Fossil groups in the Millennium Simulation

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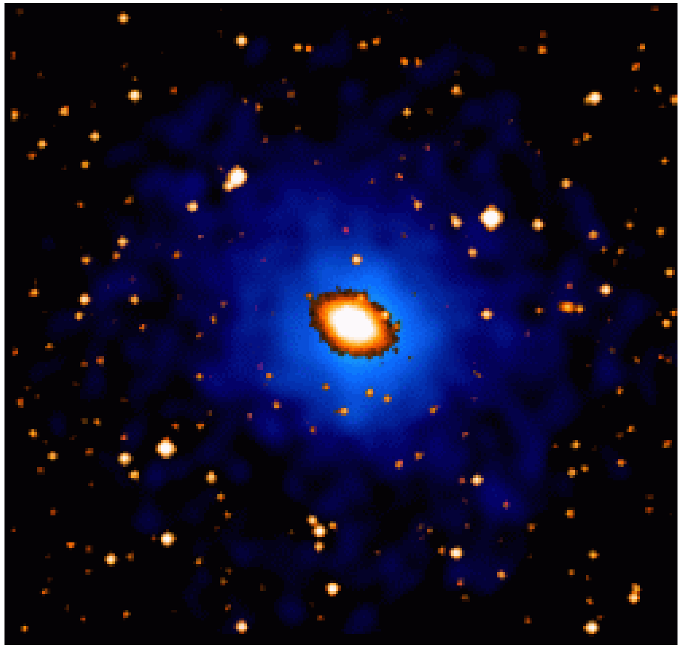
Fossil groups/clusters

- The end result of galaxy merging
- Dominated by a single giant elliptical galaxy at the centre of an extended bright X-ray halo
- $L_X \geqslant 10^{42}\ h_{50}^{-2}$ erg s^{-1}
- Within $0.5R_{vir}$ $\Delta M_{R12} \geqslant 2$ mag

(Jones et al.2003)



