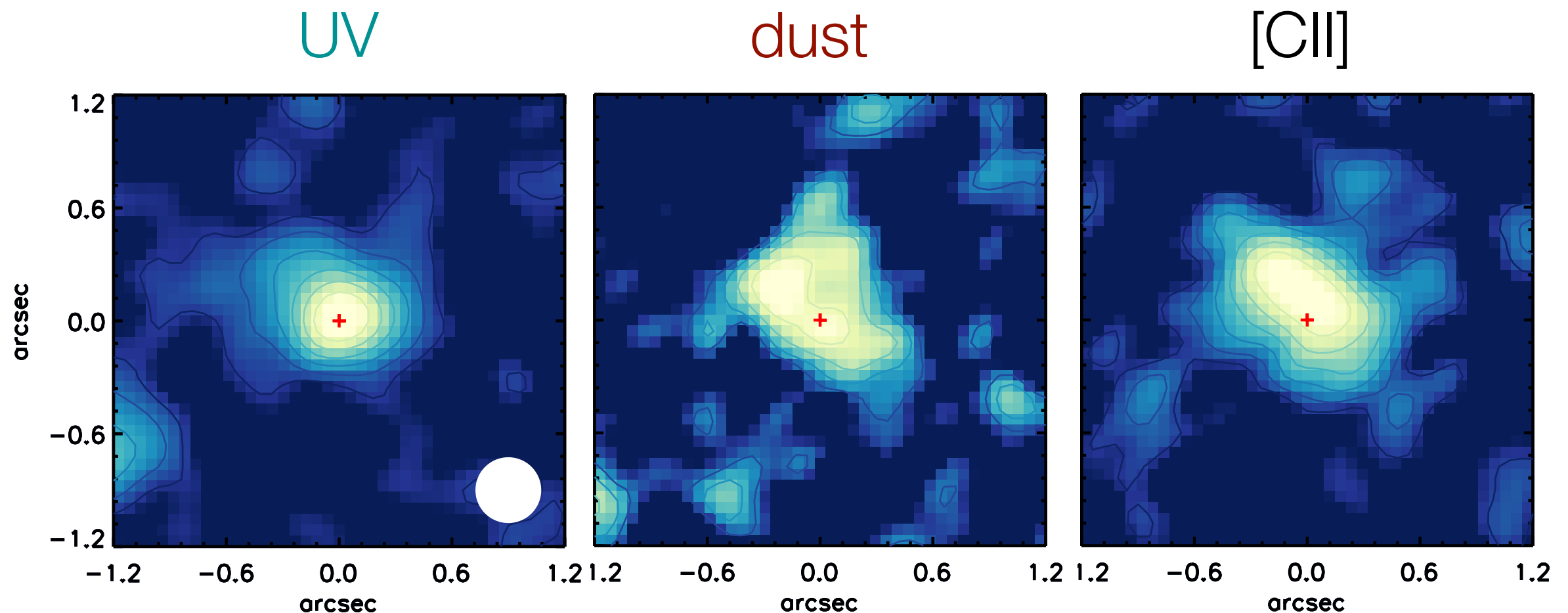
Simulations predict highly time variable morphologies, but ordered rotation is common



