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

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Introduction: observations

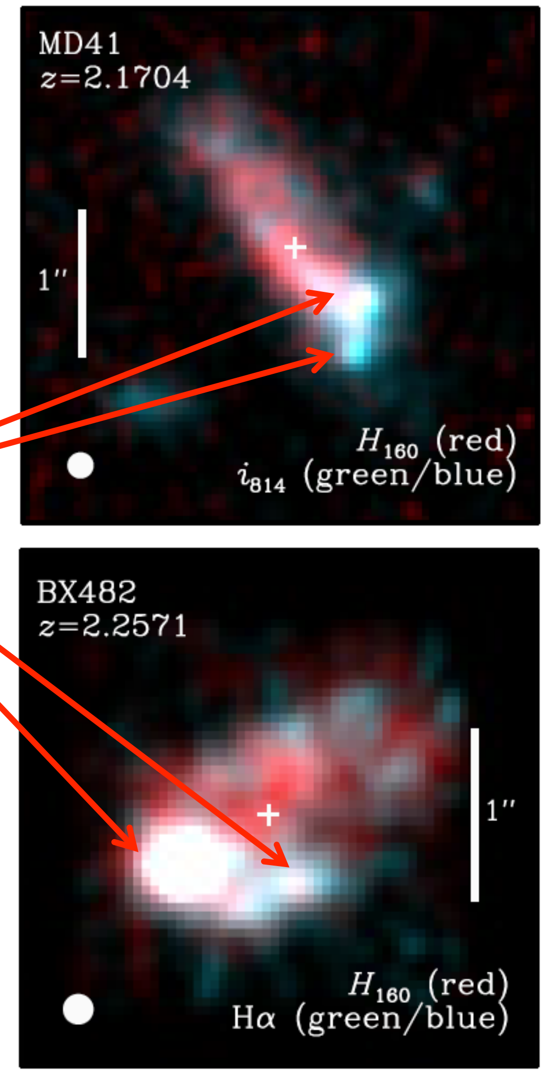
Galaxies at z ~ 2:

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

Clumps in z ~ 2 galaxies:

- have total masses ~ $10^{8\text{-}9}$ $M_{\odot}$
- have SFR ~ 20 - 50% of the total SFR of the galaxy (e.g., Genzel+08, Förster-Schreiber+11, Newman+12)

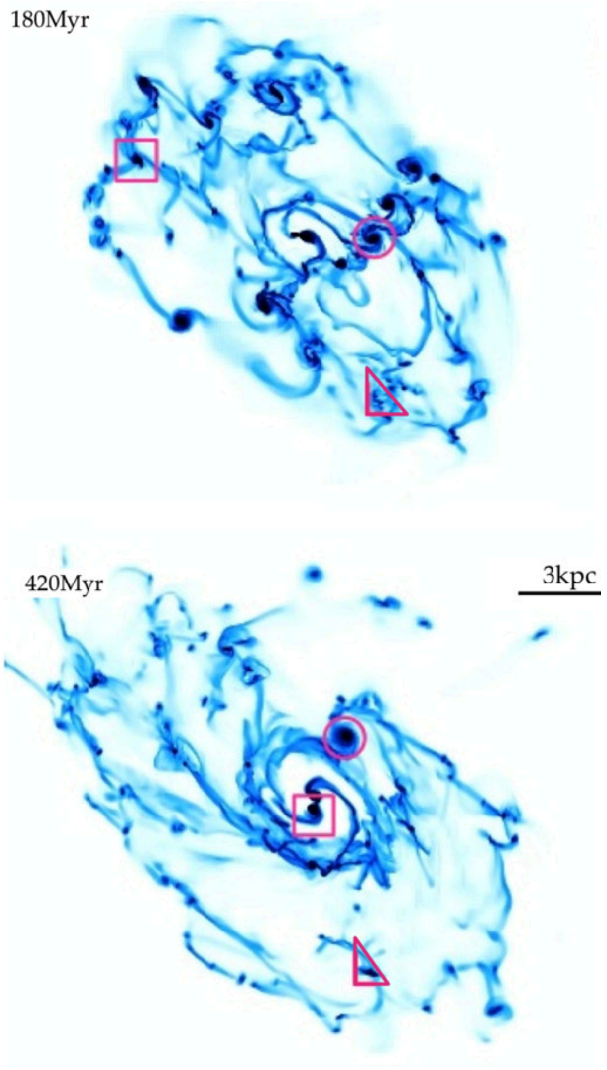
clumps



Förster-Schreiber+ 11

Introduction: simulations

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



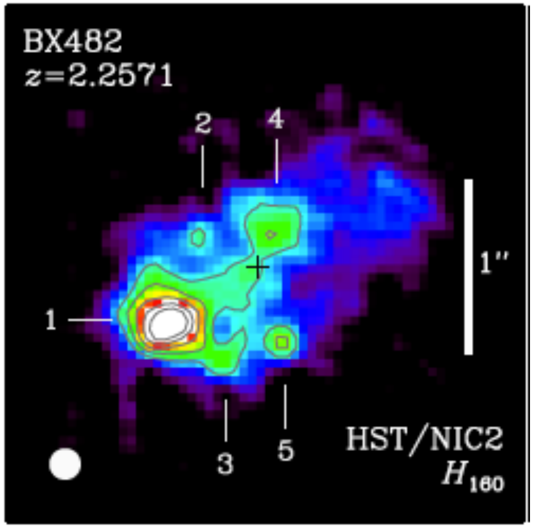
Bournaud+ 14

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) ?

Open questions we would like to answer…

- How do clumps form?
  A **newly formed** clump has never been observed.
- Which is the clumps **lifetime**?
- Are they relevant for **bulge formation**?
- Which is the role of **feedback**?
- Which is the clumps **star formation efficiency**?

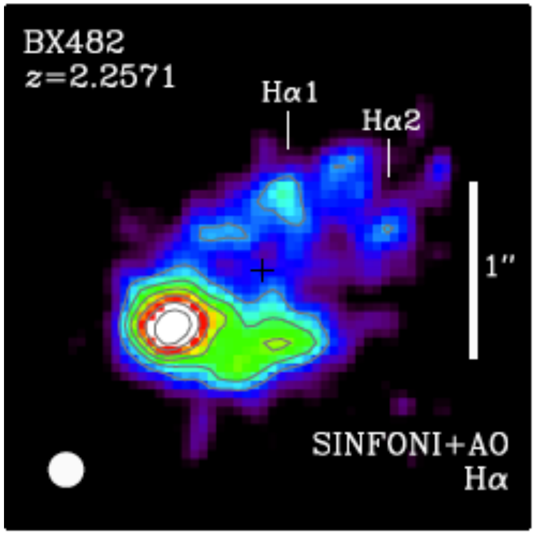


H_{160}

…key ingredients we need

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

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



Hα

Förster-Schreiber+ 11

Sample

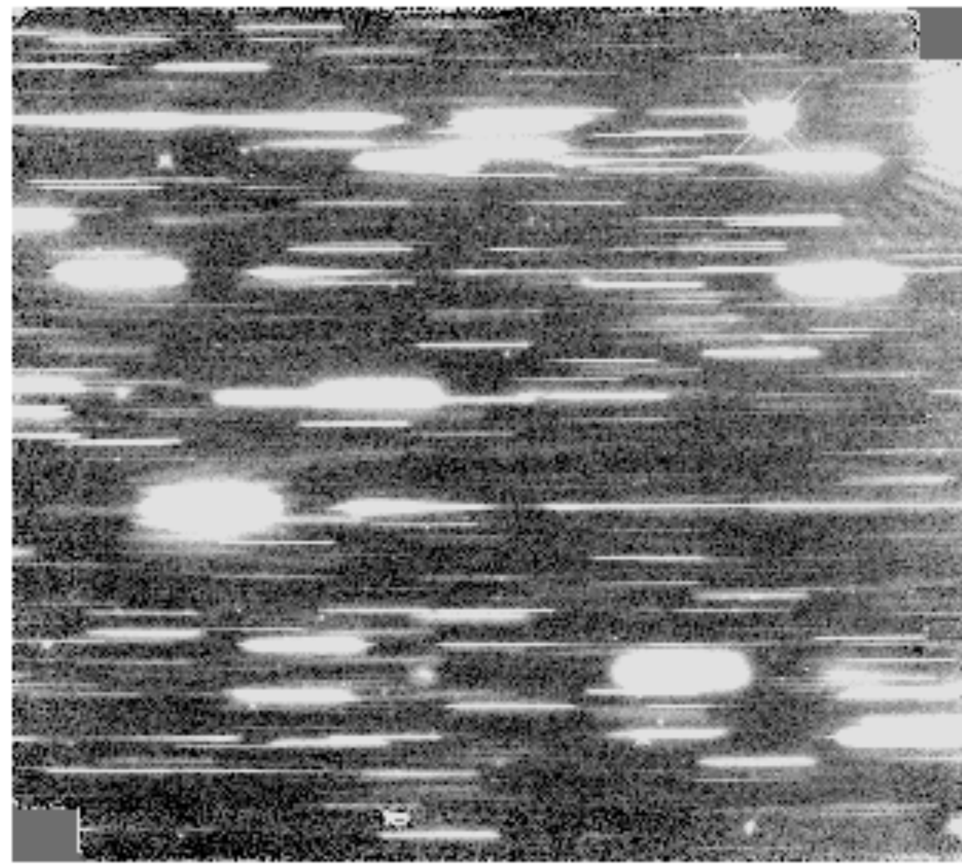
68 **[OIII] emitting** galaxies at $1 \leq z \leq 2$

