Wednesday 26th June 2019

European Week of Astronomy and Space Science, Lyon, France

Symposium "Dynamics of disk galaxies in the era of large surveys"

Zoom-in cosmological hydrodynamical simulation of a star-forming, barred spiral galaxy at redshift z=2

Vincenzo, Kobayashi, Yuan, 2019, arXiv:1903.07958, under review

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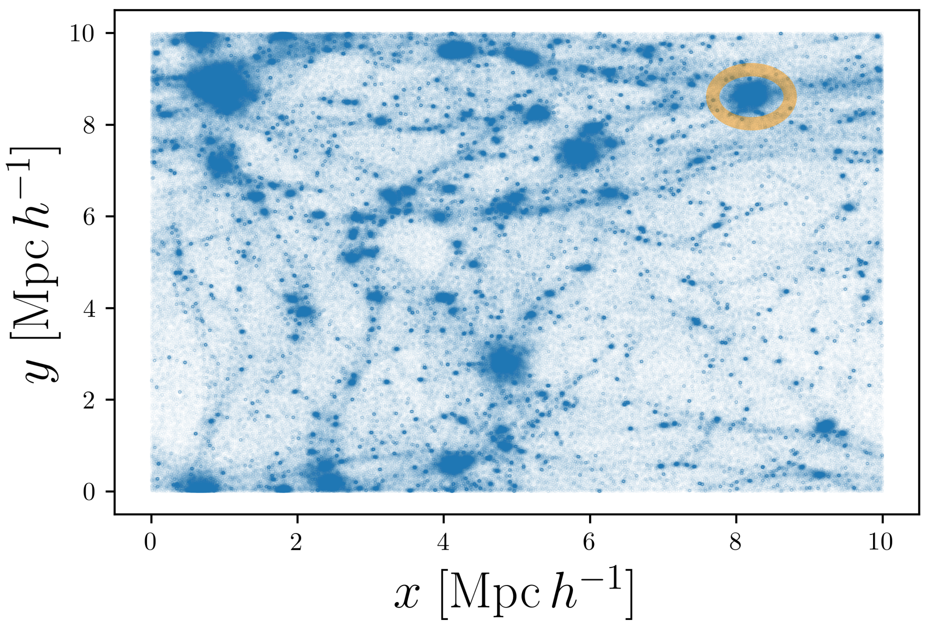
Zoom-in simulation of a star-forming barred spiral galaxy at z=2

The simulation code

- Assumed code: GADGET 3 (Springel et al., 2001; Kobayashi et al., 2007)
- Chemical enrichment and thermal energetic feedback by core-collapse Supernovae + hypernovae + Type Ia Supernovae + AGB stars

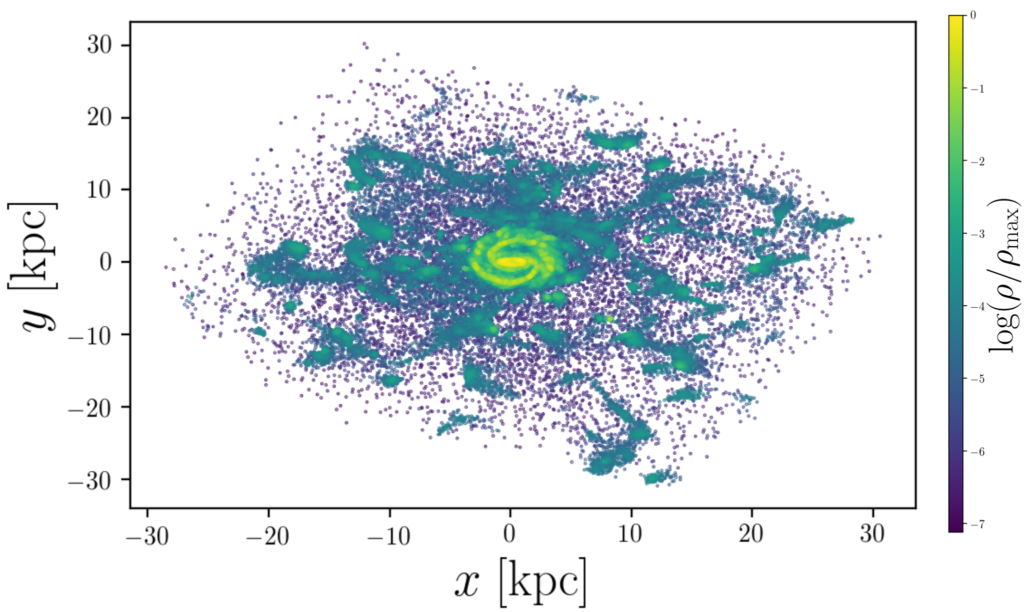


Parent cosmological hydrodynamical simulation

$N_{DM} = N_{gas} \sim 2 \times 10^6$

$M_{gas,res} \sim 6.3 \times 10^6\ M_\odot/h$

$M_{DM,res} \sim 3.5 \times 10^7\ M_\odot/h$



Zoom-in simulation

$N_{DM} = N_{gas} \sim 5 \times 10^6$

$M_{gas,res} \sim 9.9 \times 10^4\ M_\odot/h$

$M_{DM,res} \sim 5.4 \times 10^5\ M_\odot/h$

developed using MUSIC (Hahn & Abel, 2011)

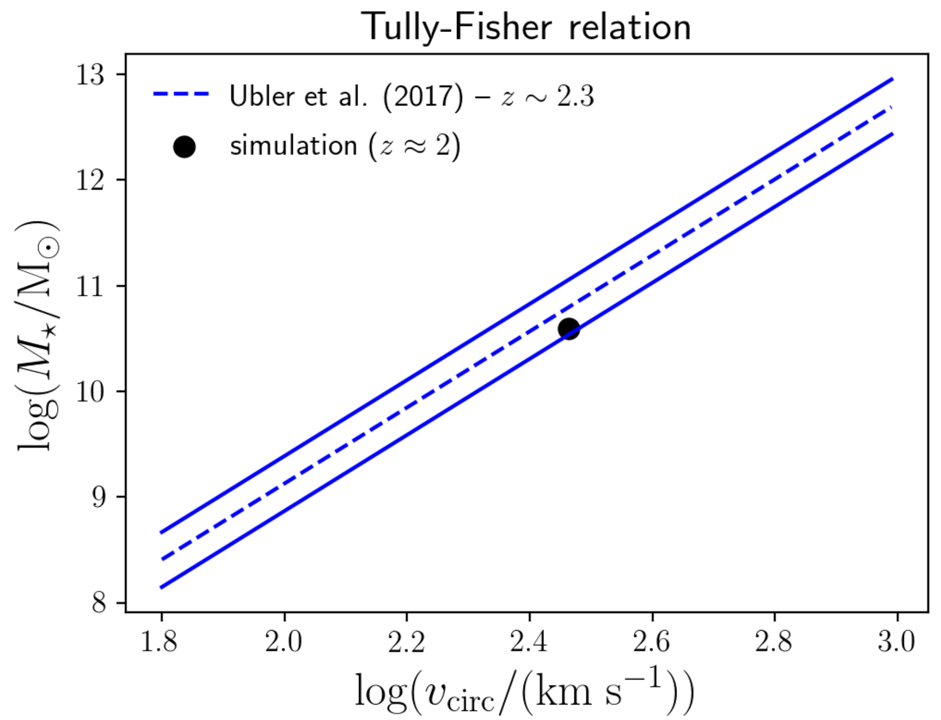
Zoom-in simulation of a star-forming barred spiral galaxy at z=2

