Turbulence and Star-formation in Hα luminous galaxies

Chicken or Egg?

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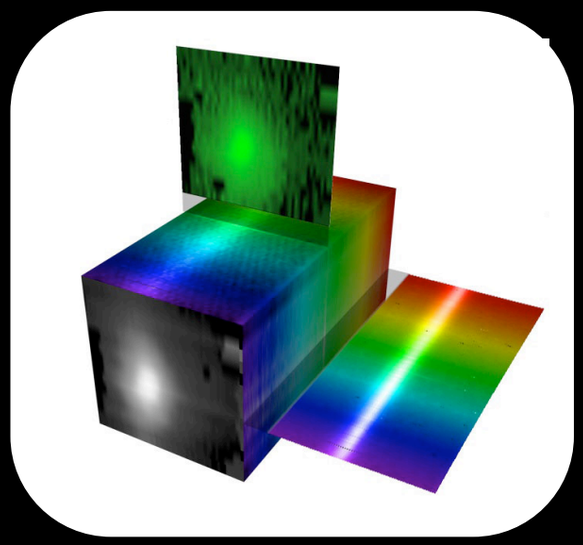
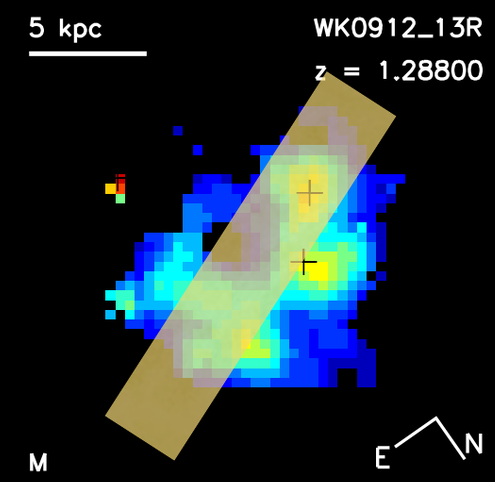
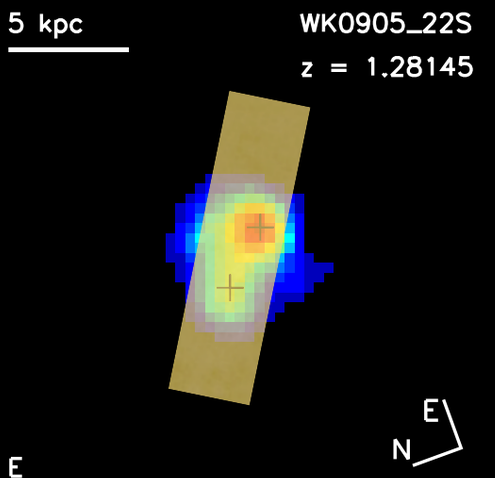
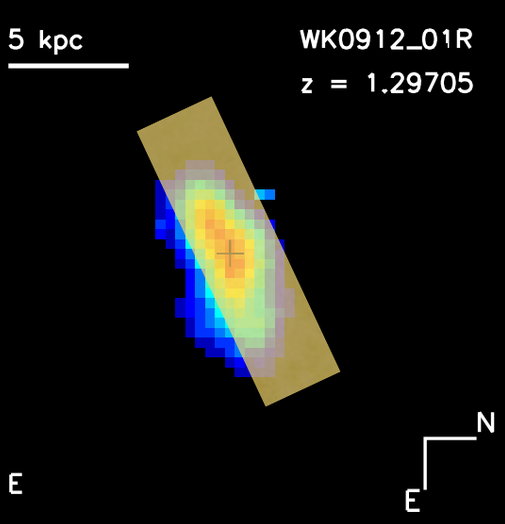
z>1 IFS kinematics

Wisnioski et al.
in press
arXiv:1107.3338



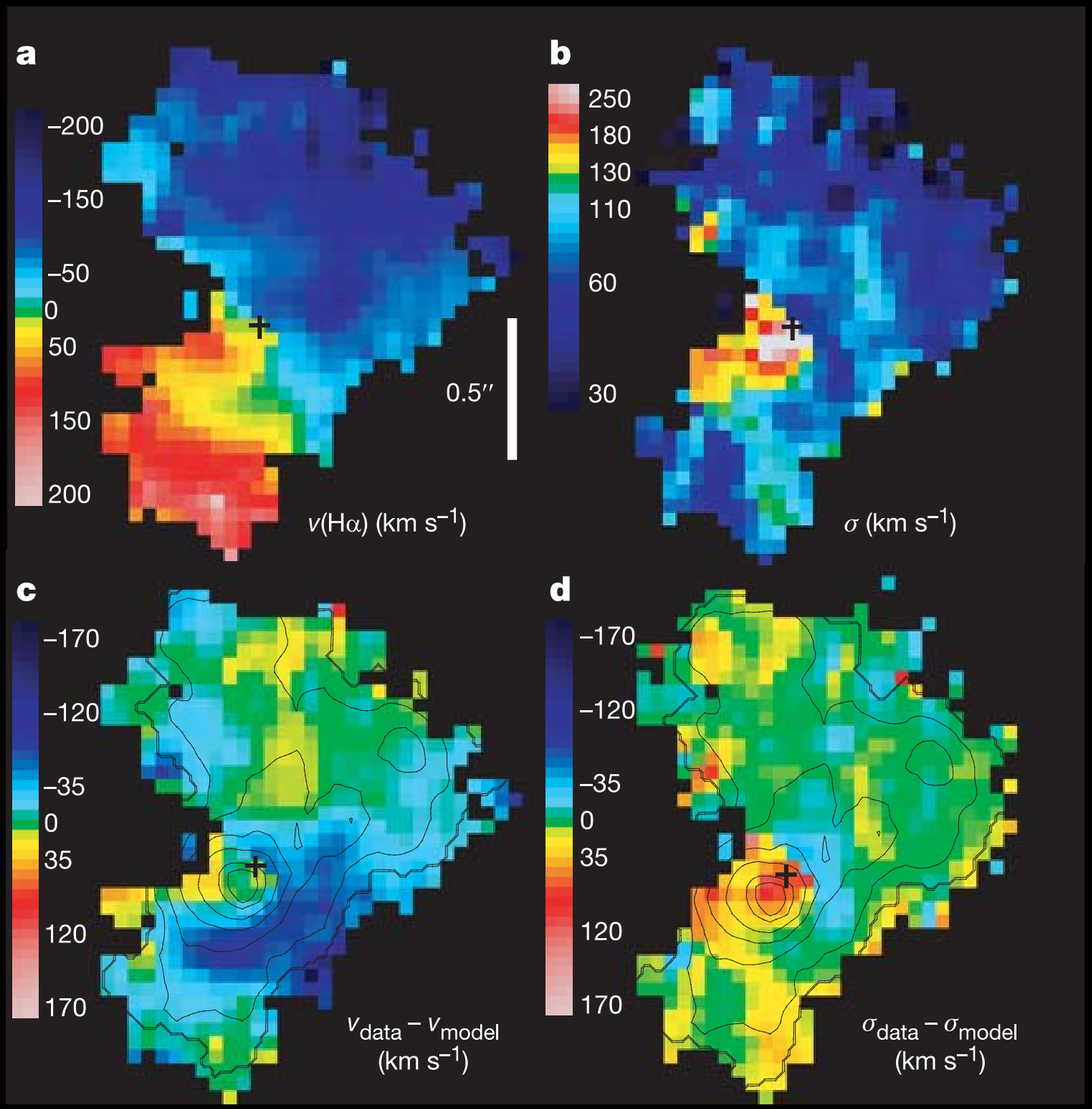






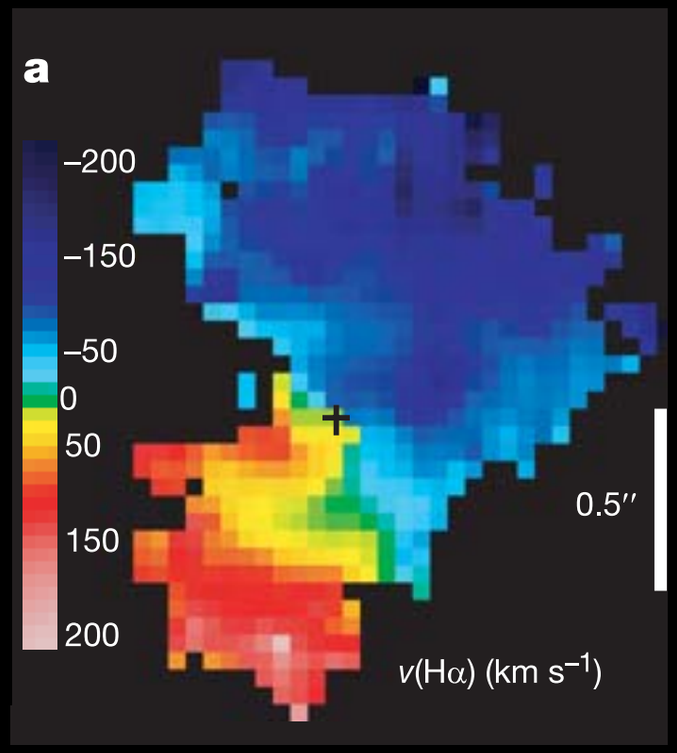
The rapid formation of a large rotating disk galaxy three billion years after the Big Bang

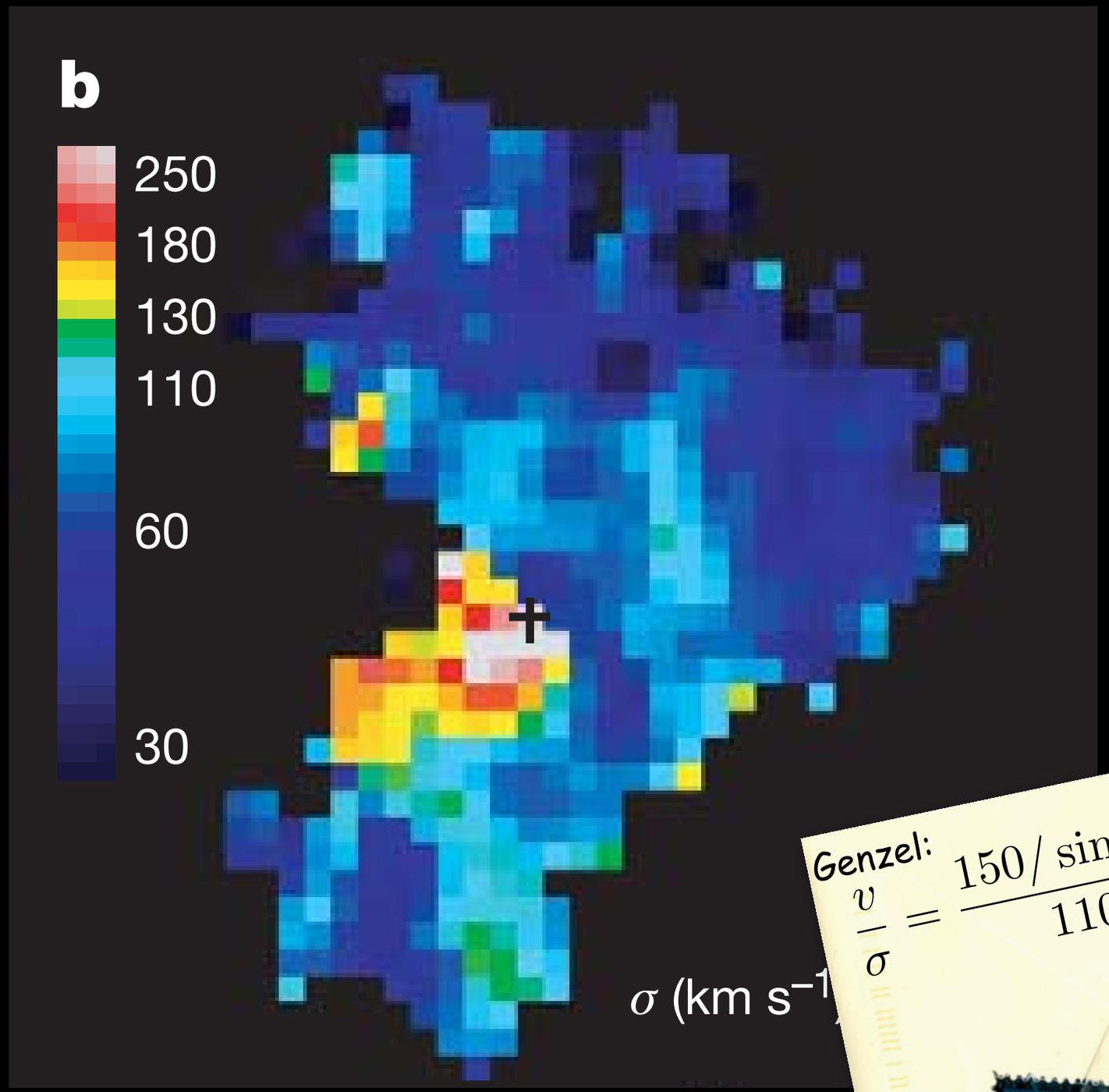
R. Genzel[1,2], L. J. Tacconi[1], F. Eisenhauer[1], N. M. Förster Schreiber[1], A. Cimatti[1,3], E. Daddi[4], N. Bouché[1], R. Davies[1], M. D. Lehnert[1], D. Lutz[1], N. Nesvadba[1], A. Verma[1], R. Abuter[1], K. Shapiro[5], A. Sternberg[6], A. Renzini[7], X. Kong[8], N. Arimoto[9] & M. Mignoli[10]



SFR=140 $M_\odot$/yr

‘turbuluent’ disk?