Observations: WFC3 on board HST

Slitless spectroscopy: G_{141} (λ = 0.8 – 1.2 μm)

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

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

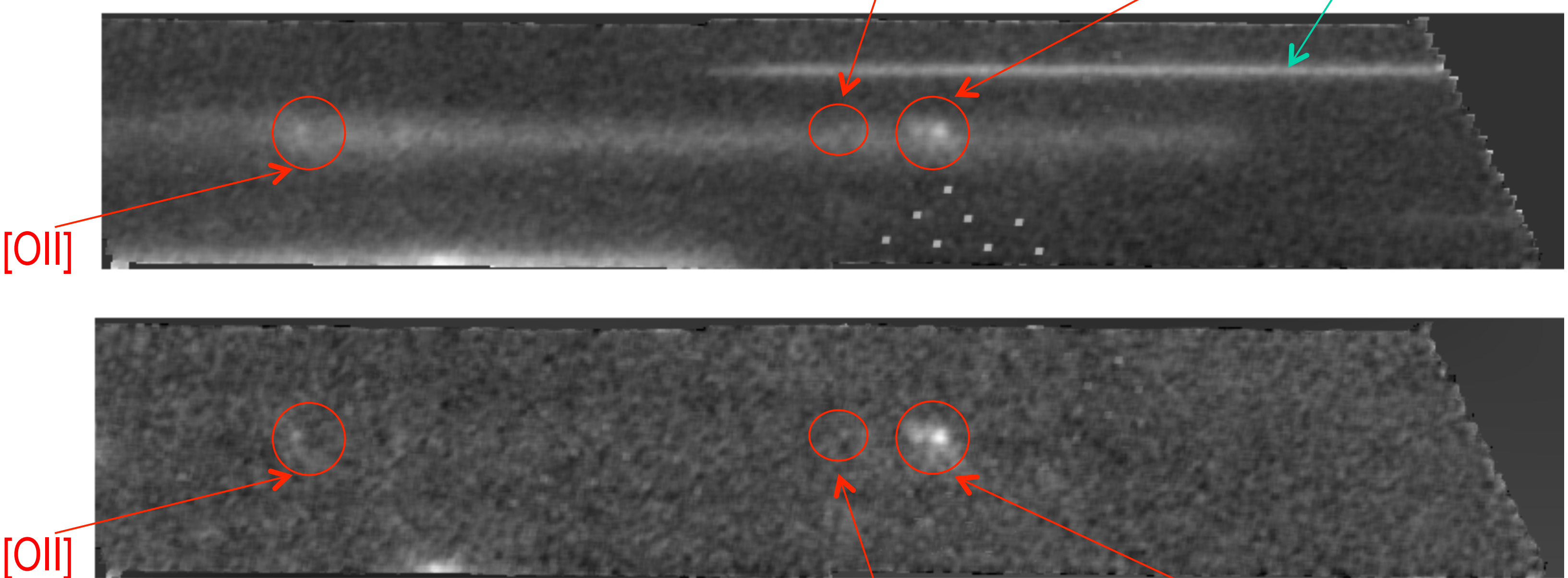


Slitless spectroscopy: 6.4 arcmin^2

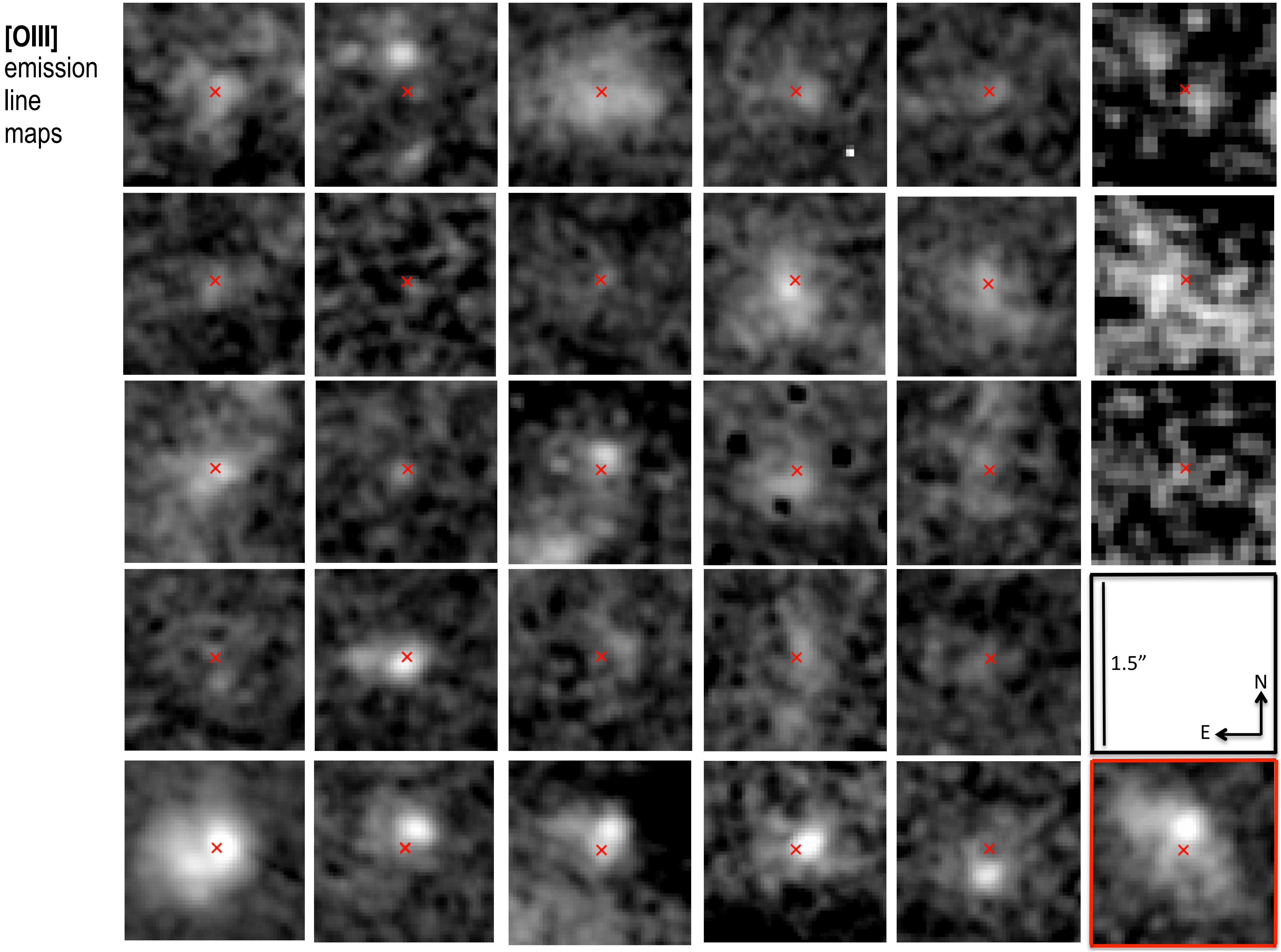
Emission line maps

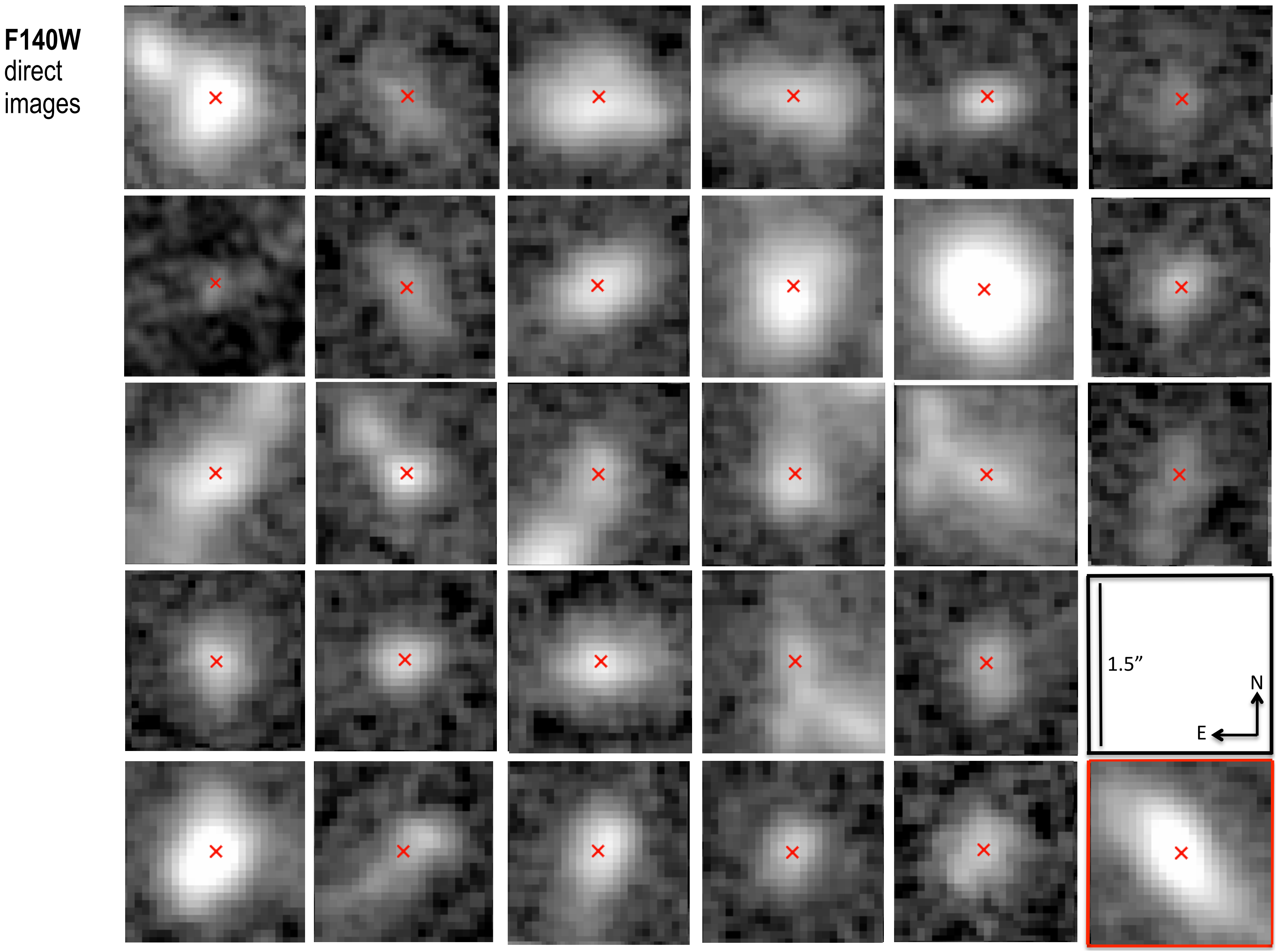
Contamination correction

Continuum subtraction



Cross correlation


[OIII]
emission
