PART I

Galaxy Formation Models

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PART I: Building synthetic universes

PART II: The parameters of galaxy formation

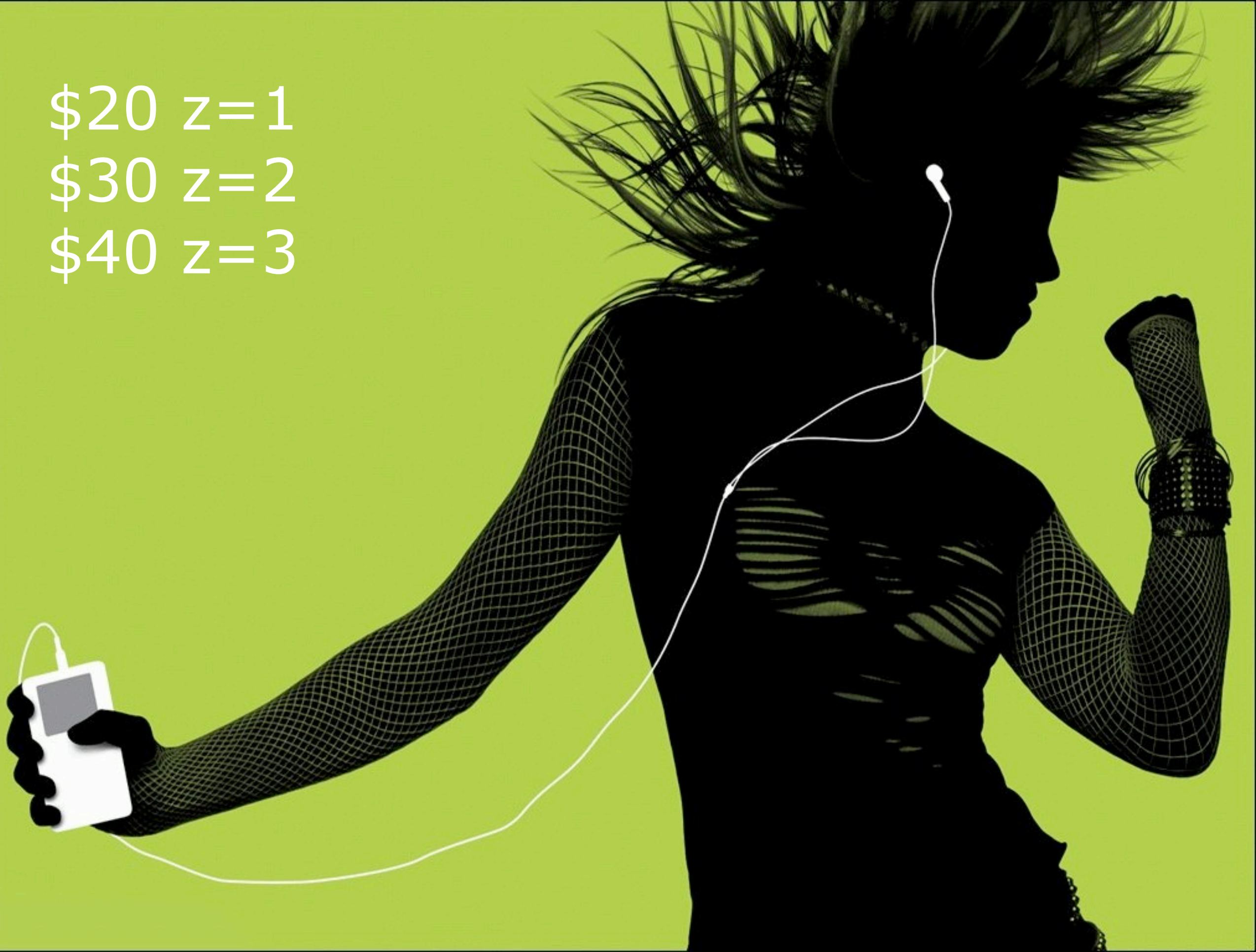
PART III: The universe in the cloud

The basics of how galaxies are built and evolve

The uses and limitations of semi-analytic galaxy models

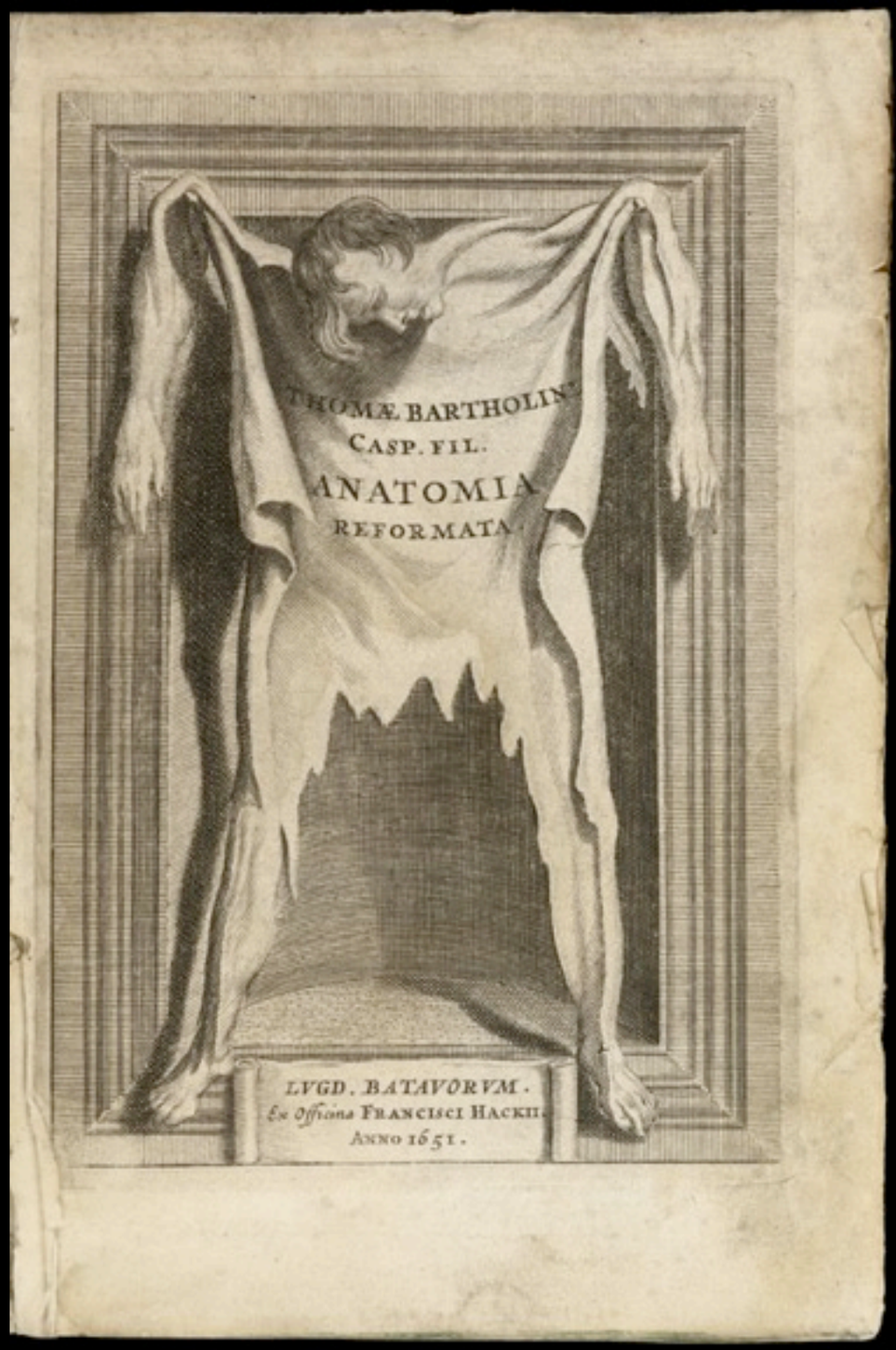
The challenge of data access and delivery

