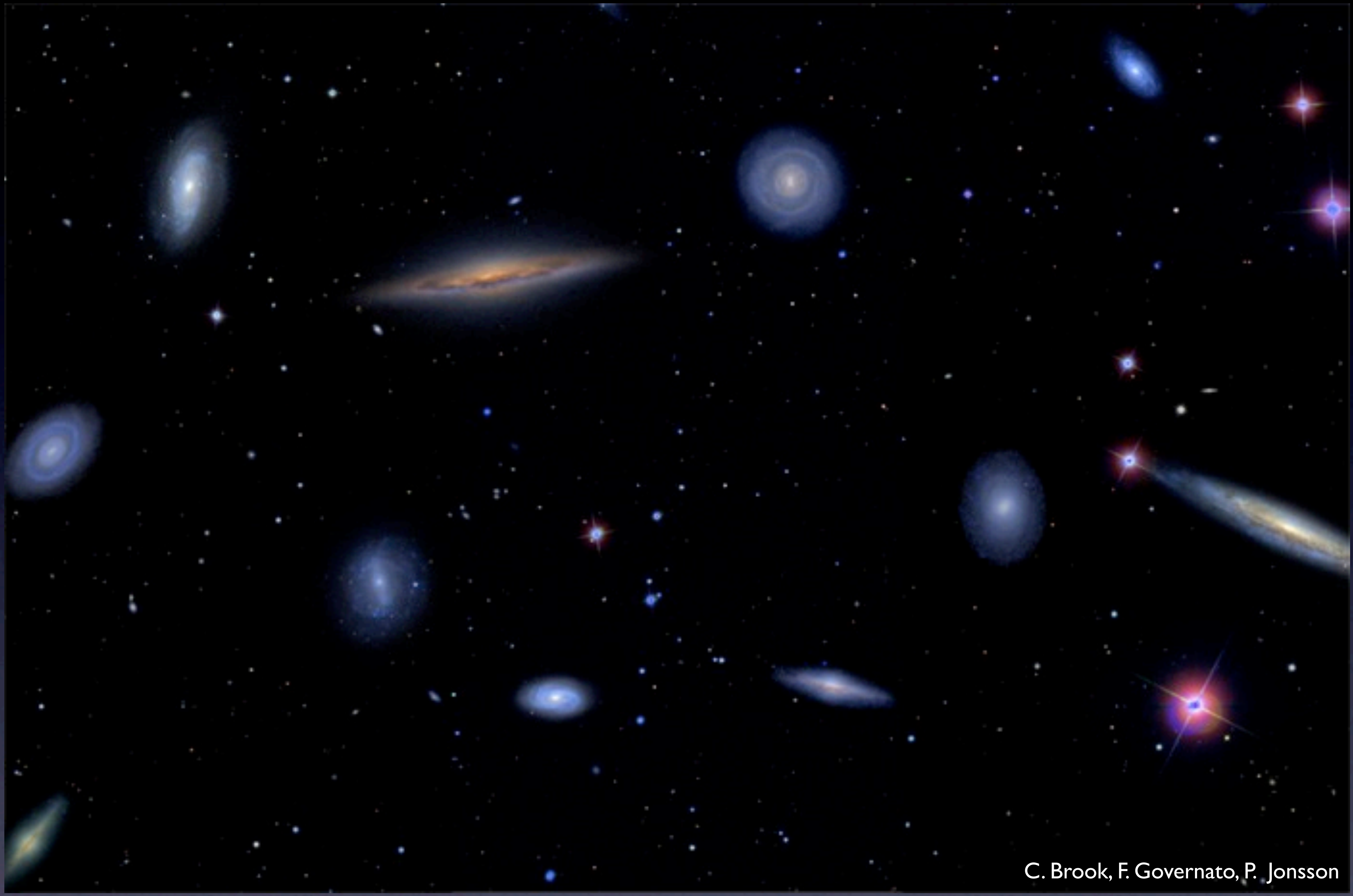
Cosmological Merger Rates



Not Phil Hopkins
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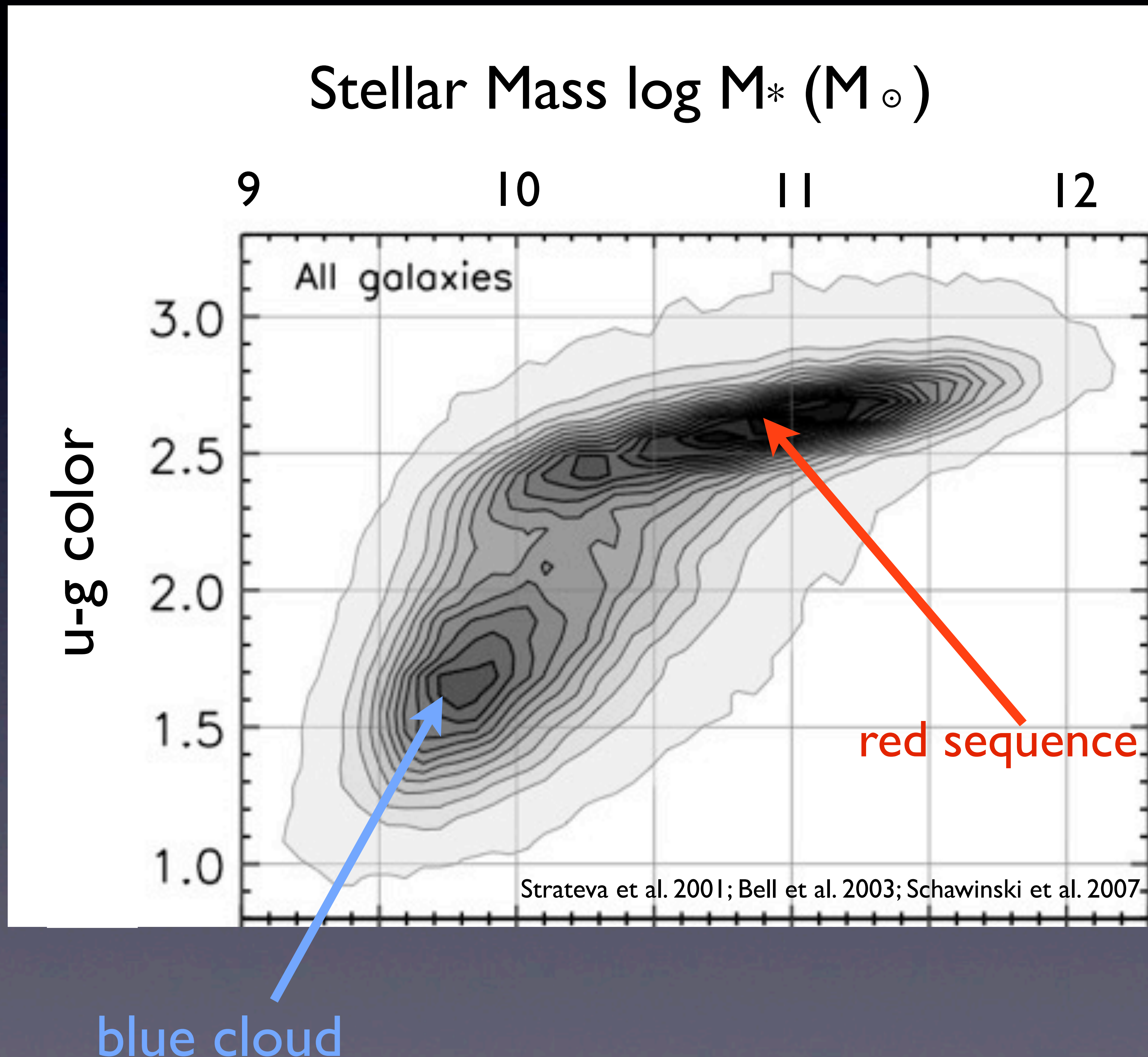
Why do we care so much about the merger rate?

Galaxy mergers transform star-forming disks (blue cloud) to 'dead' spheroids (red sequence)



Why do we care so much about the merger rate?

Galaxy mergers trigger starbursts (Luminous-IR galaxies, Lyman break galaxies, kickstart reionization?, enrich the IGM?)

Why do we care so much about the merger rate?

Galaxy mergers feed super-massive black holes and ignite AGN (DiMatteo + Springel 2005)

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We'd like to know:

'Galaxy merger rate' as a function of time, mass, environment....

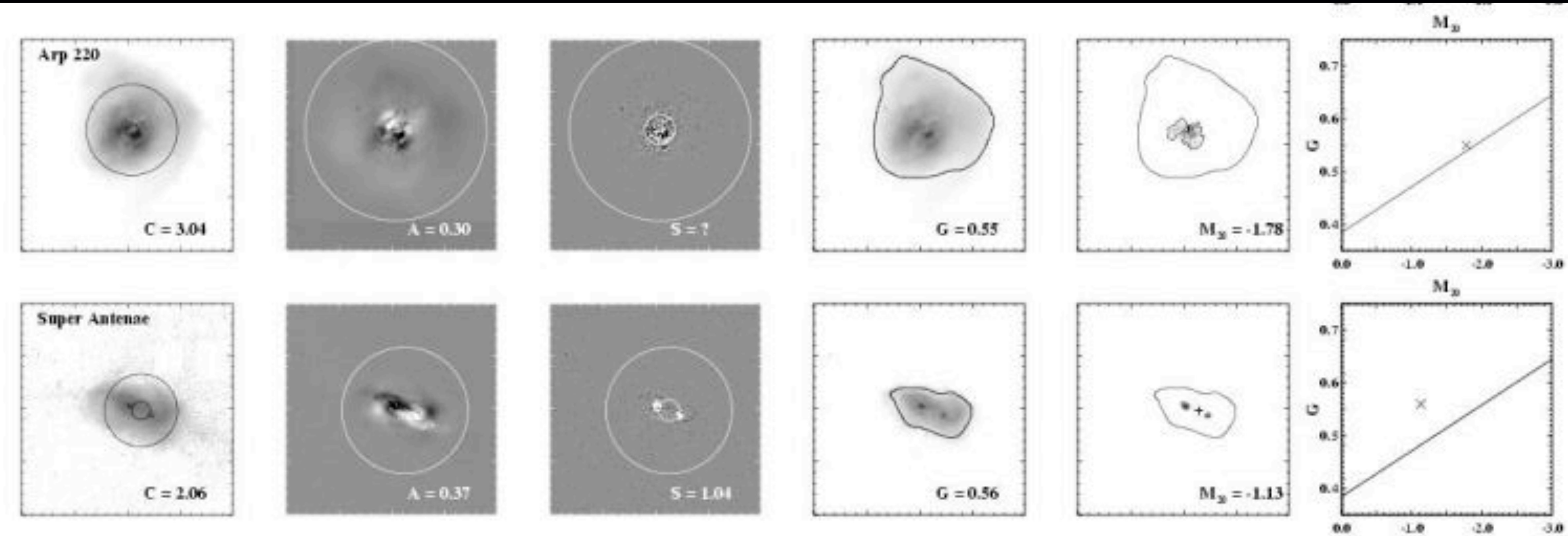
Galaxy merger rate == # major galaxy mergers/Gyr/Mpc^3

First step: identify galaxy mergers.

