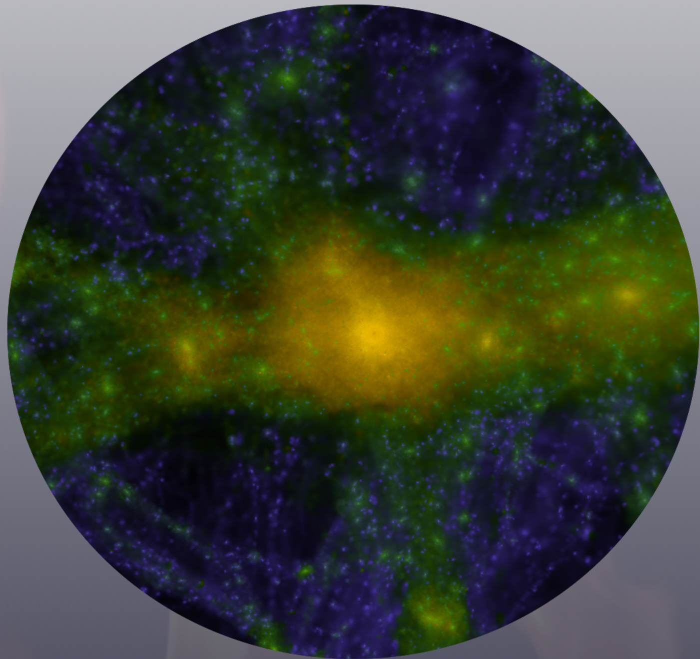
The Dynamical Lives of High Redshift Galaxies



Greg Poole

... and the rest of the DRAGONS team ...

Stuart Wyithe, Simon Mutch, Paul Geil (Melbourne)
Alan Duffy (Swinburne), Andrei Mesinger (SNS, Pisa)
Paul Angel, Yuxiang Quin, Chuanwu Liu (Melbourne)

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DRAGONS

Dark Ages Reionization and Galaxy Formation Observables from Simulations

Greg Poole

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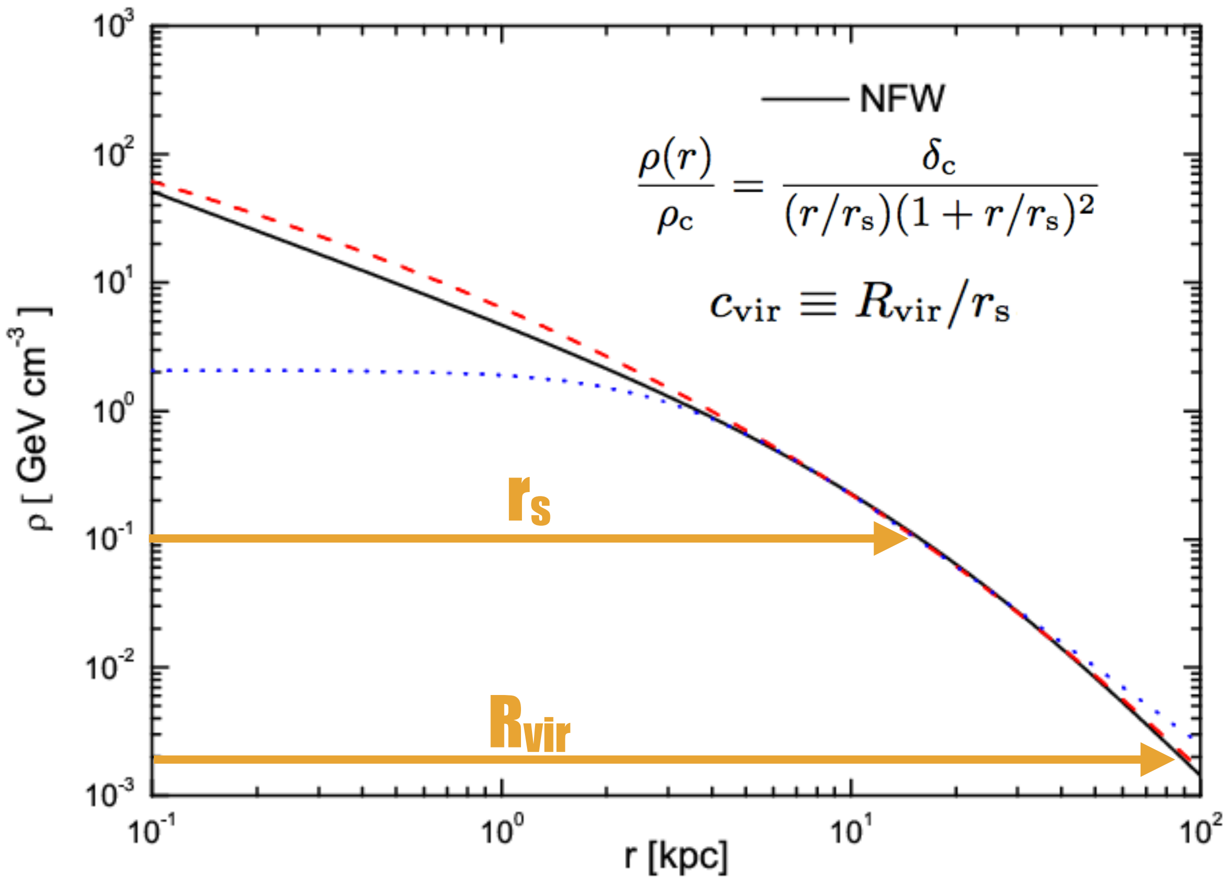
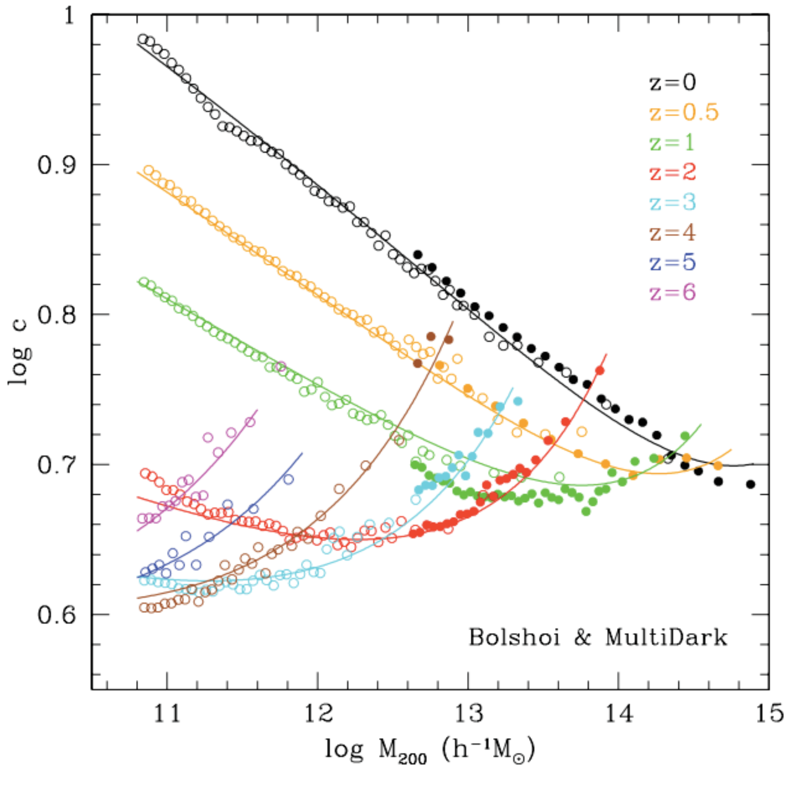
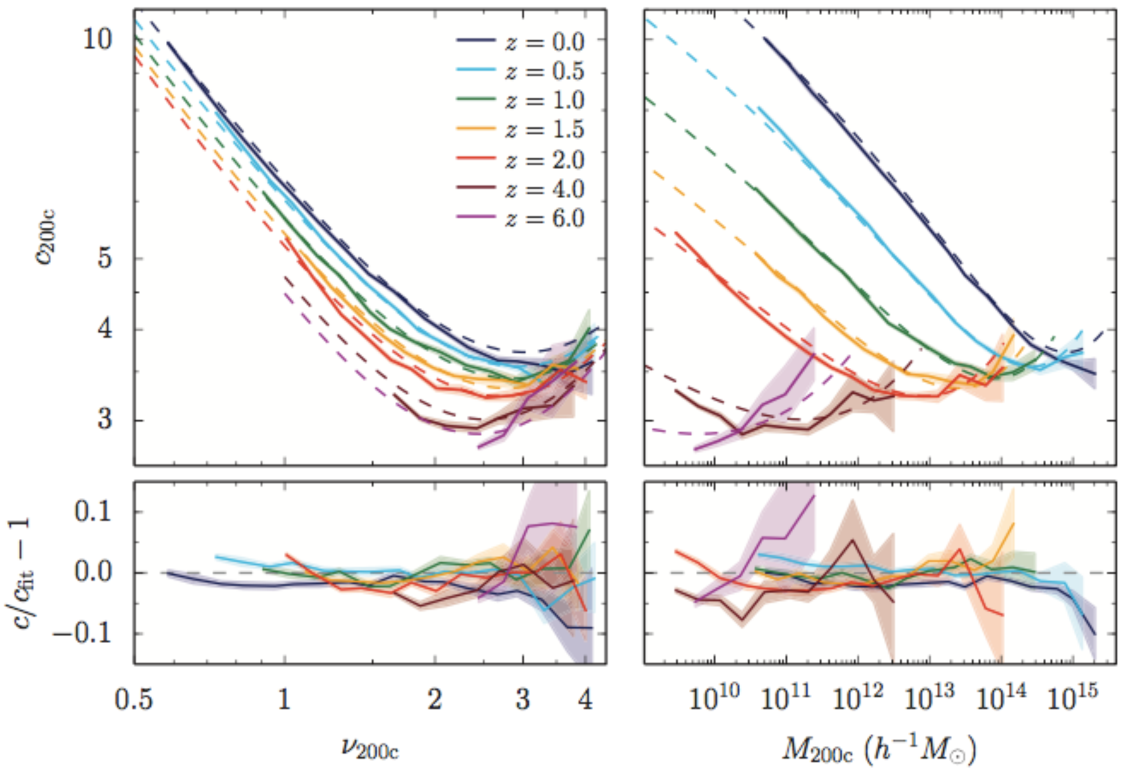
Halo Structure: Universal Profiles