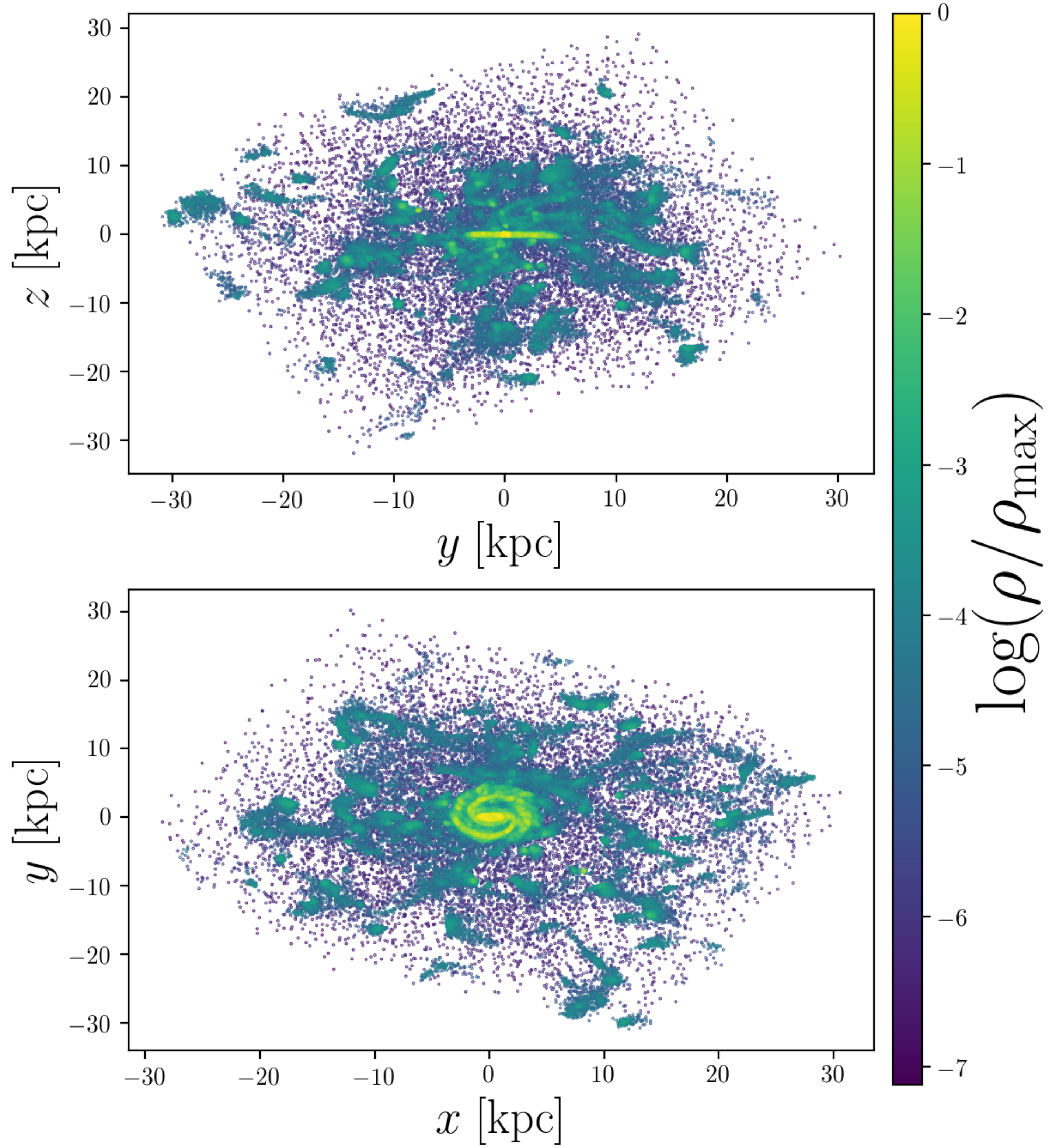
Galaxy properties at z=2

$M_{\rm gas}(z=2) \approx 9 \times 10^9\ {\rm M}_\odot$

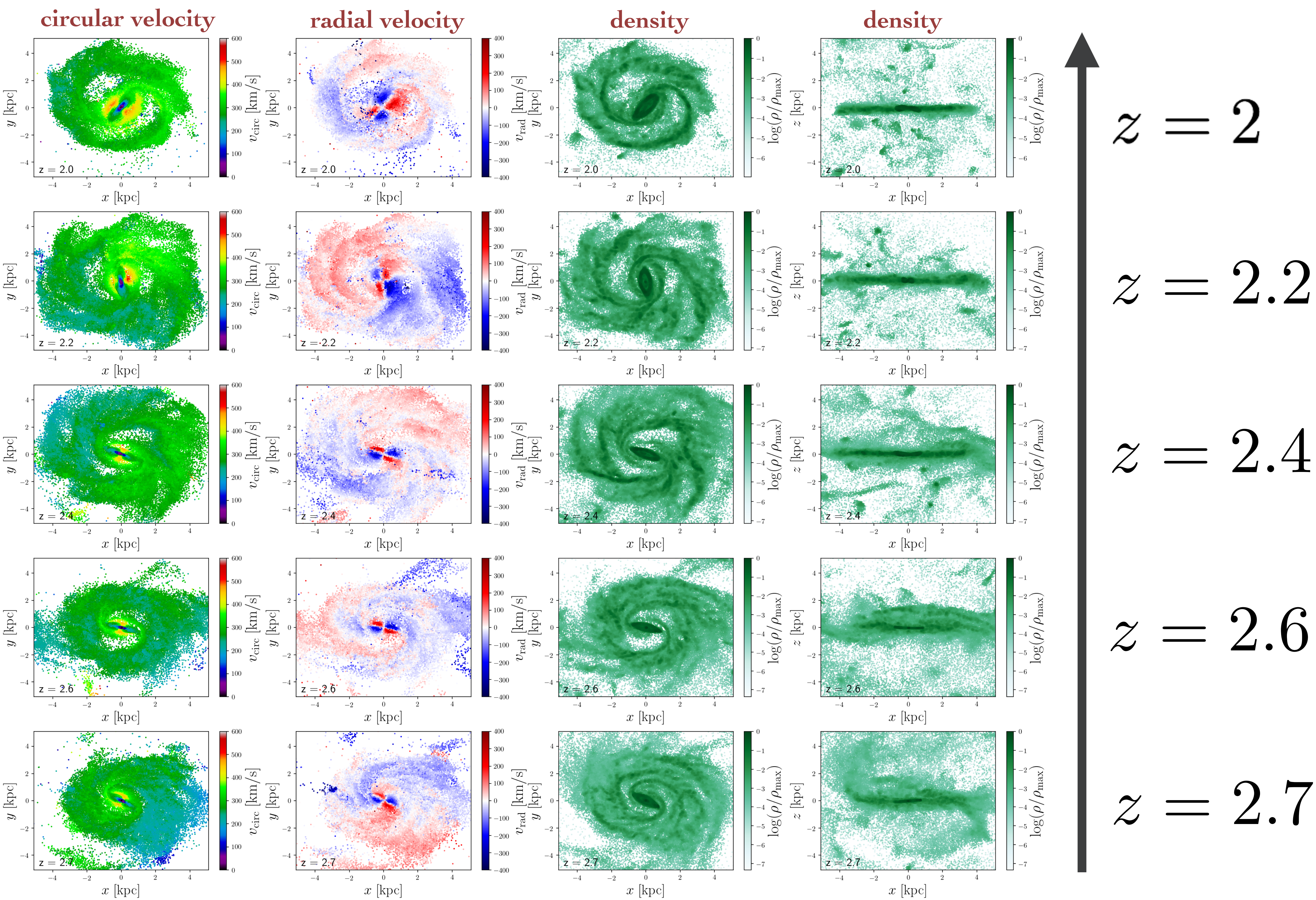
$M_\star(z=2) \approx 4 \times 10^{10}\ {\rm M}_\odot$

