A dynamically cold disk galaxy in the early Universe

F. Rizzo, S. Vegetti, D. Powell, F. Fraternali, J. P. McKean,
H. R. Stacey & S. D. M. White

Xiaohan Wang
2021. 12. 3

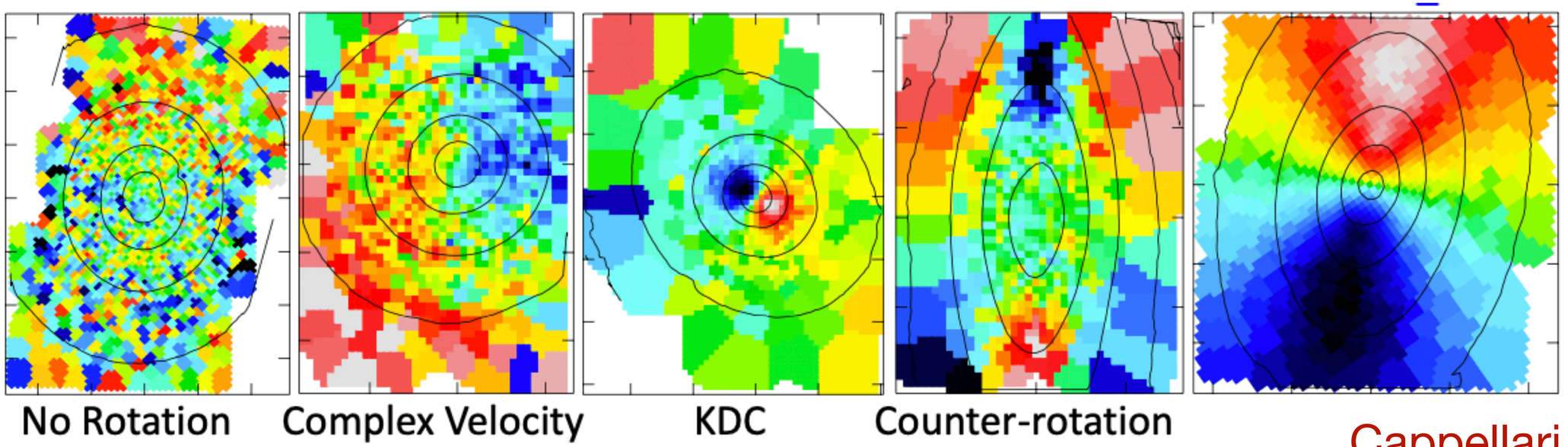
Dynamically hot vs Dynamically cold

- Dispersion: standard deviation of LOSVD → Random motion
- Rotation velocity: mean value of LOSVD → Rotation