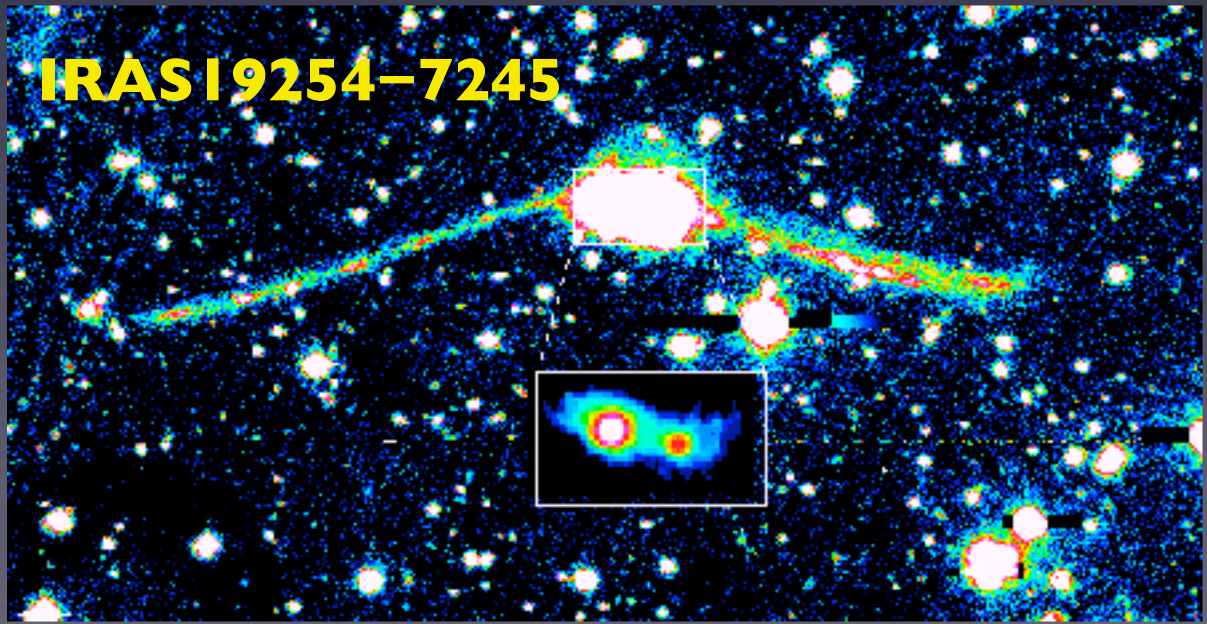
Identifying galaxy mergers observationally: close pair counts

galaxies within v < 500 km/sec, separated by R <100 kpc

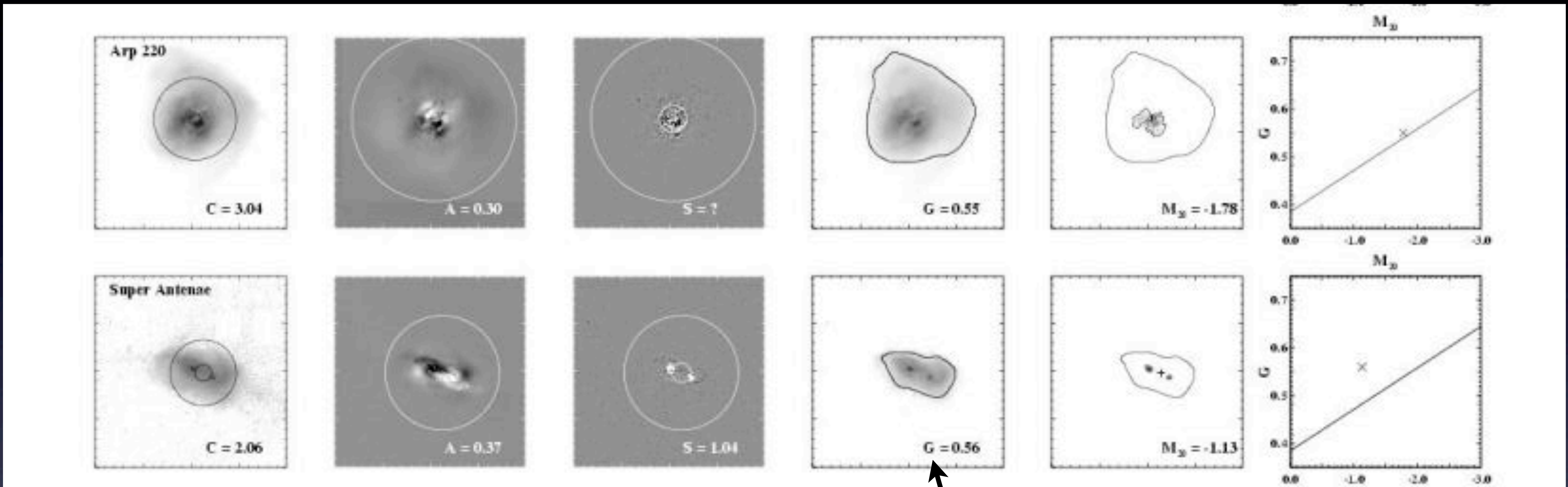
Identifying galaxy mergers observationally: morphological transformation indicators



Lotz et al. 2003; Abraham et al. 2003



Identifying galaxy mergers observationally: morphological transformation indicators



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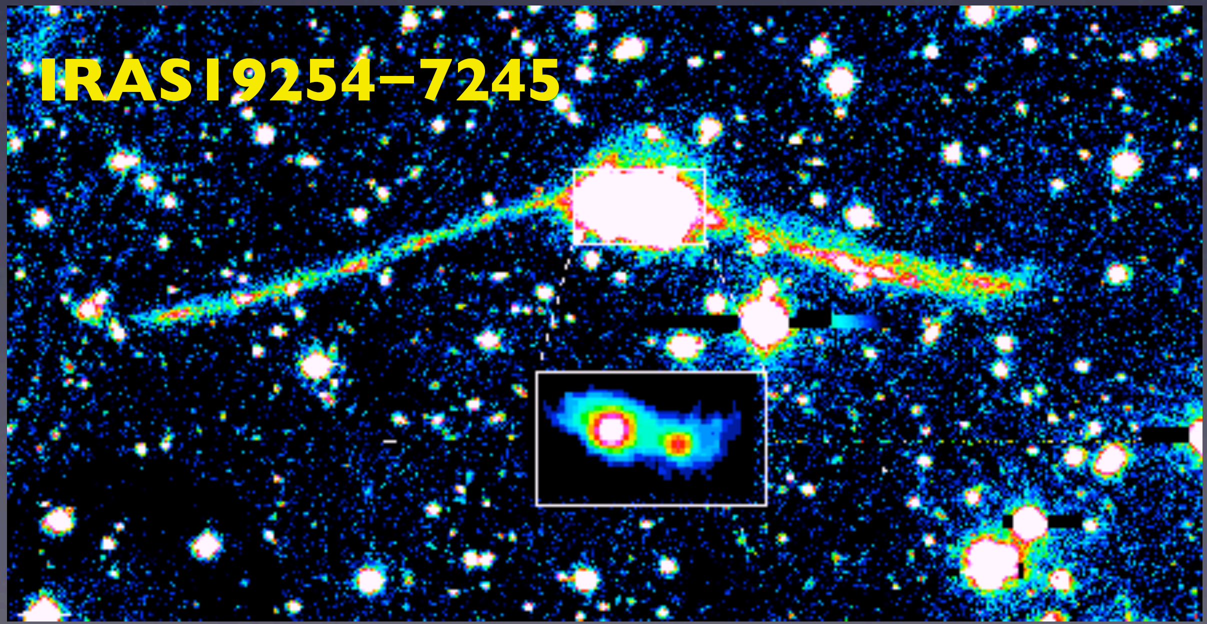
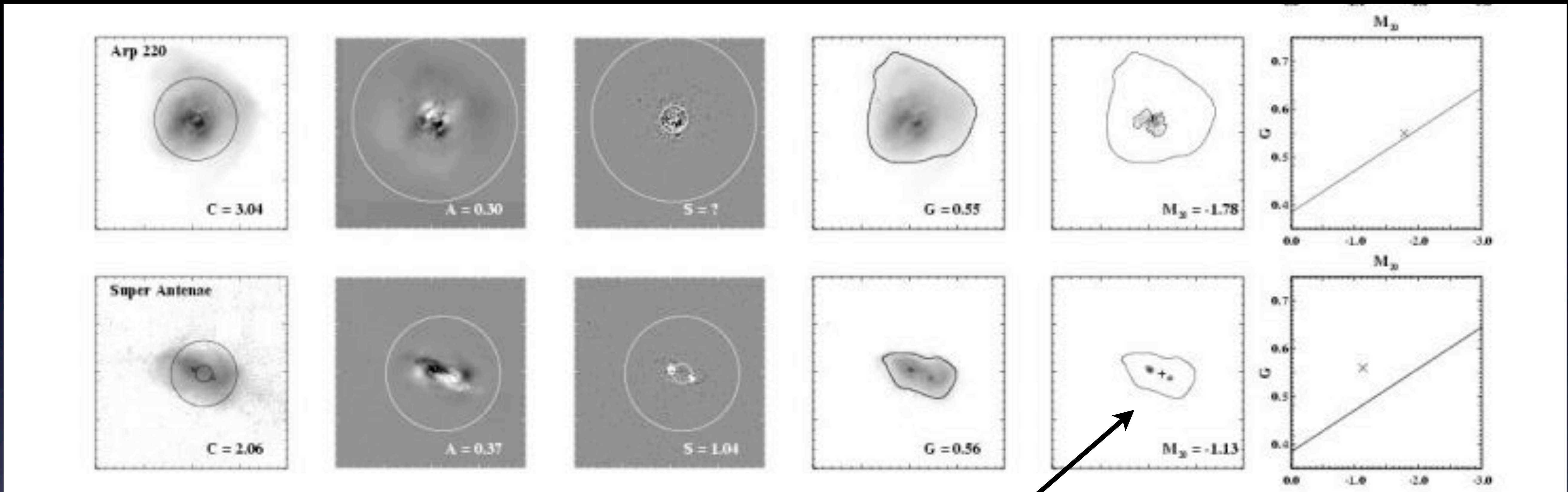