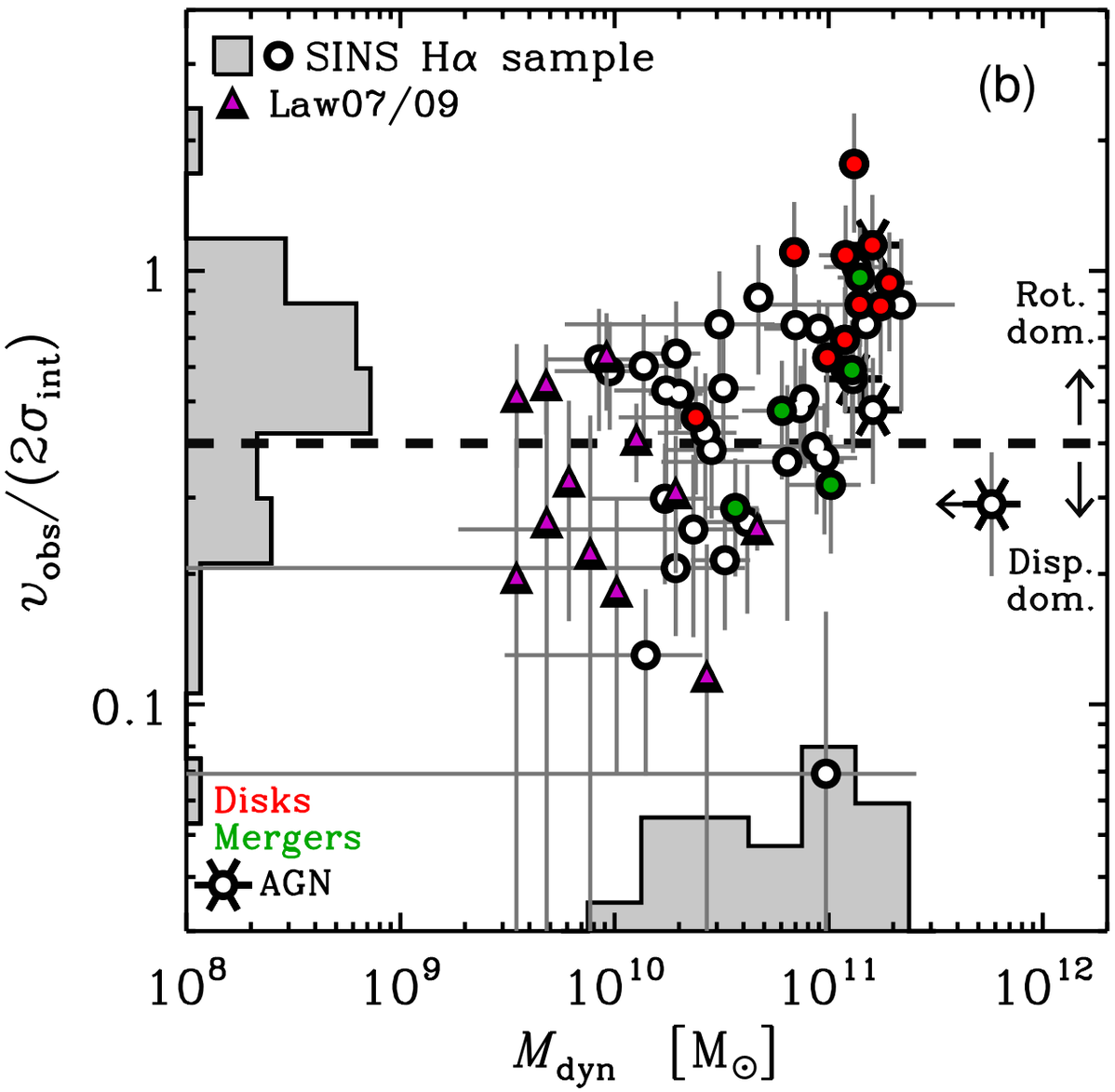
Genzel:

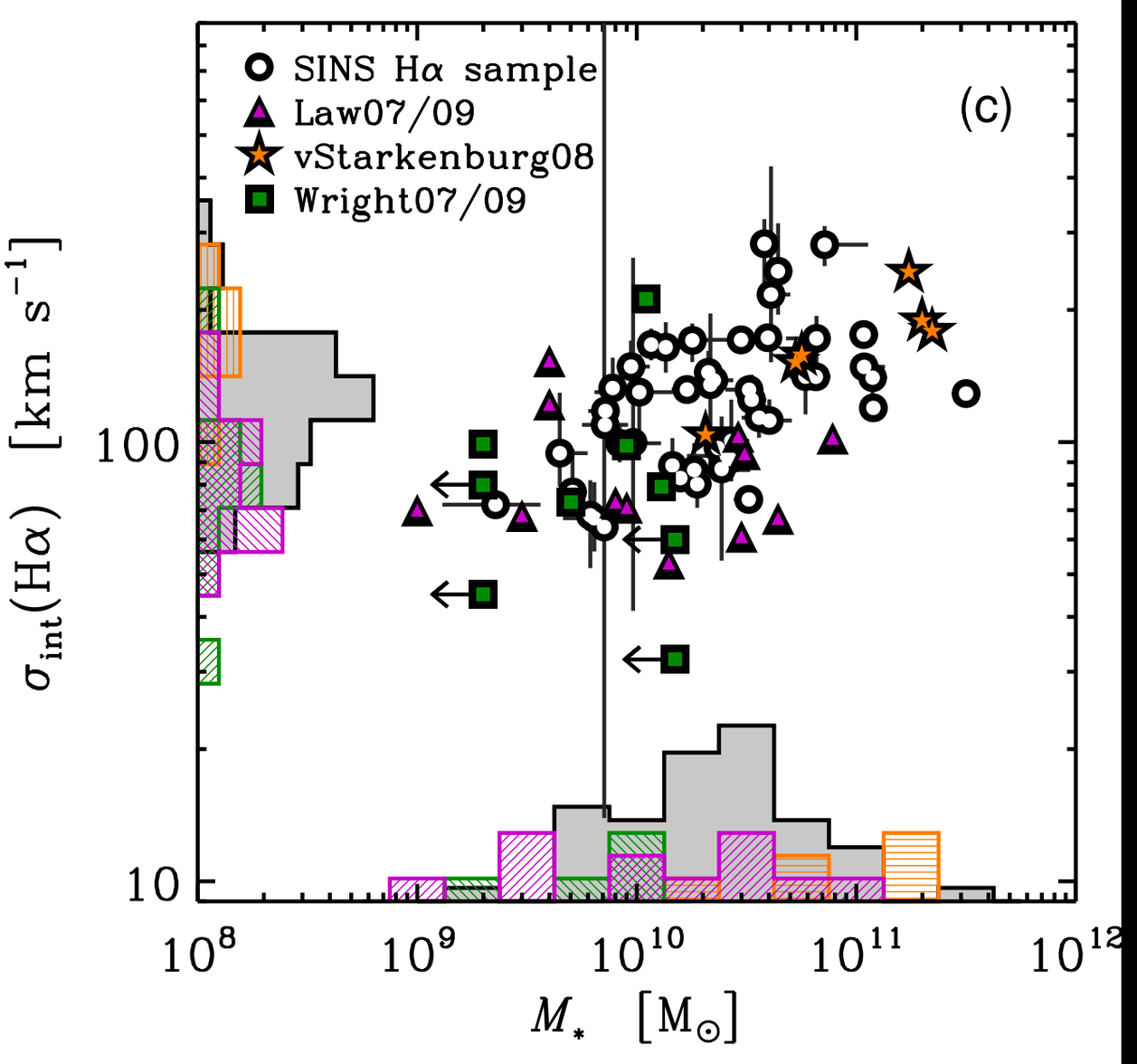
$$\frac{v}{\sigma} = \frac{150/\sin 48^\circ}{110} \approx 2$$

z~2 galaxies

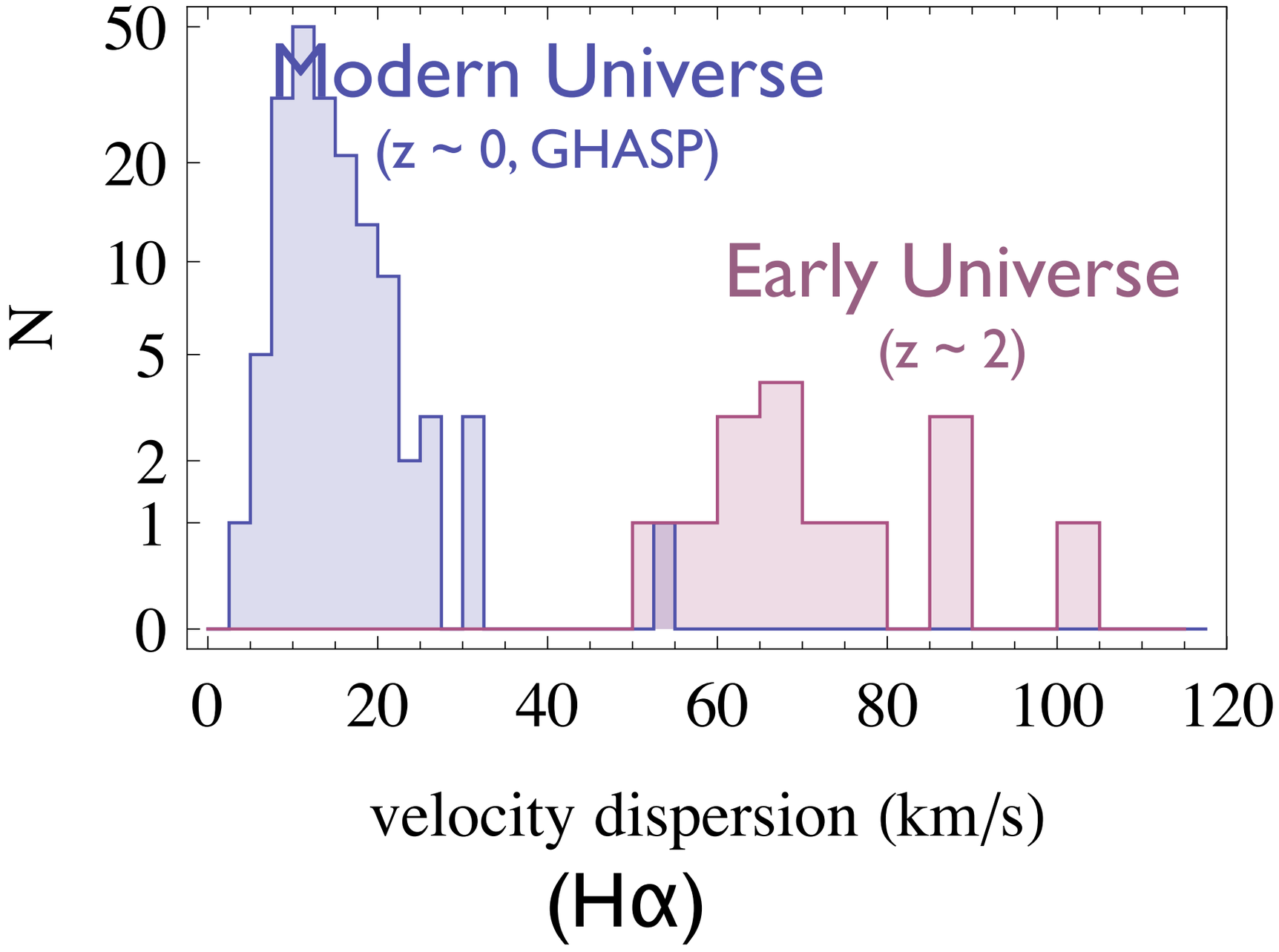
LOW v/σ's

High σ's





Förster Schreiber et al. (2009)

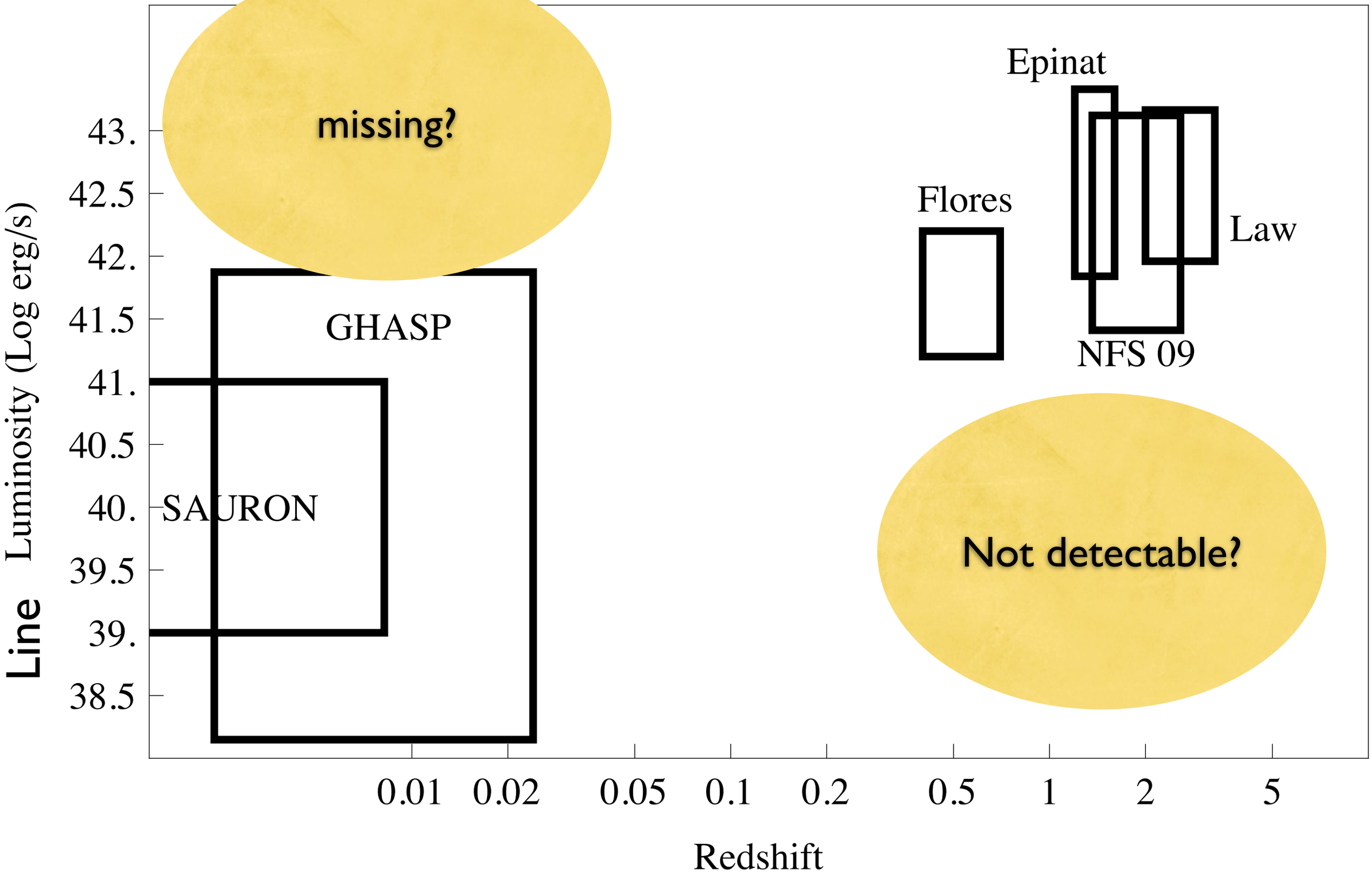

Modern Universe
(z ~ 0, GHASP)
Early Universe
(z ~ 2)
N
50
20
10
5
2
1
0
0
20
40
60
80
100
120
velocity dispersion (km/s)
(Hα)