Dynamically hot: Random motion dominated

Dynamically cold: Rotation dominated

Dynamically hot vs Dynamically cold



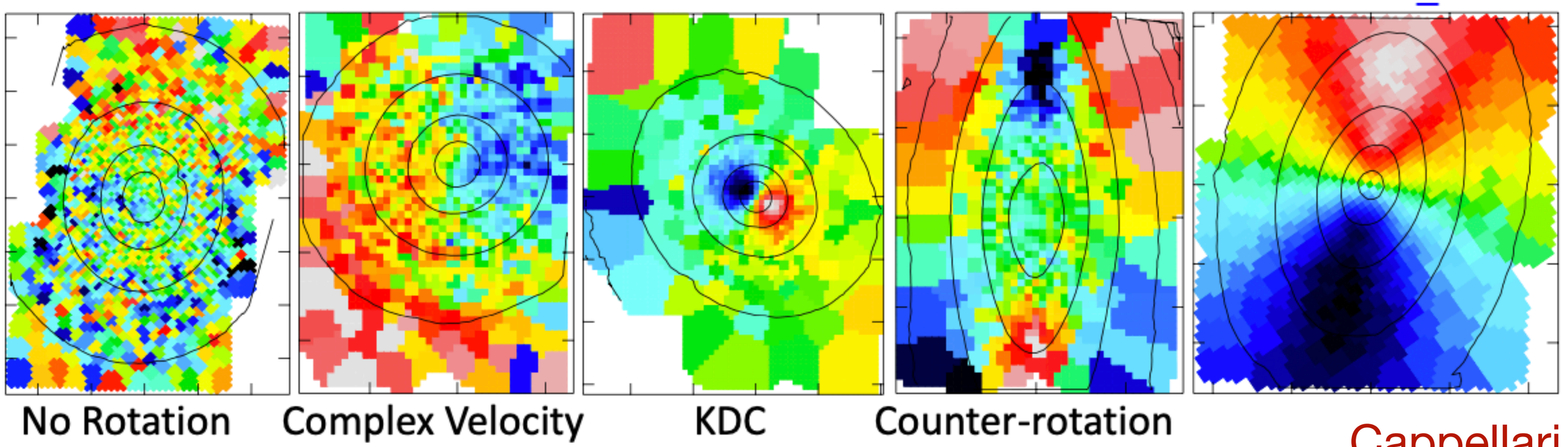
Cappellari 2016

Dynamically hot → **Dynamically cold**

High dispersion,
Low velocity

Low dispersion,
High velocity

