Are Primordial Galaxies Dispersion-dominated Systems?

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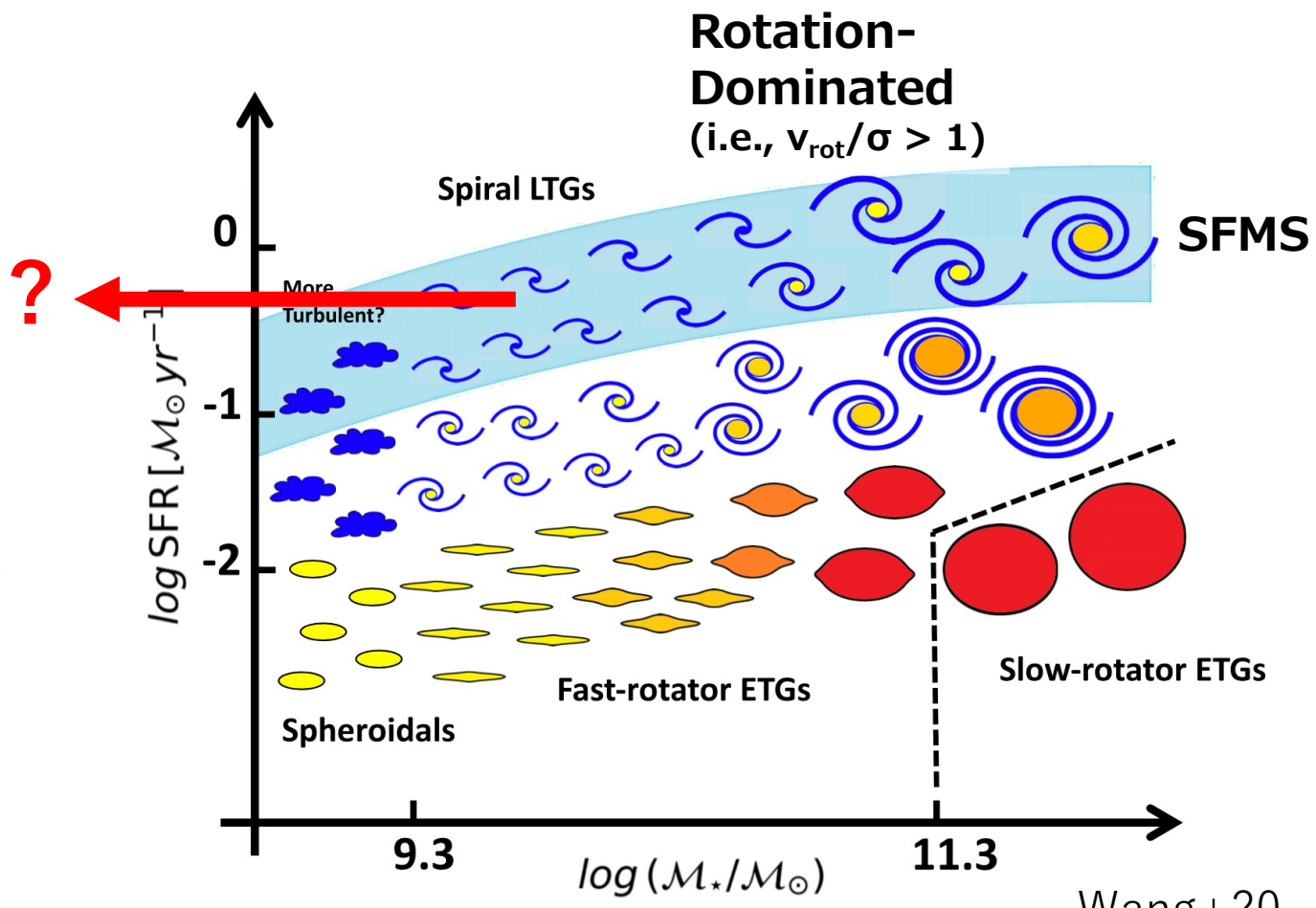
Frontier of galaxy kinematics

Instead of high-z primordial galaxies,
local extremely metal-poor galaxies
(**EMPGs**) as analogs
(cf. Moka and Yi's talks)



Wang+20

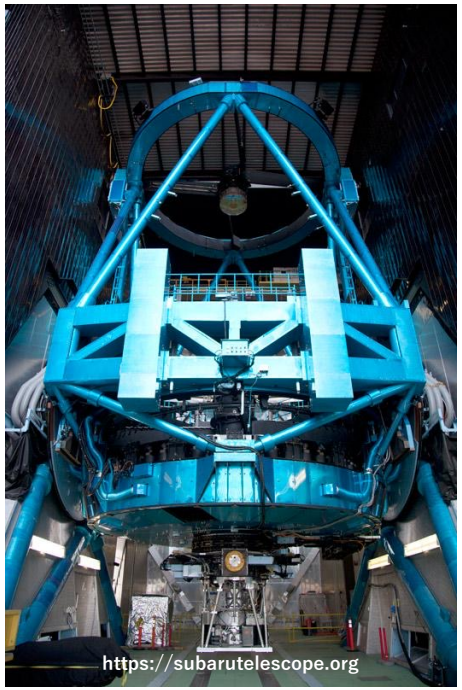
Observational challenge

Requirement

- EMPGs are faint due to low M_* ($\lesssim 10^7$ $M_\odot$)
  → **High-sensitivity** integral field unit (**IFU**)

- Velocity gradient and dispersion are expected to be small
  → **High wavelength-resolution** IFU

→ Subaru/**FOCAS IFU** with
mid-high-dispersion grism (VPH680; $R \sim$ **7500**)!



Subaru: 8-m telescope

IFU installed in FOCAS

EMPRESS 3D (PI: M. Ouchi)

Goal

z ~ 0.01–0.03

Hα kinematics of local extremely metal-poor galaxies (EMPGs)

$Z \leq 10\% \, Z_\odot$ (cf. Moka and Yi's talks)

with **FOCAS IFU**

30 EMPGs to be observed

Lowest Z so far

(J1631+4426; Kojima+20)