Gini index -- a measure of how equitably the light is distributed

Identifying galaxy mergers observationally: morphological transformation indicators



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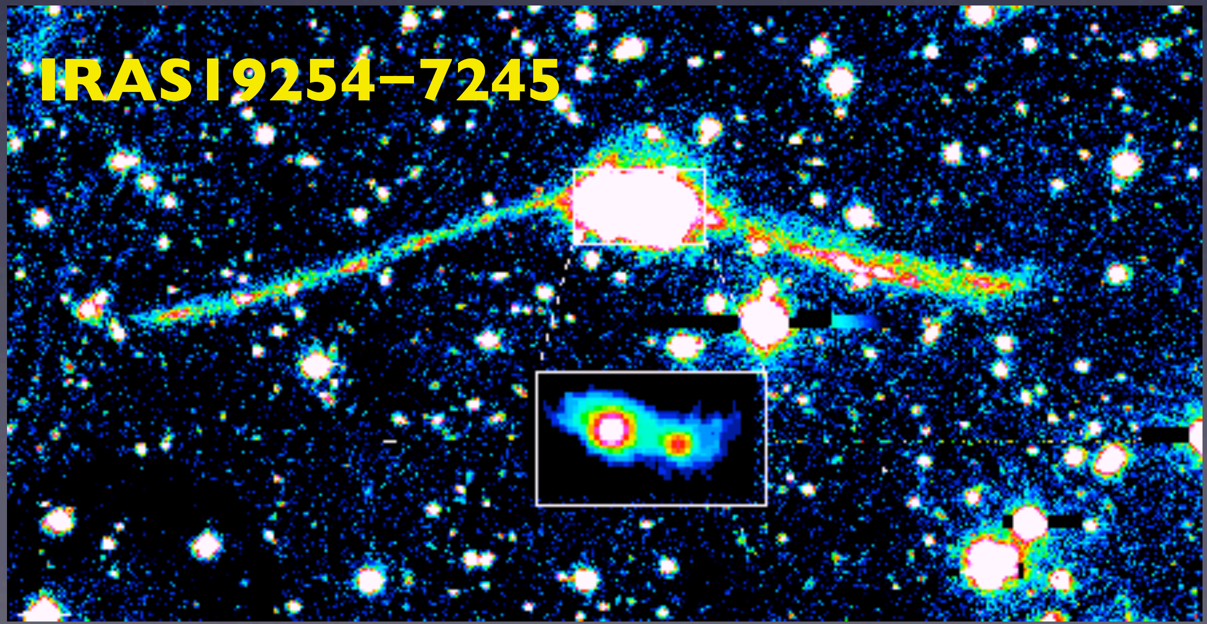
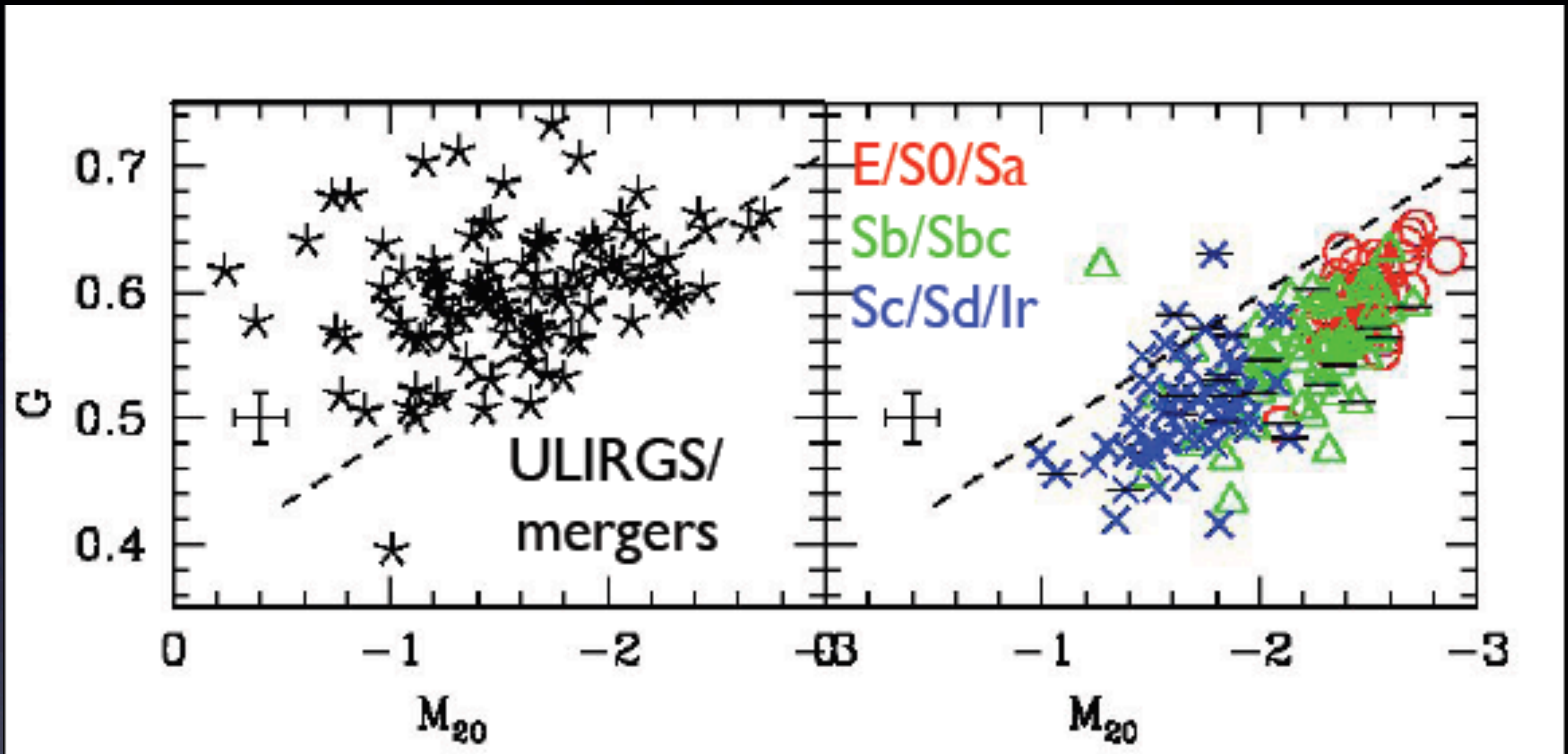


M20 index --a more generic form of concentration

Toward a quantitative merger criterion...