${\rm SFR}(z=2) \approx 8.5\ {\rm M}_\odot\ {\rm yr}^{-1}$





Zoom-in simulation of a star-forming barred spiral galaxy at z=2



Similar velocity and density structures over a relatively large redshift range

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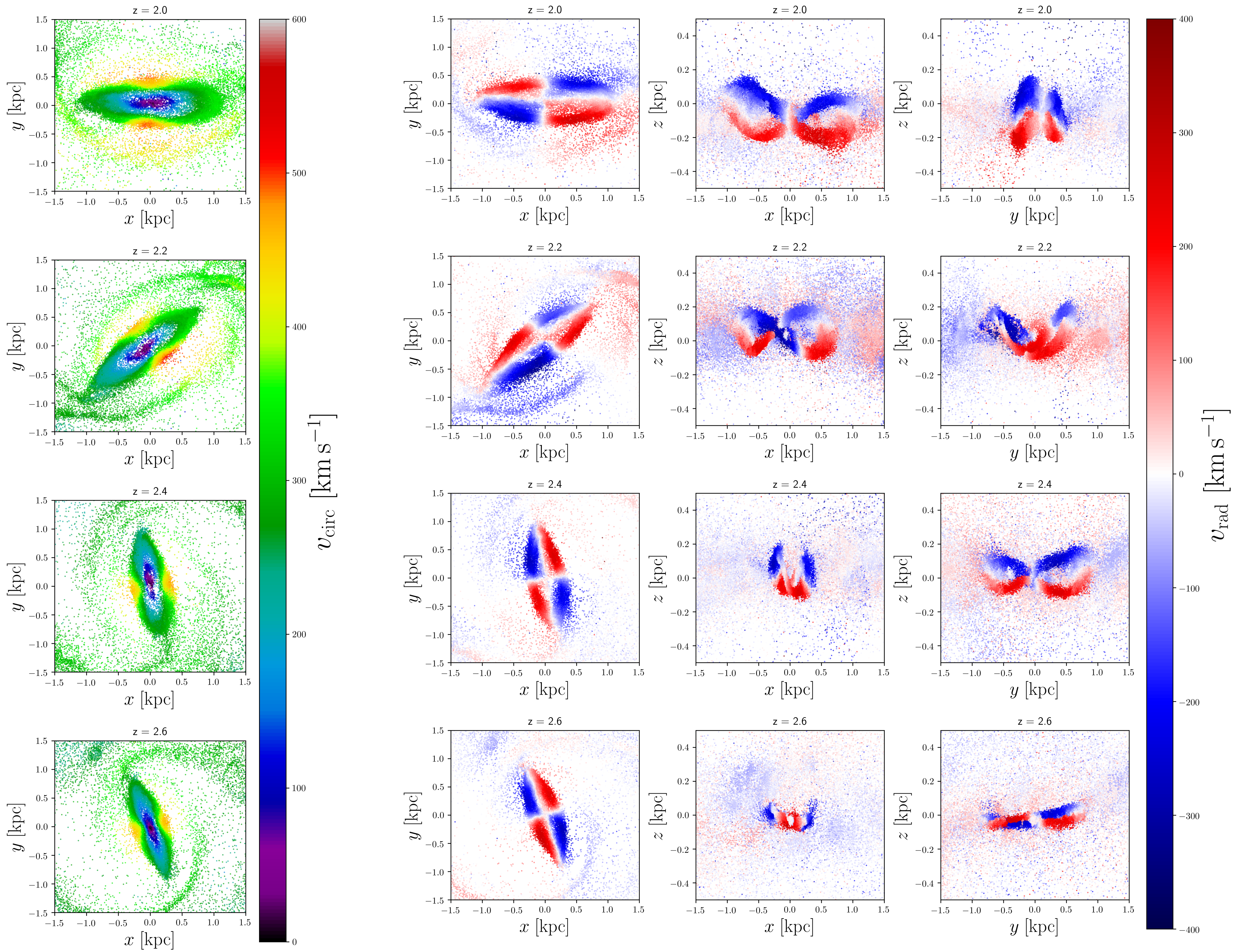
Kinematical properties of the bar

