THE NATURE AND ASSEMBLY OF PRIMEVAL GALAXIES REVEALED BY ALMA

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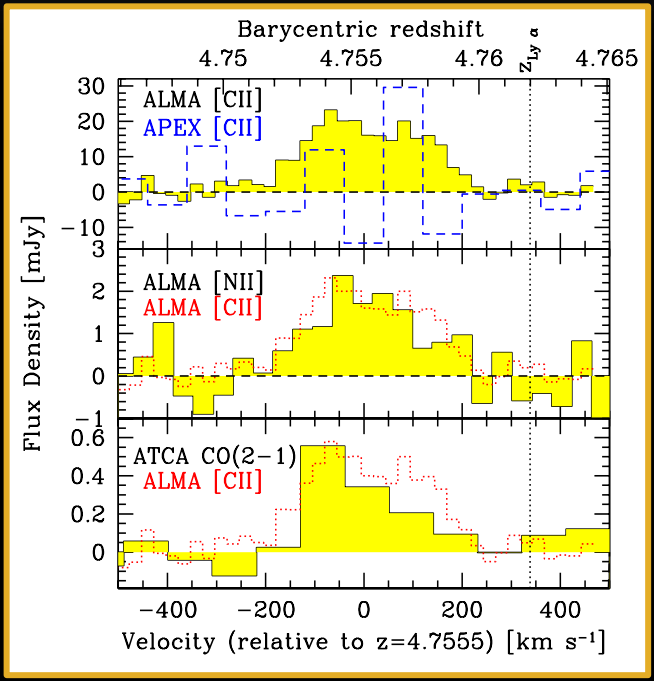
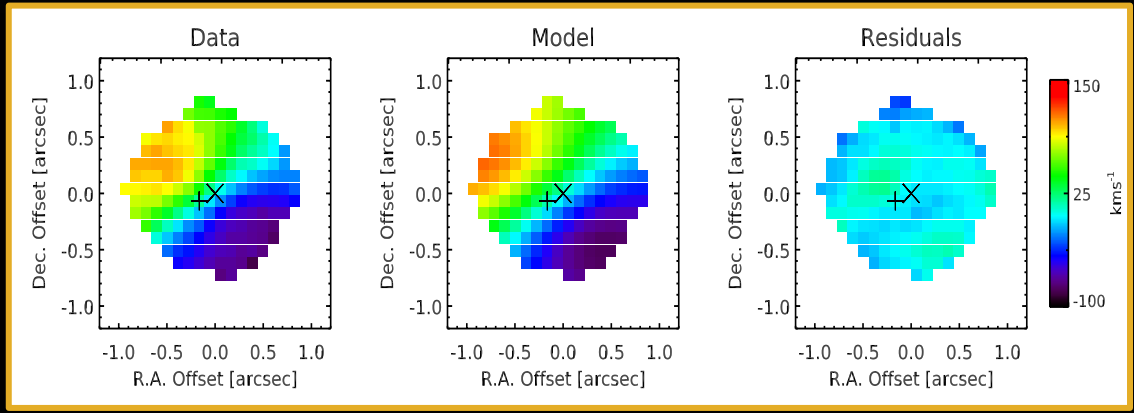
So far far-IR detections of distant/primeval galaxies (z>4) are mostly on extreme objects: SMGs/ULIRGs/QSOS