Lotz et al. 2004; Conselice 2004



Major mergers separate from 'normal galaxies' in Gini-M20 space

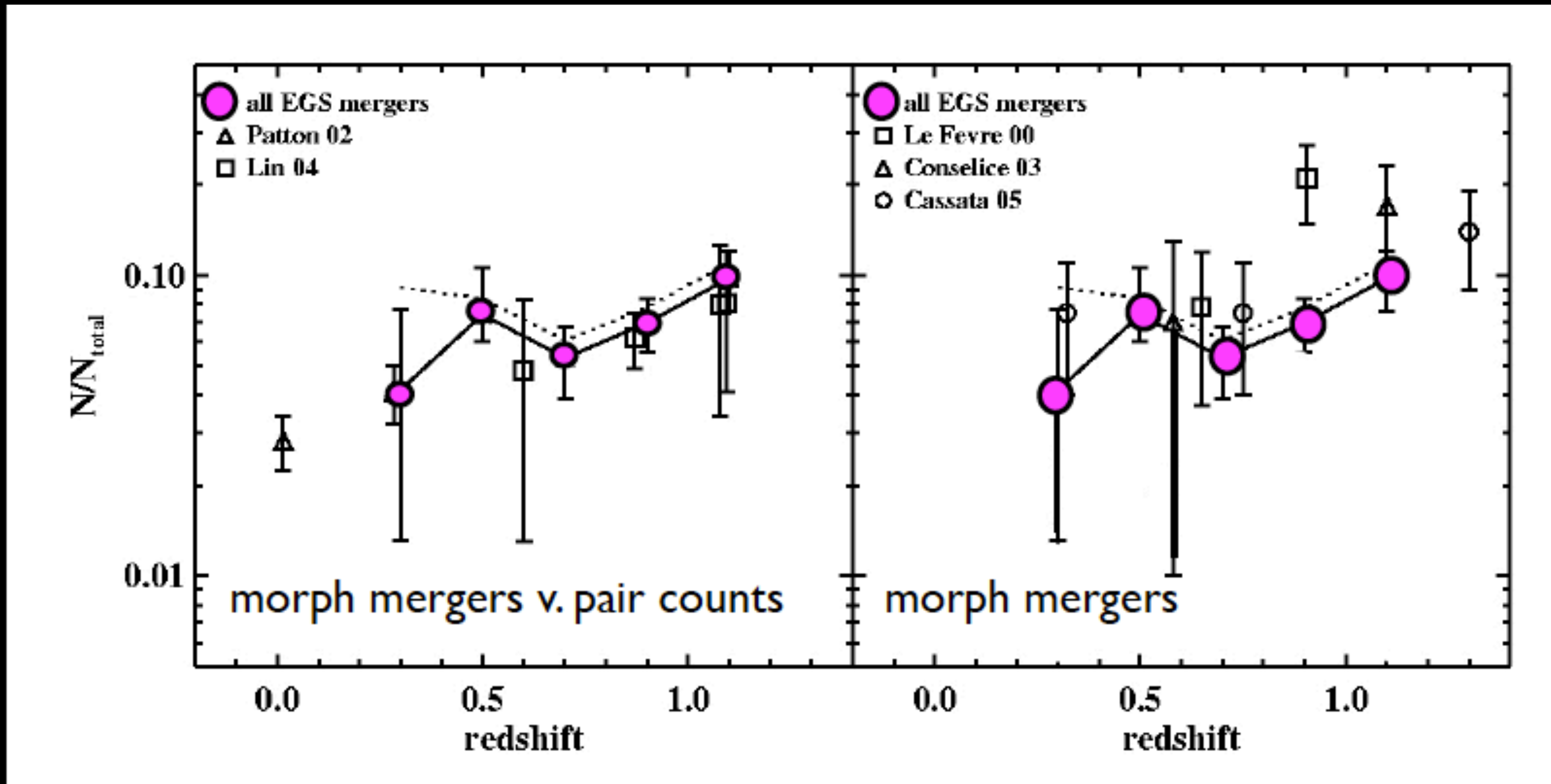
We'd like to know:

'Galaxy merger rate' as a function of time, mass, environment....

Galaxy merger rate == # major galaxy mergers/Gyr/Mpc^3

Next step: estimate the merger timescale.

Evolution in Merger Fraction at z<1.2

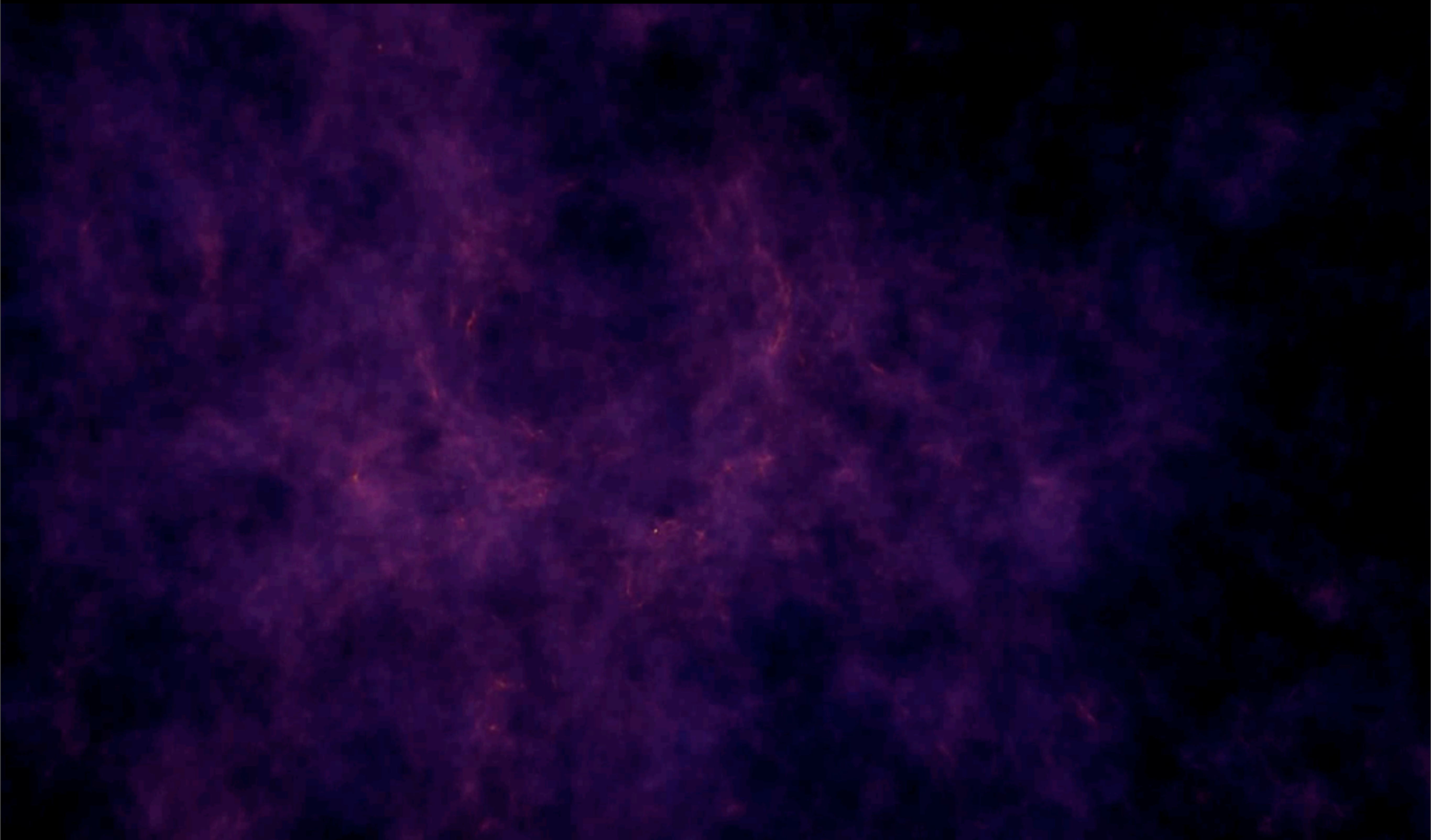


$f_{merger} \sim (1+z)^m \Rightarrow m = 1.12 \pm 0.60$ (excludes ambiguous candidates)

$= 0.26 \pm 0.64$ (all Gini-M20 candidates)

(Lotz et al. 2008; see also Bundy et al 2004, 2005, de Propis et al 2005, Bell et al 2006, Ilbert et al 2006...)

Theory: Galaxy dynamics is predicated on the dynamics of dark matter



Ω_{matter} = 0.2669 +/- 0.03 Ω_{baryon}= 0.0449 +/- 0.0028 $\Omega_{dark\ energy}$ = 0.734 +/- 0.029

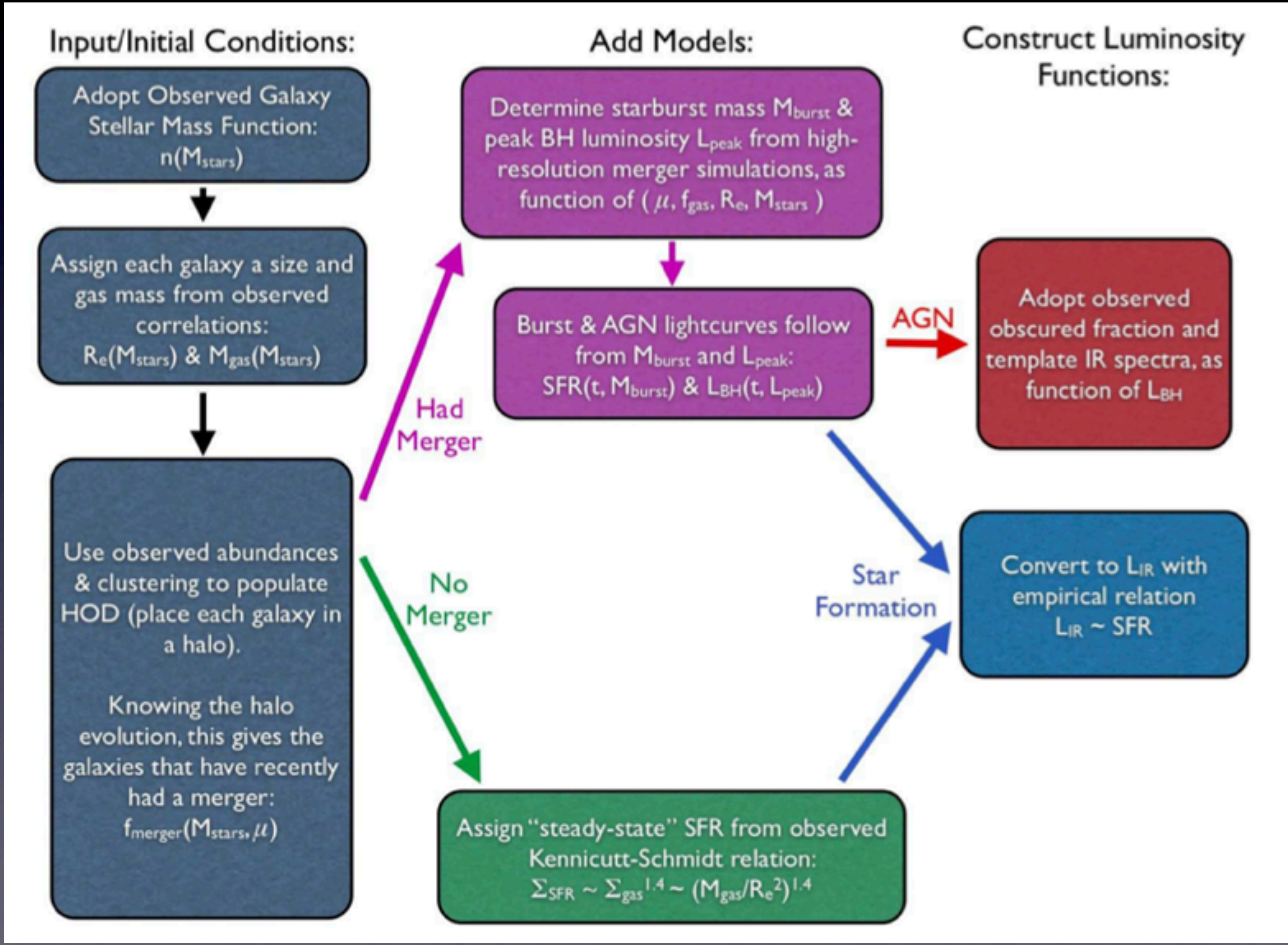
Problem: major halo merger $\neq$ major galaxy mergers