Halo Structure at Low-z: General Agreement

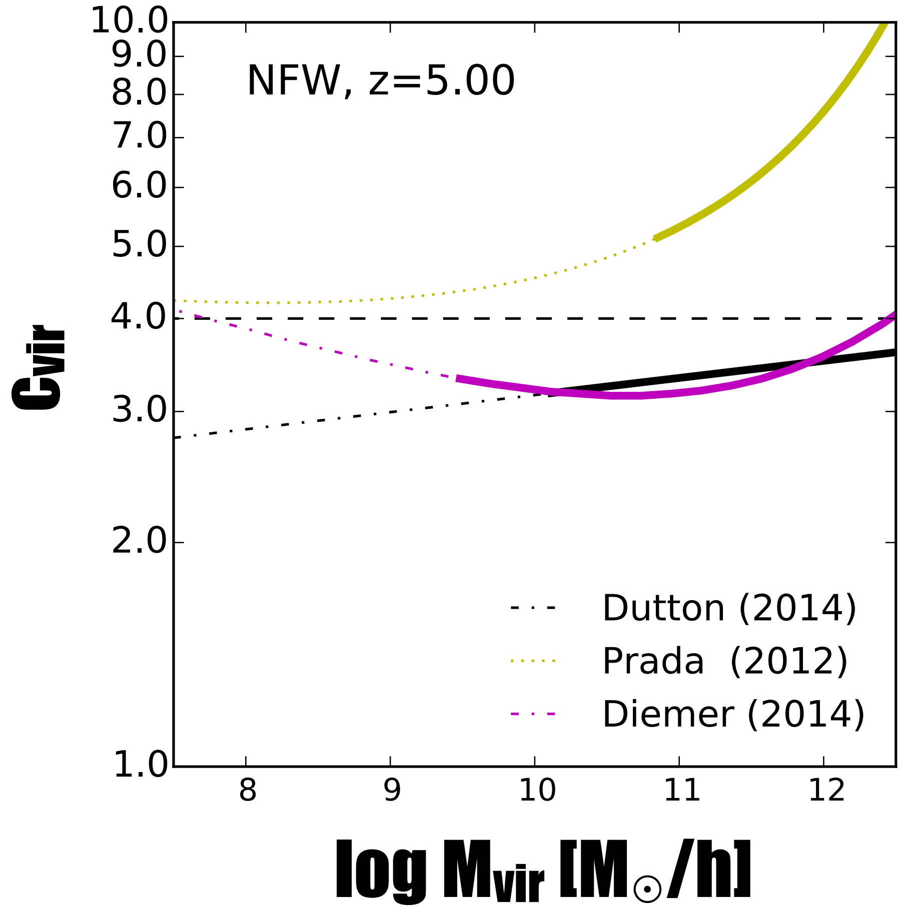


Prada et al,2012



Diemer et al,2015

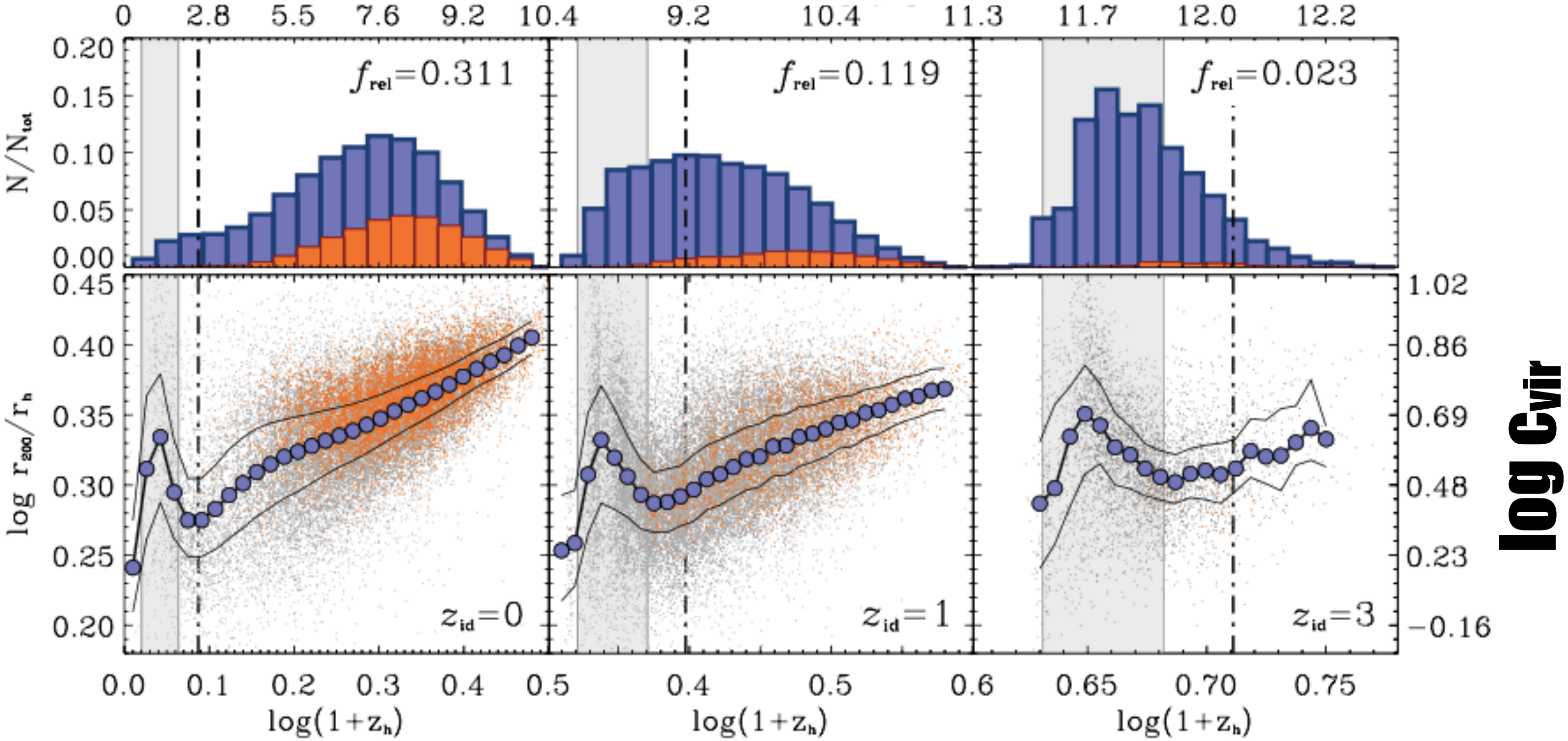
Halo Structure at High-z: Confusion in the Literature



Halo Structure at Low-z: Depends on Dynamical State

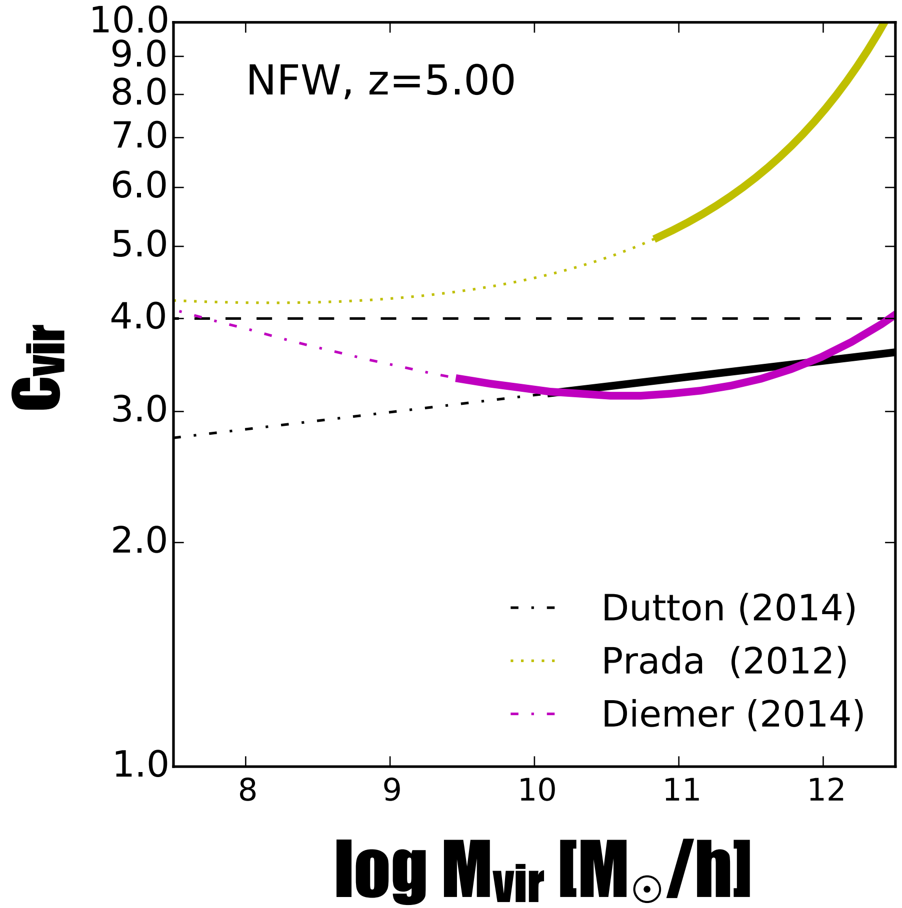
More quiescent halos have higher concentrations

halo age [Gyrs]