e.g. LESS 73.1: SMG at z = 4.76 observed with ALMA

C. De Breuck et al., 2014

- Multiple mm/far-IR lines detected





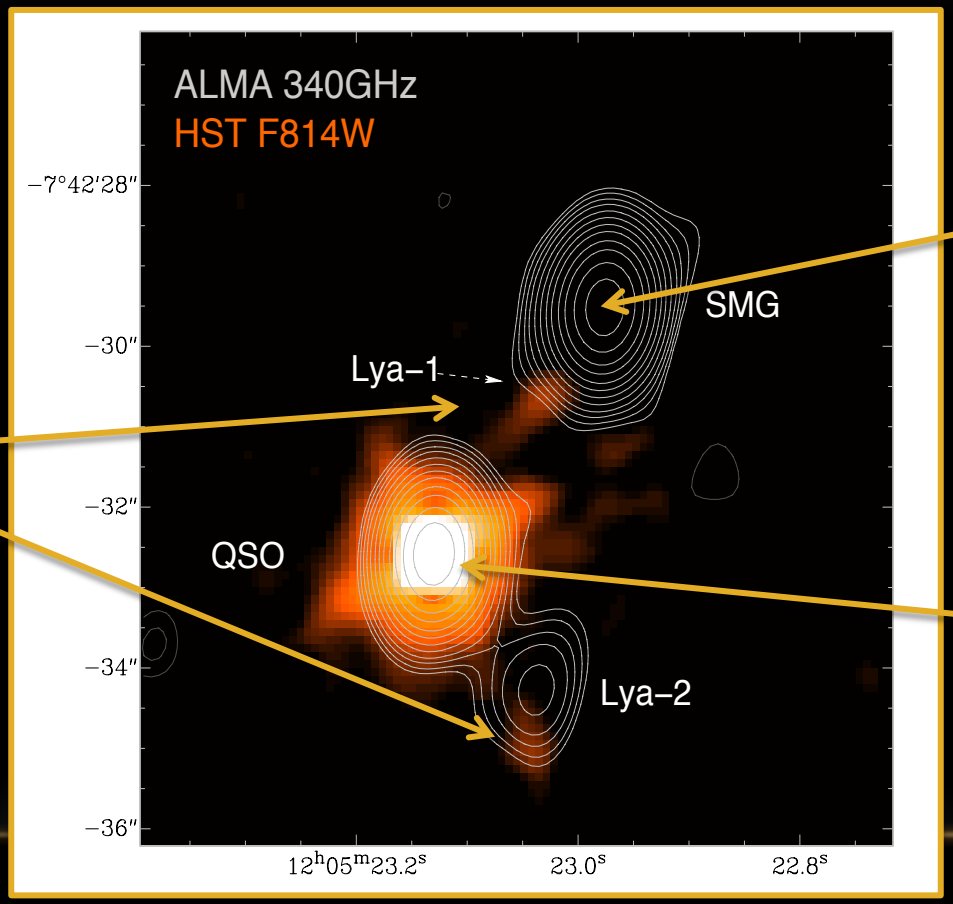
- Velocity field is dominated by rotation and no indications of major merging

=> SFR ~ 1000 $M_{\odot}yr^{-1}$ (!!!) does not seem to be triggered by major dynamical disturbance, high-SFR likely due to very gas rich unstable disk with low Q parameter

But NOT representative of the bulk of the galaxy population at high-z …

BRI1202-0725 (z = 4.7)

- First ALMA detection of [CII]158μm at high-z (Wagg+12 & Carilli+13, Carniani+14)



Optically obscured SMG

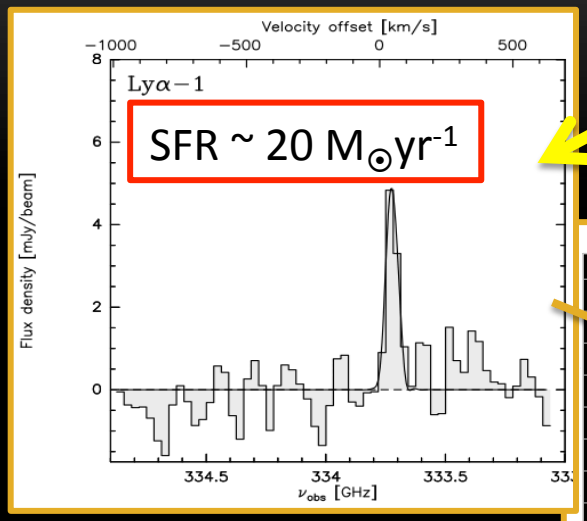
Serendipitous [CII] detections of Lyα emitting systems

