The birth of a star-forming clump in a disk galaxy at z ~ 2

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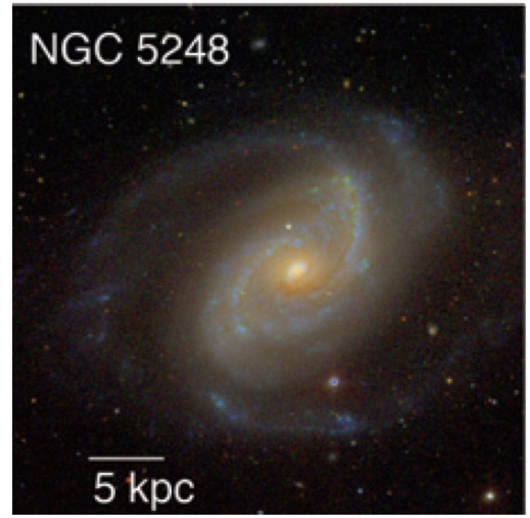
with E. Daddi, E. Le Floc'h, F. Bournaud et al.

Chania, 28th May, 2015

Introduction: observations

Galaxies at z ~ 2:

- are gas dominated (Daddi+10, Tacconi+ 10)
- host giant star forming regions = clumps (e.g., Elmegreen+05, 09, Förster-Schreiber+ 06)



Local galaxy
d = 15.40 Mpc

Gas fraction ~5–10%

(Elmegreen+ 13)

High-z galaxy
z = 2.05

Gas fraction ~ 50%

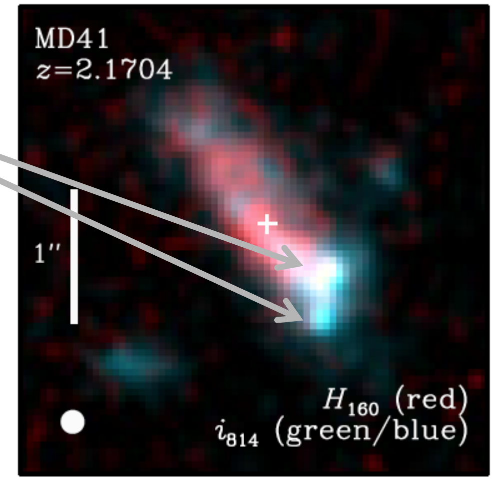
(Wuyts+ 12)

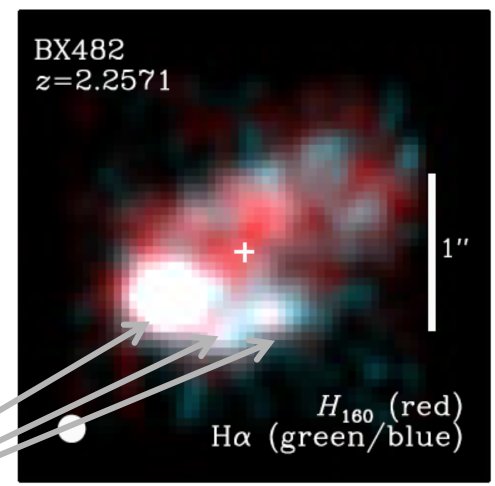
Introduction: observations

Clumps in z ~ 2 galaxies:

- mostly identified in *HST* rest-frame UV imaging
- have total masses ~ $10^{8\text{-}9}\ M_\odot$
- size ~ 1 kpc
- have SFR ~ 20 - 50% of the total SFR of the galaxy

(e.g., Genzel+08, Förster-Schreiber+11, Newman+12)





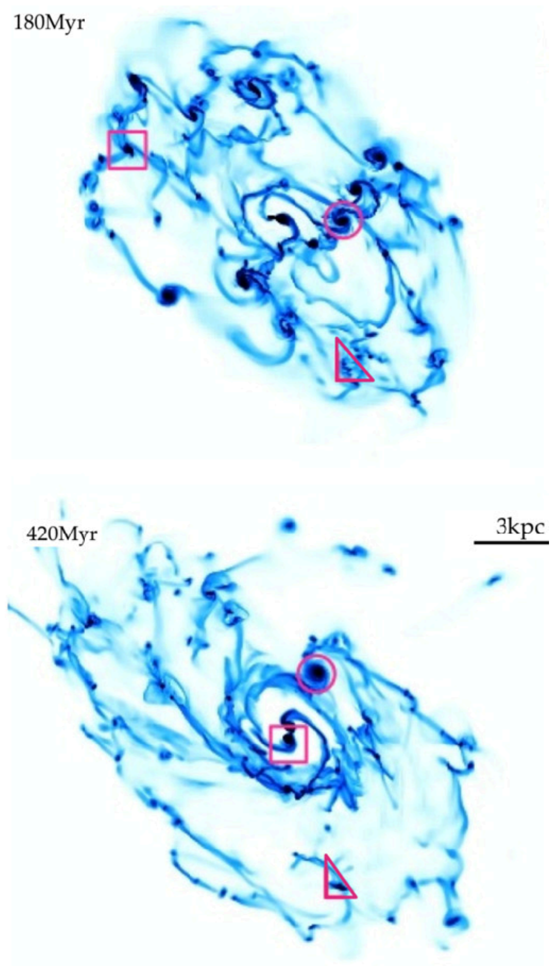
Förster-Schreiber+ 11

Introduction: simulations

- At high z: large scale gas inflows feed galaxies with gas (Keres+ 09, Dekel+ 09)
- Due to high gas fraction, violent disk instability fragments disks into giant clumps (Bournaud+ 09)

But which is the fate of giant clumps?

- Do they migrate inward and form the **galaxy bulge**? (Dekel+ 11, Bournaud+ 14)
- Are they disrupted by stellar **feedback** in short **timescales?** (Genel+ 12, Murray+ 10) ?



Bournaud+ 14

Open questions we would like to answer…

How do clumps form?

Clumps lifetime?

Do clumps form the bulge?