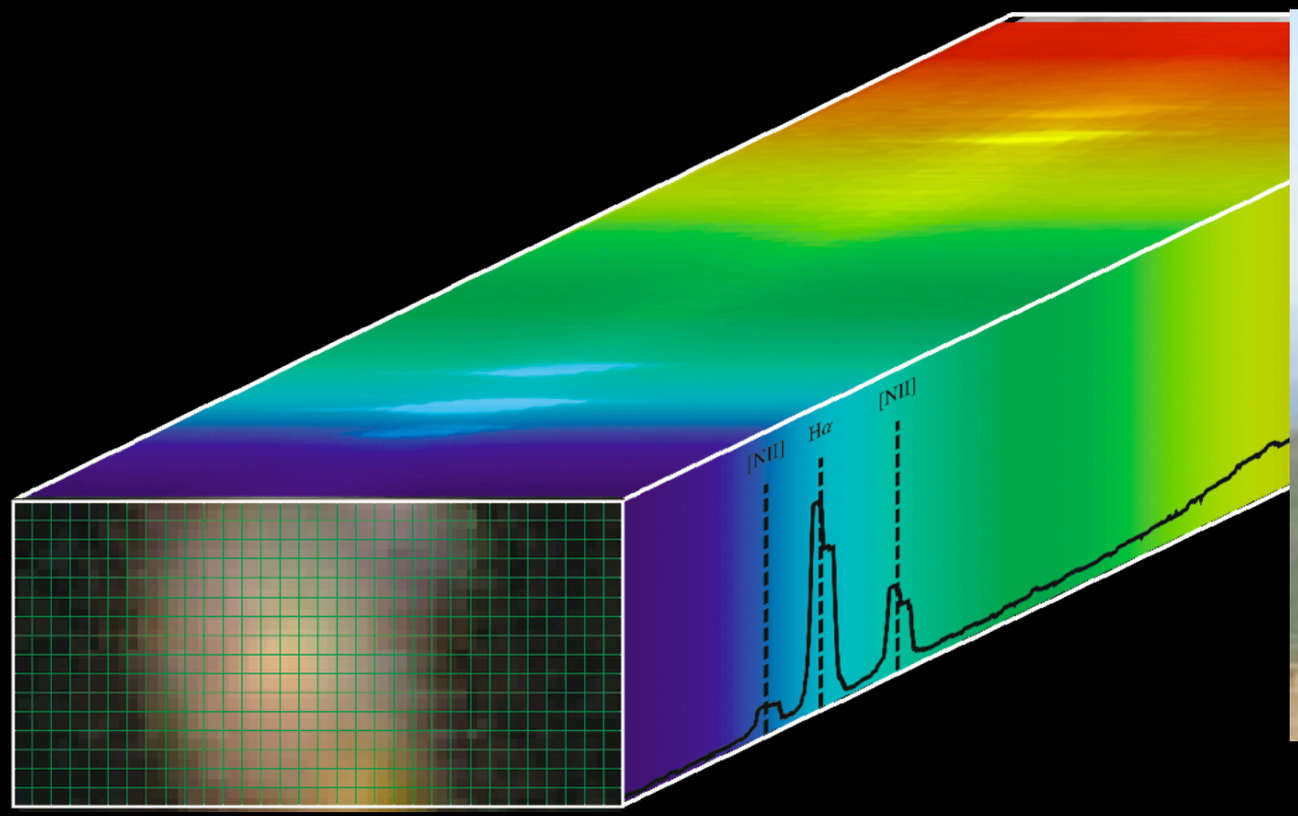
High-$\sigma_{H\alpha}$: Interpretations

- Thick turbulent gas-rich disk in hydrostatic equlibrium traced by Hα (Genzel 2006, 2010, Elmegreen) σ→SFR (large clumps, fed by z~2 cold flows?)
- Winds/feedback from star-formation/SNe (Lehnert 2009, Green 2010) SFR→σ
- Energy injection from cosmic accretion (Elmegreen & Burkert 2010)

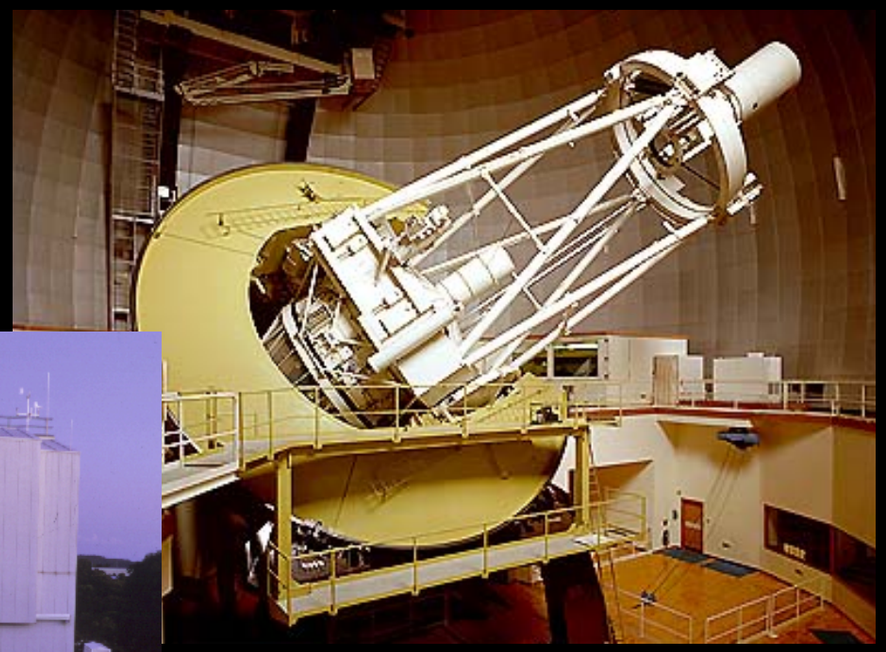
Are high-z galaxies really different?

IFU kinematic surveys





- Uniform Hα kinematic sample from large volume
- Analyse high S/N 2D dynamics same as z~2
- Test SB effects, artificial redshifting, 2D Tully-Fisher

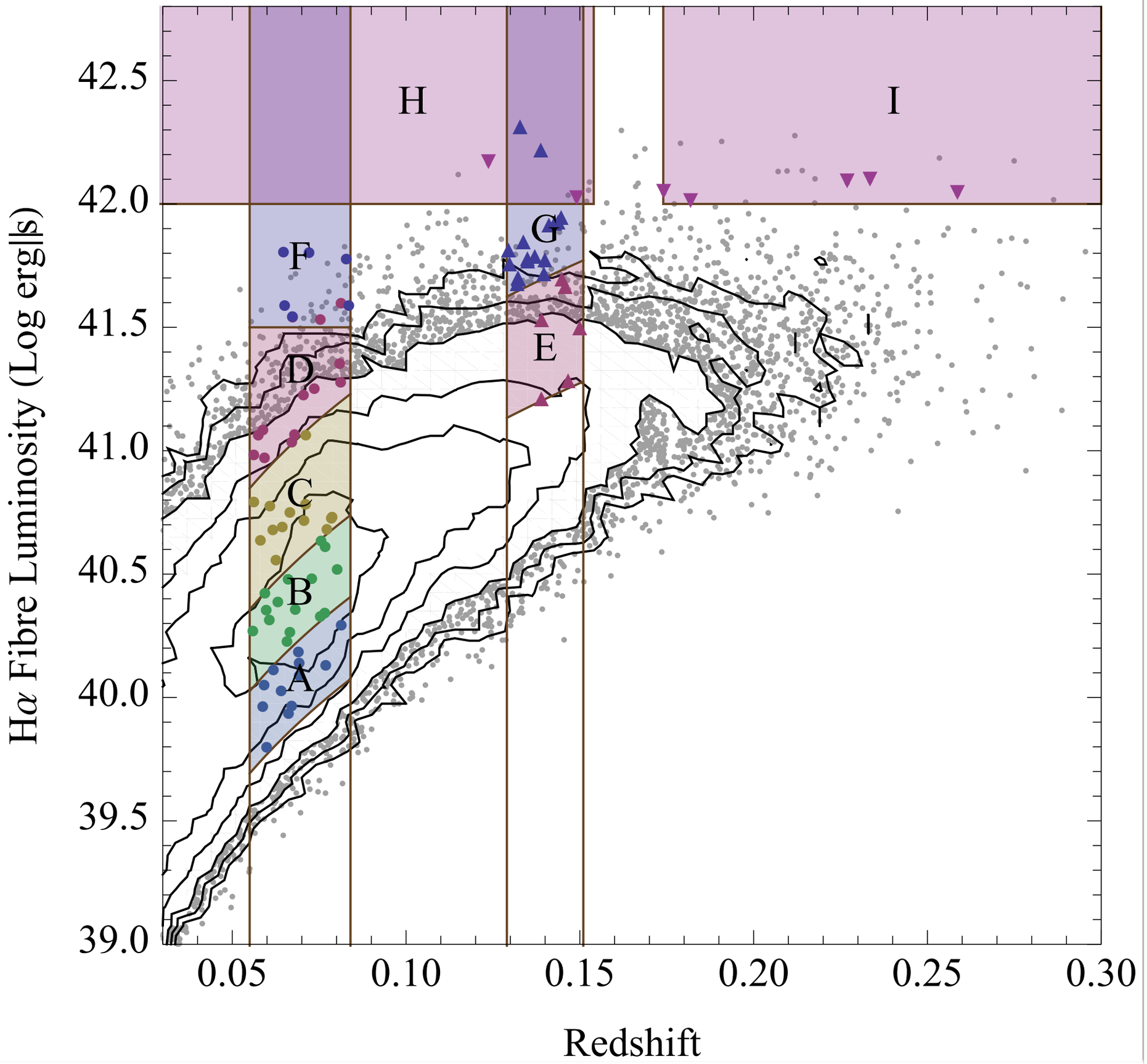


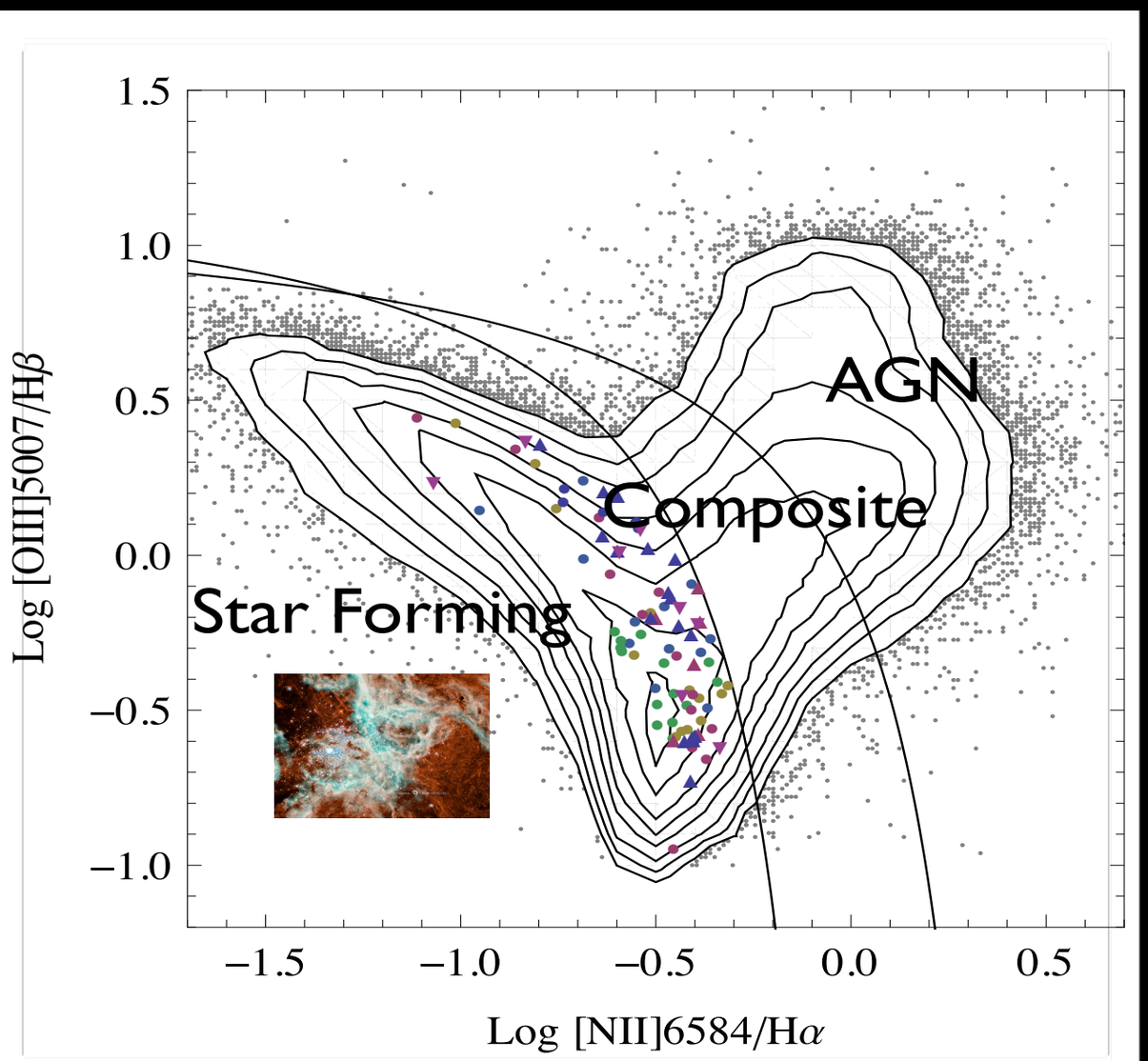
- 90 most Hα galaxies (non-AGN) from SDSS

