Environmental effects on sizes of gas disk and stars

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Environmental effects on satellite galaxies

- Satellite galaxies are redder, less active than their central counterparts;
- Satellite galaxies are HI-deficient;
- The quenching time-scale is long, and is difficult to be reproduced in hierarchical models.
- Theoretical processes of gas removal — strangulation, ram-pressure, tidal stripping, which one is dominate?

Environmental effects on size

- Theoretical deduction: A satellite suffering ram-pressure and tidal stripping have decreasing Rgas/Rstar; if it is suffering strangulation, the size ratio is a constant;
- Observation: truncated Ha profile and gas density profile, extended star forming tail, similar stellar size-mass relation between central and satellite;
- All the differences between galaxies in is based on the hypothesis that central and satellite galaxies of given mass reside in similar 'environment' before accretion. What if they were already different at accretion time — effect of assembly bias?

Motivation

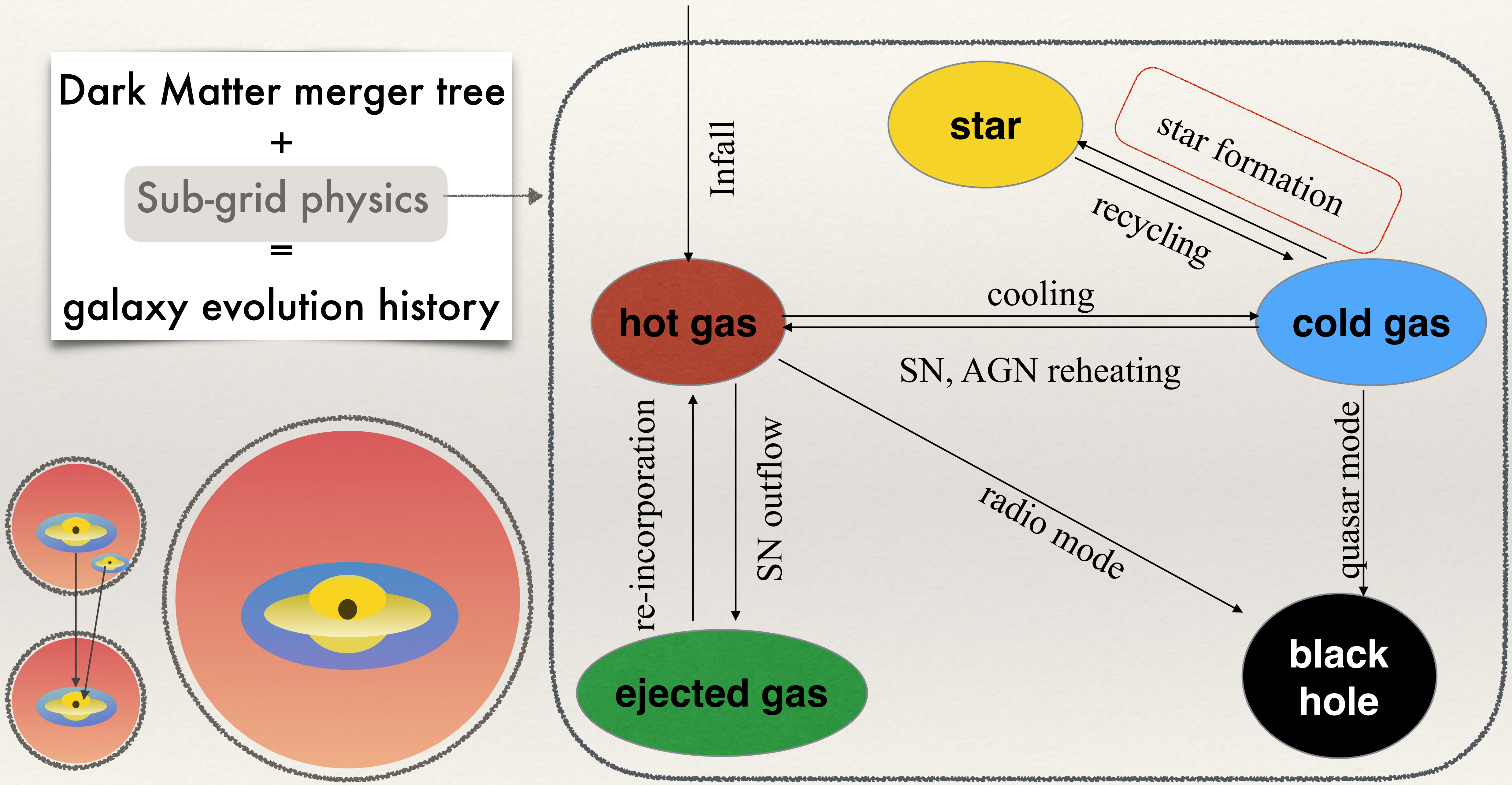
- Do central and satellite galaxies have different SF and stellar sizes?
- When did central and satellite galaxies become different — before (-assembly bias) or after (-environmental effects) accretion?
- Can galaxy formation model reproduce the observed difference? and why or why not?