$20 z=1
$30 z=2
$40 z=3

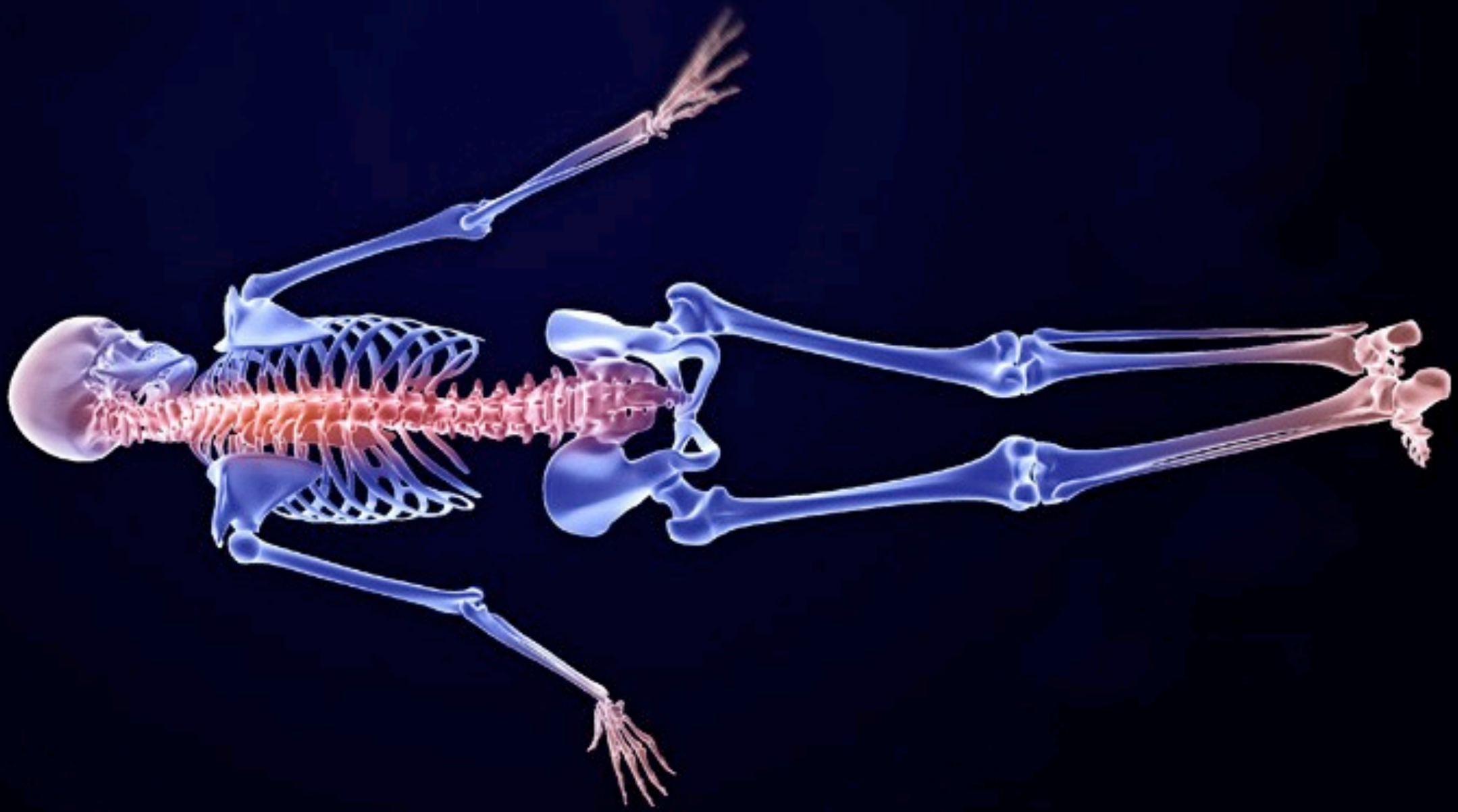


Galaxy formation primer

The skeleton

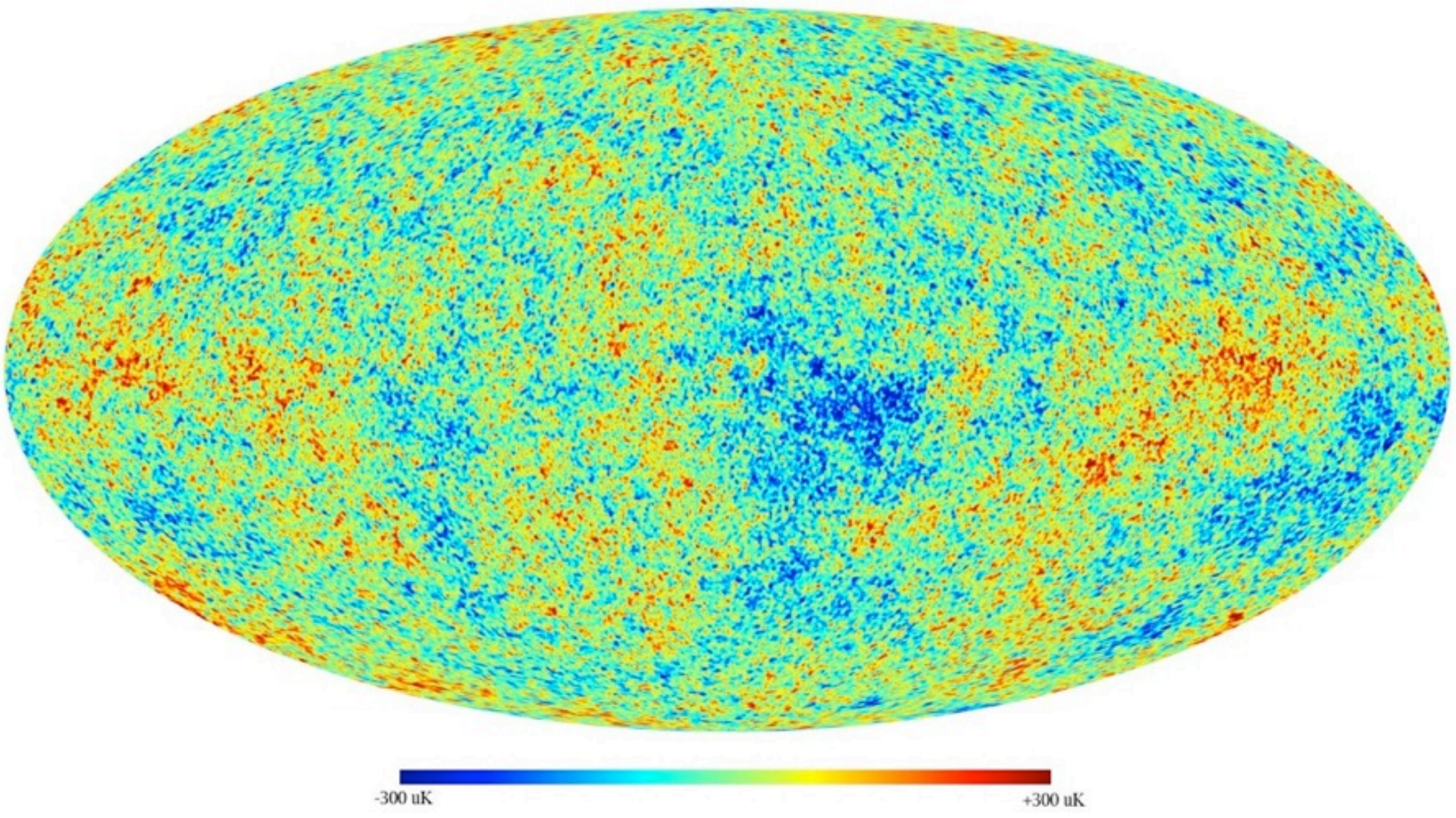


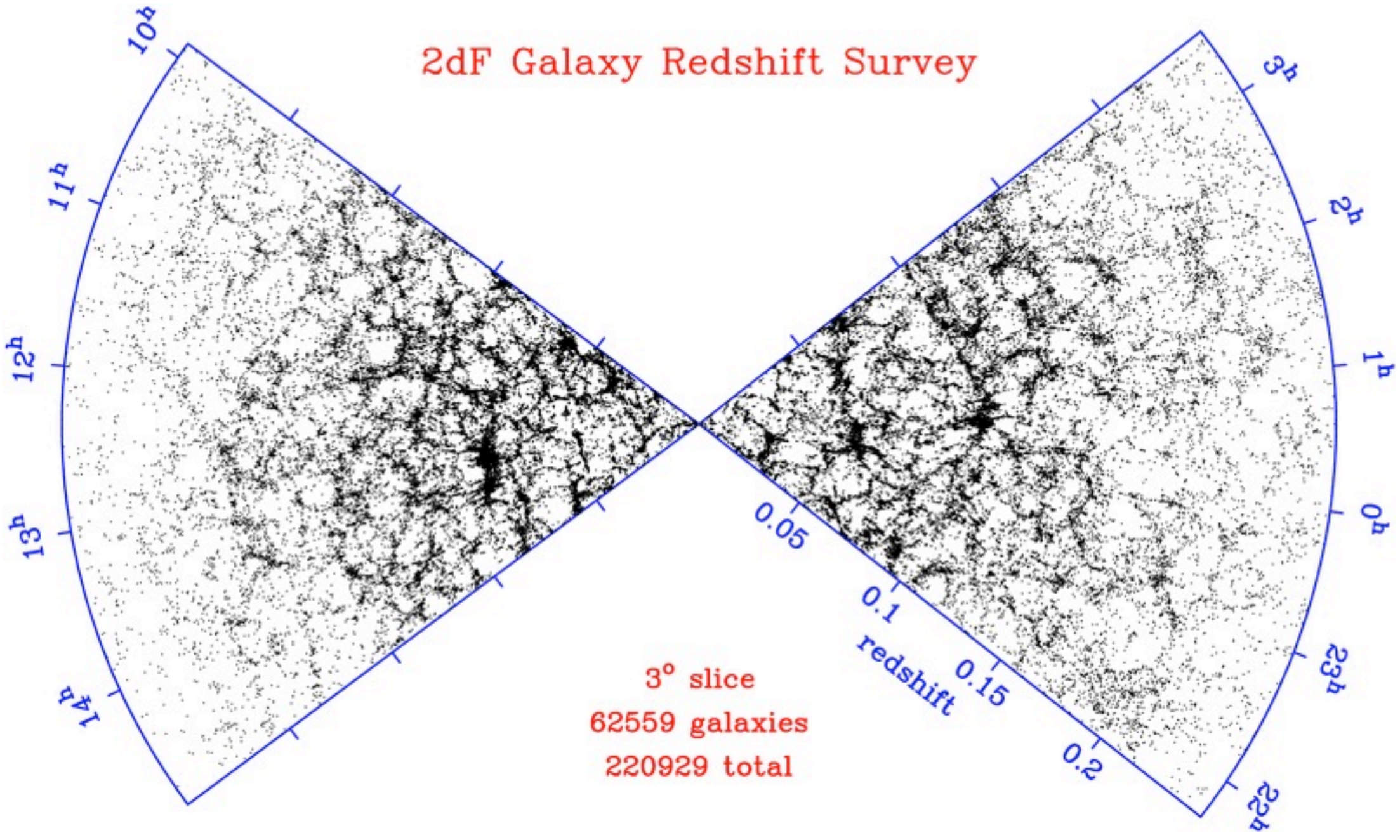
The flesh

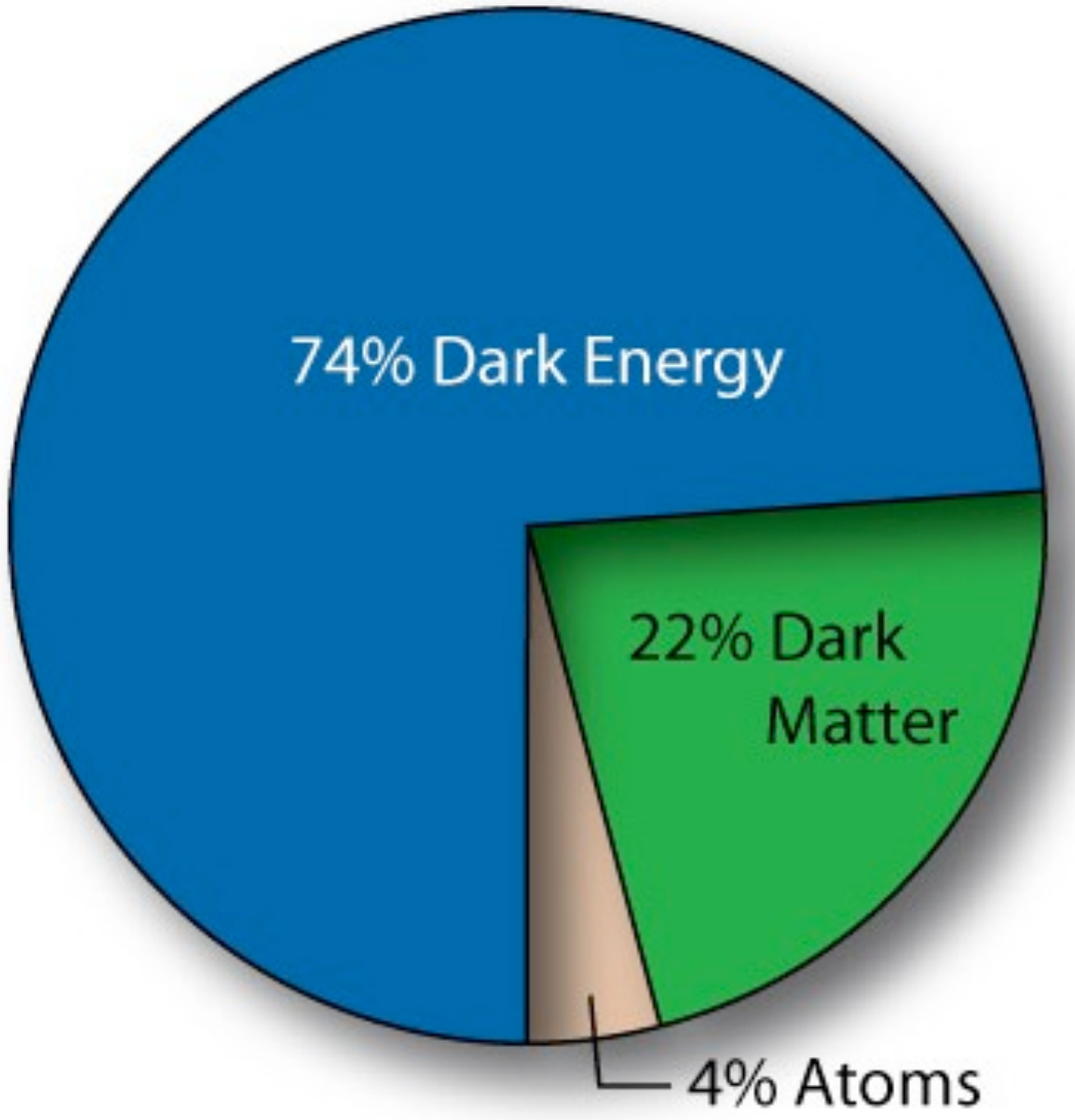


1. The skeleton: N-body simulations

2. The flesh: interwoven analytic models of the physics of galaxy formation


-300 uK
+300 uK


2dF Galaxy Redshift Survey
10h
11h
12h
13h
14h
3h
2h
1h
0h
23h
22h
0.05
0.1
0.15
0.2
redshift
3° slice
62559 galaxies
220929 total