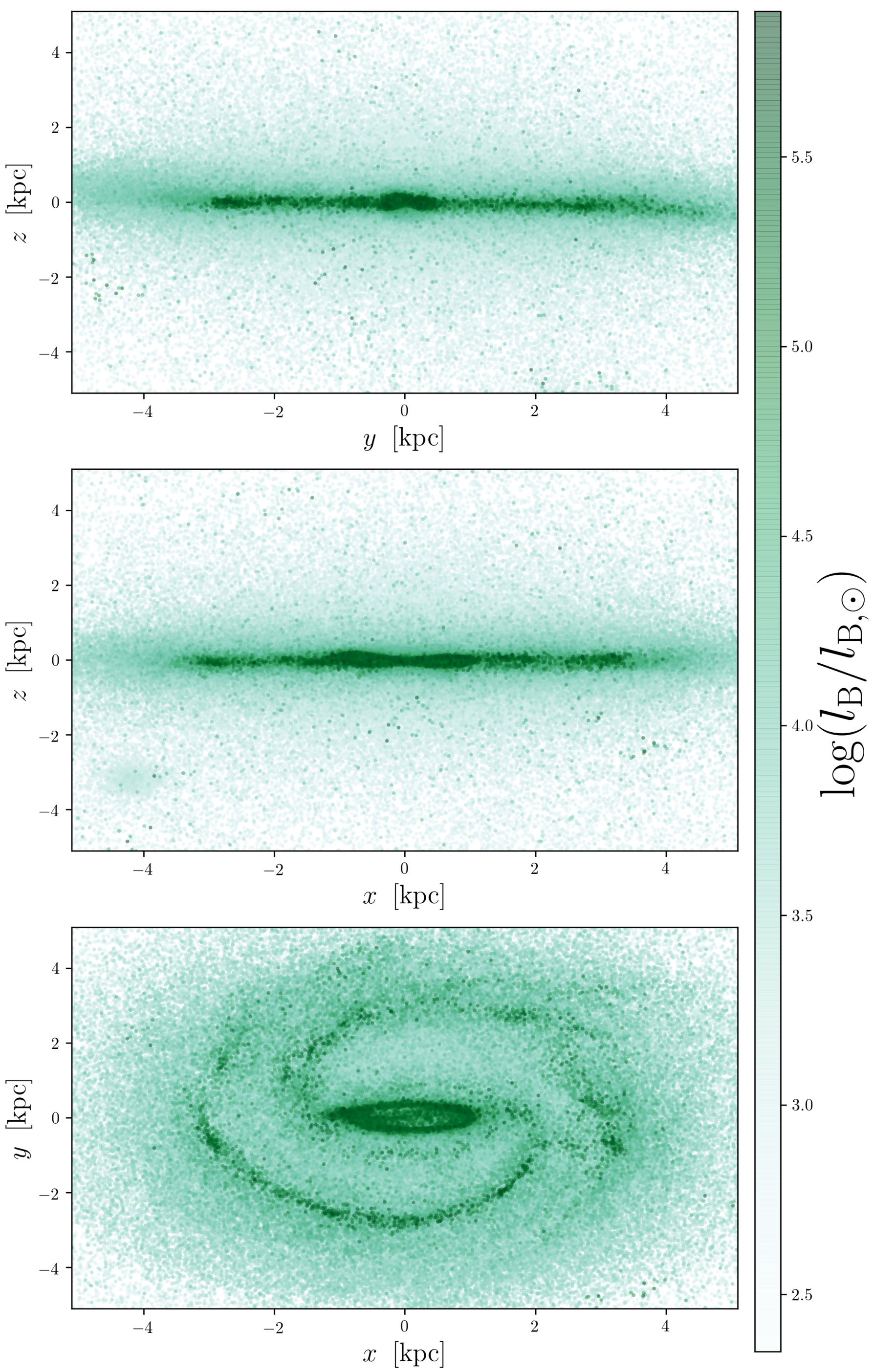
face-on circular velocity | face-on radial velocity | edge-on radial velocity | edge-on radial velocity



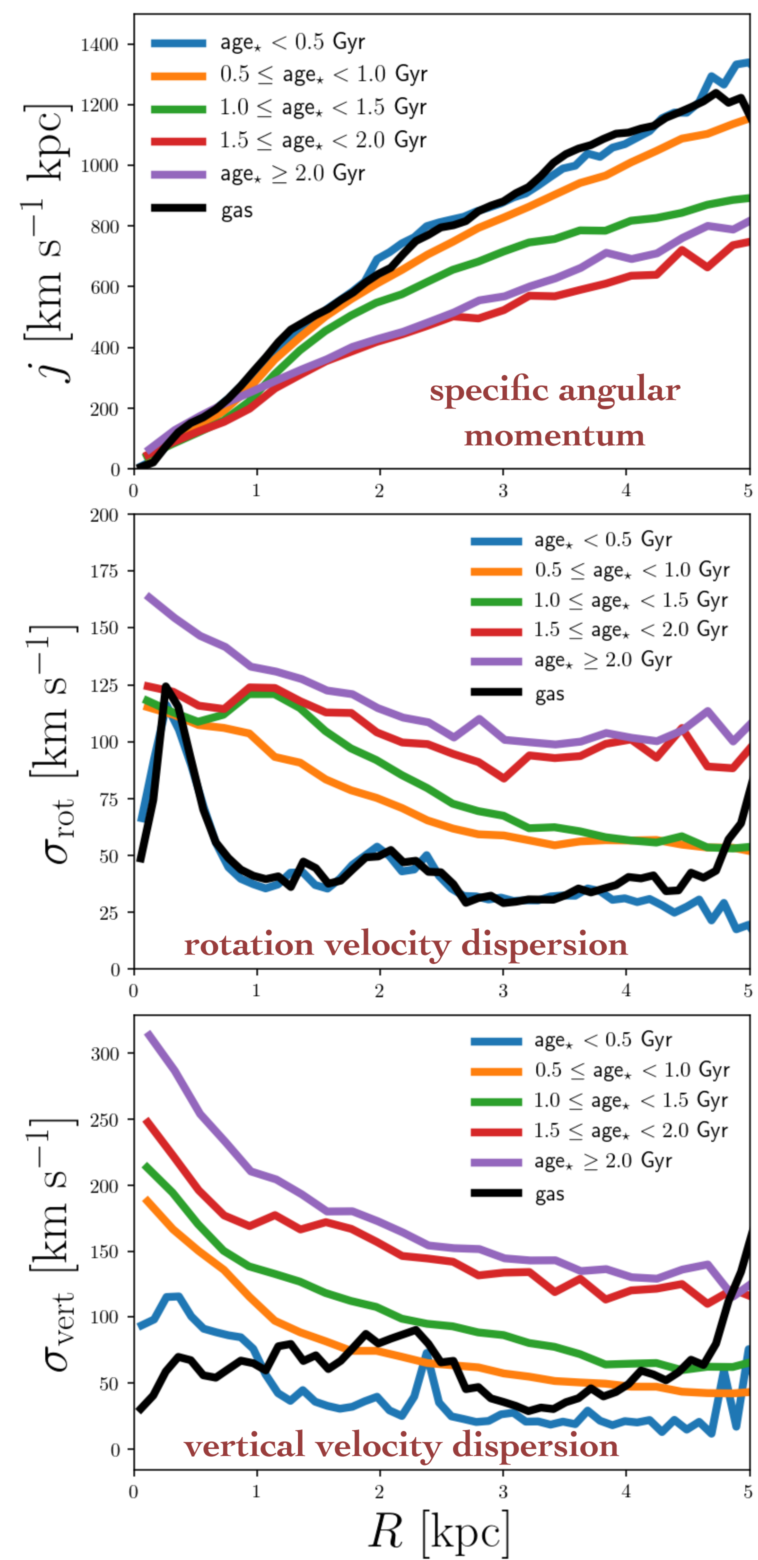
Kinematical properties of the galaxy stellar and gas components