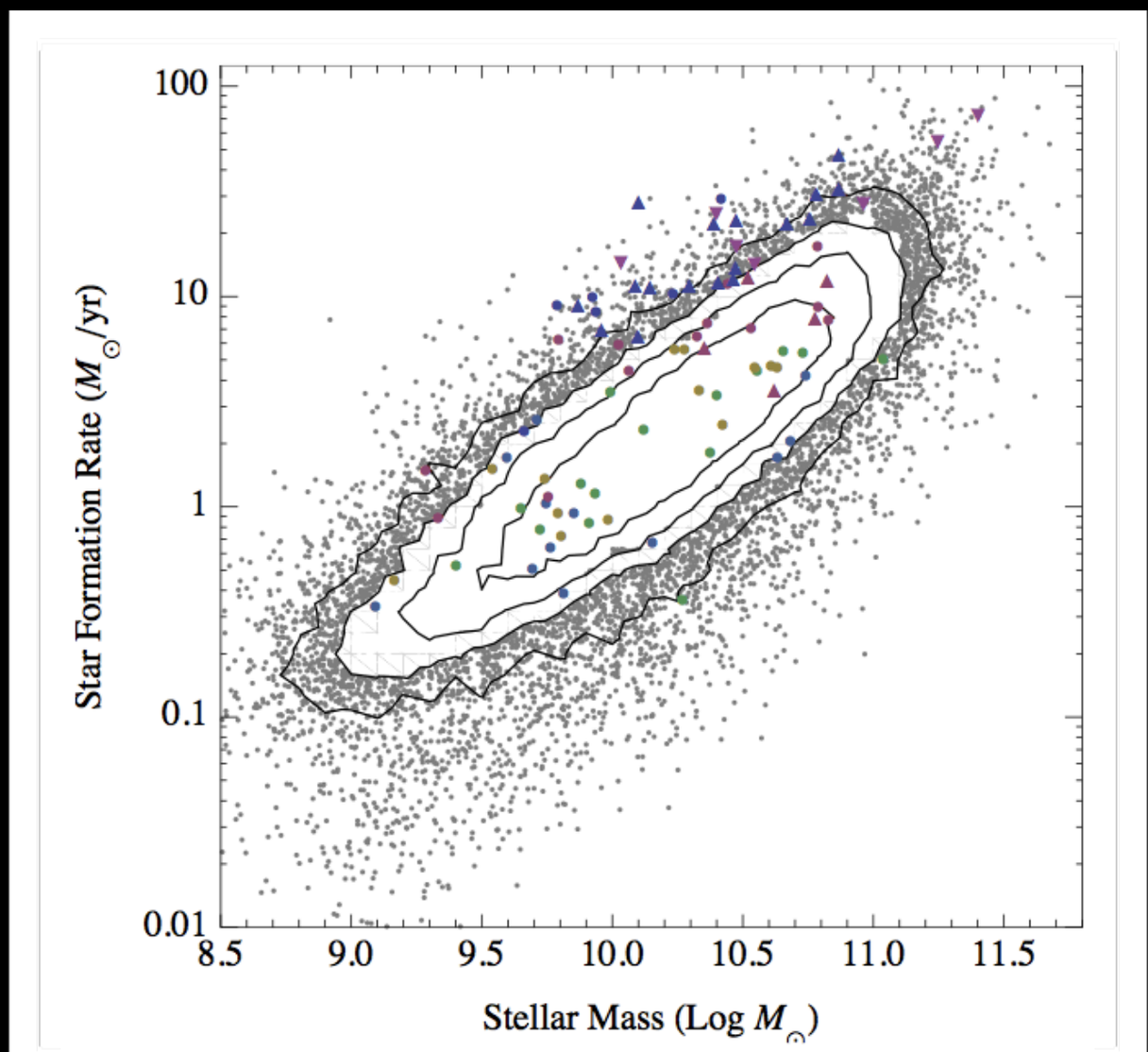
- IFU observations covering ~ 30 kpc (AAT/ SPIRAL 2.3m/WiFES)

- Spatial resolution 2.3 kpc (≈AO at z=2)

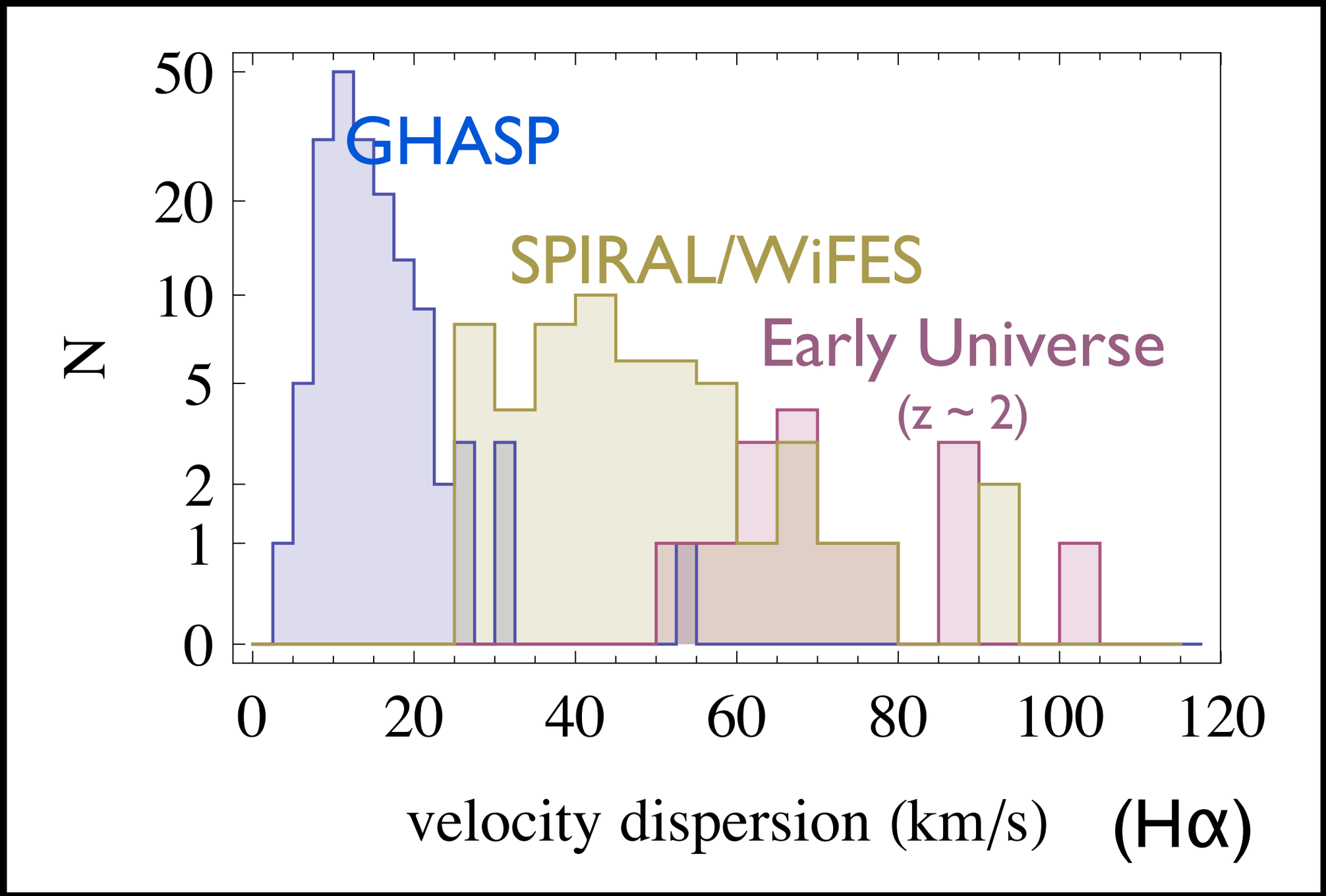
- Spectral resolution R~10,000 (c.f. CALIFA)

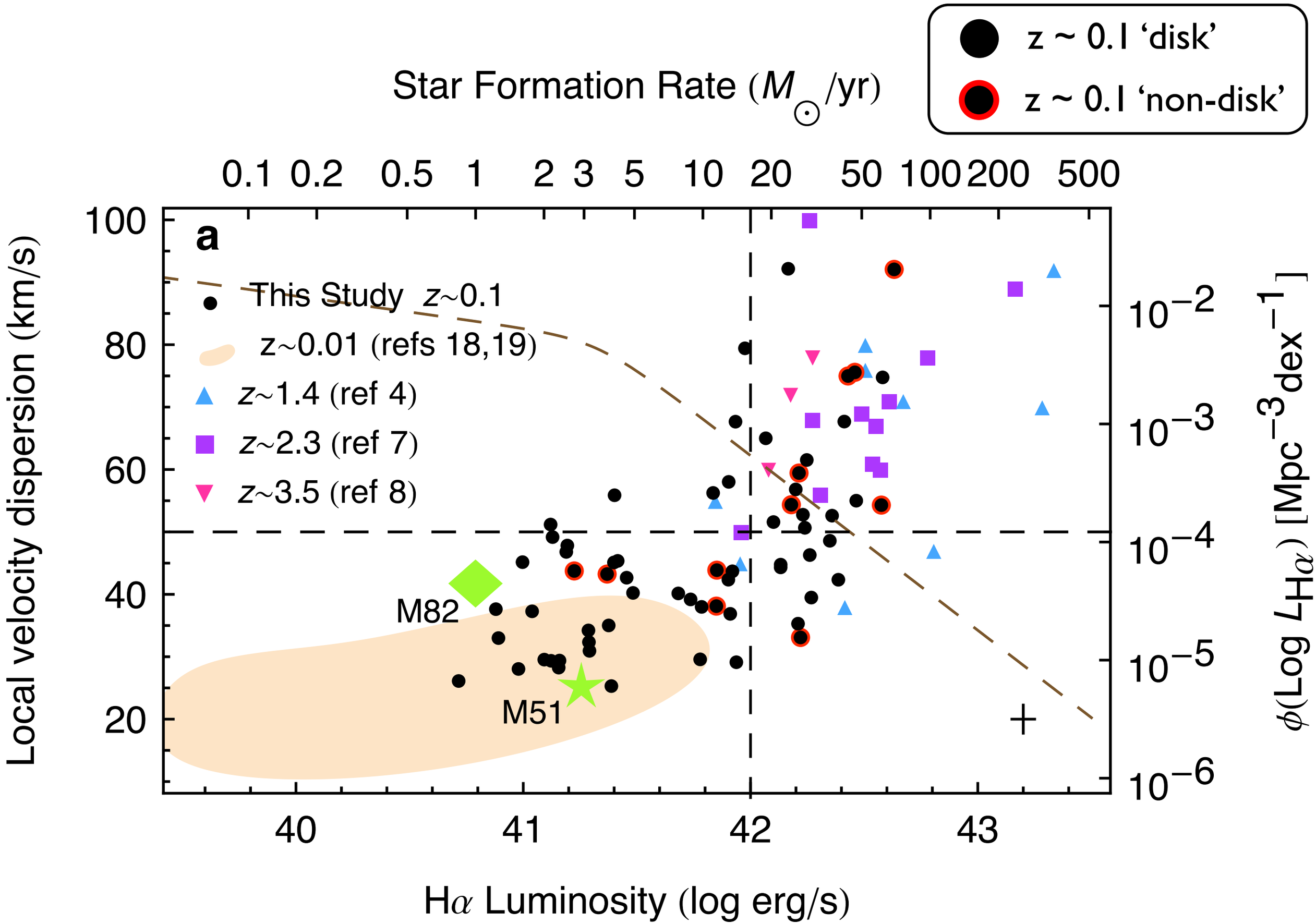

H
I
F
G
E
D
C
B
A
42.5
42.0
41.5
41.0
40.5
40.0
39.5
39.0
0.05
0.10
0.15
0.20
0.25
0.30
Hα Fibre Luminosity (Log erg|s)
Redshift


AGN
Composite
Star Forming
Log [OIII]5007/Hβ
Log [NII]6584/Hα
1.5
1.0
0.5
0.0
−0.5
−1.0
−1.5
−1.0
−0.5
0.0
0.5


Star Formation Rate ($M_\odot$/yr)
Stellar Mass (Log $M_\odot$)
100
10
1
0.1
0.01
8.5
9.0
9.5
10.0
10.5
11.0
11.5

The Big Surprise...


GHASP
SPIRAL/WiFES
Early Universe
(z ~ 2)
N
50
20
10
5
2
1
0
0
20
40
60
80
100
120
velocity dispersion (km/s)
(Hα)



Green et al. (Nature 2010)

Are they really turbulent *disks*?

SDSS *gri* Image

Hα Integrated Linemap

Velocity Map

Model Velocity Map

‘Rotating Disk’

$i_r = 52.8°$

$M_* = (5.7 \pm 1.1) \times 10^{10}\, M_\odot$

$L_{H\alpha} = 28.69 \times 10^{41}\,\mathrm{erg\,s^{-1}}$

RD

$v_{2.2} = 533 \pm 63$ km/s

Hα Fit Flux

Velocity Width

Velocity Fit Resid.

