Birth and physical properties of giant star-forming clumps at 1 ≤ z ≤ 2

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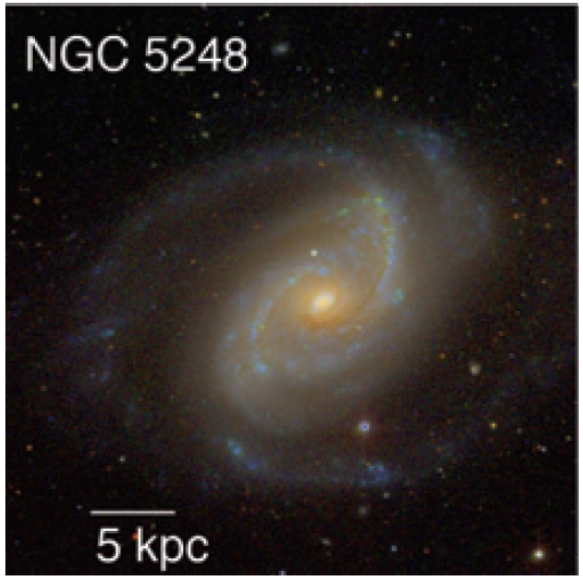
with E. Le Floc'h, E. Daddi, F. Bournaud, F. Valentino et al.

Sesto, 12th January, 2016

Introduction: observations

Local galaxy
Gas fraction ~5–10%



Elmegreen+13

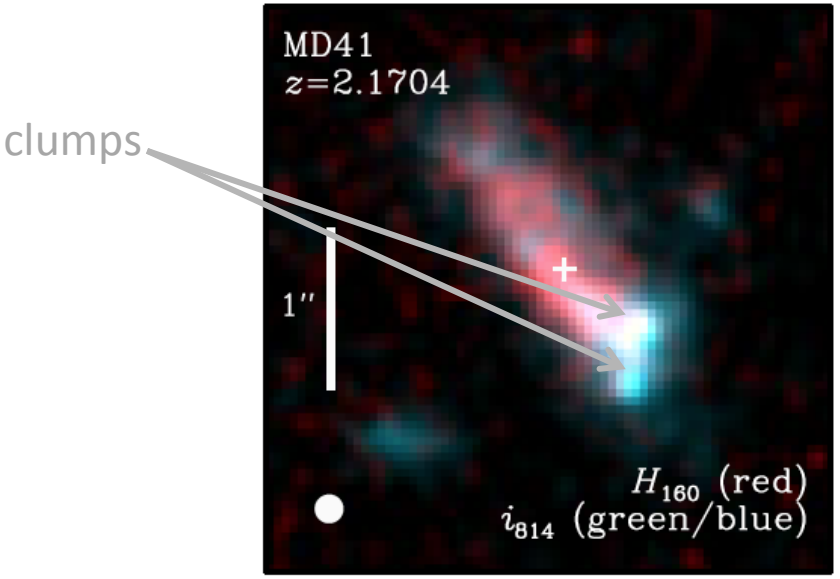
Wuyts+12

High-z galaxy
Gas fraction ~ 50%

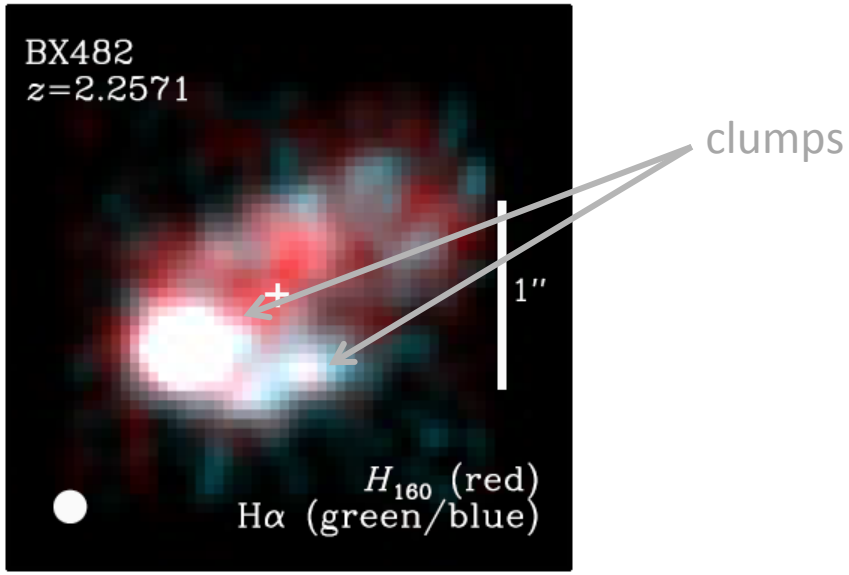
Galaxies at z ~ 2 are gas dominated (Daddi+10, Tacconi+ 10)

host giant star forming regions (**clumps**)
(e.g., Elmegreen+05, 09, Förster-Schreiber+ 06)

Introduction: observations



Förster-Schreiber+ 11



Förster-Schreiber+ 11

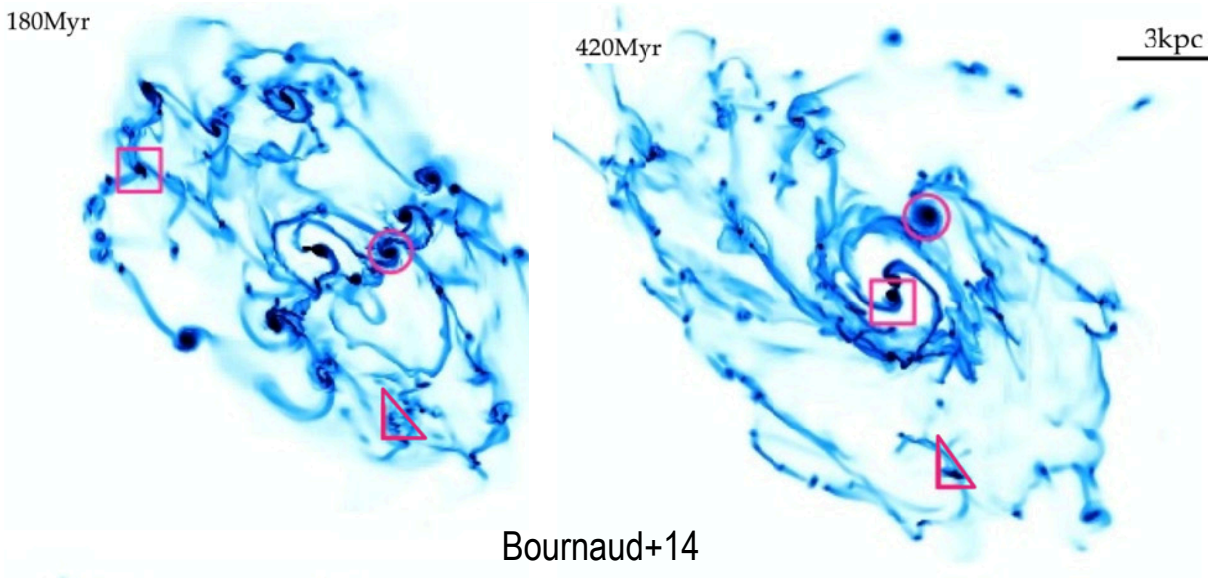
Clumps in z ~ 2 galaxies total masses ~ $10^{8\text{-}9}$ $M_\odot$

size ~ 1 kpc

SFR ~ 20 - 50% of the total SFR of the galaxy

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

Introduction: simulations



Bournaud+14

Clumps are the result of violent disk instability, **but which is their fate**?