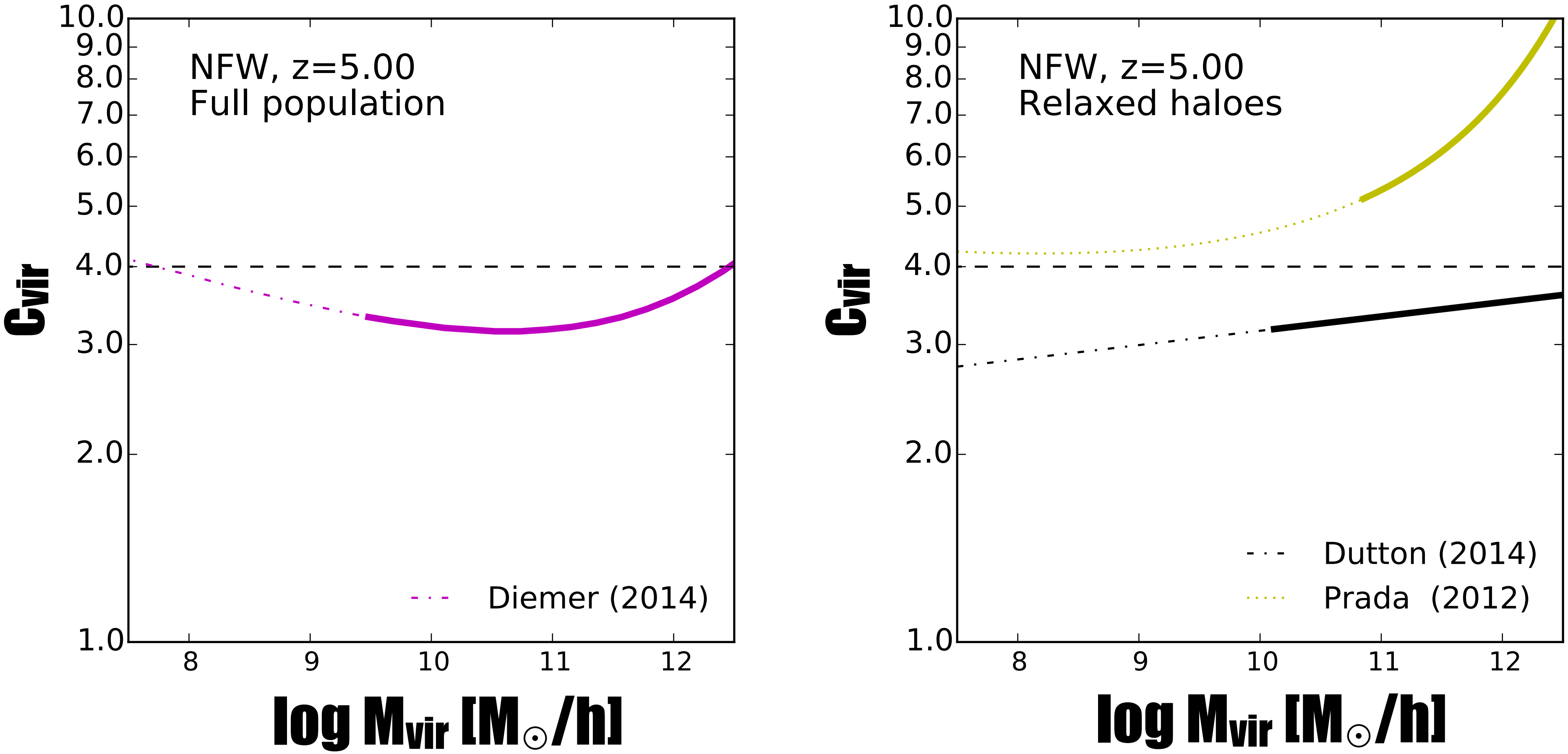


Ludlow et al,2012

Halo Structure at High-z: Confusion in the Literature



Halo Structure at High-z: Confusion in the Literature



TIAMAT

- Suite resolving structures down to ~$2\times10^6\ h^{-1}M_\odot$
- 100 snapshots to z=5 (one every 11 Myrs)
- Planck-2015 cosmology
- Largest run: 2160^3 particles in a 67.8 h^{-1}Mpc box

Simulation	N_p	L [Mpc/h]	m_p [$M_\odot$/h]	ϵ [kpc/h]	η	Cosmology	Halo Finding
Tiamat	2160^3	67.8	2.64×10^6	0.63	0.025	Planck-2015	SUBFIND
Medi Tiamat	1080^3	22.6	7.83×10^5	0.42	0.025	Planck-2015	SUBFIND
Tiny Tiamat	1080^3	10.0	6.79×10^4	0.19	0.025	Planck-2015	SUBFIND
Tiny Tiamat-W07	1024^3	10.0	7.11×10^4	0.20	0.010	WMAP-07	SUBFIND & ROCKSTAR

Table 1. Box sizes (L), particle counts (N_p), particle mass (m_p), gravitational softening lengths (ϵ) and integration accuracy parameters (η) for the *Tiamat* simulations as well as the cosmology and halo finding codes used for each.

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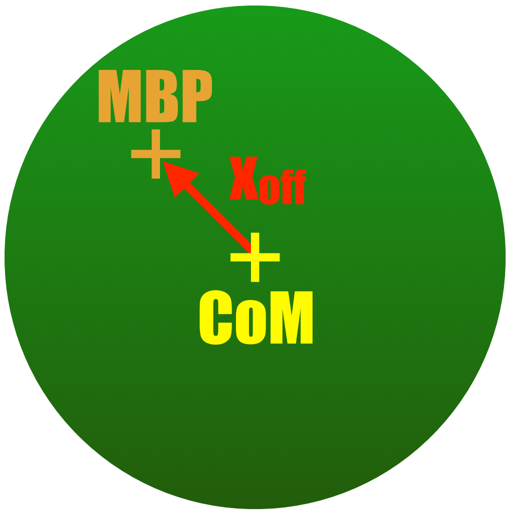
Quantifying the State of Relaxation

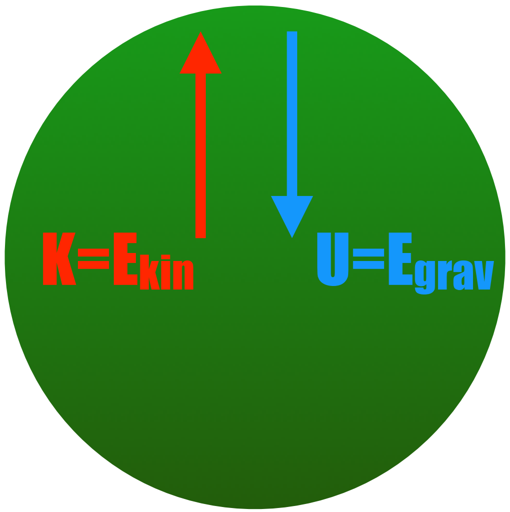
Standard practice: constraints on 3 metrics

$x_{off} < 7\% \, R_{vir}$



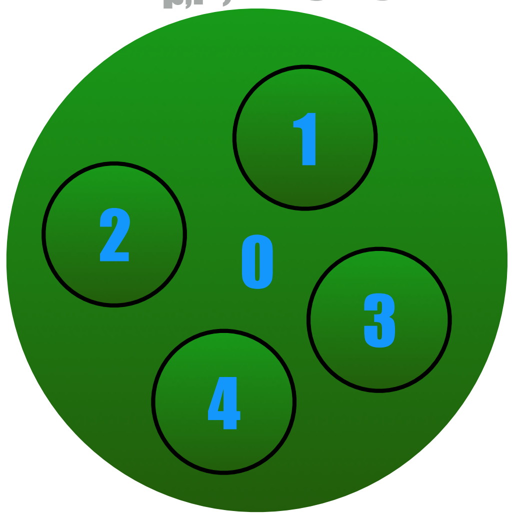
1. Centroid Offset

$2K < 1.35|U|$



2. Virial Ratio

$$f_{sub} = \frac{\sum n_{p,i} \;;\; i=1 \text{ to } n-1}{\sum n_{p,i} \;;\; i=0 \text{ to } n-1} < 0.1$$