Stellar populations

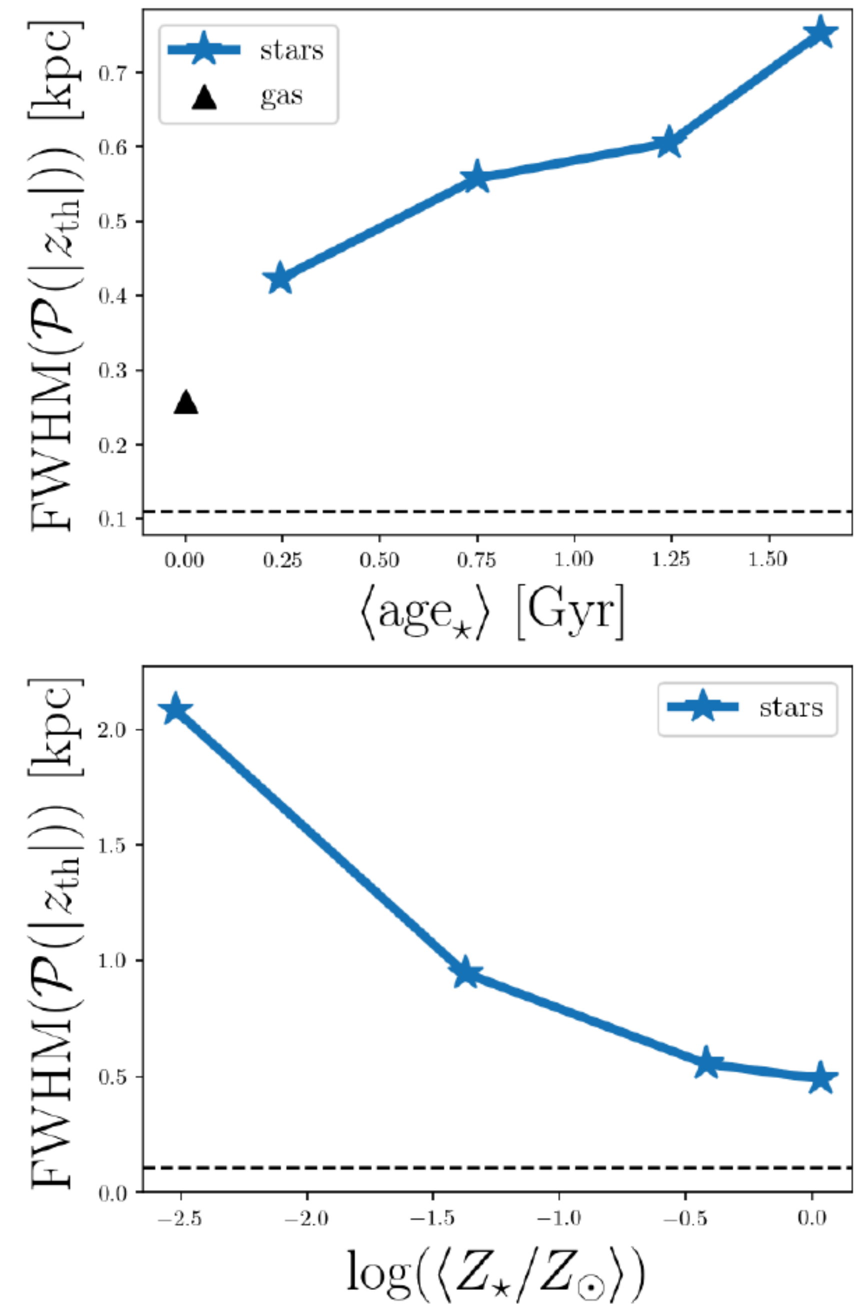
(stellar population synthesis model of Vincenzo et al., 2016)