Inward migration → **bulge formation** (Dekel+11, Bournaud+14)

Strong feedback → **disruption** in short timescale (Genel+12, Murray+10)

Open questions we would like to answer…

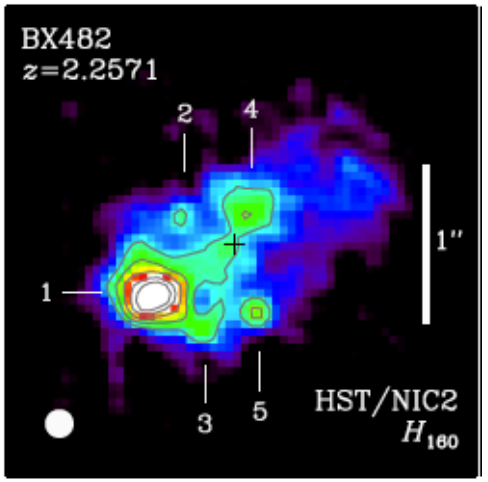
How do clumps form?

Clumps lifetime?

Do clumps form the bulge?

Role of stellar feedback?

Clumps SFE?

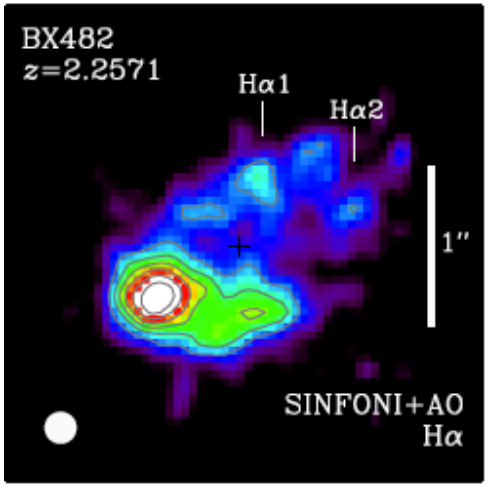


H_{160}

…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)



Hα

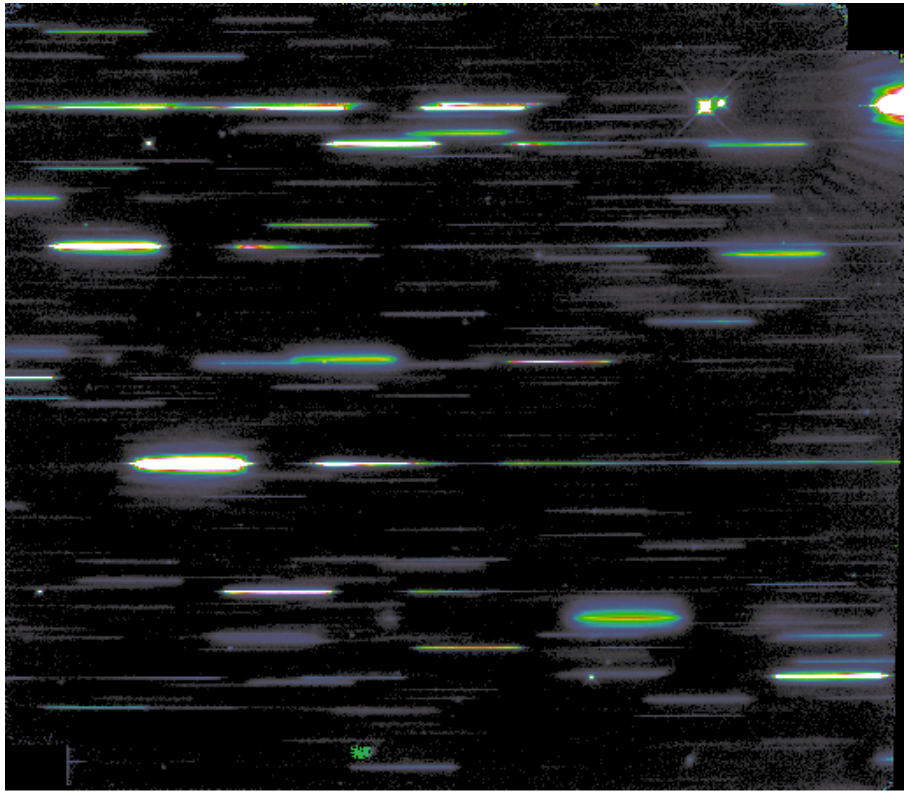
Förster-Schreiber+ 11

Sample

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

Observations: HST/WFC3

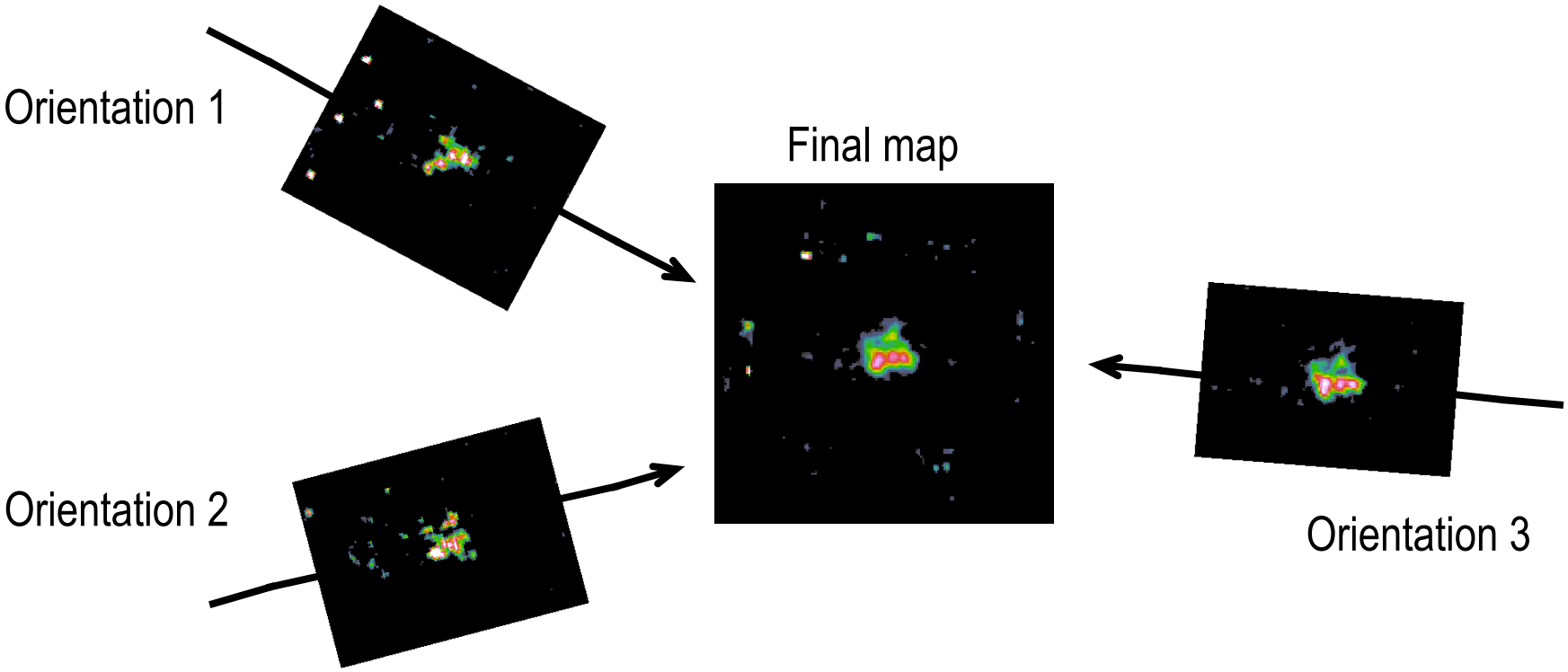
Slitless spectroscopy: G_{141}
Imaging: near-IR (F140W, F105W)
UVIS (F606W)