SDSS *gri* Image

Hα Integrated Linemap

Velocity Map

Model Velocity Map

‘Perturbed Rotator’

$i_r = 20.4°$

$M_* = (1.3 \pm 0.3) \times 10^{10}\, M_\odot$

$L_{H\alpha} = 38.21 \times 10^{41}\,\mathrm{erg\,s^{-1}}$

PR

$v_{2.2} = 114 \pm 8$ km/s

Hα Fit Flux

Velocity Width

Velocity Fit Resid.

SDSS *gri* Image

Hα Integrated Linemap

Velocity Map

Model Velocity Map

‘Complex Kinematics’

$i_r = 35.2°$

$M_* = (2.9 \pm 0.6) \times 10^{10}\, M_\odot$

$L_{H\alpha} = 37.39 \times 10^{41}\,\mathrm{erg\,s^{-1}}$

CK

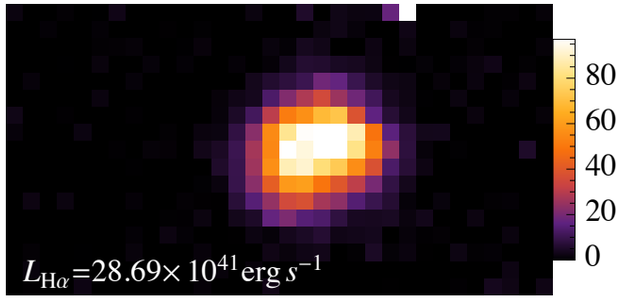
$v_{2.2} = 62 \pm 5$ km/s

Hα Fit Flux

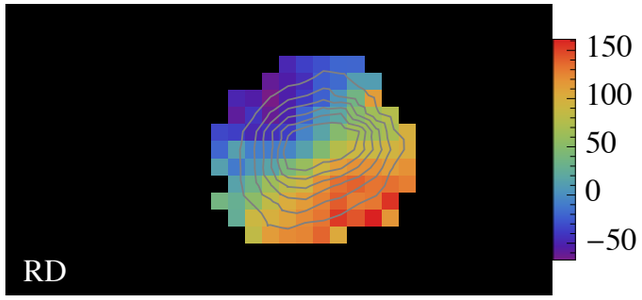
Velocity Width

Velocity Fit Resid.