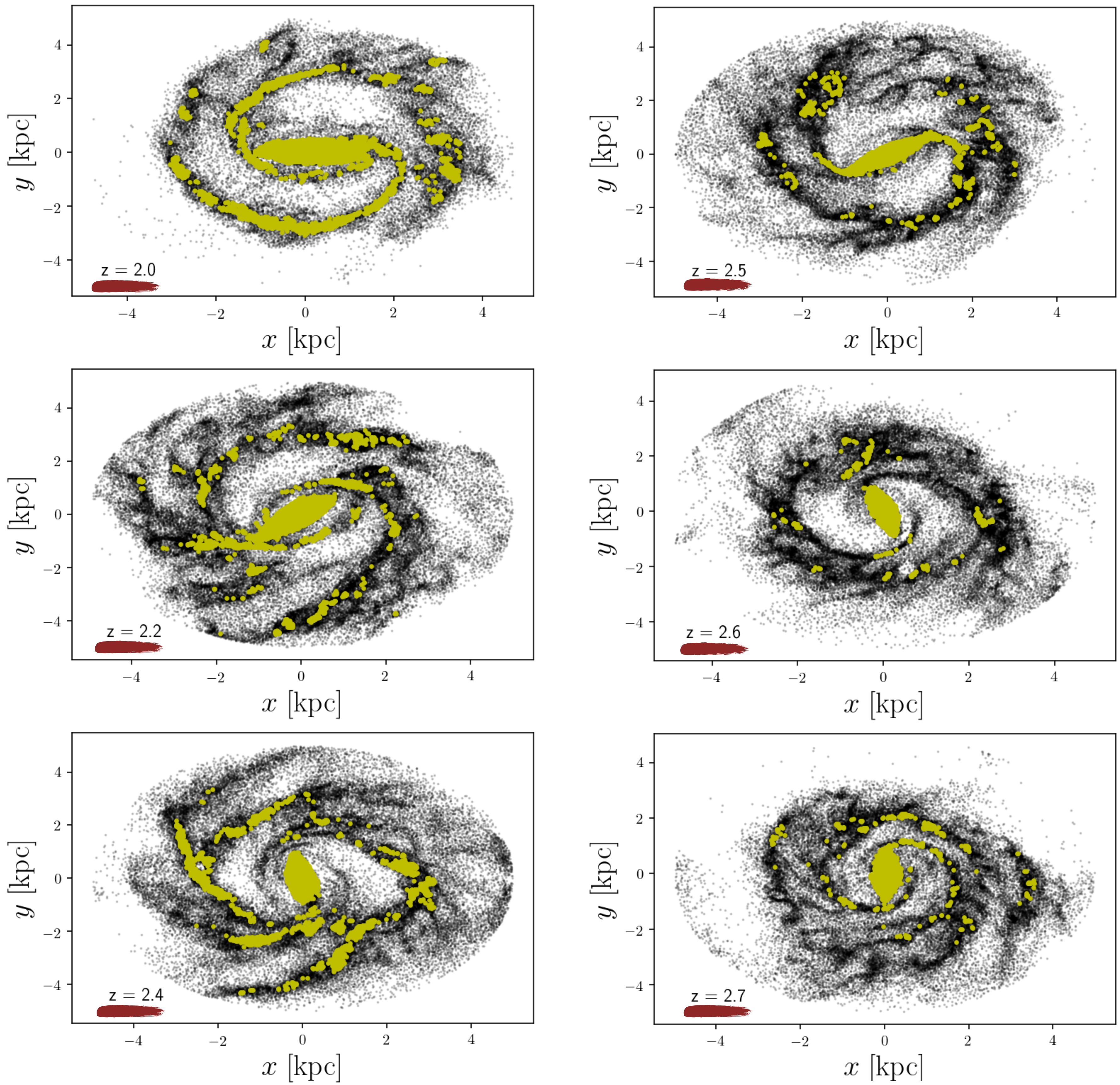
Evolution of the dynamical properties



Height distribution of the stars as a function of their age (top) and metallicity (bottom)

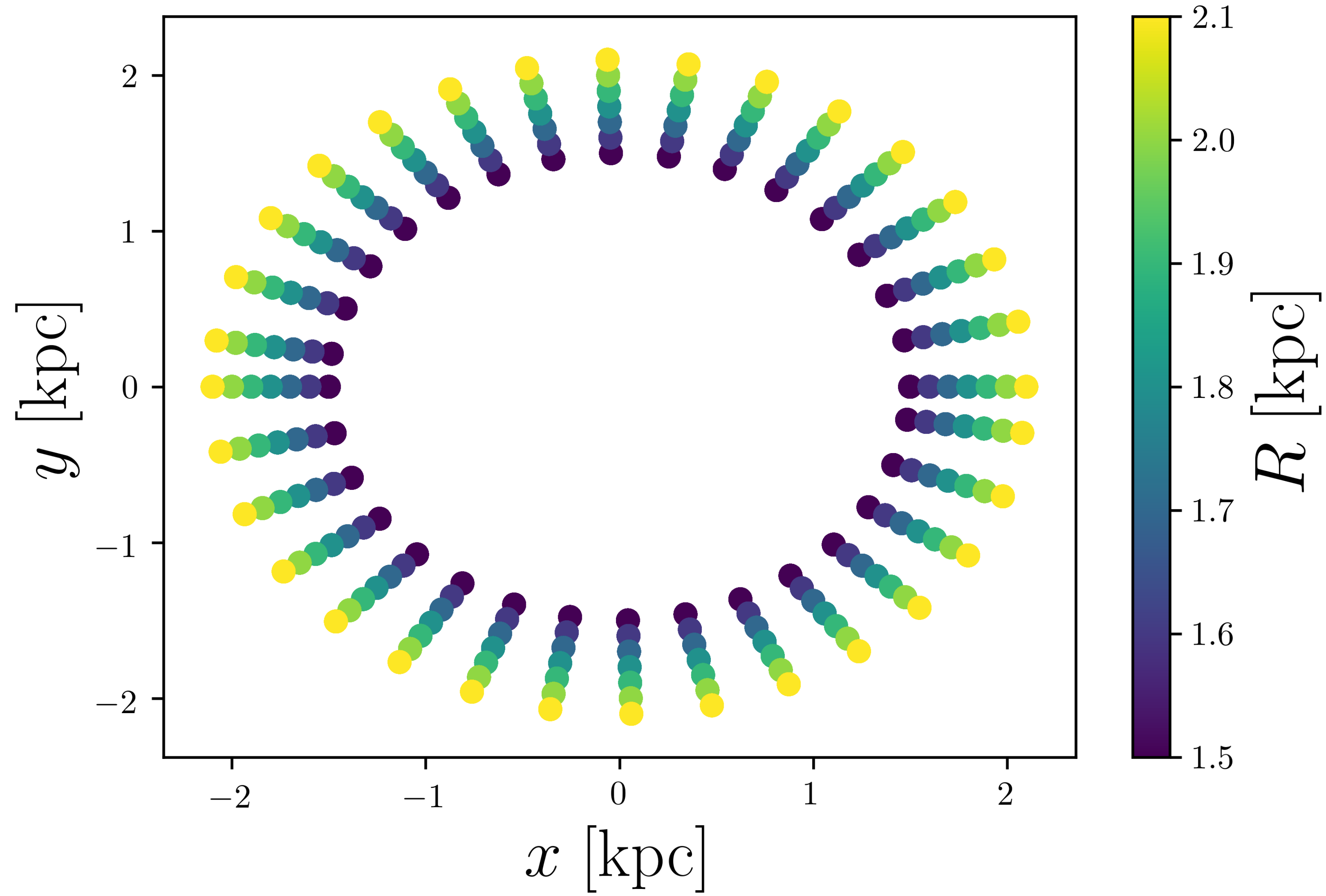


Where does SF take place in the simulation?