line
maps
1.5"
N
E


F140W
direct
images
1.5″
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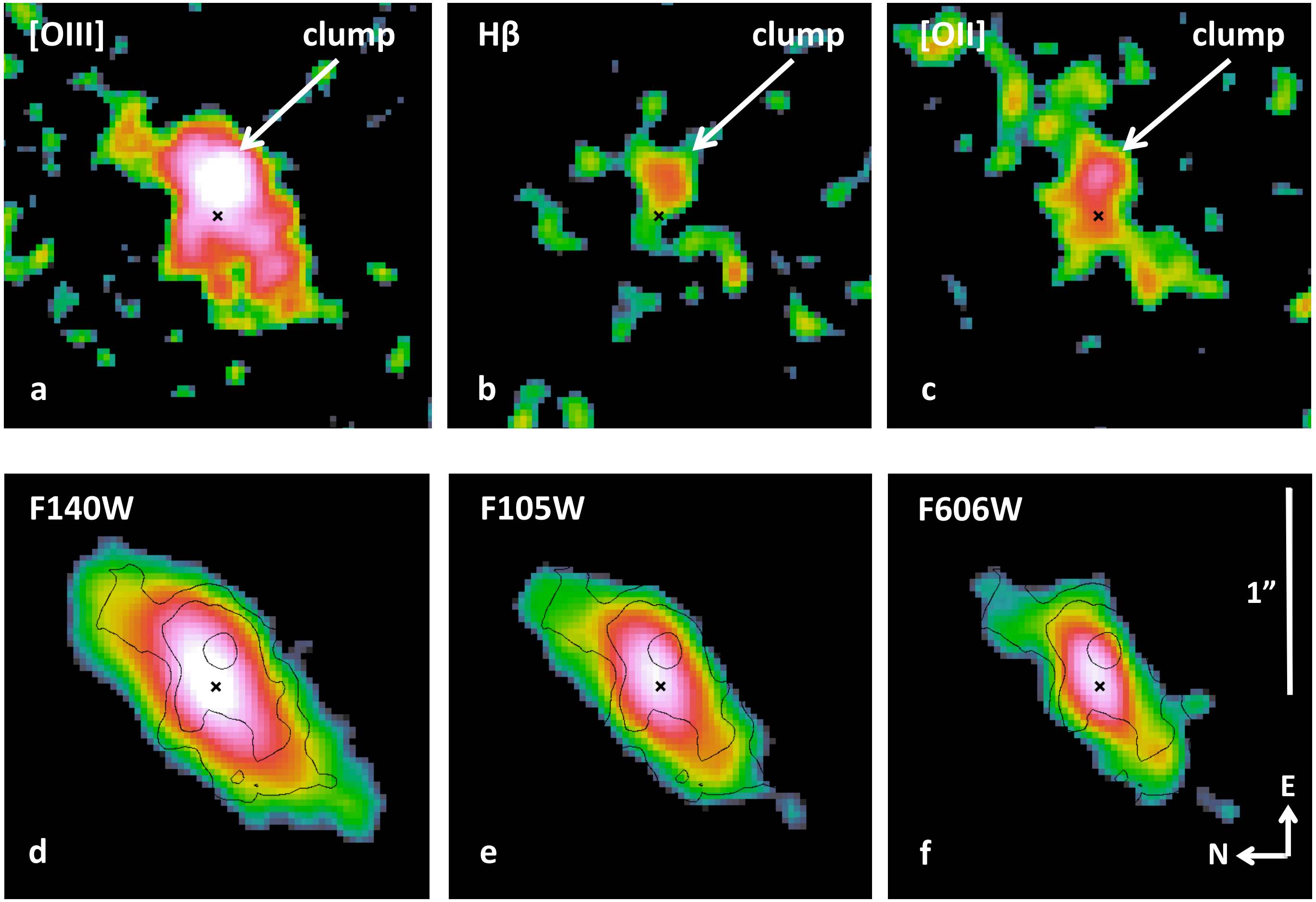
E

Emission line maps

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



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

Offset **significance ~ 8σ**

AGN hypothesis

X RAYS:
no XMM and Chandra detection

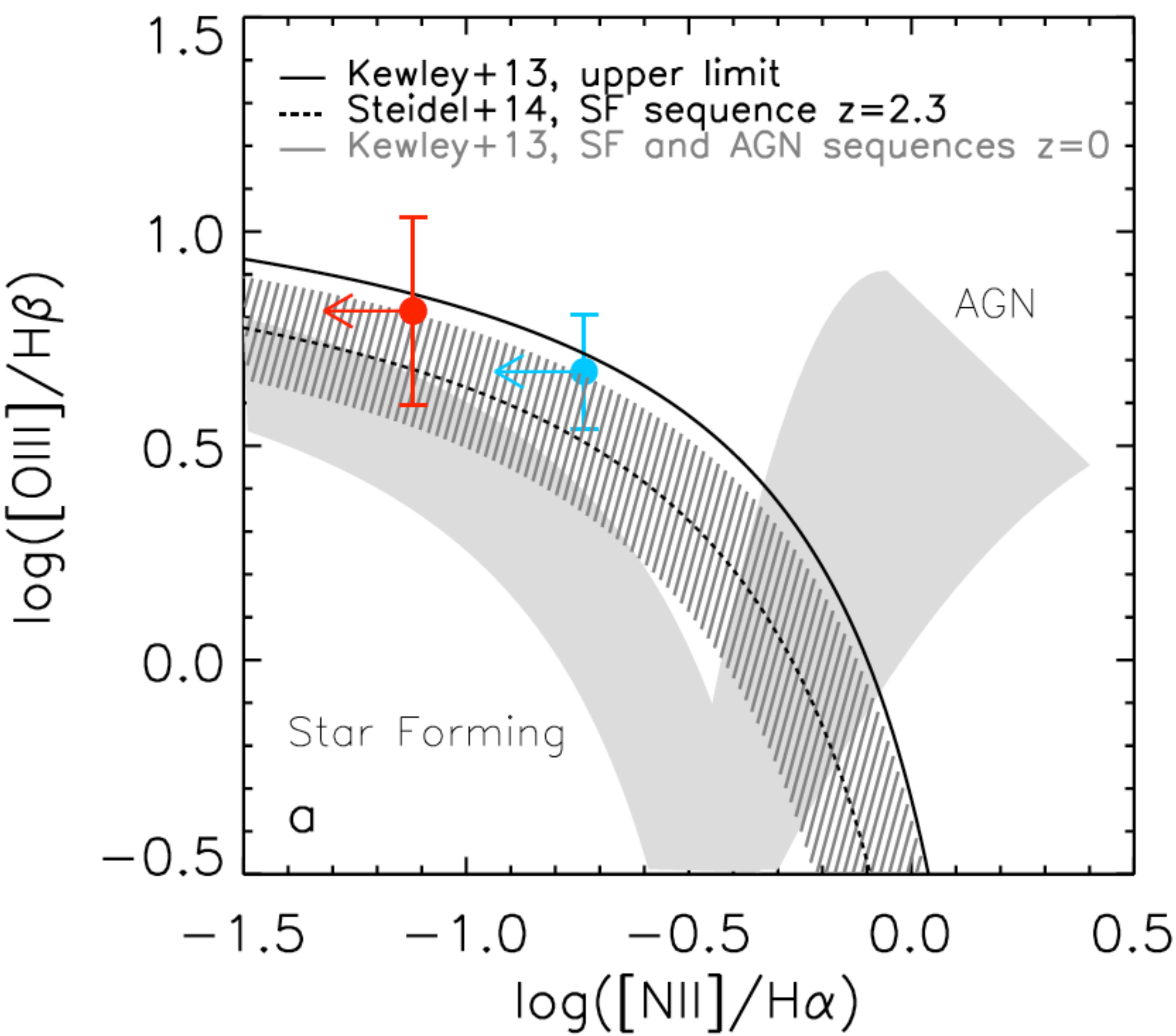
BPT (Baldwin+ 81):
in the SF region
(Subaru/MOIRCS follow up)