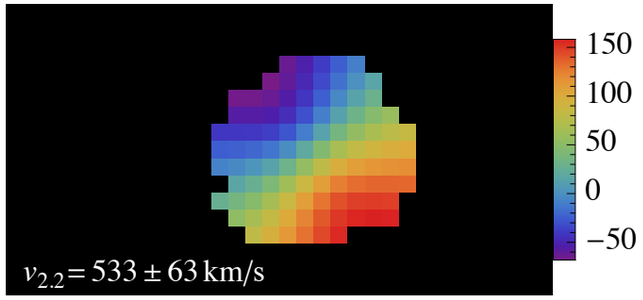
Hα Integrated Linemap



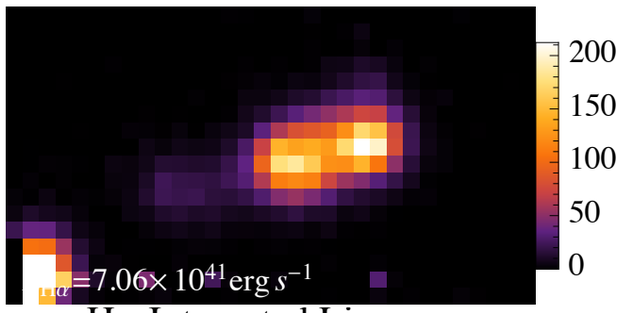
Velocity Map



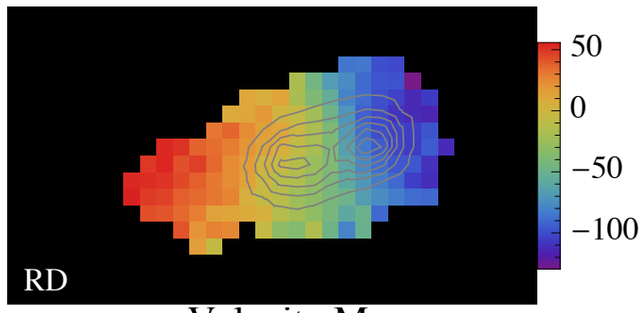
Model Velocity Map



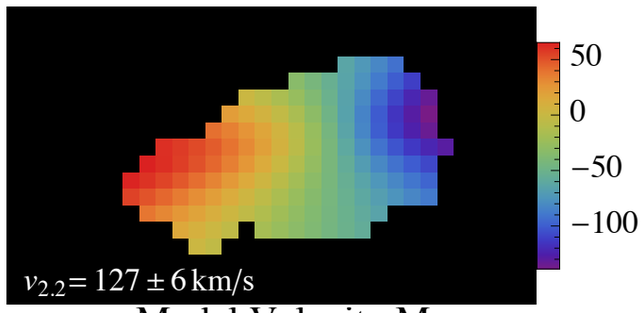
Hα Integrated Linemap



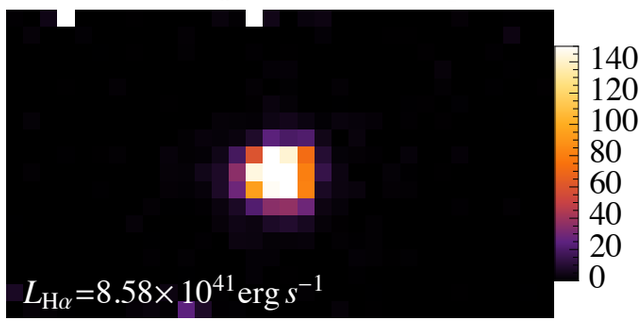
Velocity Map



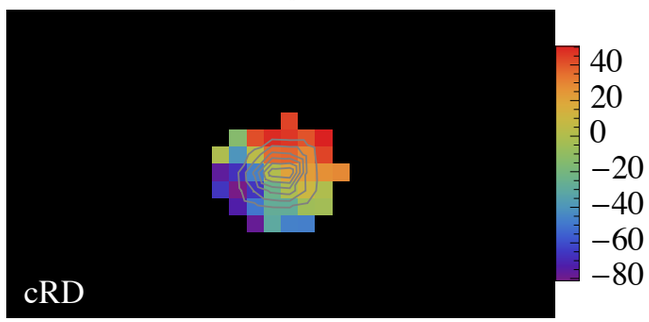
Model Velocity Map



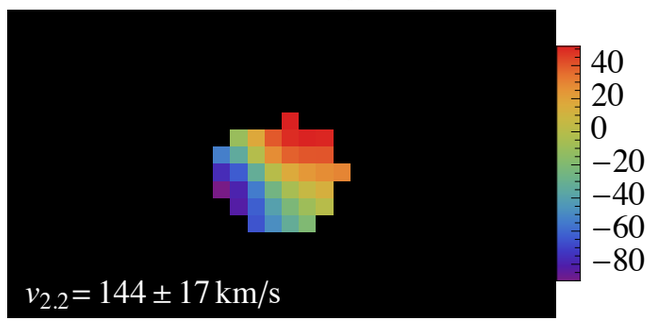
Hα Integrated Linemap



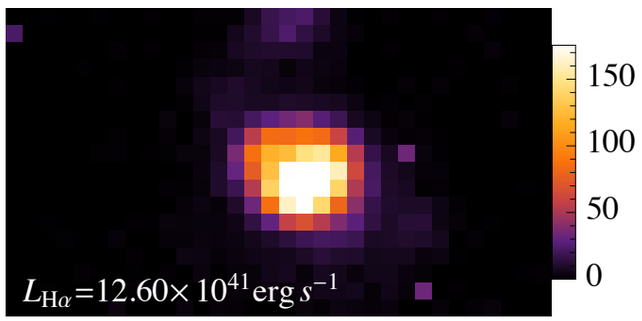
Velocity Map



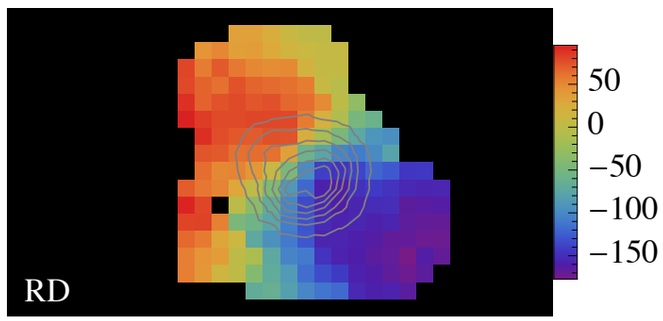
Model Velocity Map



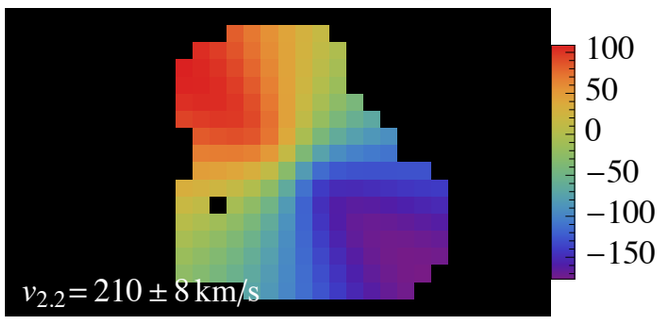
Hα Integrated Linemap



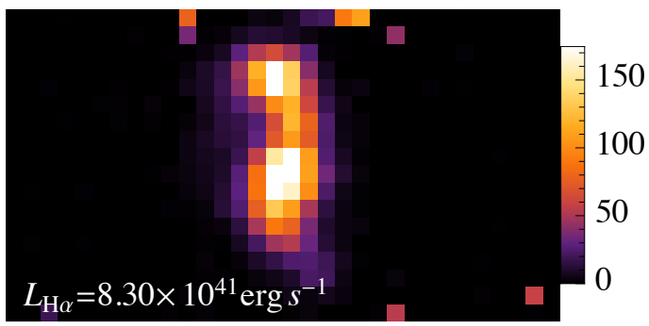
Velocity Map



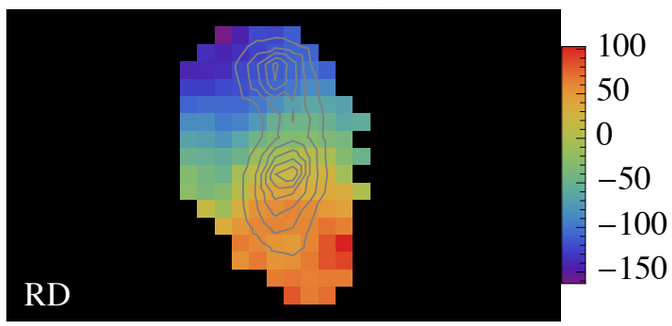
Model Velocity Map



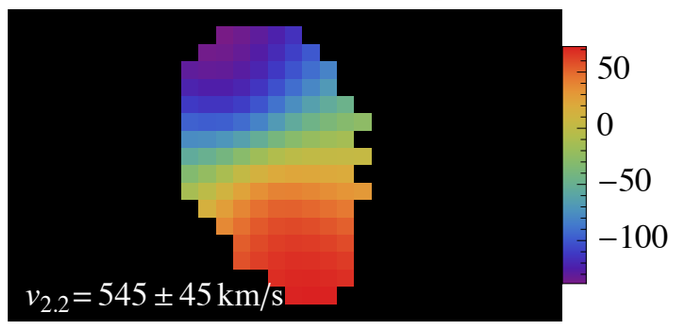
Hα Integrated Linemap



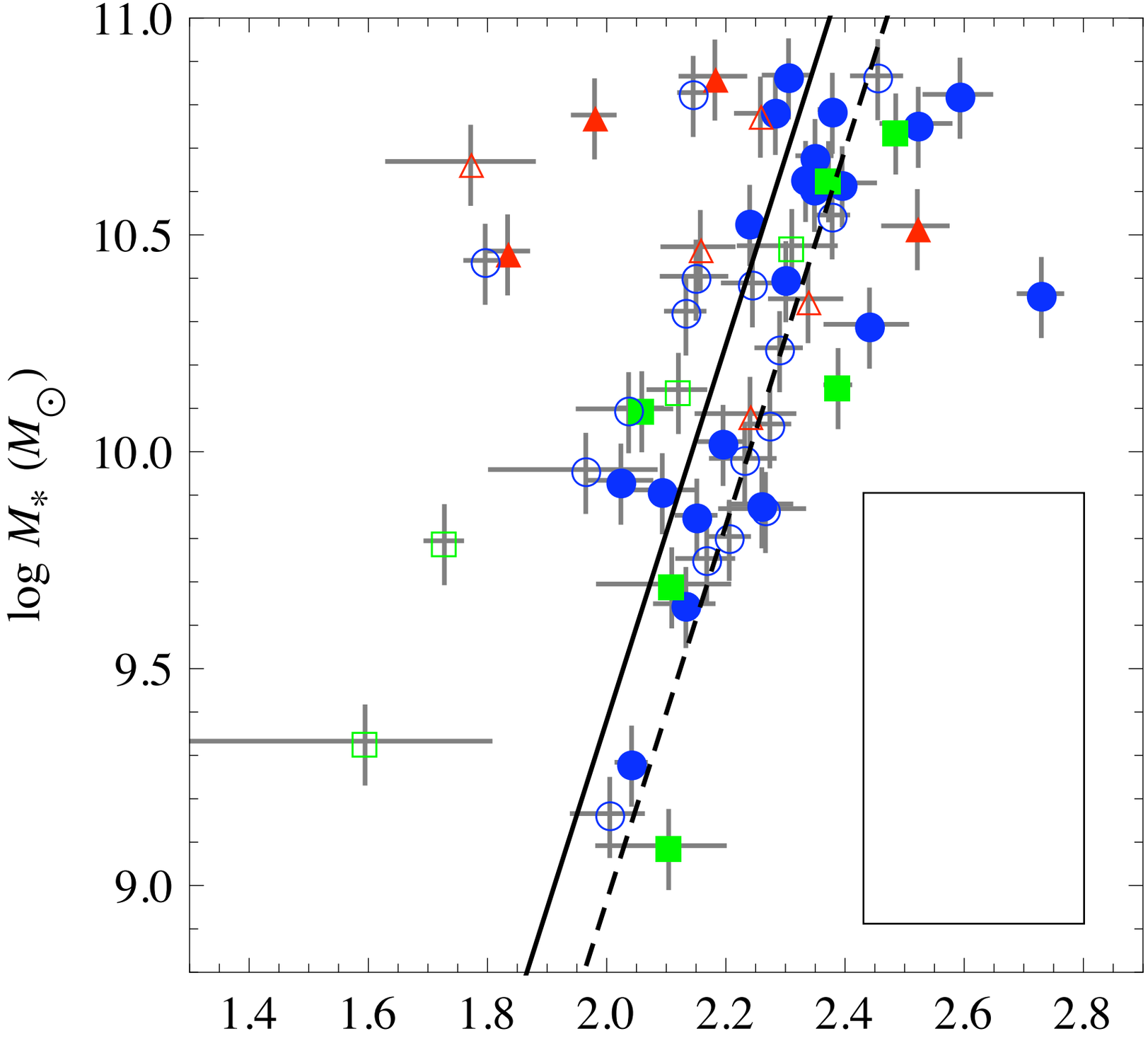
Velocity Map



Model Velocity Map



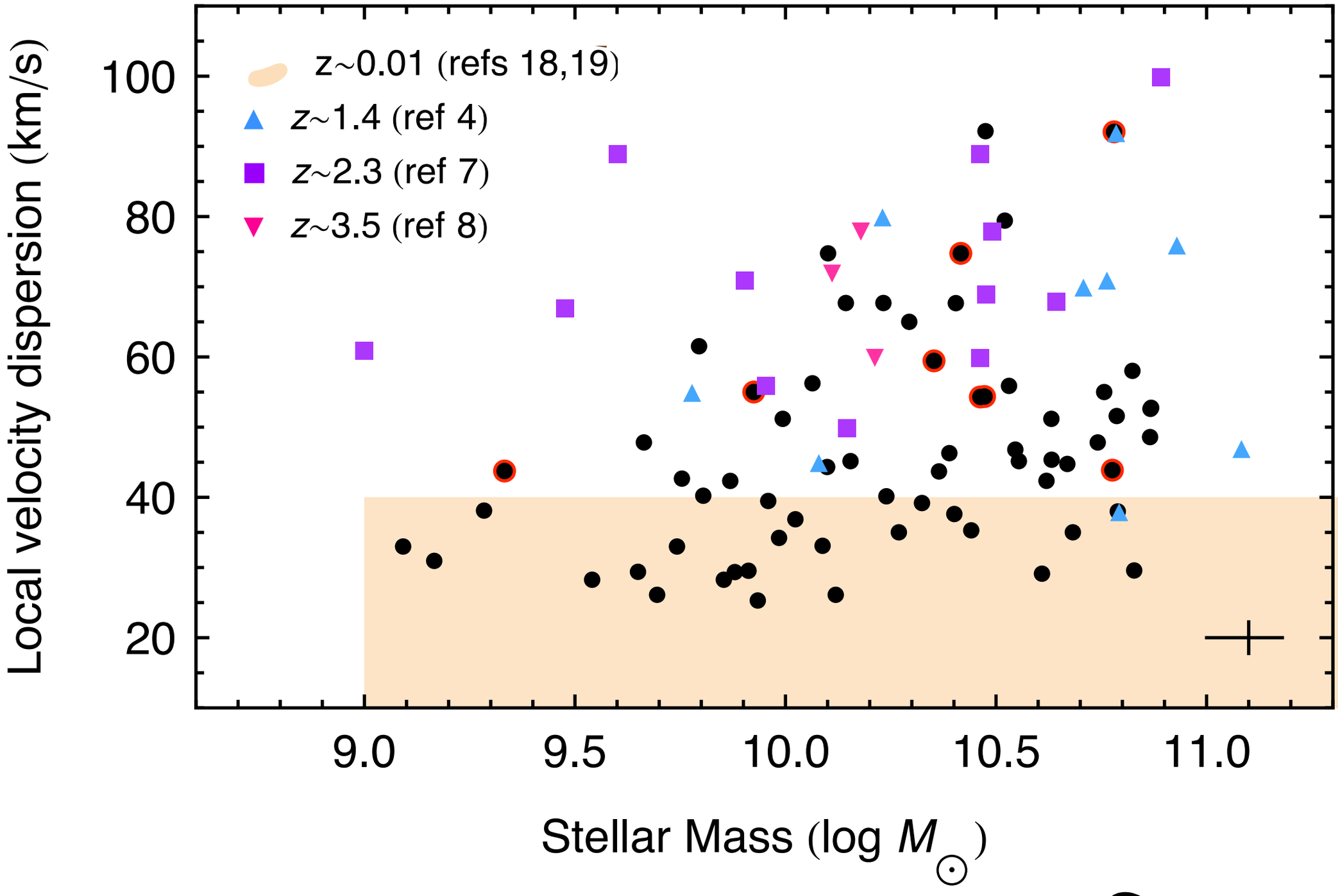
Stellar Mass TF



Green et al. (in prep.)

What drives σ_m?

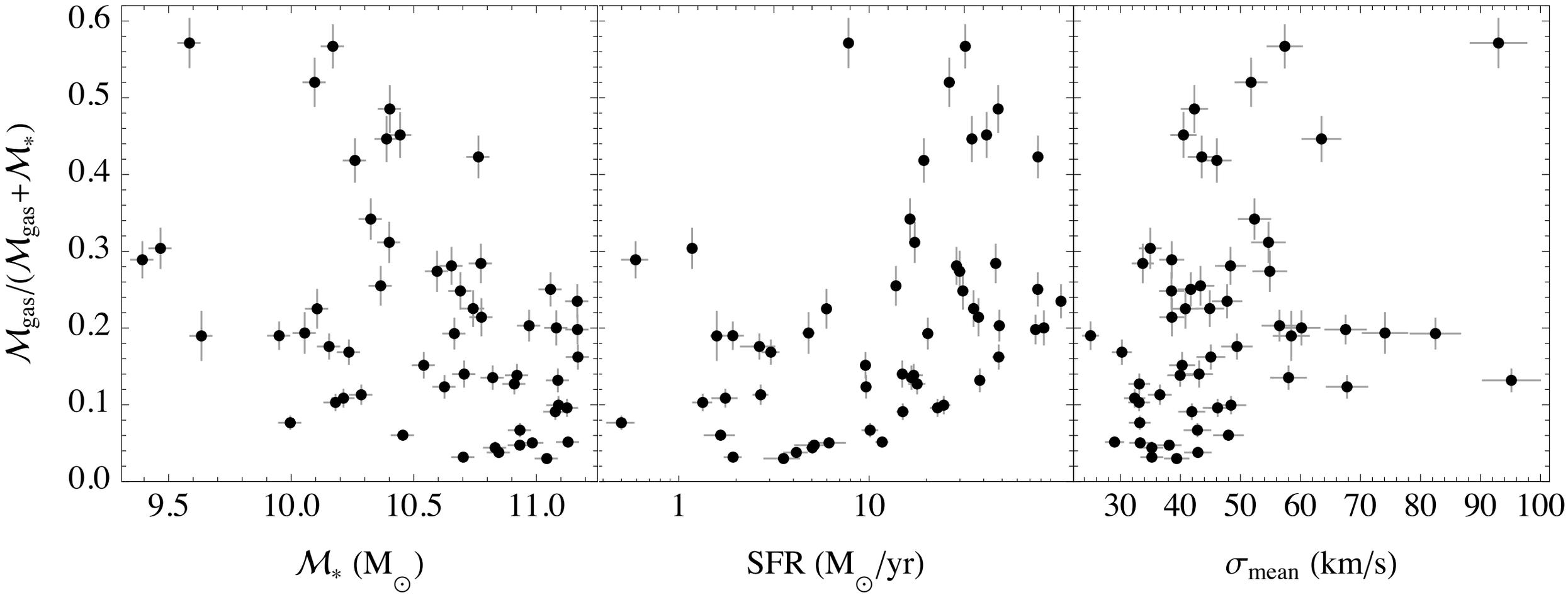
Mass?



Green et al. (2010)

Gas Fraction?

(Using KSR)

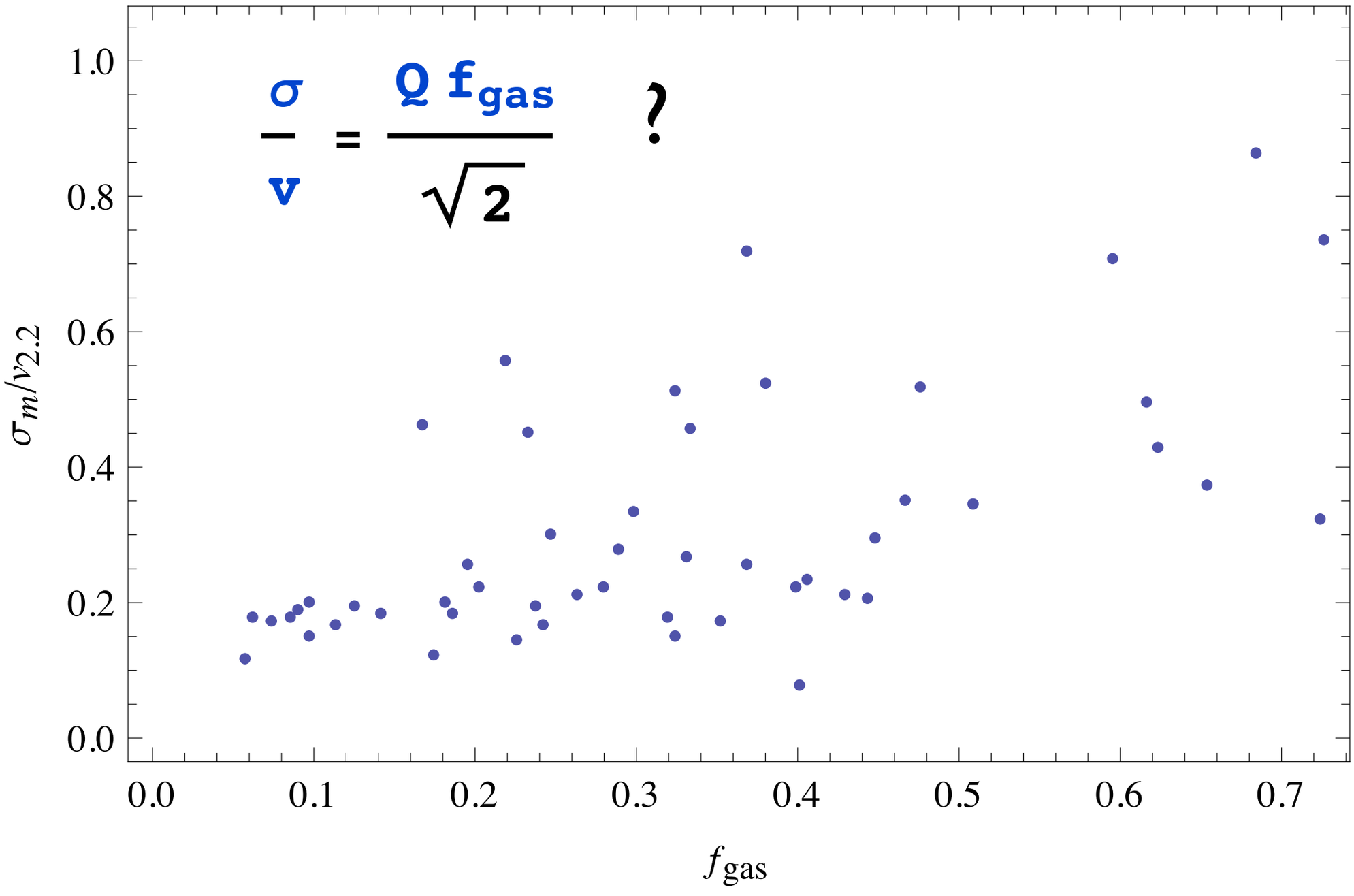


Green et al. (2011)

Gas Fraction?

