What *don't* we know about galaxy formation?

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Theory: Simon White, et al. (Virgo)
Observational: Marc Davis, et al. (DEEP2/AEGIS)

Galaxies, why we care ...

- highly non-linear evolution
- home of internal phenomena
- shaped by external influences

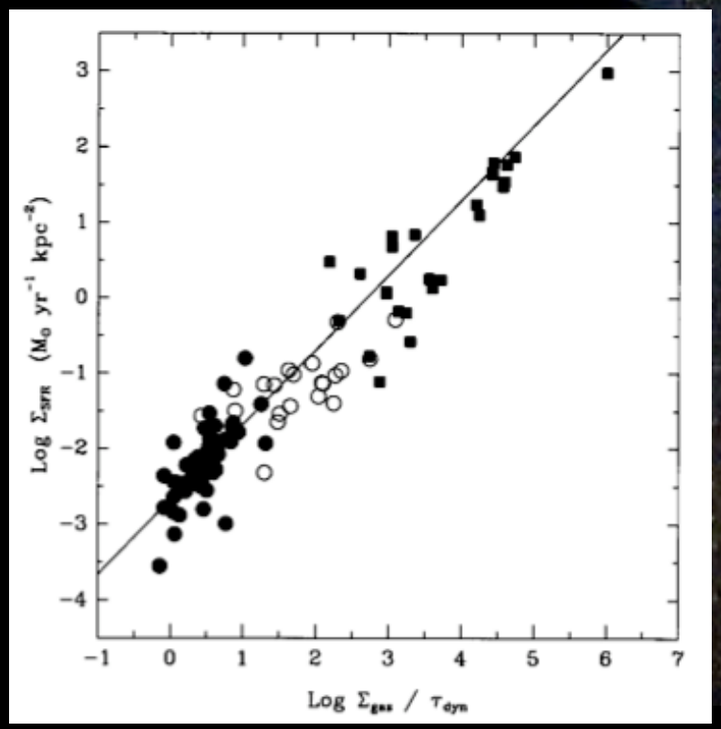
Outline

1. What we think we know
2. What we think we don’t know
3. Next generation surveys

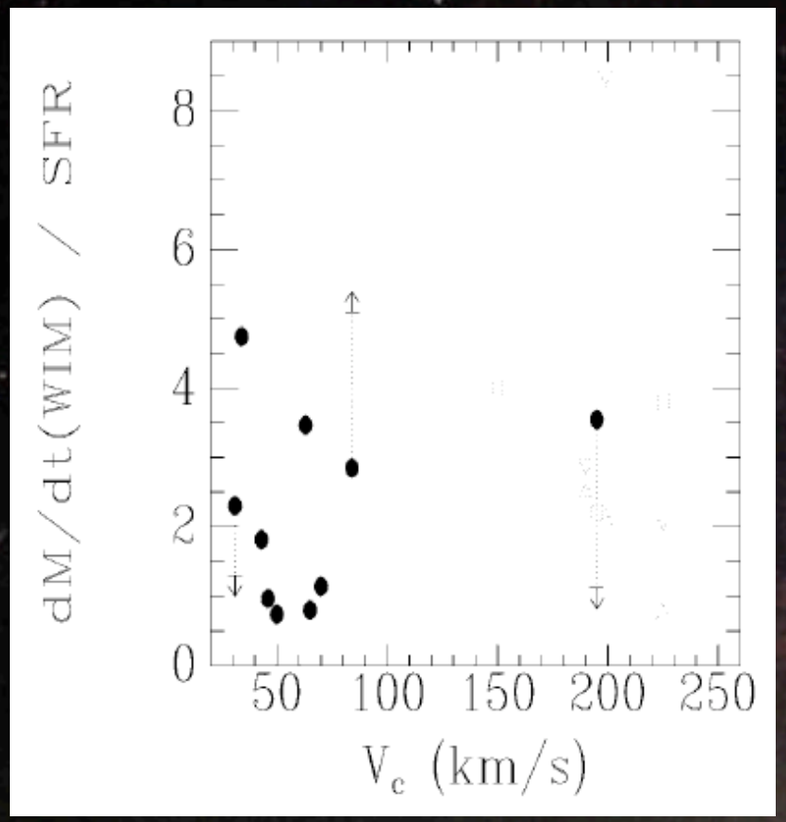
What (we think) we know

Star formation

Kennicutt 1998



M31

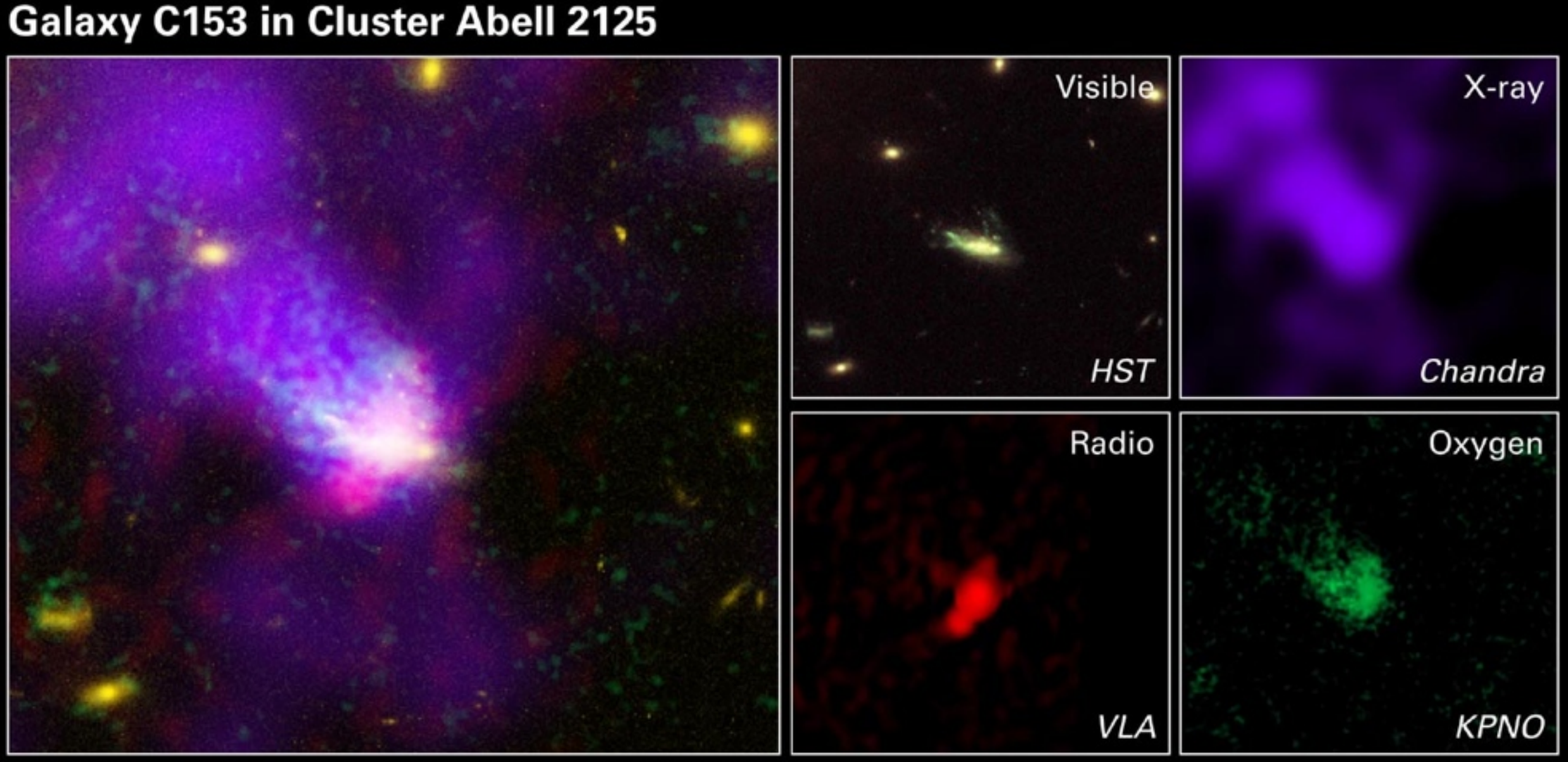


Martin 1999

M82

Supernova feedback

Satellite infall



NASA, W. Keel (University of Alabama), F. Owen (National Radio Astronomy Observatory), M. Ledlow (Gemini Observatory) and D. Wang (University of Massachusetts)

STScI-PRC04-02a

Morphological evolution

NGC 2207 & IC 2163

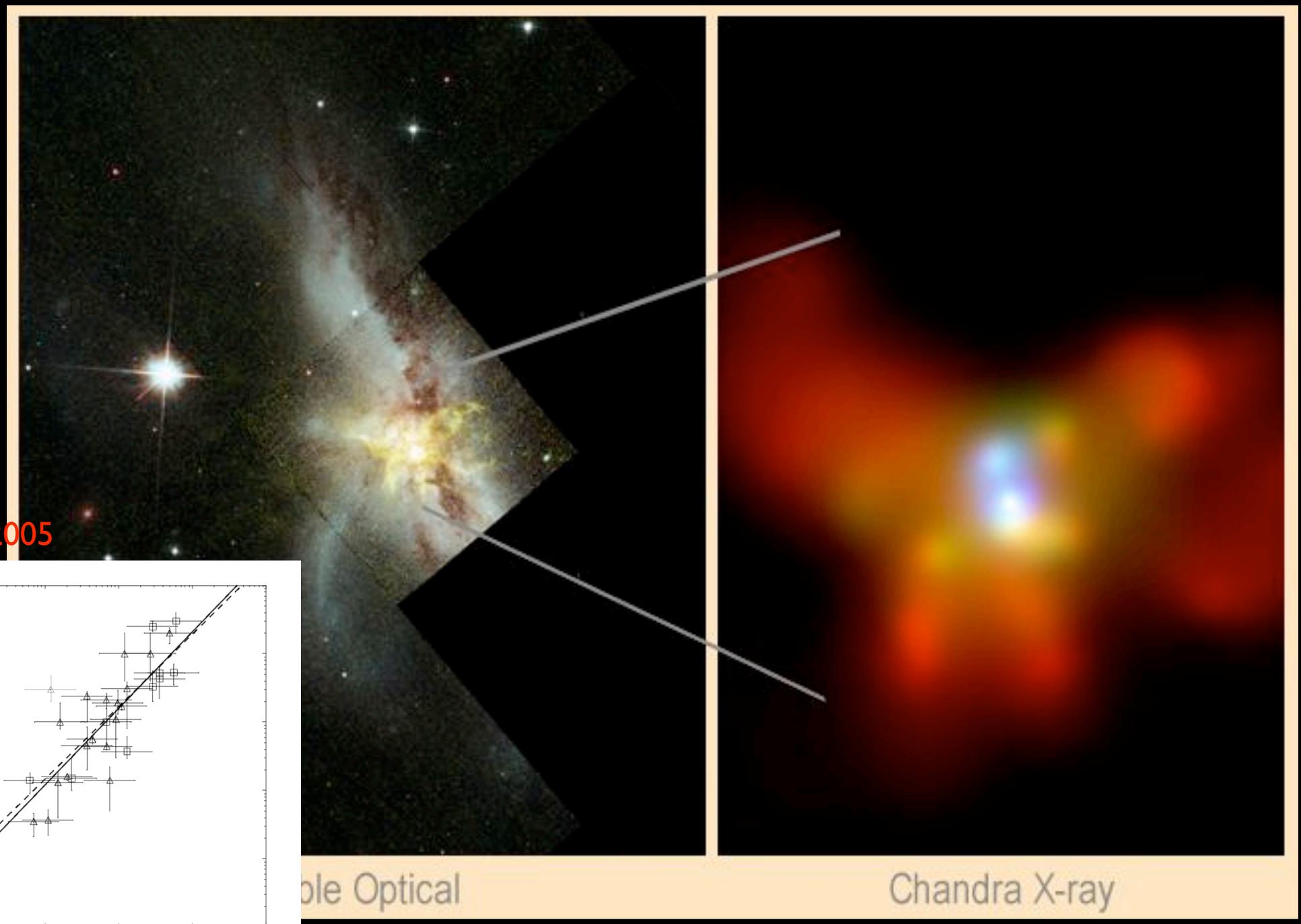
... and assembly

Seyfert's Sextet

... and death

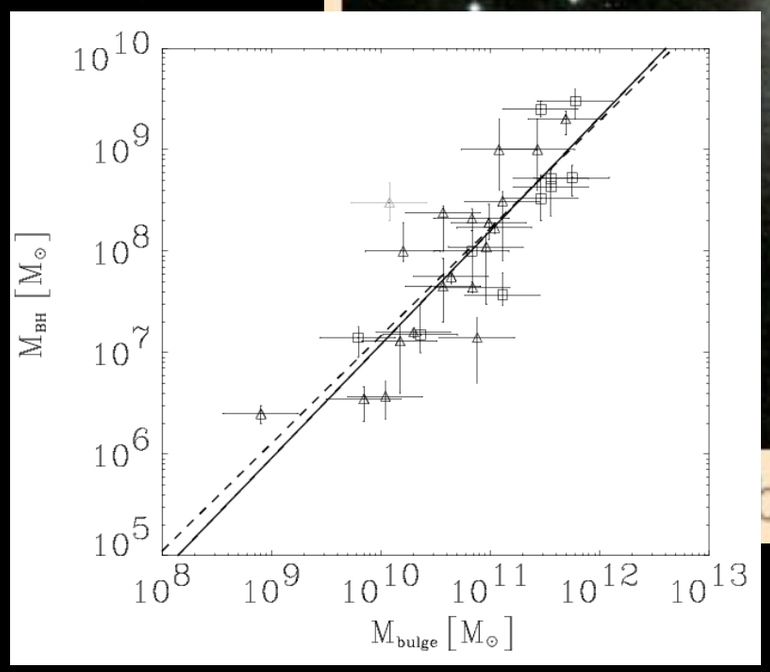
M87 (Virgo cluster)