Katz, et al., 2019

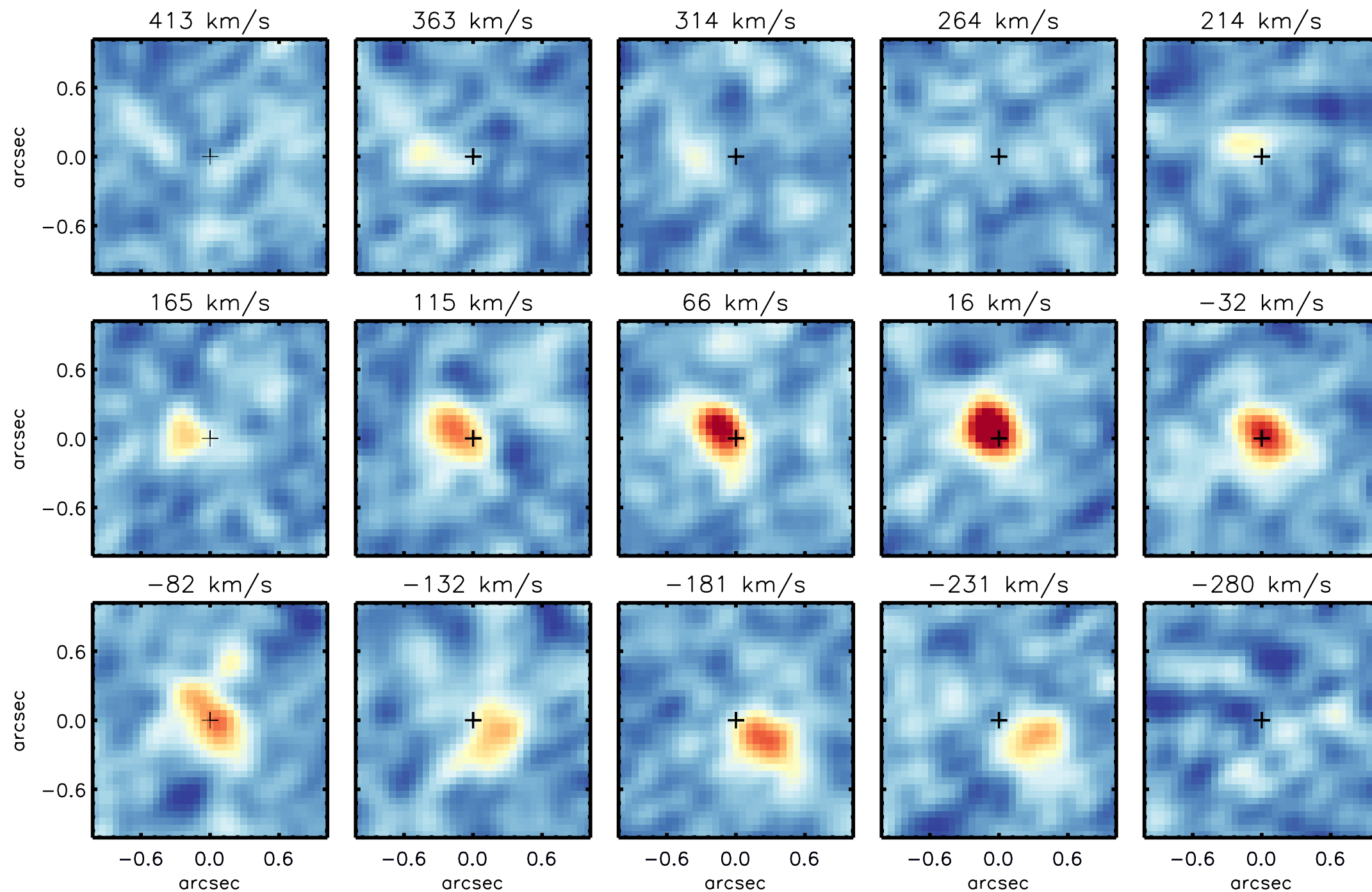
see also Pawlik et al. 2011, Romano-Diaz et al. 2011, Feng et al. 2015