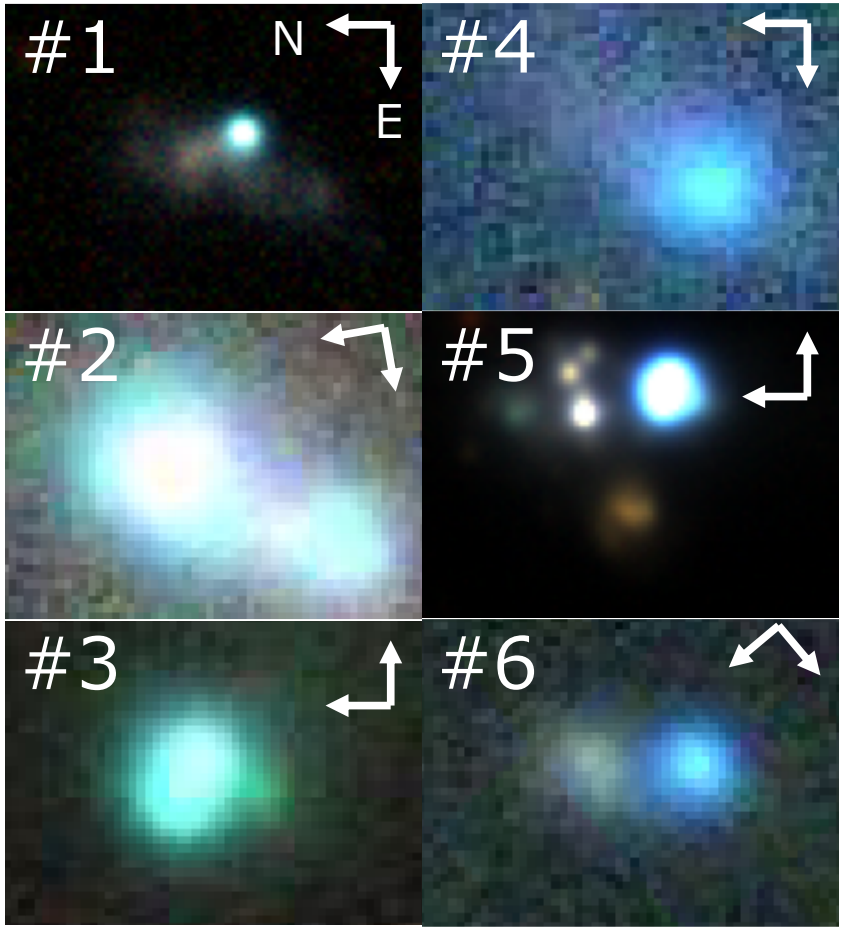
Observed: 6 EMPGs

Low O/H = **1.6%**–9.8% $Z_\odot$

Low $\log(M_*/M_\odot)$ = **4.7**–7.6

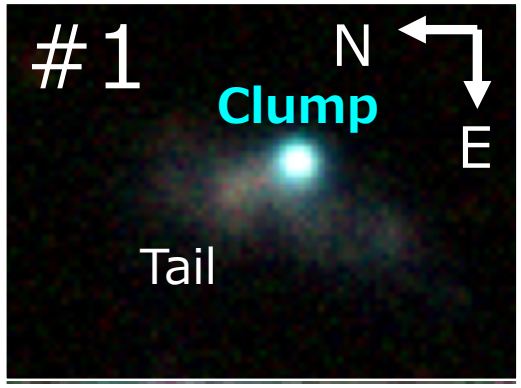
High sSFR ~ 5–**510** Gyr^{-1}

→ Comparable to **primordial galaxies**



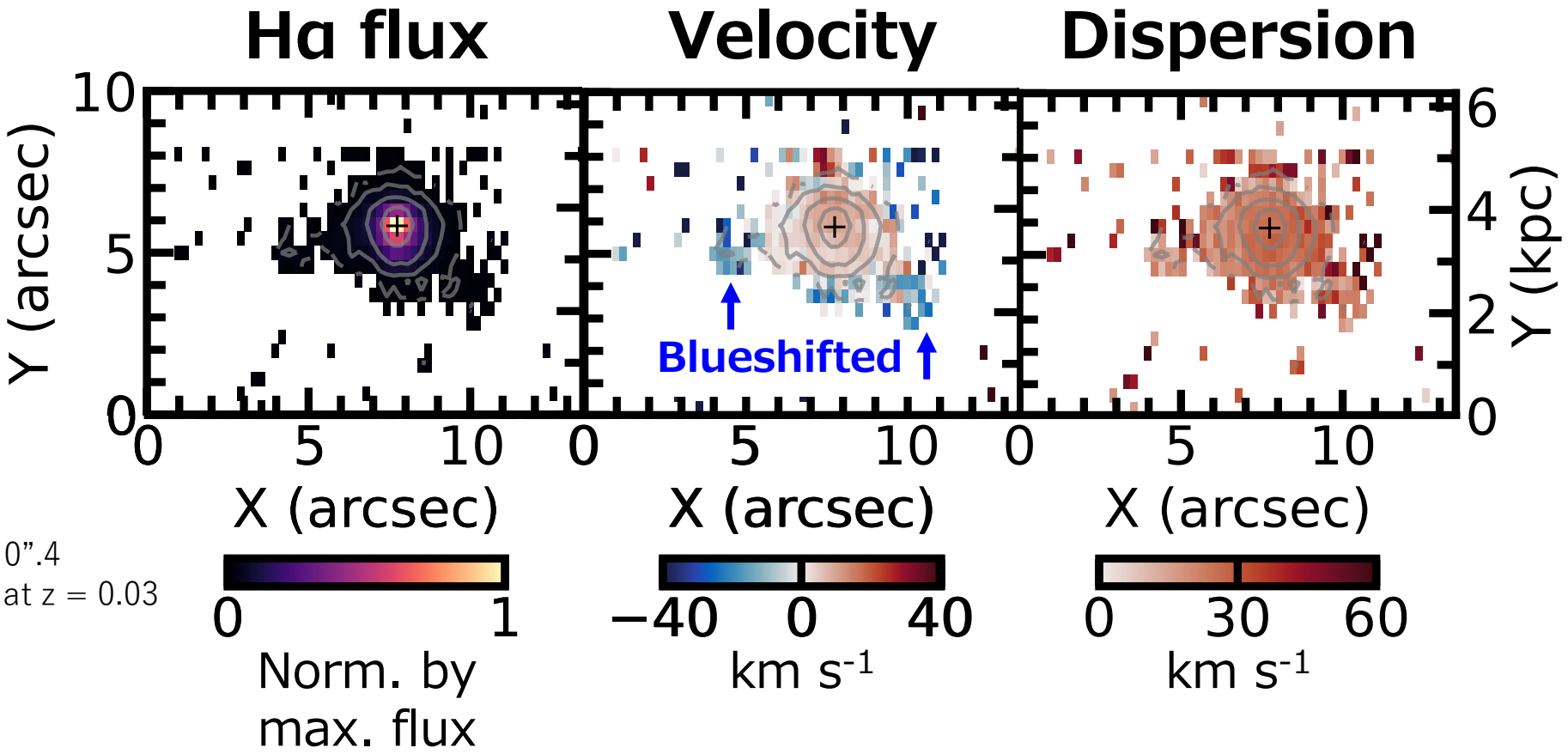
Flux, velocity, & dispersion map

***gri* image**



J1631+4426

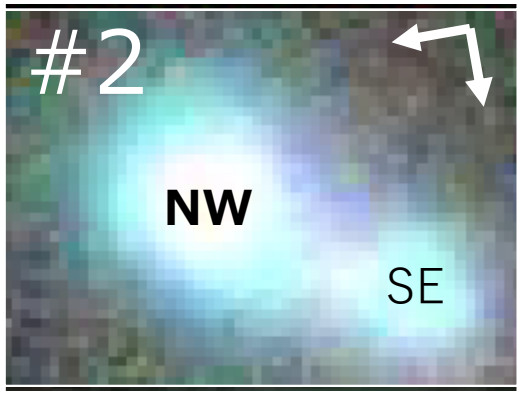
Pixel scale: 0”.2 x 0”.4
→ ~ 100 x 200 pc at z = 0.03



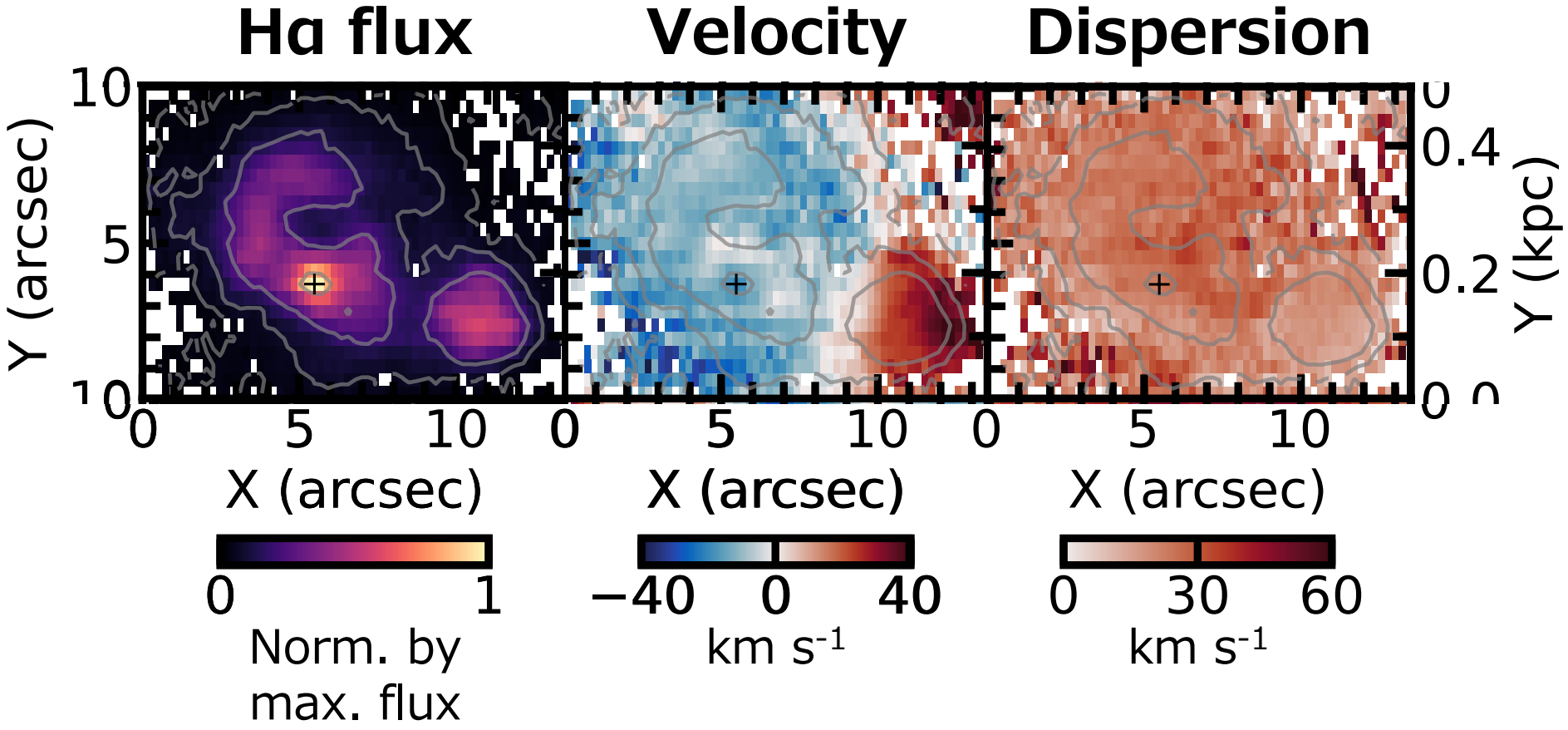
→ **No clear rotation**

Flux, velocity, & dispersion map

***gri* image**



IZw18



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Flux, velocity, & dispersion map

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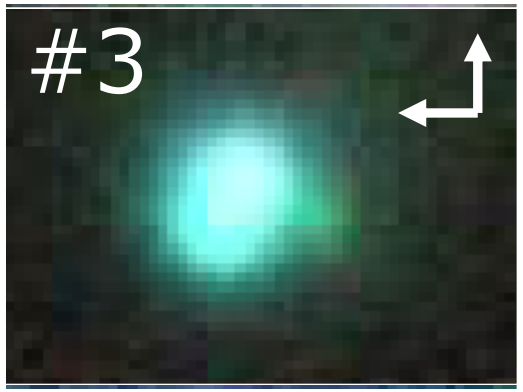

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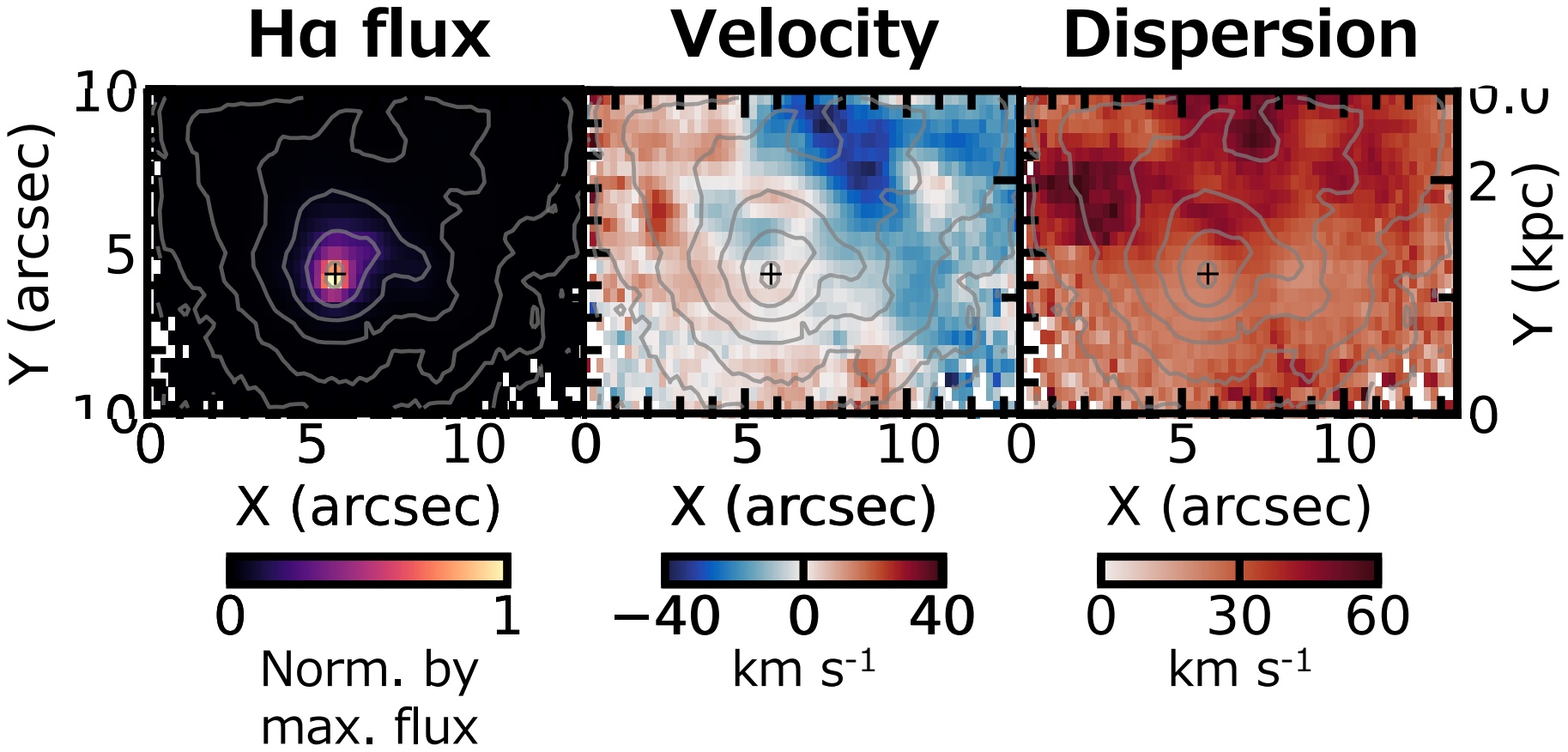