TOY MODEL:

$$\left(\frac{[\mathrm{OIII}]}{[\mathrm{NII}]}\right)_{\mathrm{AGN}} \cdot [\mathrm{OIII}]_{\mathrm{clump}} =$$

$$[\mathrm{NII}]_{\mathrm{clump}} > [\mathrm{NII}]_{\mathrm{galaxy}}$$

HIGH IONIZATION LINES
(e.g. NeV): no detection



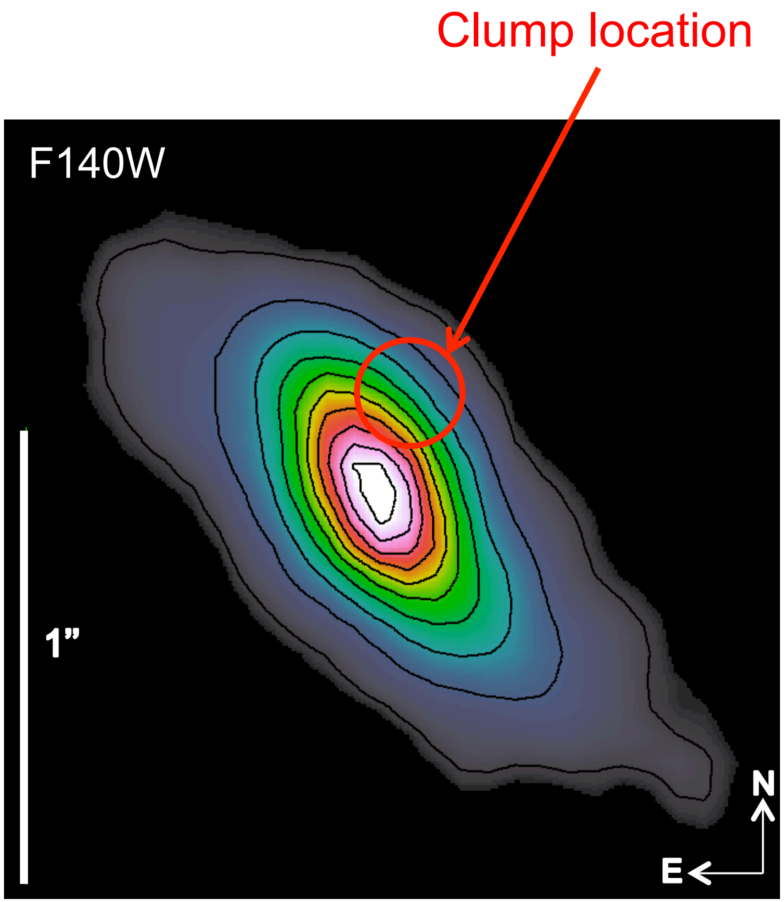
Continuum emission

No detection of the clump in the continuum

Upper limits on the continuum flux: simulations

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

Lower limit



$\mathrm{EW}_{[\mathrm{OIII}]} \geq 1700$ Å >> typical $\mathrm{EW}_{[\mathrm{OIII}]}$ of AGNs (~50-100 Å)

An extremely young SF clump

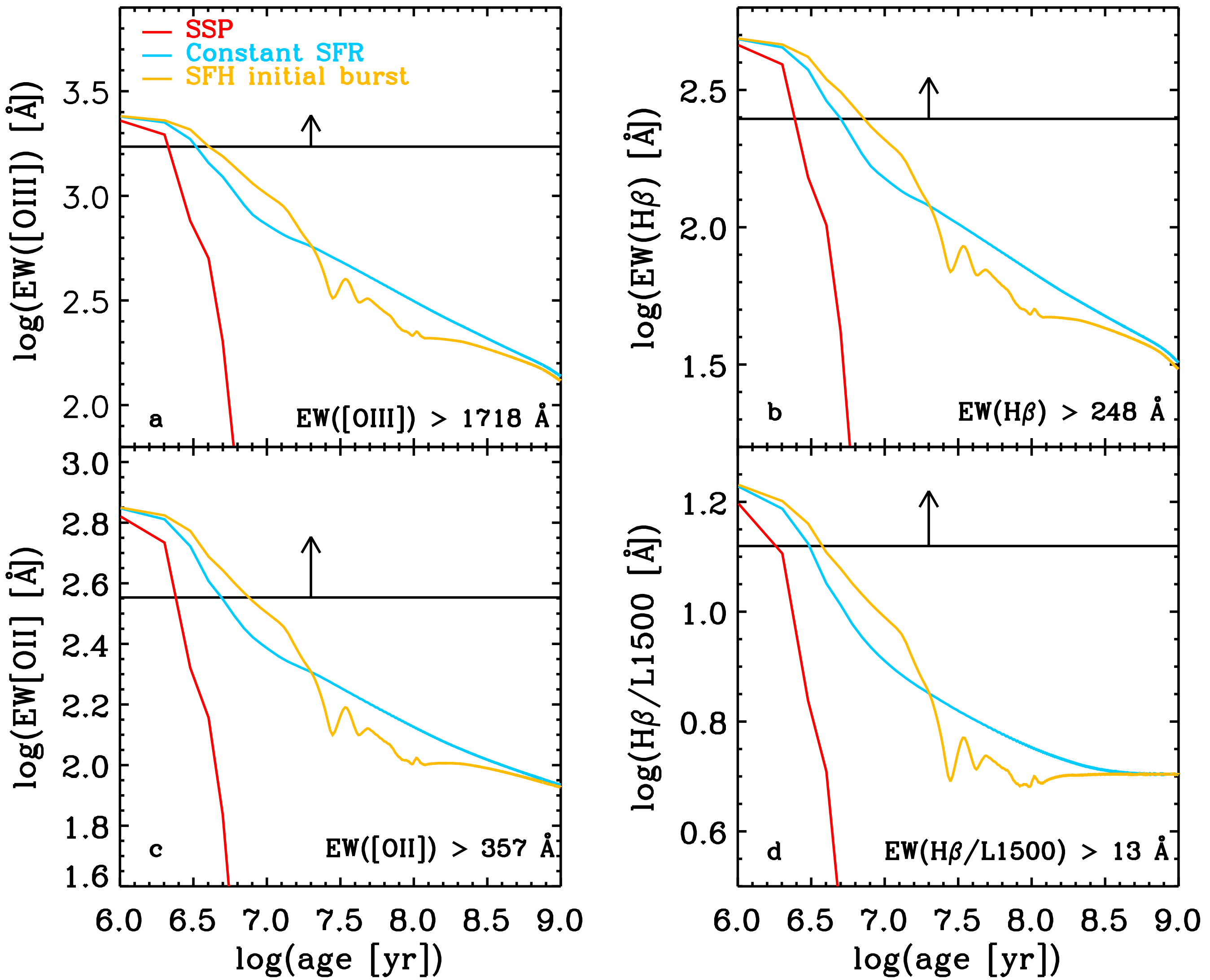
$Z \sim 0.4\, Z_o$

Re ≤ 0.5 kpc (unresolved)