Dynamically hot vs Dynamically cold



Cappellari 2016

Dynamically hot → **Dynamically cold**

High dispersion,
Low velocity

Low dispersion,
High velocity

$$V/\sigma$$

Evolution of dynamics with redshift

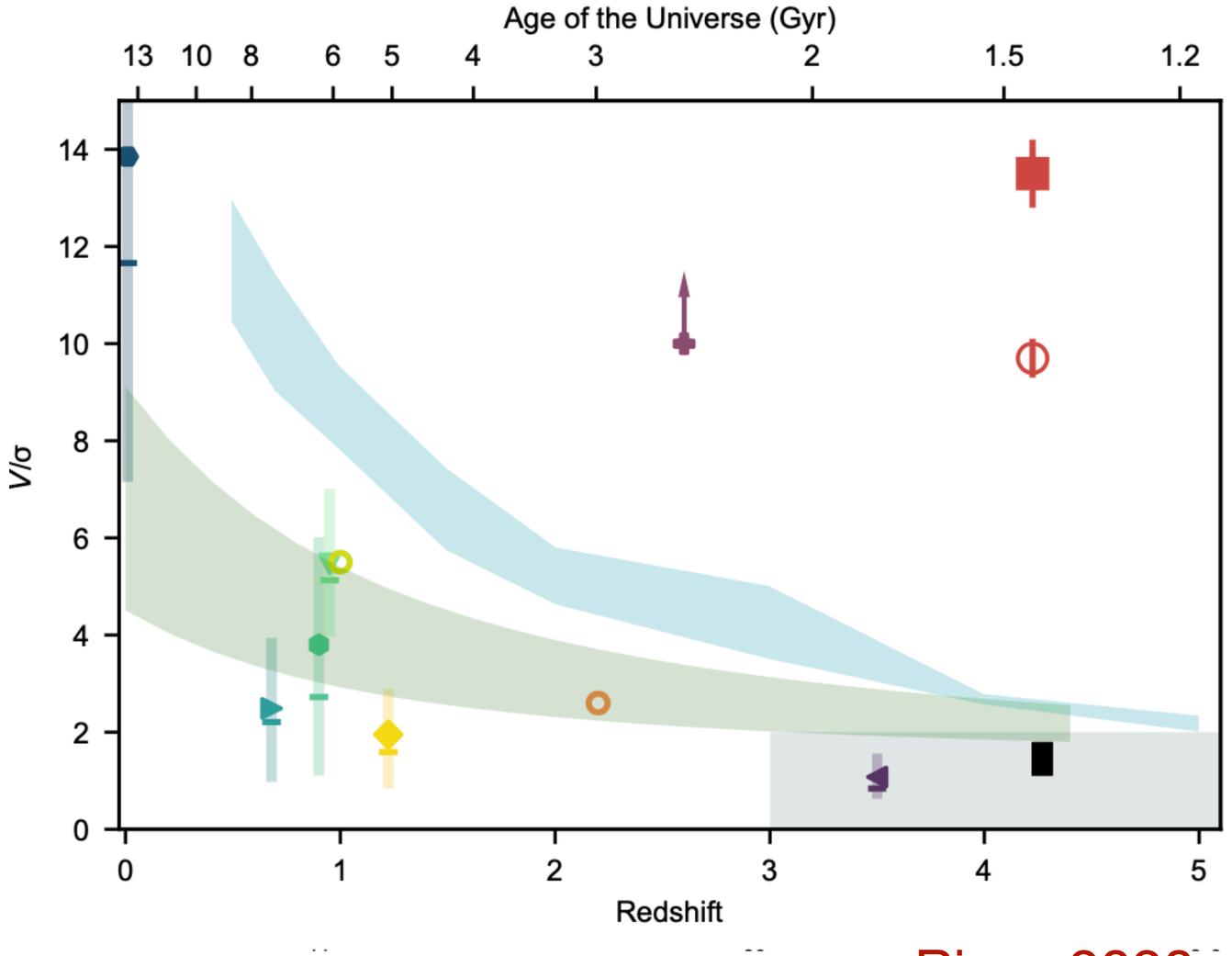
high redshift

V/σ

local Universe

- Violent environment
  - Gas