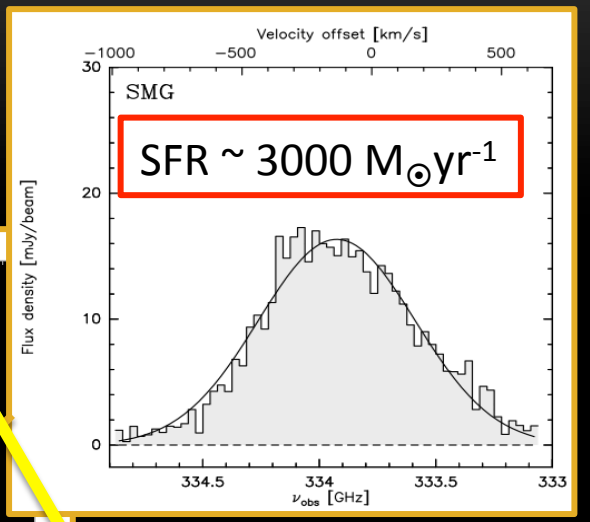
QSO

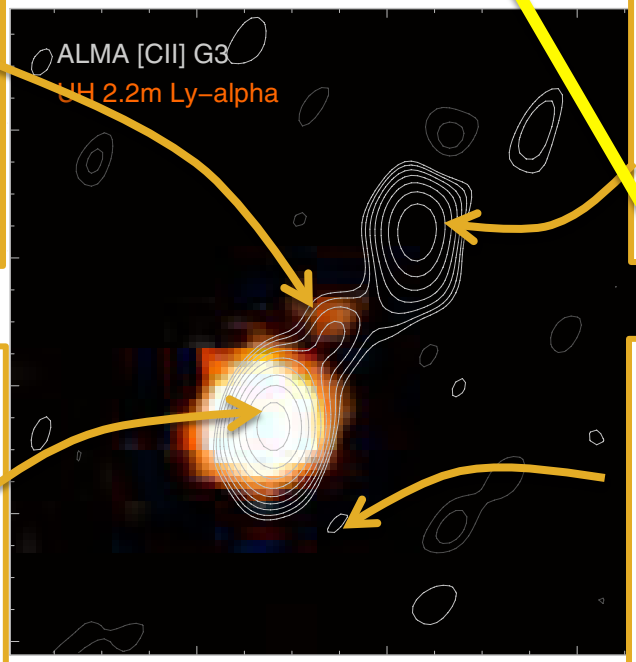
Carilli+13, Hu+96

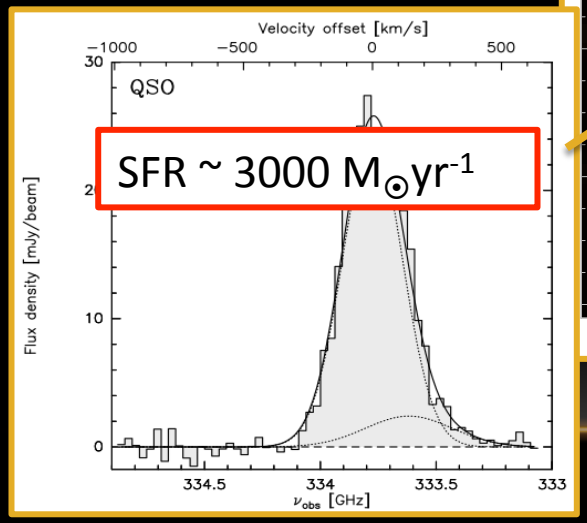
ALMA [CII] DETECTION

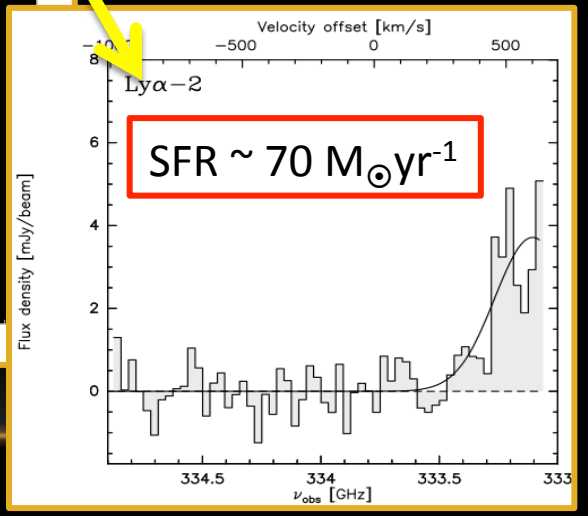
Star forming systems
more representative
of the bulk of the population
(though still on the high side)