Use semi-analytic models to study the evolution of galaxies

- Connect galaxies at high z with those at low z, trace their evolution history
- Self-consistent
- Include various galactic physics motivated by theories of observations: star formation, SN feedback, recycling, AGN feedback…
- Computational efficient: test physical models, test hypothetical theories…

From dark matter haloes to galaxies

Dark Matter merger tree
+
Sub-grid physics
=
galaxy evolution history



Galaxy Evolution and Assembly (GAEA) – a state-of-art SAM

- Detail chemical enrichment: enrich ISM accounting finite lifetime of stars; De Lucia et al. 2014
- Supernovae feedback model: good agreement with observed stellar mass function up to z~3; Hirschmann et al. 2016
- Multi-phase cold gas: H2-based star formation laws; Xie et al. 2017

gas disk, stellar disk and bulge size

- Angular momentum of gas disk:

$$\Delta J_{\rm gas} = J_{\rm cooling} - J_{\rm SF} + J_{\rm recycling} + J_{\rm merger,gas} - J_{\rm SNfb},$$

- Angular momentum of stellar disk:

$$\Delta J_{\star} = J_{\rm SF} - J_{\rm recycling} + J_{\rm merger,\star} + J_{\rm ins}$$

- The scale radius of gas disk and stellar disk (Mo, Mao & White 1998):

$$r_{\rm gas,d} = \frac{J_{\rm gas}/M_{\rm gas}}{2V_{\rm max}}, r_{\star,\rm d} = \frac{J_{\star}/M_{\star}}{2V_{\rm max}},$$

- Density profile of gas disk and stellar disk: $\Sigma_d = \Sigma_0 exp(-\frac{r}{r_d})$

- Bulge profile (Jaffe law):

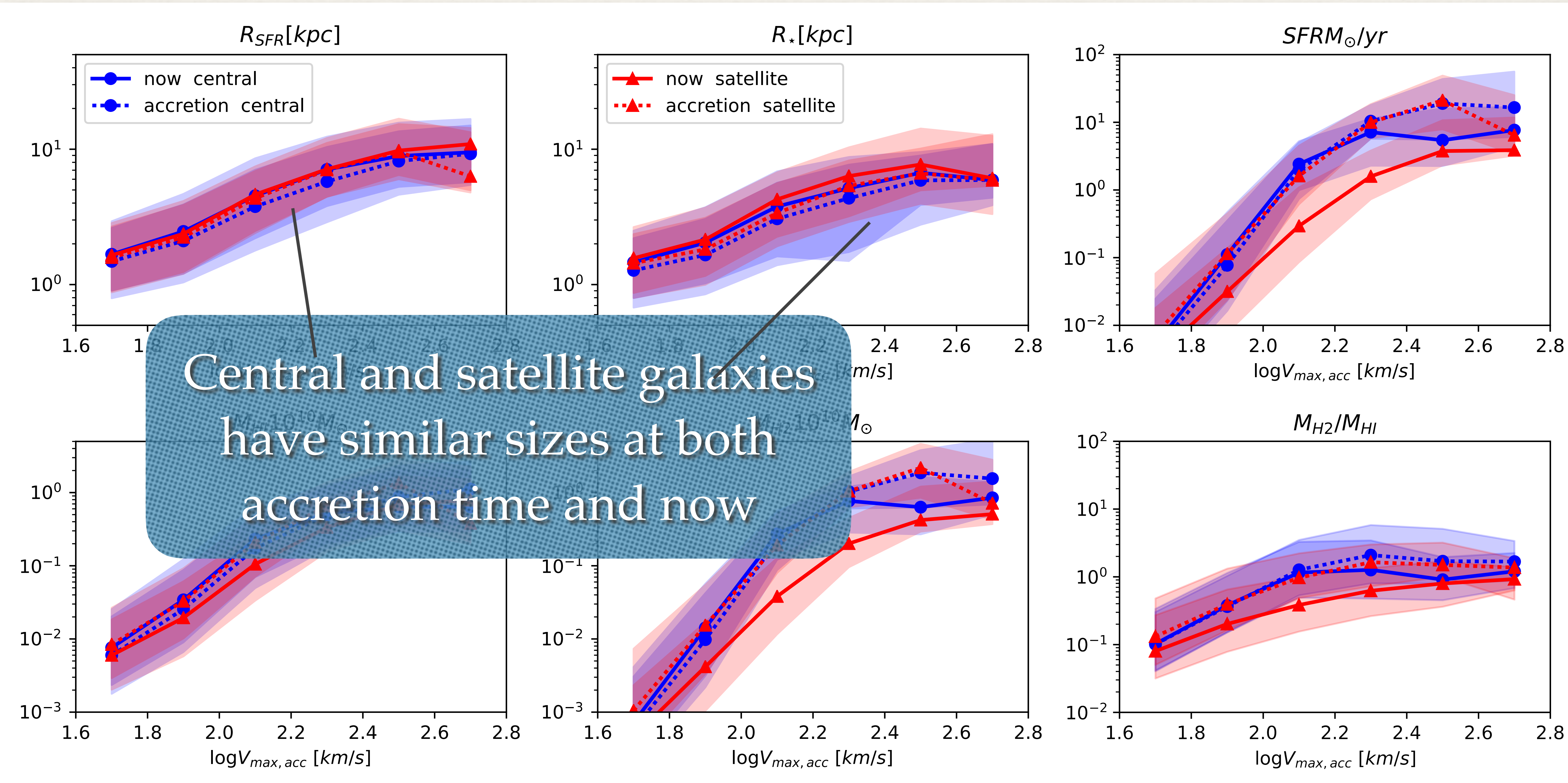
$$j_{\rm b} = \frac{M_{\rm b} r_{\rm b}}{4\pi r^2 (r + r_{\rm b})^2}$$ (3D)