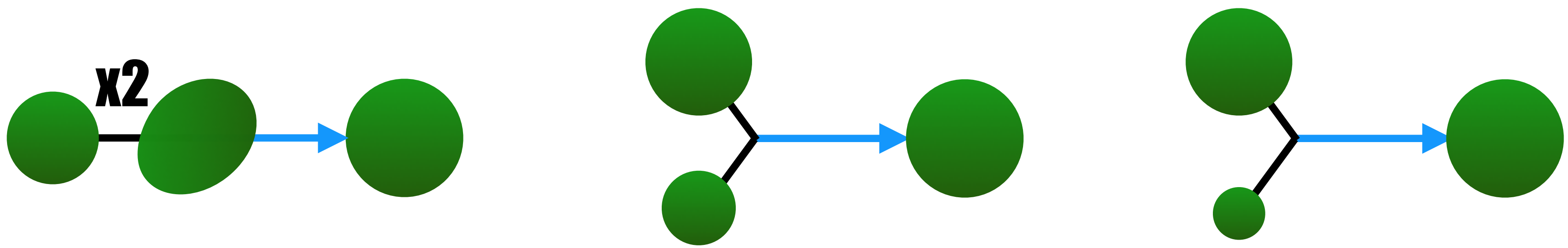


3. Substructure Fraction

Neto et al, 2007

Quantifying the State of Relaxation

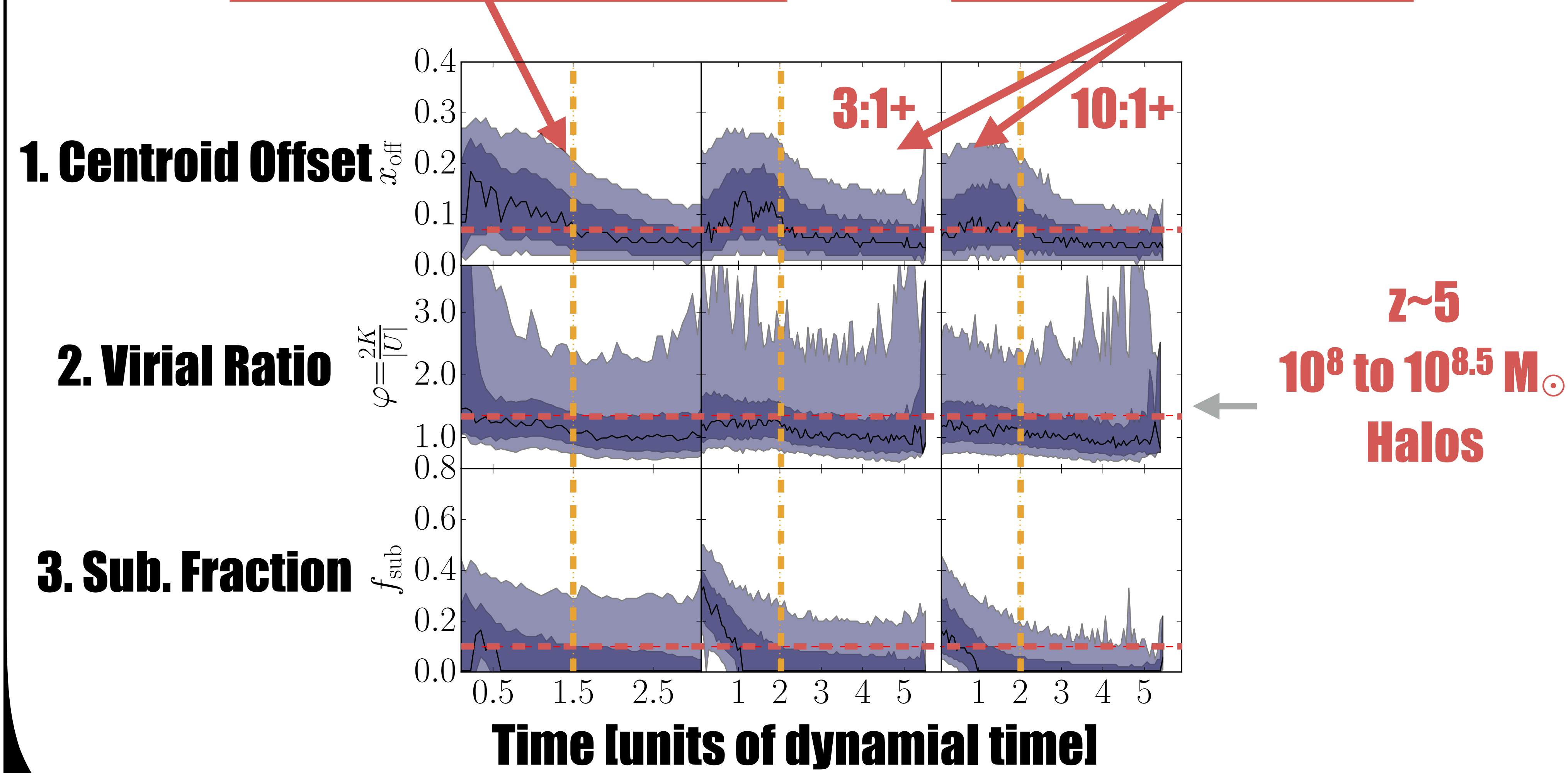
Consider relaxation following 3 dynamical events:



$\tau_{\mathrm{relax}} \sim ?$ | $\tau_{\mathrm{relax}} \sim ?$ | $\tau_{\mathrm{relax}} \sim ?$

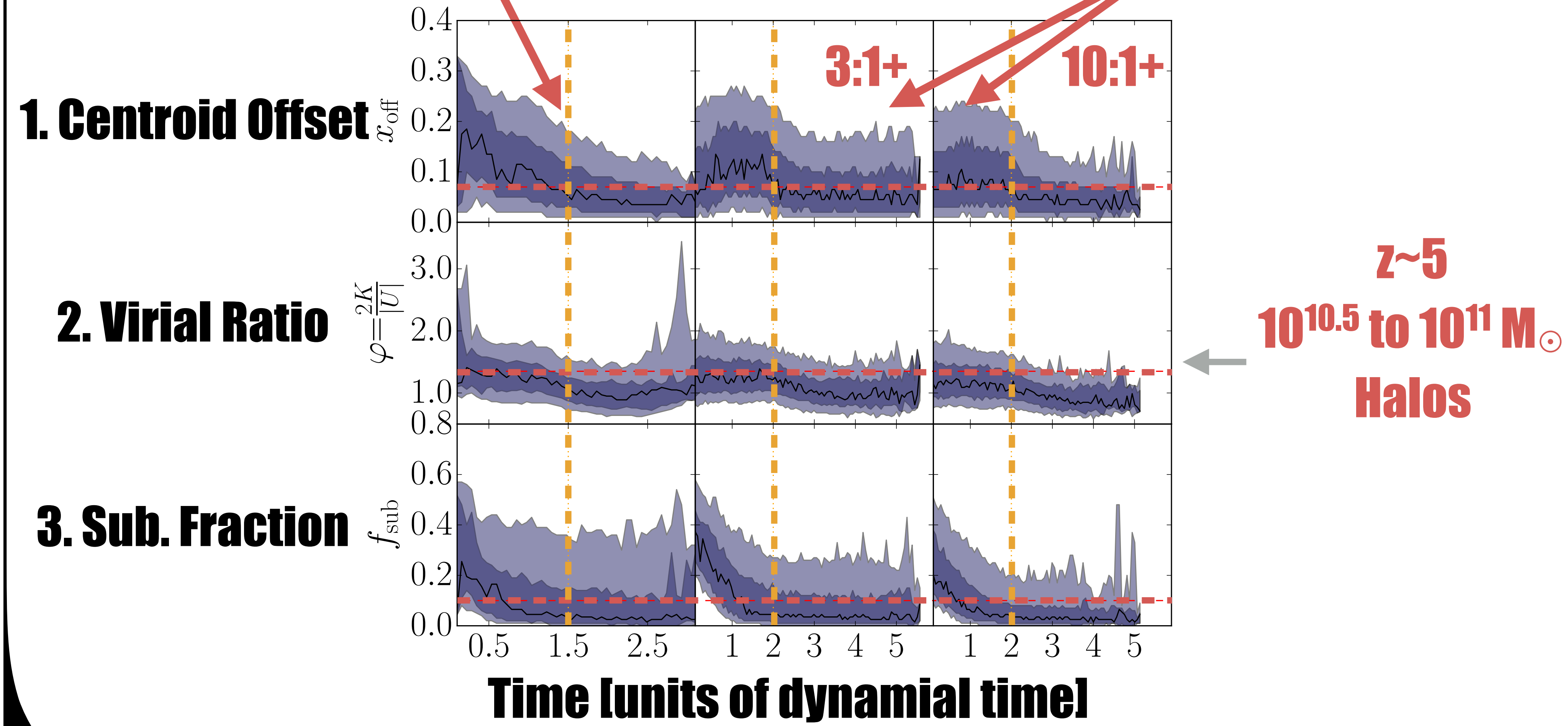
½-mass Formation | **3:1+ Mergers** | **10:1+ Mergers**