Slitless spectroscopy: 6.4 arcmin^2

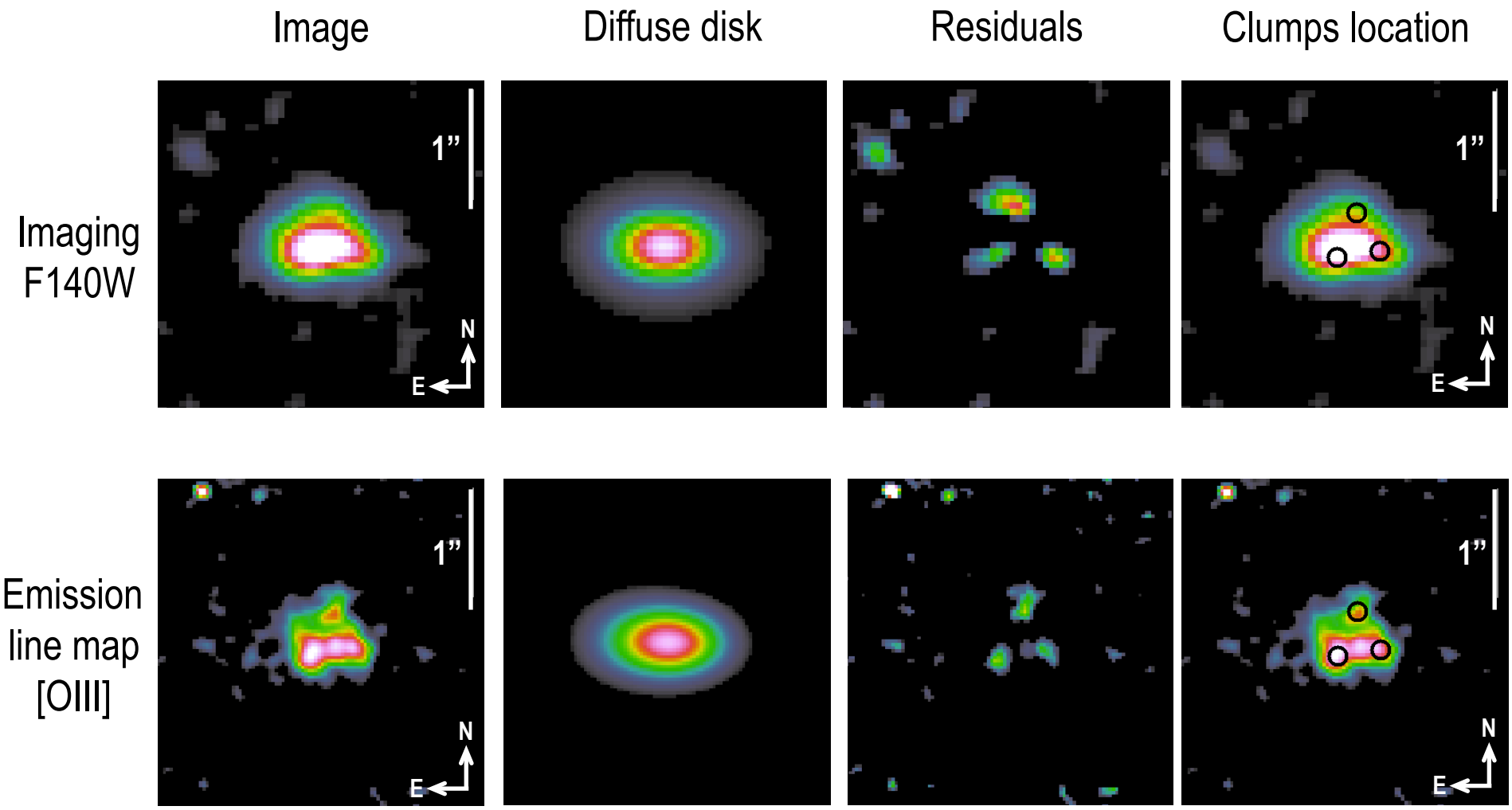
→ Spatially resolved [OIII], Hβ, [OII], Hα emission line maps