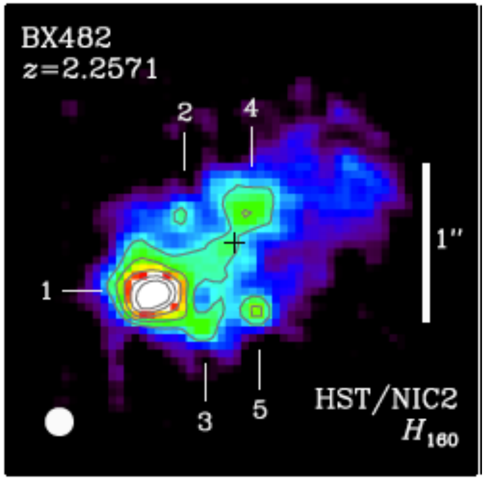
Role of stellar feedback?

Clumps SFE?

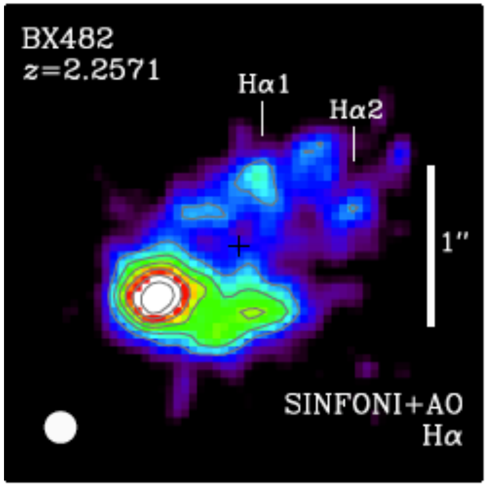
…key ingredients we need

spatially resolved probe of **stellar mass distribution**
→ **imaging**

spatially resolved probe of **star formation distribution**
→ **UV, spectroscopy** (unique for young ages)



H160



Hα

Förster-Schreiber+ 11

Sample

[OIII] emitting galaxies at $1 \leq z \leq 2$

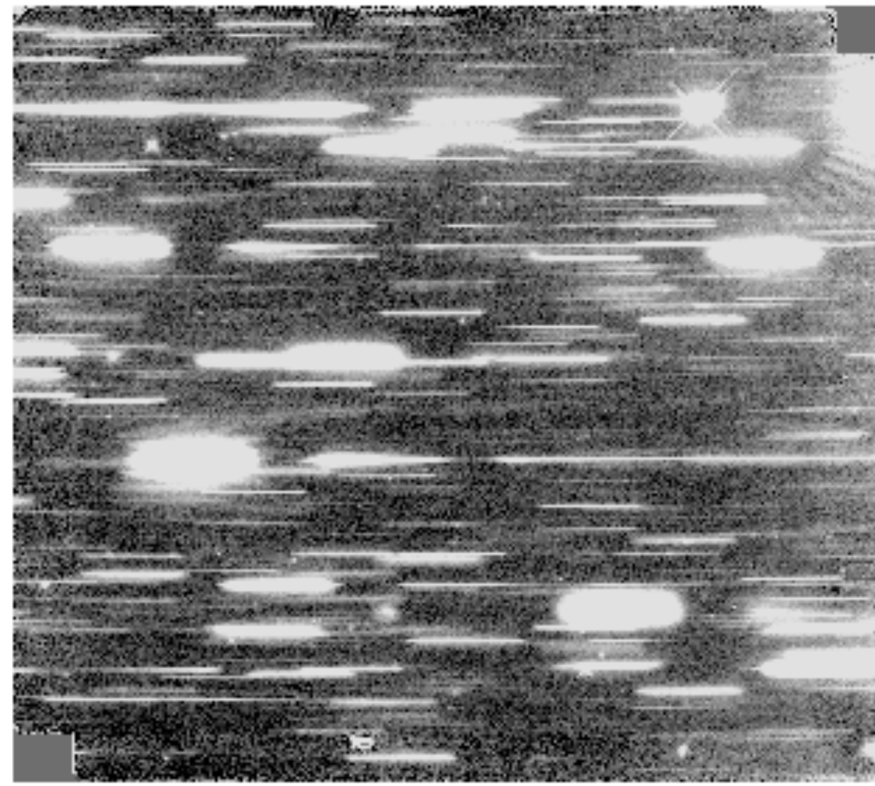
Observations: WFC3 on board HST

Slitless spectroscopy: G_{141} (λ = 1.1 – 1.7 µm)

Imaging: near-IR (F140W, F105W)
UVIS (F606W)

→ Spatially resolved [OIII], Hβ, [OII] emission line maps

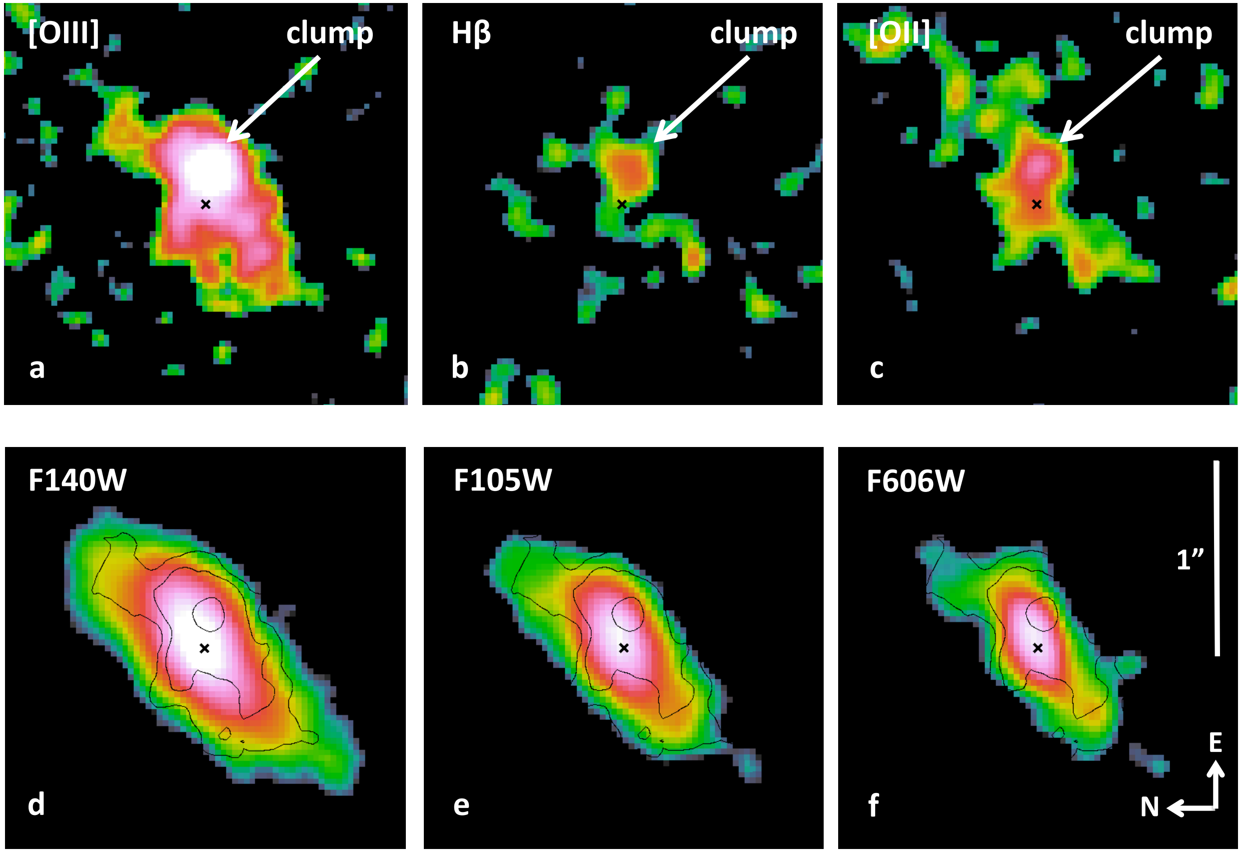
Pointed at CL J1449+0856 cluster (Gobat+ 13)