Relaxation Following Formation or Mergers



DRAGONS I: Poole et al, submitted

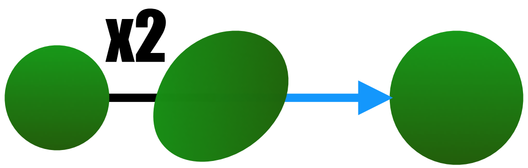
Relaxation Following Formation or Mergers



DRAGONS I: Poole et al, submitted

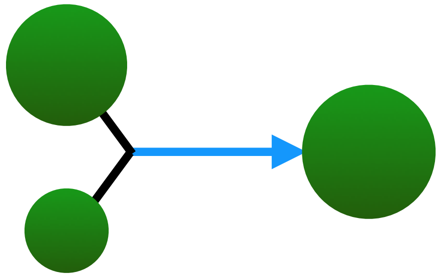
Quantifying the State of Relaxation

We define a new set of relaxation criteria:



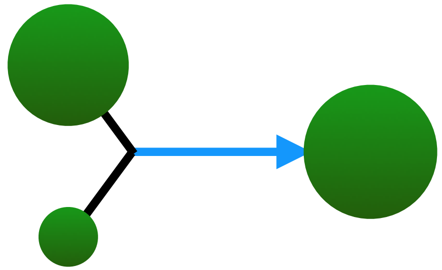
$\tau_{\mathrm{relax}} \sim ?$

½-mass Formation



$\tau_{\mathrm{relax}} \sim ?$

3:1+ Mergers

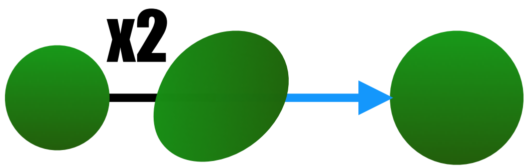


$\tau_{\mathrm{relax}} \sim ?$

10:1+ Mergers

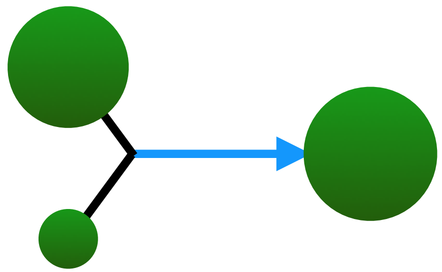
Quantifying the State of Relaxation

We define a new set of relaxation criteria:



$\tau_{\mathrm{relax}} > 1.5$

½-mass Formation



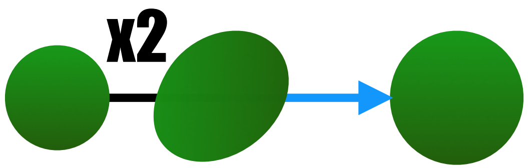
$\tau_{\mathrm{relax}} > 2$

10:1+ Mergers

Quantifying the State of Relaxation

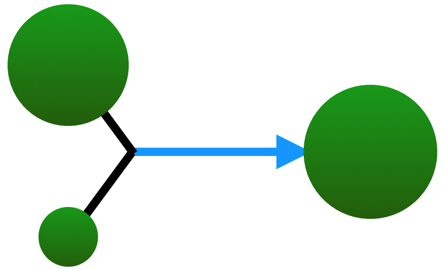
We define a new set of relaxation criteria:

Independent of mass!