Theory says that halo major merger rate ~ $(1+z)^3$
(Gottlober et al. 2001)

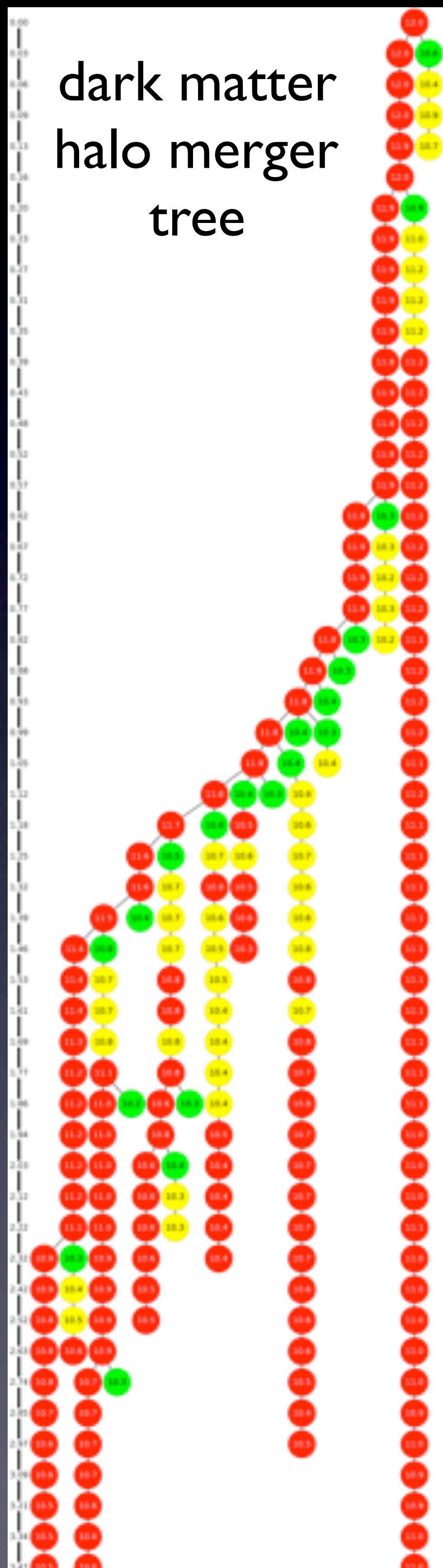
Galaxy merger rate from close pairs ~ $(1+z)^{0.5-1}$
(Berrier et al. 2006)

One way to connect galaxies to halos: Semi-Empirical Merger Models

Hopkins et al. 2010 (Conroy & Wechsler 2009; Cooray 2006; Yan et al. 2003; Perez-Gonzalez et al. 2008; Wetzel et al. 2009; Stewart et al. 2009)



Let's walk through the prediction of galaxy merger rates



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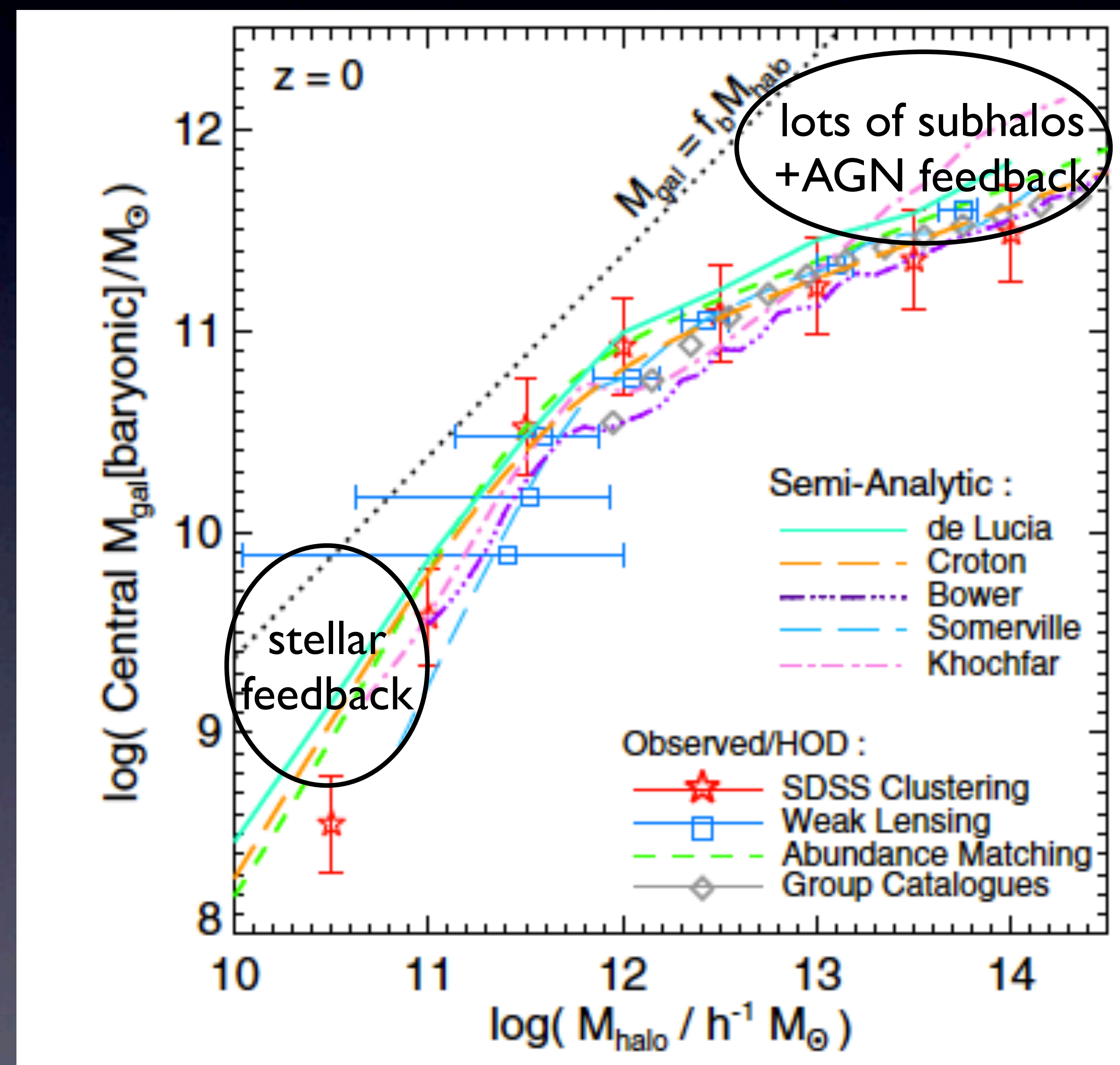
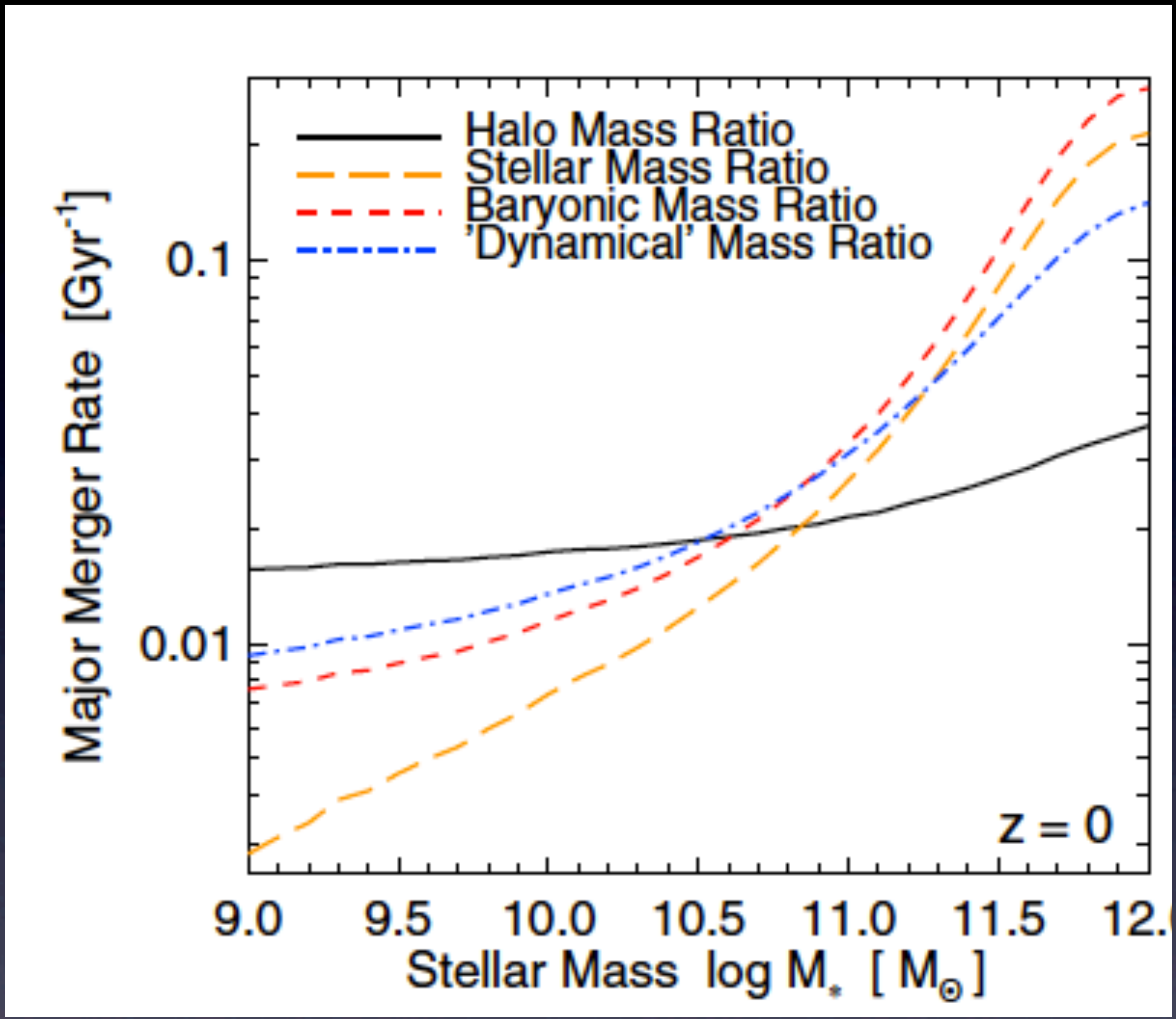