Emission line maps

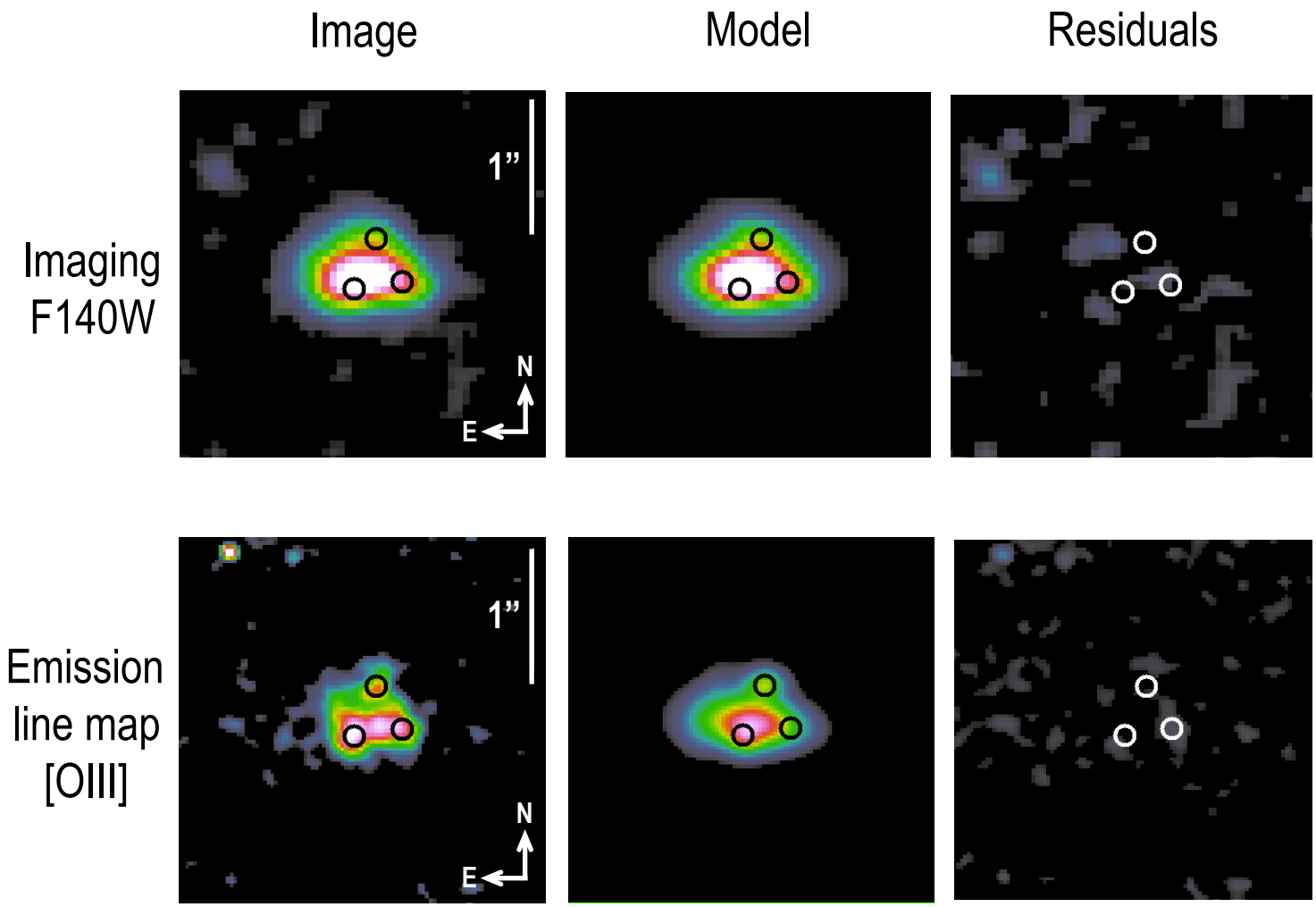


Cross correlation $CC(\lambda) = \sum_{i}^{N_{\text{width}}} \sum_{j}^{N_{\text{width}}} f_{i,j,} \times f_{i,j,}$