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Flux, velocity, & dispersion map

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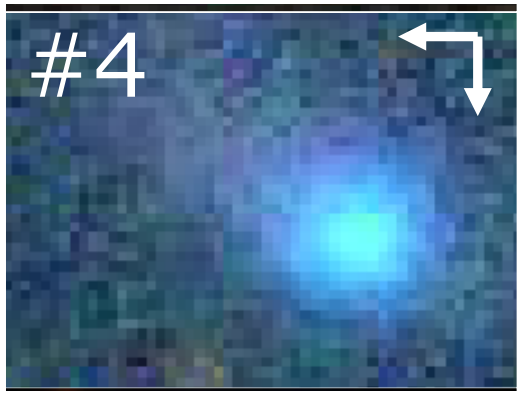
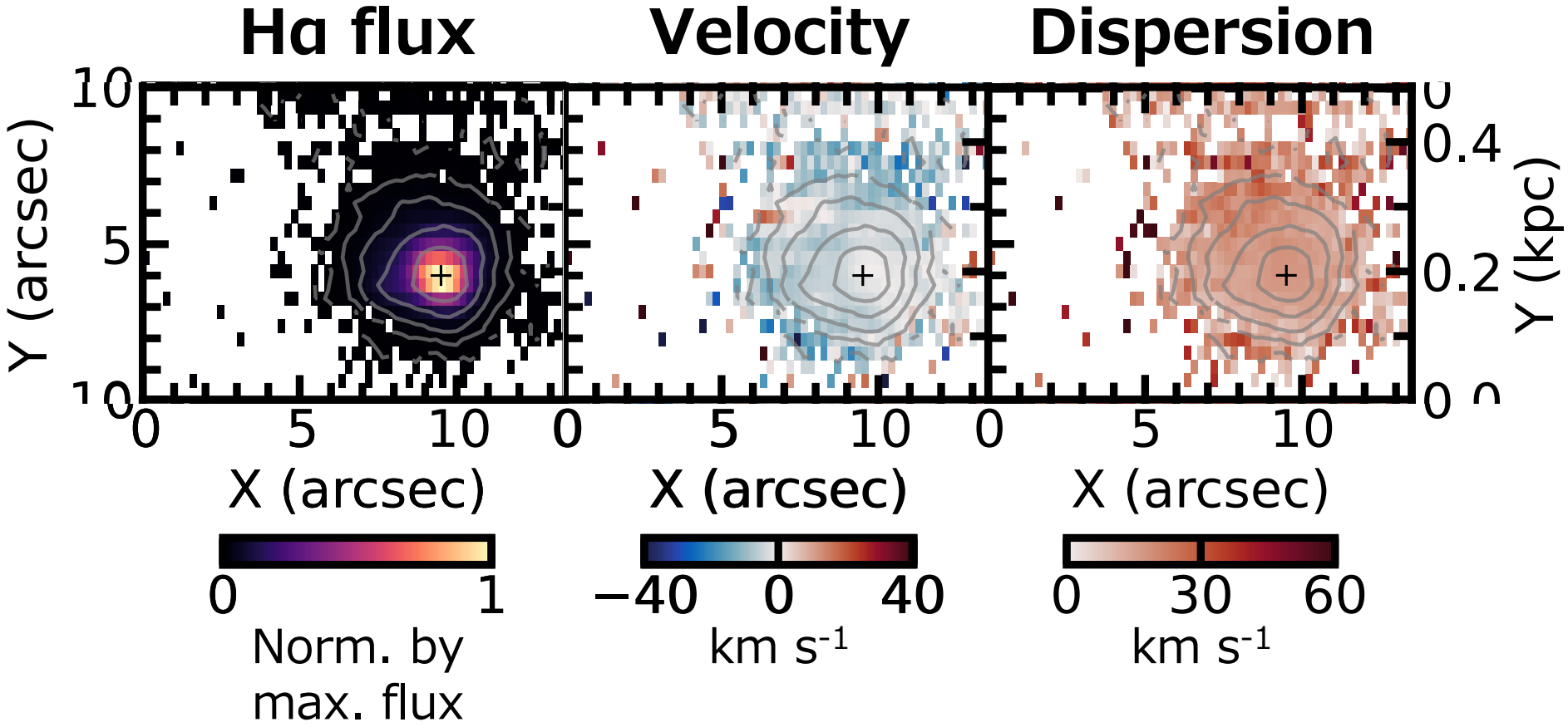


HS0822+3542



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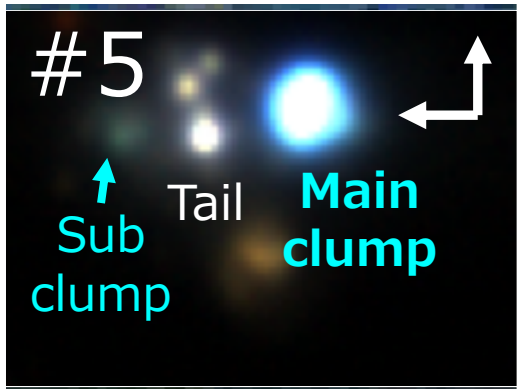
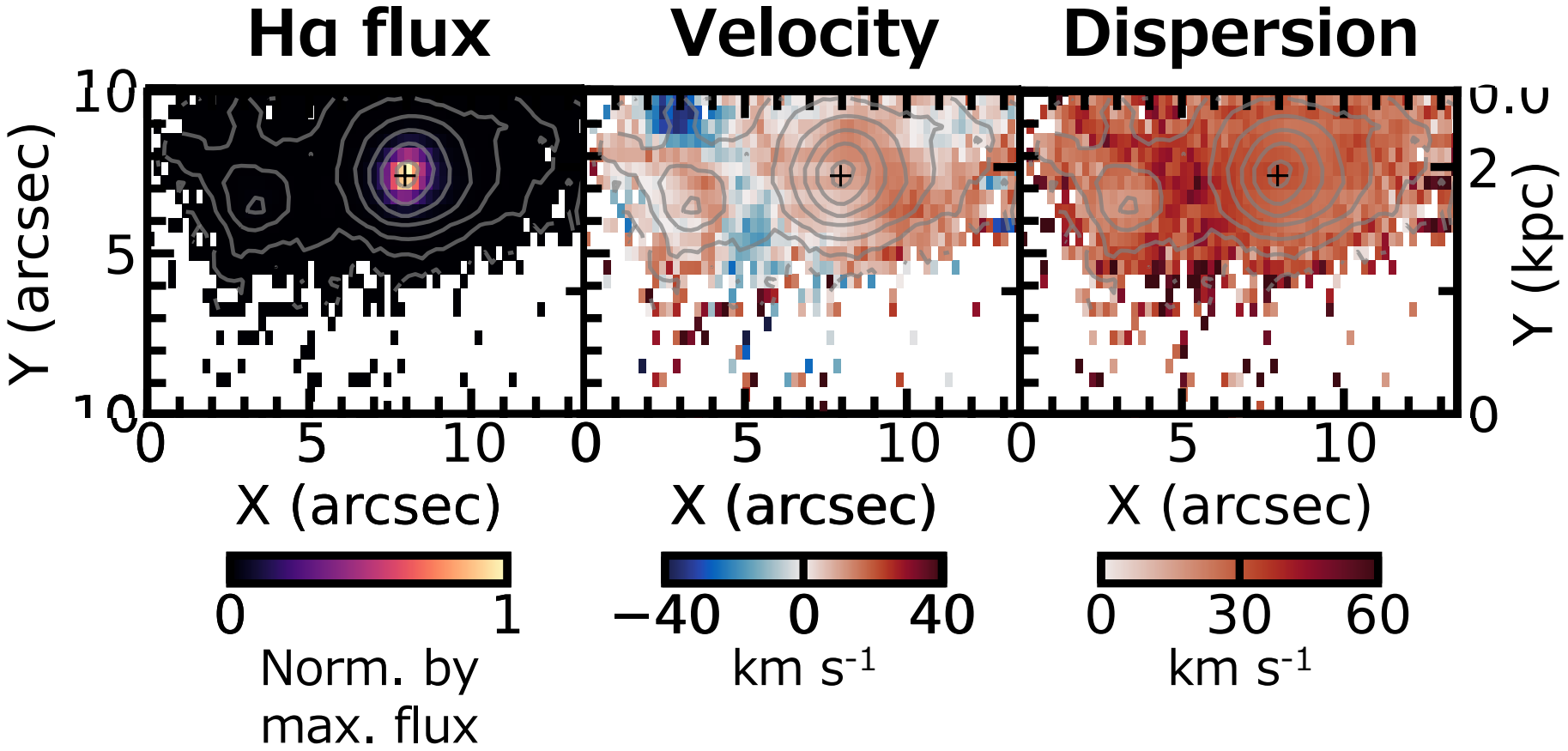
Flux, velocity, & dispersion map