Beware! Major halo mergers aren't always major galaxy mergers (and vice versa!)



Here $M_* \propto M_{halo}^{0.5}$

so 1:9 halo merger is a

1:3 stellar merger

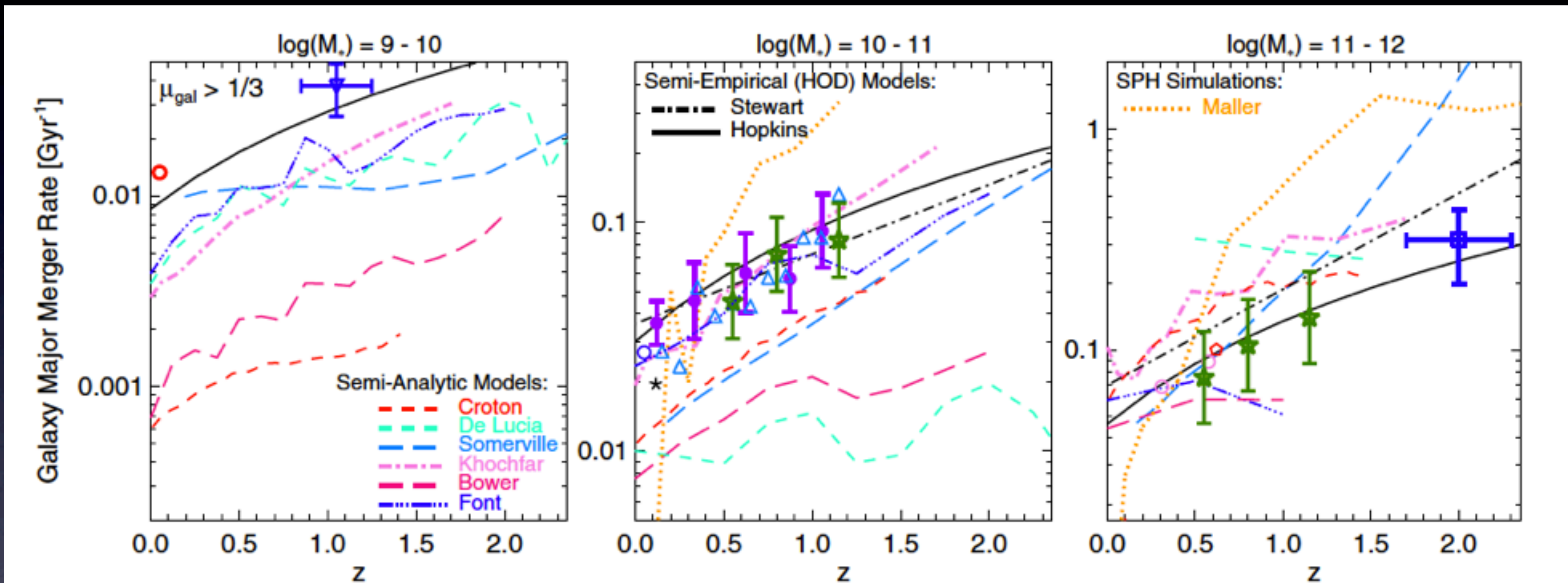
Here $M_* \propto M_{halo}^{2}$

so 1:3 halo merger is

a 1:9 stellar merger

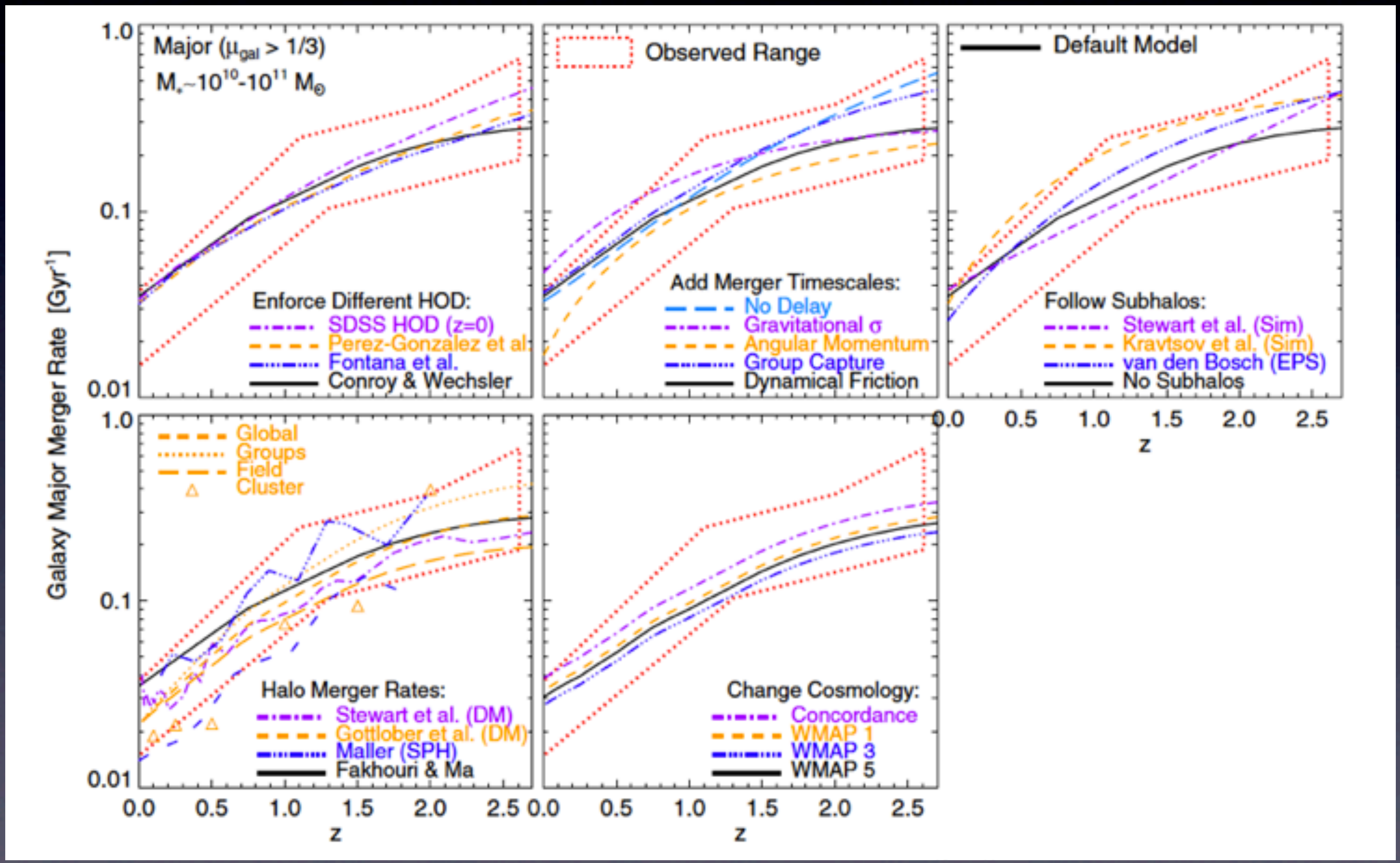
Recent semi-analytic models and high resolution SPH simulations fail to reproduce the evolution of the galaxy merger rate