Black holes



NGC 6240

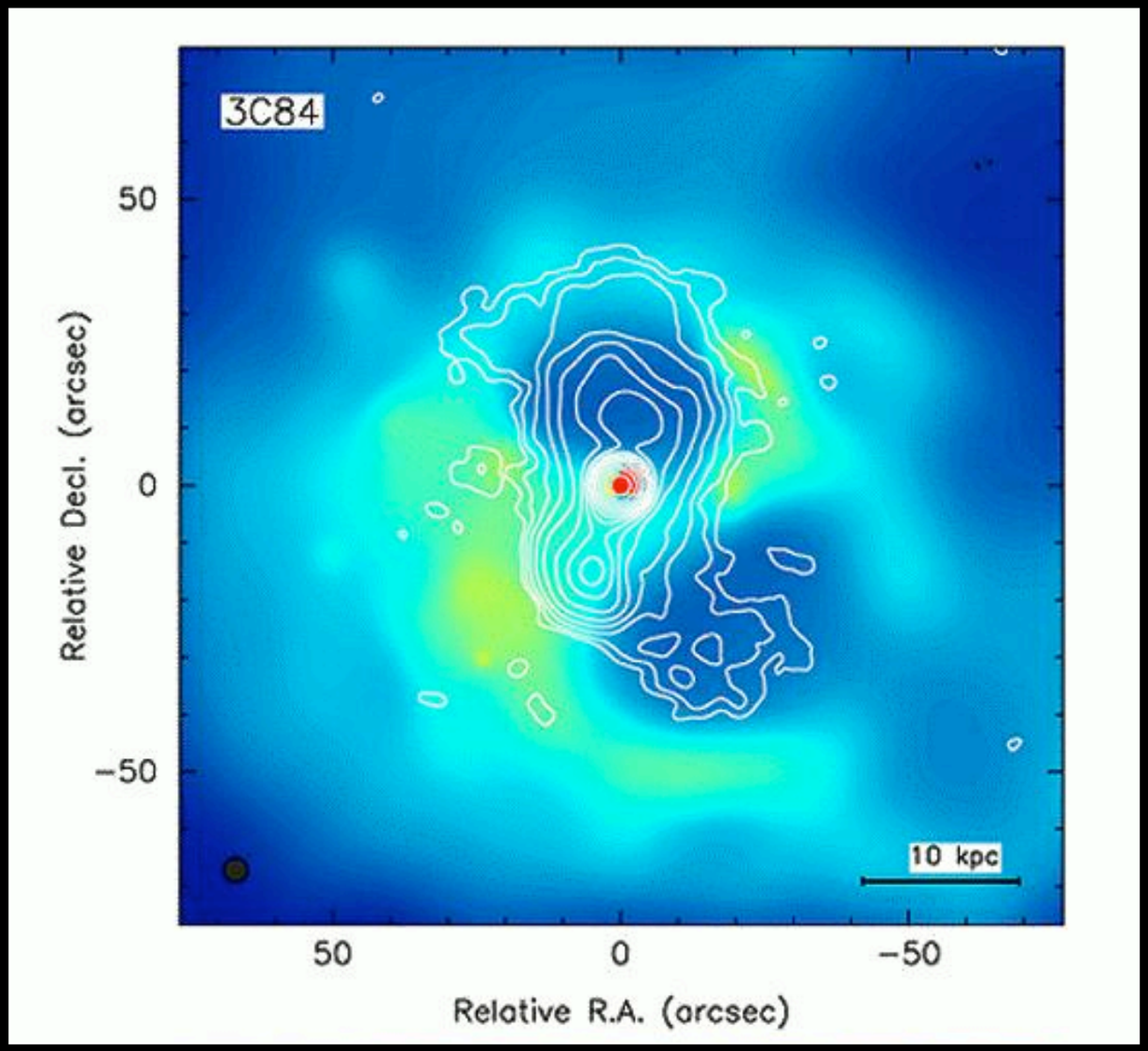
Haring & Rix 2005

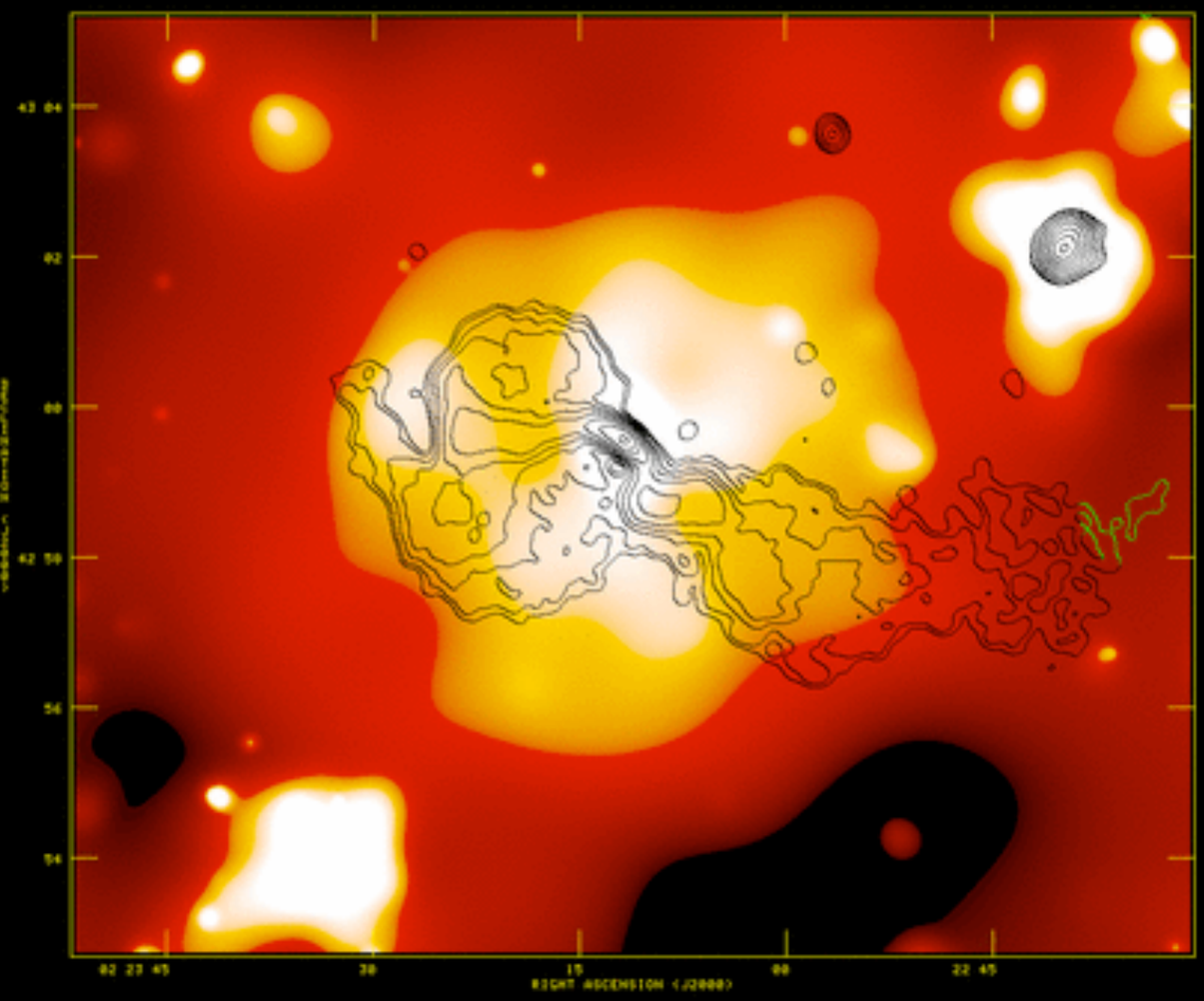


AGN jets

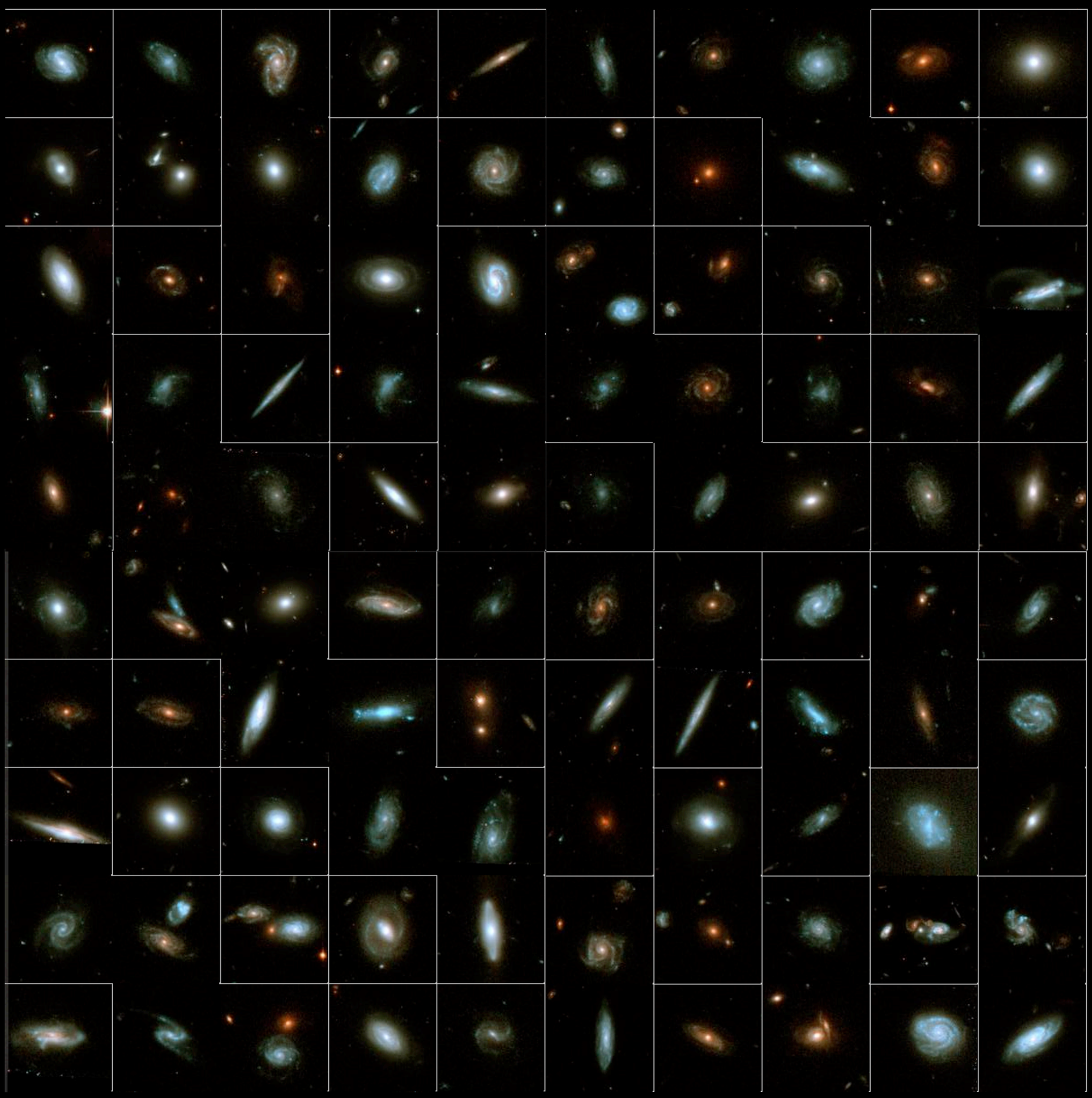
M87 (Virgo cluster)

AGN bubbles


3C84
50
0
−50
Relative Decl. (arcsec)
10 kpc
50
0
−50
Relative R.A. (arcsec)