$$I_{\rm b}(R) = \int_R^{\infty} j(r) \times \frac{r}{(r^2 - R^2)^{1/2}} dr$$ (projected)

- H2,HI, and SFR profile: count the molecular ratio and SFR in concentric annuli on the disk.

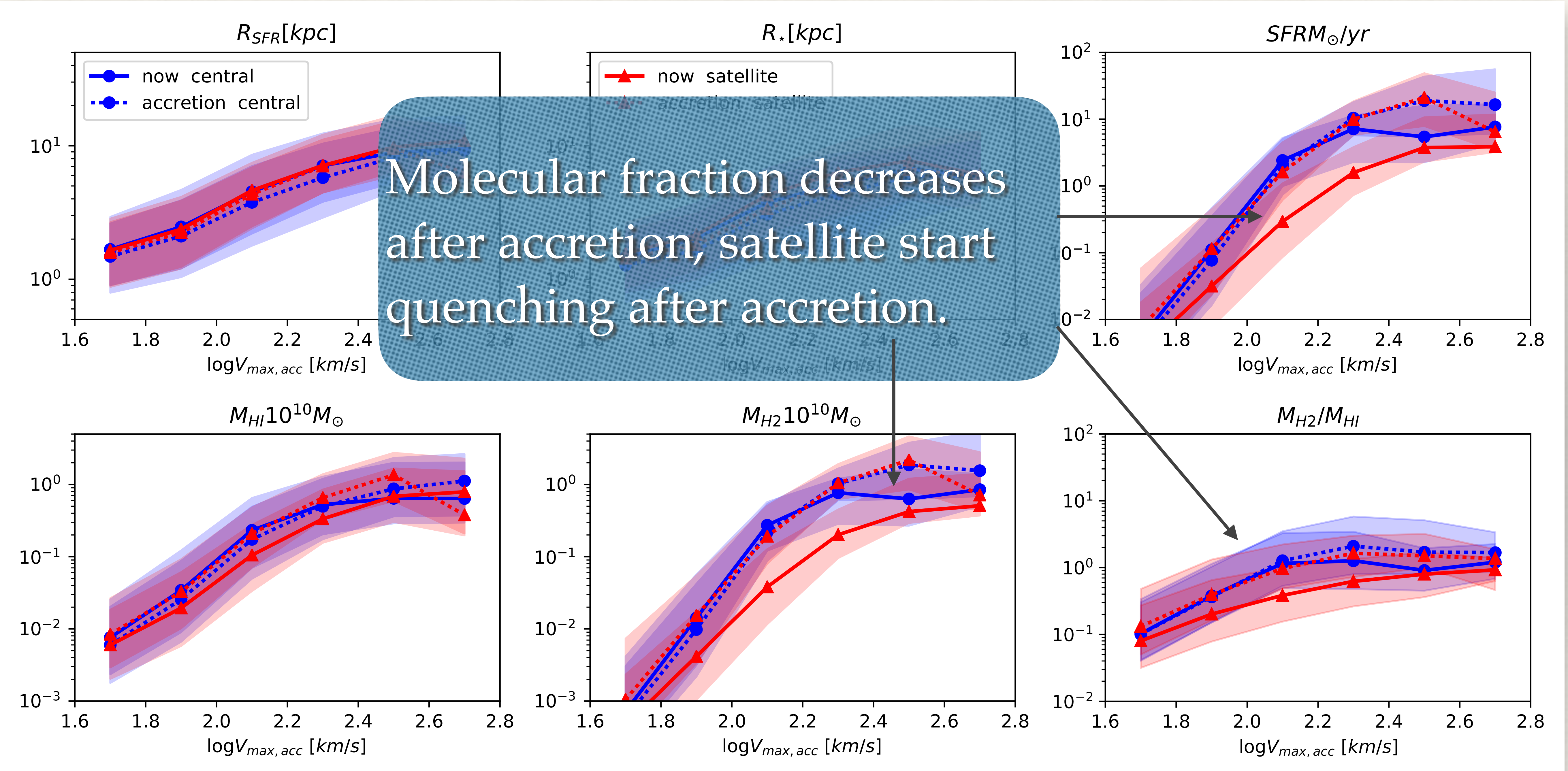
Xie et al. 2017, arXiv: 1611.09372

Late-type galaxies in the model at accretion time and now

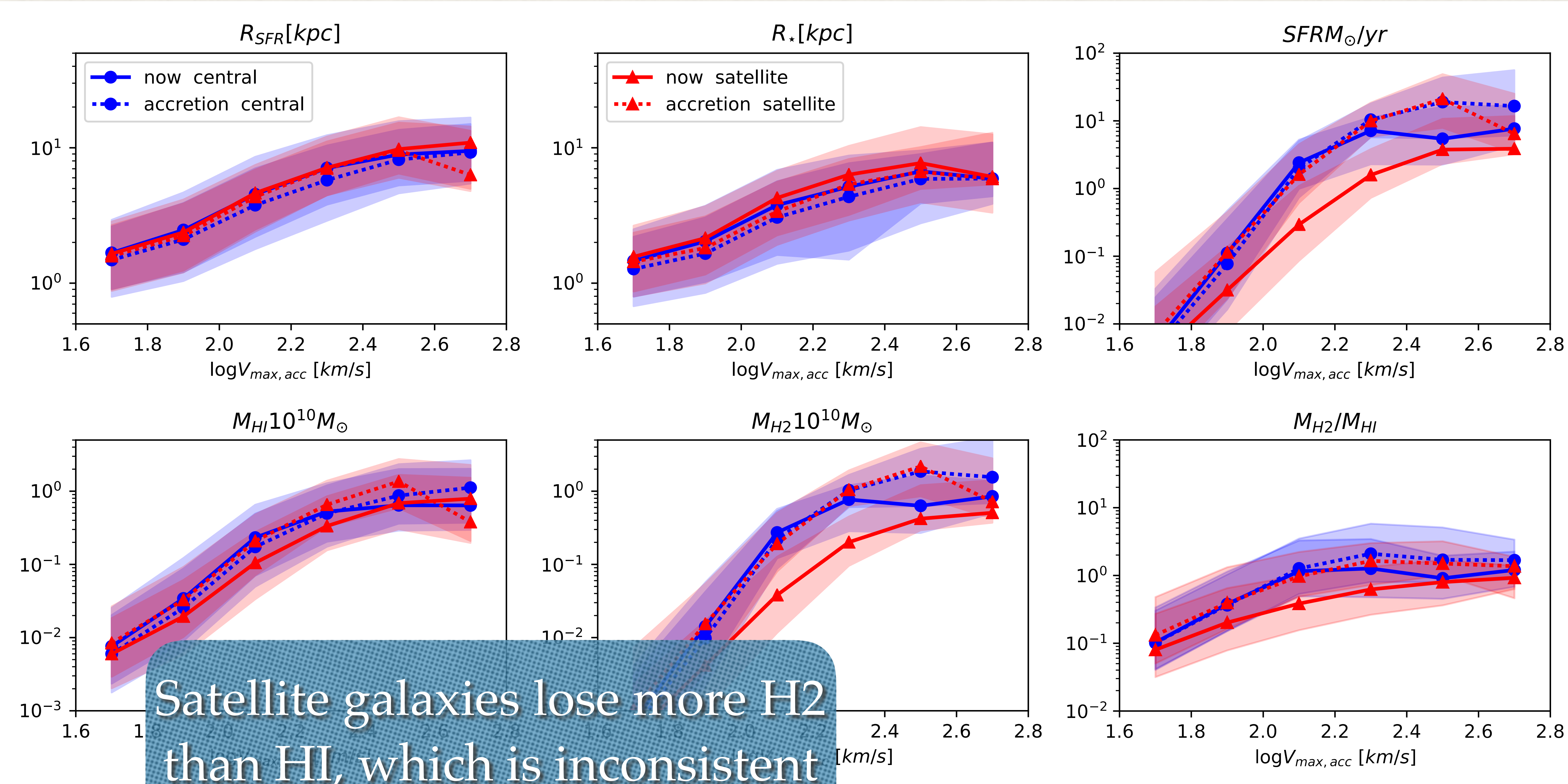