Slitless spectroscopy: 6.4 arcmin^2

Emission line maps

The case of ID568: **off-nuclear** [OIII], Hβ and [OII] emissions



GALFIT decomposition: diffuse **disk** + off-nuclear **clump**

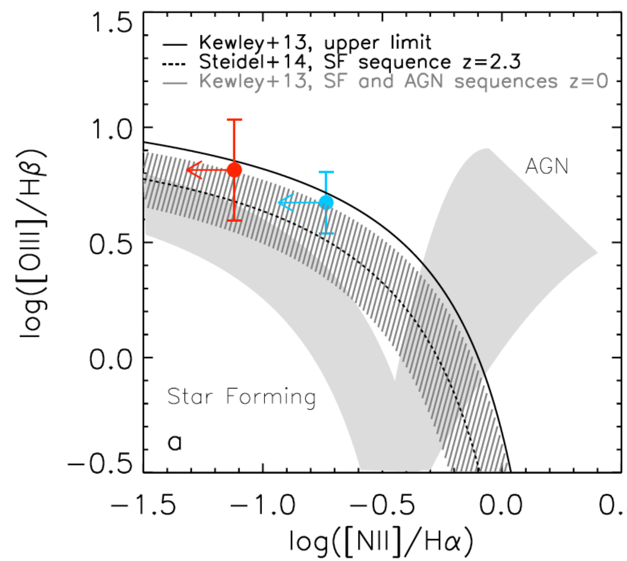
Offset **significance ~ 8σ**

A star forming clump

Discarding the **AGN** hypothesis:

X RAYS: no XMM and Chandra detection

BPT (Baldwin+81): in the SF region (MOIRCS follow up)

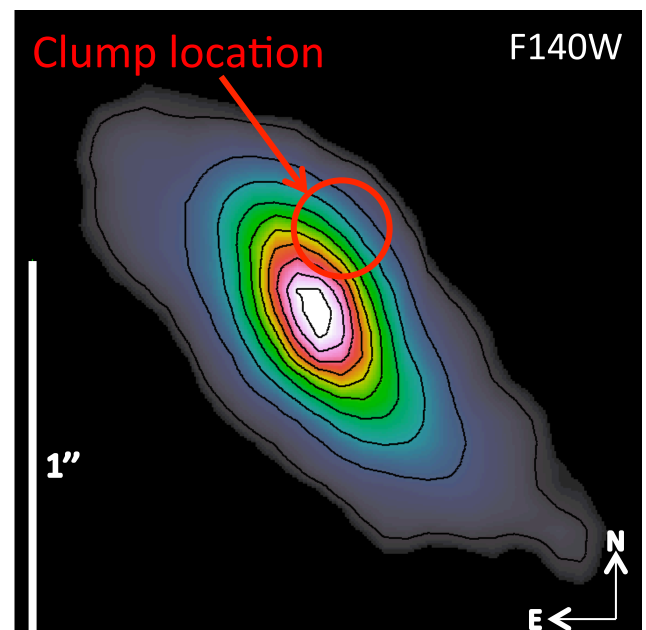


Clump equivalent width (**EW**):