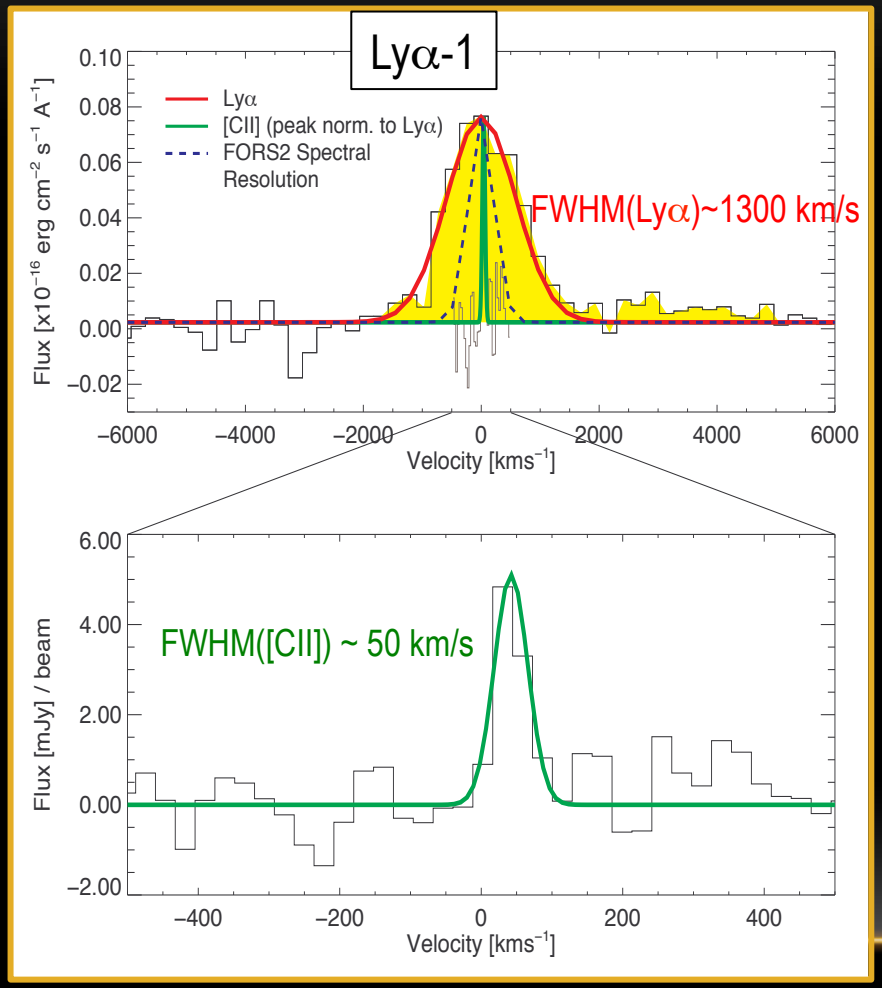






New FORS2-VLT optical spectroscopy of the two Lyα emitters: Lyα VS [CII] comparison

R.J. Williams et al. 2014



- Drastically different Lyα and [CII] profiles
- Extension: Lyα ~ 2.2”