  - Mergers
  - Stellar feedback

- z < 1: local Universe, multiple morphologies
- z ~ 1 - 3: more rotation dominated galaxies than expected
- z > 4: lack of observations



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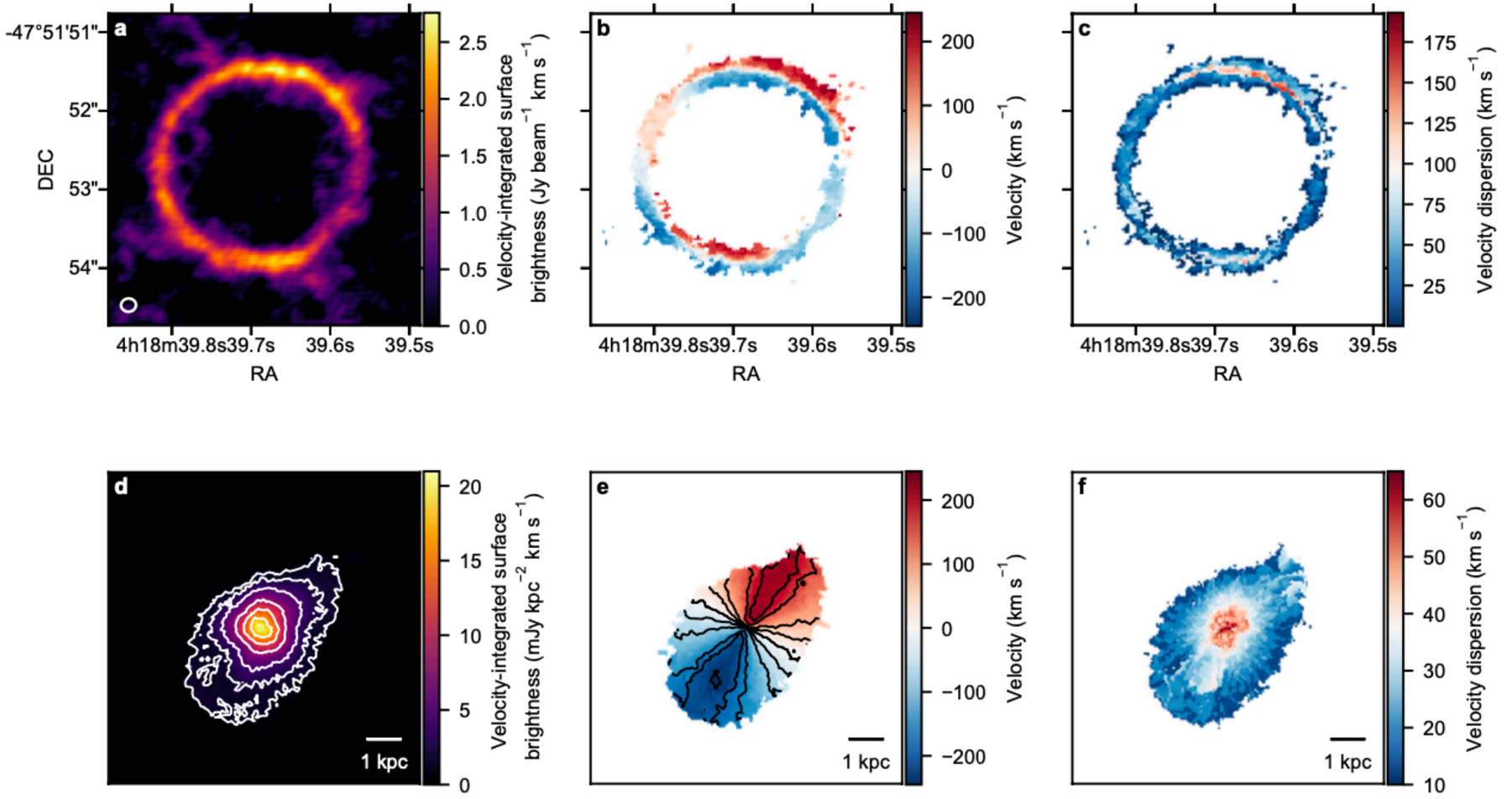
Strong lensing, [C II]