$$EW = \frac{F_{line}}{F_{continuum}}$$

Upper limits on the continuum flux: simulations

$EW_{[OIII]} \geq 1700$ Å >> typical $EW_{[OIII]}$ of AGNs



An extremely young SF clump

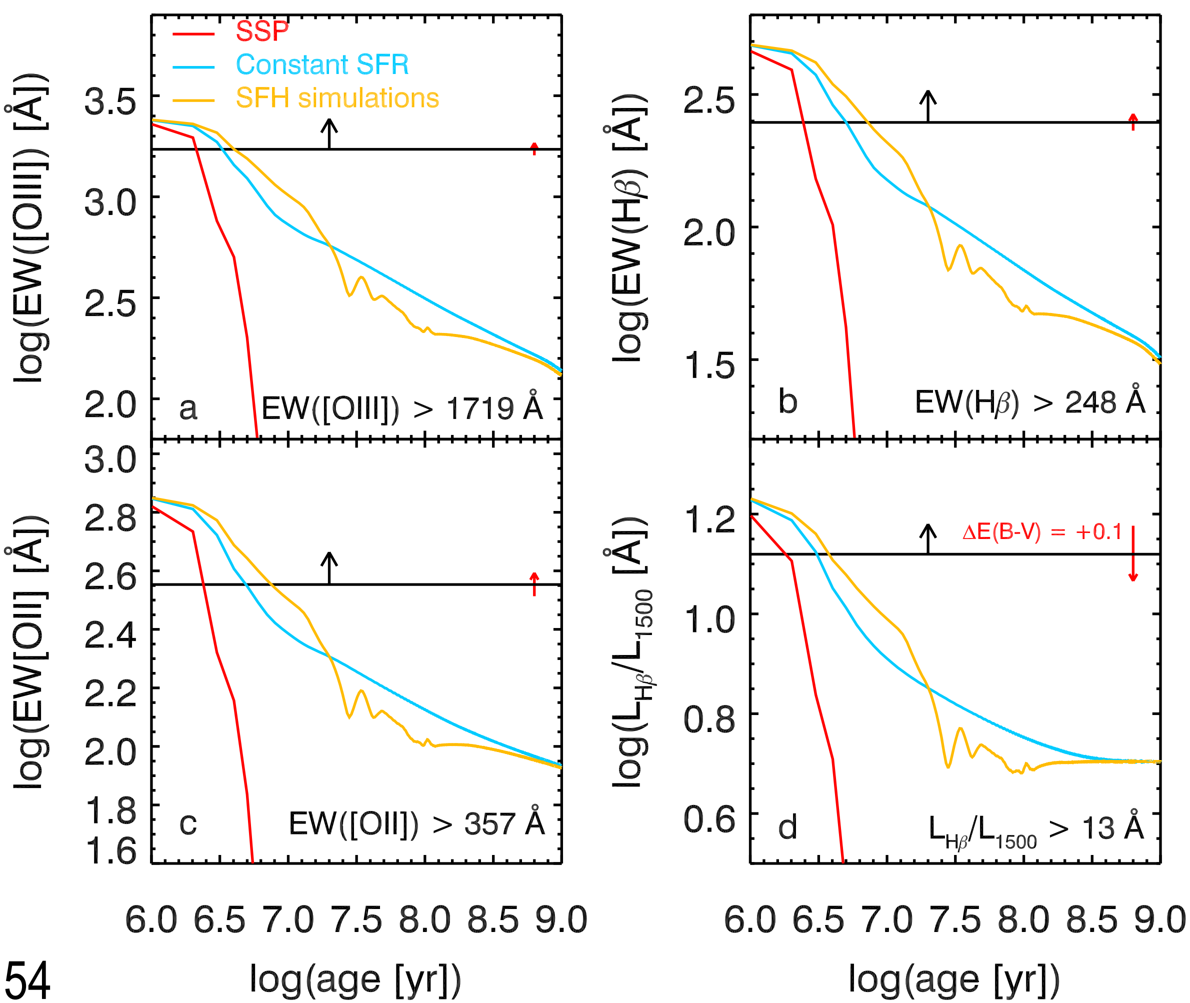
$Z \sim 0.4\ Z_\odot$

Re ≤ 0.5 kpc (unresolved)

Age < 10 Myr

First time robust **age** estimate comparable to the typical **free fall time** in a gas-rich turbolent disk

Starburst99 models



Zanella et al. 2015, **Nature**, 521, 54

Simulations (lead by F. Bournaud)

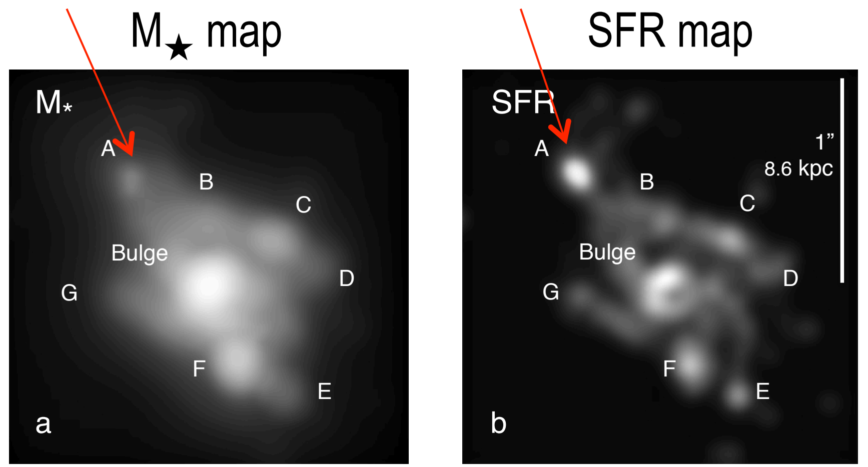
sSFR clump A = 10x sSFR other clumps

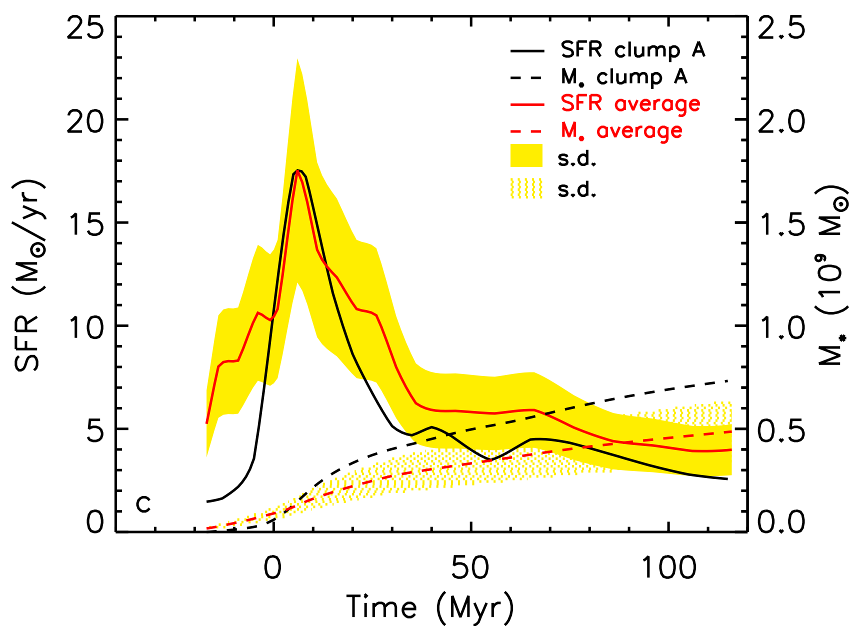
t = 0 birthtime clump A

t = 12 Myr observed time for the $M_\star$ and SFR map

other clumps are older (100 – 300 Myr)

Initial burst of SF confirmed by observations





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Do massive clumps exist?