GEMS (Rix et al. 2004)



making sense of this with models

Alien invasion

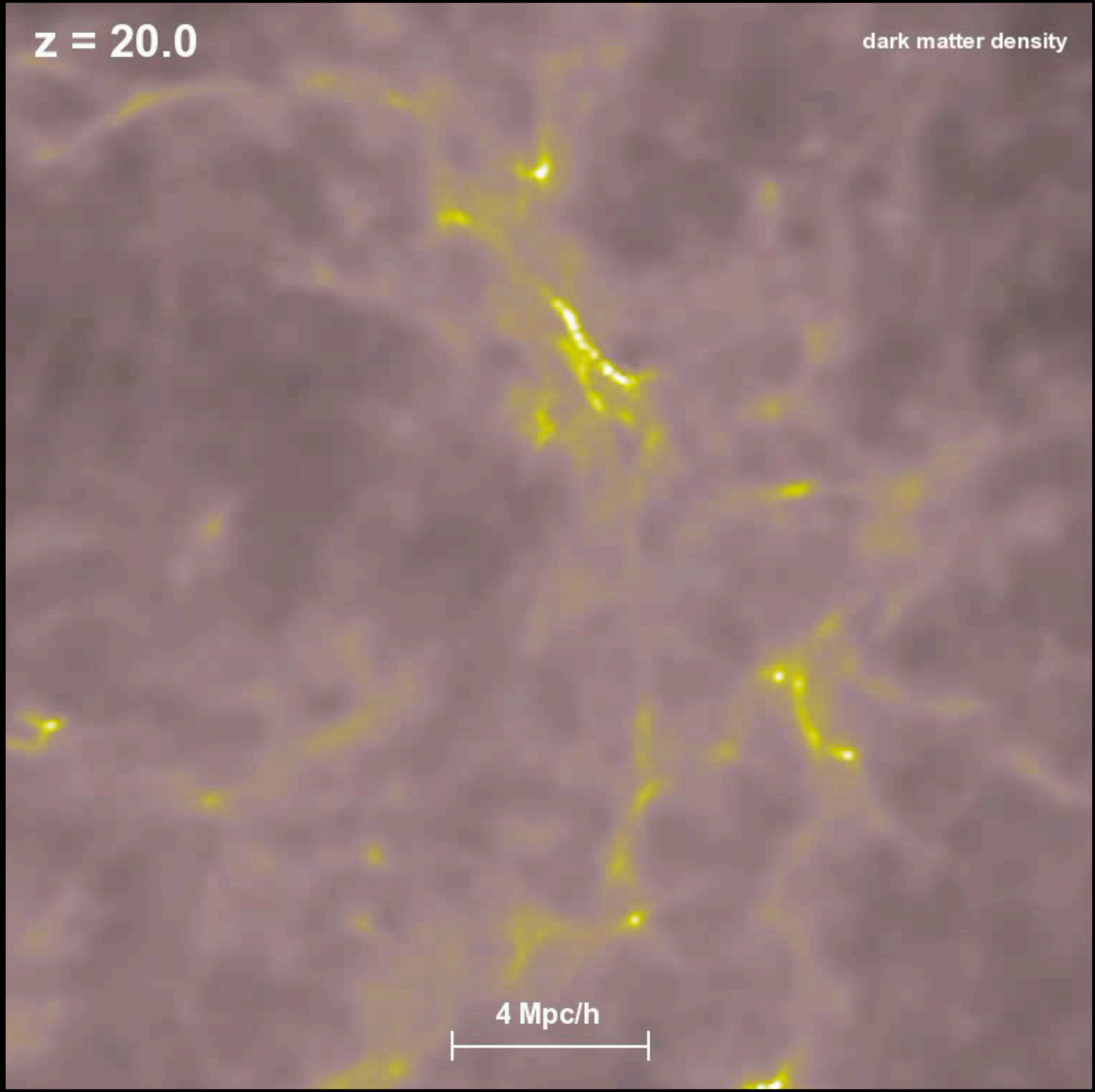
height & shape,
density, pressure,
gravity, ...

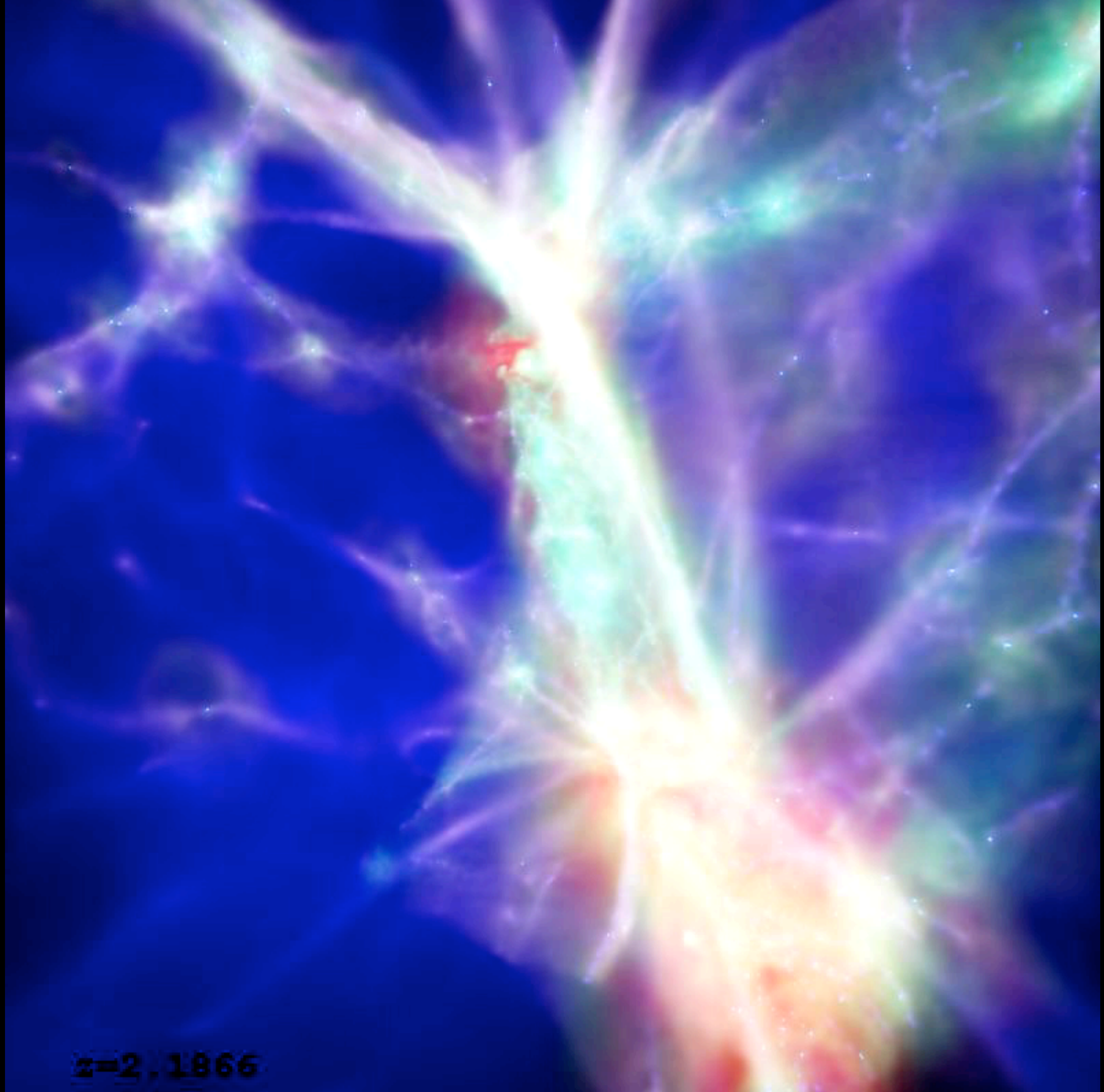
flexibility, running,
jumping,
disintegration
resistance

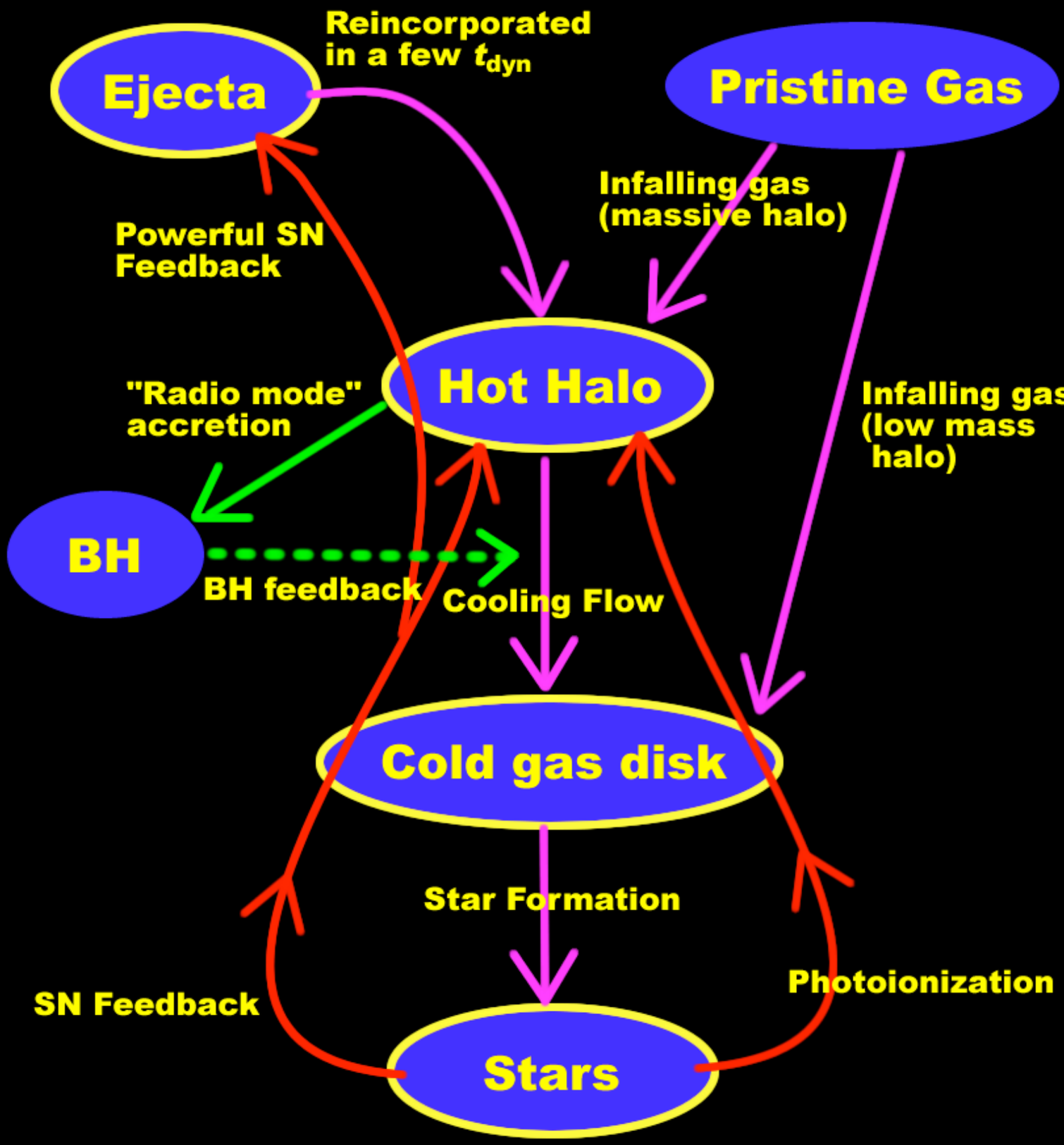
(human)

Our model is only as good as the questions we ask

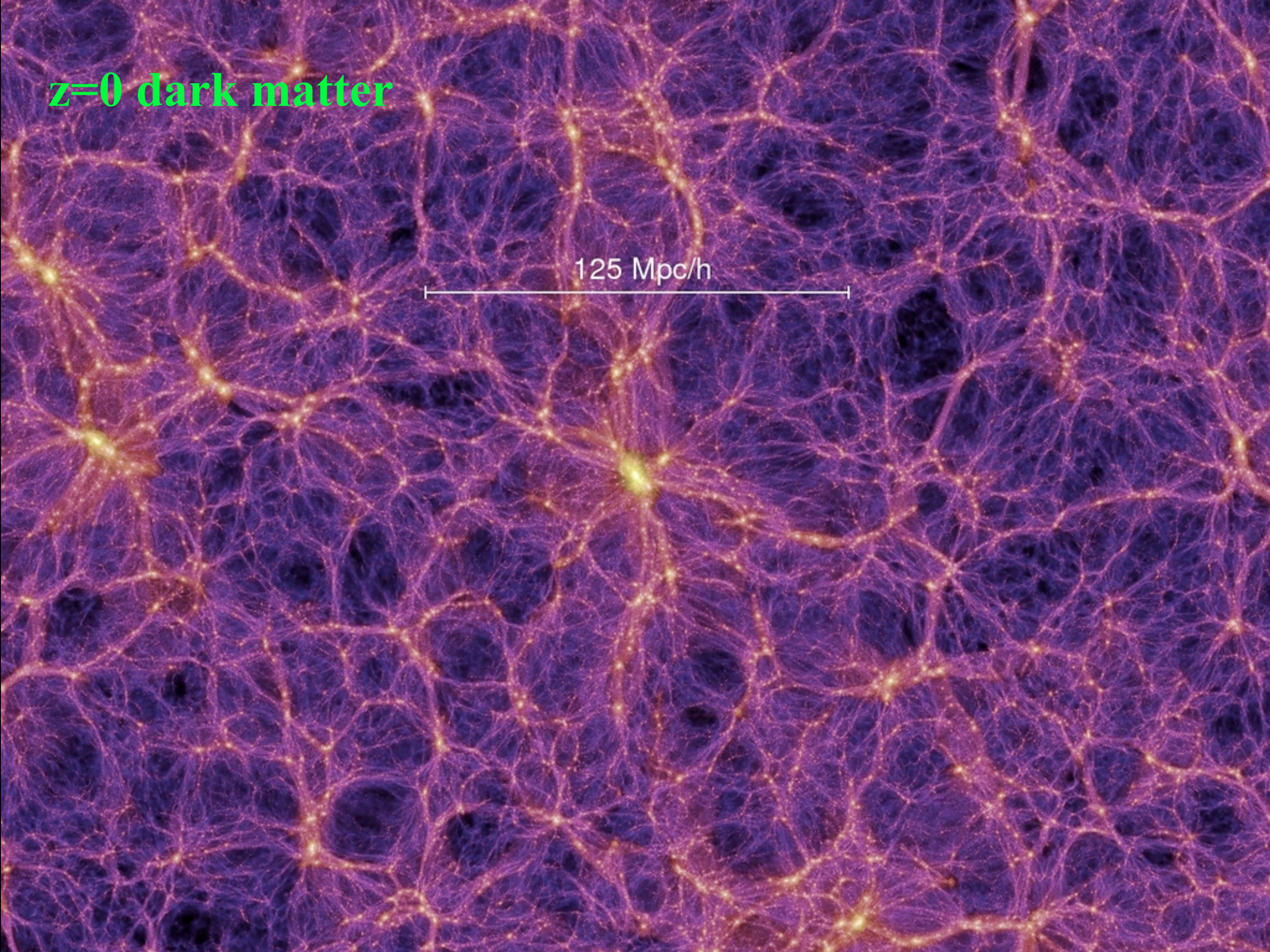
For systems with infinite levels of complexity, our model can never be “correct”