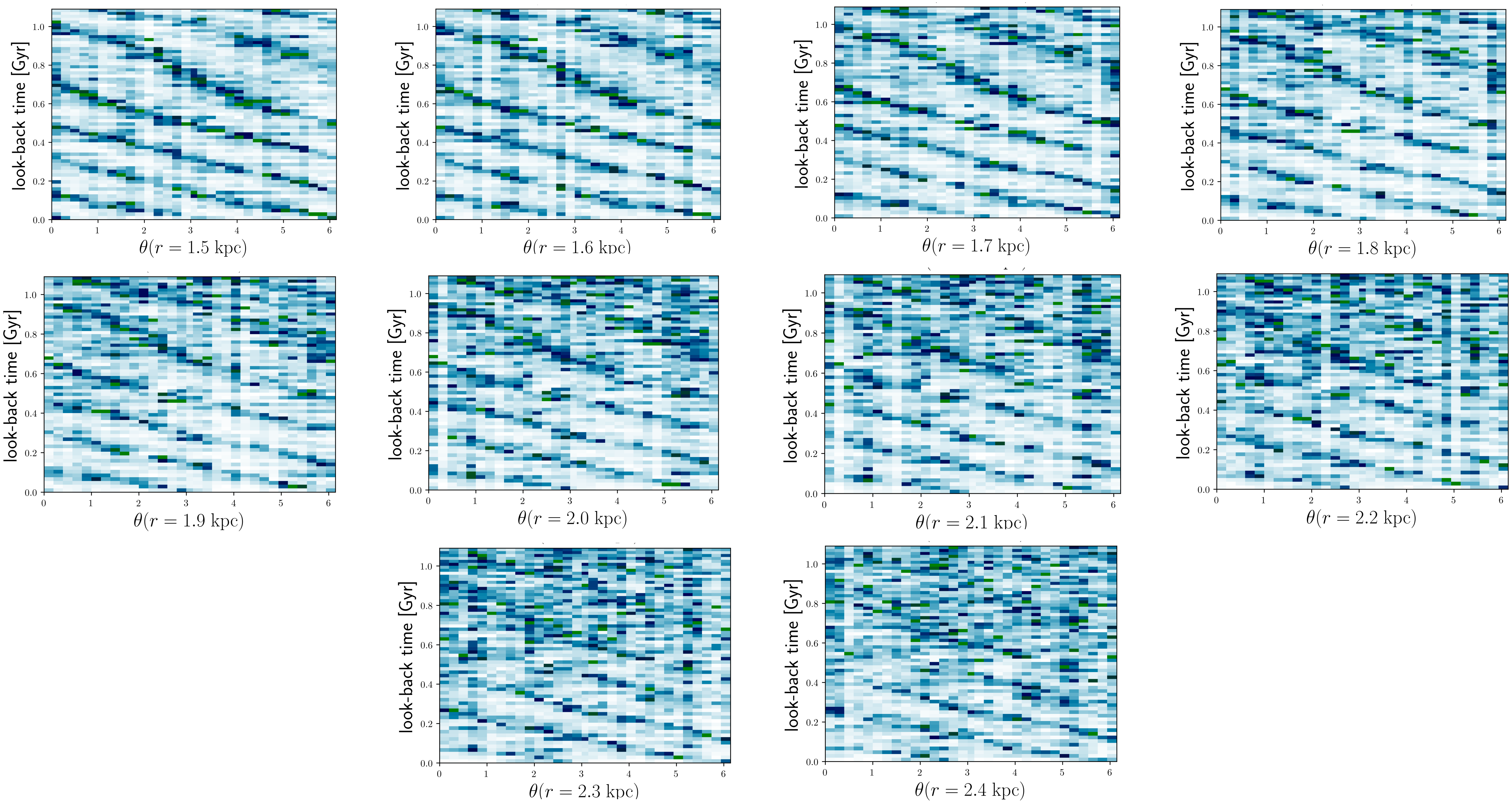
Characterising the spiral arms

Ideal observers sitting on the galaxy disc, which register the overdensity as a function of time (train of impulses), due to the passage of the spiral arms



Characterising the spiral arms

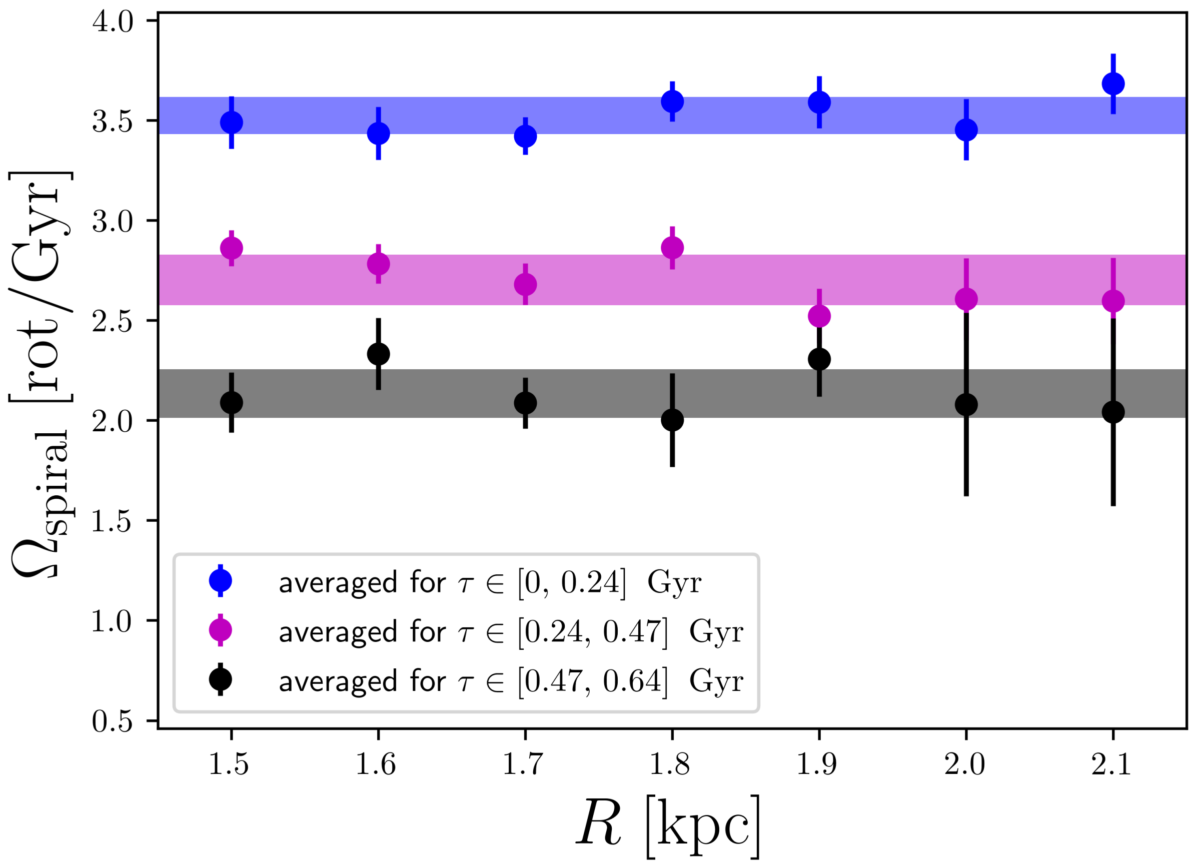
Evolution of the train of impulses seen by the ideal observers sitting on the disc, as the spiral arms cross their region, using *all* available snapshots from z=1.8 to z~3