74% Dark Energy
22% Dark Matter
4% Atoms

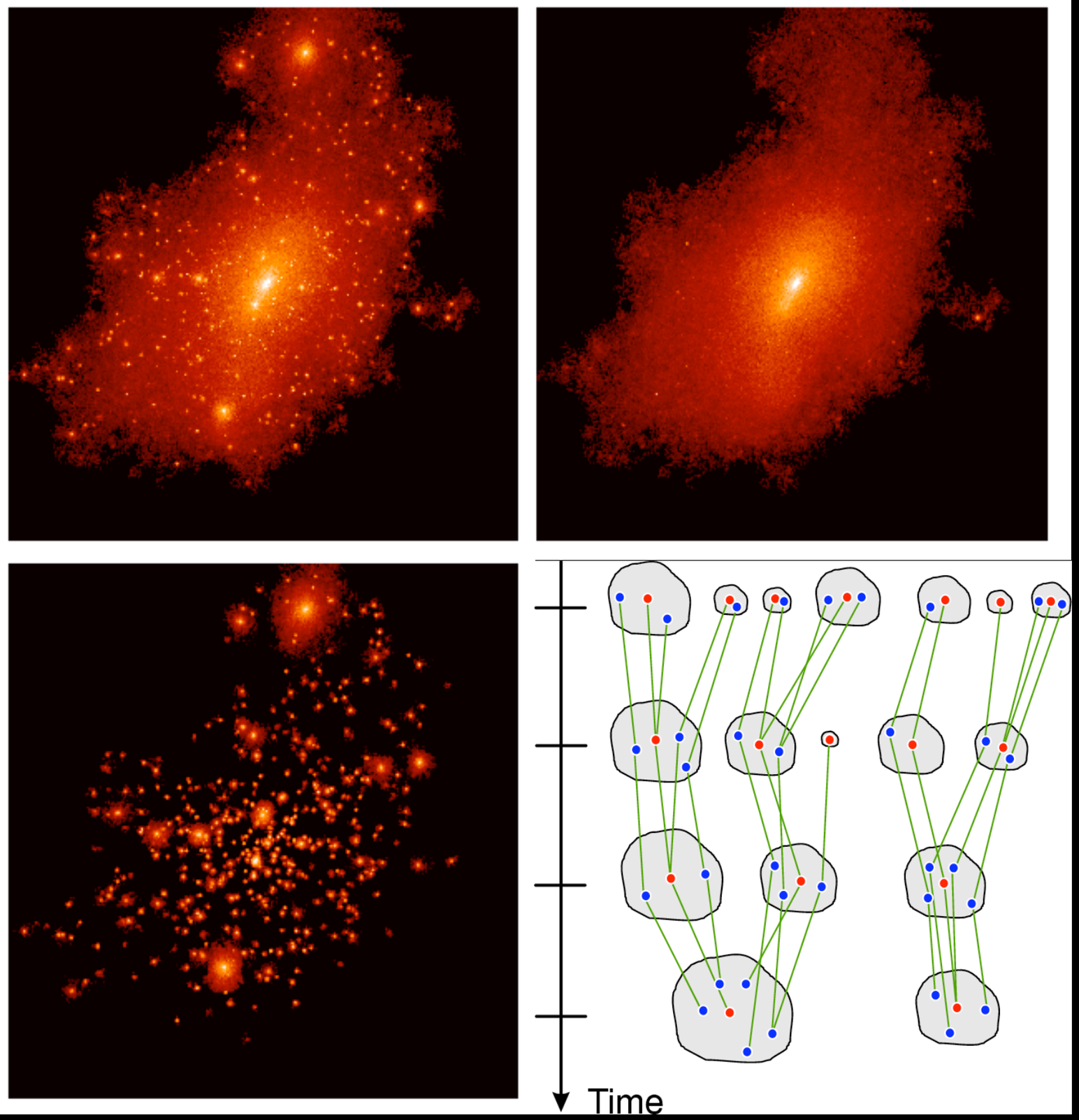

Gordon

Gregory Poole

The GiggleZ Simulation Suite

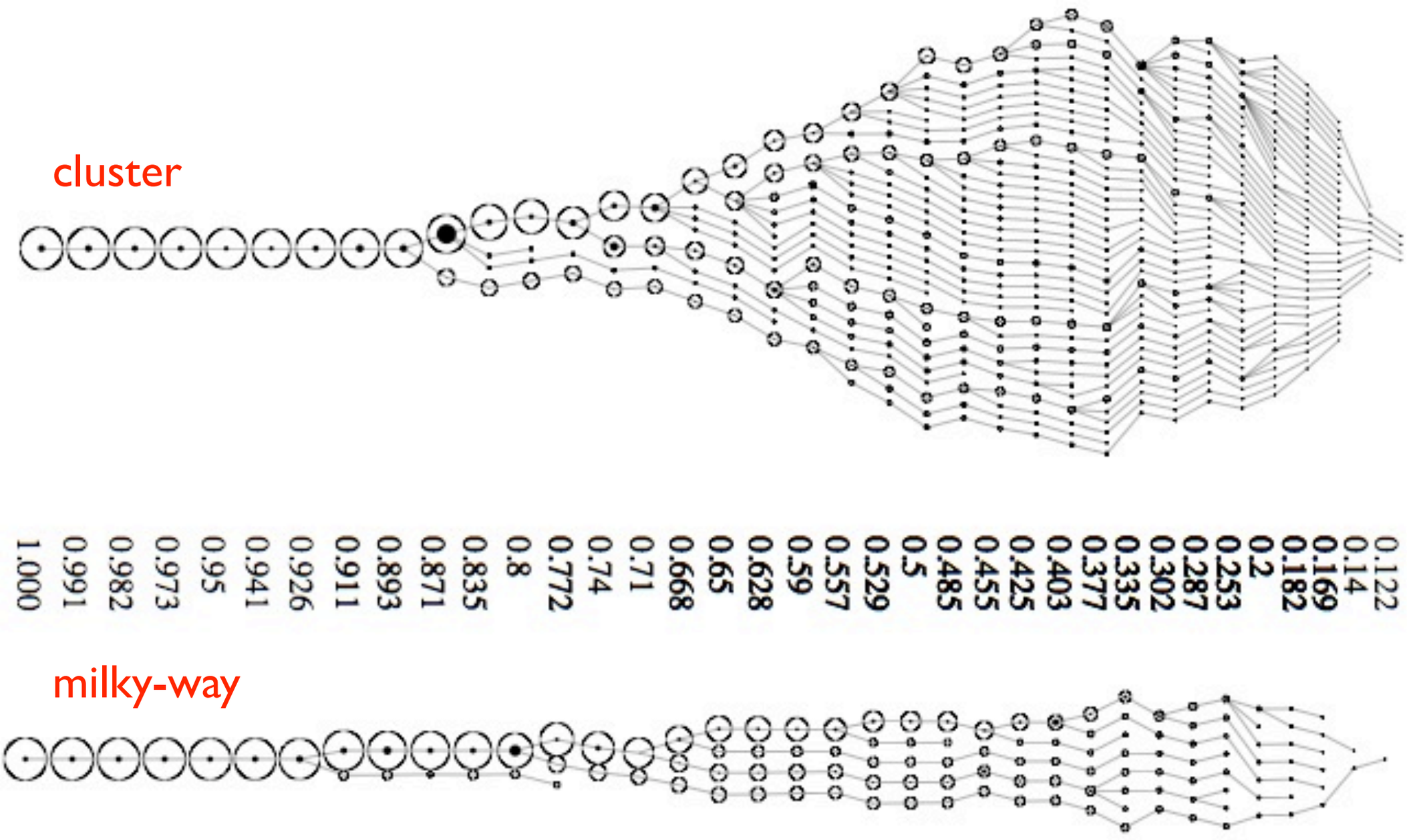
SWiN BUR * NE *

CENTRE FOR ASTROPHYSICS AND SUPERCOMPUTING


Time

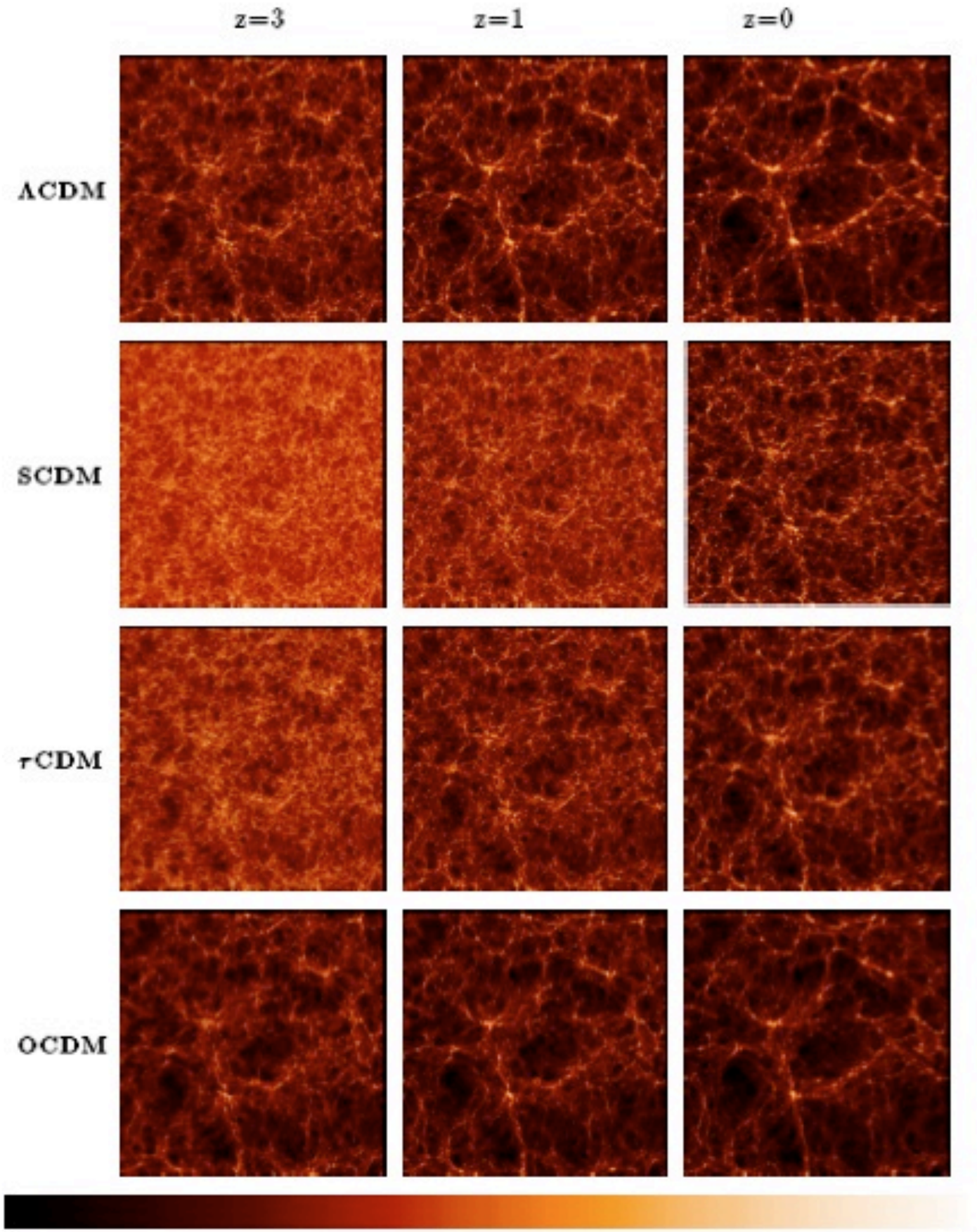
z=0 z=1 z=3 z=6

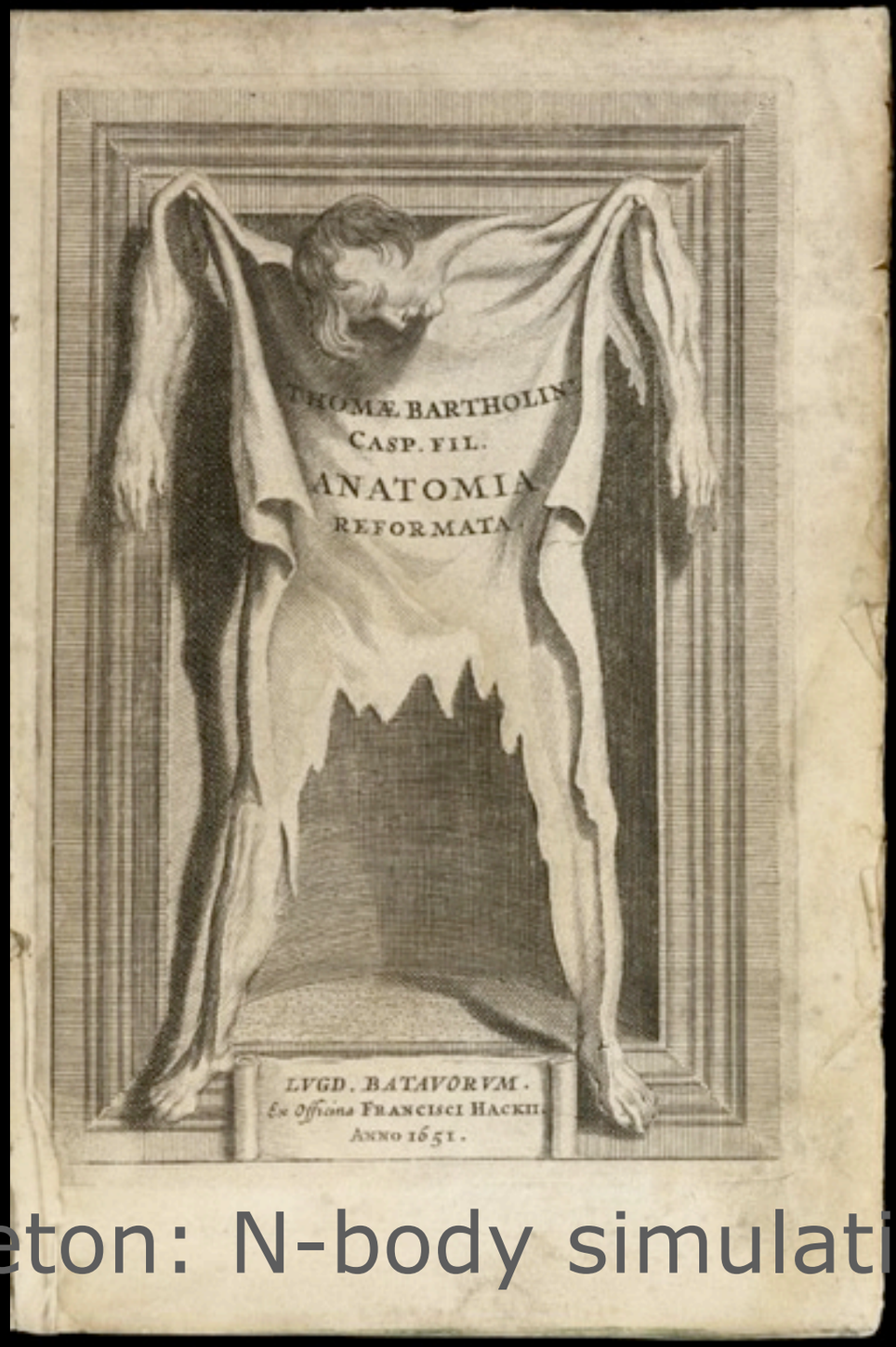
cluster



milky-way