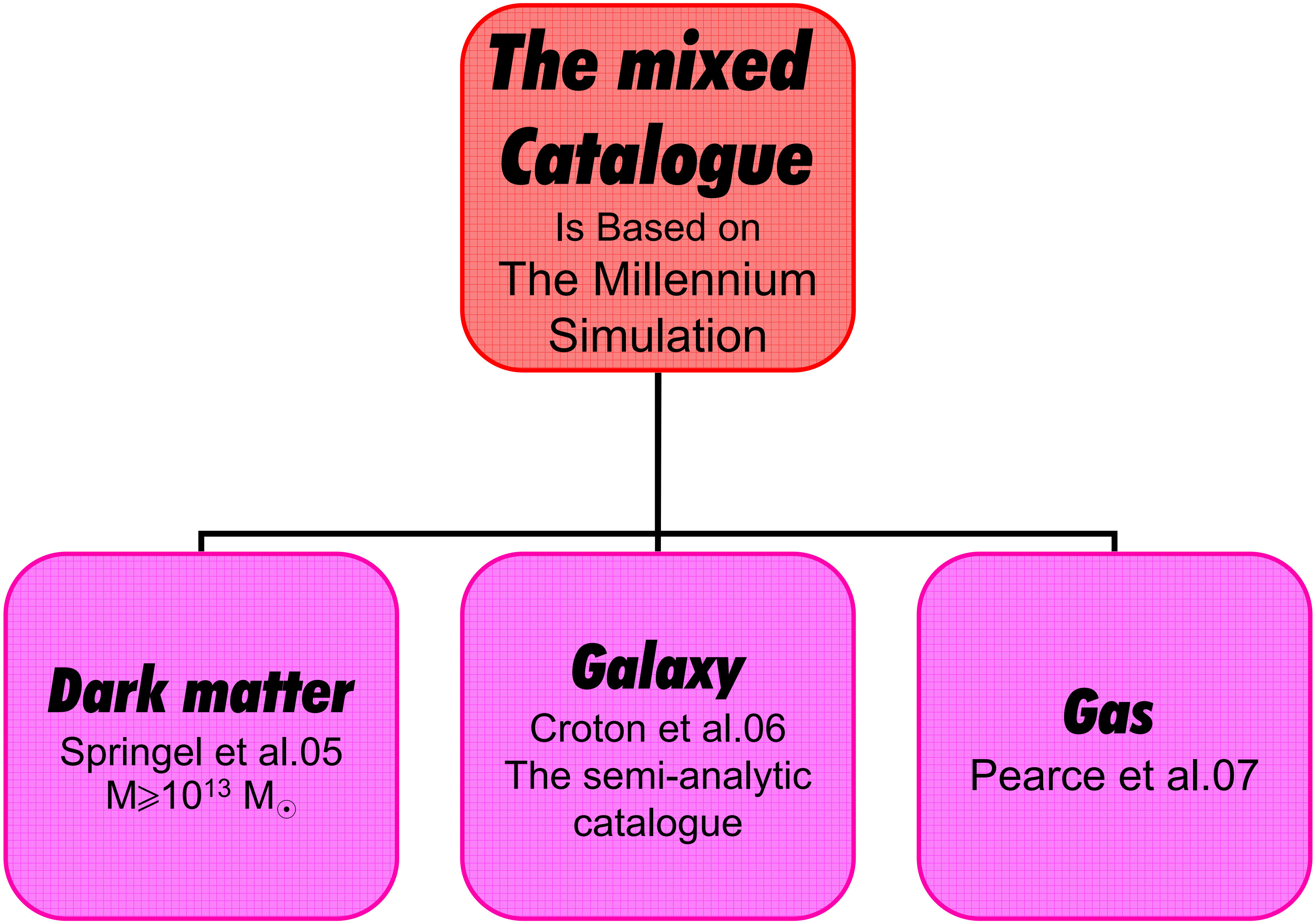
Khosroshahi et al.2004

Fossils in the Millennium
Observation vs. Simulation

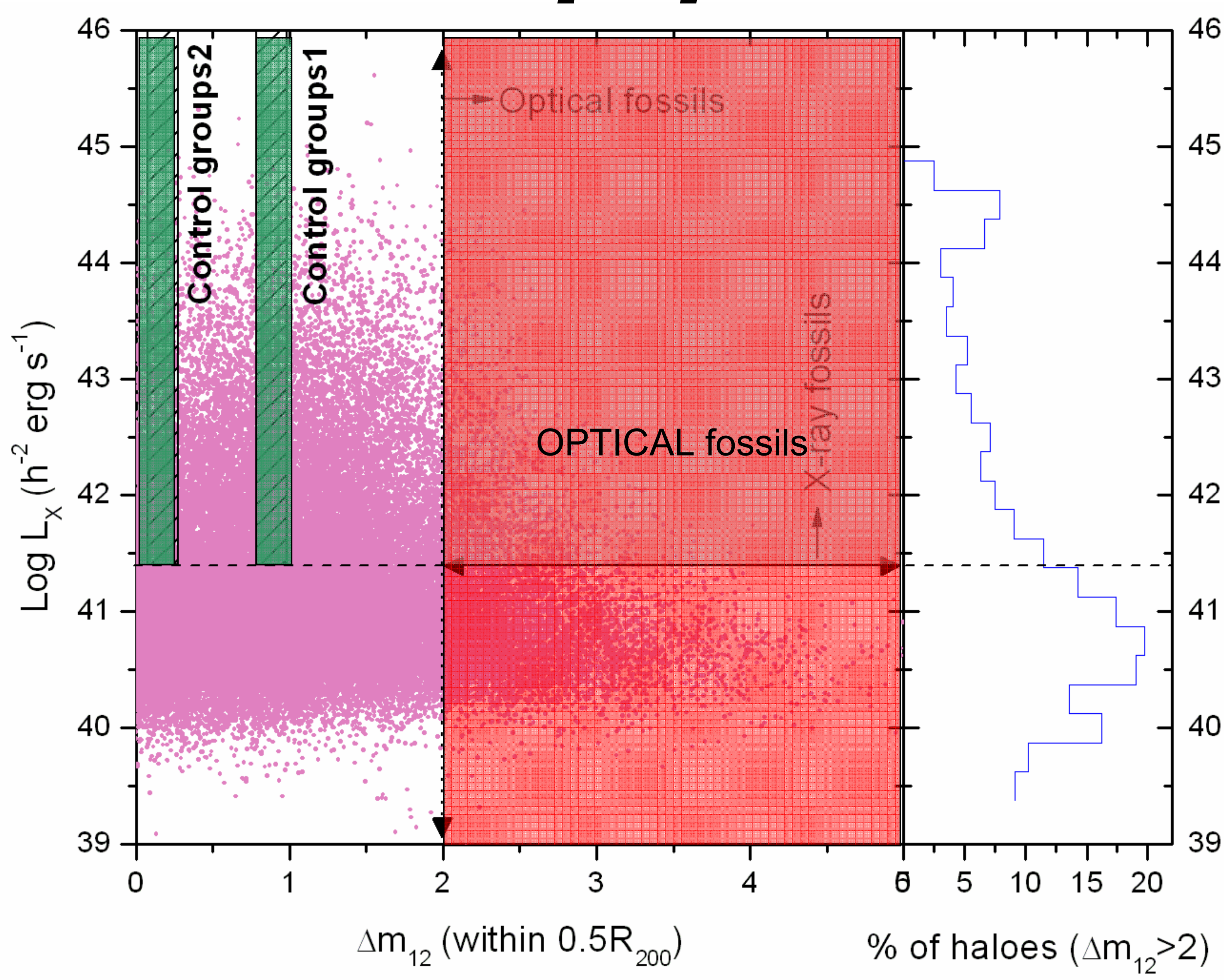
Motivation

- To what extent do simulations reproduce observed properties of fossils?
- Since fossils are extreme objects, comparison of properties provides a useful ***test of the physics*** in the millennium simulation
- Use simulation to study formation of fossils

What sort of information do we need?


The mixed Catalogue
Is Based on
The Millennium Simulation
Dark matter
Springel et al.05
M⩾10^13 M☉
Galaxy
Croton et al.06
The semi-analytic catalogue
Gas
Pearce et al.07

Halo properties



Optical , X-ray Fossils & Control groups

- X-ray fossils

$\Delta M_{R12} \geqslant 2$ mag (within $0.5 r_{vir}$)
$L_X \geqslant 10^{42}\ h_{50}^{-2}$ erg s^{-1}

- Optical fossils

$\Delta M_{R12} \geqslant 2$ mag (within $0.5 r_{vir}$)

- Control groups1 & 2

$0.8 \leqslant \Delta M_{R12} \leqslant 1$, $0.1 \leqslant \Delta M_{R12} \leqslant 0.3$ (within $0.5 r_{vir}$)
$L_X \geqslant 10^{42}\ h_{50}^{-2}$ erg s^{-1}

Space density of X-ray fossils

$L_X{}^a$	$N_f{}^b$	Density^c	Reference^d	Present study^c
> 0.25	5	320^{+216}_{-144}	J03	104 ± 3
> 2.5	3	$16^{+15.2}_{-8.8}$	J03	22.4 ± 1.3
> 2.5	4	$36.8^{+47.2}_{-18.4}$	V99	22.4 ± 1.3
> 2.5	3	~ 160	R00	22.4 ± 1.3
> 5.0	4	$19.2^{+24.8}_{-9.6}$	V99	12.8 ± 1.0