z = 20.0
dark matter density
4 Mpc/h

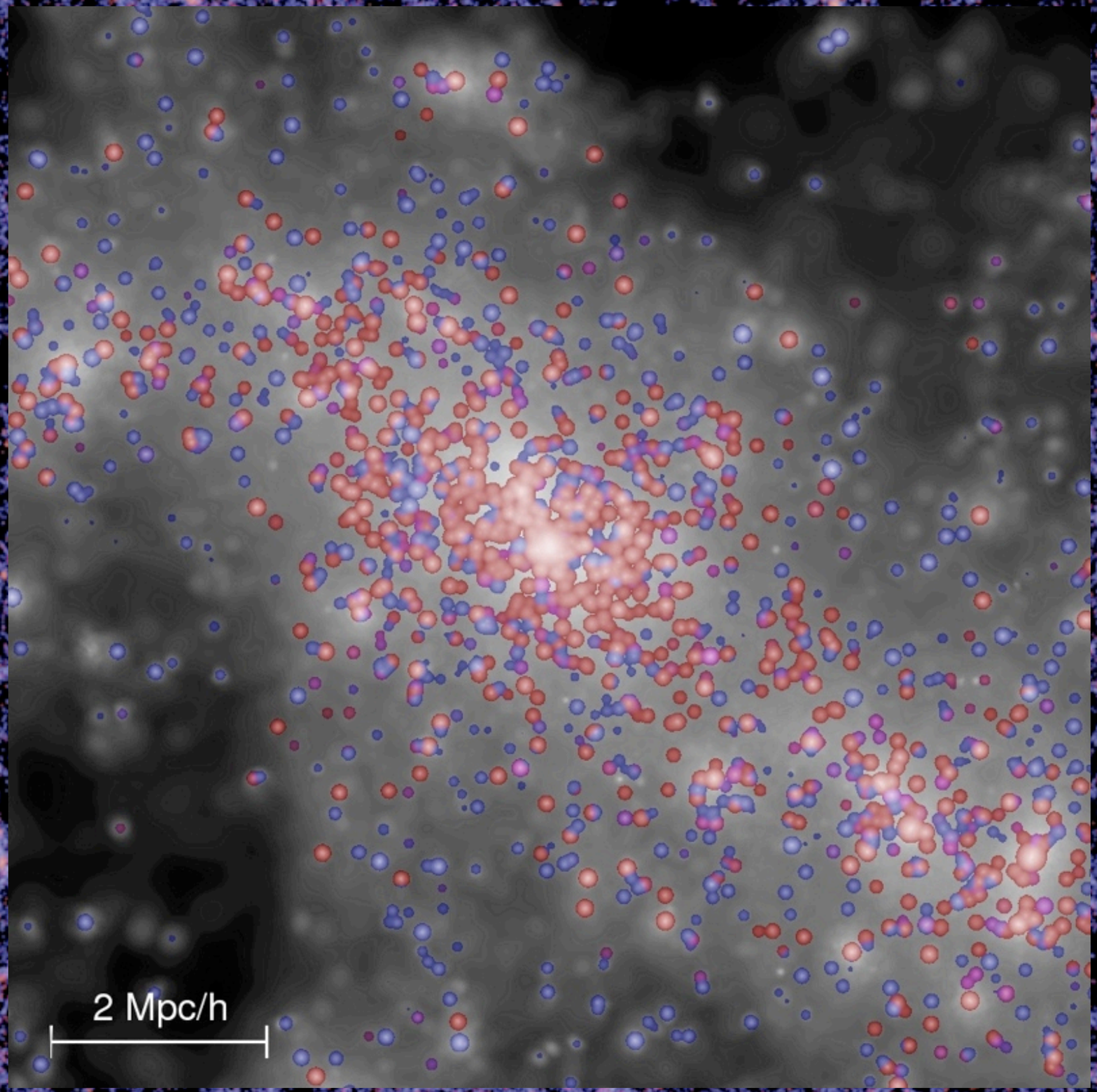

z=2.1866



- Schmidt law star formation
- SFR dependent SN winds
- satellite gas stripping
- morphological transformation
- assembly through mergers
- starbursts through mergers
- Magorrian relation BH growth
- jet & bubble AGN feedback

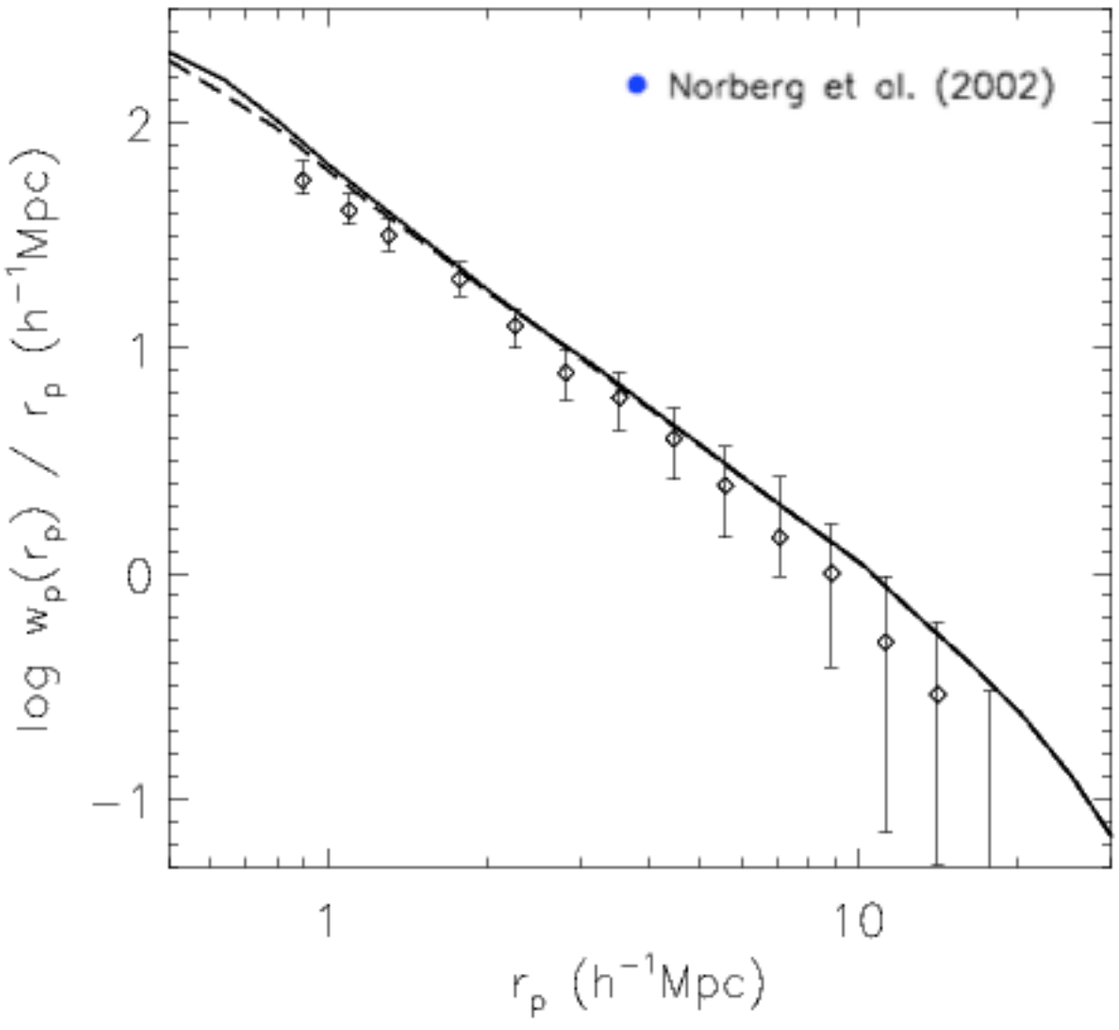

z=0 dark matter
125 Mpc/h

z=0 galaxy light

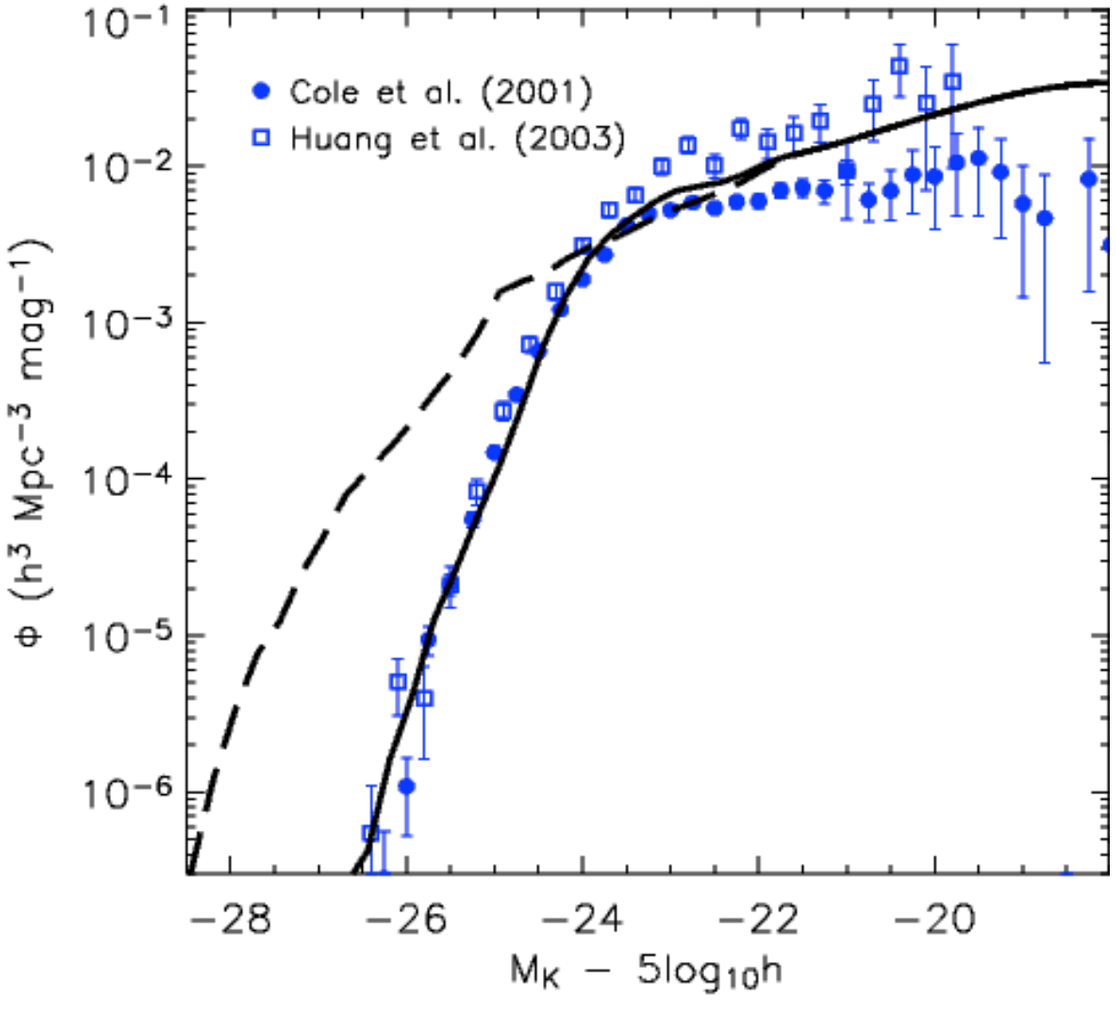


STATISTICS

Do our galaxies have the right distribution and abundance?