Central and satellite galaxies have similar sizes at both accretion time and now

Late-type galaxies in the model at accretion time and now

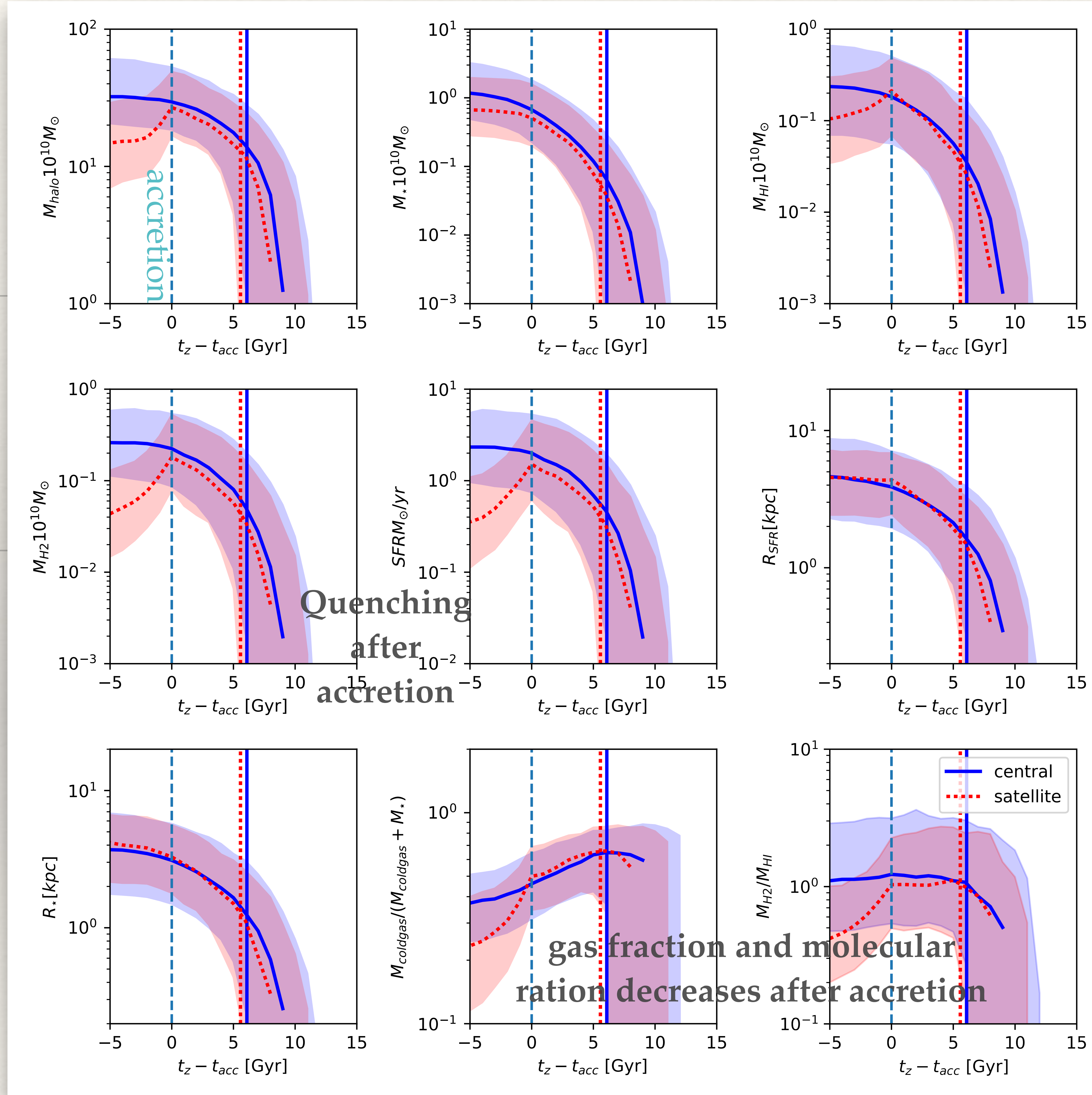