Hopkins et al. 2011

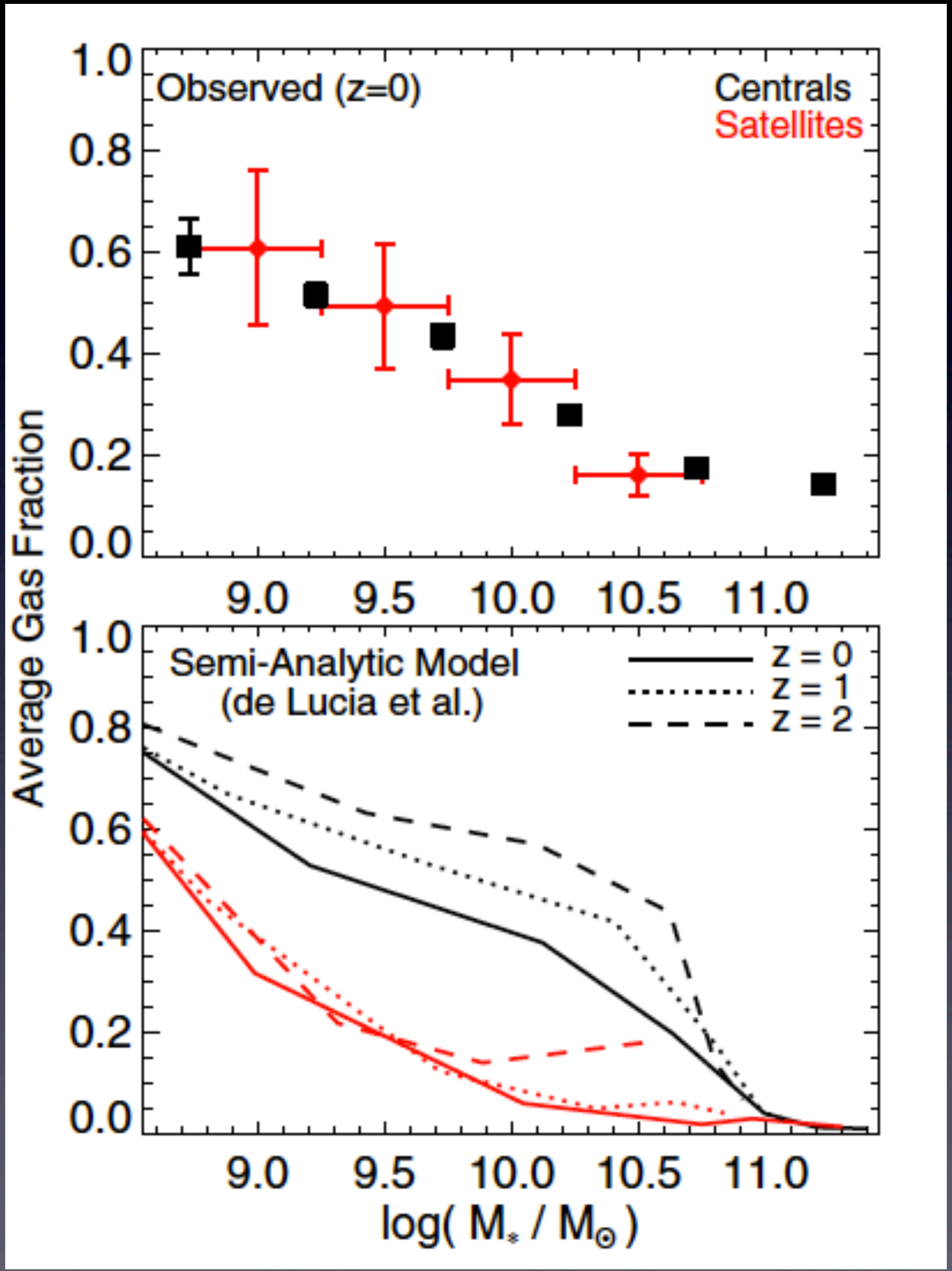


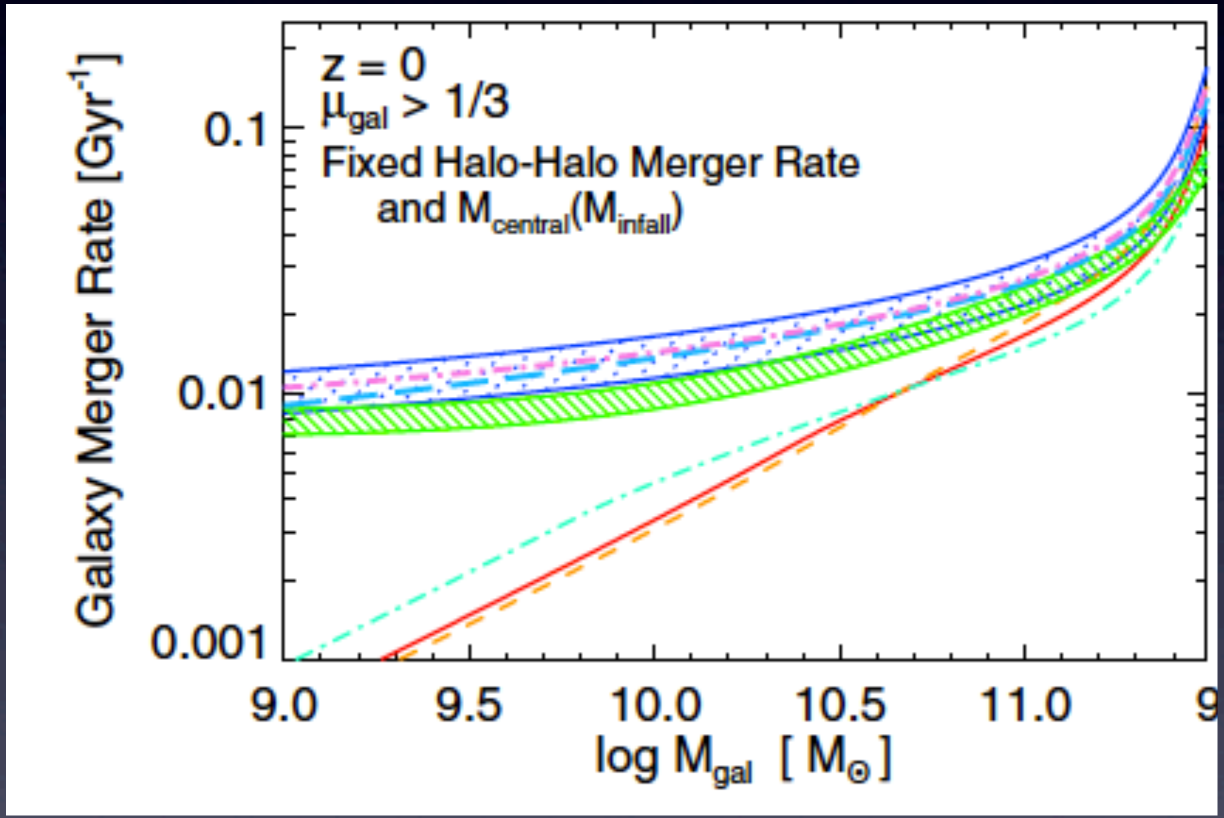
Kartalepe et al. 2007; Conselice et al. 2009; Lin et al. 2004, 2008; Xu et al. 2004,2008; De Propris et al. 2005; Bluck et al. 2009; Bundy et al. 2009; Bell et al. 2006a,b

Changing the way you deal with dark matter/ gravitational dynamics contributes to a factor of ~2 uncertainty in galaxy merger rates



‘Overquenching’ the gas in satellite galaxies makes the biggest difference in galaxy merger rates





Another approach: using high resolution SPH simulations of galaxy mergers to better inform the semi-analytical models

these were sbcr_hr_f_stars_c.mov and (next slide) the gas counterpart but stupid keynote=too big

Hopkins et al. 2011

What we learn: major mergers don't quench the 'satellite'

Here:

Radiation pressure imparts momentum to gas

Stellar winds from young and old stars

Photo-ionization heats the gas

Supernovae deposits energy and vents to the IGM

Hopkins et al. 2011

What we learn: 'Cold' Flow accretion feeds the galaxy and satellite well into the merger

Keres et al. 2005; Bellovary et al. in prep.