Masses of observed giant clumps are overestimated due to blending caused by insufficient resolution?

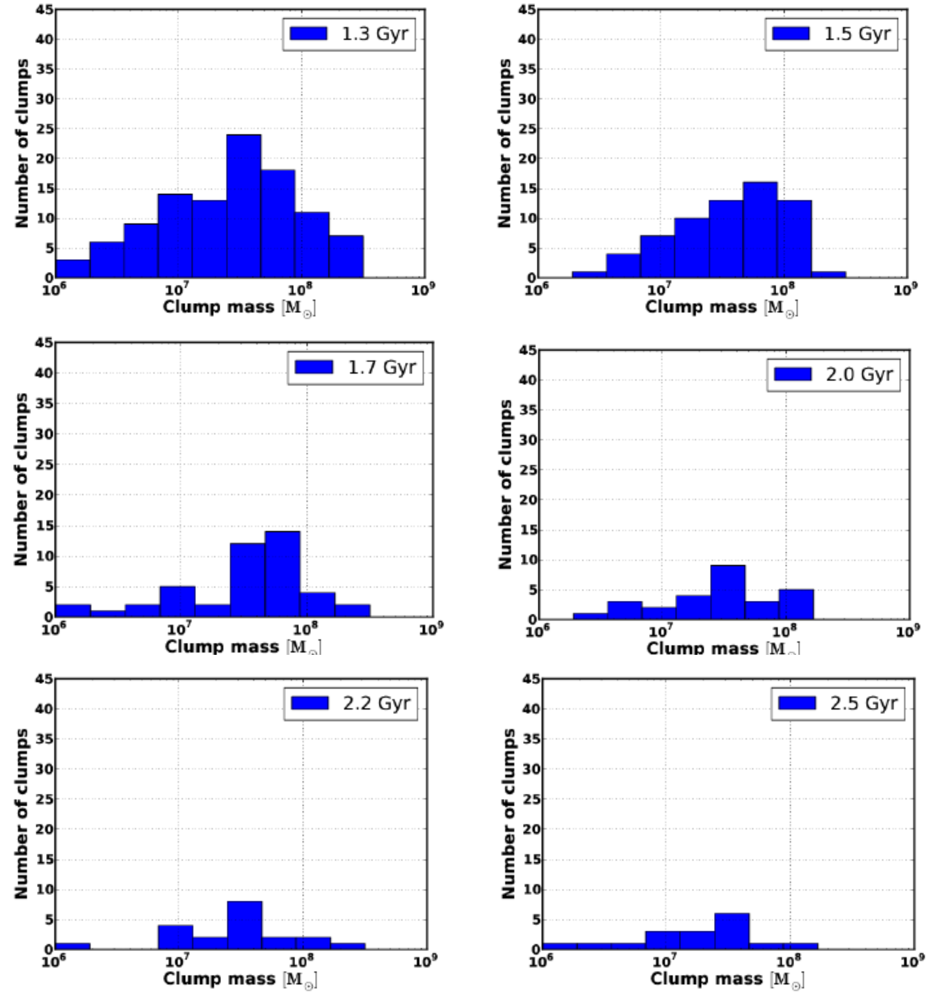
For our young clump:

Stellar mass: $M_\star \leq 3 \times 10^8 M_\odot$

from M/L ratio and simulations

Gas mass estimate: $M_{gas} \leq 2.5 \times 10^9 M_\odot$

from Jeans mass and simulations → $M_J \sim \frac{\sigma^4 R_d^2}{M_d}$



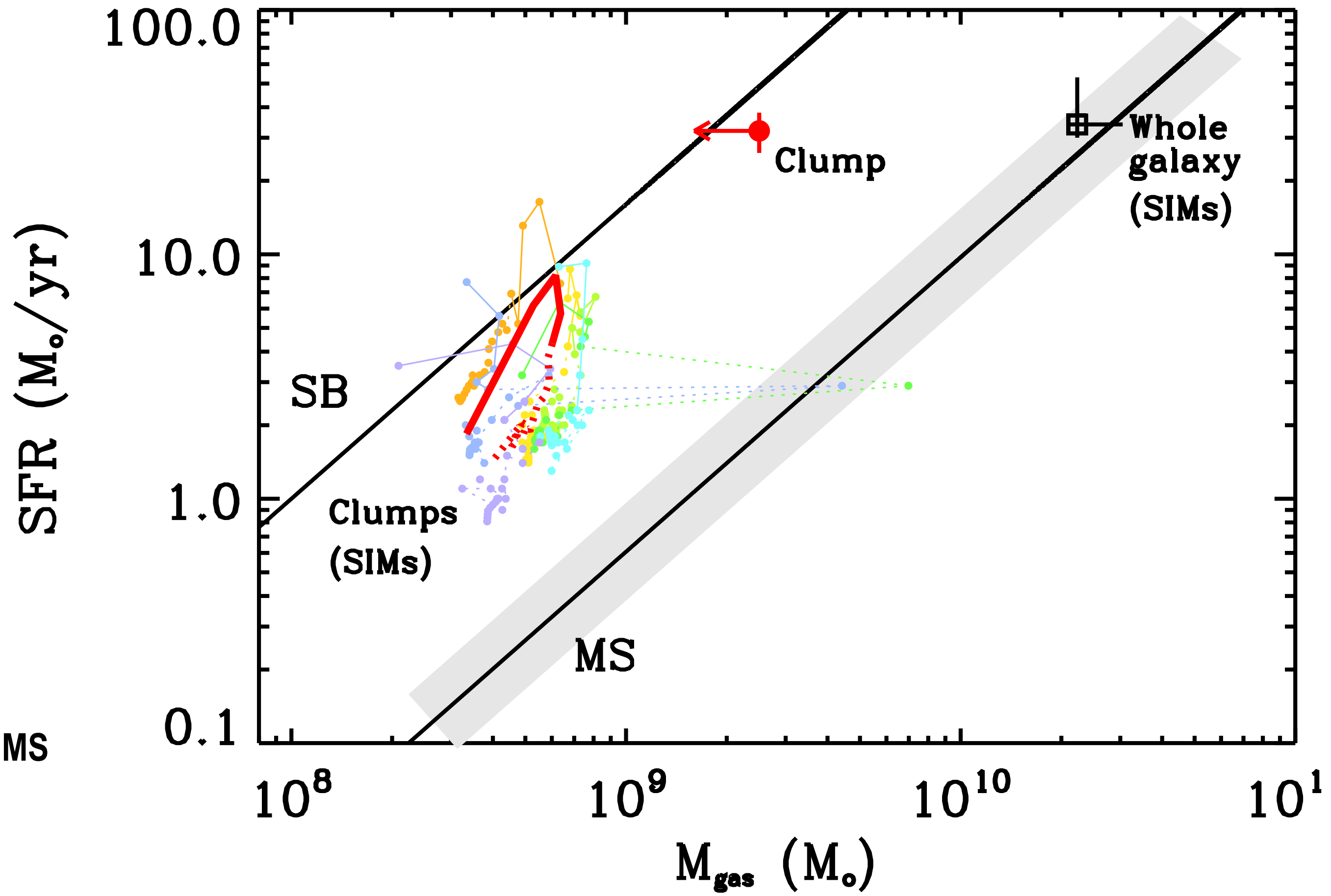
Tamburello+ 14

Newly born clumps behave like mini-starbursts

SFR ~ 30 $M_\odot$/yr

$M_\star \lesssim 3 \times 10^8\ M_\odot$

$M_{gas} \lesssim 2.5 \times 10^9\ M_\odot$



sSFR > 30x sSFR$_{gal,MS}$

SFE > 10x SFE$_{gal,MS}$

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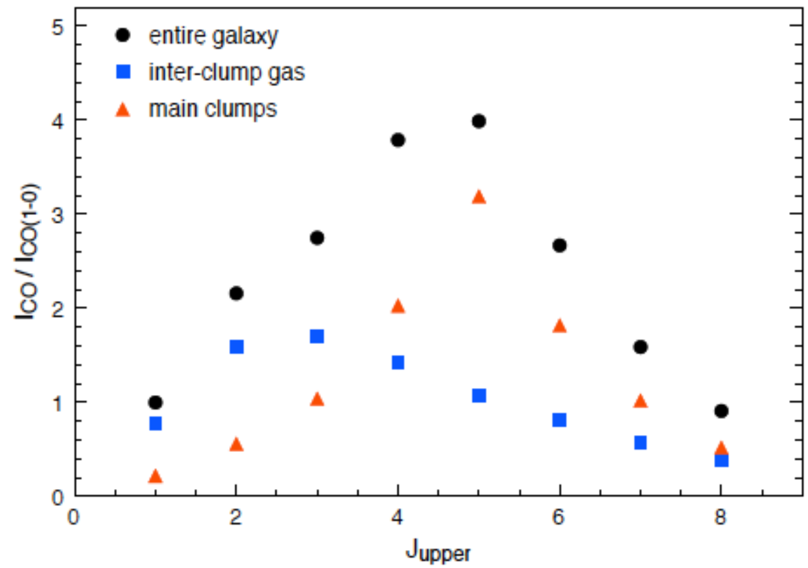
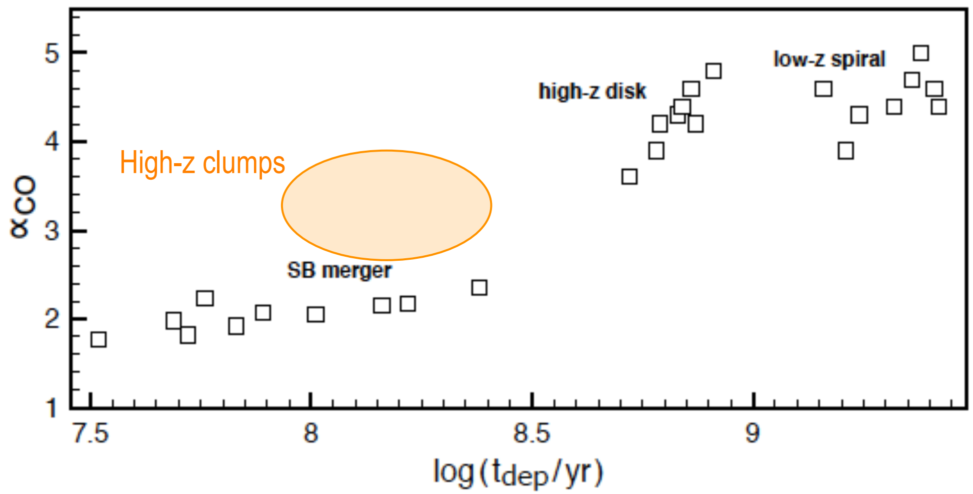
Clumps drive high SFE and CO excitation

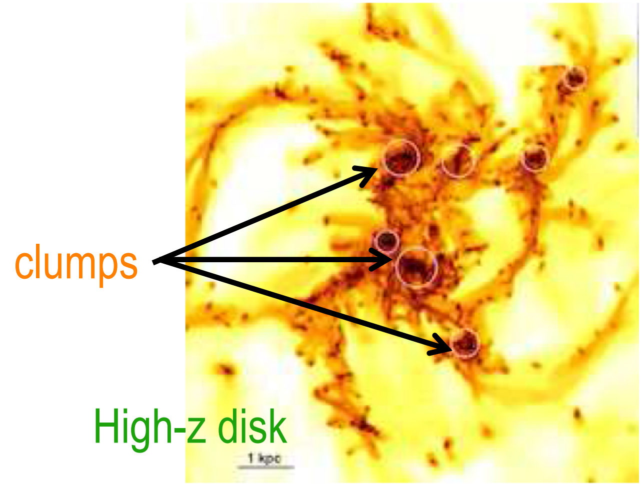


Bournaud et al. 2015



α_{CO} clump < α_{CO} host galaxy:
consistent with **clumps starburst-like behaviour**