Zooming in on a ‘typical’ LBG

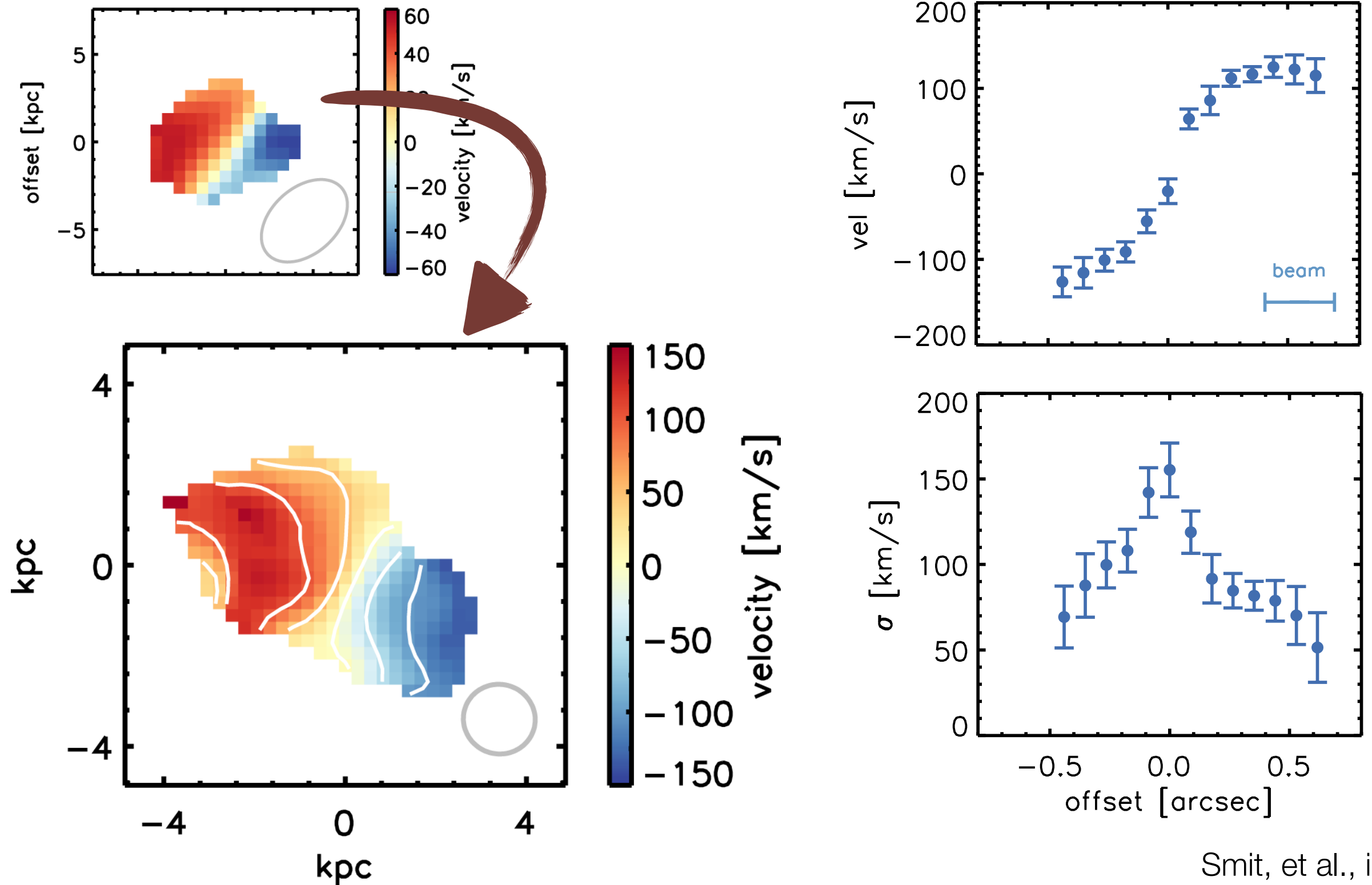


Deep, modest resolution ALMA
imaging of a galaxy with
 $\text{SFR}_{\text{UV}} \sim 19 \text{ M}_{\odot}/\text{yr}$, $\text{SFR}_{\text{IR}} \sim 16 \text{ M}_{\odot}/\text{yr}$