Finding clumps

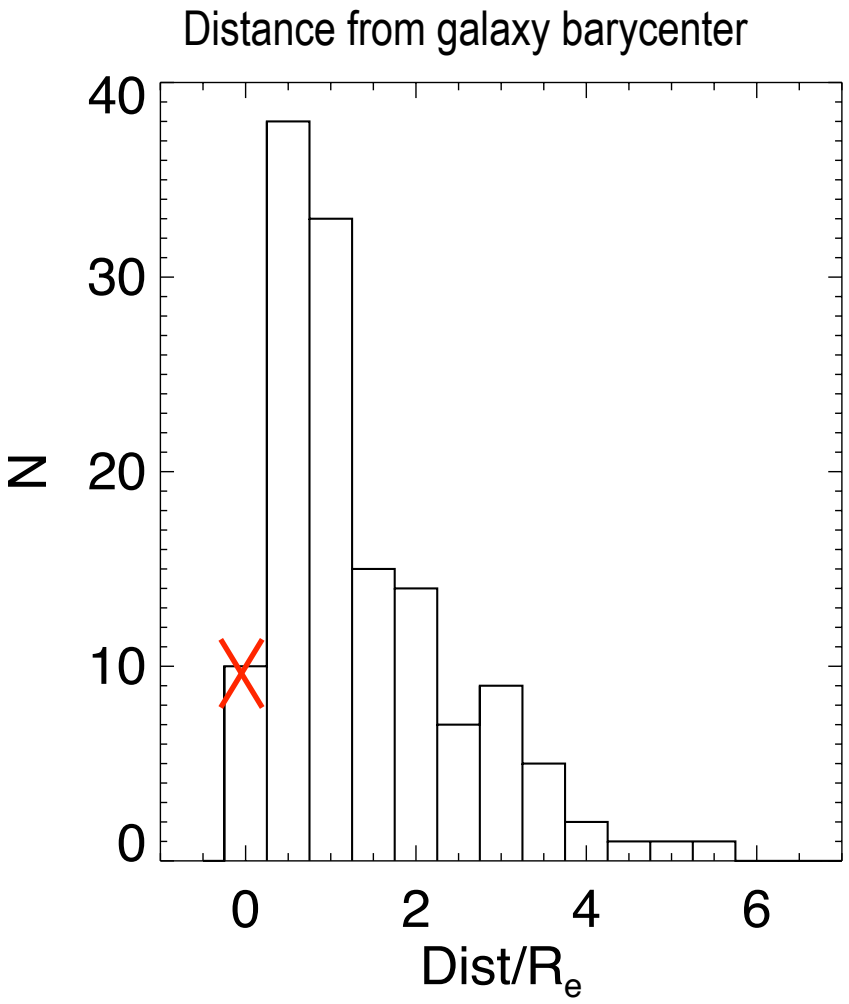


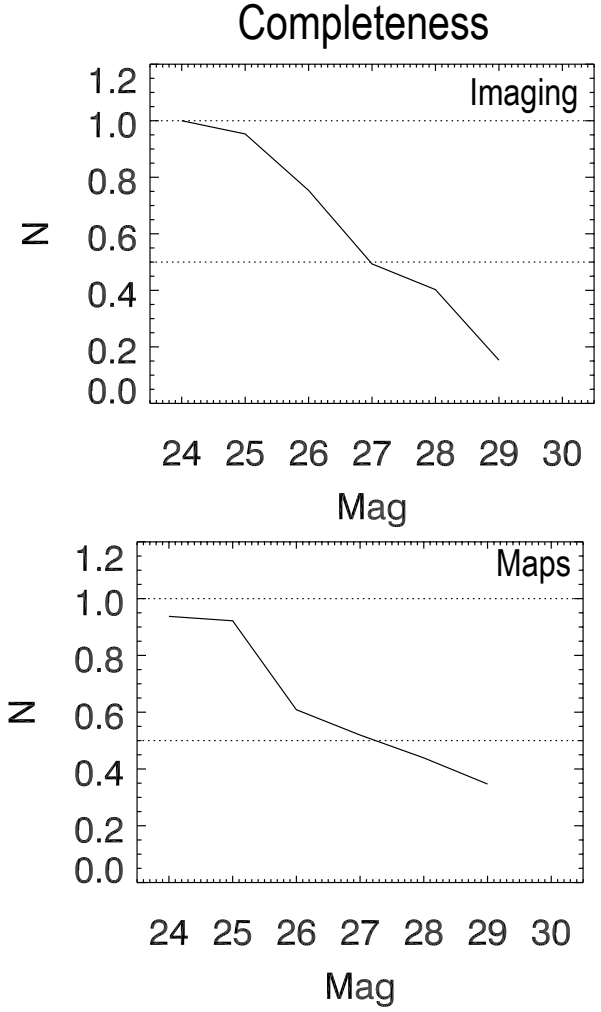
Modelling light profiles



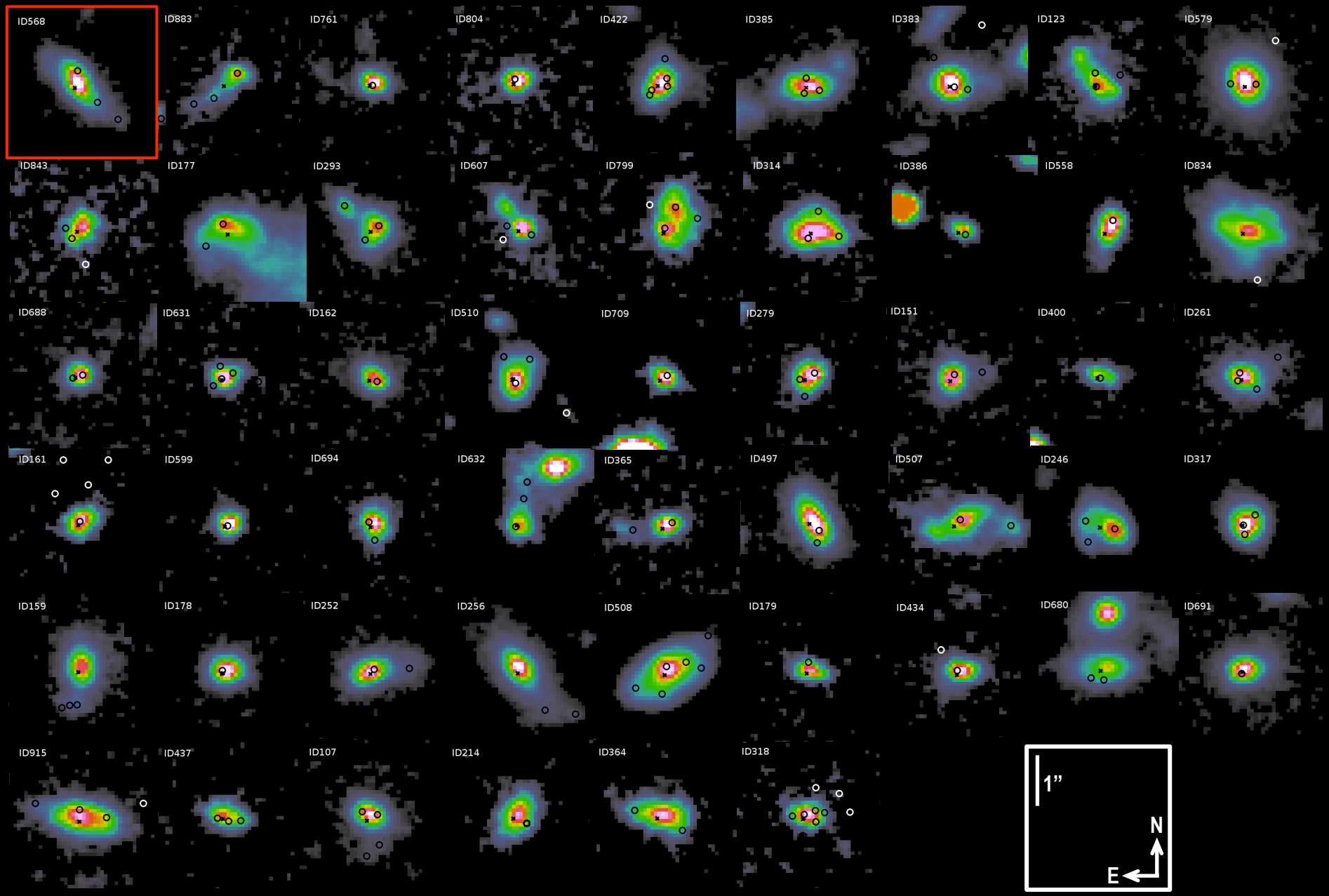
Ongoing analysis!

Clumps properties





Imaging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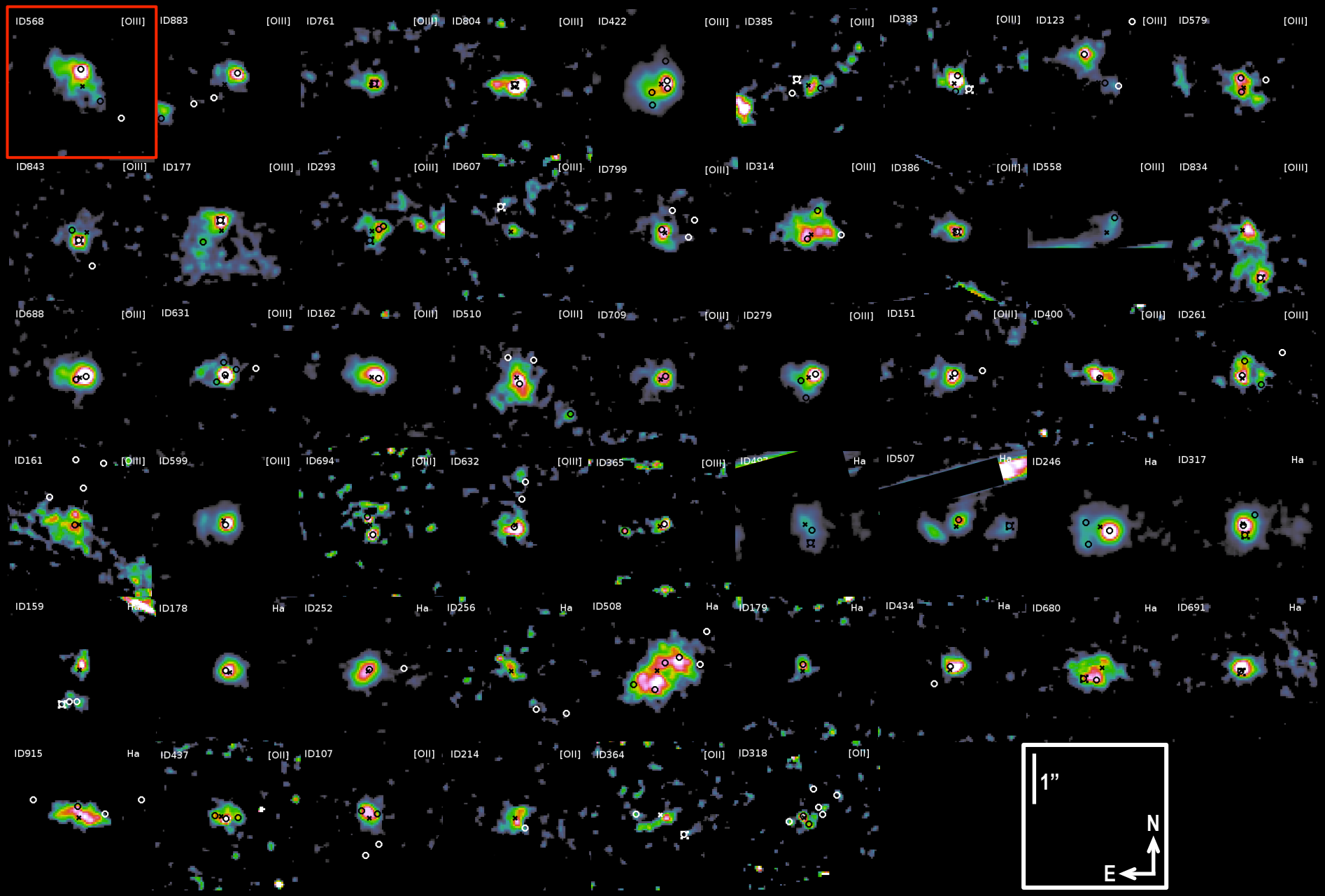
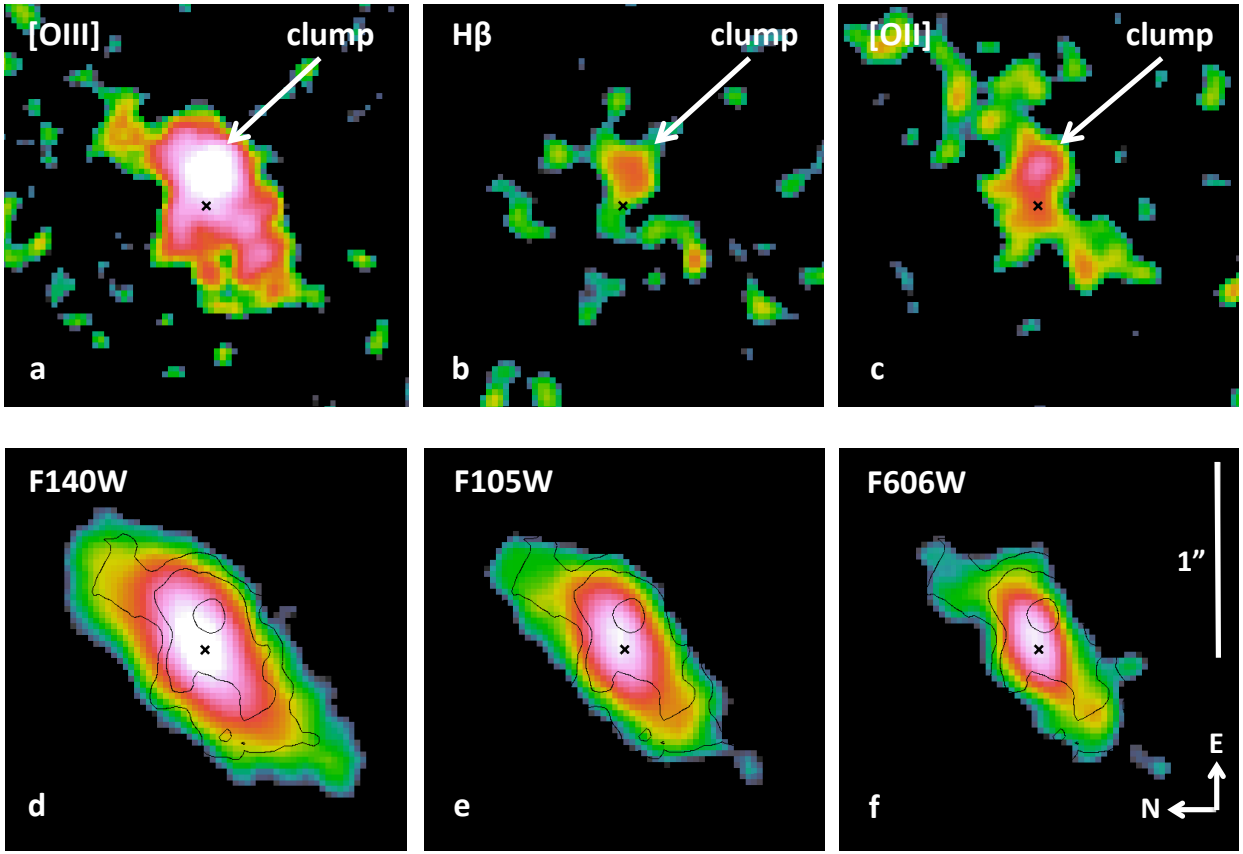
Emission line maps