ALMA
SPT–S J041839–4751.9

Z ~ 4.2



v

dispersion

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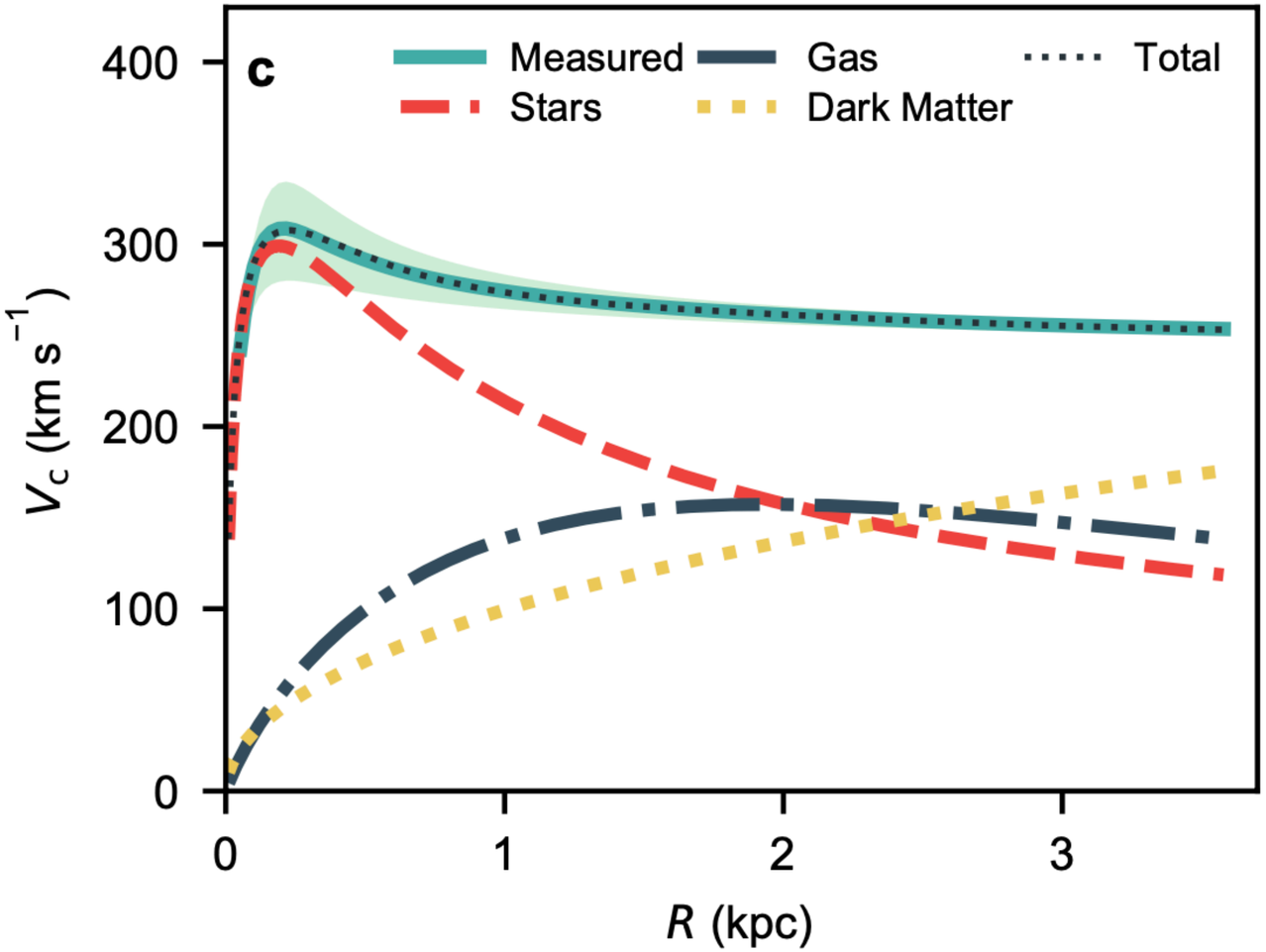
Kinematic properties