Late-type galaxies in the model at accretion time and now



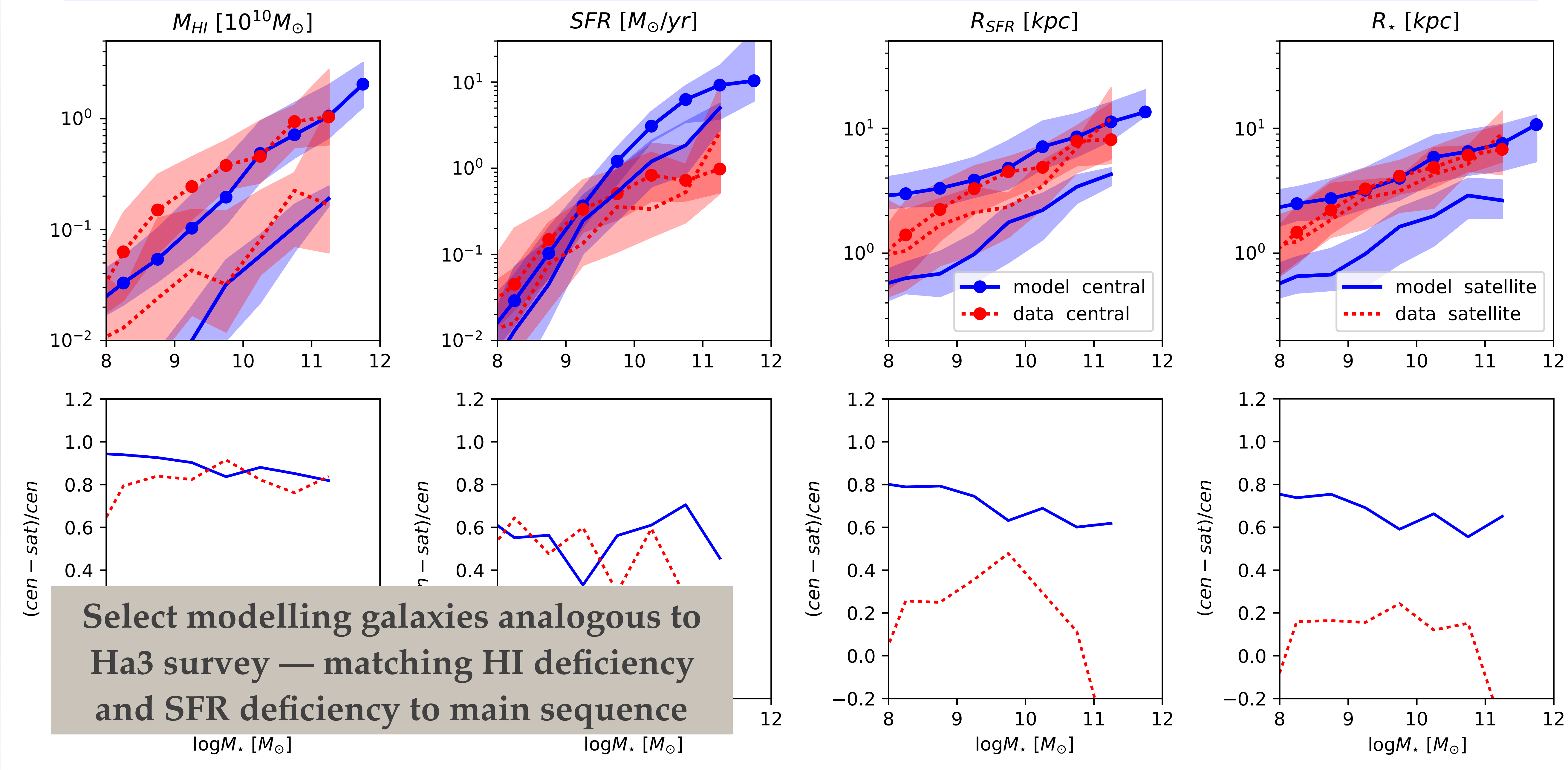
Satellite galaxies lose more H2 than HI, which is inconsistent with observation.