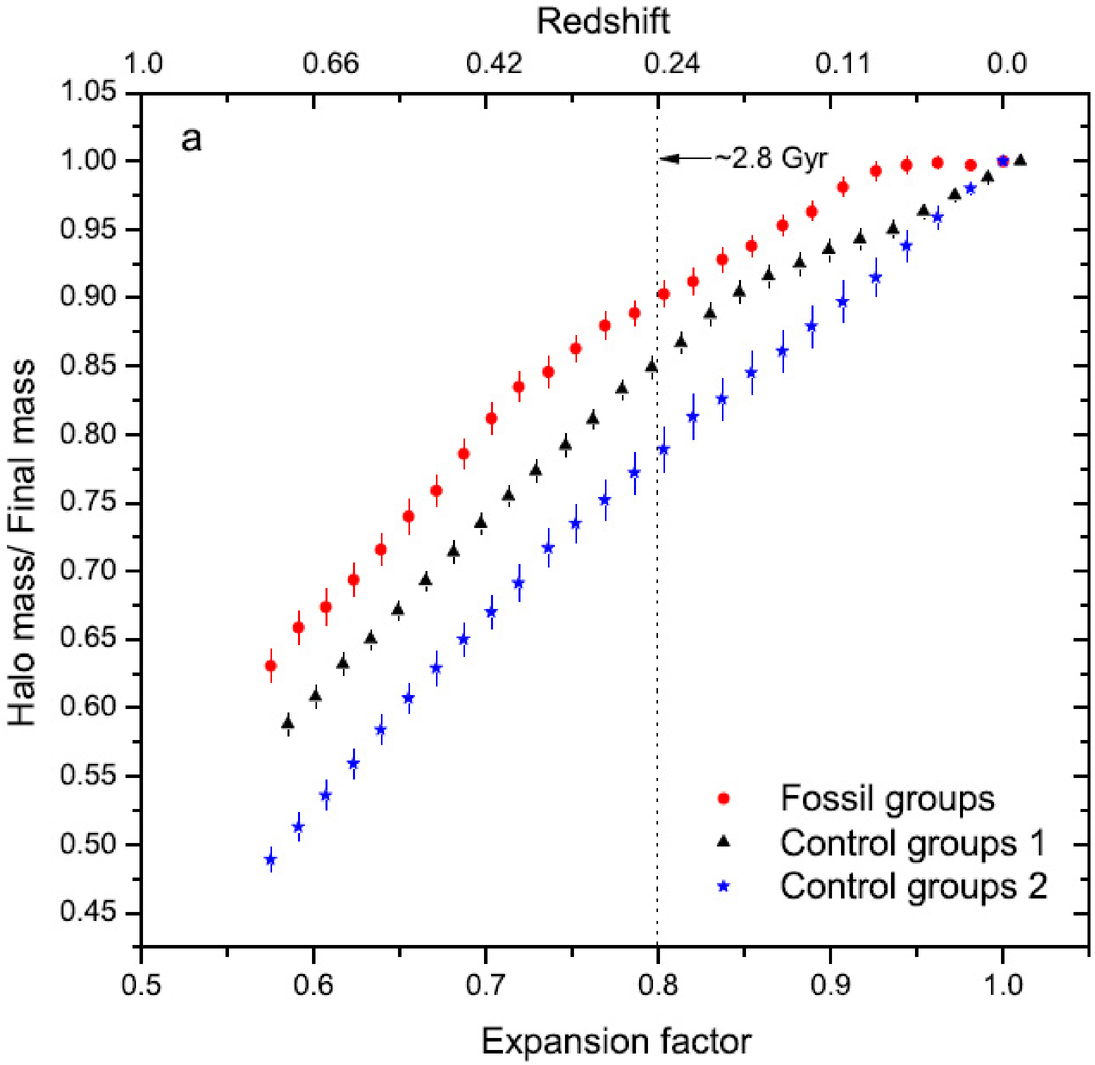
^{a} In units of $10^{42} h^{-2}$ erg s^{-1}