Wechsler et al. 2002


z=3
z=1
z=0
ΛCDM
SCDM
τCDM
OCDM



1. The skeleton: N-body simulations

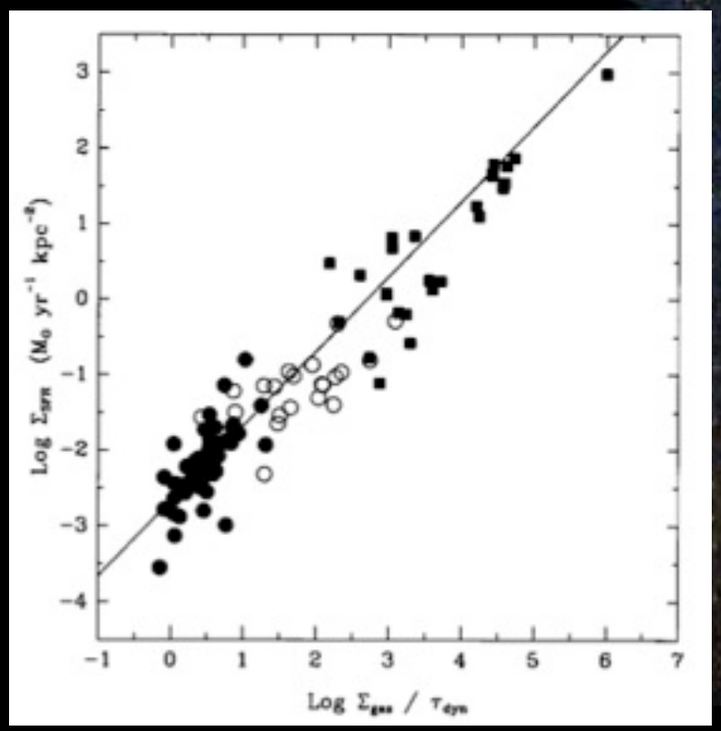
2. The flesh: interwoven analytic models of the physics of galaxy formation

Galaxies, why we care ...

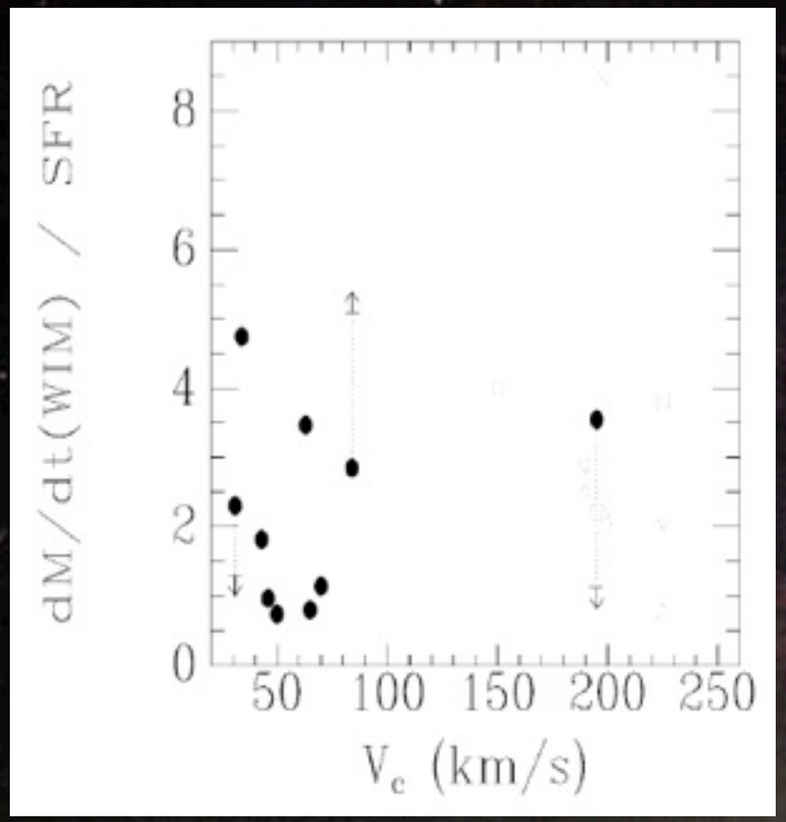
- highly non-linear evolution
- home of internal phenomena
- shaped by external influences