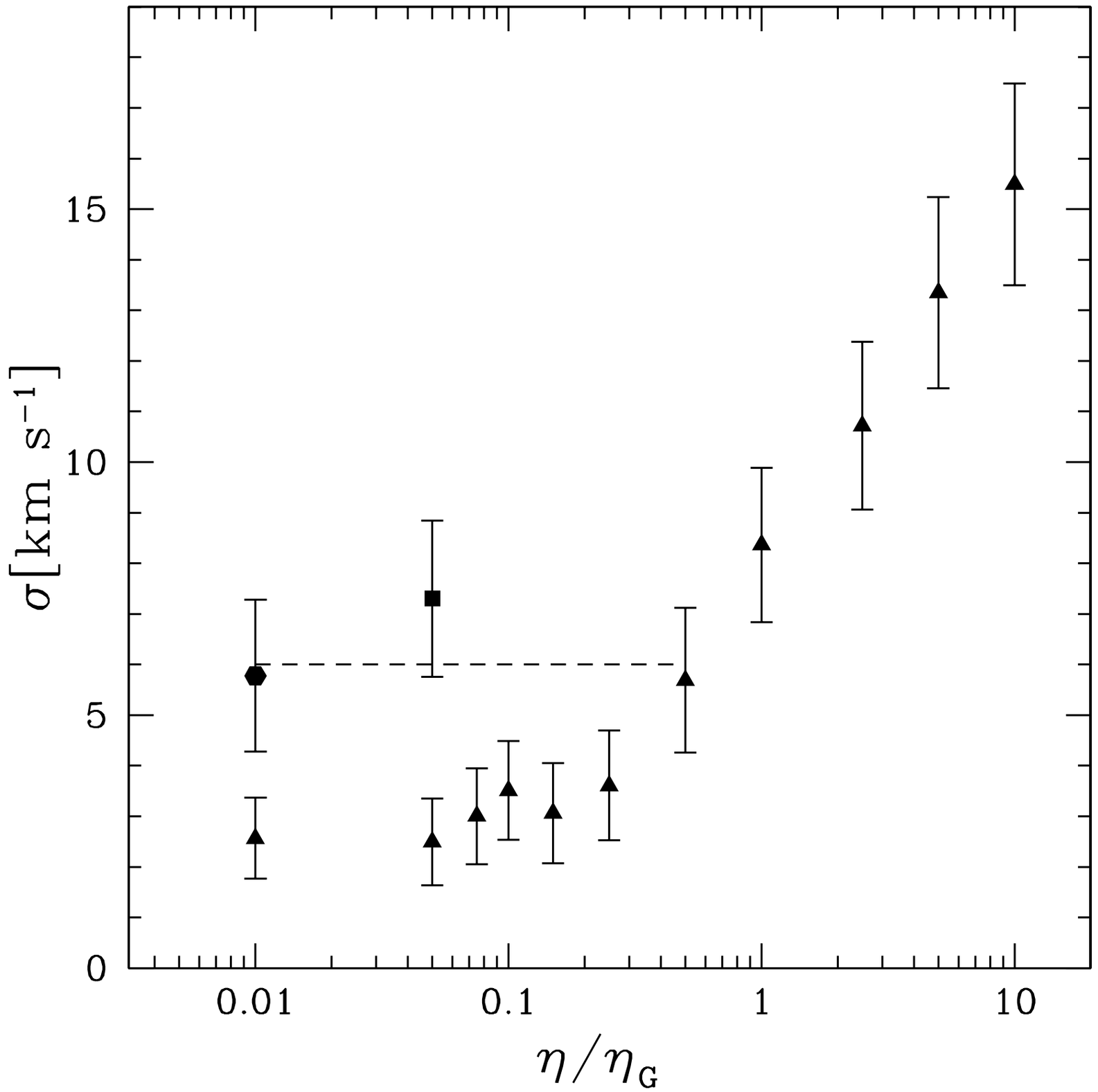
(Using KSR)

$$\frac{\sigma}{v} = \frac{Q\, f_{gas}}{\sqrt{2}} \quad ?$$



Green et al. (2011)

SFR drives ISM turbulence

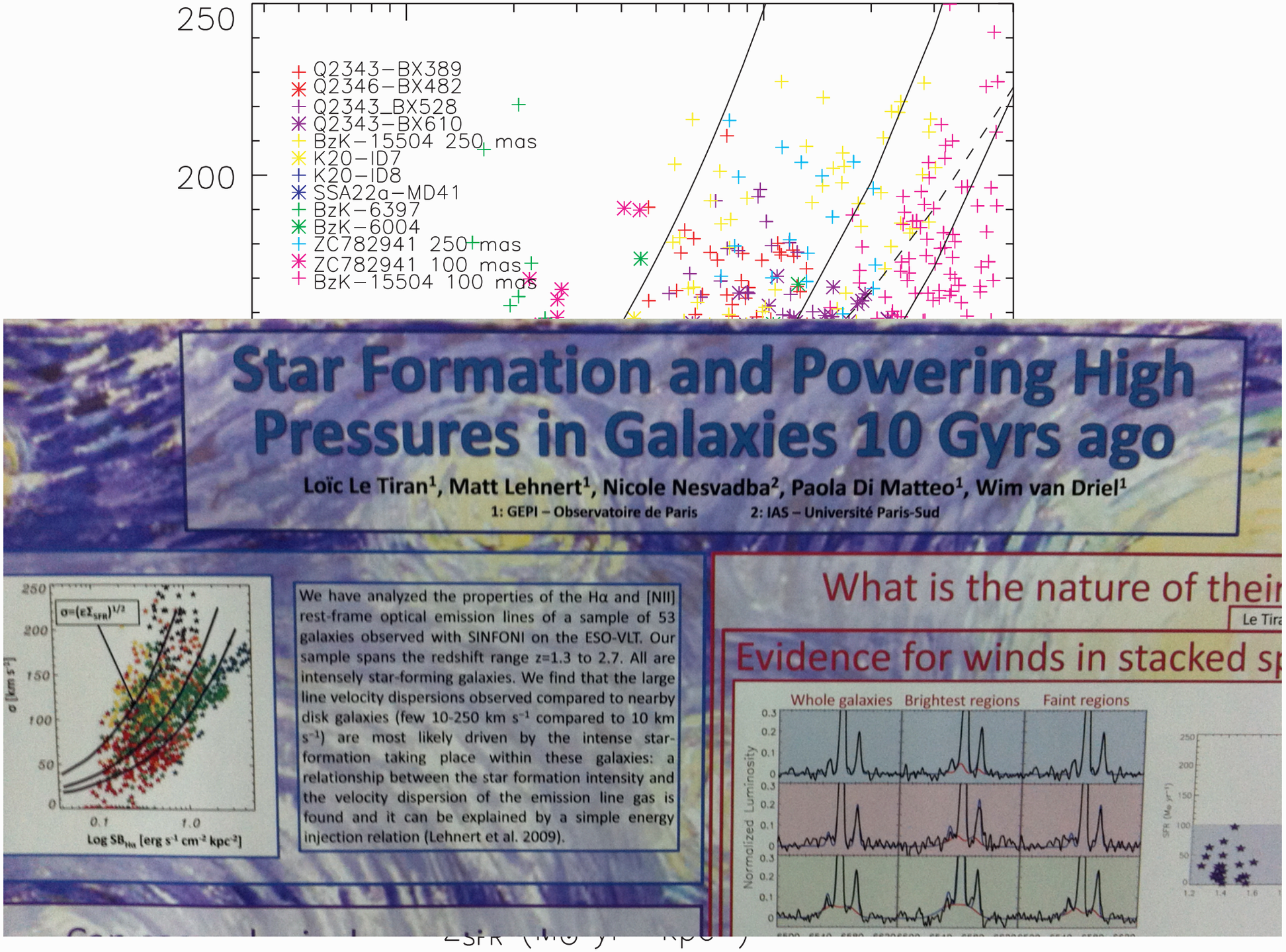


ISM simulations of Dib et al. (2006)

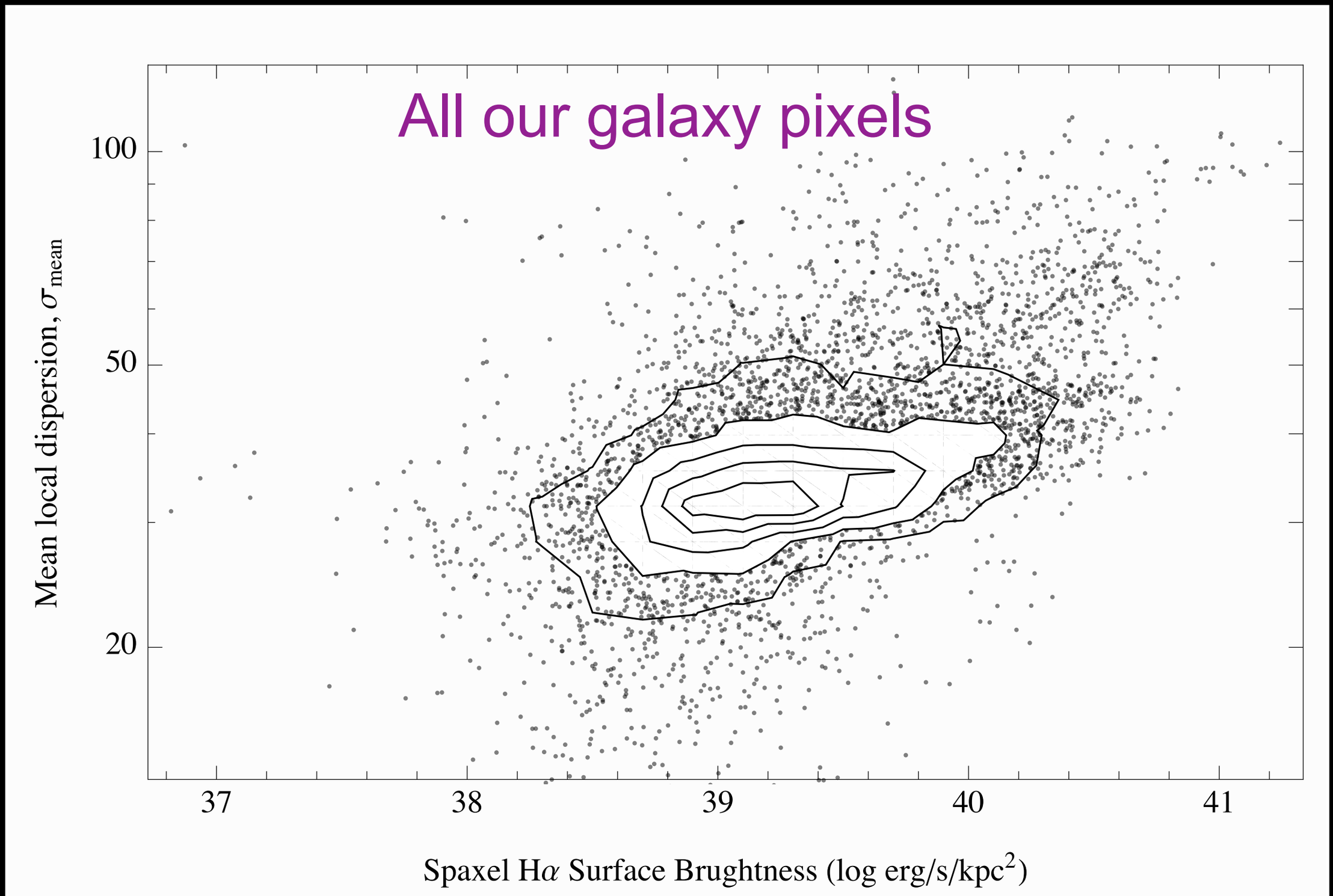
SNe rate / Galactic

Resolved SFR-σ?

Lehnert et al. (2009) – z~2 SINS galaxies



Resolved Σ_{SFR}-σ?



SFR-σ

Green et al. 2011
(in prep.)

Local SFR-σ correlations are worse than global ones???

HfluxLz 14−1

HfluxLz 13−1

MfluxLz 14−2

MfluxLz 13−3

HfluxLz 15−3

HfluxLz 23−1

HfluxLz 22−1

MfluxLz 13−1

∝Hα

∝σ_m

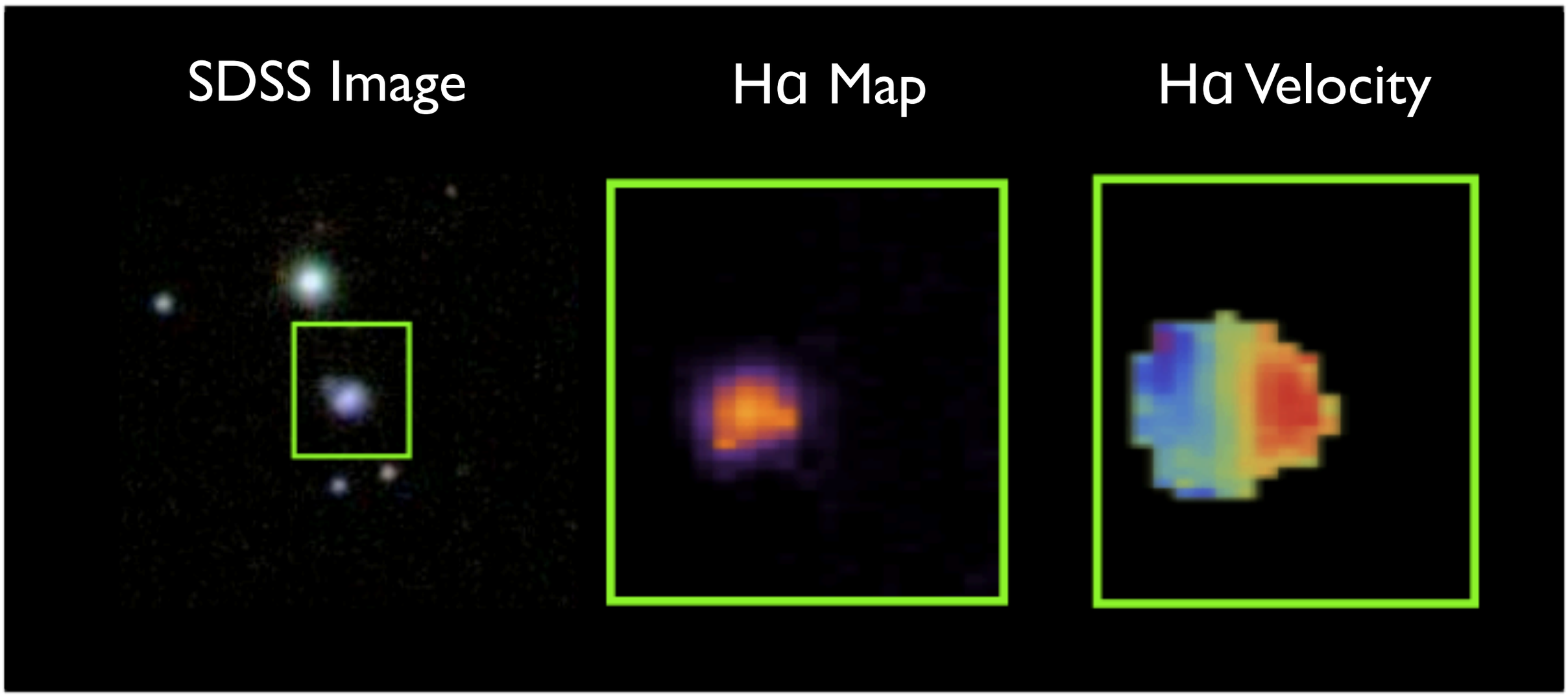
HfluxLz 22−2

One more thing...