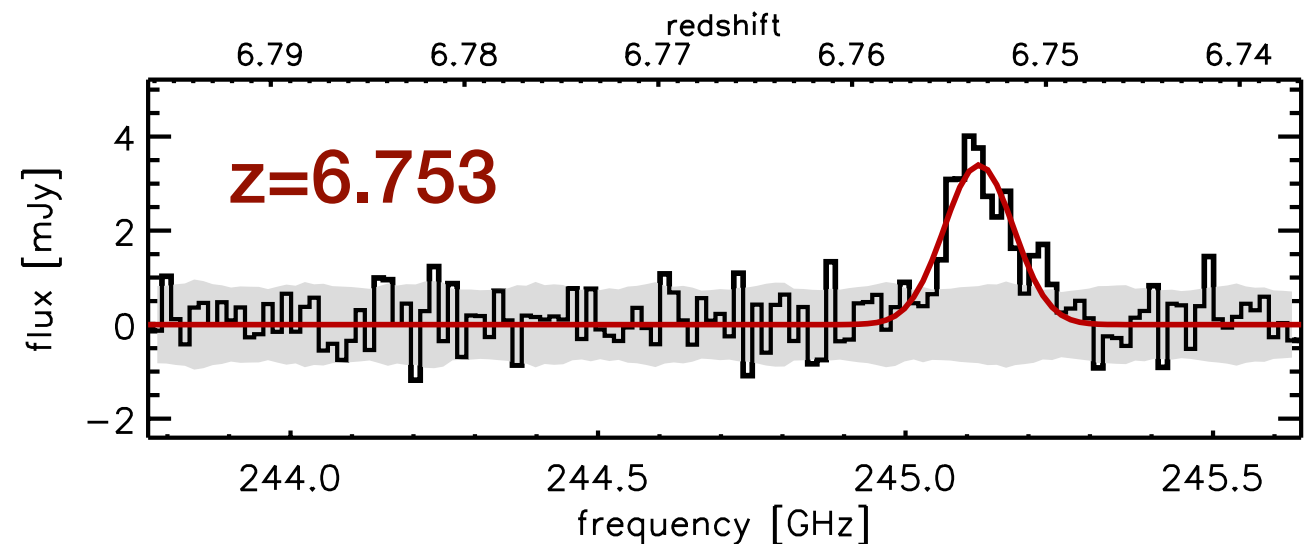
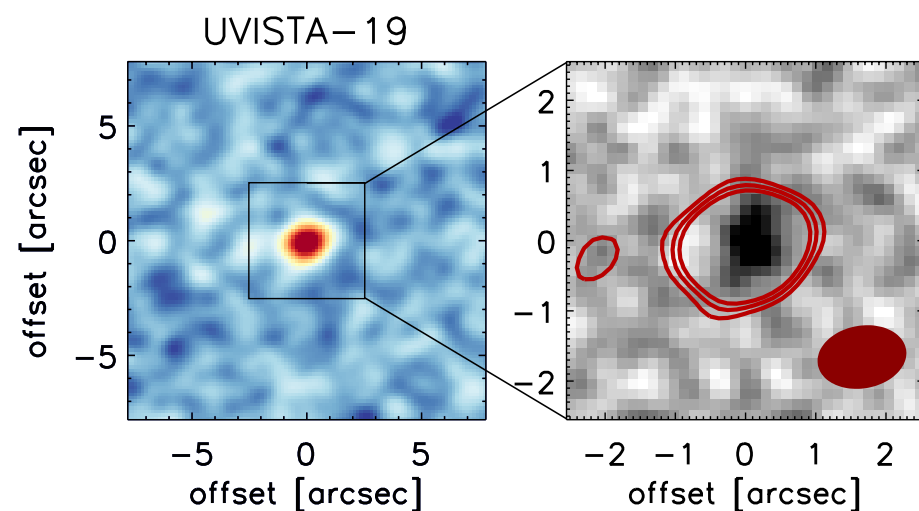
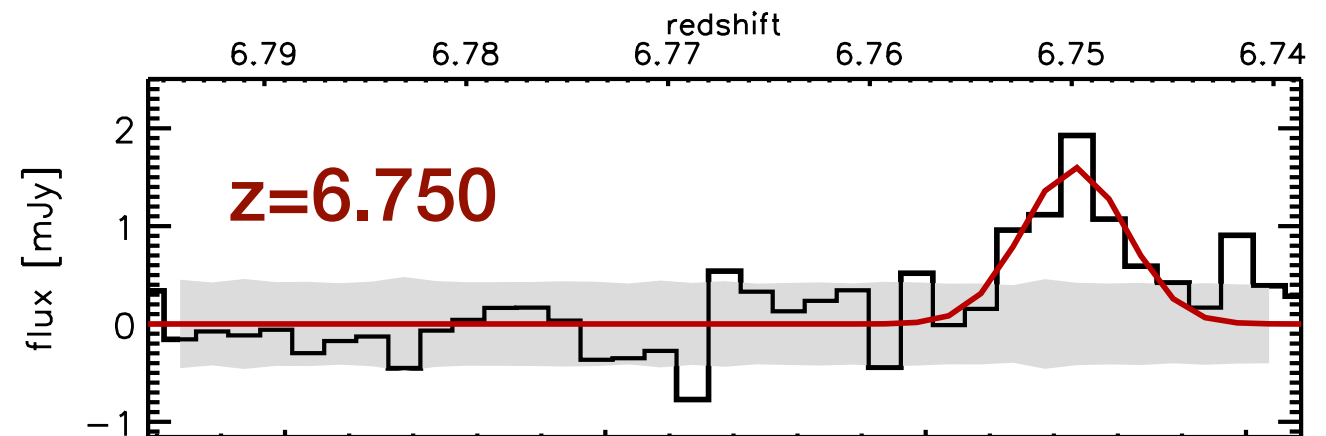