$^{a}V_{\rm max}$ (km s^{-1})	308±4
$^{b}\sigma_{\rm m}$ (km s^{-1})	32±1
$^{c}V_{\rm max}/\sigma_{\rm m}$	9.7±0.4
$^{d}V_{\rm flat}$ (km s^{-1})	259±1
$^{e}\sigma_{\rm ext}$ (km s^{-1})	18±1
$^{f}V_{\rm flat}/\sigma_{\rm ext}$	13.5±0.7



Q ~ 1: clumpy star forming regions

bump in rotation curve: a bulge is already in place

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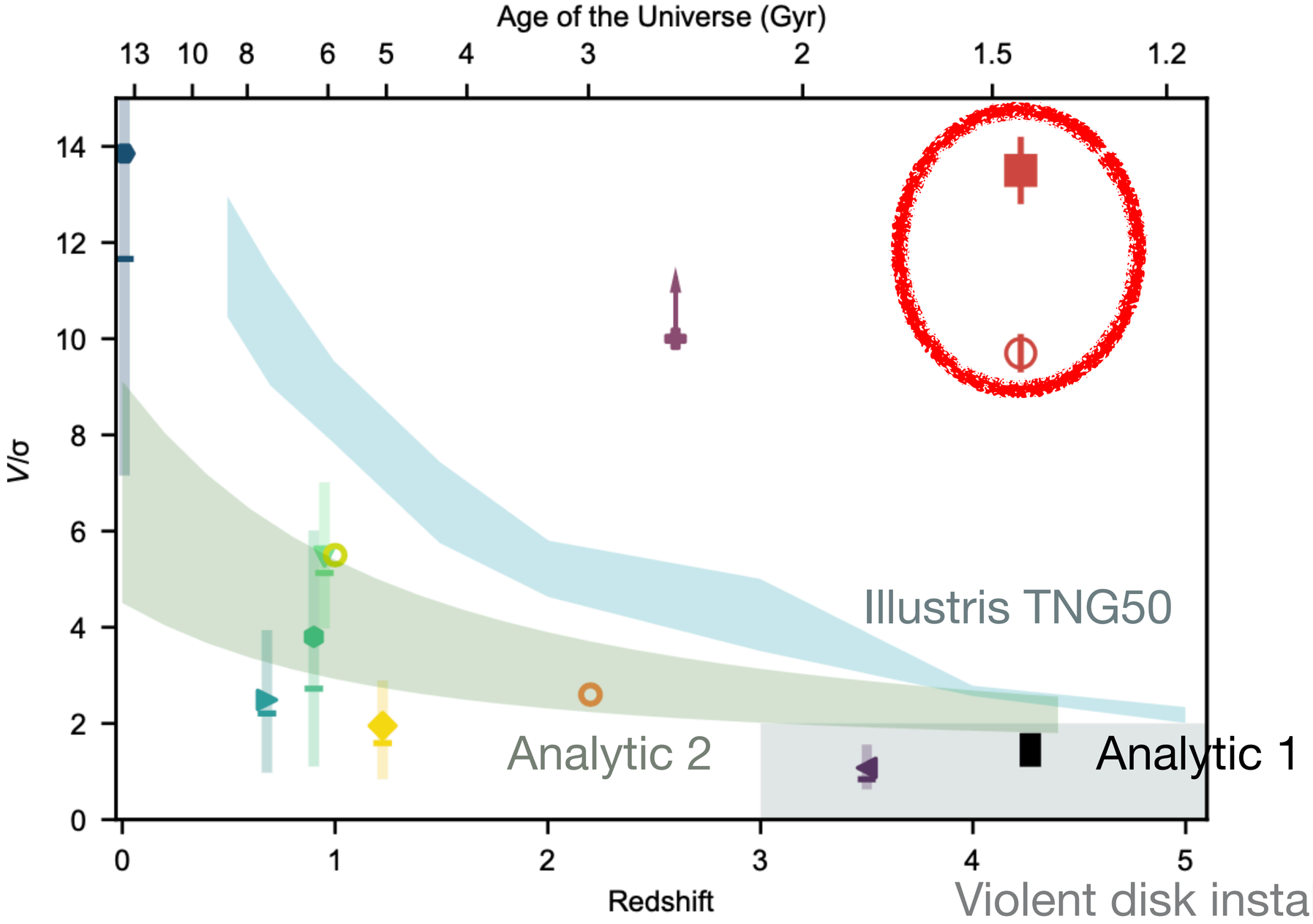


Violent disk instabilities Rizzo 2020

Take-home message

- A dynamically cold galaxy in the early Universe
- Possible progenitor for early-type galaxy in the local Universe
- Dispersion measured can be explained by stellar feedback driven turbulence