→ clumps have **shorter gas depletion timescales** than their host



Observations:

clumps have higher CO excitation than the host (Daddi+15)

Clumps formation rate

Constraints on **clumps formation rate** (CFR):

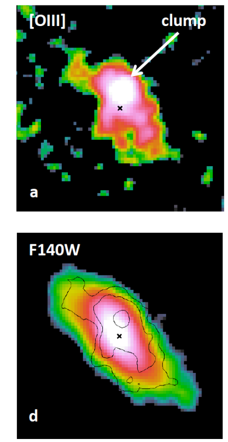
$$\mathrm{CFR} = \frac{\mathrm{N_{young}}}{\mathrm{t_V N_{gal}}}$$

→ # of young clumps = 1

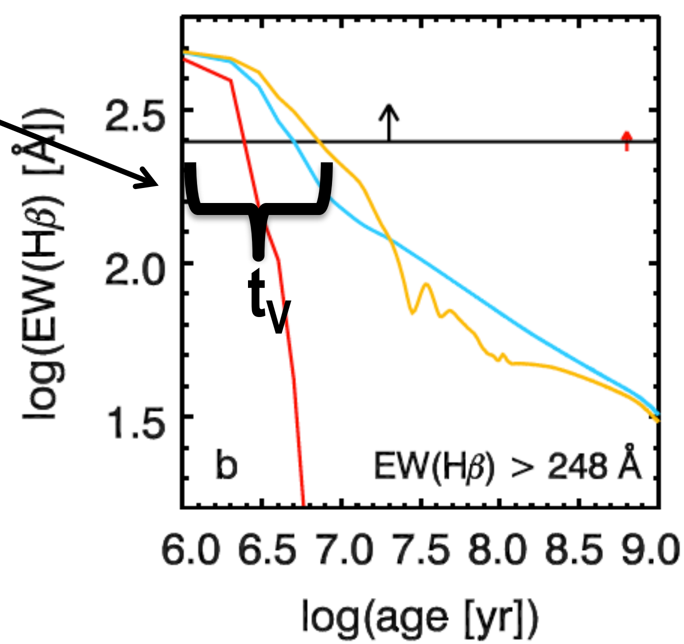
→ # of sample galaxies = 57

↓ Visibility window = 7 Myr

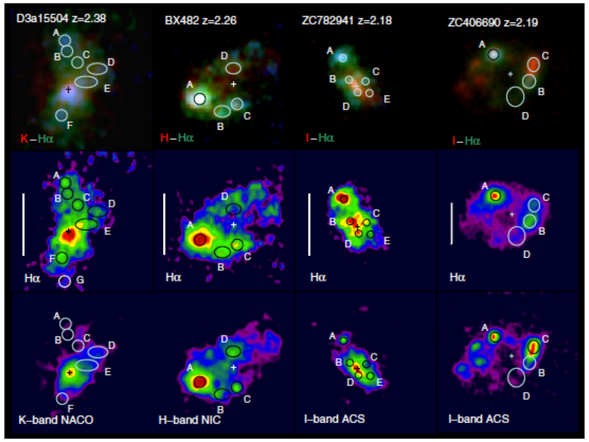
CFR ~ 2.5 clumps/galaxy/Gyr



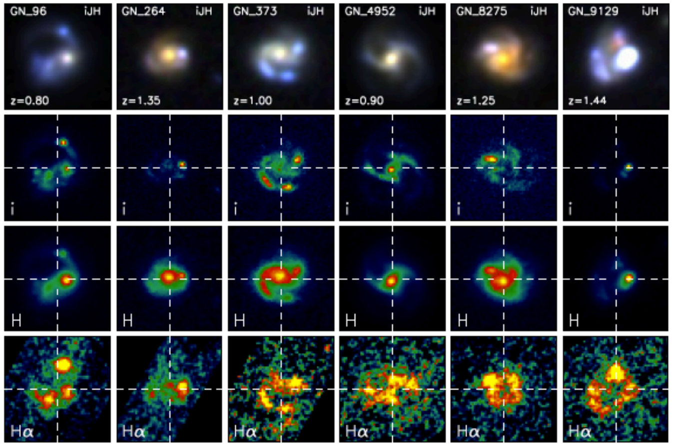
ID568



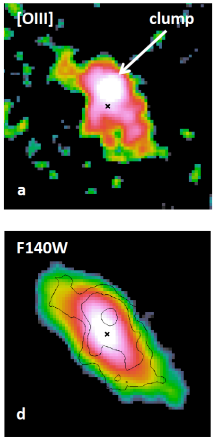
Clumps lifetime



Genzel+ 11



Wuyts+ 13



ID568

Constraints on **clumps lifetime** (LT):

$$LT = \frac{N_{cl/gal}}{CFR}$$

→ # of clumps/galaxy with $M_{tot} \geq 2.5 \times 10^9\ M_\odot$

LT ~ 500 Myr → clumps seem to survive stellar feedback

Could the clump mass be much lower?

Jeans mass:

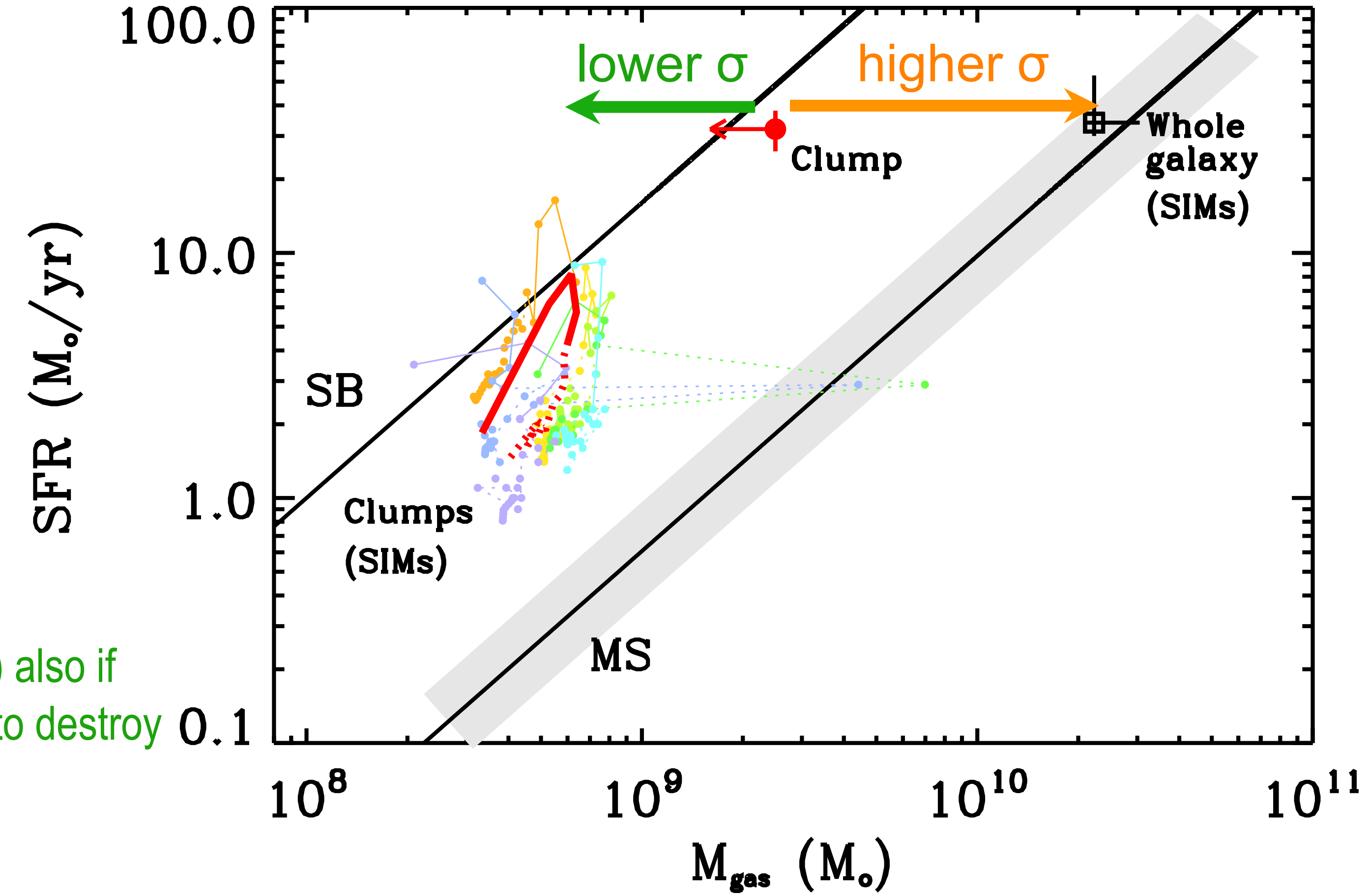
$$M_J \sim \frac{\boxed{\sigma^4} R_d^2}{M_d}$$

Lifetime:

$$LT = \frac{\boxed{f_{cl/gal}}}{CFR}$$ → ~ M^{-2}

> σ : all M_{gas} of the host concentrated in the clump

< σ : too long lifetimes (Gyrs) also if low mass clumps are easier to destroy



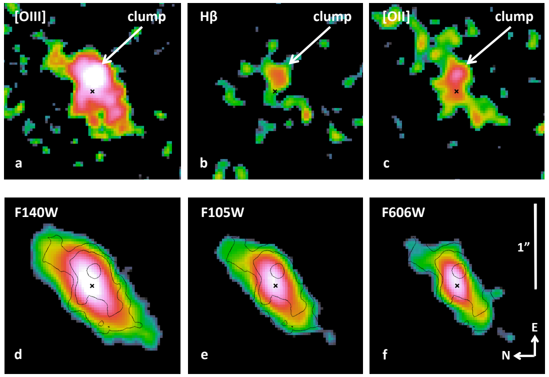
We are getting high resolution data from **SINFONI** and **KMOS** to measure the gas velocity dispersion

→ CO **ALMA** data would be great to probe **molecular gas content** of the clump!

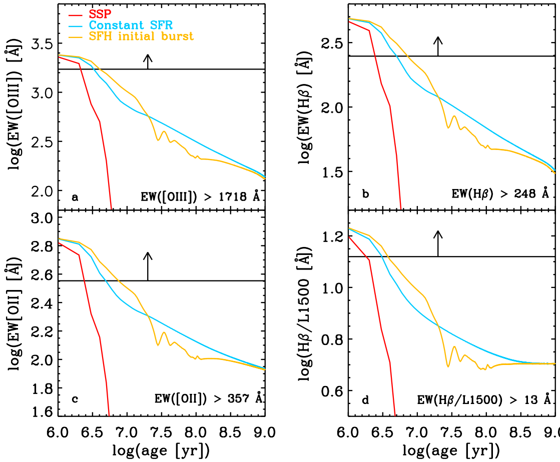
Summary

The birth of a star forming clump…

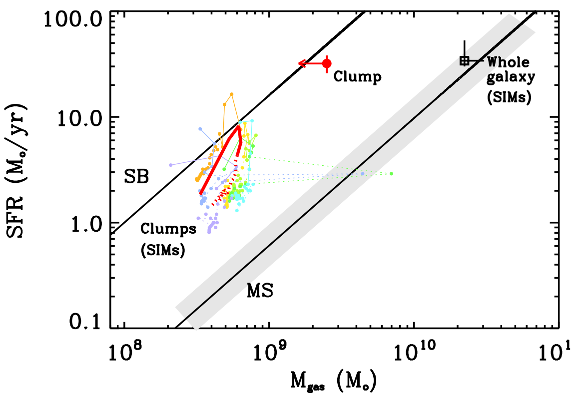
- Spatially resolved emission line maps of a SF galaxy at z ~ 2: bright off-nuclear [OIII] without a continuum counterpart



- The emission lines are powered by star formation



- It is an **extremely young star forming clump** likely **formed due to violent disk instability**
- It is the first direct observation of the clumps' formation phase
- **Young clumps behave like mini-starbursts** (obs. + sim.) Old clumps have enhanced SFE (sim.)



- It supports the scenario where **clumps survive stellar feedback**

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