Star formation

Kennicutt 1998



M31

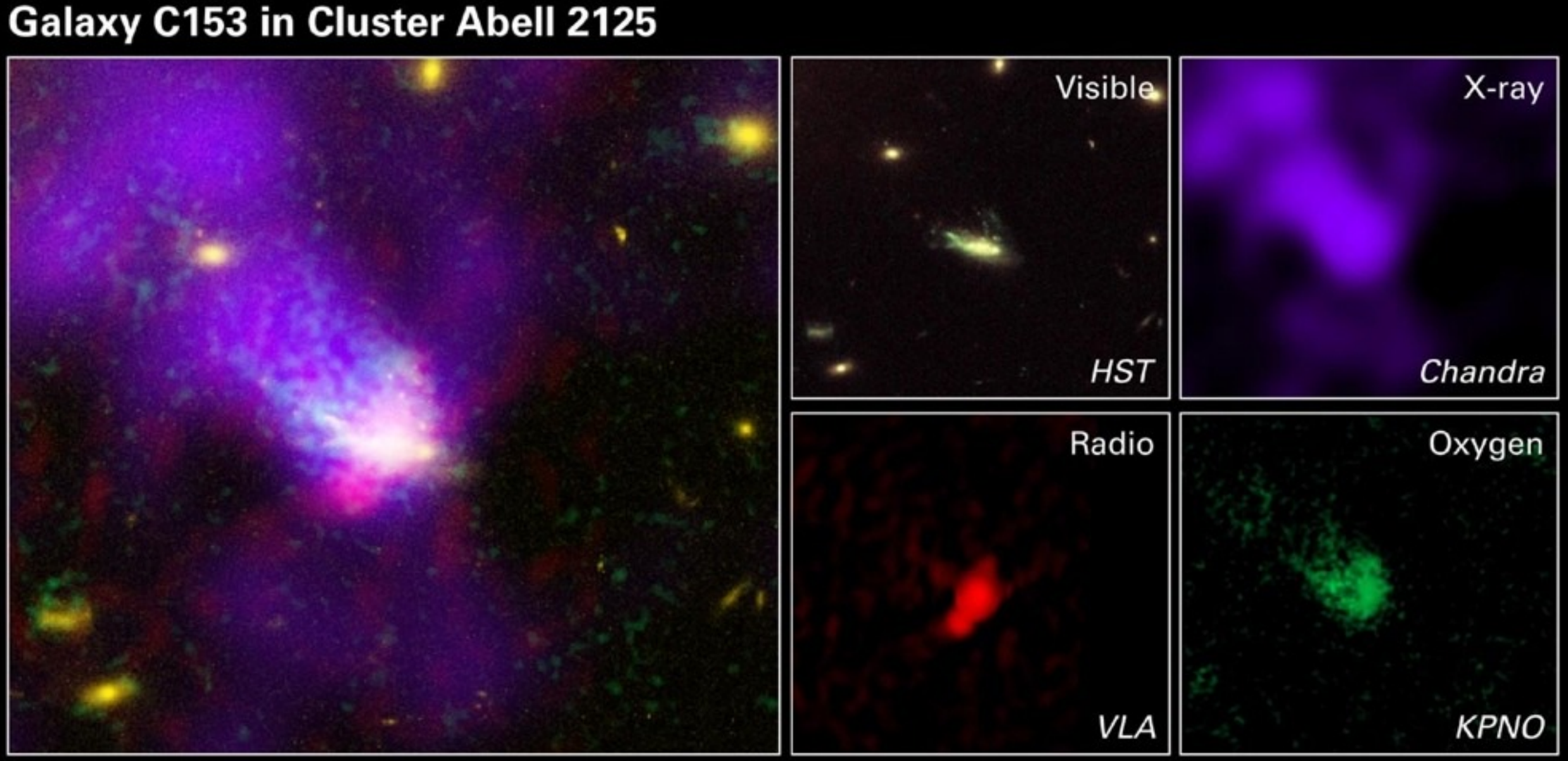


Martin 1999

M82

Supernova feedback

Satellite galaxies



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

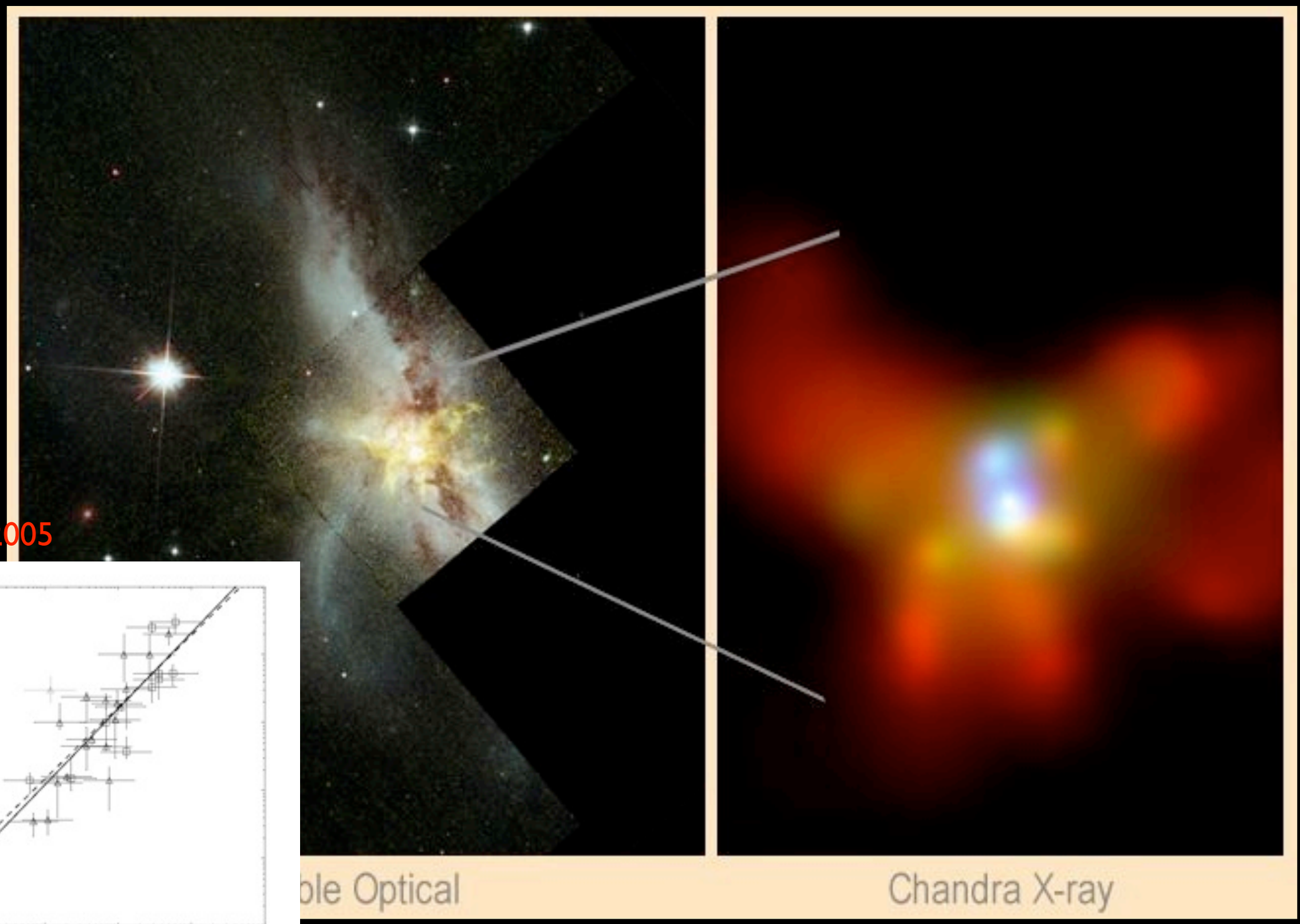
… and assembly

Seyfert’s Sextet

… and death

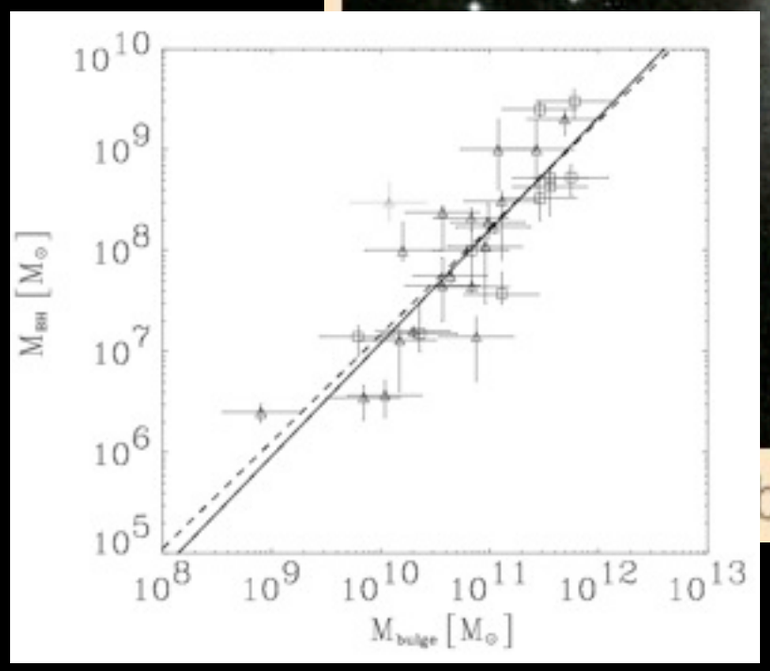
M87 (Virgo cluster)