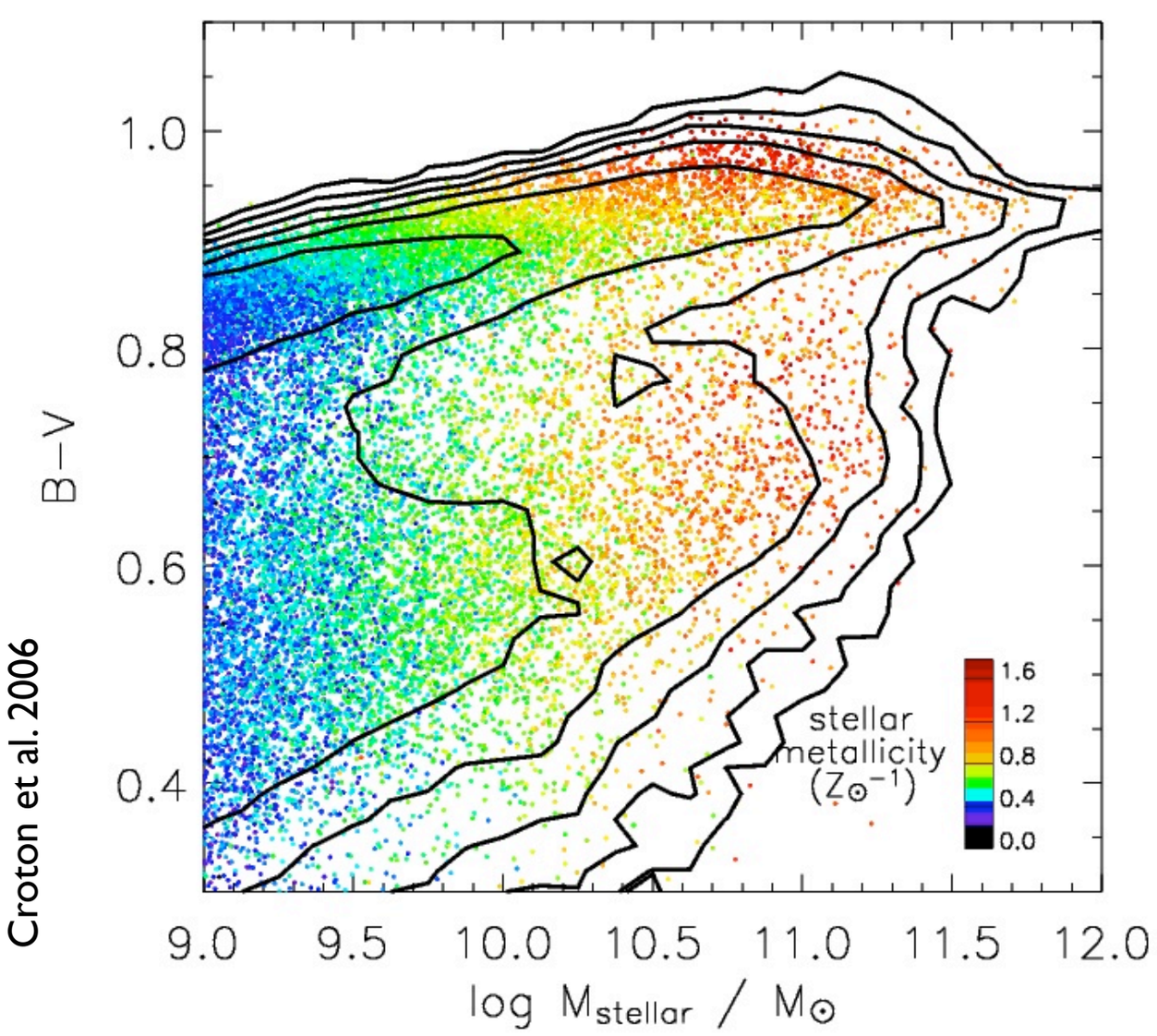


< clustering >

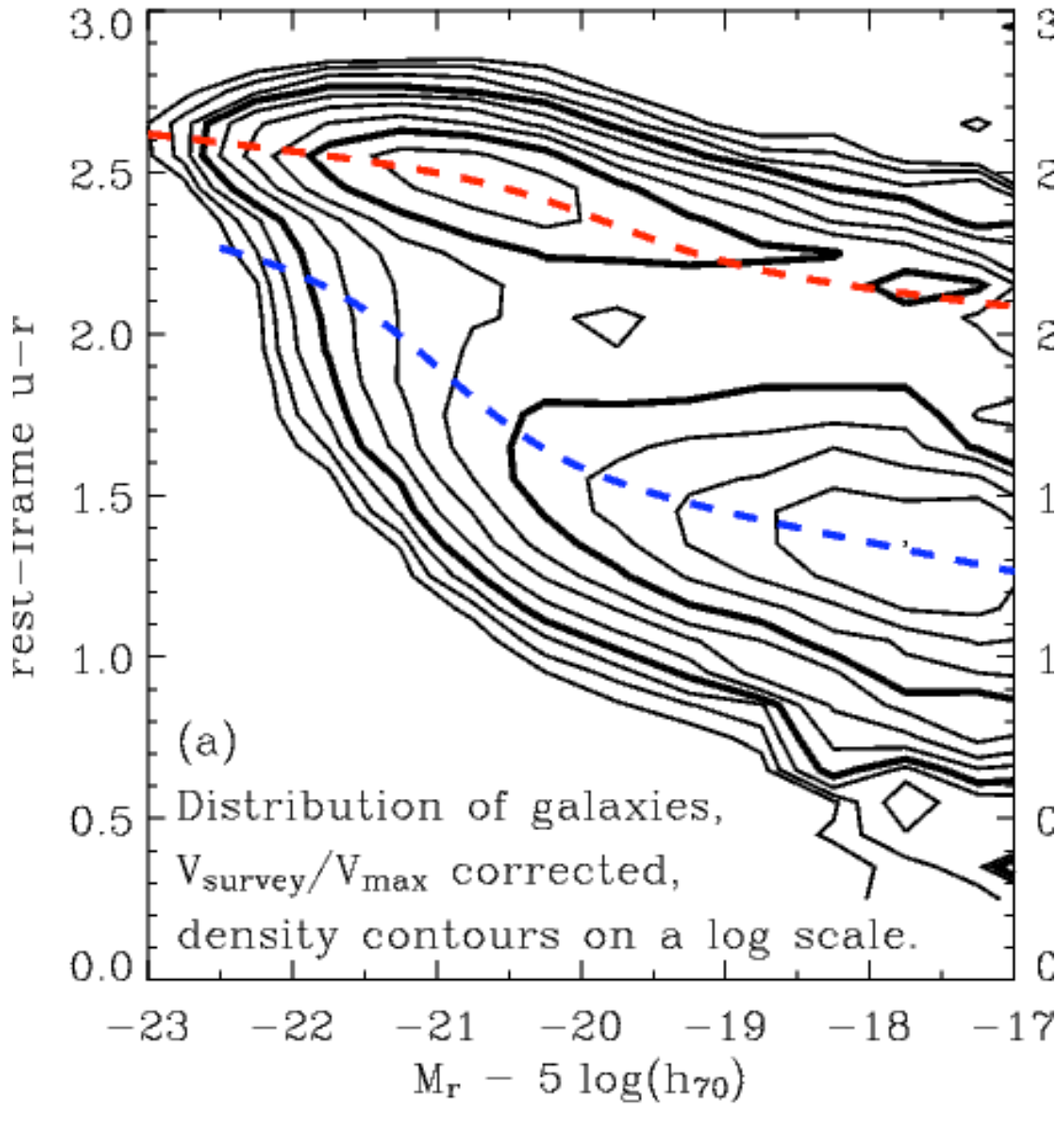


< luminosity function >

... and the right colours?