$\tau_{relax} > 1.5$

½-mass Formation



$\tau_{relax} > 2$

10:1+ Mergers

Dynamical Ages

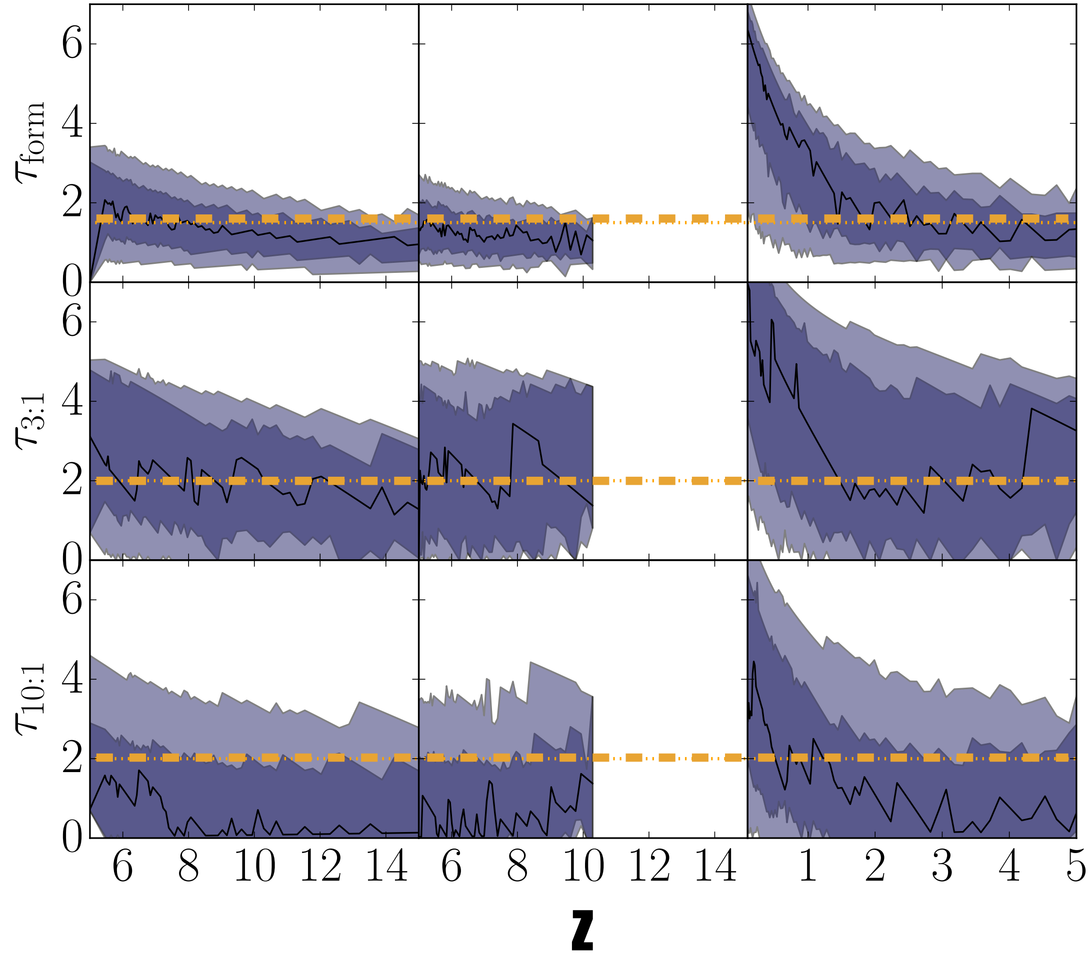
Formation is fast; mergers frequent

	z>5	z>5	z<5
	$10^{8} \rightarrow 10^{8.5}$ M$_\odot$	$10^{10.5} \rightarrow 10^{11}$ M$_\odot$	$10^{12} \rightarrow 10^{12.5}$ M$_\odot$