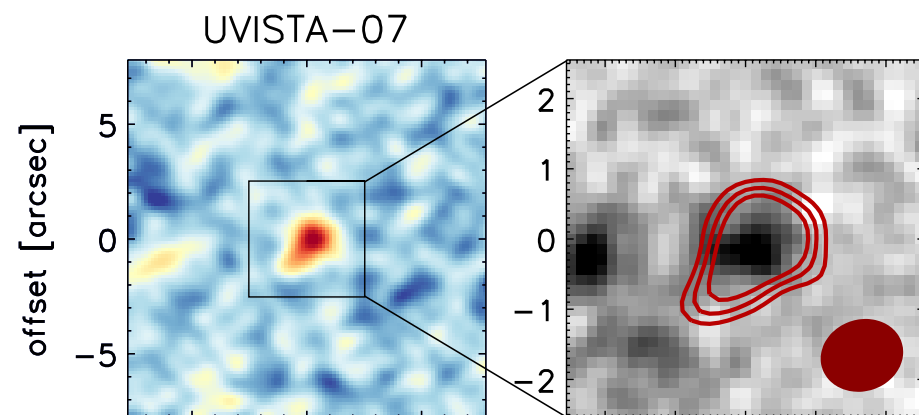
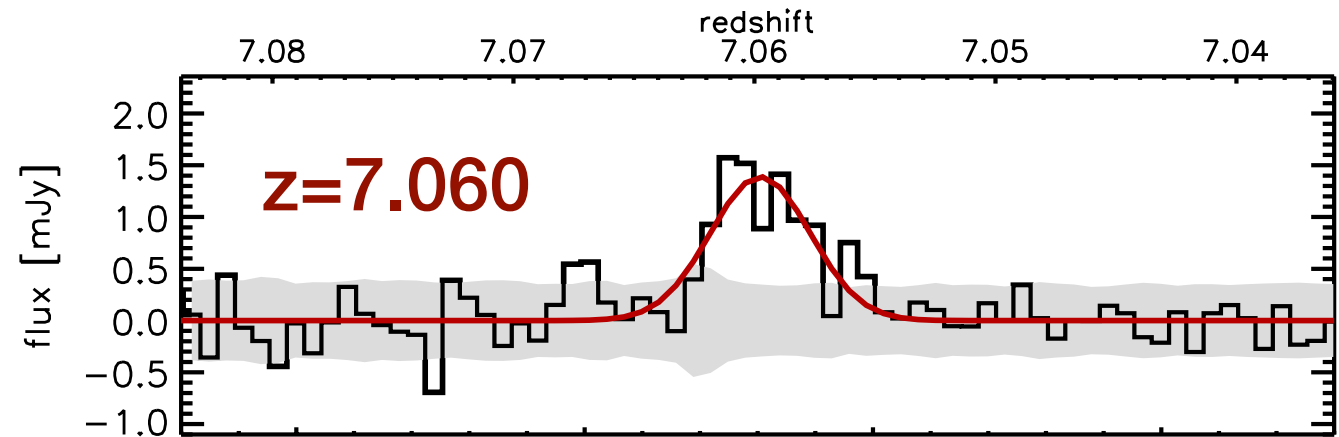
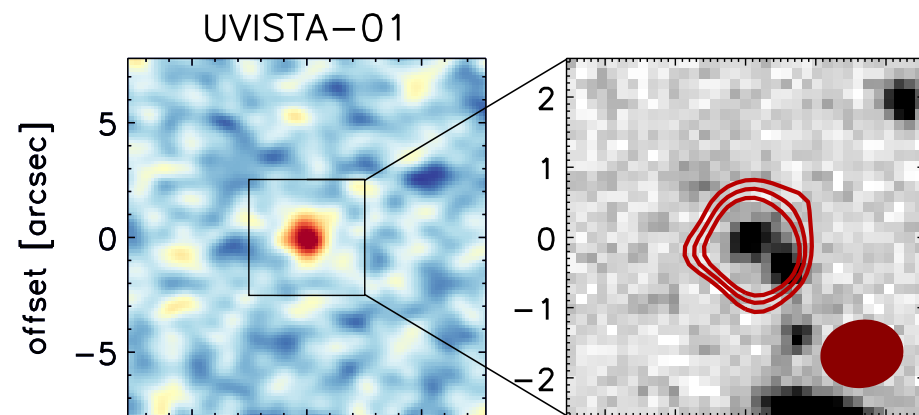
Zooming in on a gas disk with ALMA