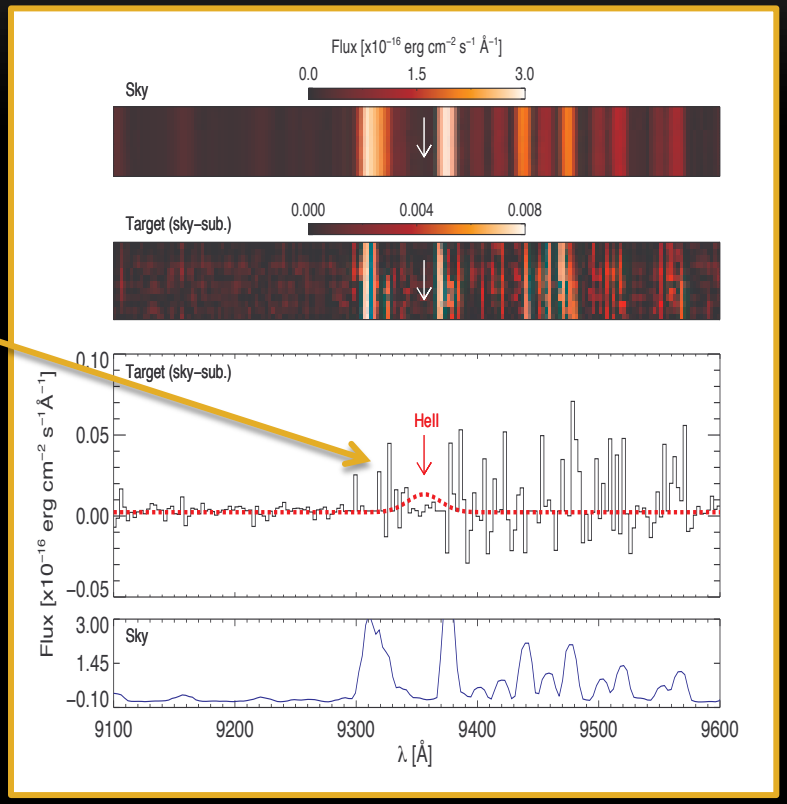
  [CII] < 1”
- Consistent with recent simulations (e.g. Vallini+13)
- Possibly traces highly in-homogeneous ISM and different star formation environments

Similar result for Lyα-2

Lyα emitters photo-ionized by the QSO?

R.J. Williams et al. 2014

- Do not detect any other high ionization emission lines (CIV, SIV, NV)
- He II should be detectable regardless of metallicity
- Estimate fraction of Lyα emission produced by ionization from QSO **< 10%**



=> Powered by **in-situ star formation**.

Scenarios for large velocity width of Lyα

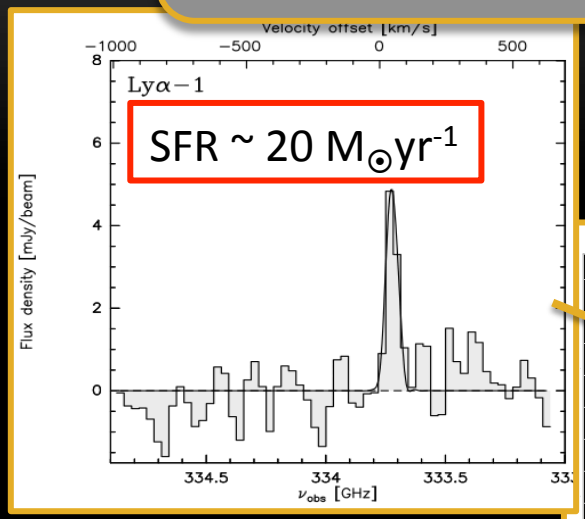
- Strong tidal sheering where compact clumps are less affected and traced by [CII]. However separation from primary massive galaxy (> ~10 kpc) suggests this is unlikely
- Could be tracing 'strong positive feedback' predicted by recent models (e.g. Ishibashi & Fabian+12, Zubovas+13, Silk+13): With star formation triggered in AGN-driven outflow

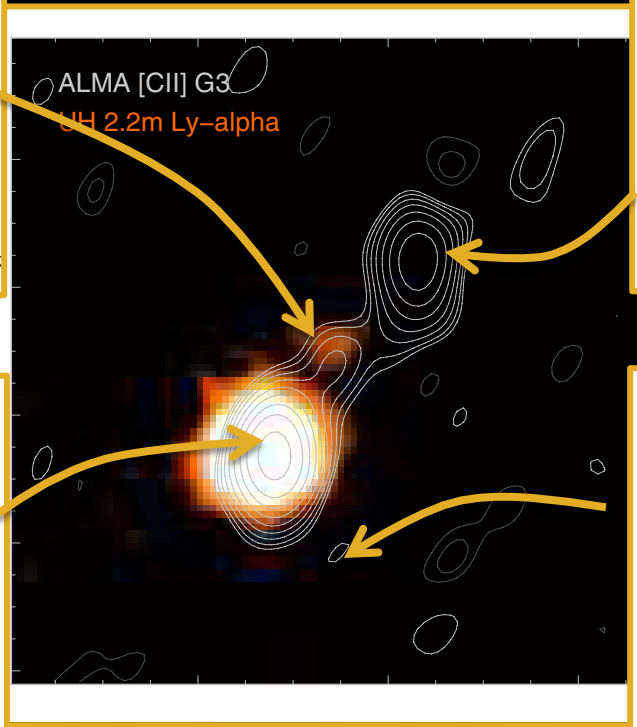
Difference in FWHM between Lyα and [CII]