Age < 10 Myr

First time robust **age** estimate comparable to **free fall time**

Starburst99 models



Zanella et al. 2014, submitted

Simulations

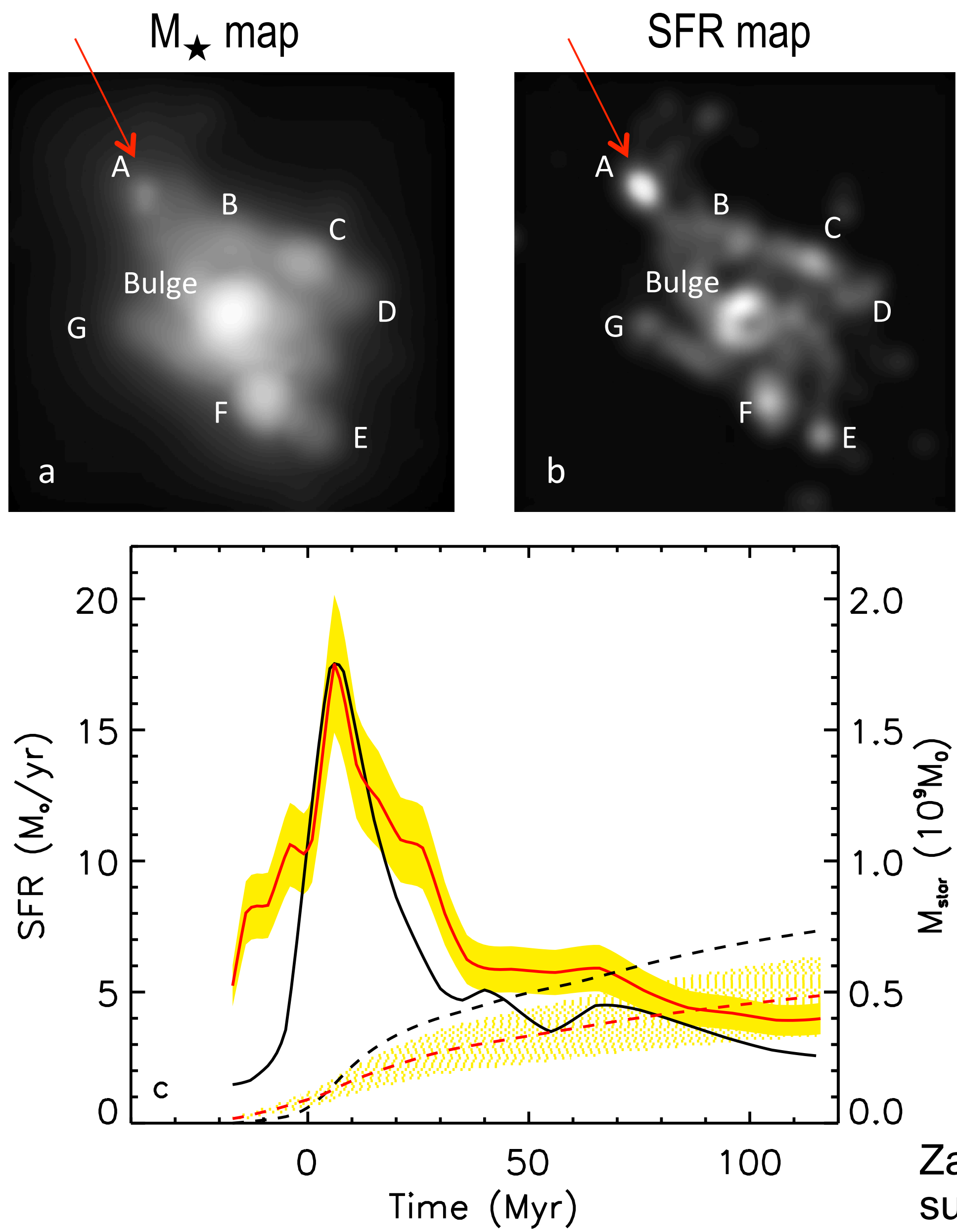
sSFR clump A = 10x sSFR other clumps

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



Zanella et al. 2014, submitted

Newly born clumps behave like mini-starbursts

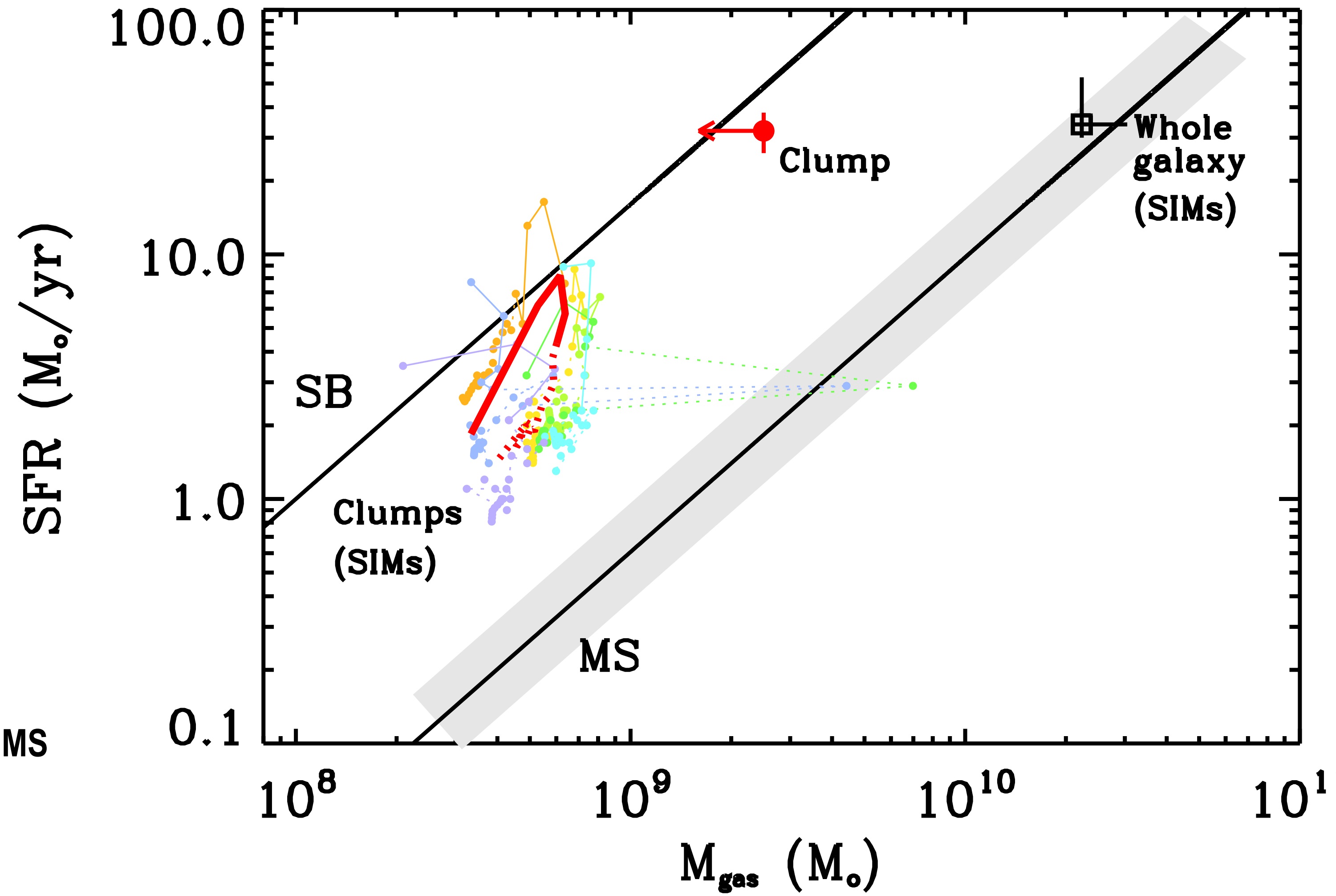
SFR ~ 30 M_o/yr

$M_\star \leq 3 \cdot 10^8\ M_o$

$M_{gas} < 2.5 \cdot 10^9\ M_o$

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

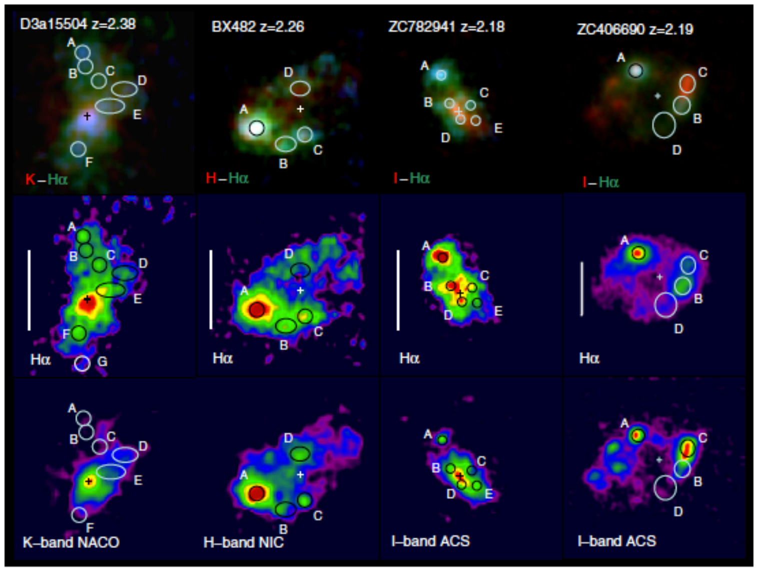
$SFE > 10x\ SFE_{gal,MS}$



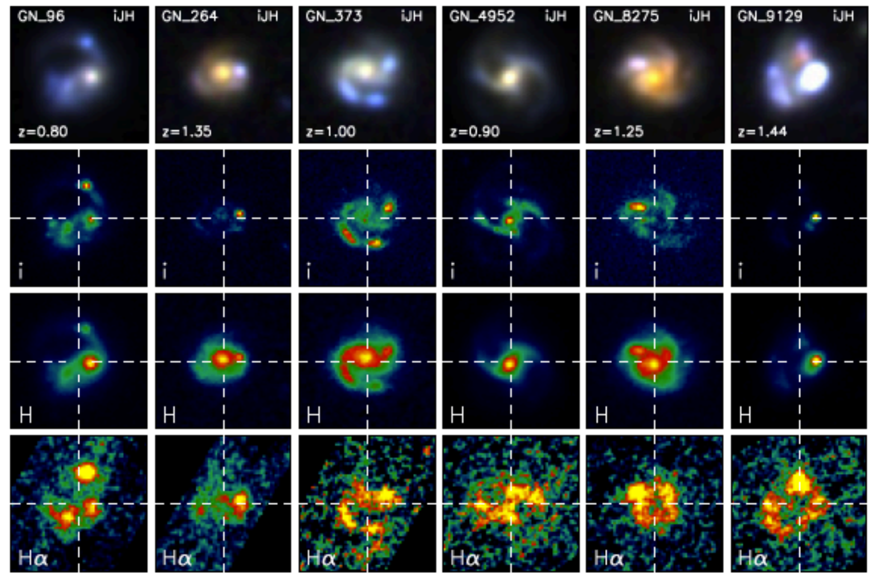
Zanella et al. 2014, submitted

First insights on the collapse phase

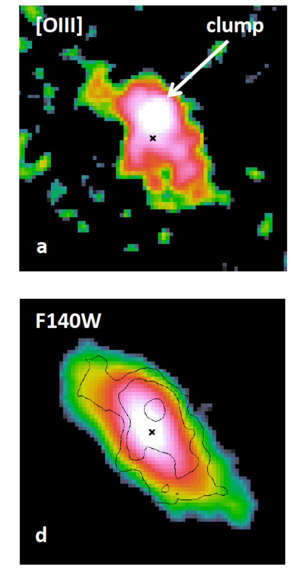
1. Direct evidence of clumps' **formation phase**