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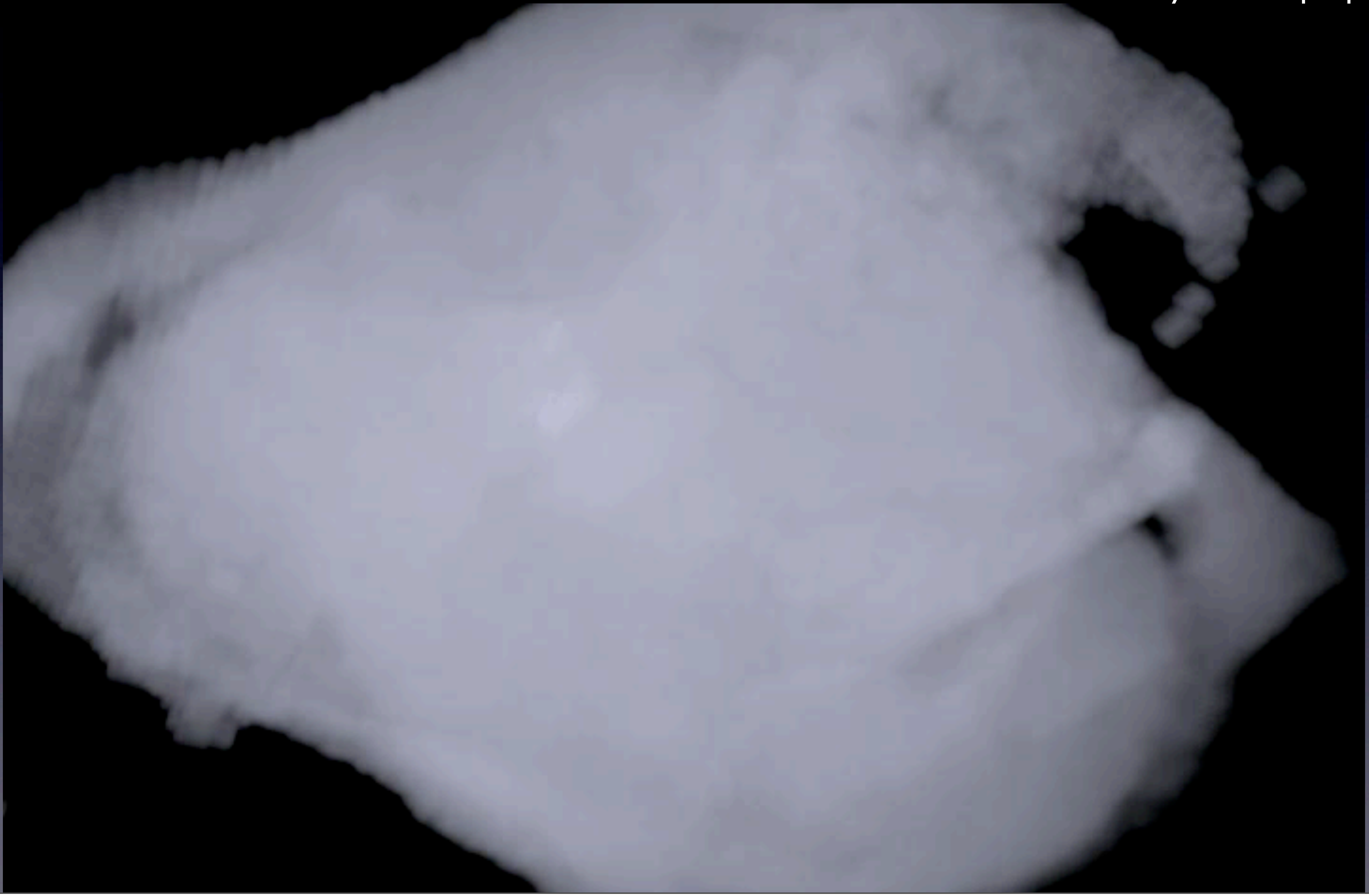
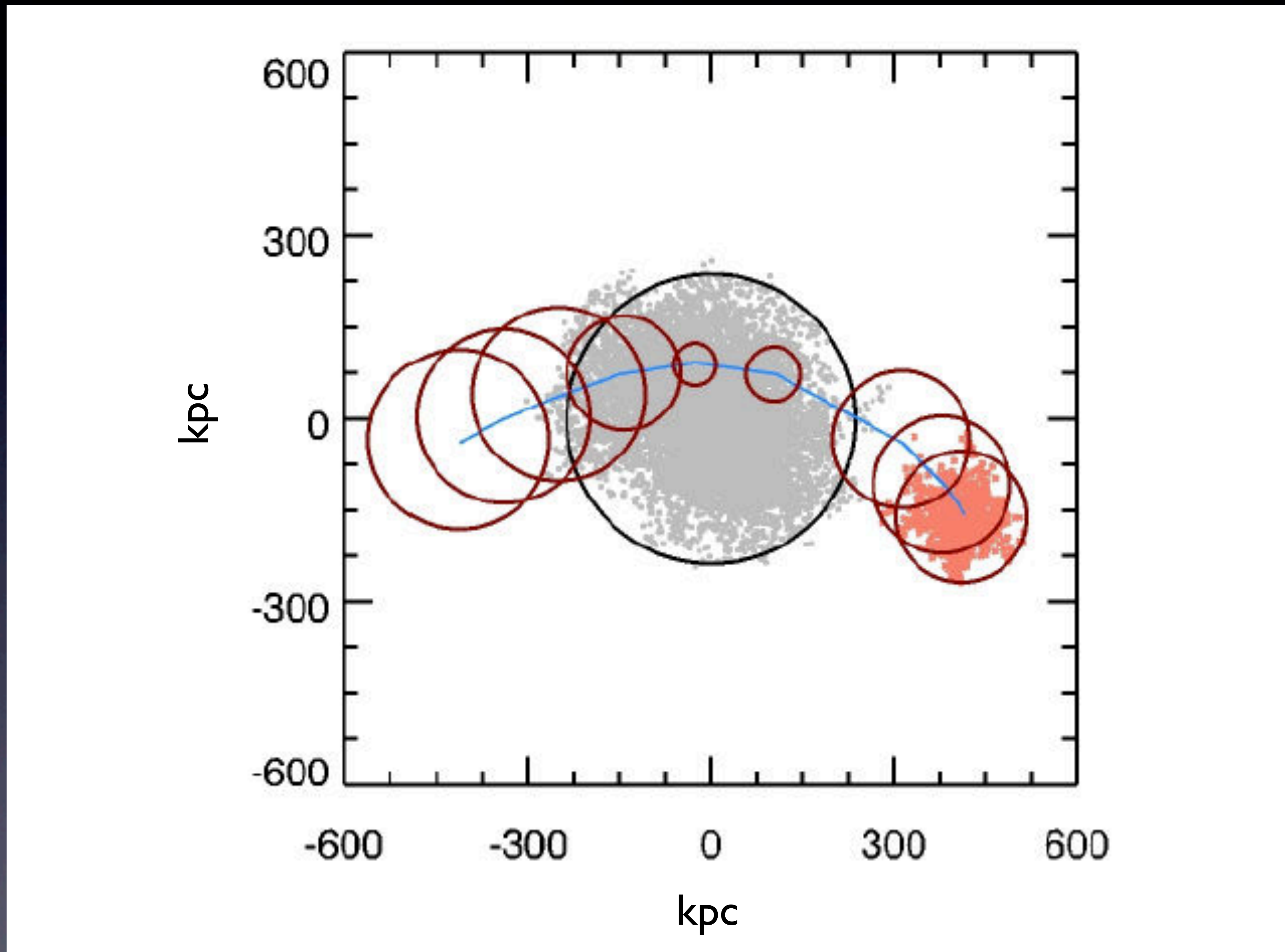
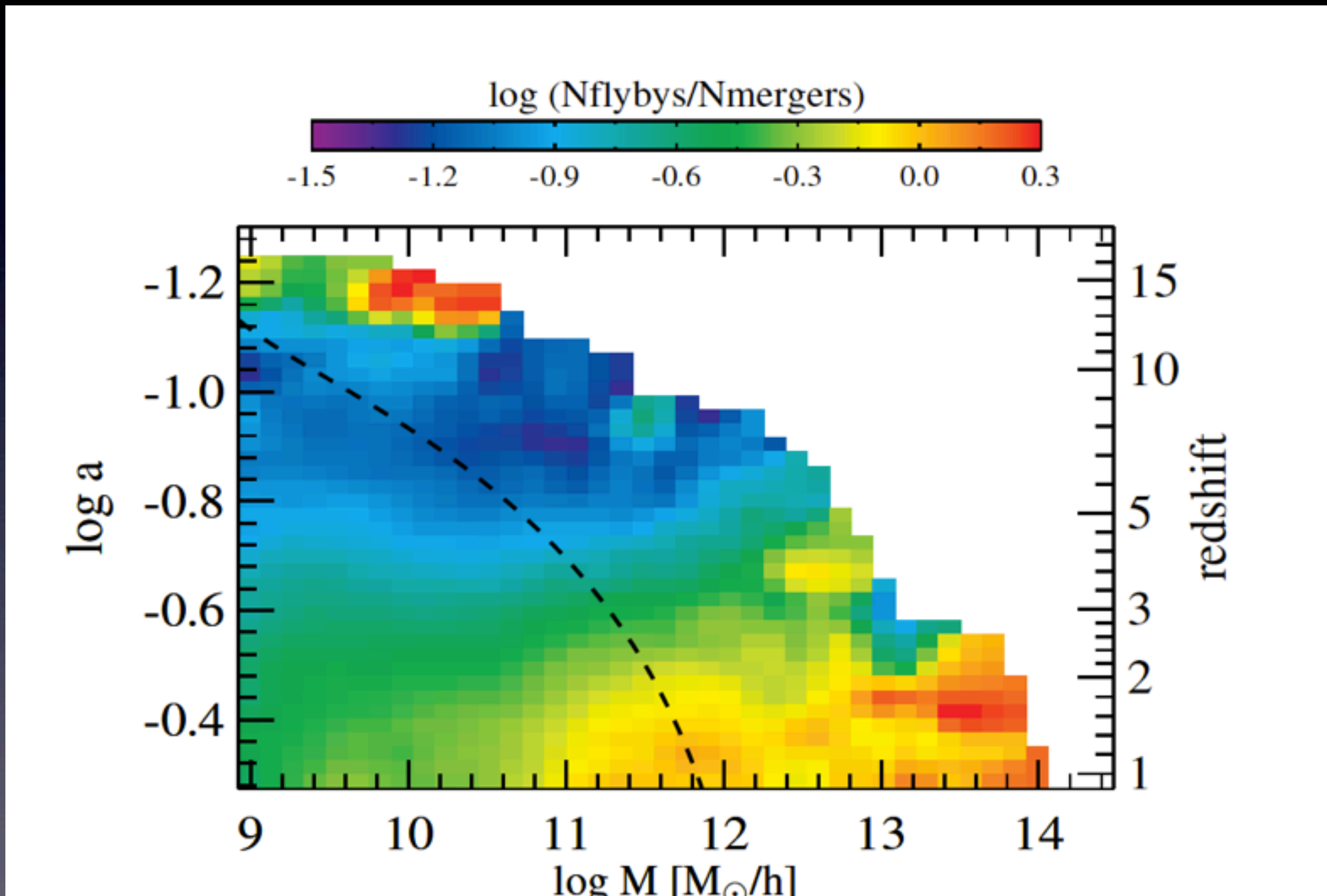


Cautionary note: Galaxy Flybys may matter

Sinha + KHB 2012



Flyby encounters can happen just as often as mergers -- *currently ignored in hierarchical growth scenarios*



Sinha + KHB 2012

Why this matters: galaxy flybys can strongly perturb the galaxy

Vesperini+Weinberg 2001

Mayer et al 2011

...which can funnel gas to the center, excite star formation, may feed the SMBH...

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Recap: Finding the major galaxy merger rate is a subtle business

- Though major halo mergers strongly increase with redshift, major galaxy merger evolution is more modest.
- At z=0, major halo mergers depend weakly on halo mass, but major galaxy mergers occur ~ 10x more often for massive galaxies.
- To match the observed galaxy merger rate, the biggest error source is in removing the satellite baryons.
- Flybys/Cold mode accretion may be important/neglected mechanism for galaxy transformation.

That's all folks!!

Thanks!