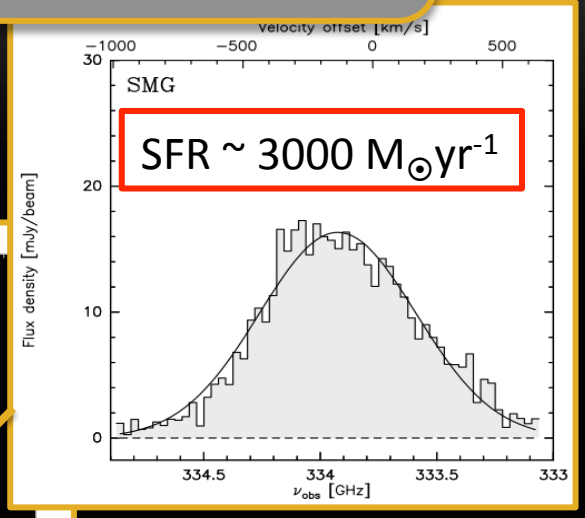
- Difference in FWHM between Lyα and [CII] also possibly explained in the context of primeval galaxy models (Vallini et al. 2013)
- The ionized gas (Lyα) and neutral gas [CII] trace different regions within the ISM

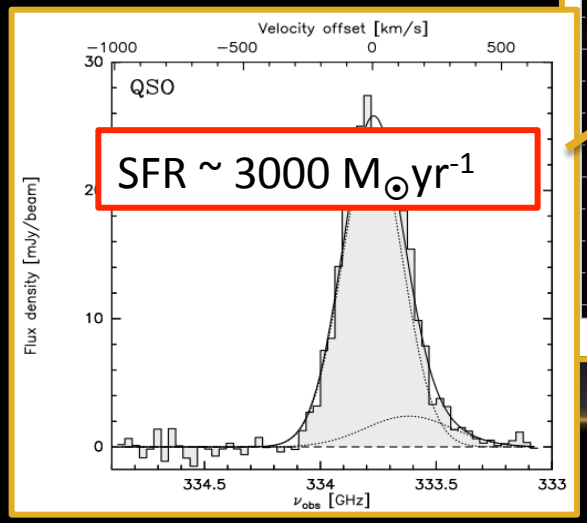
… more later

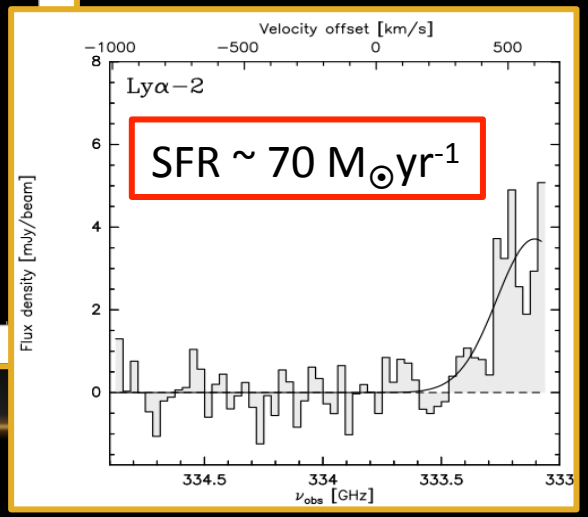
Yet, these Lyα emitters are in a peculiar environment (overdense + QSO)











CONCLUSIONS

- High S/N ALMA observations of a rotating [CII] disc shows velocity modelling is possible at z=4.7.
- Multi-band studies of galaxies can provide further insight into the physical processes of galaxy evolution, especially when studying galaxies with lower-SFR (more representative of galaxy population).
- For example, we see different Lyα & [CII] profiles at z=4.7 tracing different regions of the ISM.