***gri* image**



J1044+0353



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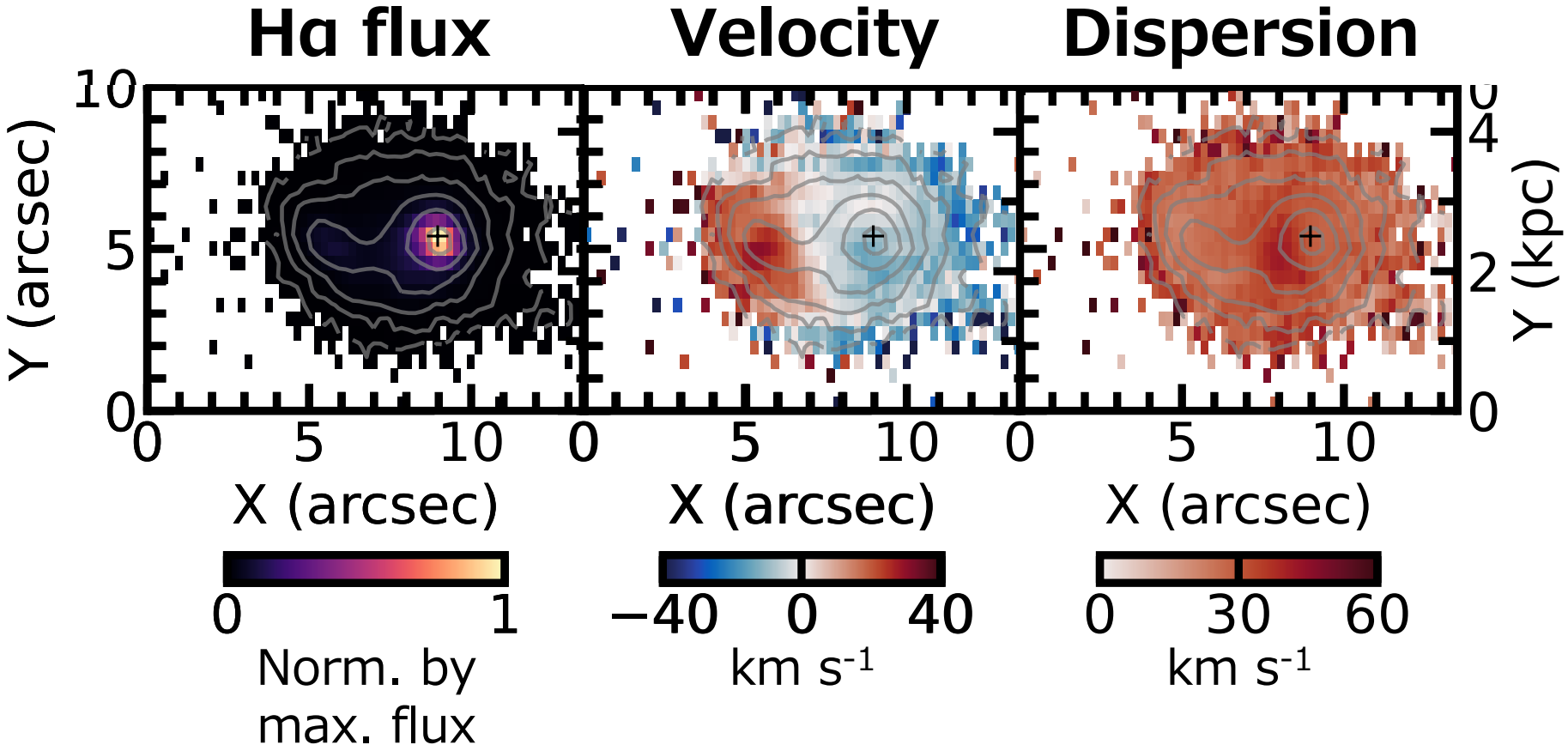
Flux, velocity, & dispersion map