The special case of ID568

Off-nuclear [OIII], Hβ and [OII] emissions



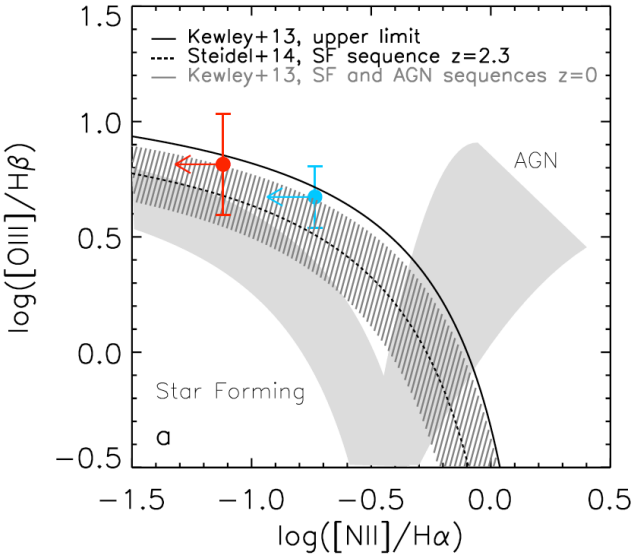
Diffuse **disk** + off-nuclear **clump**: offset **significance ~ 8σ**

A star forming clump

Discarding the **AGN** hypothesis:

X RAYS: no XMM and Chandra detection

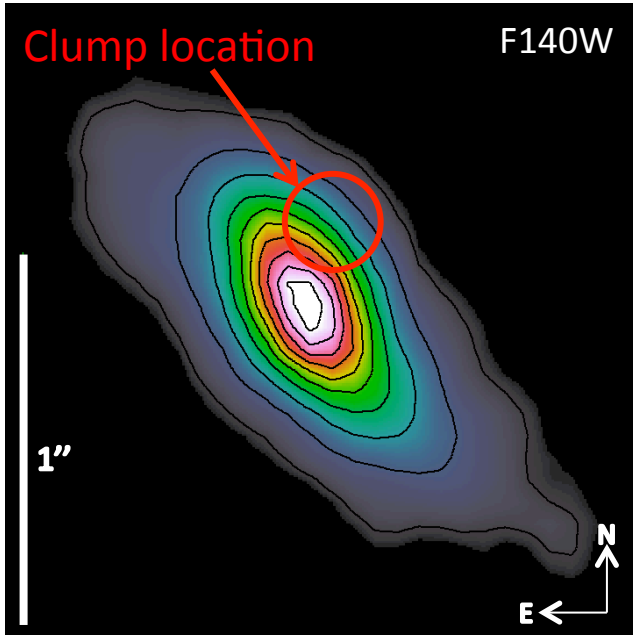
BPT : in the SF region (MOIRCS follow up)



Clump equivalent width (**EW**):