Croton et al. 2006

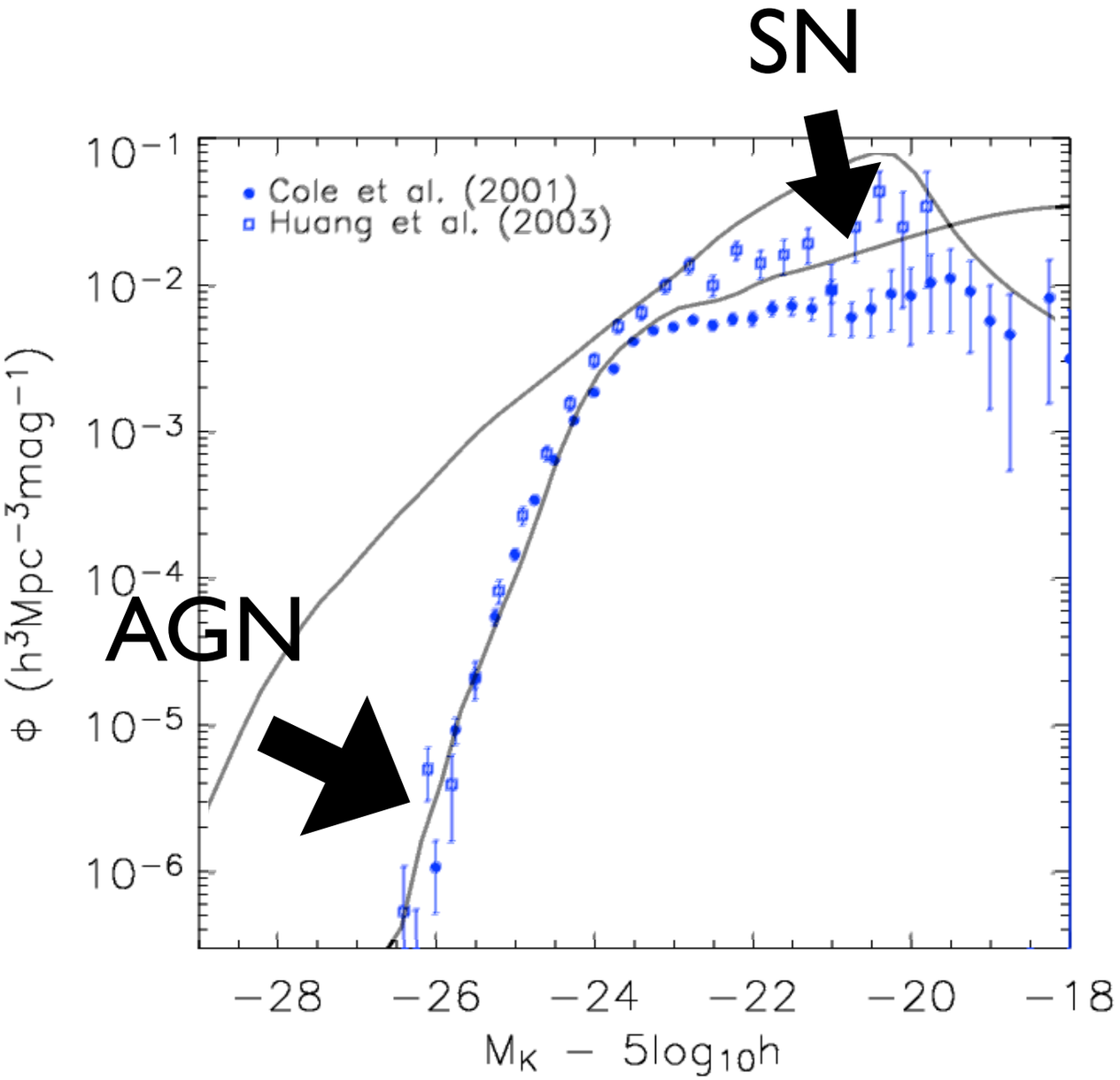


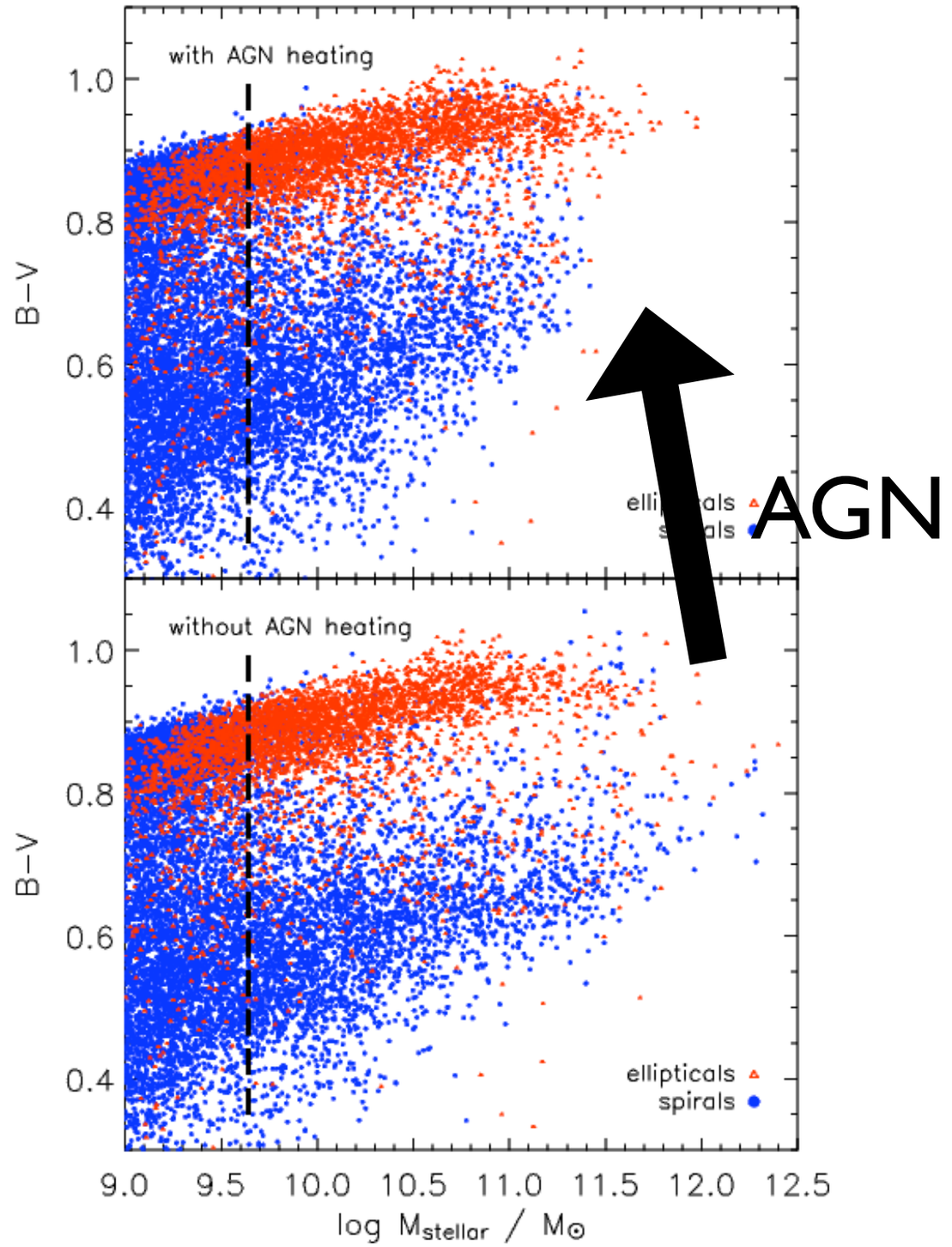
Baldry et all. 2005

< model >

< SDSS >

Physical consequences





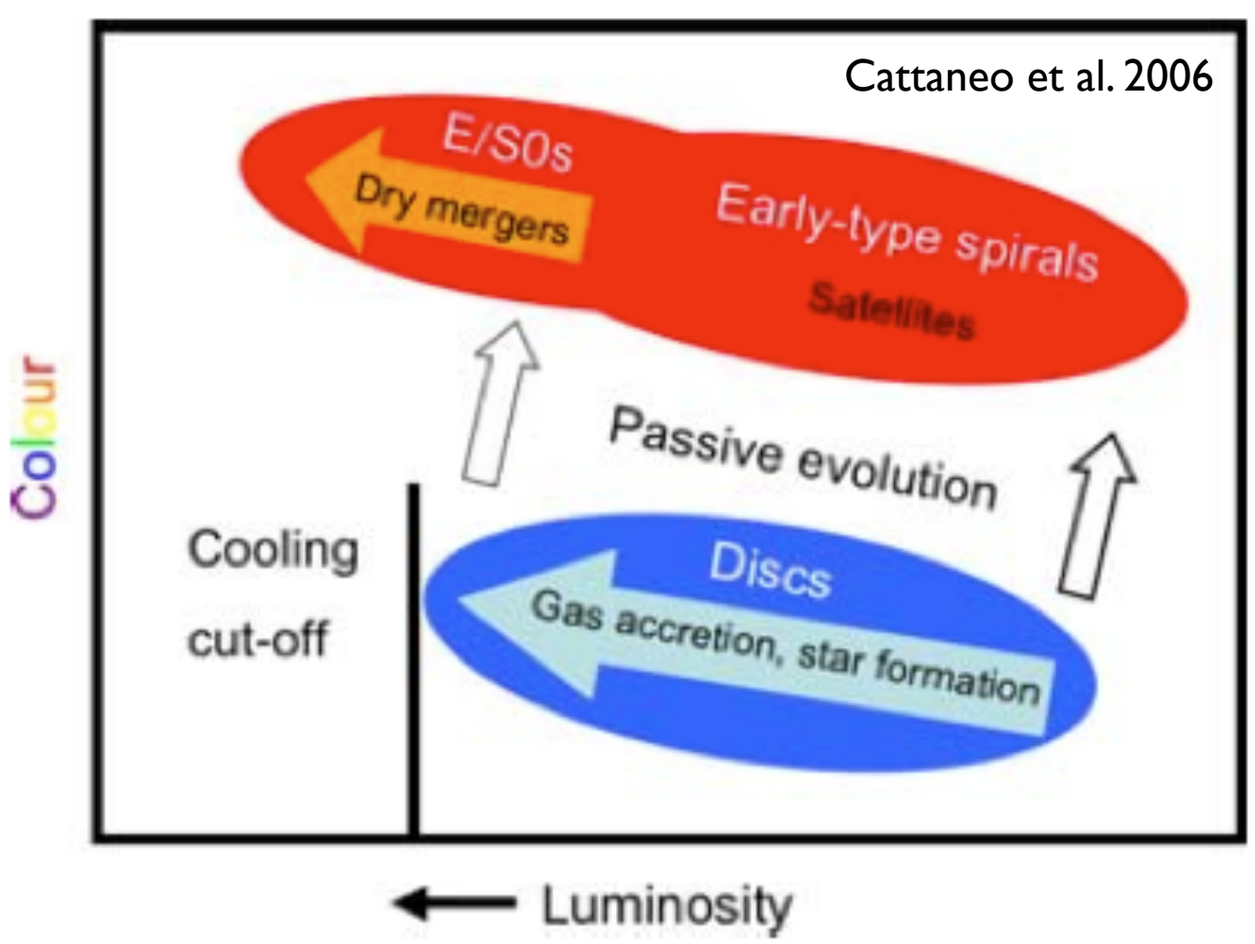
What we think we don’t know

What really shuts down star formation?

(or: how do galaxies evolve across the CMD?)

(or: to what degree is AGN even needed?)

- Important, why?
- Current understanding?
- Solutions?



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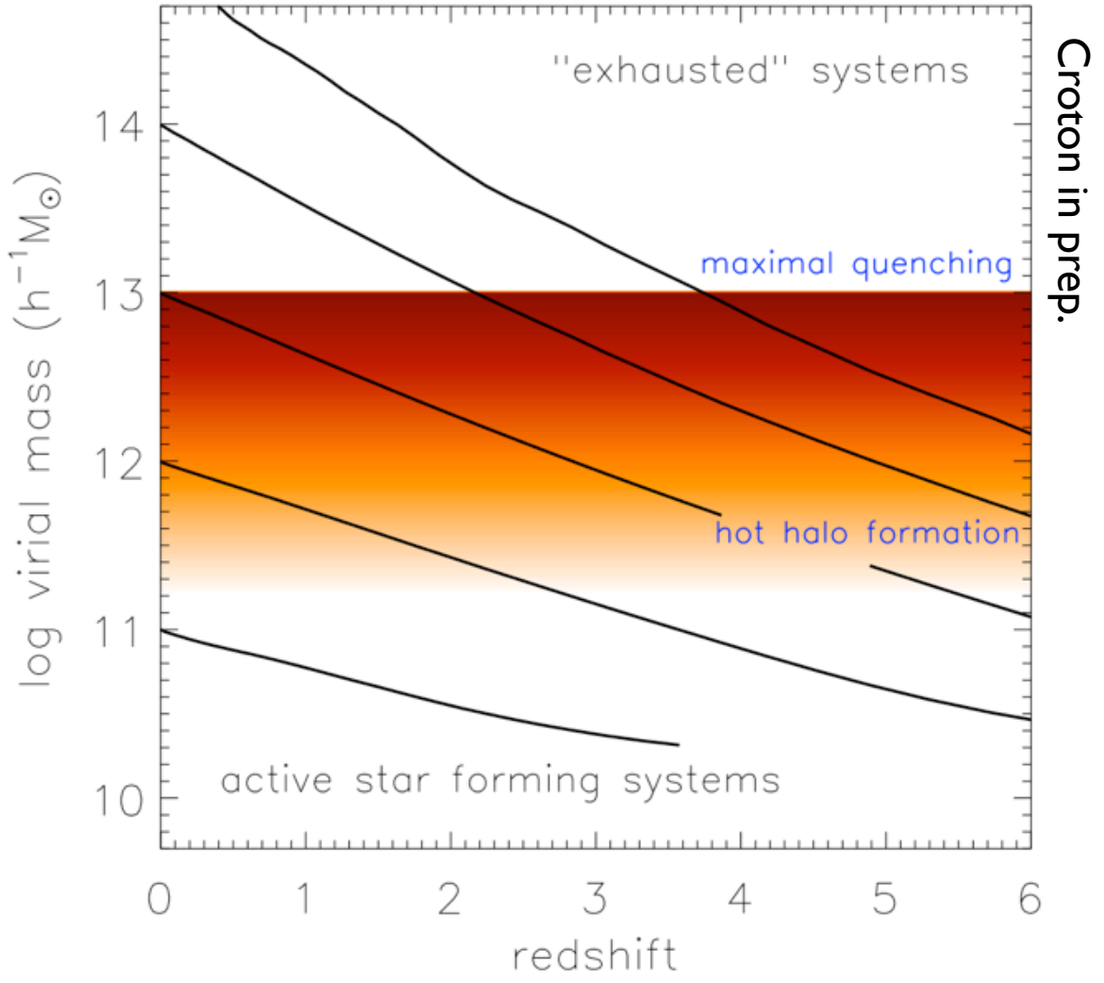

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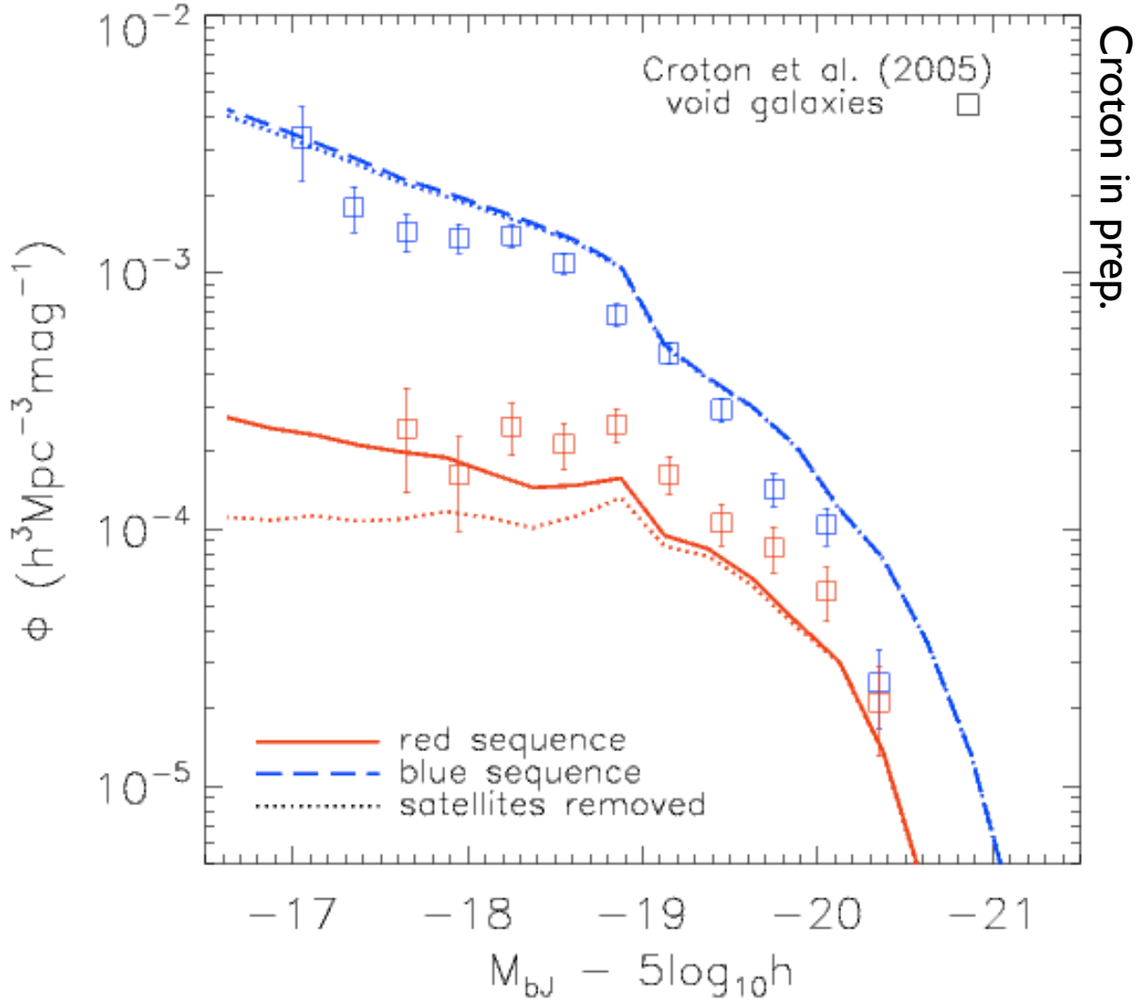

Croton in prep.