***gri* image**

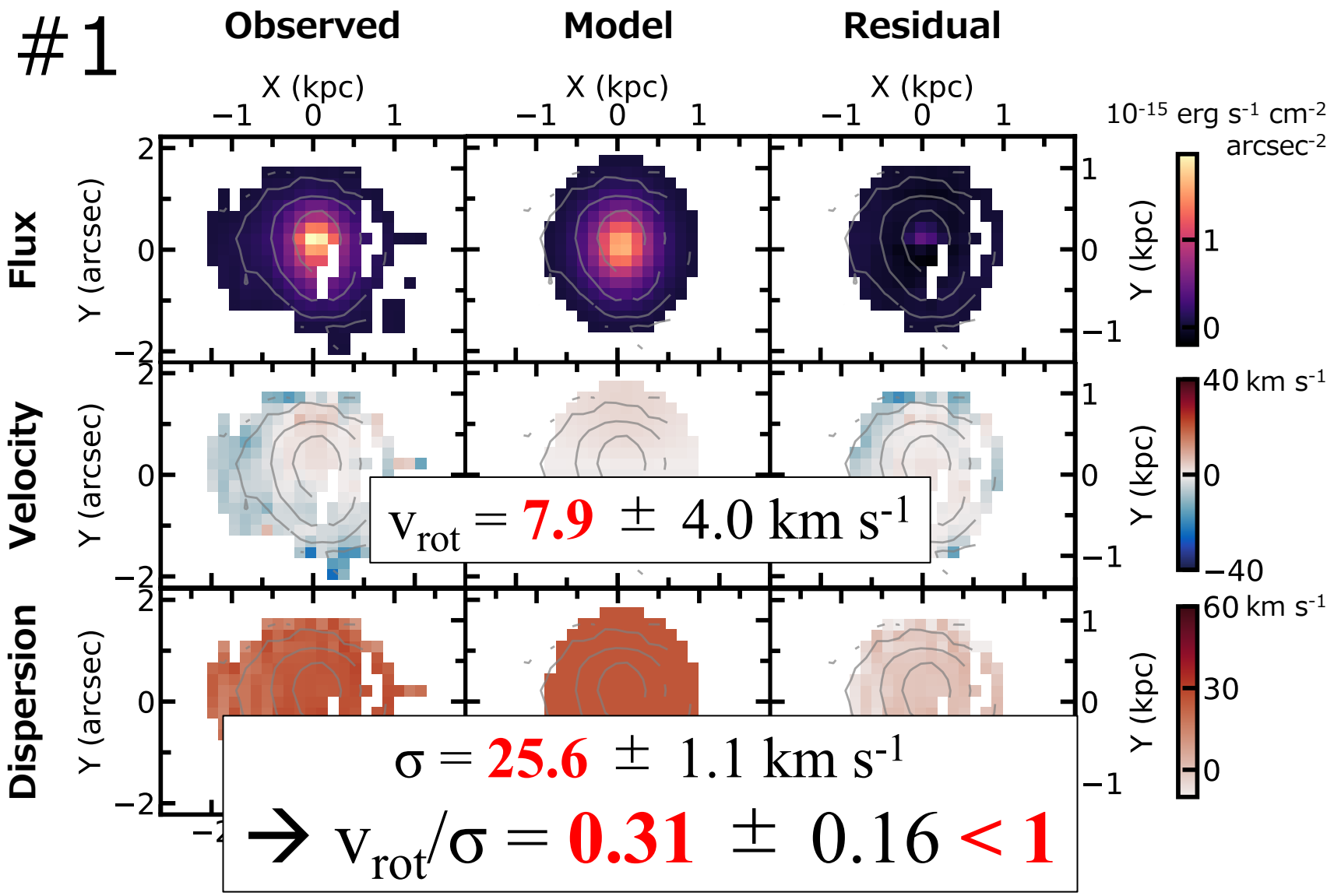
J2115-1734



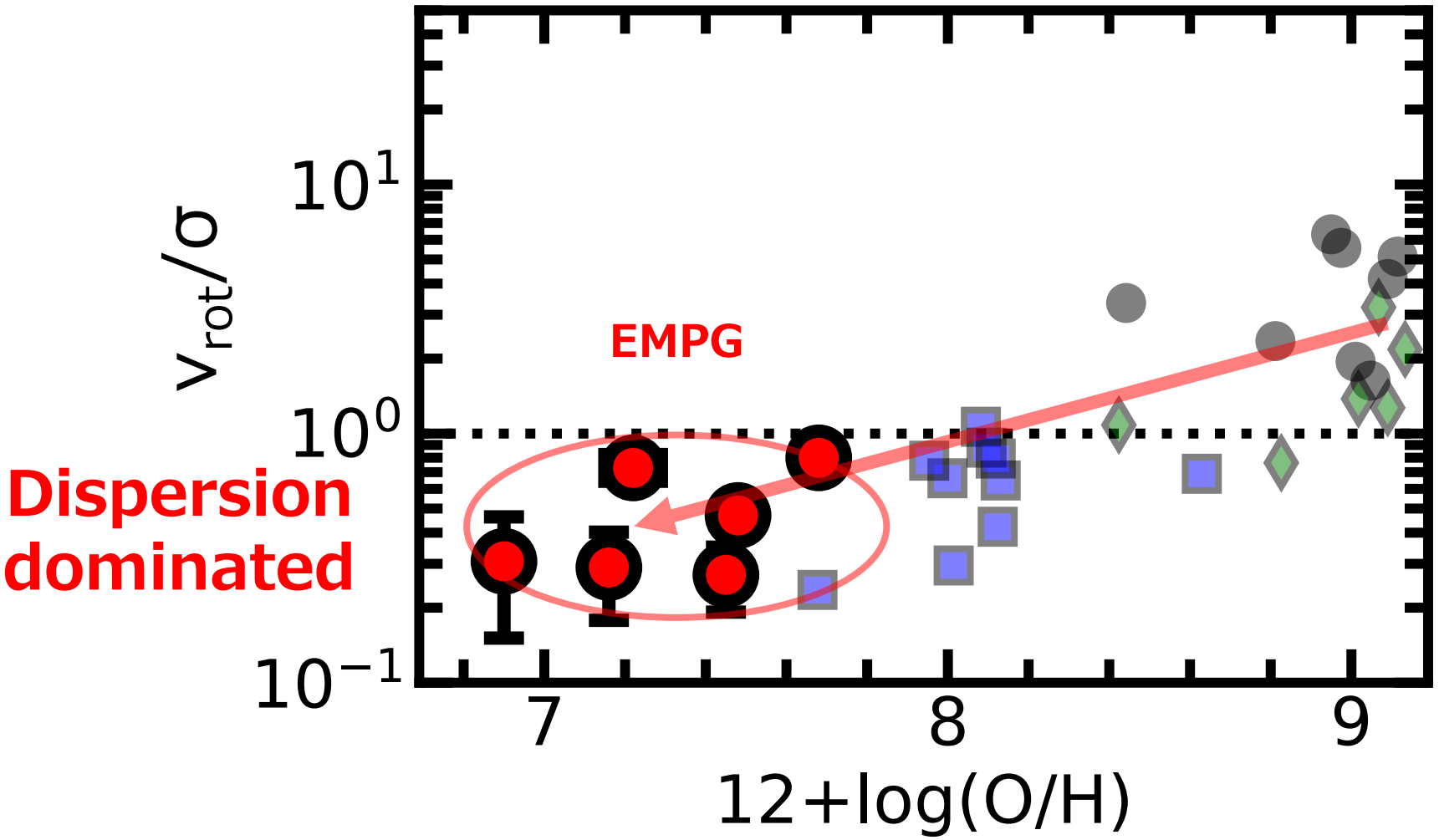
→ No clear rotation

More quantitively, 3D disk model → v_{rot}, σ

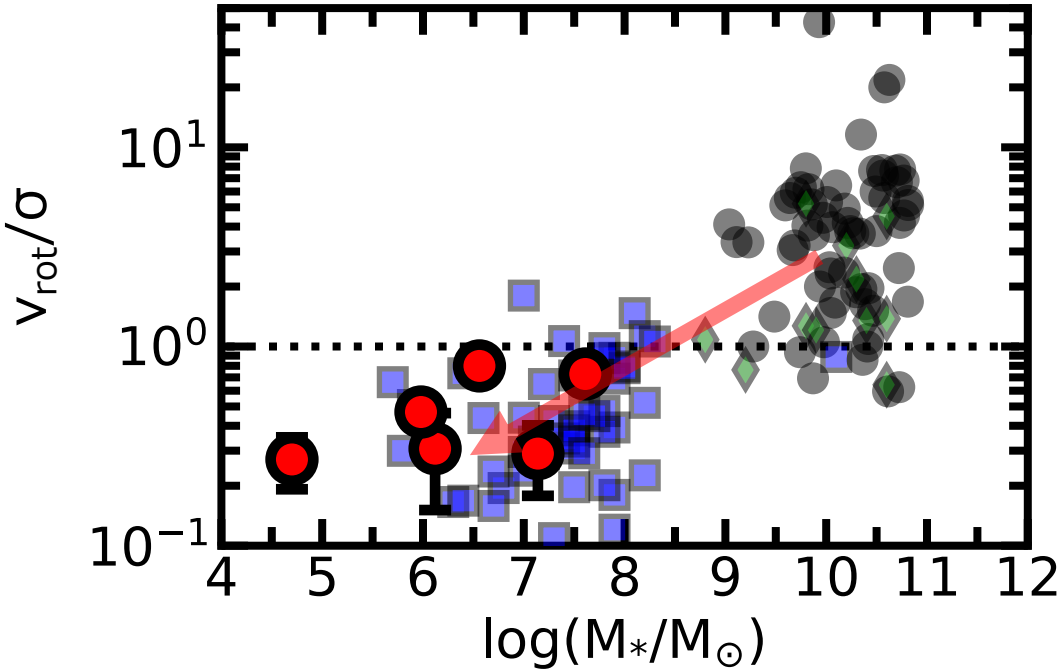
3D disk model (w/ GalPaK^{3D} software; Bouché+15)

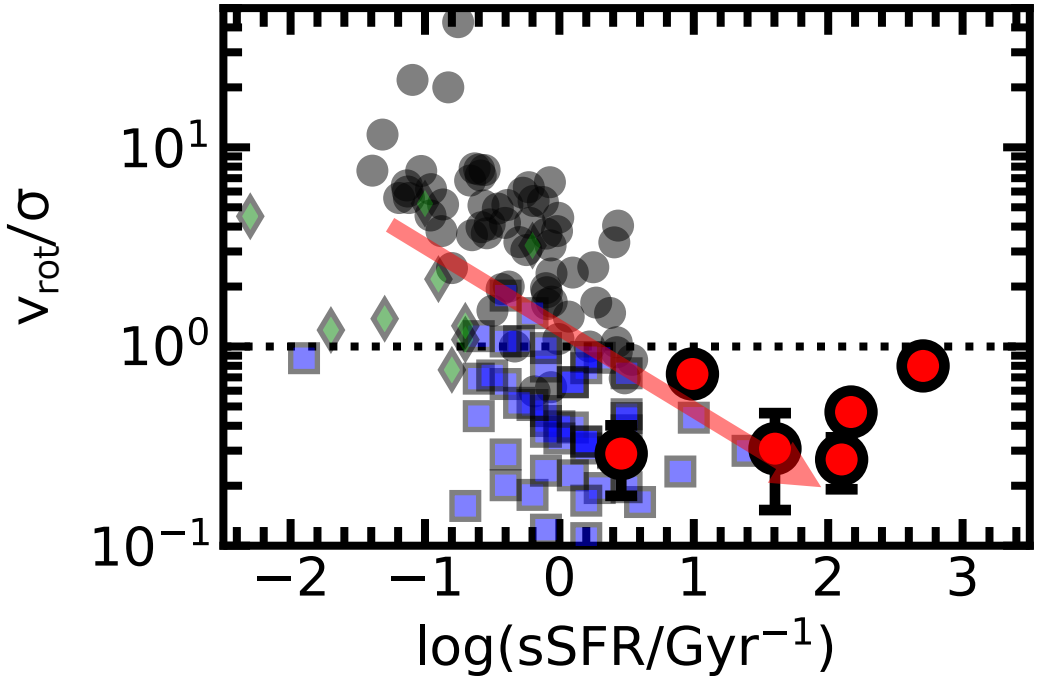


Rotation or dispersion?



v_{rot}/σ vs. M_*, sSFR



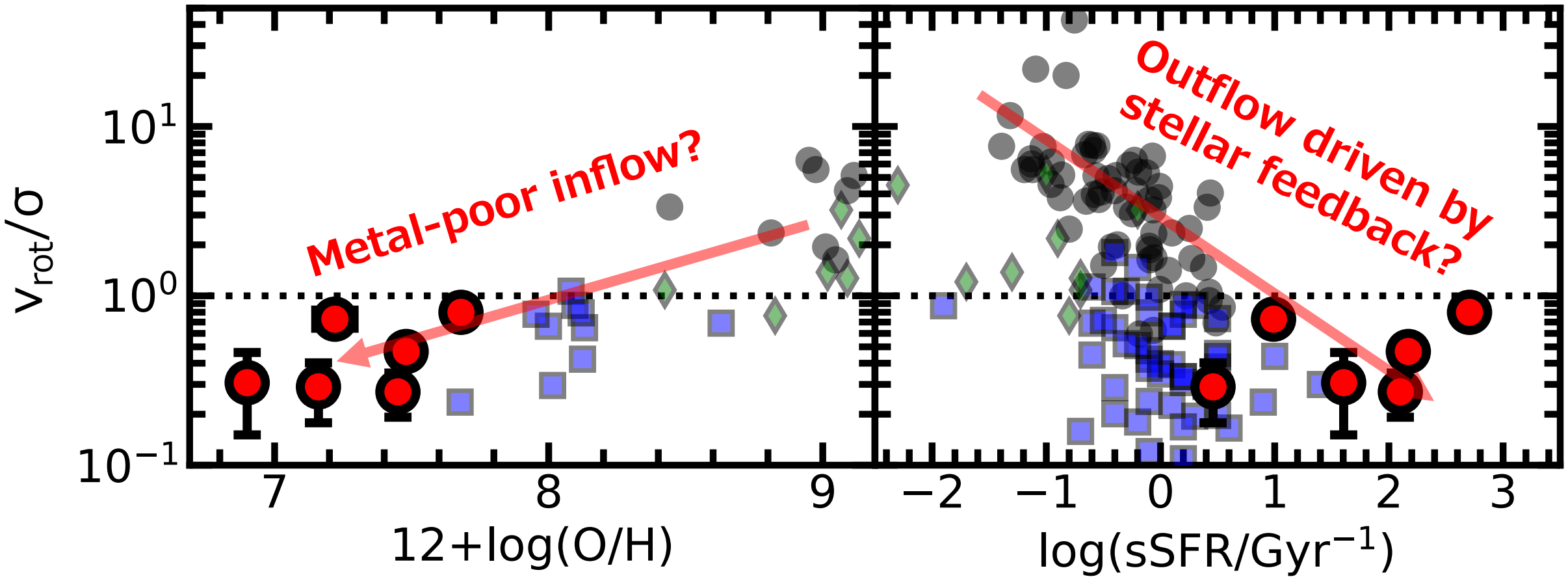


→ Primordial galaxies can be **dispersion-dominated**!