Genzel+ 11



Wuyts+ 13



ID568

2. Constraints on **clumps formation rate** (~2 clumps/Gyr) and **lifetimes** (~500Myr)
   → clumps survive stellar feedback

Future developments

Kinematics constraints with AO spectroscopy
→ pending time request

Detailed analysis of the rest of the sample

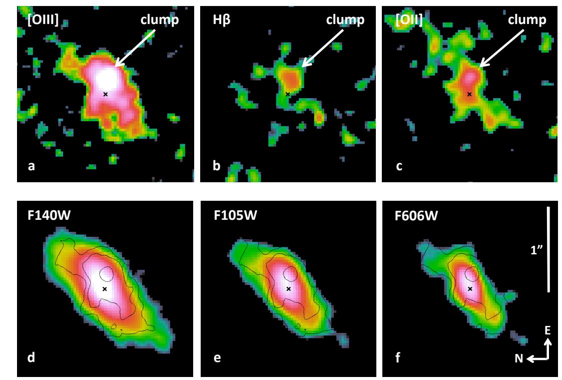
- **sSFR** vs age? → constraints on stellar feedback role
- clumps **formation rate**? → constraints on the clumps' lifetime
- **age** gradient? → constraints on clump migration

Increase of the statistics analyzing other fields

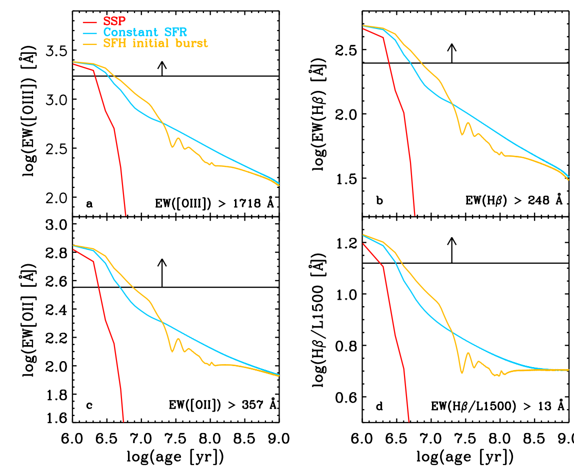
Summary

The birth of a star forming clump…

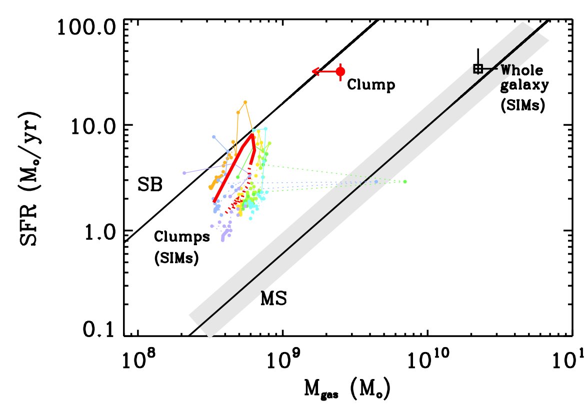
- We considered a sample of 68 [OIII] emitters at $1 \leq z \leq 2$
- We created spatially resolved emission line maps
- The case of ID568:
  bright off-nuclear [OIII] without a continuum counterpart



- The emission lines are powered by star formation and not AGN
- It is an extremely young star forming clump

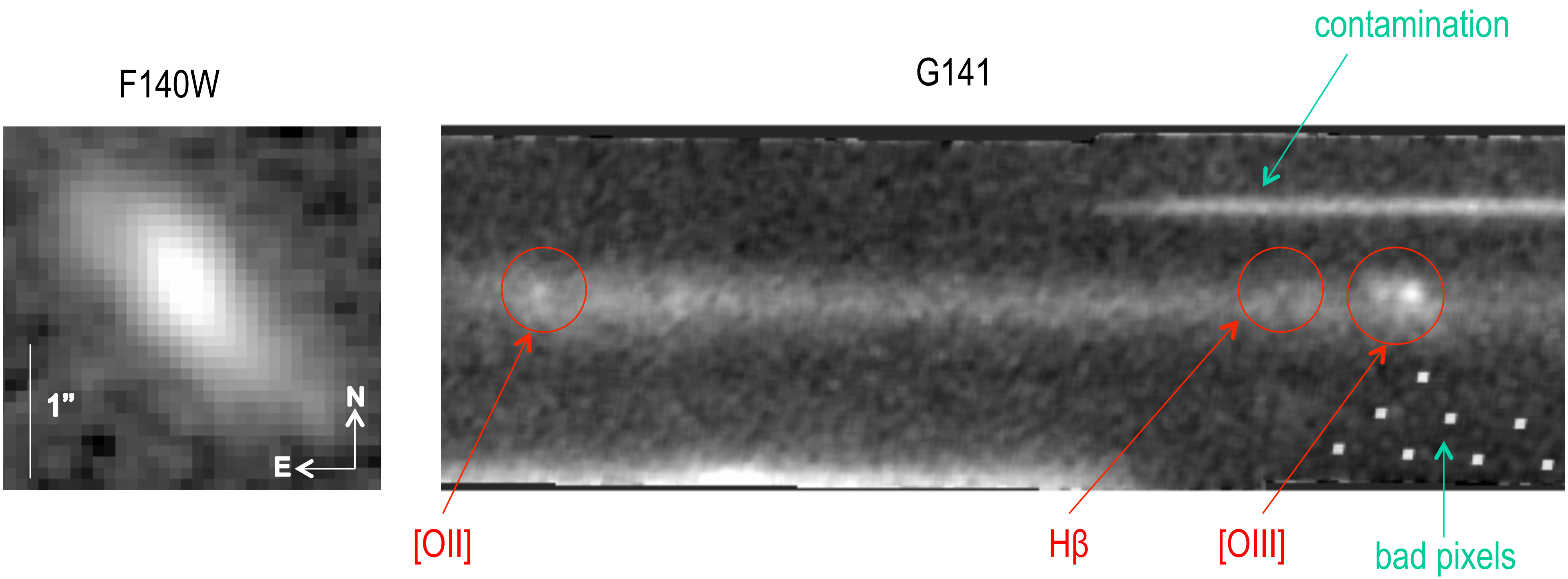


- It is the first direct observation of the clumps' formation phase
- Young clumps behave like mini-starbursts (obs. + sim.)
  Old clumps have enhanced SFE (sim.)
- It supports the scenario in which clumps survive stellar feedback