Transformation to ETGs

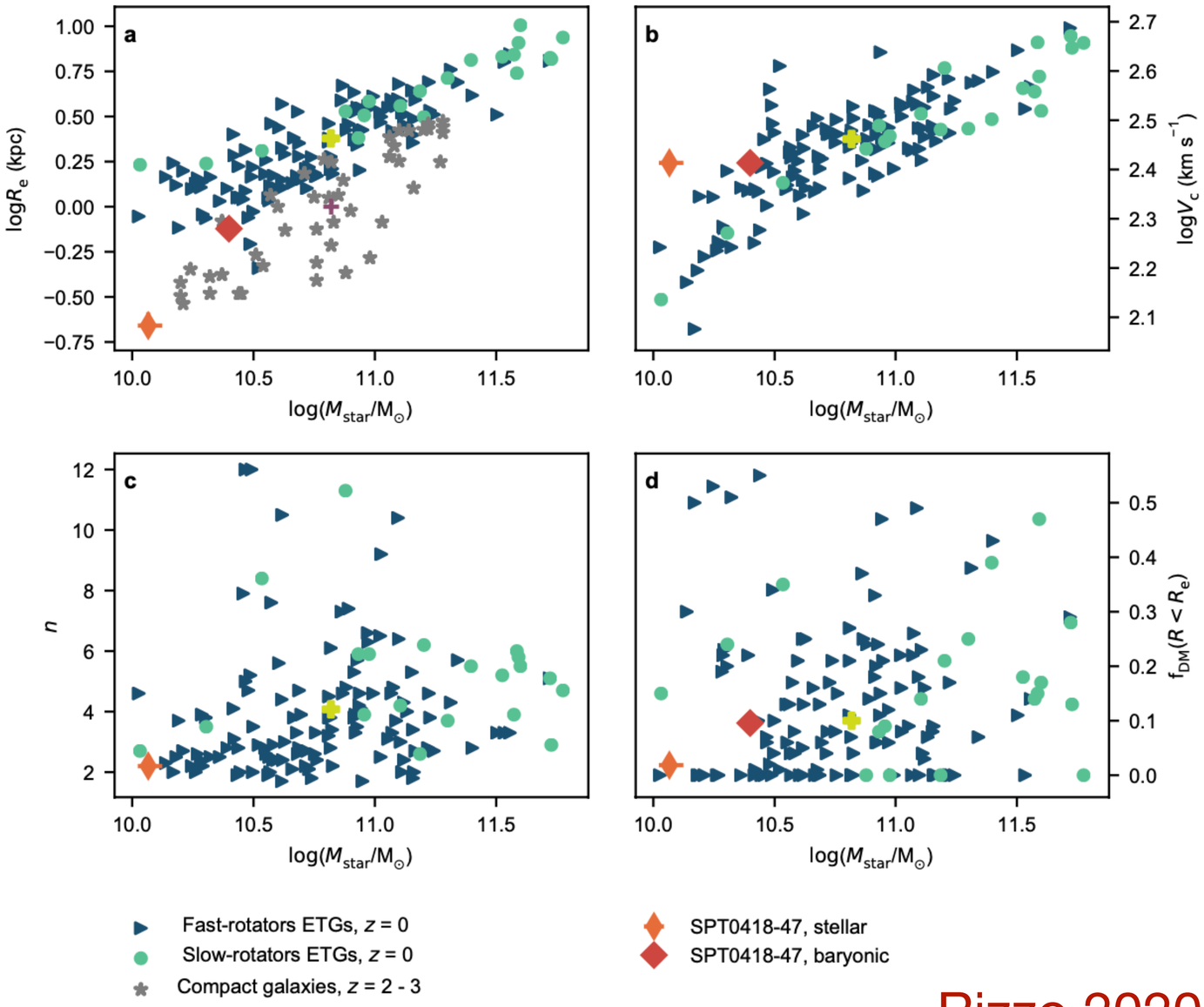
dusty starburst galaxies at high redshift

massive early-type galaxies in local Universe

1. dusty-starburst phase
2. quenching phase: AGN feedback leads to gas consumption and heating
3. quiescent galaxies at $z \approx 2$
4. dry minor mergers

Where will SPT–S J041839–4751.9 be in the local Universe?

Transformation to ETGs



- evolve smoothly into a **low-mass ETG** after the consumption and/or heating of **the cold gas reservoir**
- reach **the bulk of the ETG** population in the size–mass plane as predicted by **merger** scenario

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A dynamically cold galaxy in the early universe

Possible explanation for dispersion

$$E_{SNe} \approx E_{kin} \approx 5 \times 10^{56} erg$$

- velocity dispersion measured for SPT0418–47 can be explained as being produced by turbulence driven by stellar feedback
- compatible with dispersion measured for starburst galaxies at low and high redshifts(z ~ 2.6)