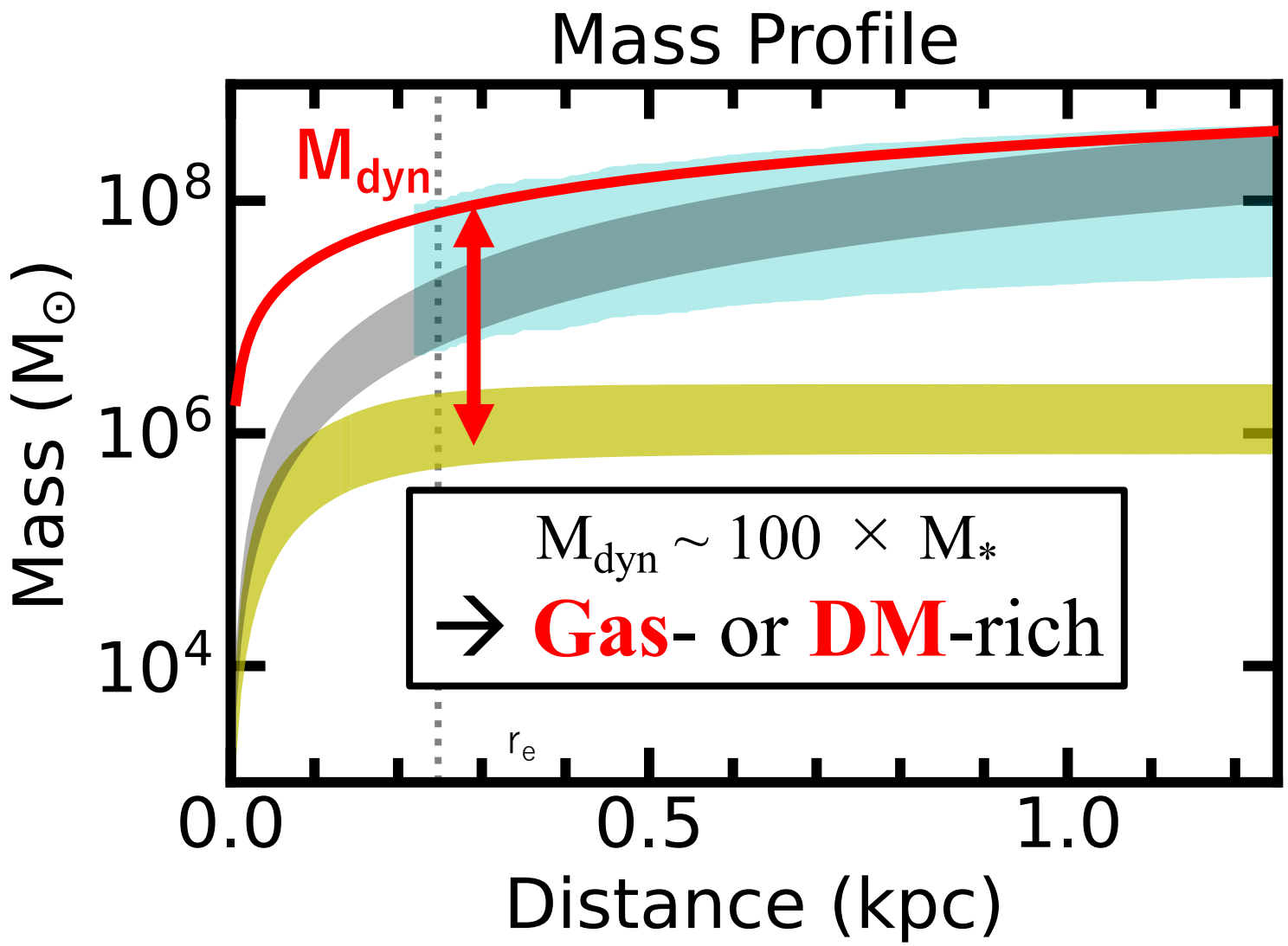
Possible origin of low v_{rot}/σ

Both **inflow** and **outflow** can raise σ (e.g., Grazebrook13)