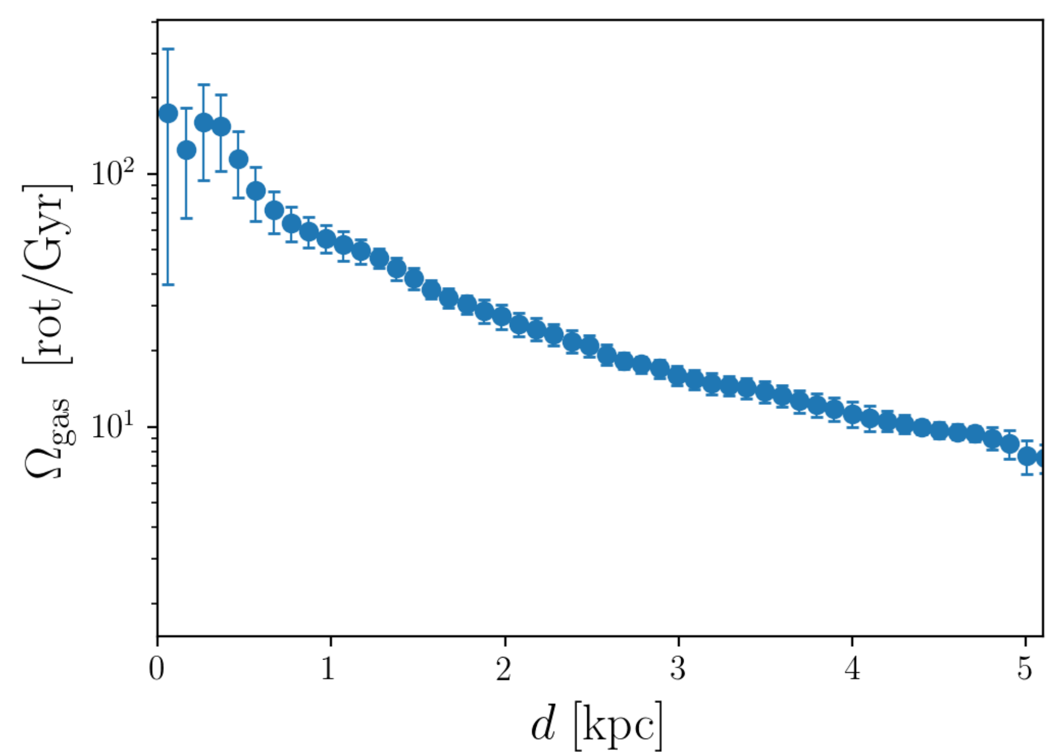
Slope of ***theta*** versus ***t*** relations gives the angular velocity of the spiral arms at that galactocentric distance and time interval

Characterising the spiral arms

Evolution of the angular velocity of the spiral pattern
(fitting the *theta* versus *t* relations with simple straight lines…)



Angular velocity of the gas on the thin disc at redshift z =2



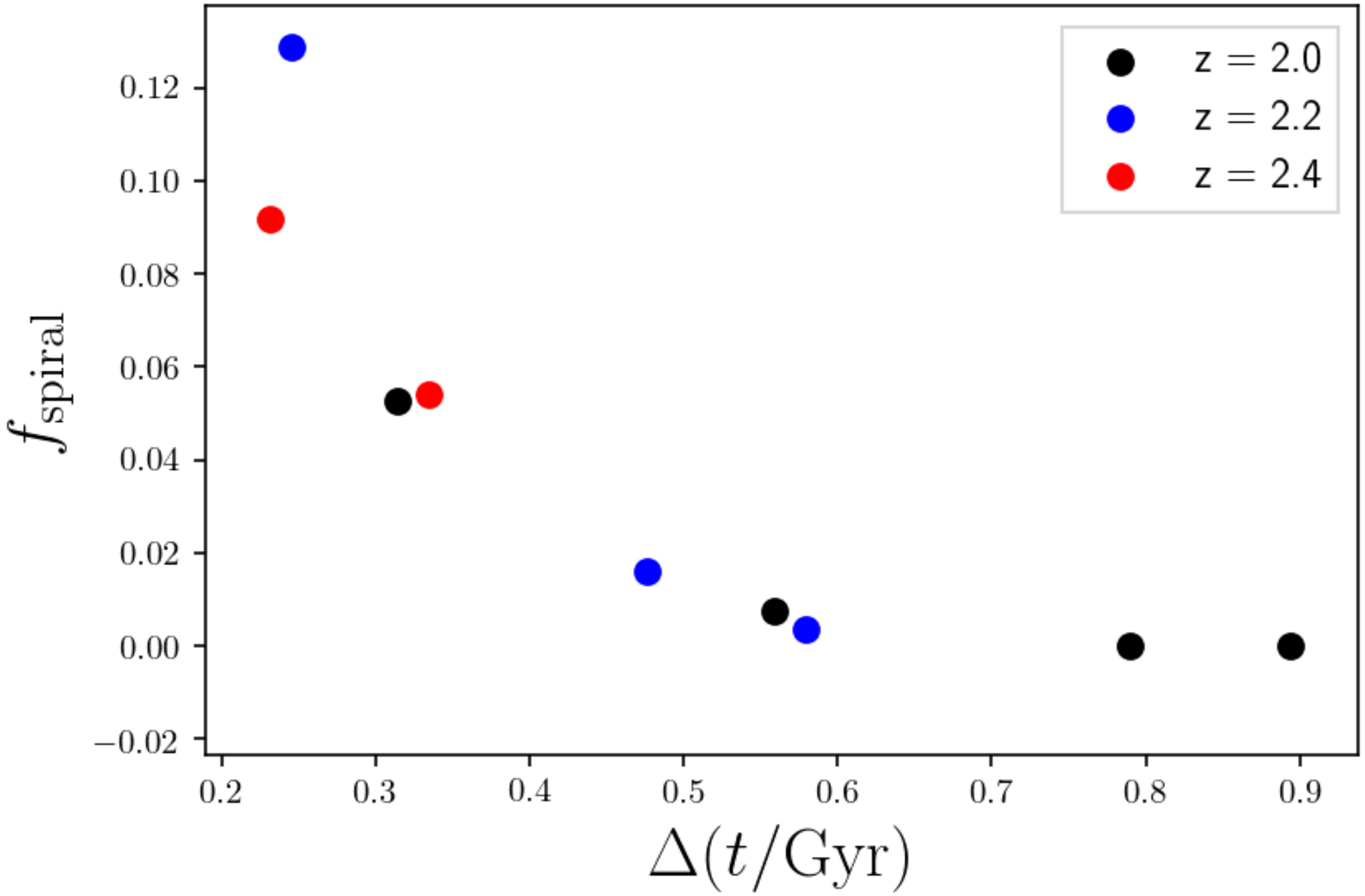
The spiral pattern speeds up as a function of time, keeping its constant angular velocity radial profile

co-rotation radius

$$\Omega_{\rm gas}(R_{\rm cor}) = \Omega_{\rm spiral}$$

Characterising the spiral arms

Fraction of stars on the spiral arms in common between different redshifts



$$f_{\text{spiral}} = \frac{\text{stars on the spiral arms in common between } z_1 \text{ and } z_2}{N_\star \text{ on the spiral arms at } z_1}$$

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Summary

Formation and evolution of a SF barred spiral galaxy at high redshift

The main physical properties resemble those of the local spirals, even though the ISM condition at high redshifts are more turbulent

Questions:

Are we dealing with (generally speaking) **density-waves**?

Spiral arms in the simulation host star-forming ISM regions + young stars + rotate with constant angular velocity.

The dynamical structure of the spiral arms in the simulation is different than that of the stars and gas on the thin disc

N.B. other theories (e.g., **manifold theory**) can give rise to an *apparent* constant angular velocity of the spiral arms with time.

How do spiral arms affect the metallicity gradients in the galaxy ISM in the simulation?

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