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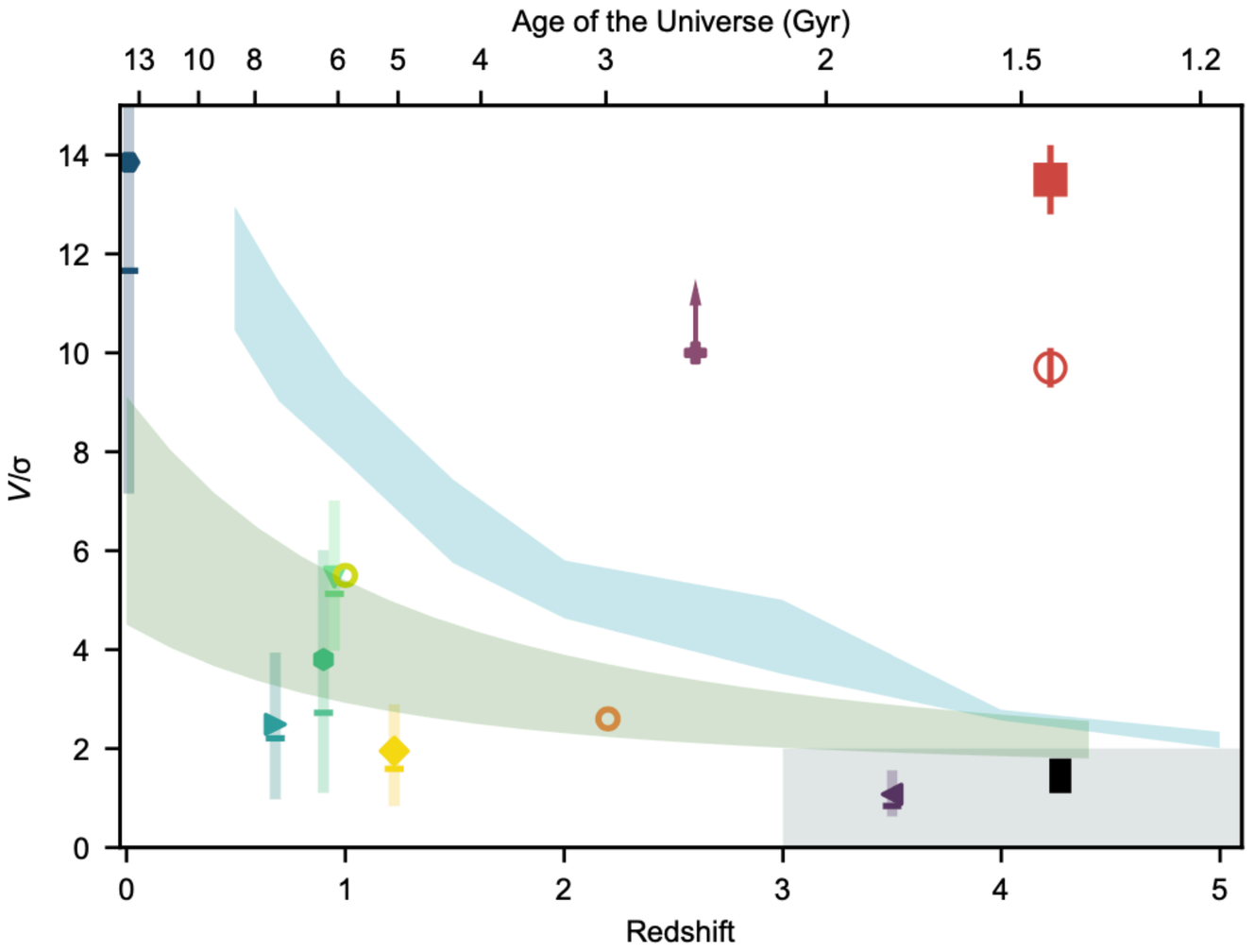
Related observations and Theories



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Observation of galaxies

Lelli et al. 2018

Loiacono et al. 2019

Neeleman et al. 2020

Lelli et al. 2021

etc.

Possible theories

Semenov et al. 2021

Fraternali et al. 2021

etc.

Questions

- Evolution of this galaxy
  - Can it smoothly evolve into low mass end of ETGs?
  - How could it only experience 1 single merger event?
- Comparison with galaxies at z~2?
- How could this galaxy gain such a high speed?
- What is the environment like?