Zooming in on a gas disk with ALMA



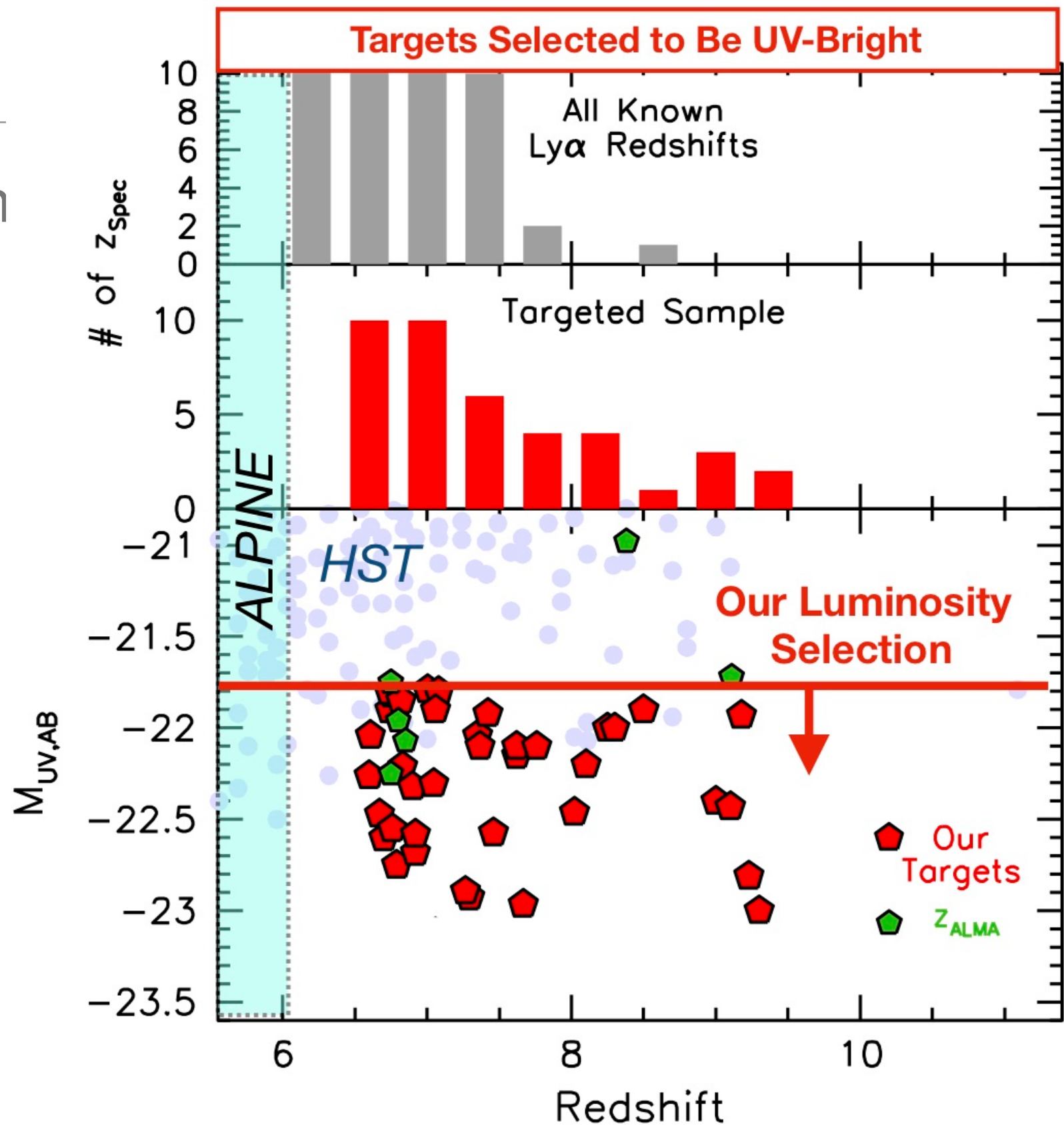
ALMA kinematics limited to available samples