Black holes

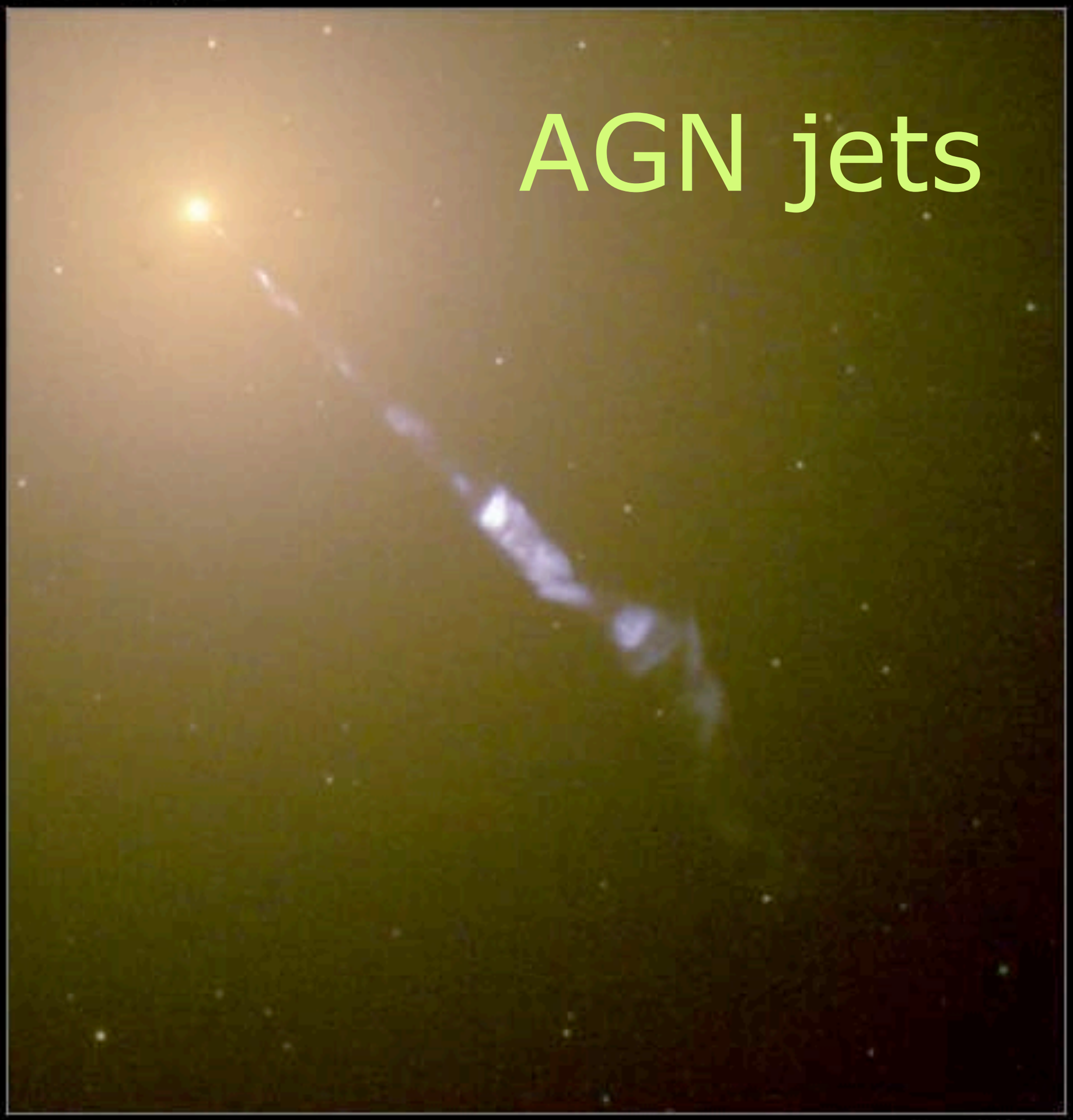


NGC 6240

Haring & Rix 2005

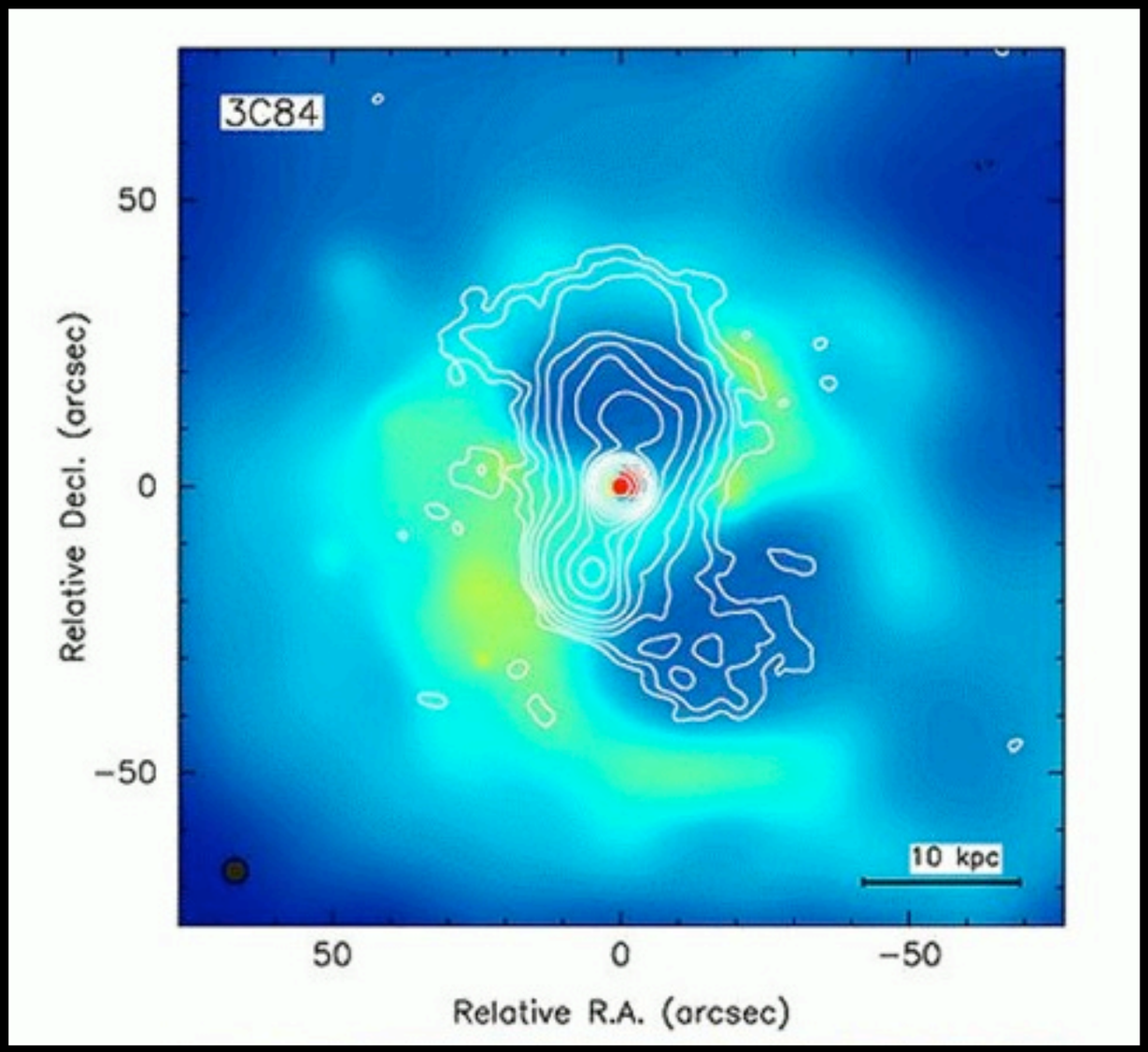


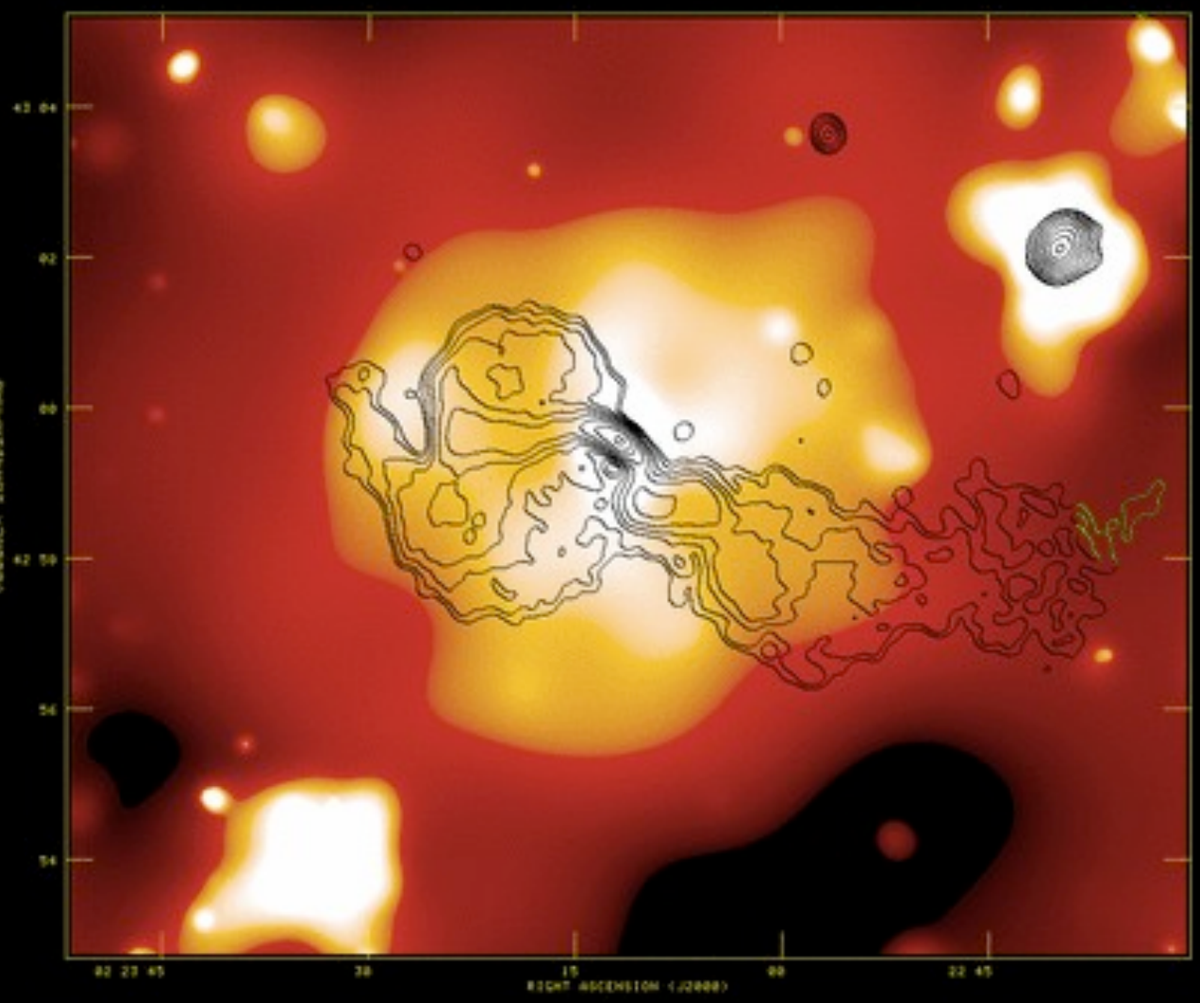
AGN jets



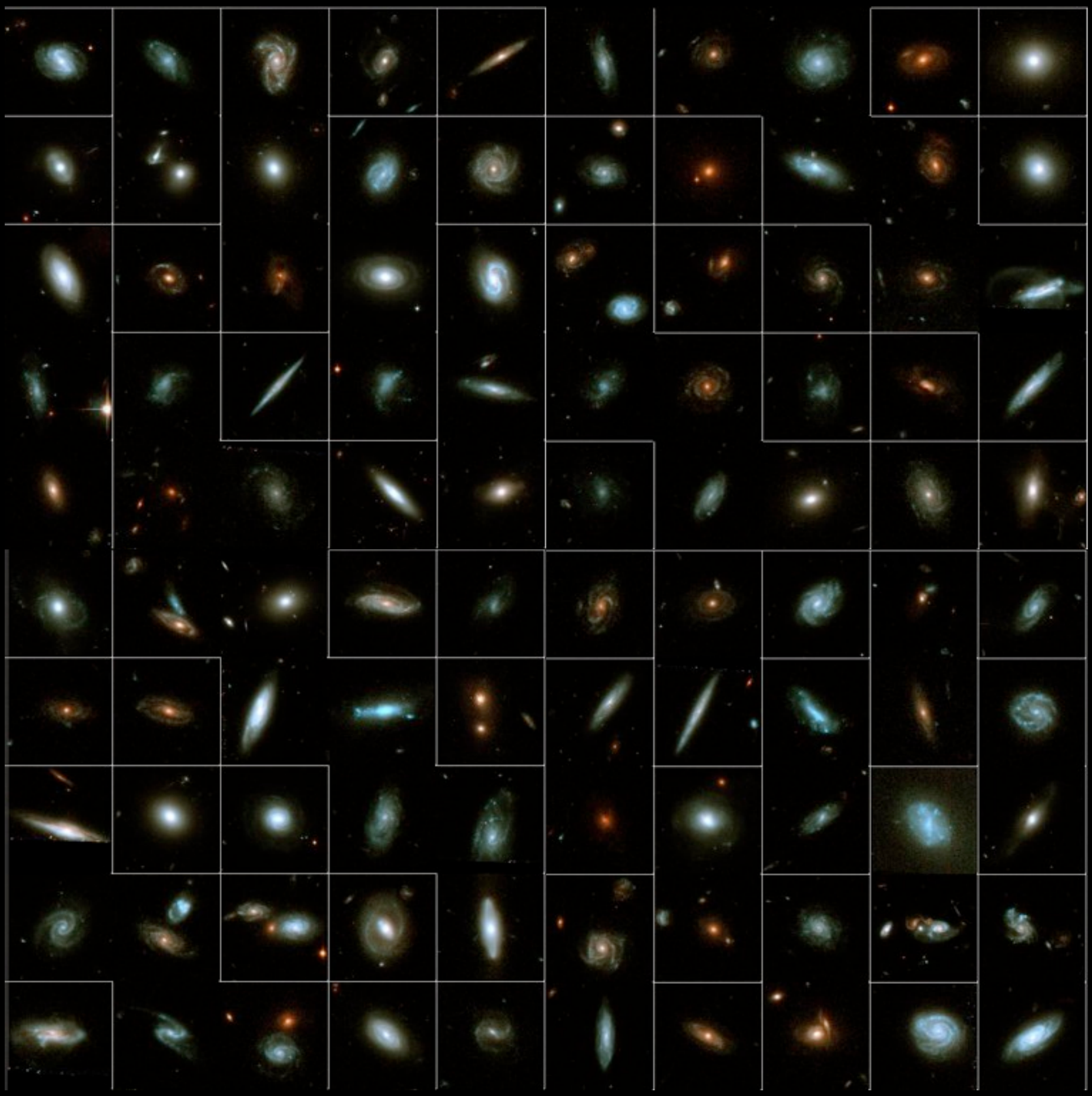
M87
(Virgo cluster)

AGN bubbles

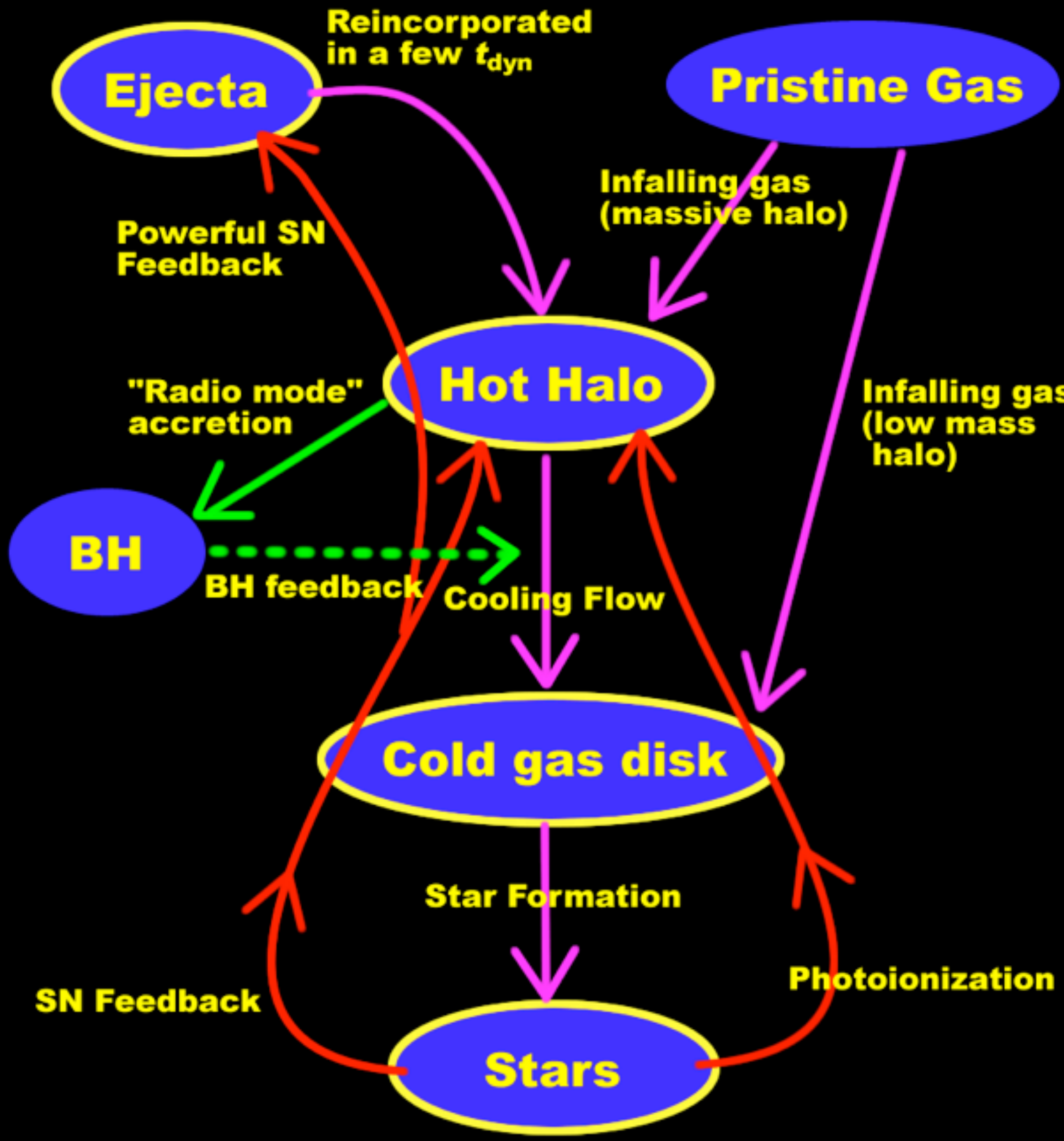

3C84
50
0
−50
Relative Decl. (arcsec)
10 kpc
50
0
−50
Relative R.A. (arcsec)