Time since formation

Time since 3:1+ merger

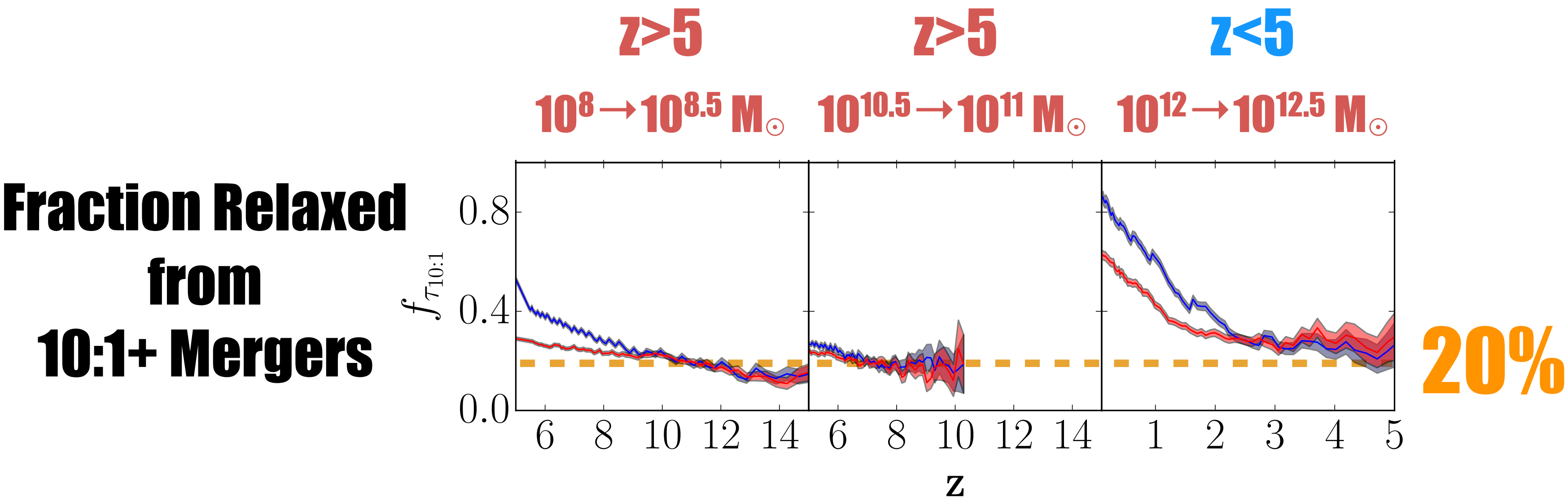
Time since 10:1+ merger



DRAGONS I: Poole et al, submitted

Relaxed Fractions

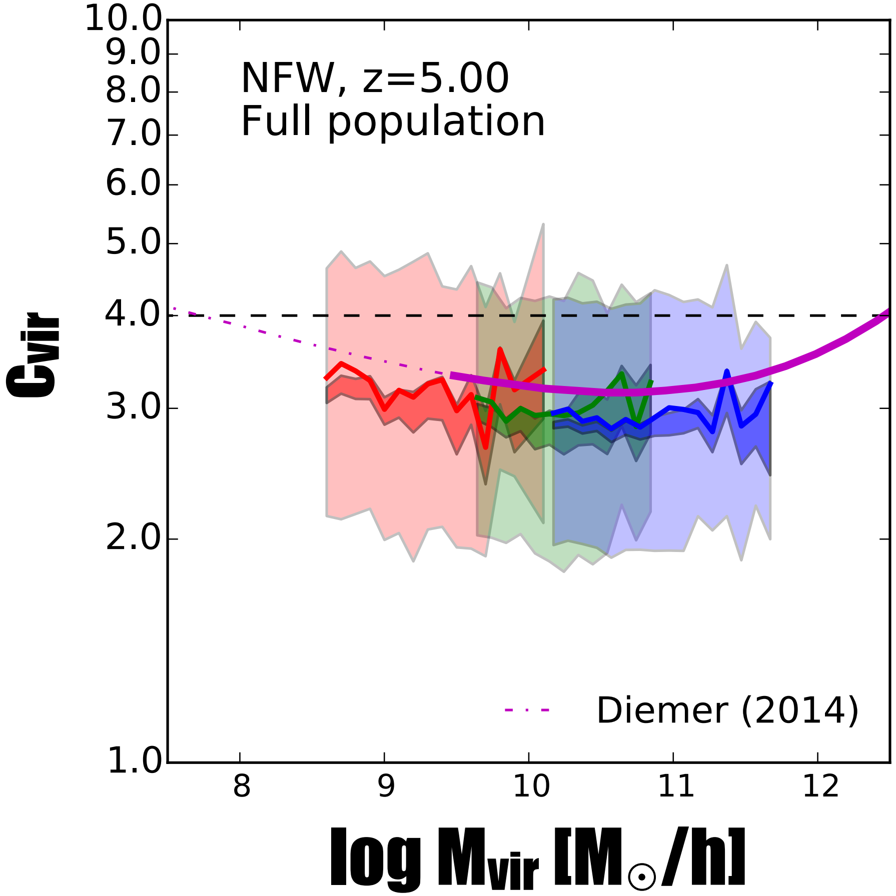
Very few halos are relaxed at high-z

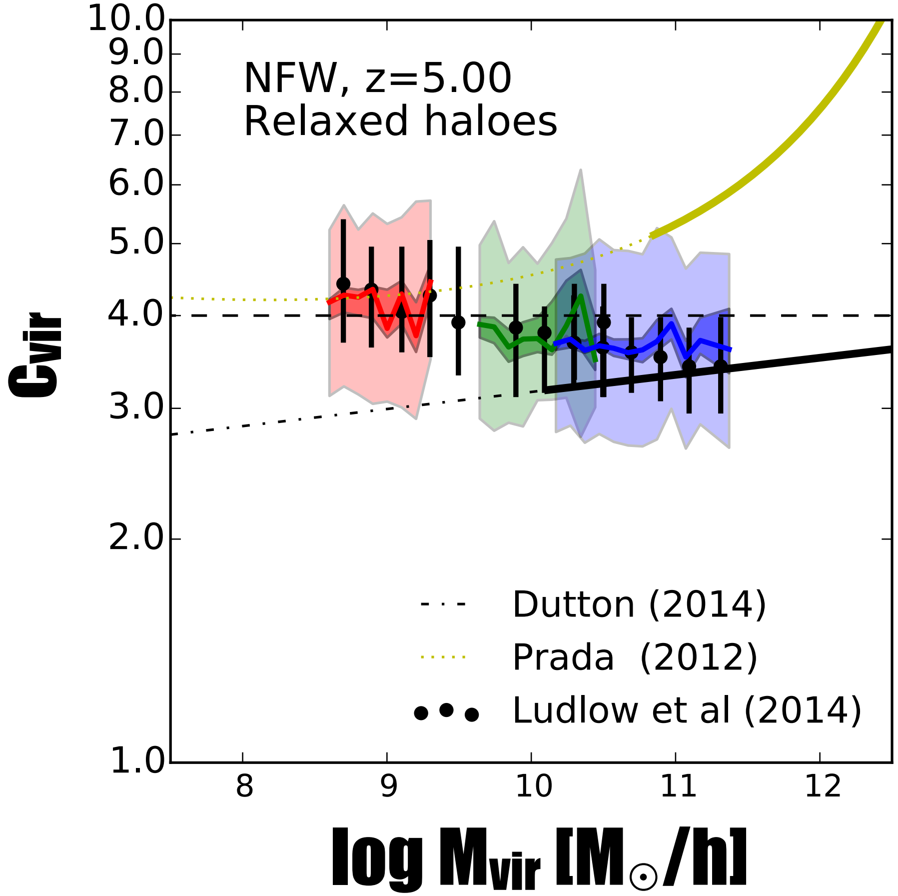


Red	Blue
Fraction meeting the Neto+07 criteria	Fraction meeting our merger criterion

DRAGONS I: Poole et al, submitted

Halo Structure at High-z: Tiamat Results





DRAGONS II: Angel et al, submitted

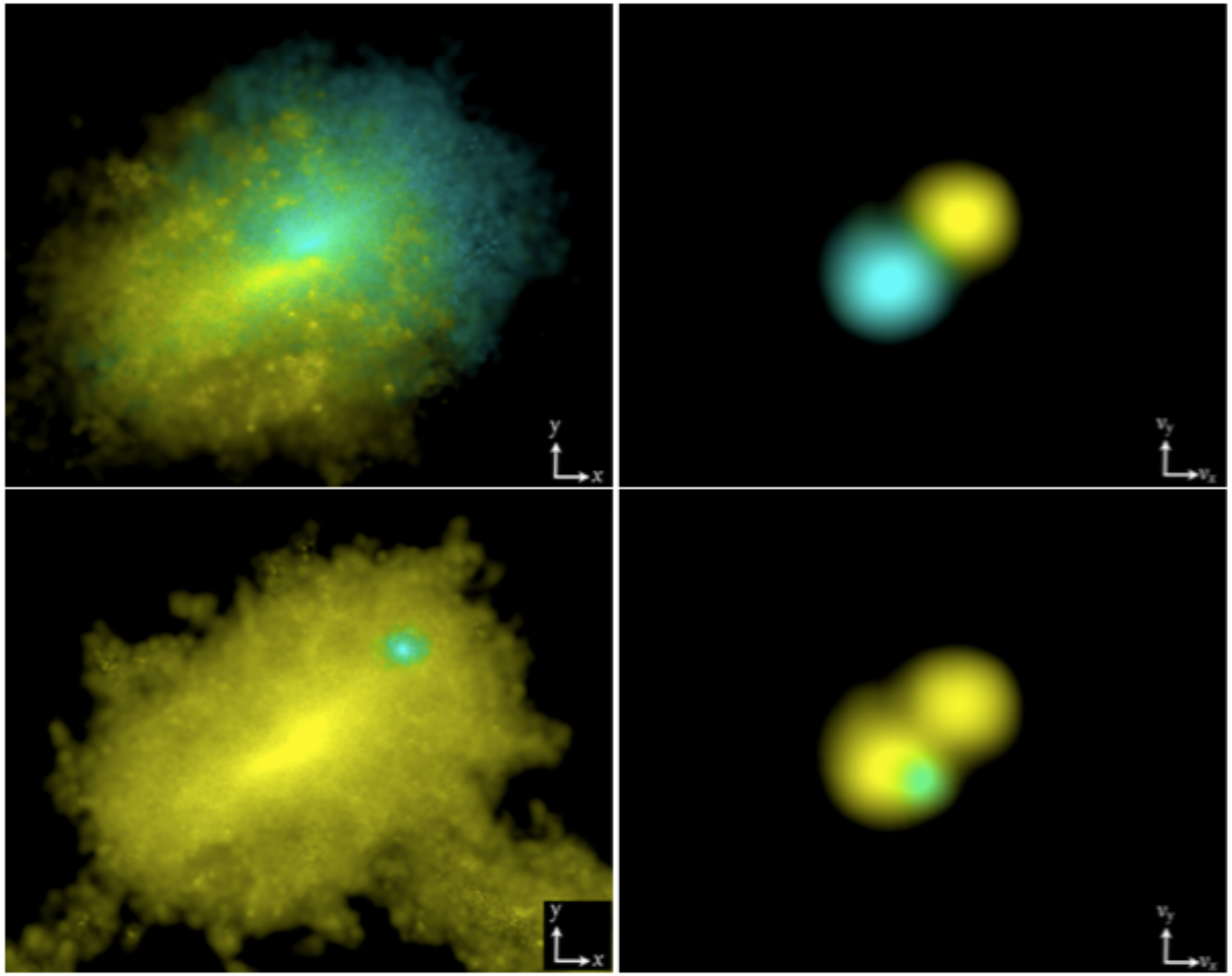
... an interesting aside ...

Large-Scale Phase Space Substructures at High-z

Configuration Space | Velocity Space

ROCKSTAR (phase-space) Subhalos

Subfind (config.-space) Subhalos



Yellow: Most Massive Substructure

Cyan: 2nd Most Massive Substructure

The Dynamical Lives of High Redshift Galaxies

- Structure and dynamical evolution across galactic scales: REMARKABLY invariant at z>5
  - Evolution of relaxation metrics: independent of mass
  - NFW/Einasto concentrations: insensitive to mass
- Only ~20% of galactic halos are relaxed at z>5
- Large-scale phase-space substructures: ubiquitous

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