Evolution of central and satellite galaxies



Compare with observation

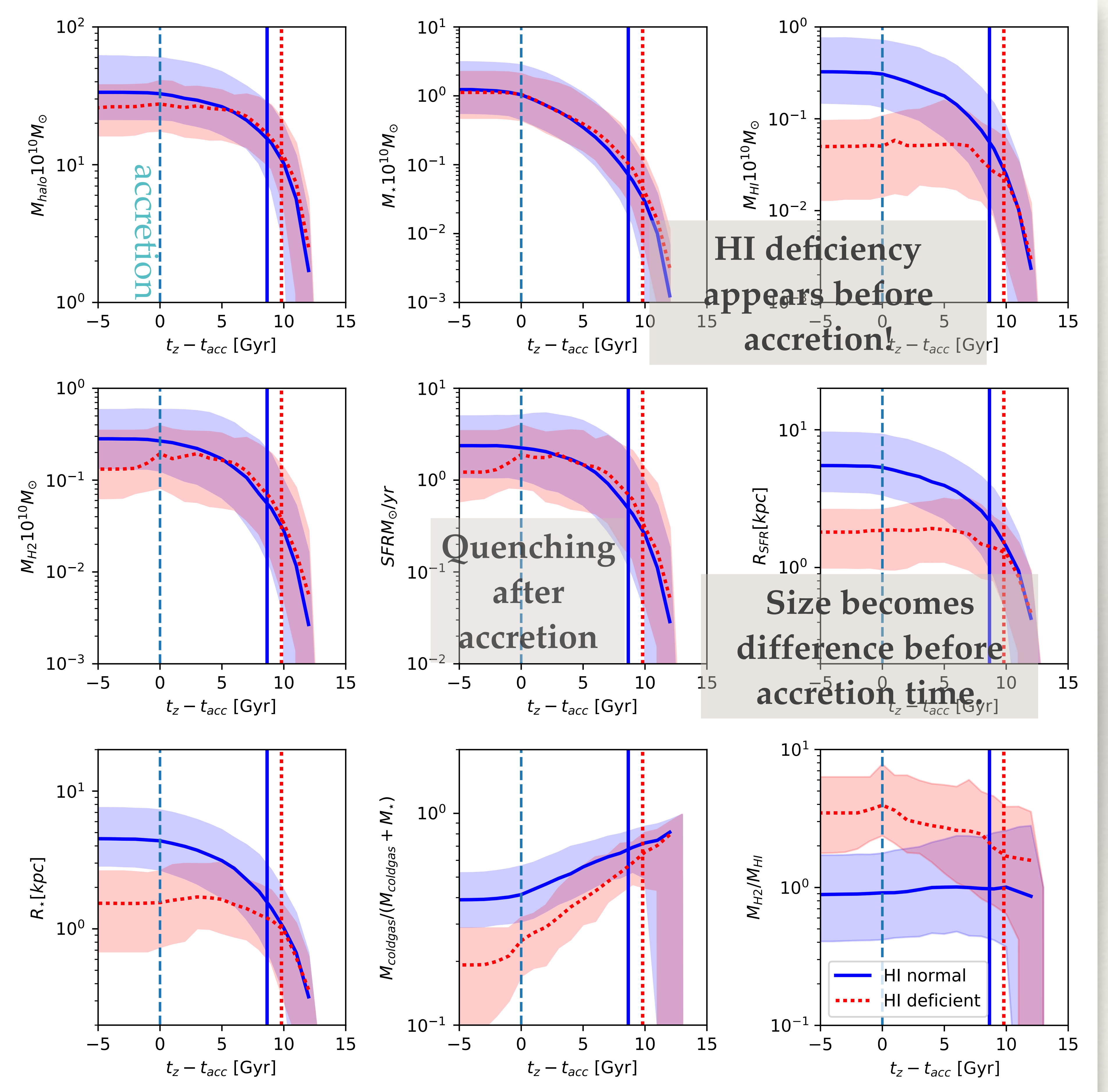
Divide central and satellite galaxies by HI deficiency — HI-rich = central; HI-poor = satellite