└ Large impact on low-mass galaxies



Mass profile

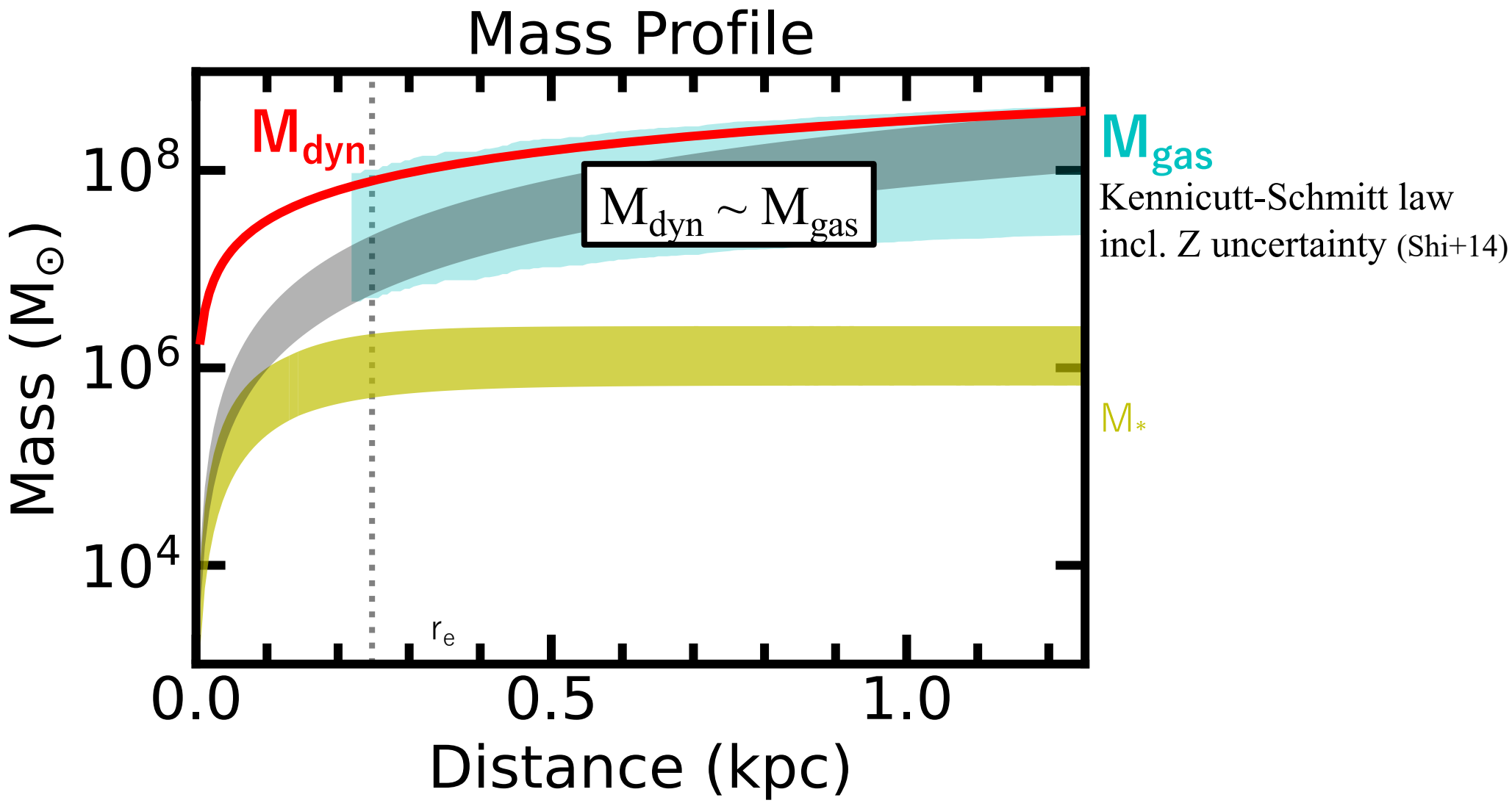


$$M_{dyn} = M_* + M_{gas} + M_{DM}$$

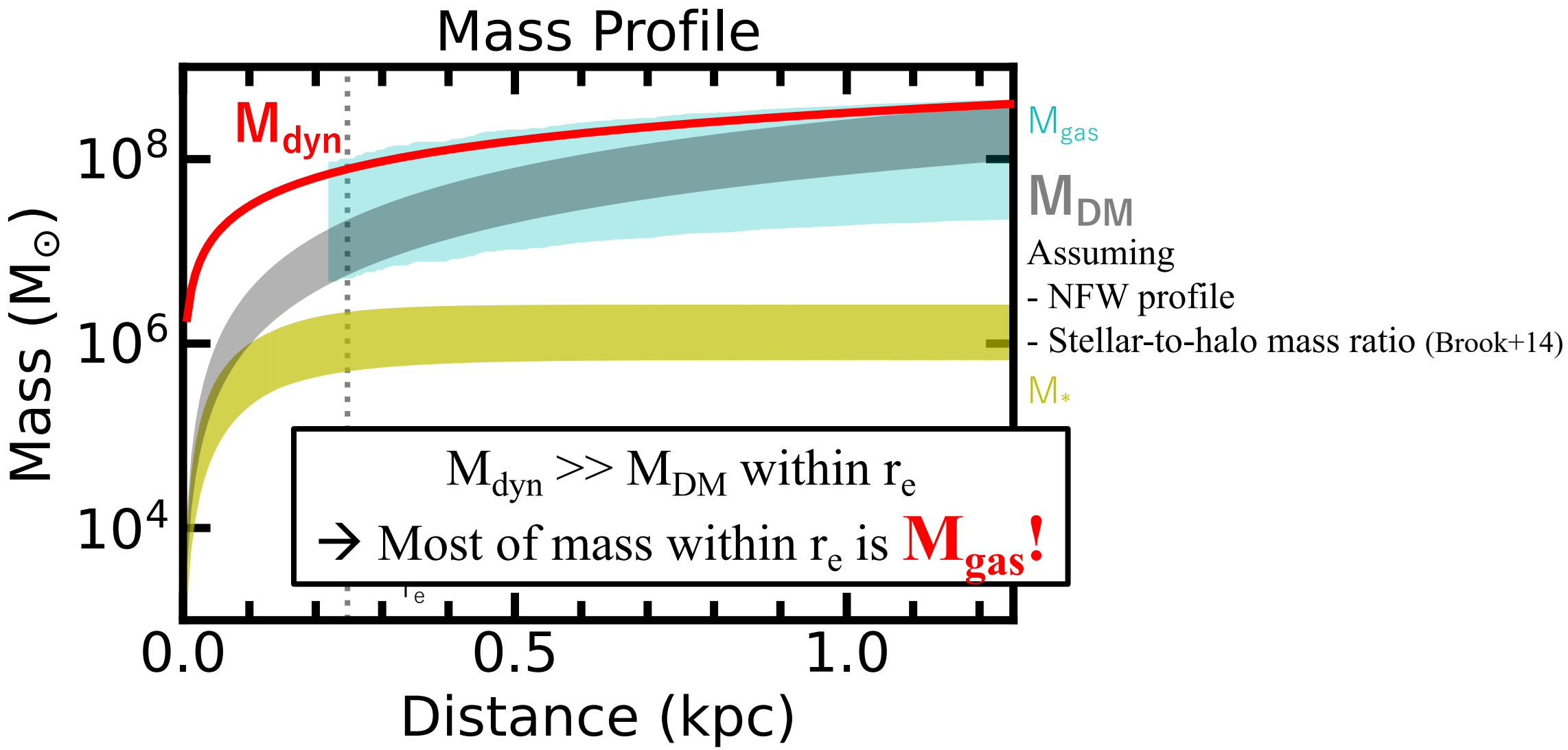
M_*

Assuming Sérsic profile

Mass profile



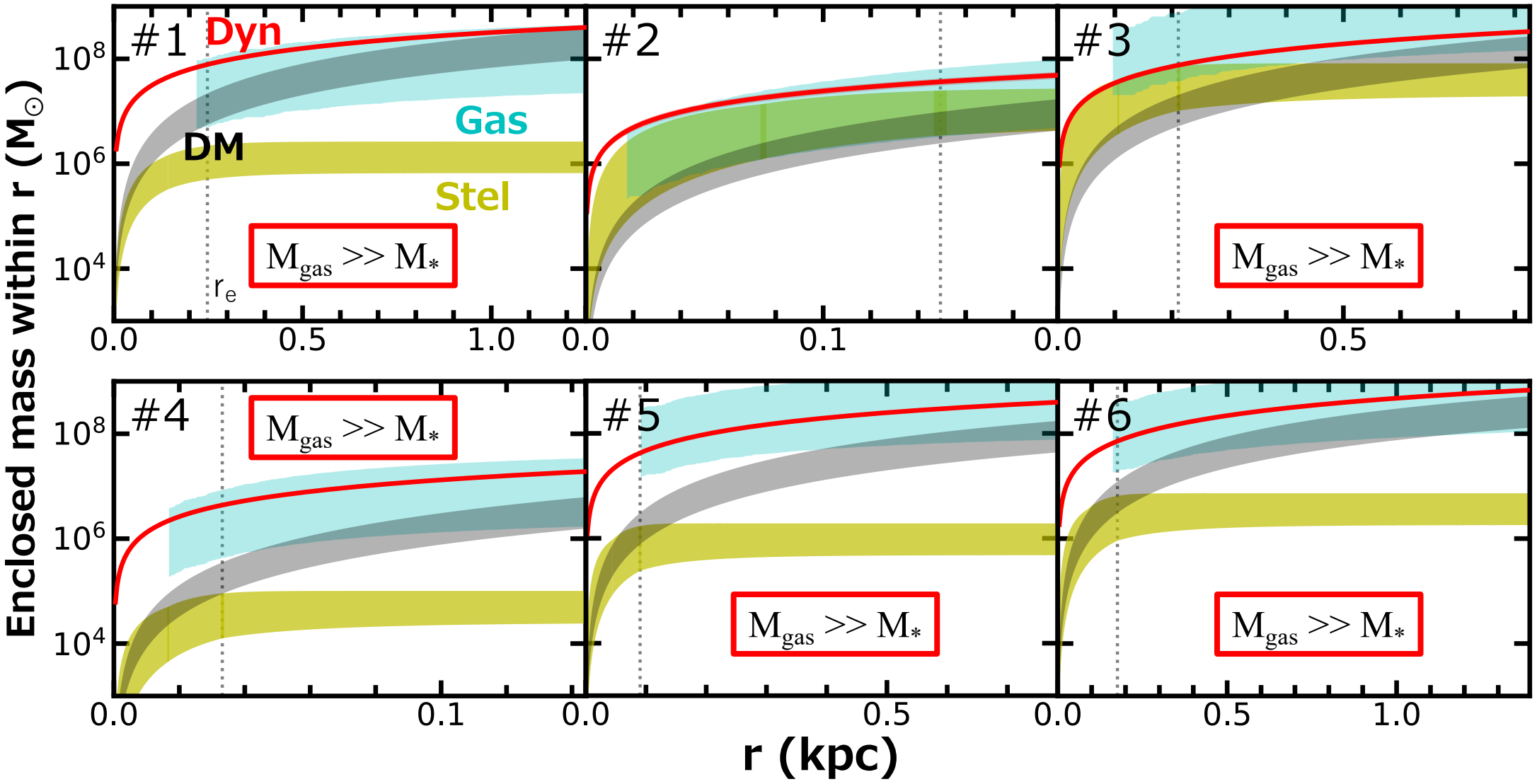
Mass profile



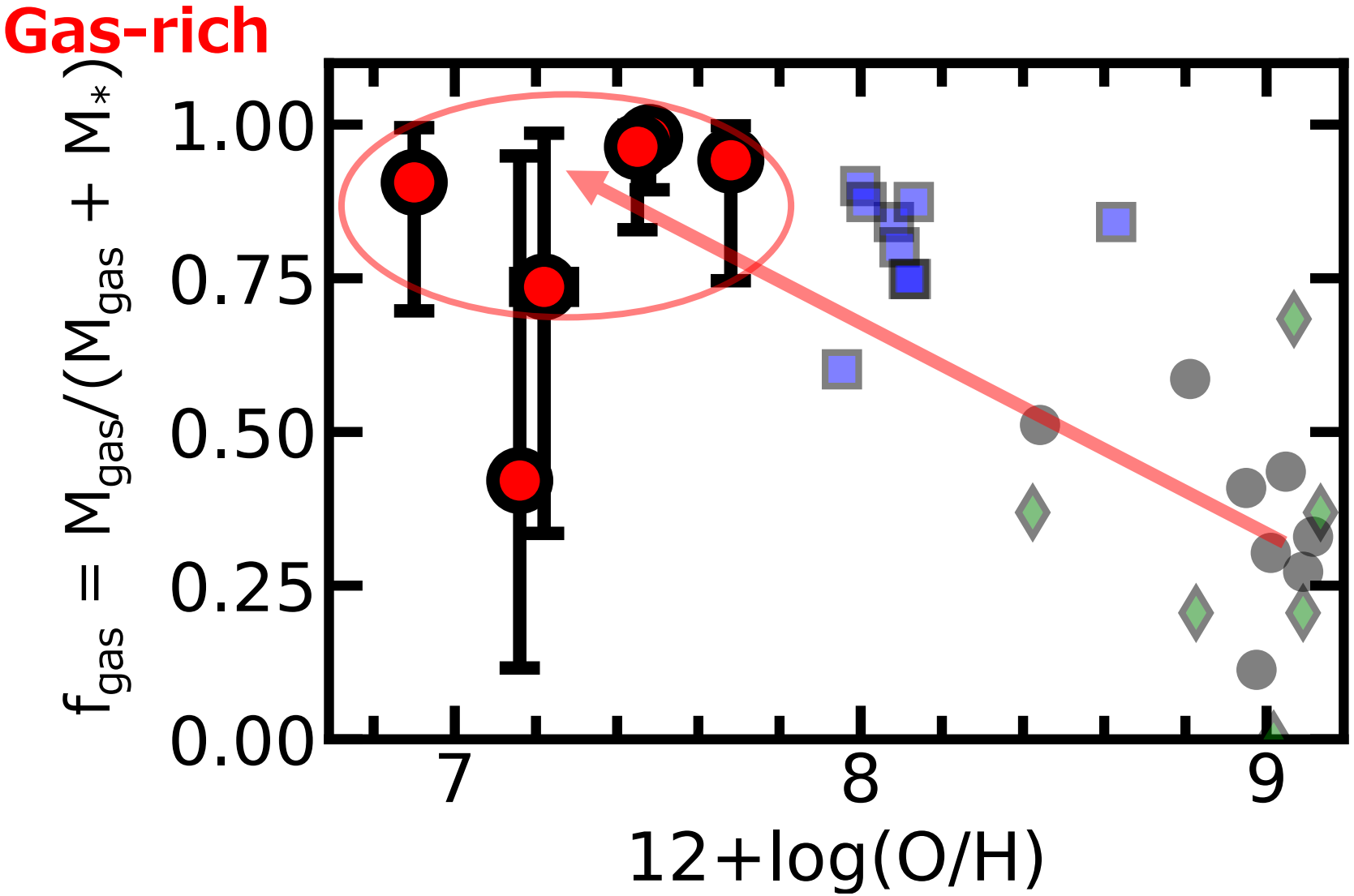
$M_{dyn} >> M_{DM}$ within r_e

→ Most of mass within r_e is **M_{gas}!**

Mass profiles of the 6 EMPGs



Gas mass fraction f_{gas}

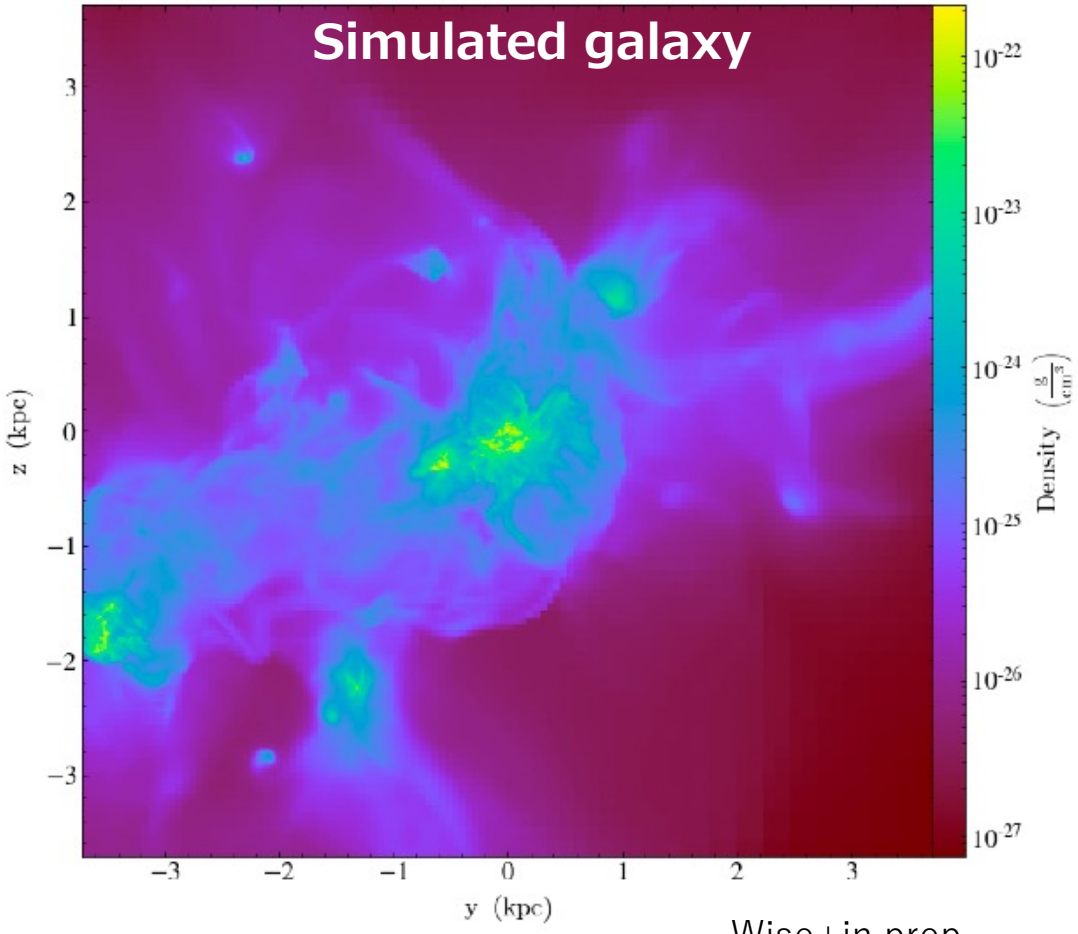


→ Primordial galaxies can be **gas-rich**!