The assembly of massive galaxies?

(or: at what point does DM & baryon growth de-couple?)

(or: monolithic or hierarchical? a problem for CDM?)

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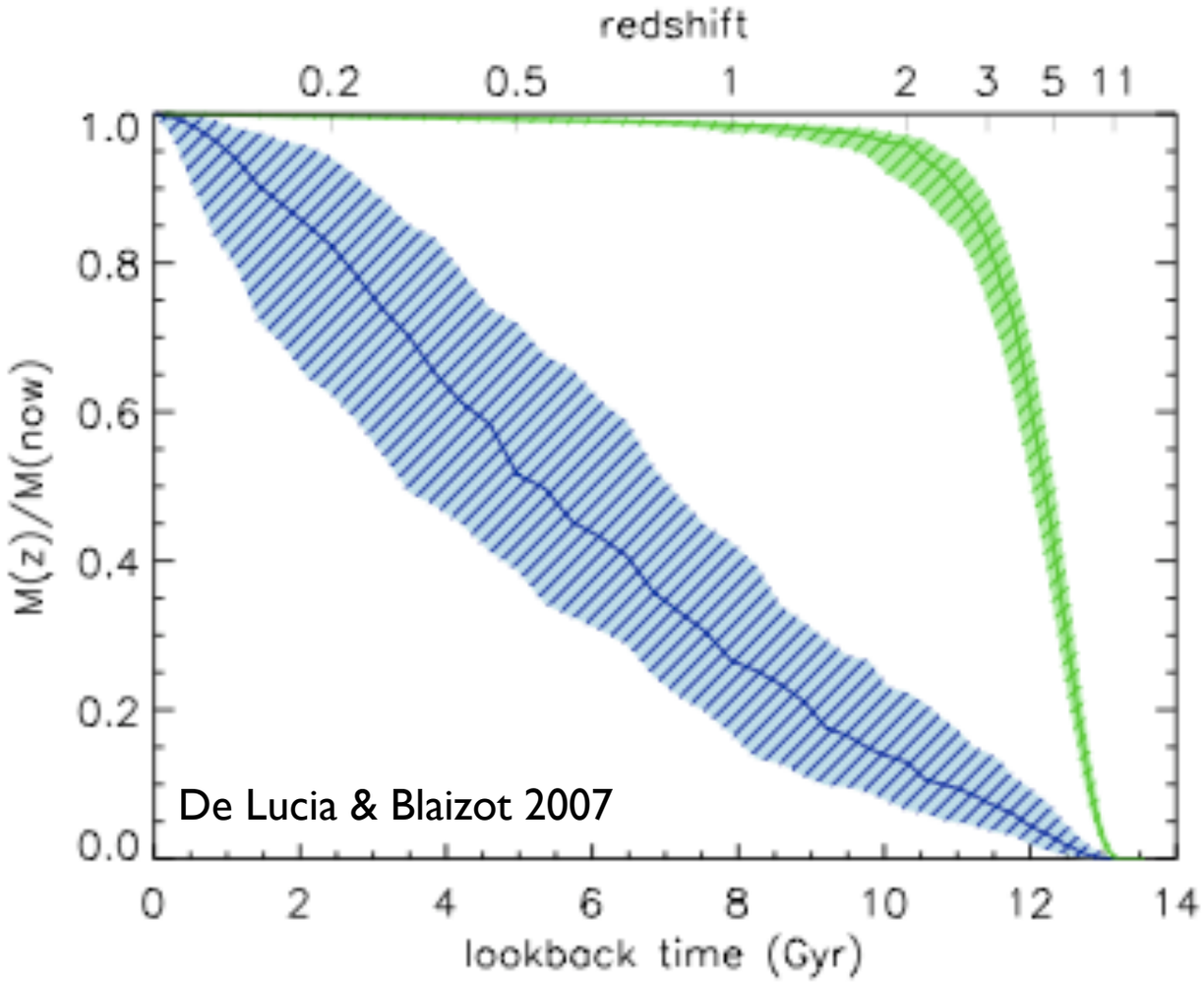

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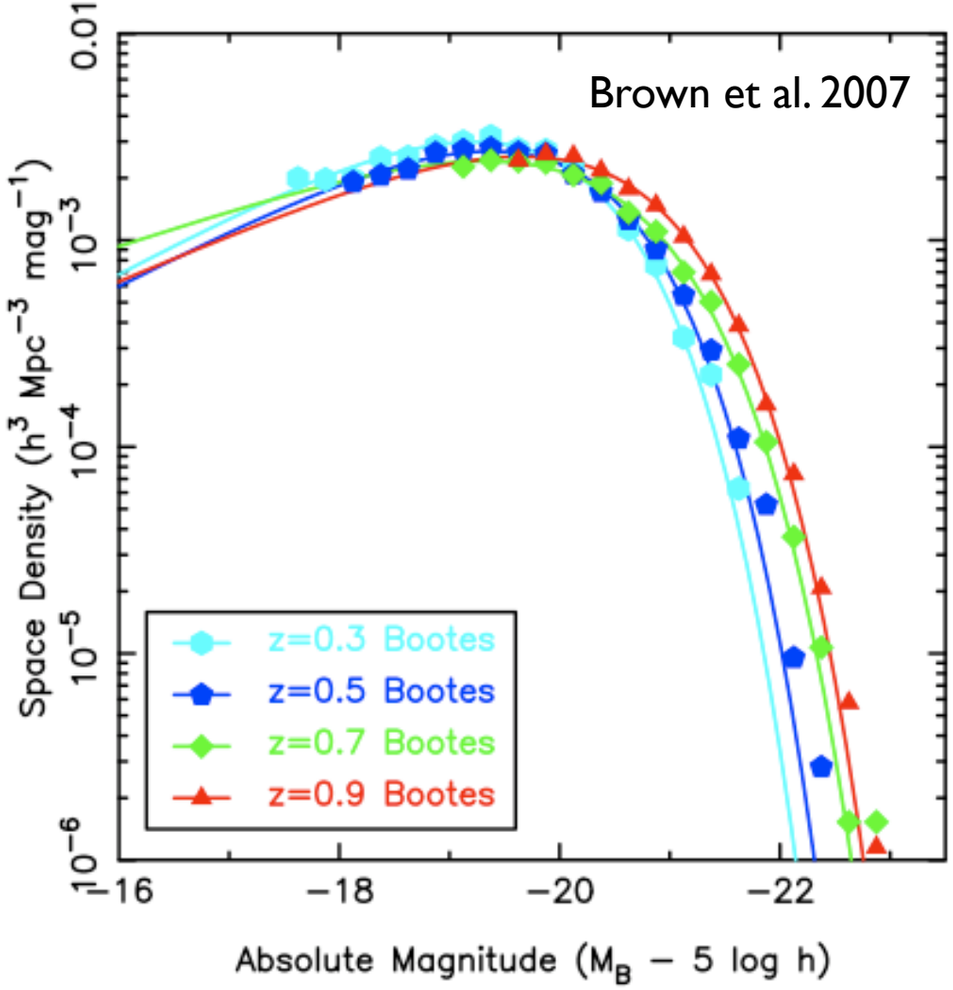


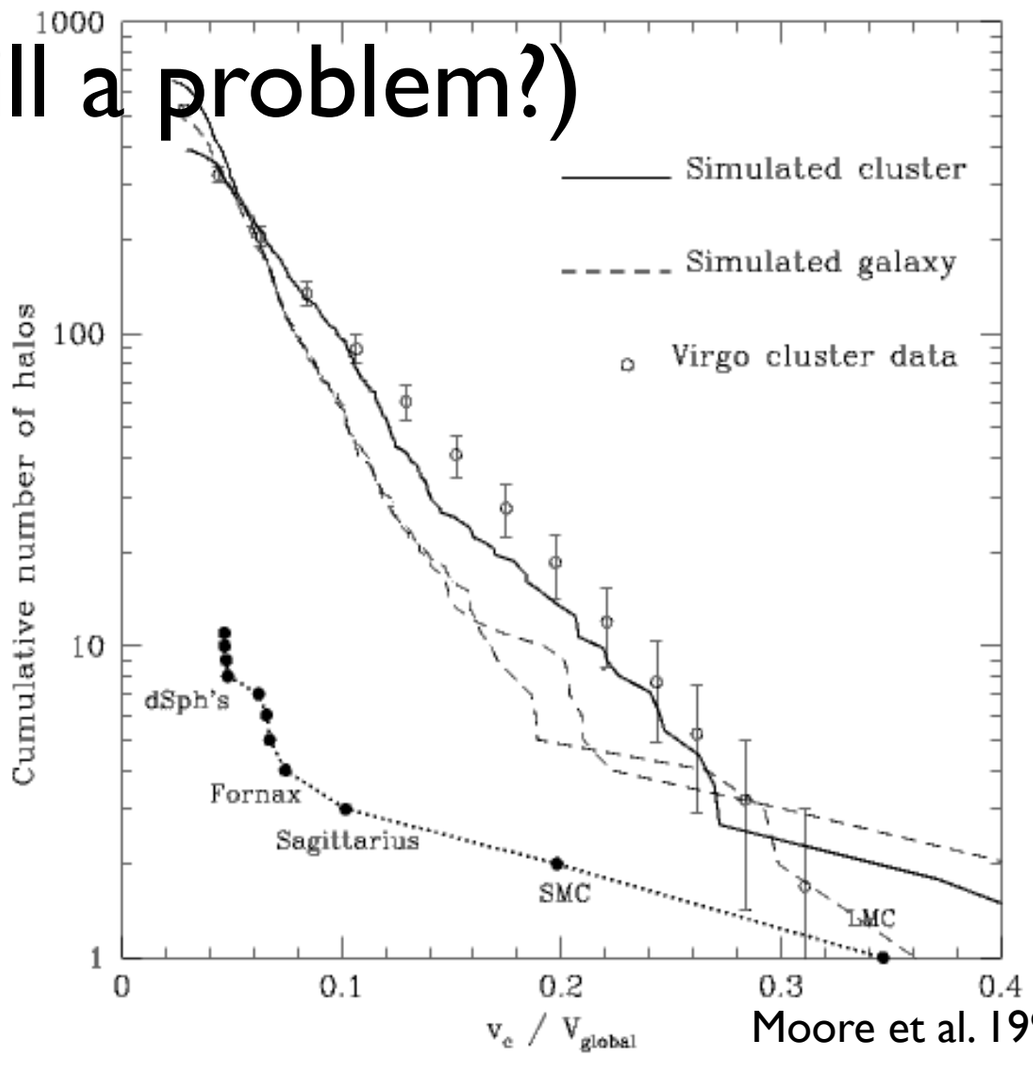
Satellite galaxy evolution?

(or: do central and satellite galaxies evolve differently?)

(or: merging vs. ICL?)

(or: is sub-structure still a problem?)

- Important, why?
- Current understanding?
- Solutions?