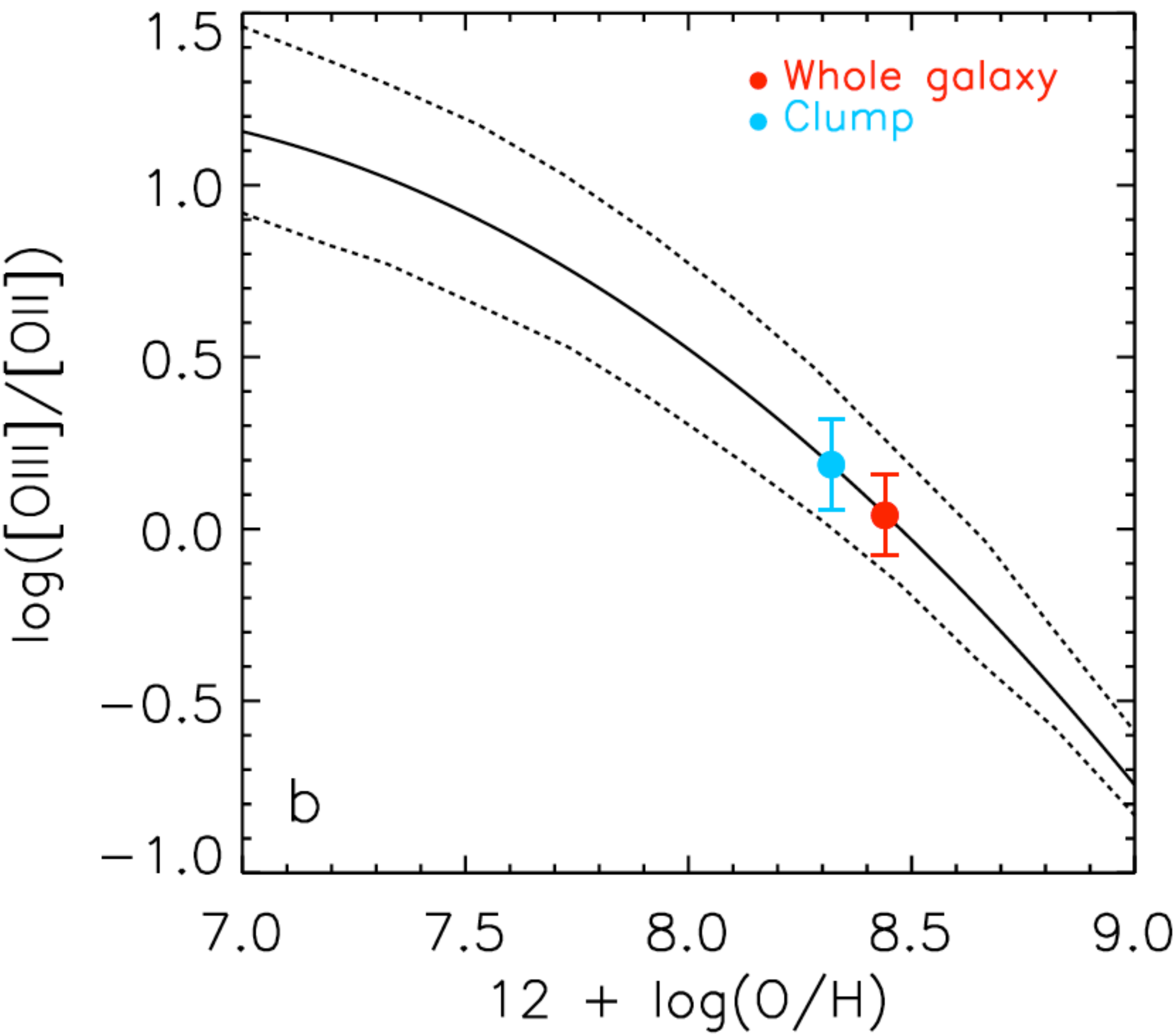
Backup slides

Sample

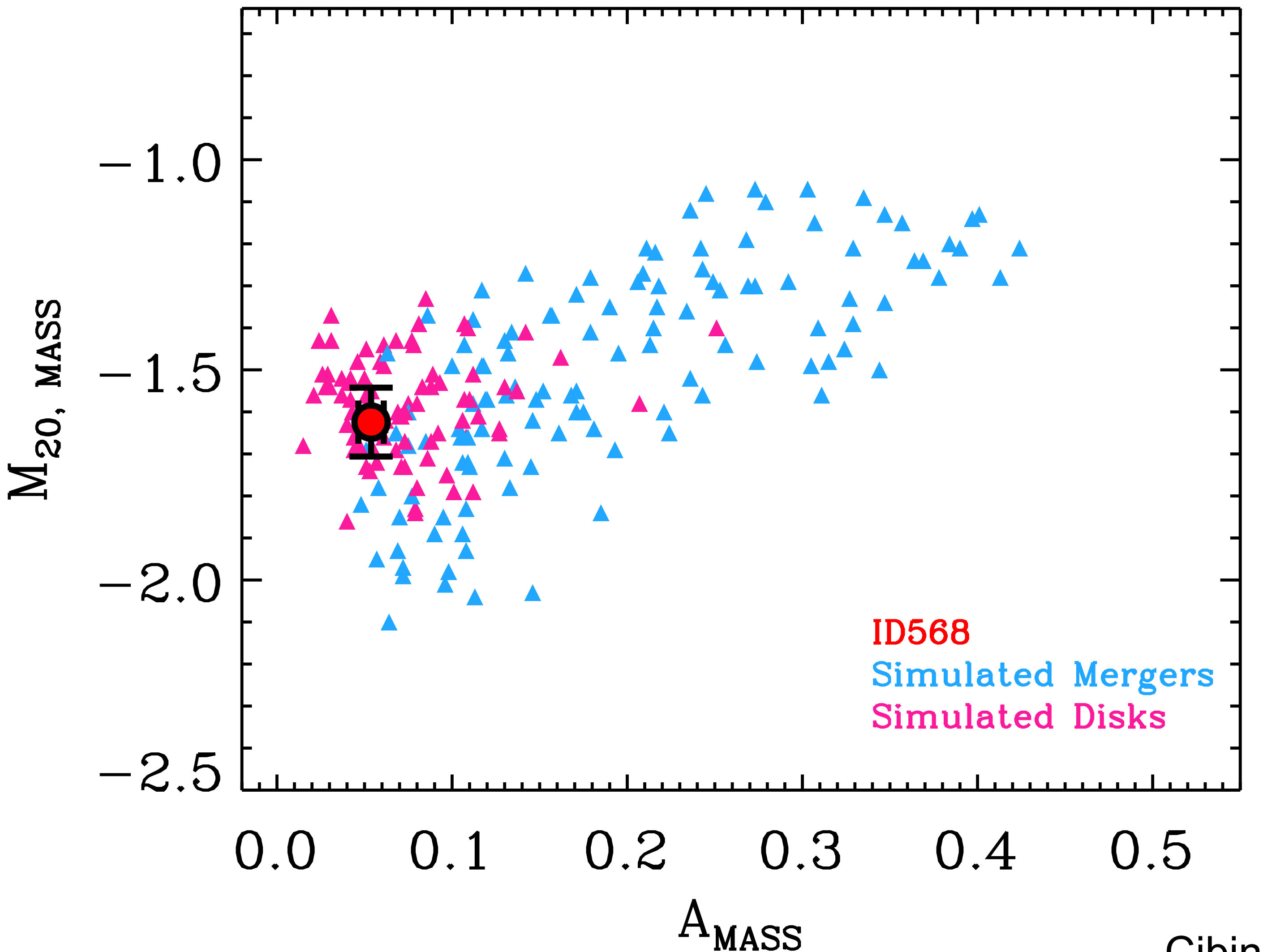


Emission line width = velocity broadening +
intrinsic broadening +
“morphology broadening”