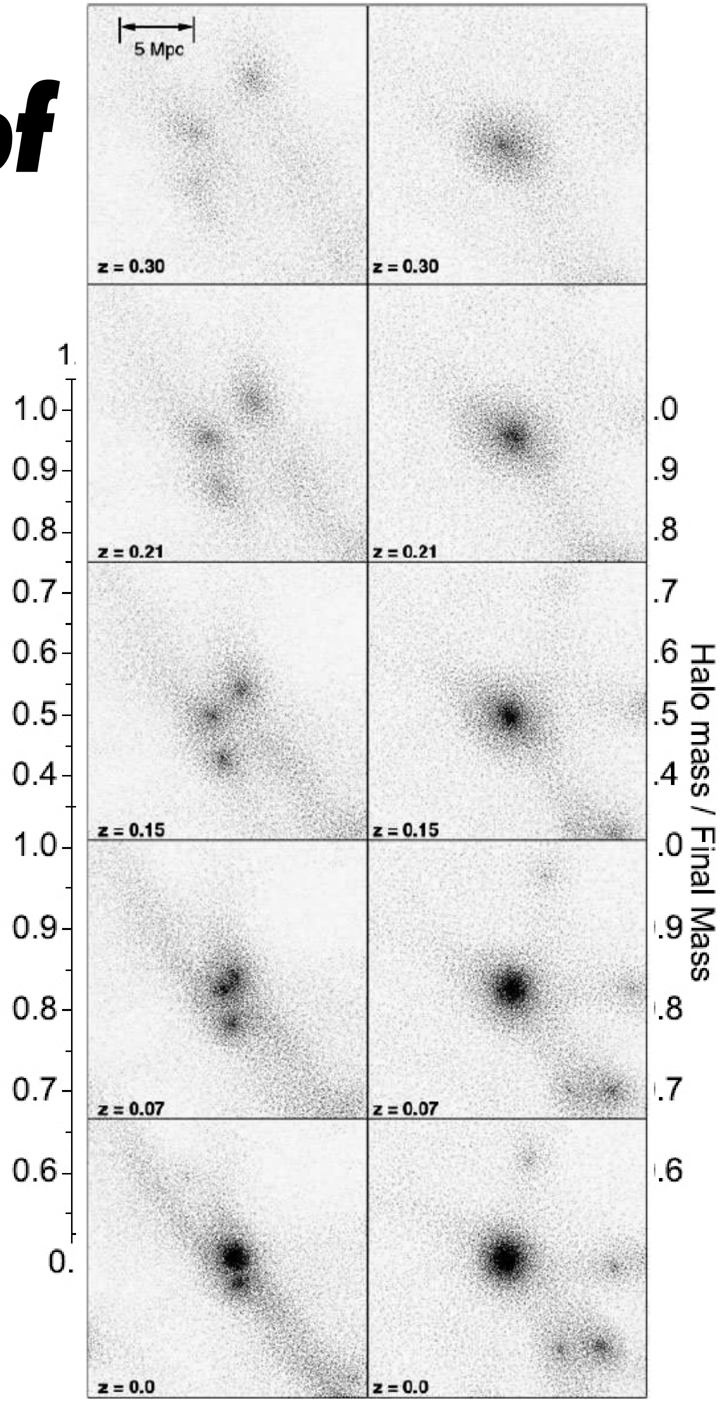
^{b} Number of fossils

^{c} In units of $10^{-7} h^3$ Mpc^{-3}

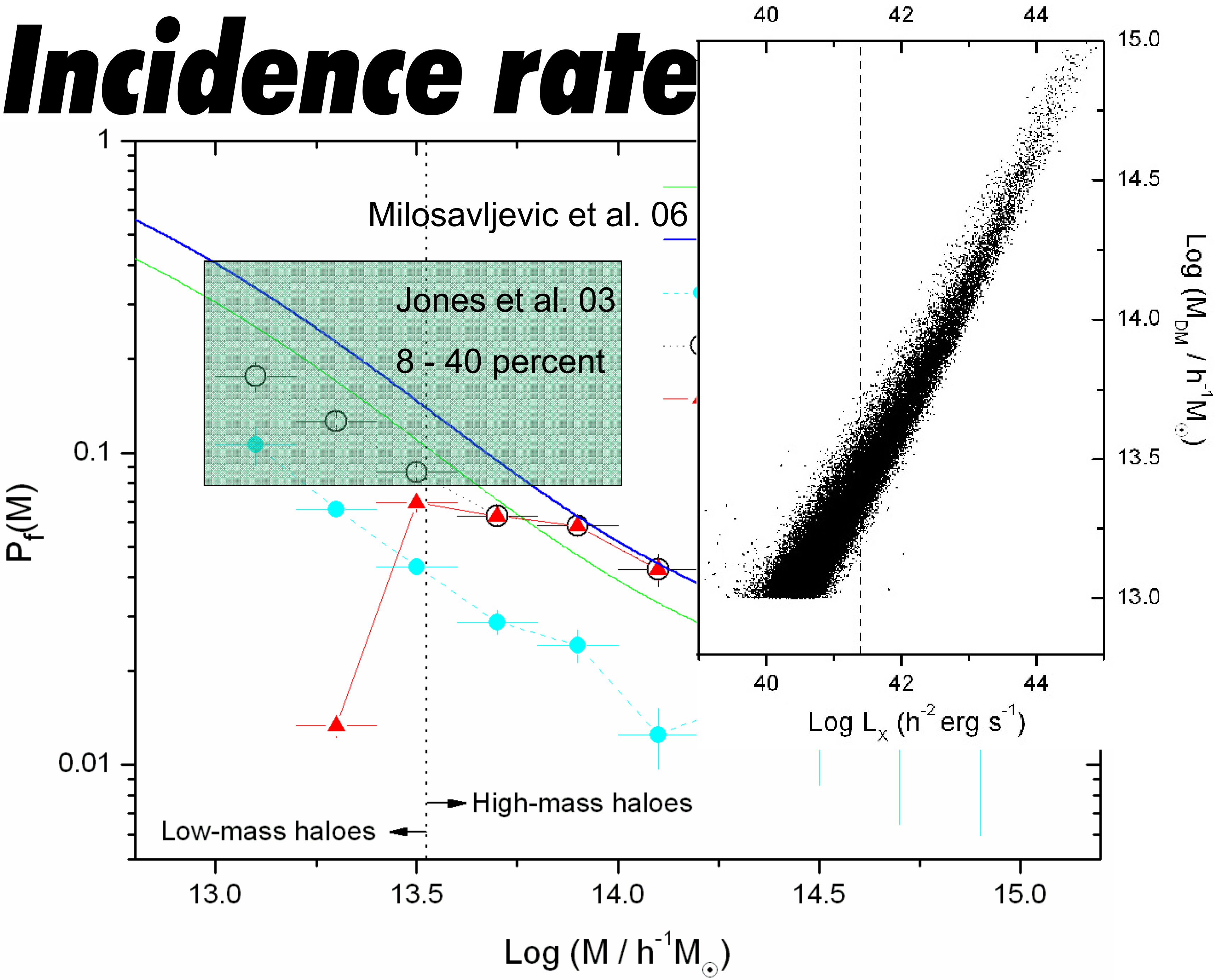
^{d} V99:Vikhlinin et al. (1999), R00:Romer (2000), J03:Jones et al. (2003)

Mass Evolution of





Incidence rate



Results

- The space density of X-ray fossil groups is in remarkably good agreement to the observed space density of fossils. Although for low luminosity fossils we find roughly 1/3 of the (very uncertain) observed fossil space density.

- The probability of finding optical fossils with mass **M**, i.e, **P_f (M; optical)** is a decreasing function of:

(a) group dark matter halo mass and,
(b) the fraction of the virial radius within which the second brightest galaxy is searched for.

- As dark matter halo mass become small, the probability **P_f (M;X-ray)** for X-ray fossils decreases, due to the low L_X of low mass halos.

- More massive X-ray fossil groups are found to have assembled 90% of their final mass by a redshift of z = 0.24. The corresponding mass fraction is about 70−80% for two different sets of control samples.