Moore et al. 1999

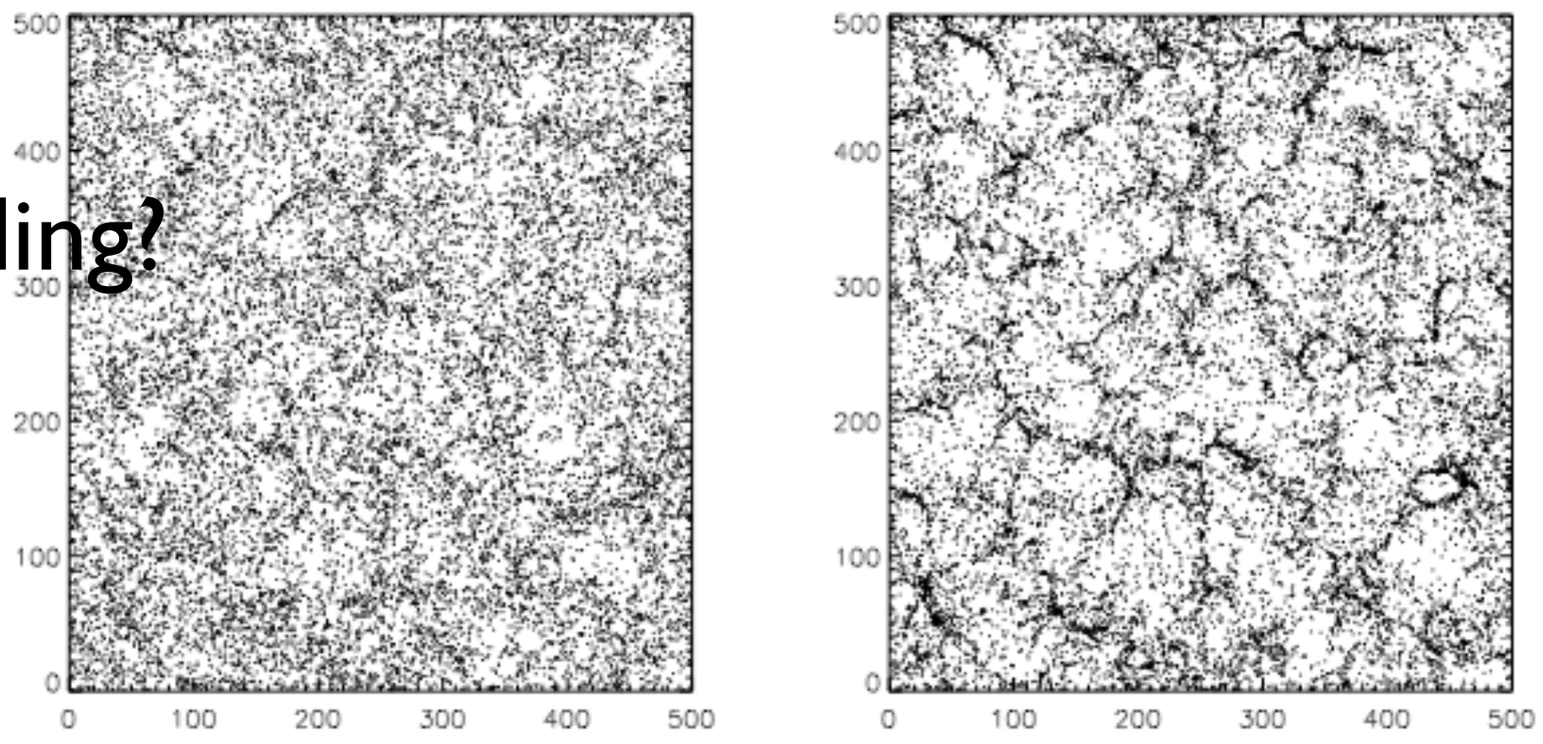
The role of environment?

(or: how important for cosmological measures?)

(or: is halo mass the fundamental property?)

- Important, why?
- Current understanding?
- Solutions?

Gao et al. 2005



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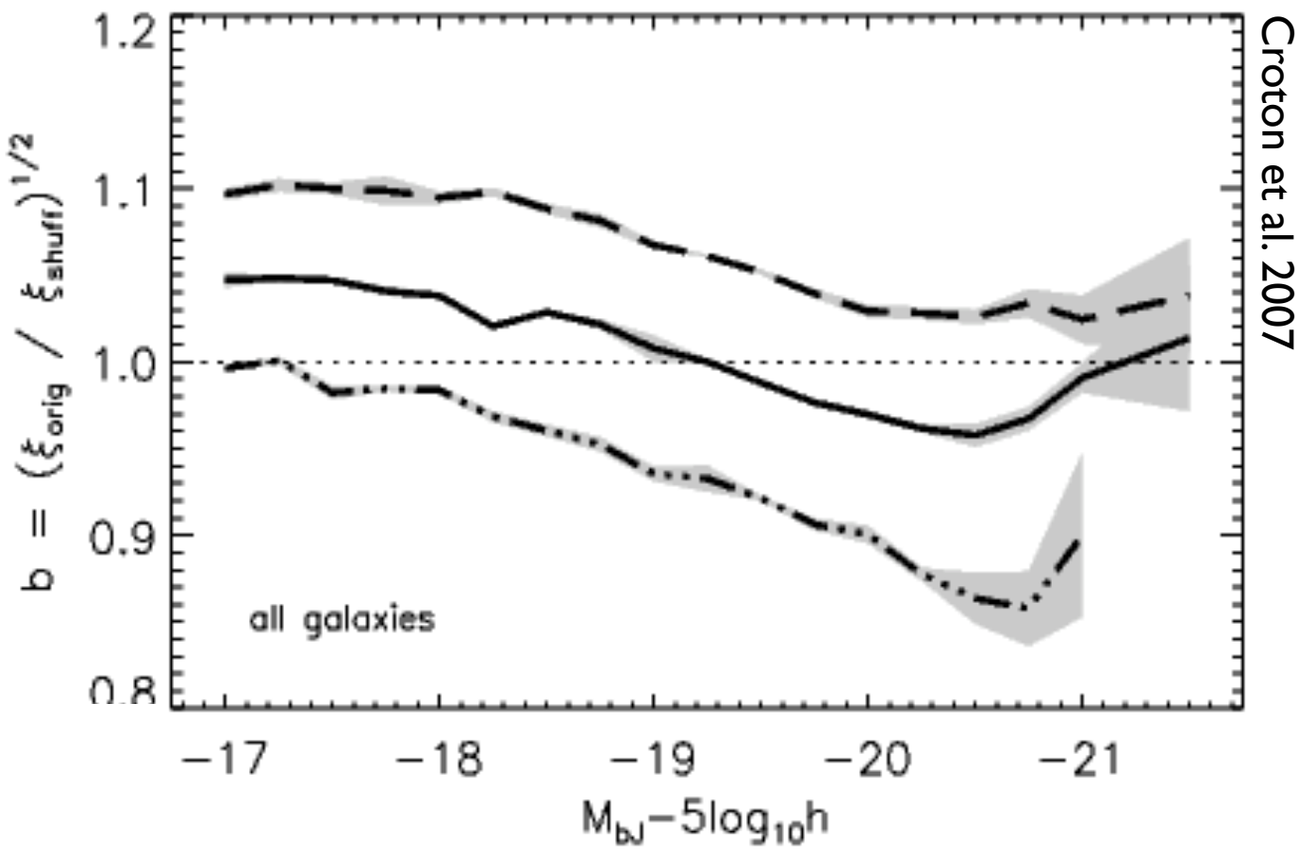


Next generation surveys

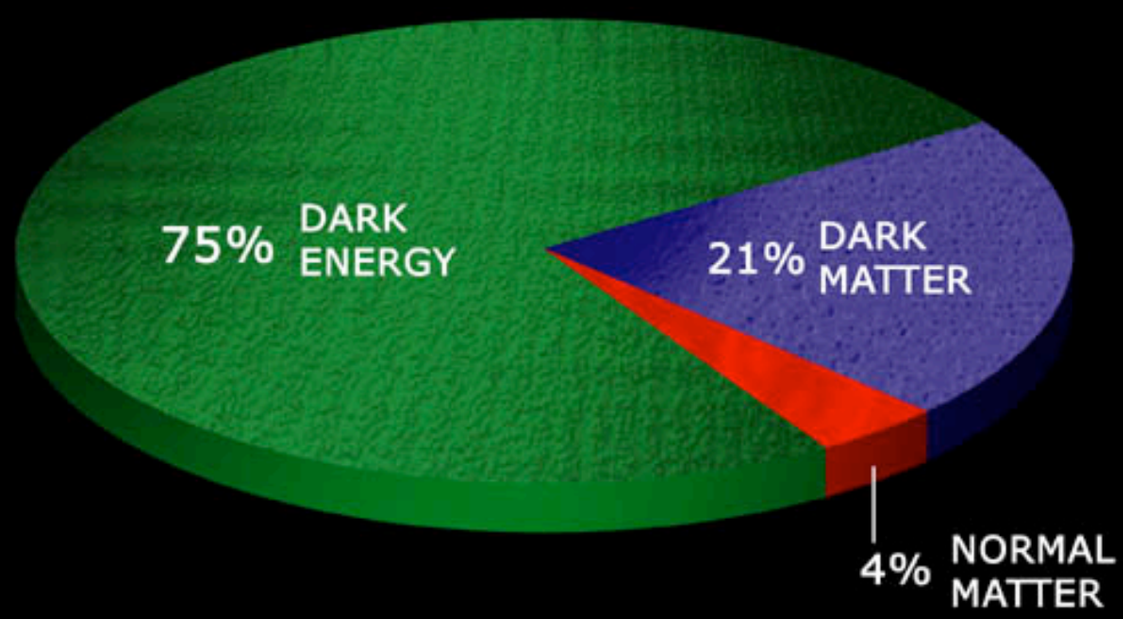
Probing dark energy

Weak & strong lensing

BOA's

Cluster counts

Supernova



- DES: ~**300 million galaxies** across 5,000 sq-degrees out to z~1.3 in 4 bands (r<24.1).

- LSST: **billions of galaxies** across 20,000 sq-degrees out to z~4 in 6 bands (AB<29.0).

- Other surveys/instruments: PanSTARRS, SKA, JWST, GLAST, ... will provide equivalent multi-wavelength data sets.

What can you do with millions/billions of galaxies?

Statistics:

SDSS volume limited catalogue of ~50k galaxies can at most be sub-divided 1-2 more times

Next generation catalogues can be sub-divided multiple times on any property of interest

What can you do with millions/billions of galaxies?

Objects:

Muilt-wavelength catalogues can be cross-correlated and studied together

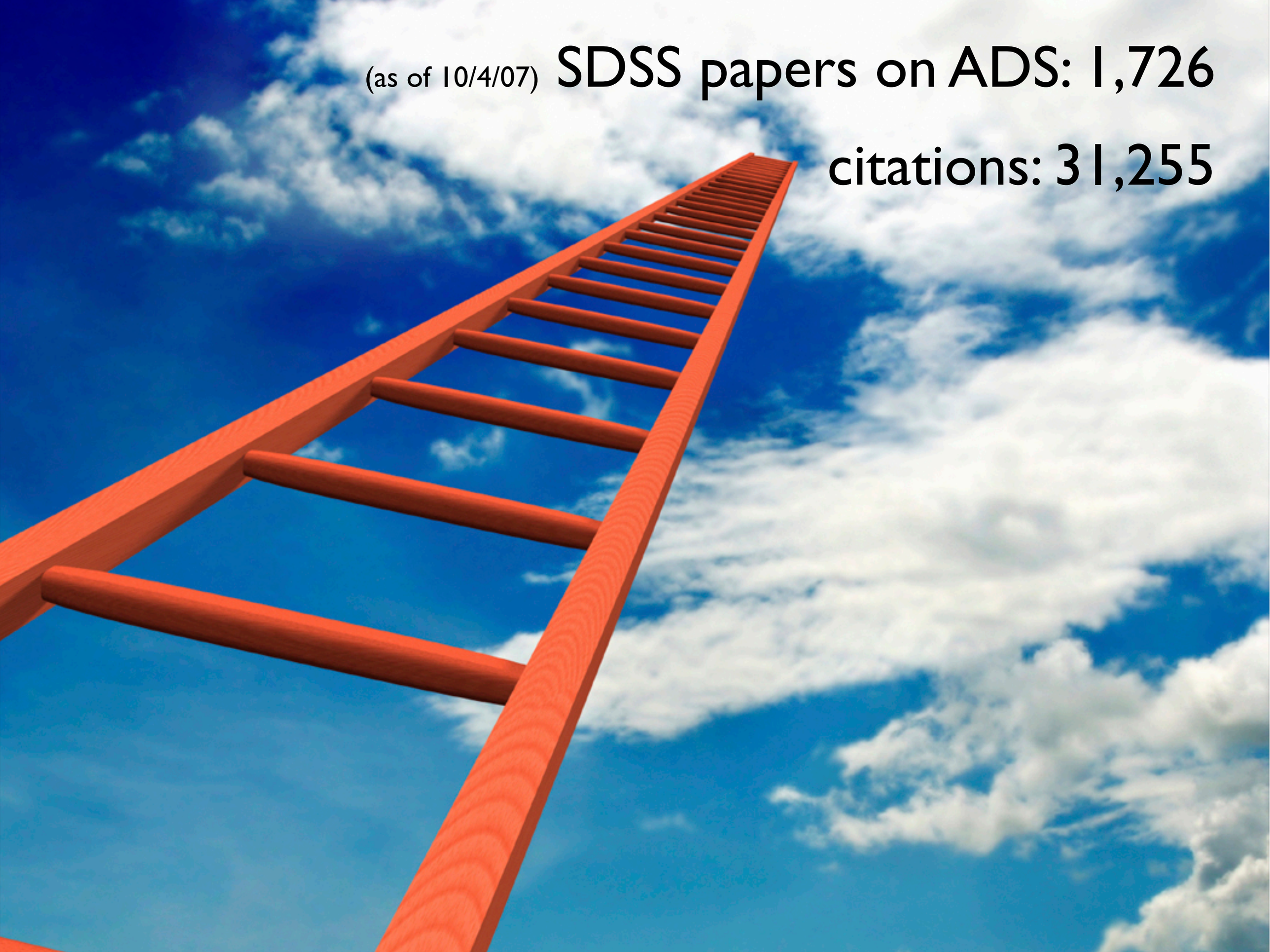
Rare objects will become commonplace and will be analysed with statistical confidence

Extra-galactic astronomy covers a vast range of disciplines.

These data sets will produce vast amounts of science

(as of 10/4/07) SDSS papers on ADS: 1,726

citations: 31,255



Outlook

(1) Simple models help interpret the data, and more complex observations require more complex modelling.

(2) Our understanding of galaxy evolution is still mostly phenomenological.

(3) Future surveys have the potential to overwhelm us with information, but also answer key questions.