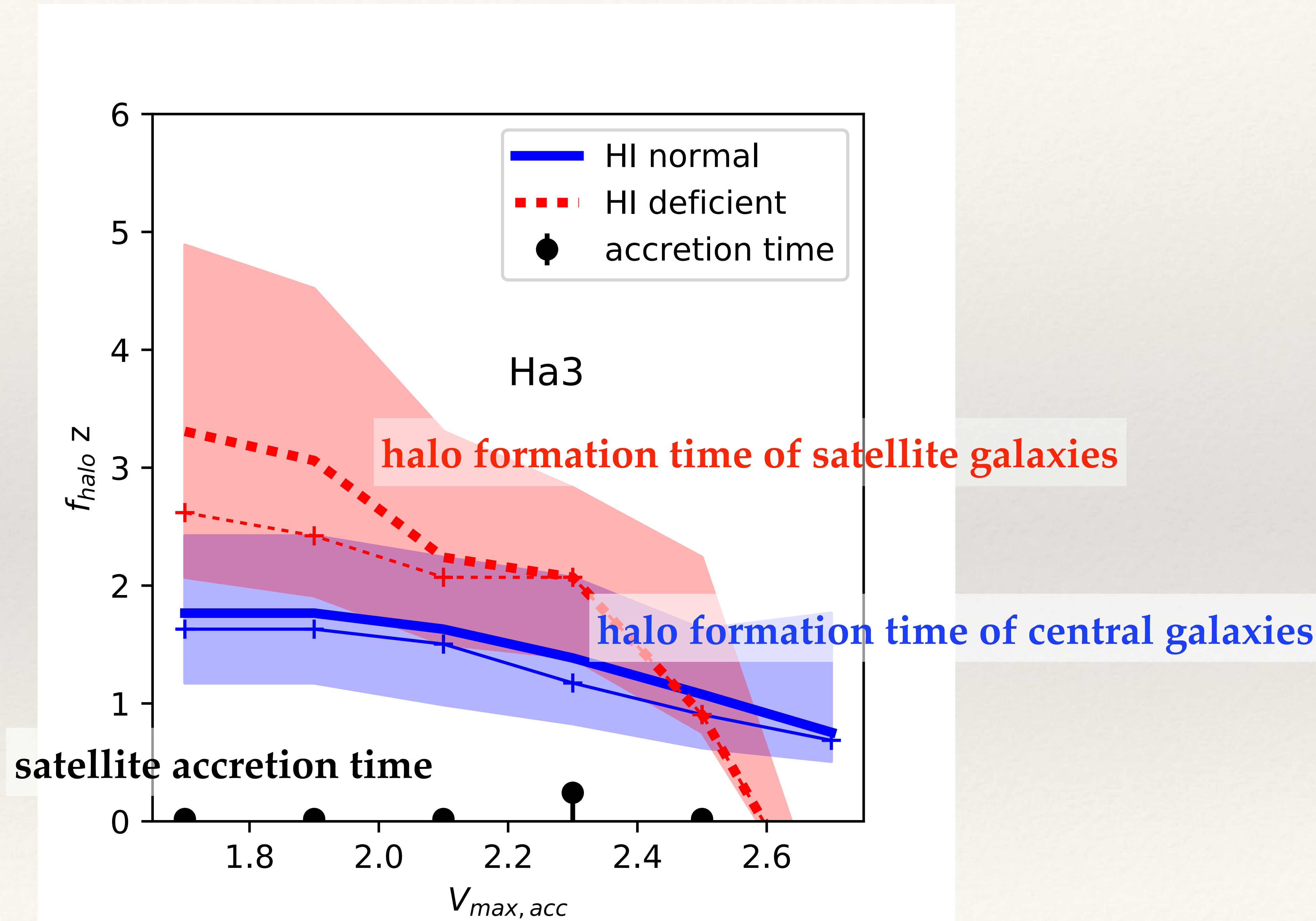
Select modelling galaxies analogous to Ha3 survey — matching HI deficiency and SFR deficiency to main sequence

Modelling galaxies show larger size differences between central and satellite galaxies

Evolution of central and satellite galaxies



Size relates to the assembly time of host halo/subhalo



Model results against observed facts

- Satellite galaxies have decreasing molecular fraction.
- Mock galaxies are way too compact than observed ones — the constraint of HI-deficiency forced us to select galaxies formed at very early time.
- With ram-pressure stripping in the model, it is possible to solve these problems — future work.

Conclusion

Based on a semi-analytic model with only strangulation as environmental effects on satellite galaxies, we find that:

- The differences in SF disk and stellar sizes between central and satellite galaxies depend on the selection criteria.
- Size differences between central and satellite occur before accretion, indicating they are results of different assembly history.
- Late-type satellite galaxies start quenching after accretion time.
- HI fraction of a galaxy is affected by its assembly history.
- Without ram-pressure, it is unlikely to reproduce both HI difference and size differences between central and satellite galaxies.