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

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



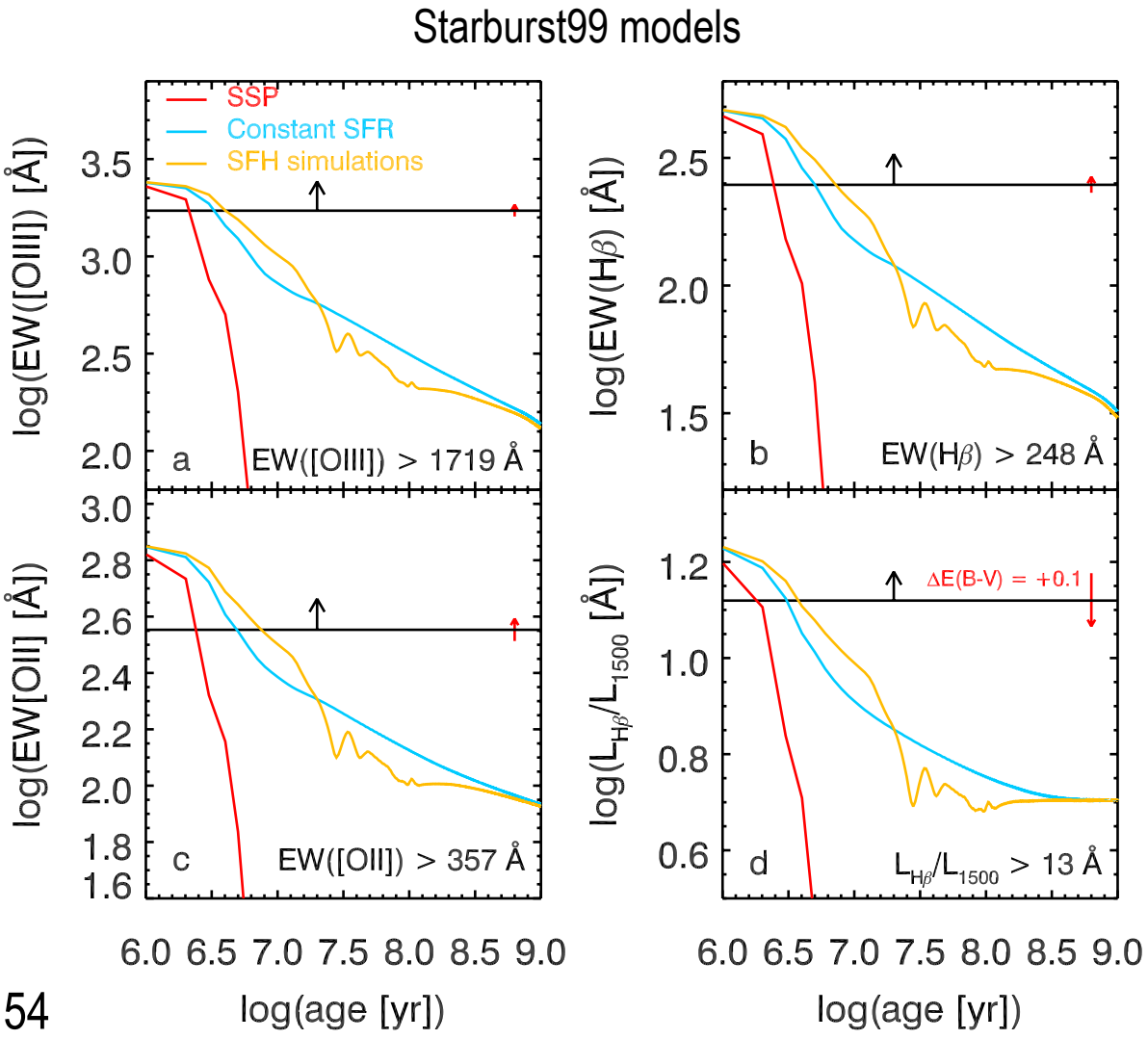
An extremely young SF clump

$Z \sim 0.4\ Z_{\odot}$

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



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

Simulations (led by F. Bournaud)