REBELS: an ALMA Cycle 7 LP

- REBELS: **R**eionization **E**ra **B**right **E**mission **L**ine **S**urvey
- 70 hr scanning 40 bright LBGs for [CII] / [OIII] at $6.5 < z < 9.5$

Core team: Rychard Bouwens (PI), Rebecca Bowler, Valentino Gonzalez, Ryan Endsley, Hanae Inami, Pascal Oesch, Sander Schouws, Renske Smit, Daniel Stark, Mauro Stefanon

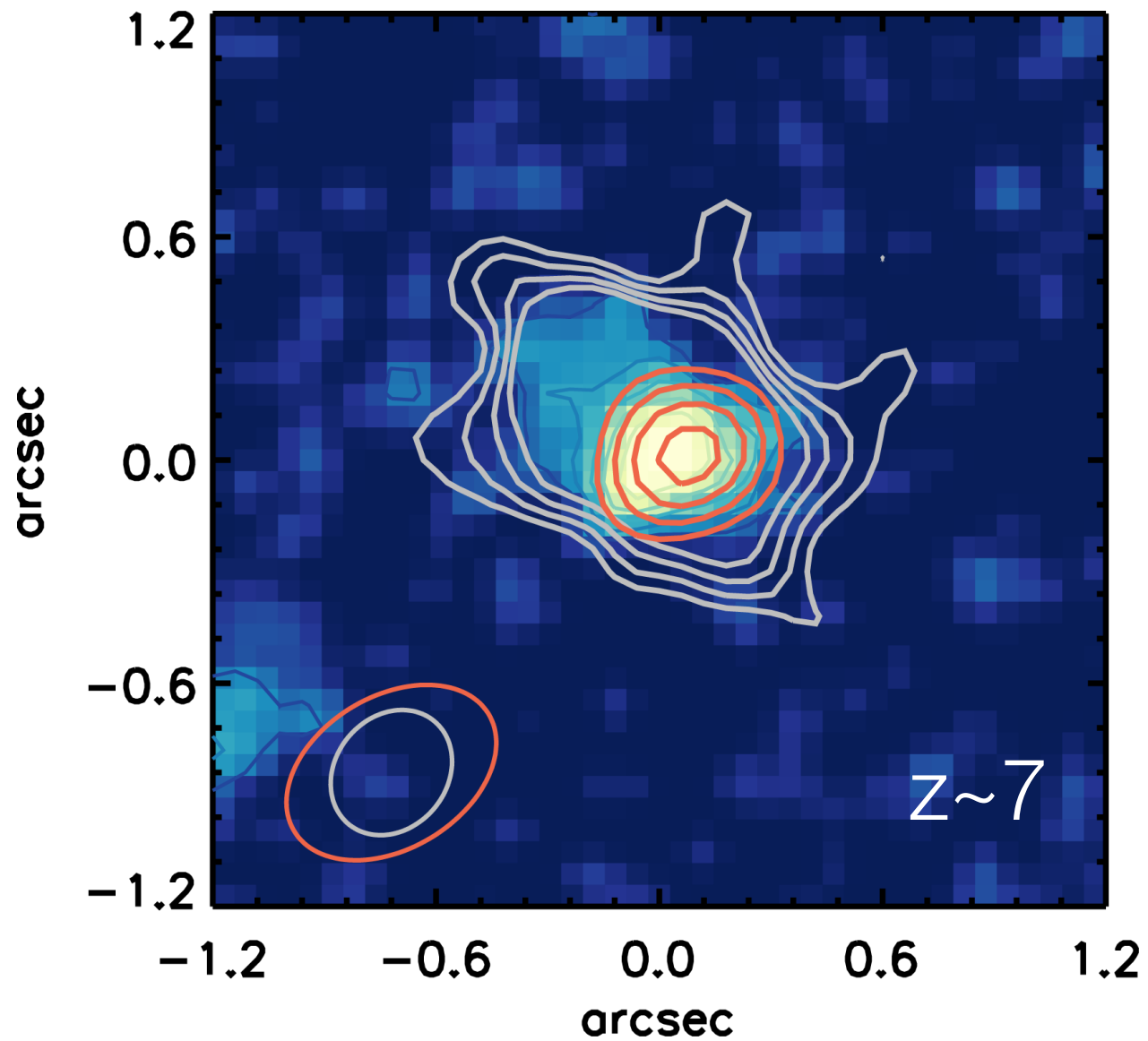


Summary

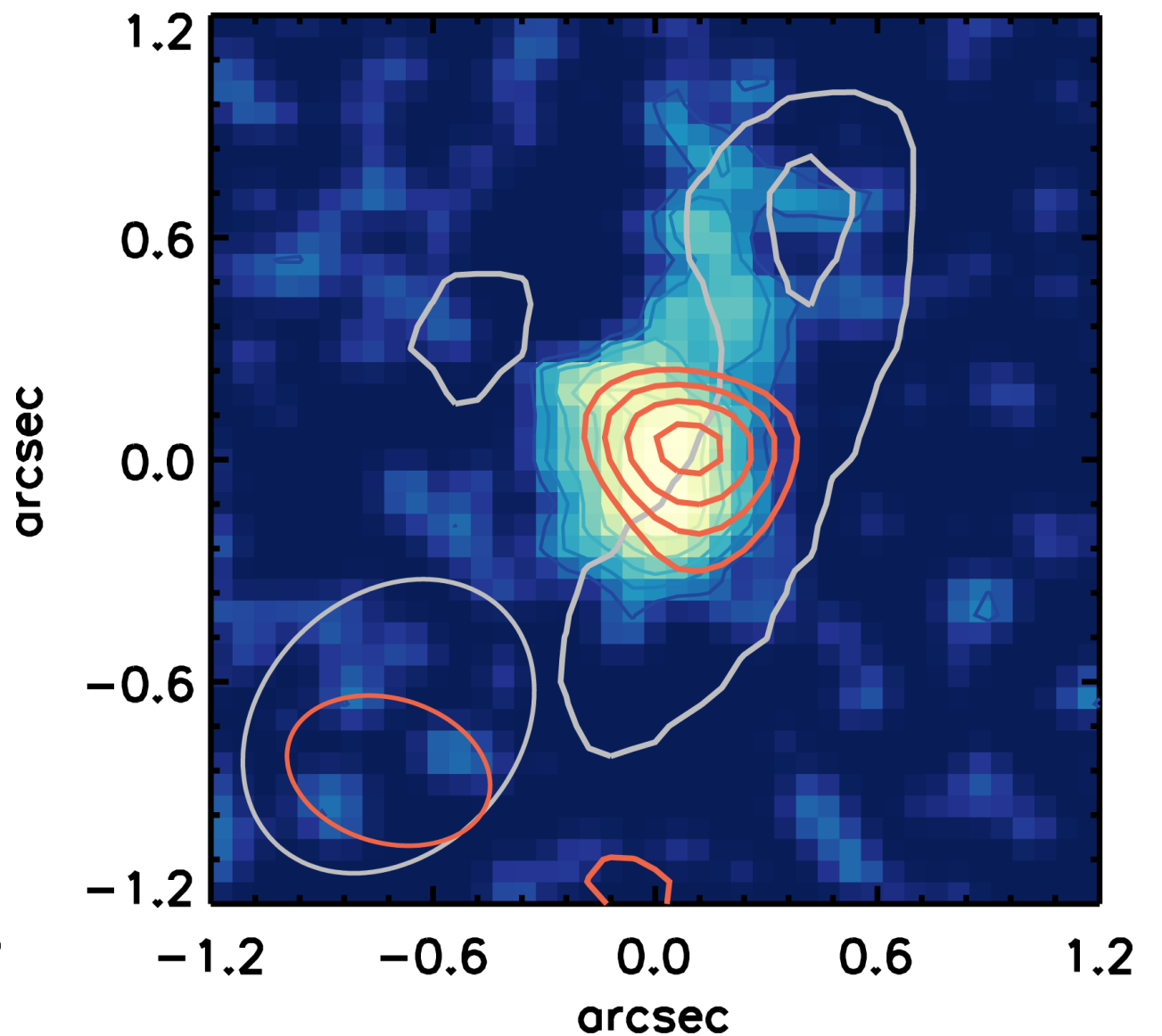
- ALMA is starting to fulfil its promise as ‘redshift machine’ for the first generations of galaxies
- Dust continuum and [CII] can show markedly different morphologies from their UV counterparts
- First [CII] kinematics suggest smooth accretion might contribute significantly to galaxy growth
- First modest spectroscopic samples might soon become available with the upcoming REBELS program

[OIII] alignment with the UV

COS-3018



COS-2987



Dynamical masses