Metallicity

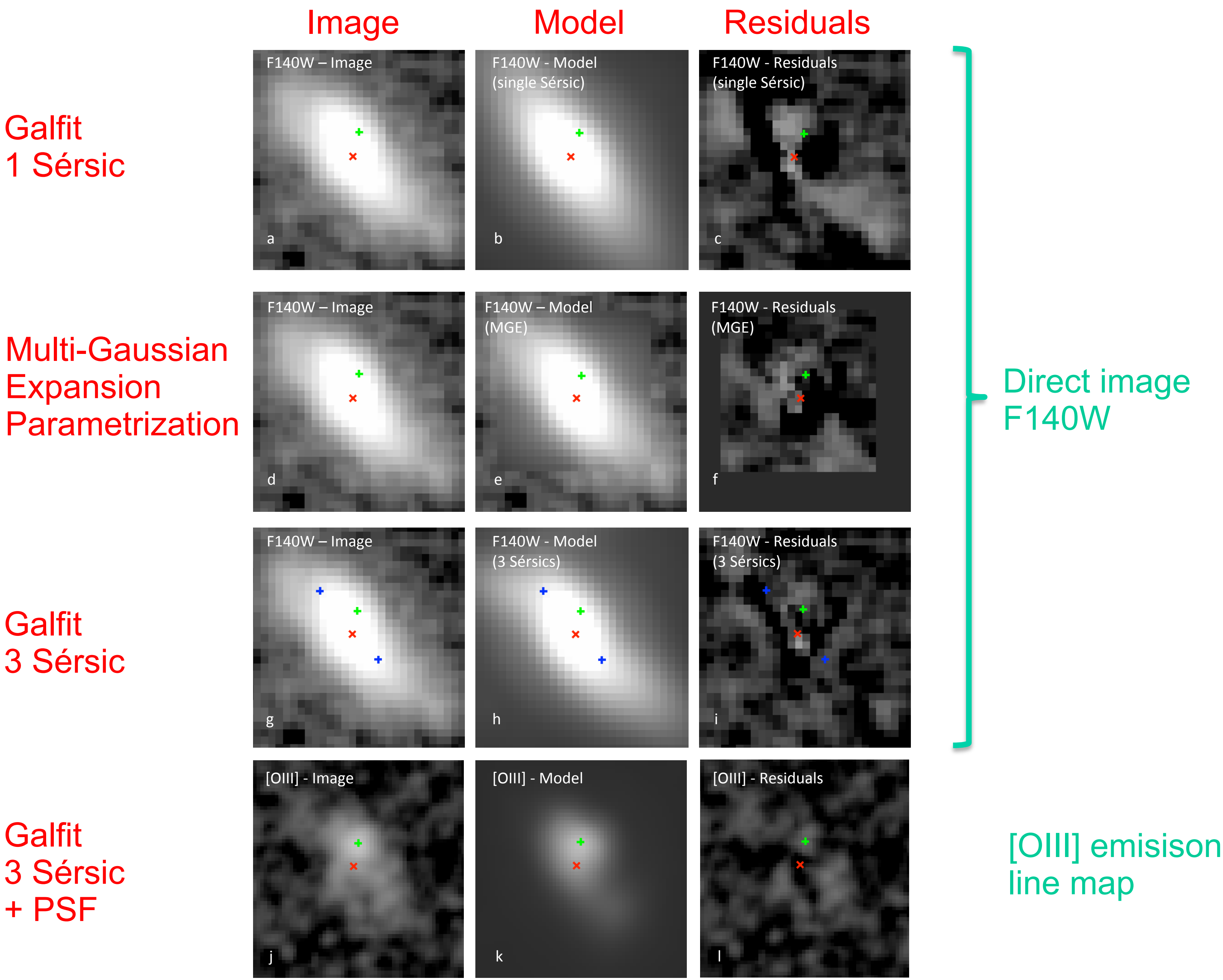


Classification asymmetry - M_{20}

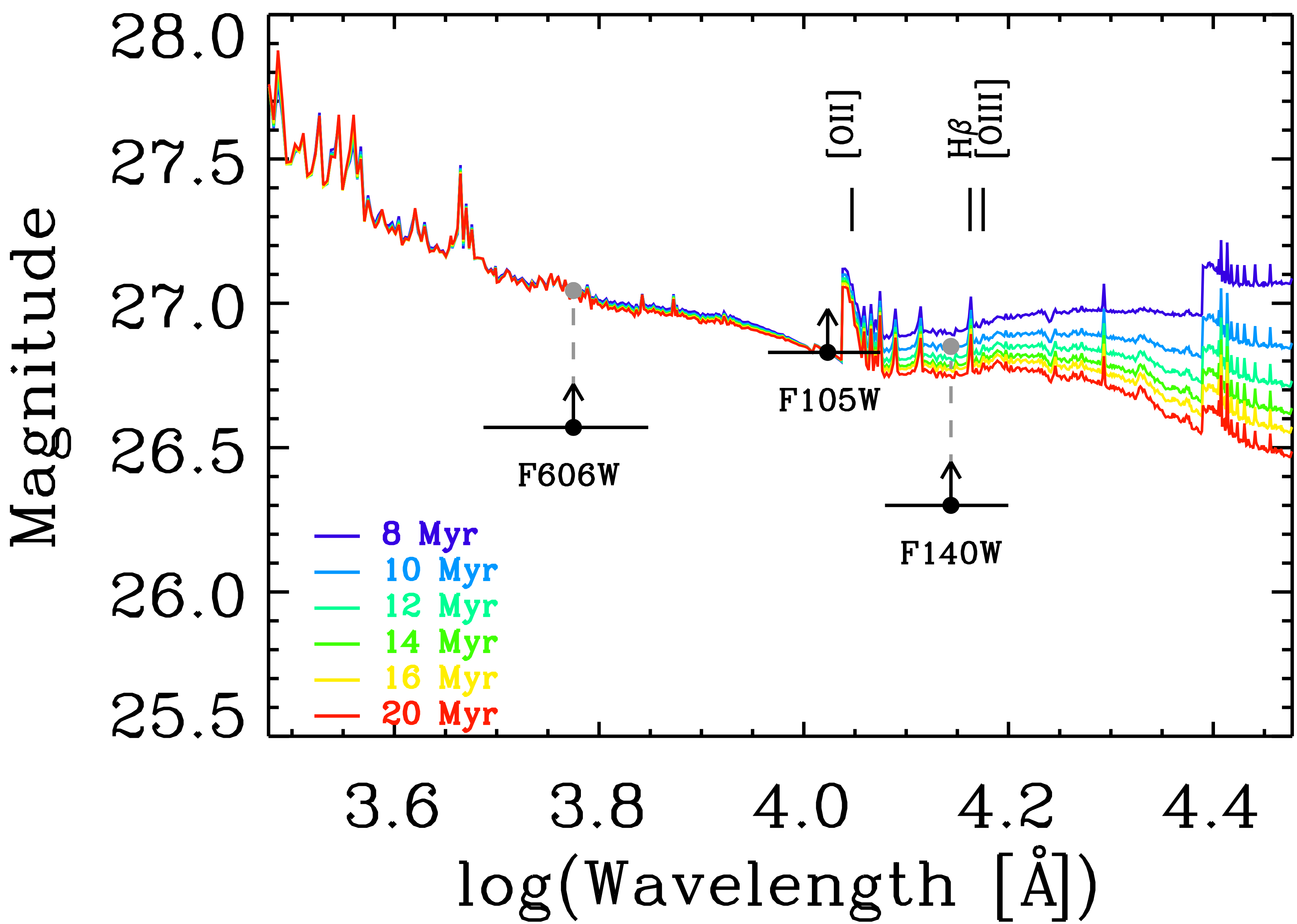


Cibinel+ 14, in prep.

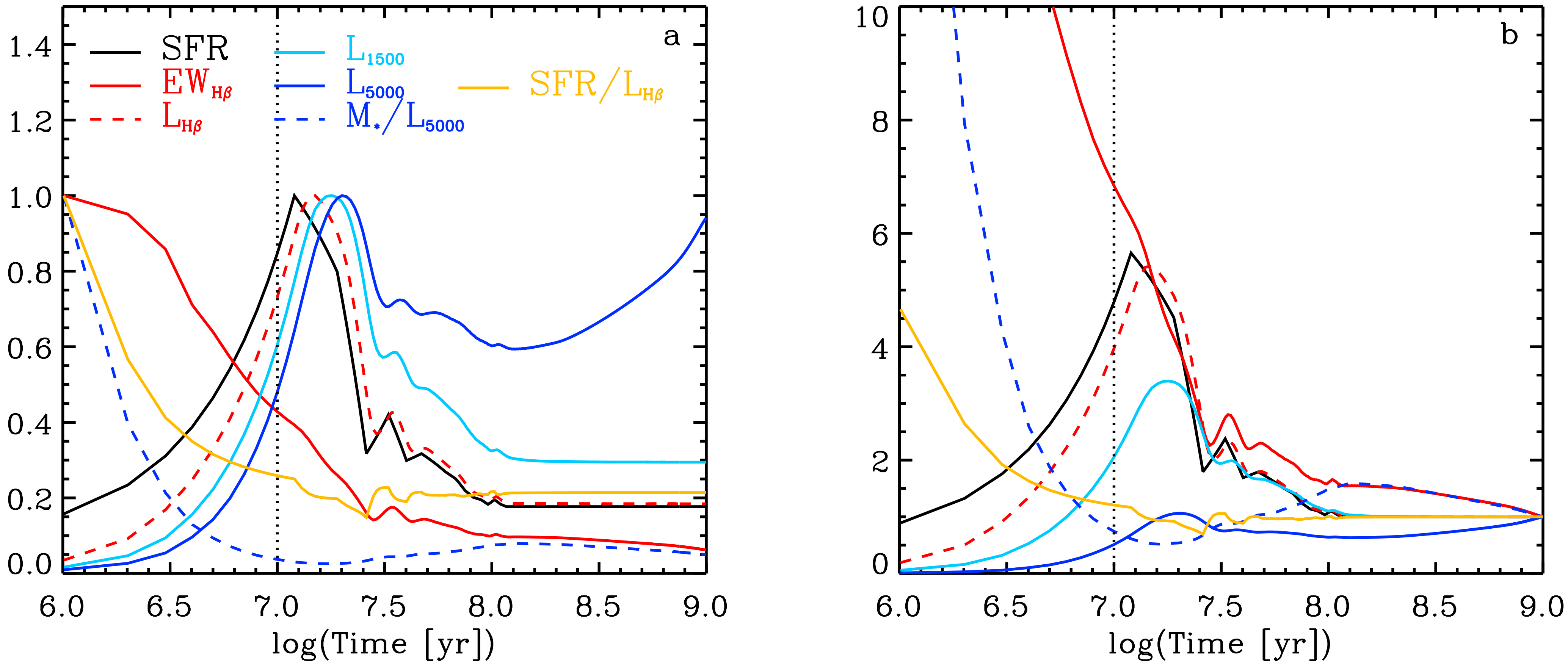
Galfit decomposition



Continuum upper limits



Physical quantities vs Age



Properties of the galaxy and the clump

Table 1: Properties of the galaxy and the clump.

	Radius [kpc]	SFR [$M_\odot$/yr]	$\log(M_\star)$ [$\log(M_\odot)$]	$\log(M_{gas})$ [$\log(M_\odot)$]	Z [$Z_\odot$]	$F^{obs}_{[OIII]}$ [10^{-17} erg s^{-1} cm^{-1}]	$F^{obs}_{H\beta}$ [10^{-17} erg s^{-1} cm^{-1}]	$F^{obs}_{[OII]}$ [10^{-17} erg s^{-1} cm^{-1}]
Galaxy	$8.54^{+1.81}_{-0.80}$	77 ± 4	$10.3^{+0.2}_{-0.3}$	-	0.6 ± 0.2	10.4 ± 0.8	1.5 ± 0.8	6.5 ± 1.7
Clump	< 0.5	32 ± 6	< 8.5	< 9.4	0.4 ± 0.2	4.5 ± 0.3	0.9 ± 0.3	1.9 ± 0.6