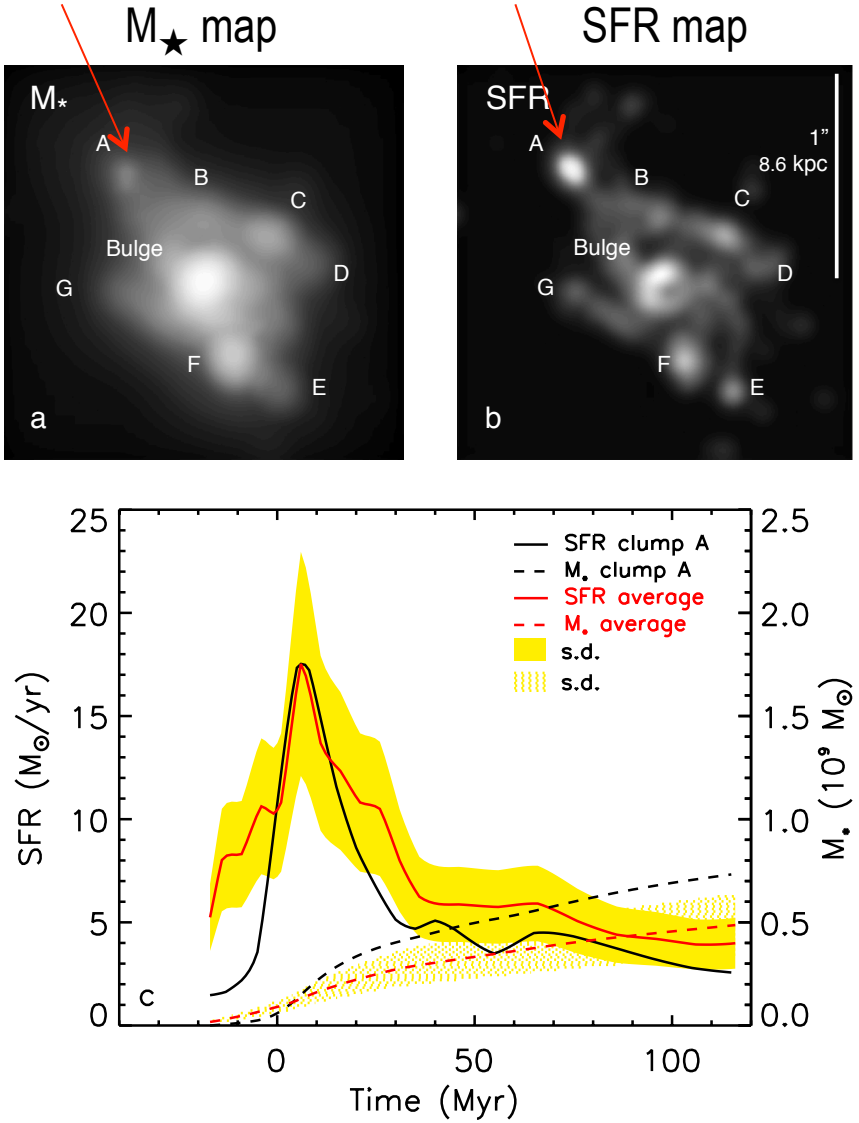
sSFR clump A = 10x sSFR other clumps

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



Newly born clumps behave like mini-starbursts

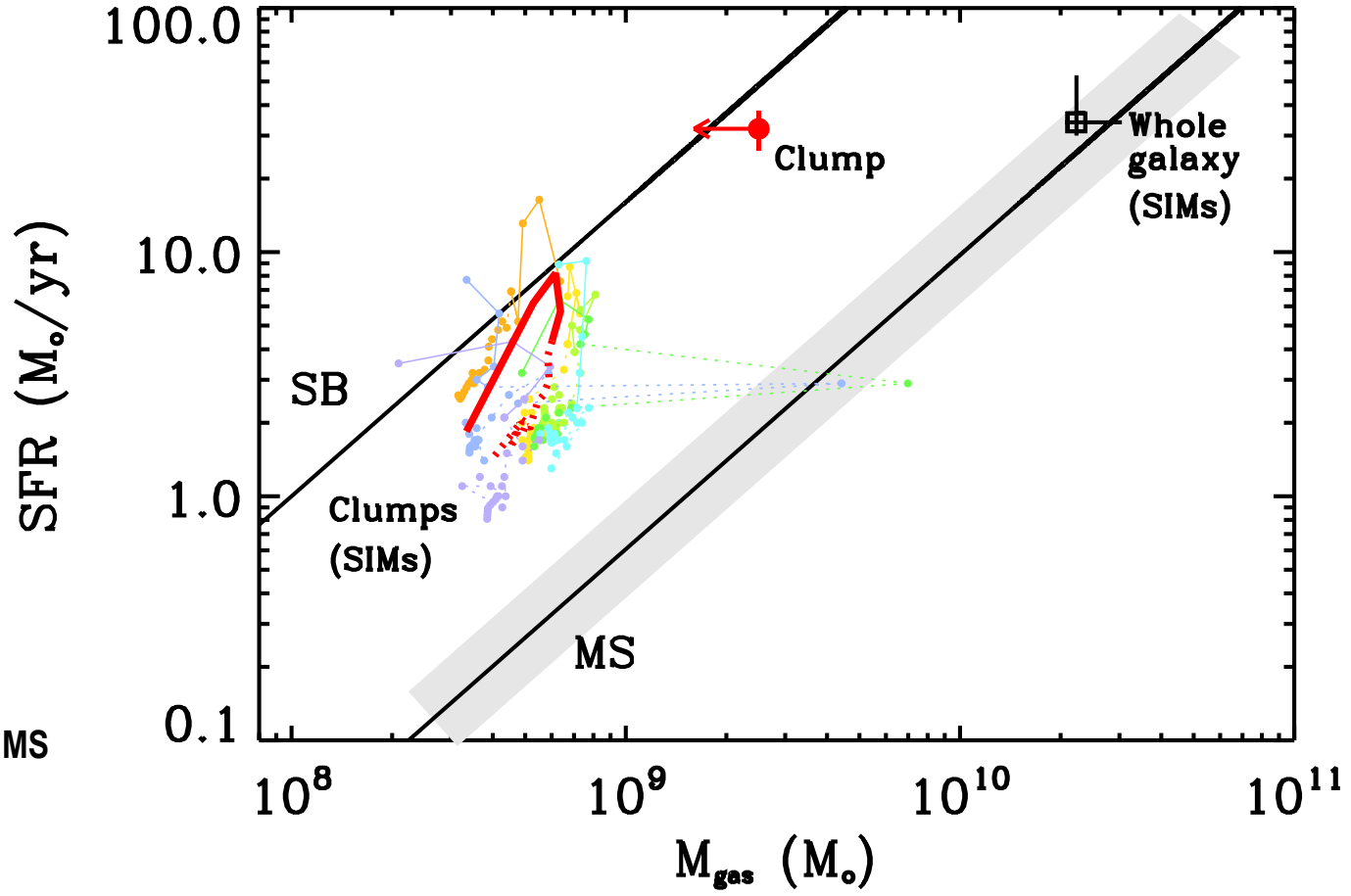
SFR ~ 30 $M_\odot$/yr

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

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

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

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



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

Clumps formation rate

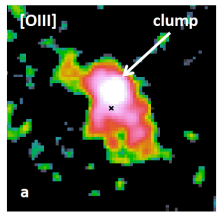
Constraints on **clumps formation rate** (CFR):

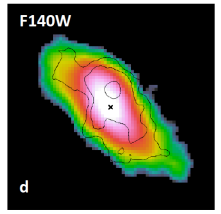
$$\mathrm{CFR} = \frac{N_{young}}{t_V N_{gal}}$$

N_{young} → # of young clumps = 1

N_{gal} → # of sample galaxies = 57

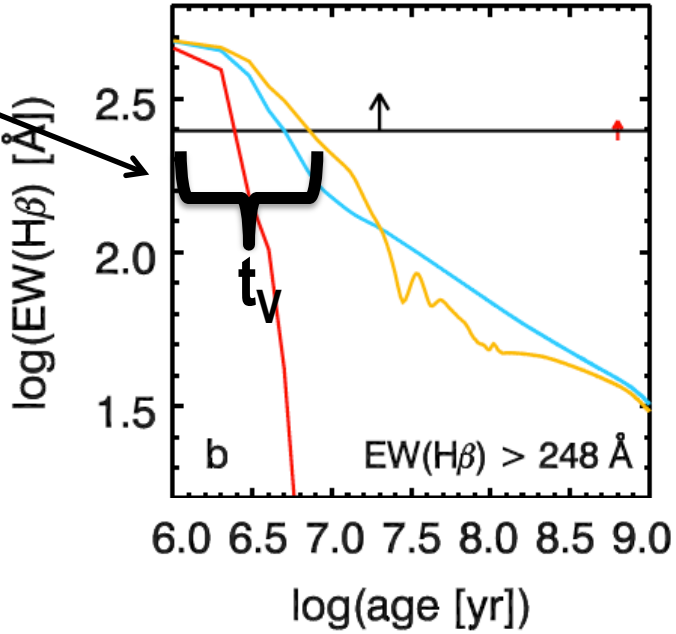
t_V → Visibility window = 7 Myr



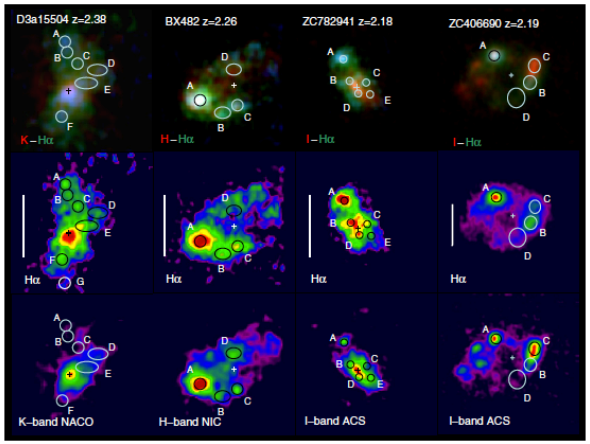


ID568

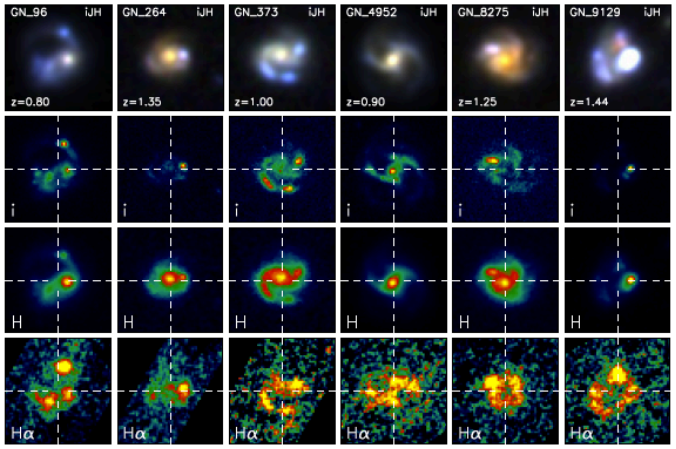
CFR ~ 2.5 clumps/galaxy/Gyr



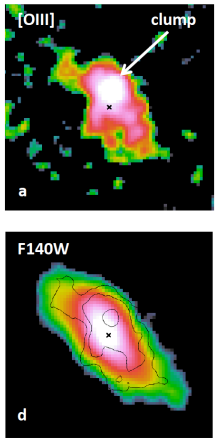
Clumps lifetime



Genzel+ 11



Wuyts+ 13



ID568

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

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

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

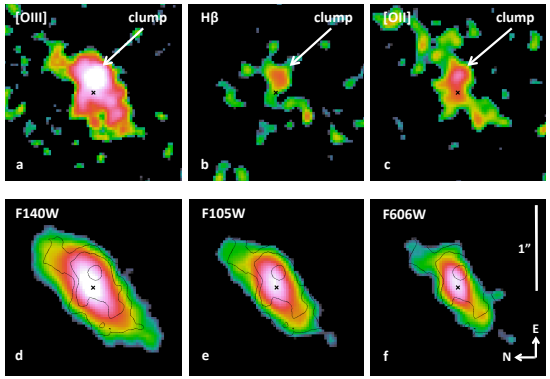
LT ~ 500 Myr → clumps seem to survive stellar feedback

Summary

The birth of a star forming clump…

- Spatially resolved emission line maps of SF galaxy at z ~ 2: a new way to find young and intermediate age clumps

Zanella et al., in preparation



- Discovery of an **extremely young star forming clump** likely **formed due to violent disk instability**

- **Young clumps behave like mini-starbursts** (obs. + sim.) Old clumps have enhanced SFE (sim.)

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

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