SDSS Image

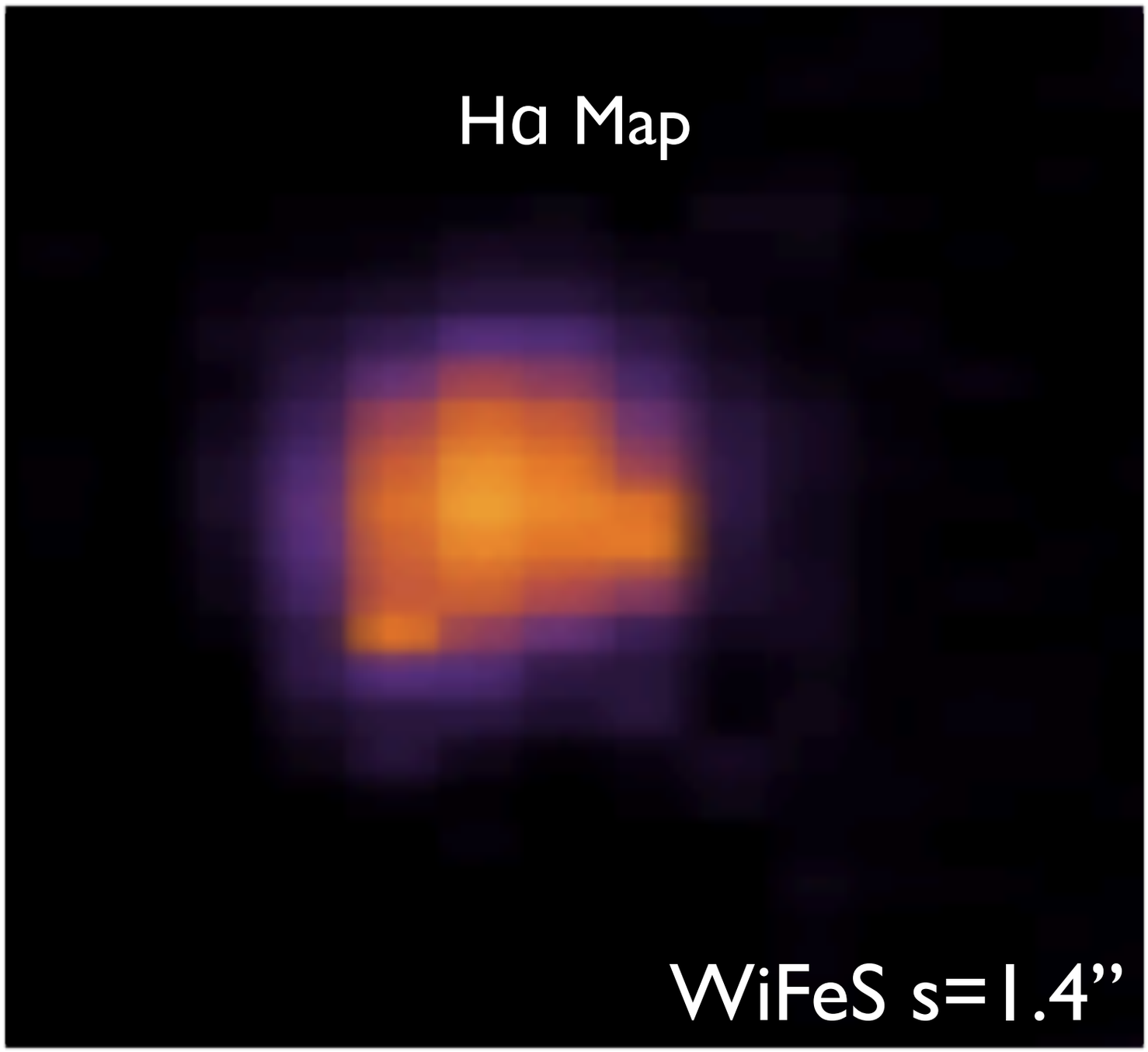
Hα Map

Hα Velocity



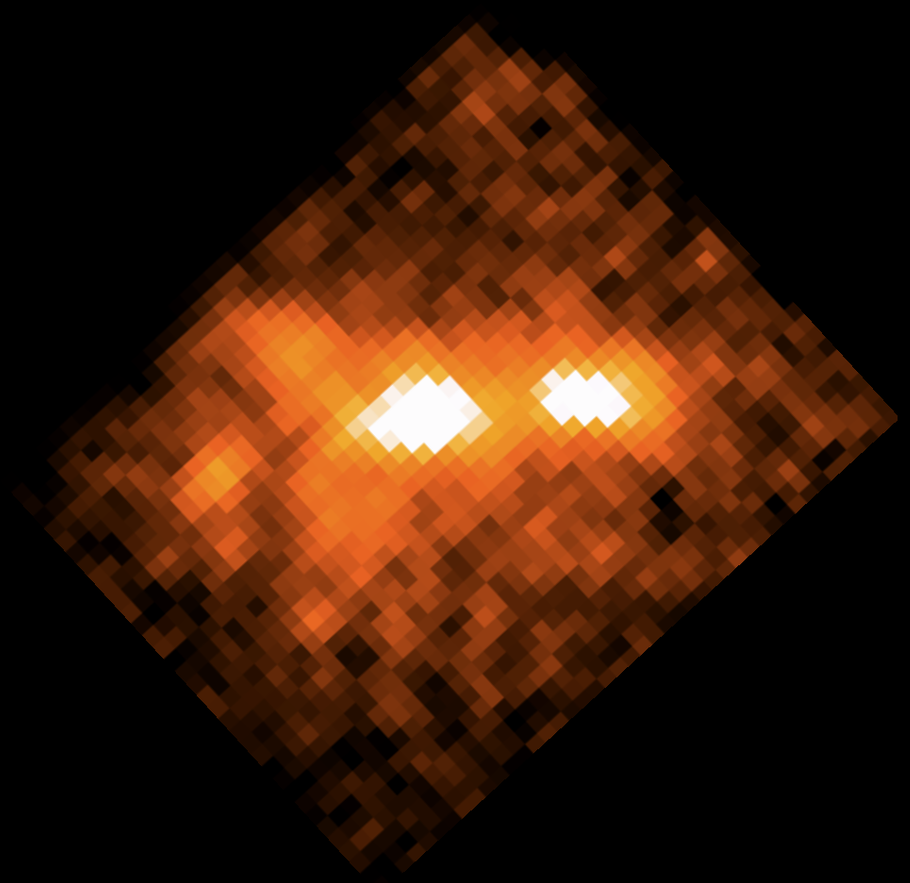
z=0.15

Ha Map



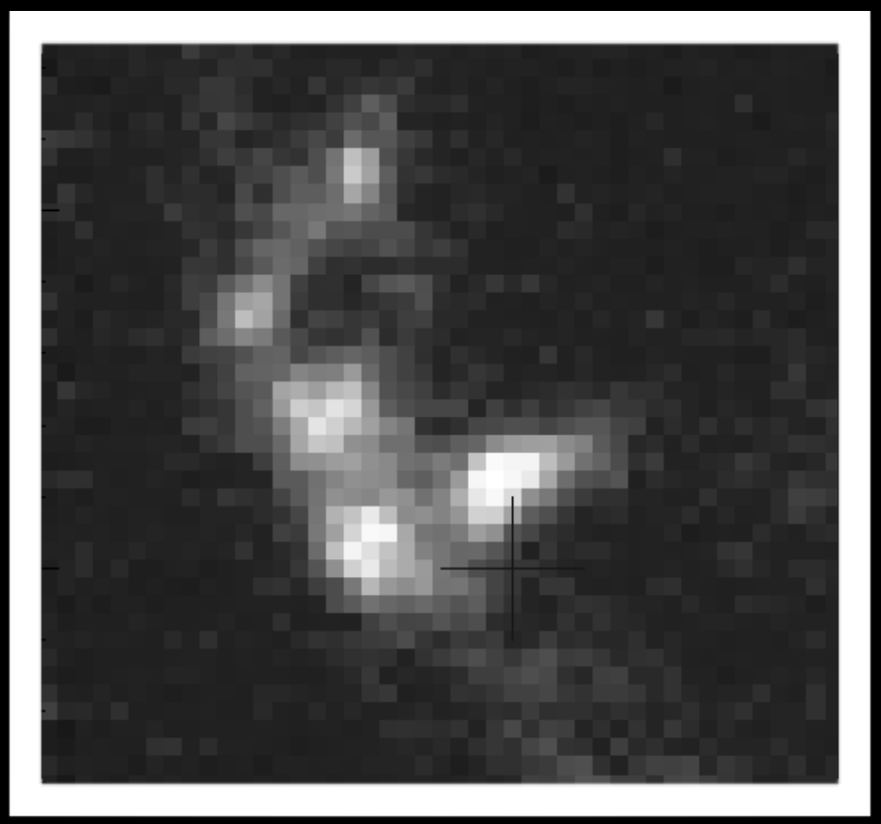
WiFeS s=1.4”

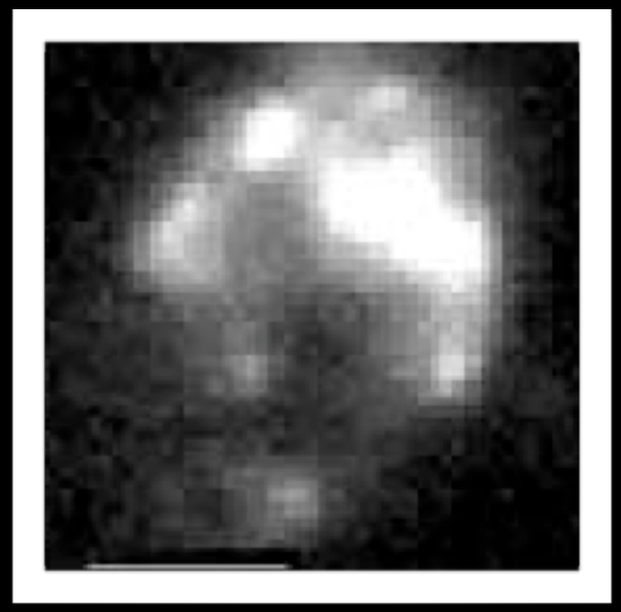
Paschen-α Map



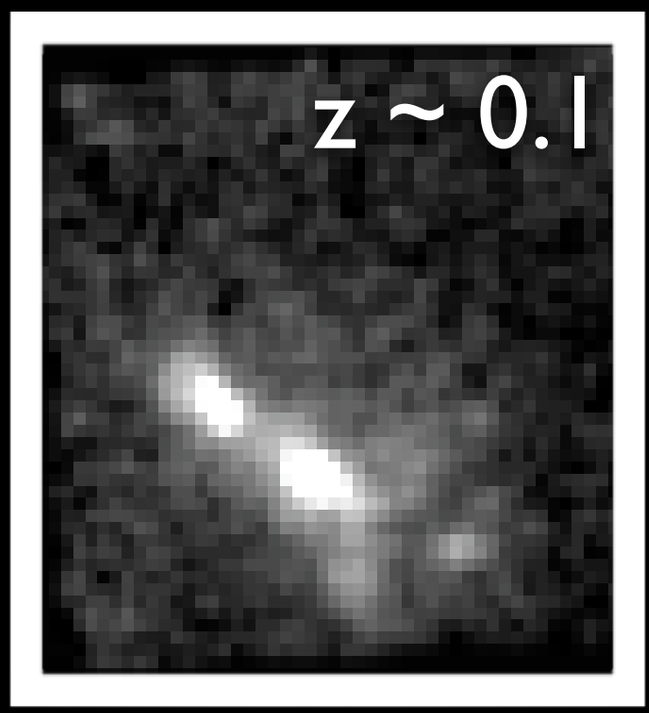
Keck/OSIRIS AO FWHM=150 mas

Ultra Deep Field Clump Clusters

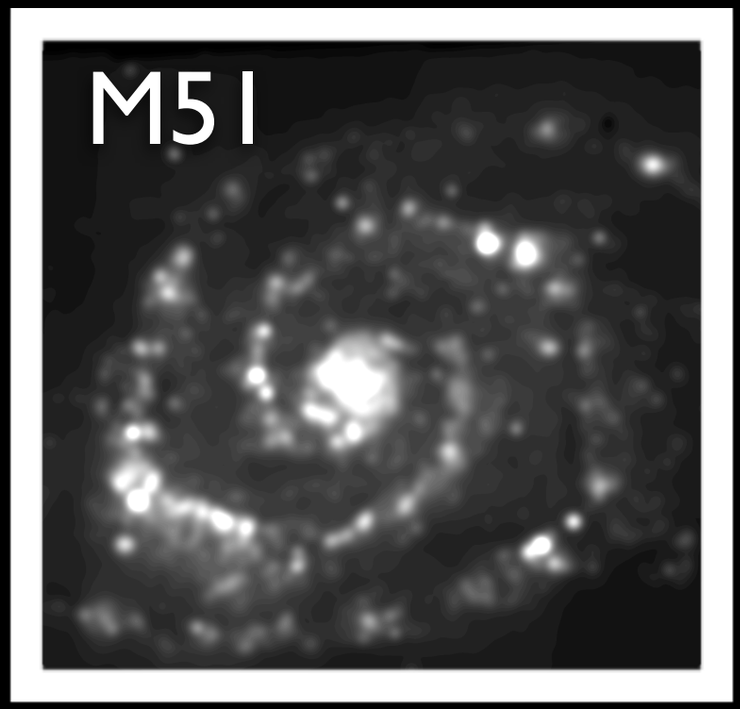




5 kpc



(Images in SFR sensitive bands – UV, Hα, Pα)



Need more than one!

Summary

- High-z: star-formation mostly takes place in situ, ~half in clumpy, turbulent disks

- If we select similar galaxies locally, we find a similar fraction of turbulent disks. (‘Similar’ = factor of 10-100x rarer than z~2)

- See giant SF clumps?, Hα turbulence decoupled from SF?

- These local archetypes are a new window on to the physical processes of early galaxy assembly

Outstanding questions?

- What are their physical morphologies on the sub-kpc scale? Do they contain giant clumps? – AO/HST imaging (Pα, continuum)
- What is the role of neighbours? 'Stirring up SF?' – More analysis
- What are the stellar kinematics/age? – 8m IFU spectroscopy (in progress!)
- What are the cold gas masses/kinematics? – ALMA? CABB?
- What are the dust contents? – HERSCHEL/ ALMA?

Thank You!