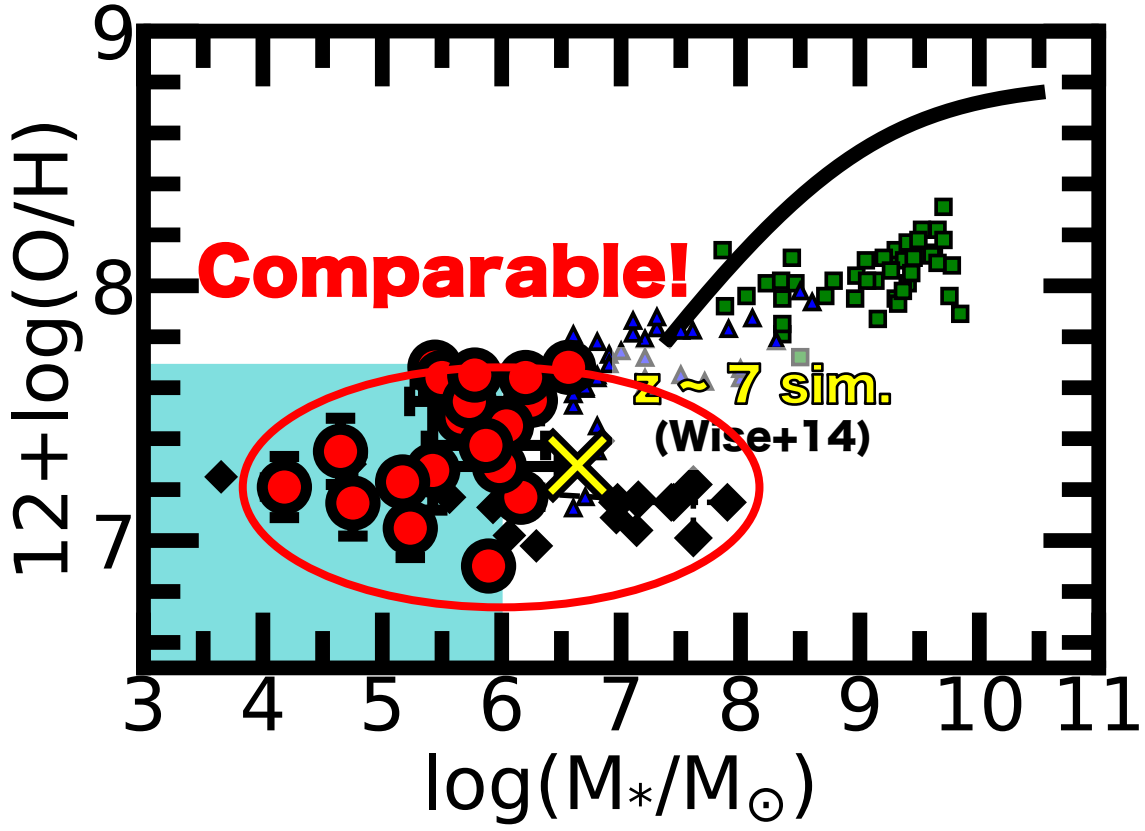
Simulated high-z primordial galaxy

Cosmological hydrodynamical simulation (Wise+14):

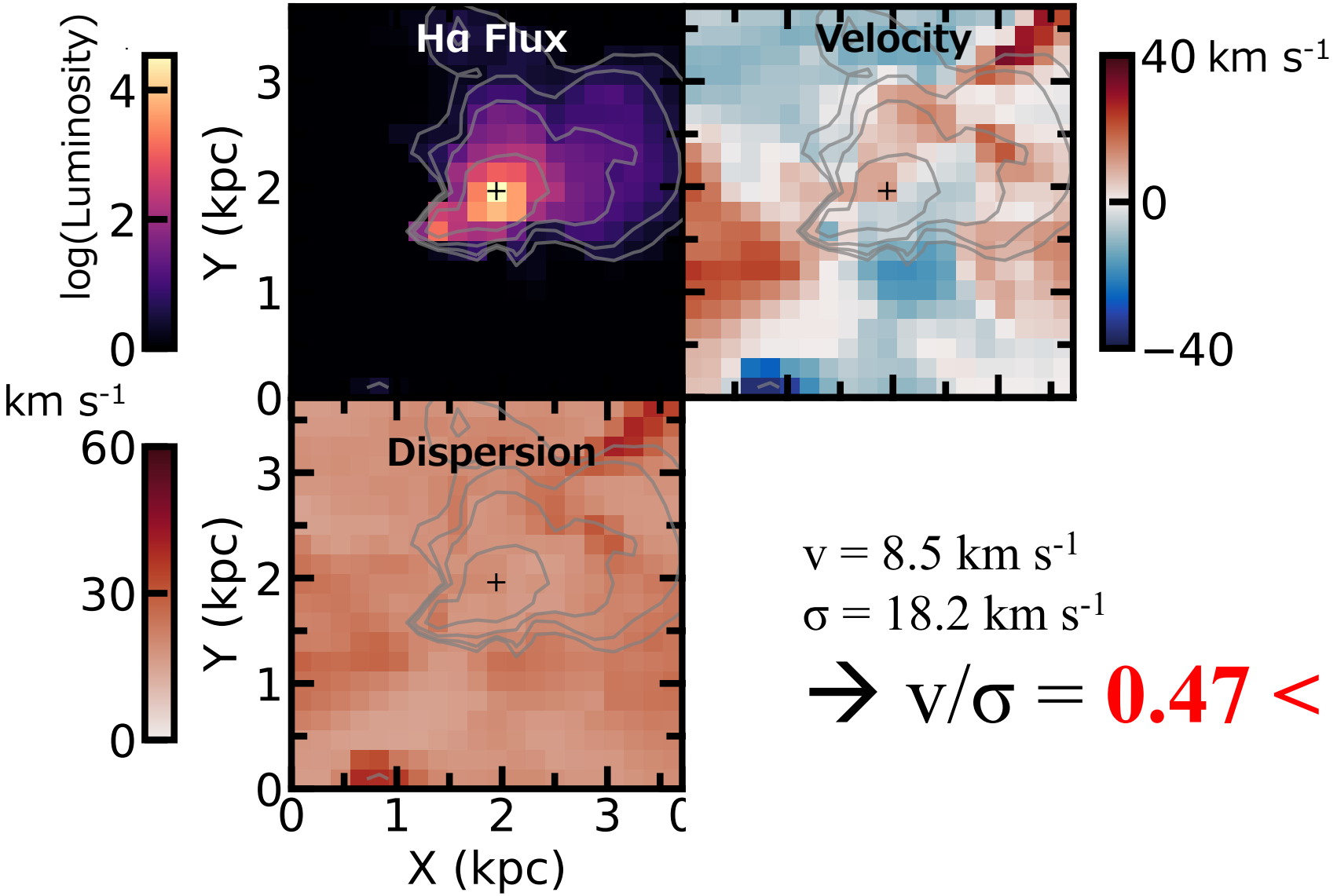
Galaxy at $z = 7.3$: $Z \sim 4\%\ Z_\odot$, $M_* \sim 4 \times 10^6\ M_\odot$, sSFR $\sim 5\ \mathrm{Gyr}^{-1}$, $f_{gas} \sim 1.0$



Wise+in prep.



Hα Kinematics of simulated galaxy

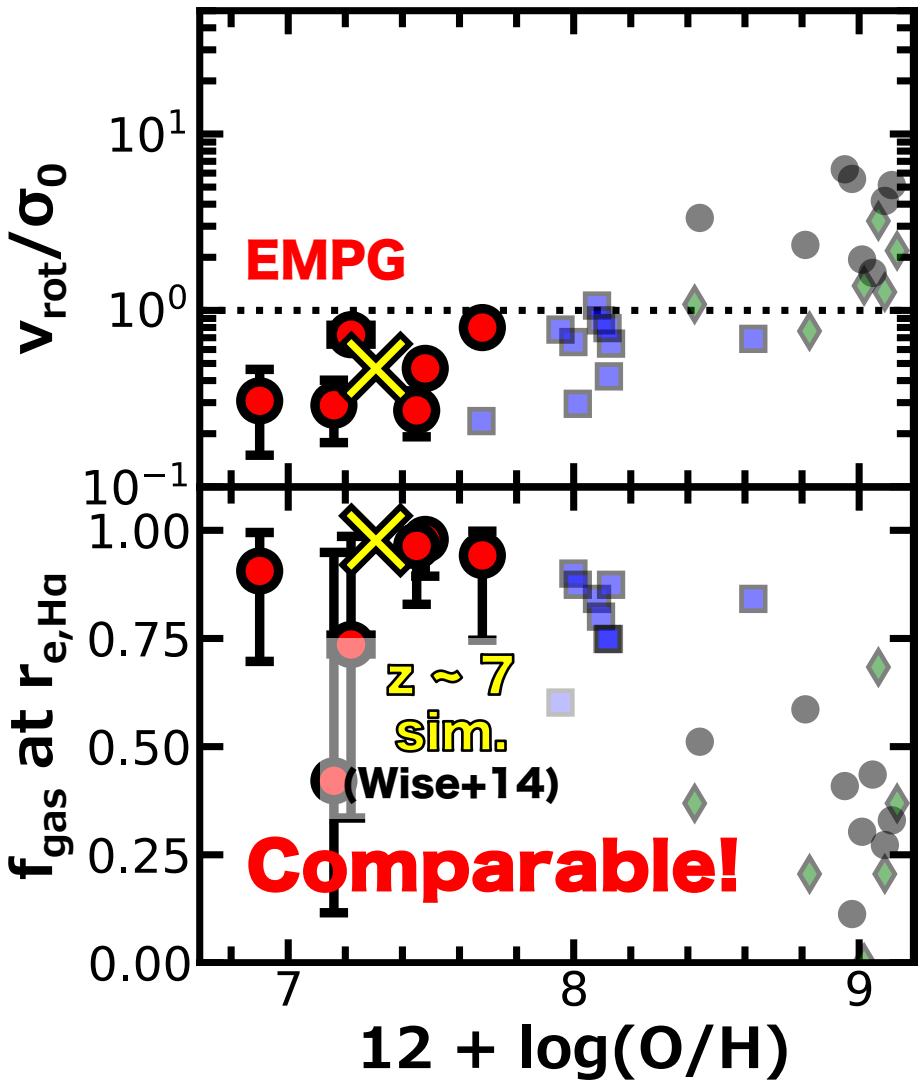


$v = 8.5$ km s^{-1}

$\sigma = 18.2$ km s^{-1}

→ $v/\sigma = \mathbf{0.47 < 1}$

Comparison b/w EMPGs and simulation



→Actual high-z primordial galaxies expected to be

- **dispersion-dominated**
- **gas-rich**

Waiting for JWST/NIRSpec IFU observations!

Summary

Both local EMPGs and simulated high-z primordial galaxies have

- Low $\mathbf{v_{rot}/\sigma < 1}$
- High $\mathbf{f_{gas} \sim 1}$

→ Actual high-z primordial galaxies are also expected to be **dispersion**-dominated **gas-rich** systems

The low v_{rot}/σ may originate from inflow and/or outflow