GEMS (Rix et al. 2004)



iPad



- 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

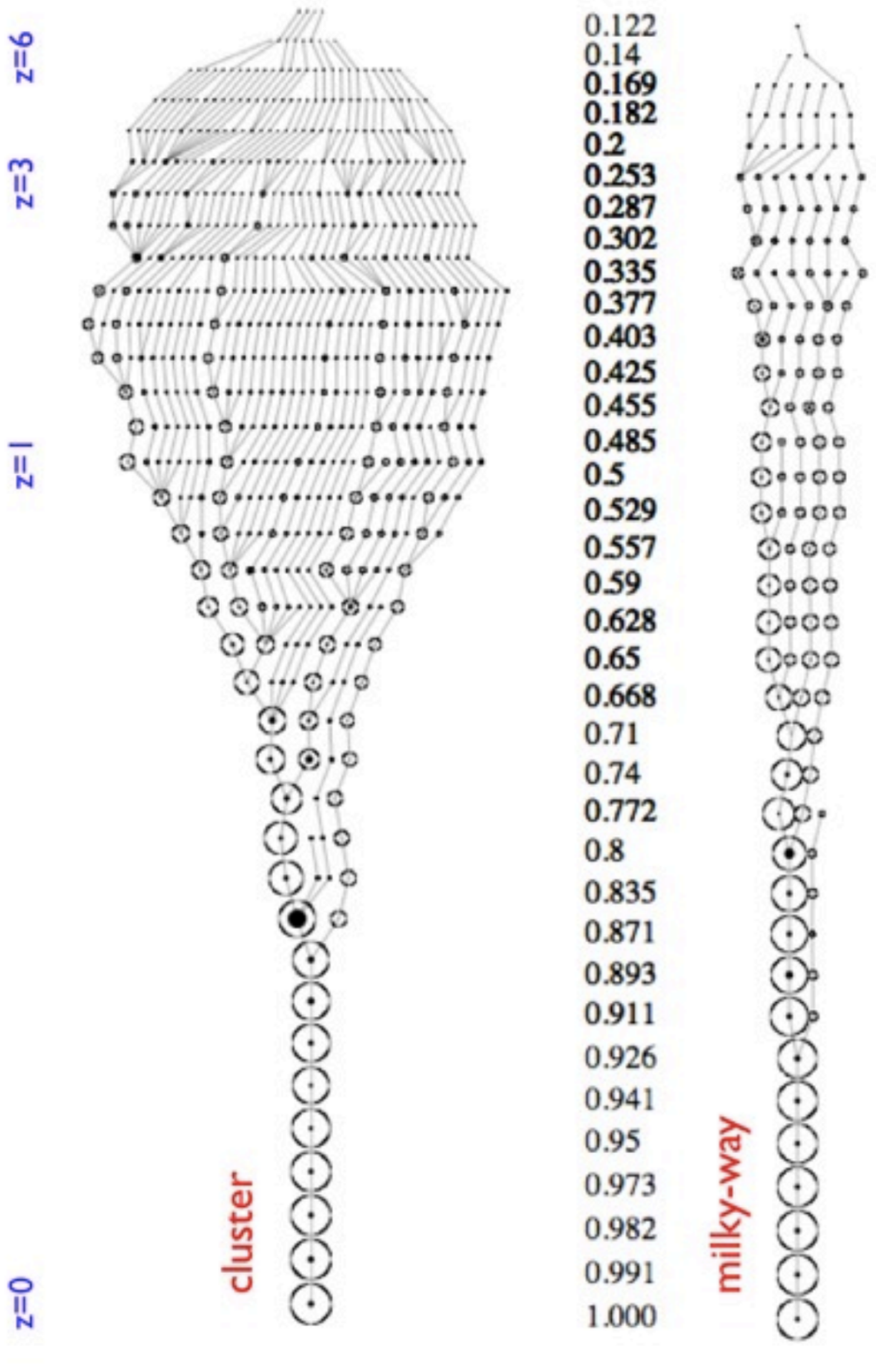
Croton et al. 2006

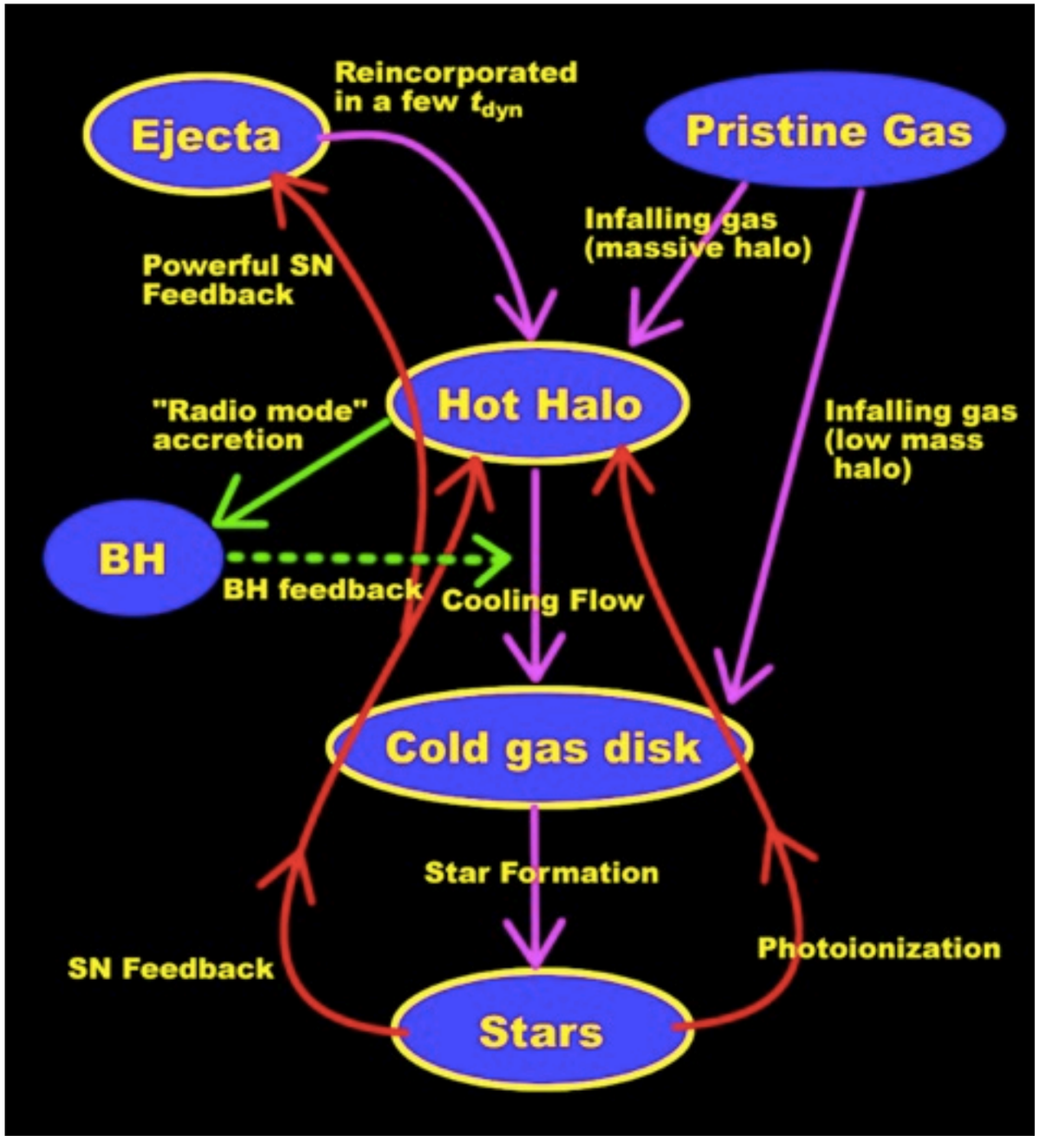
z=0 dark matter

125 Mpc/h

Remember:

Numerical Simulation + Analytic Simulation

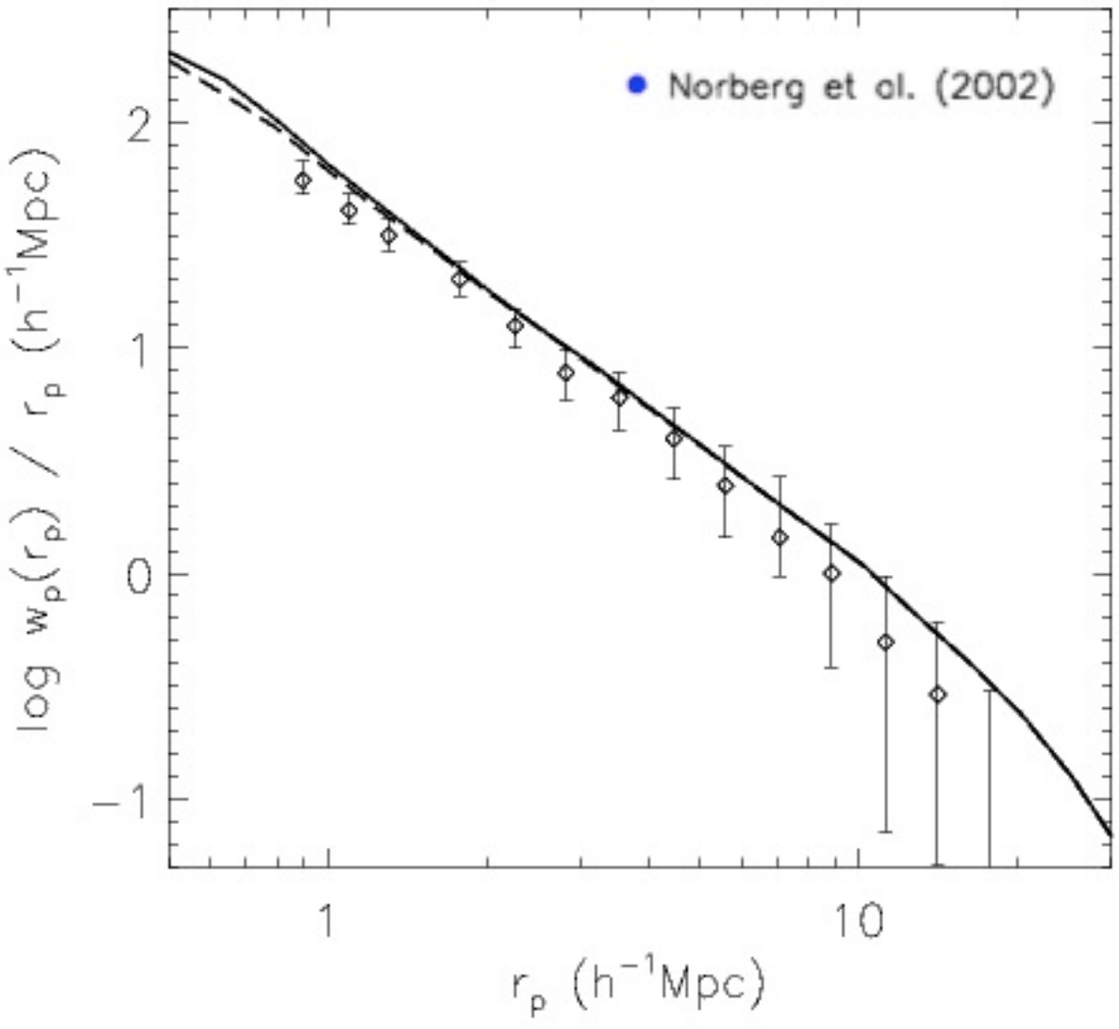




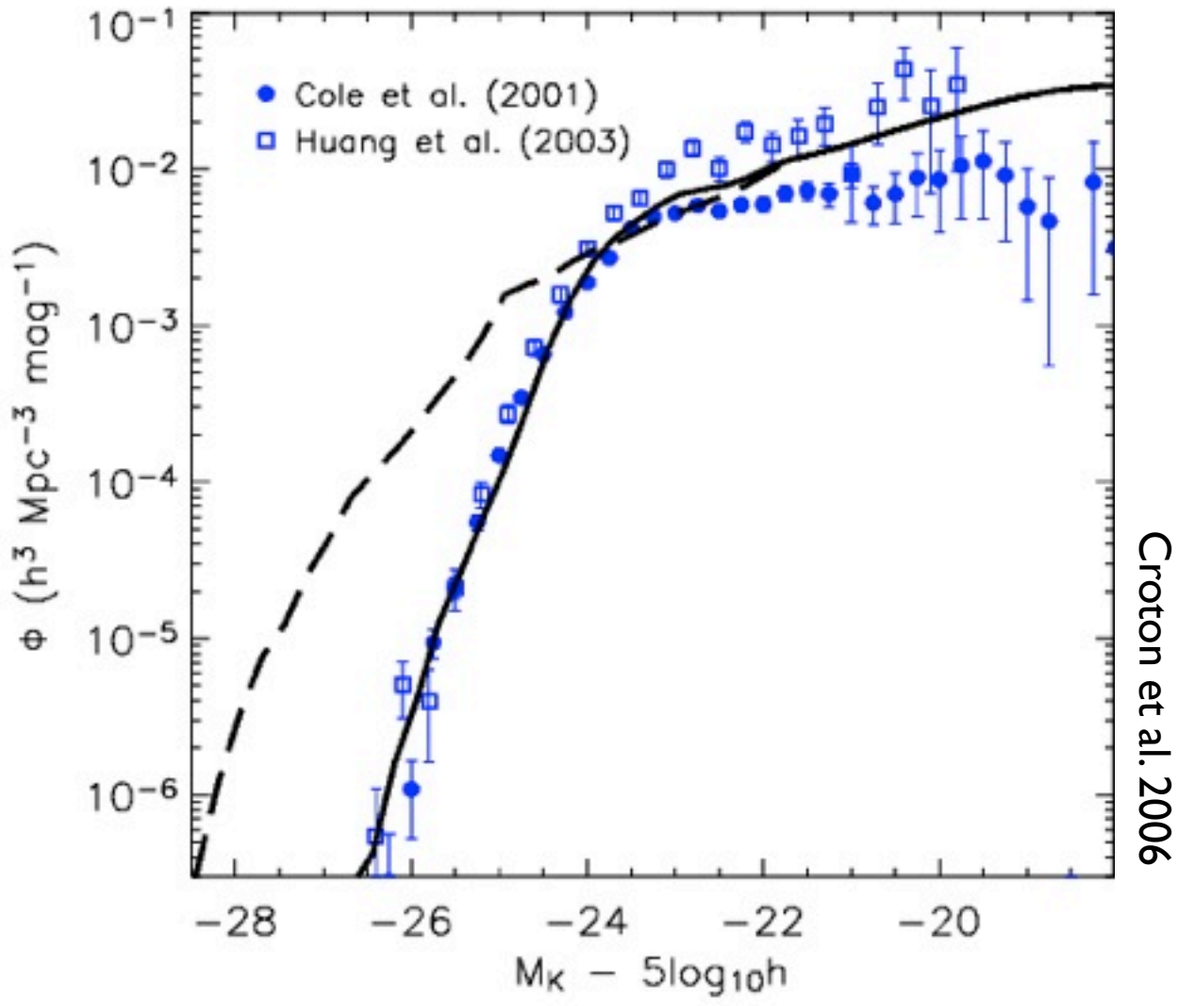
z=0 galaxy light

2 Mpc/h

Galaxy spatial and luminosity distributions



-clustering-

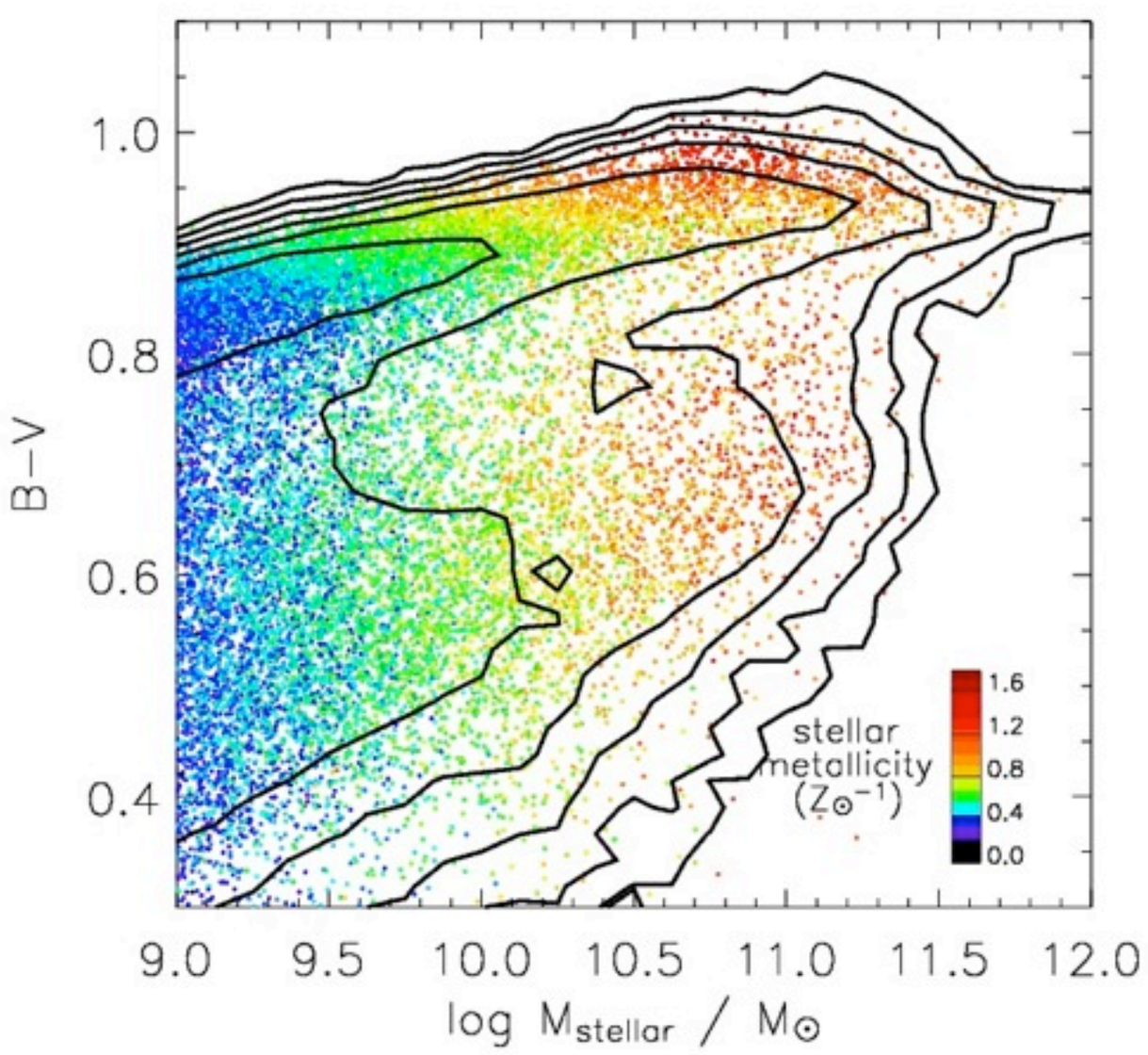


Croton et al. 2006

-luminosity function-

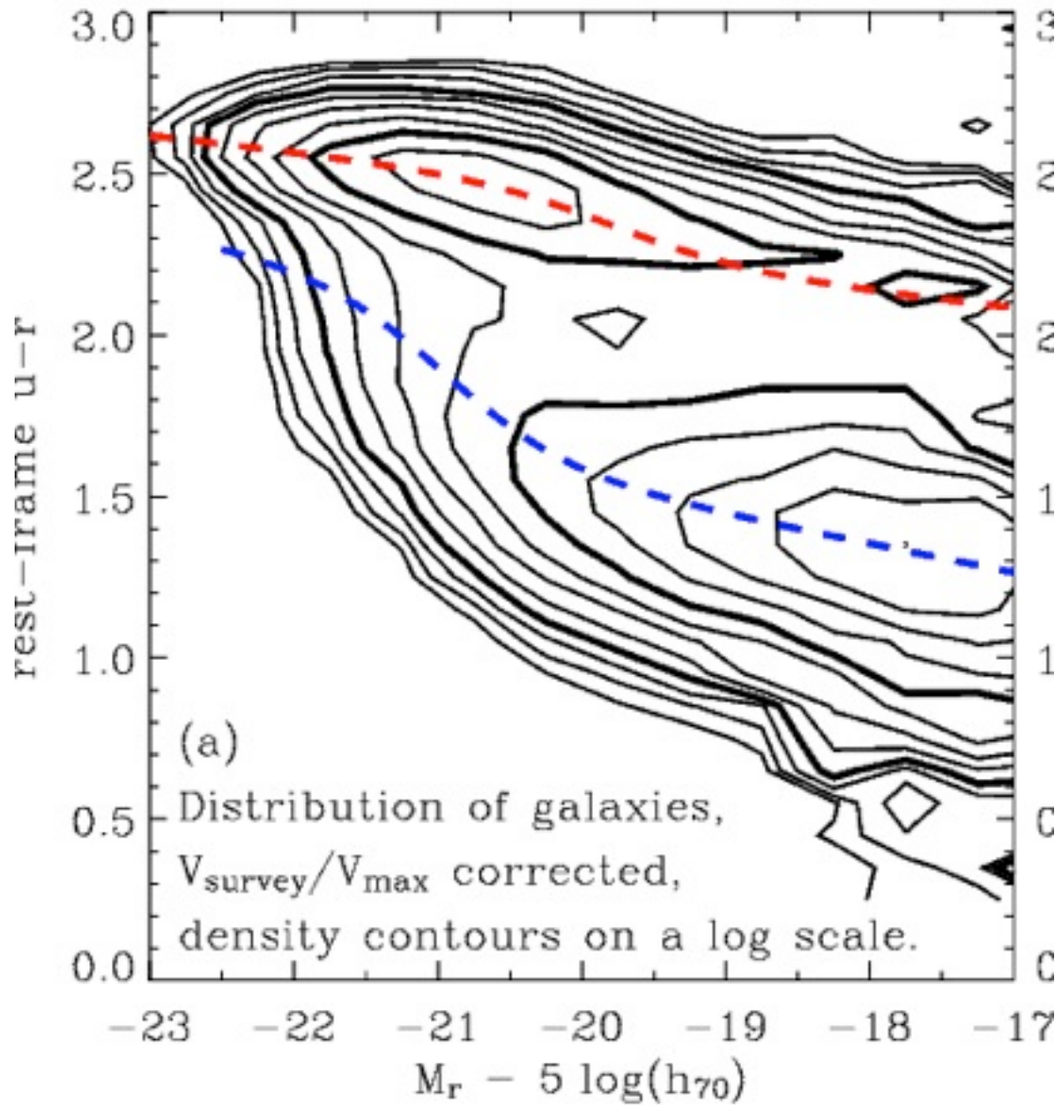
Galaxy colour distribution

Croton et al. 2006



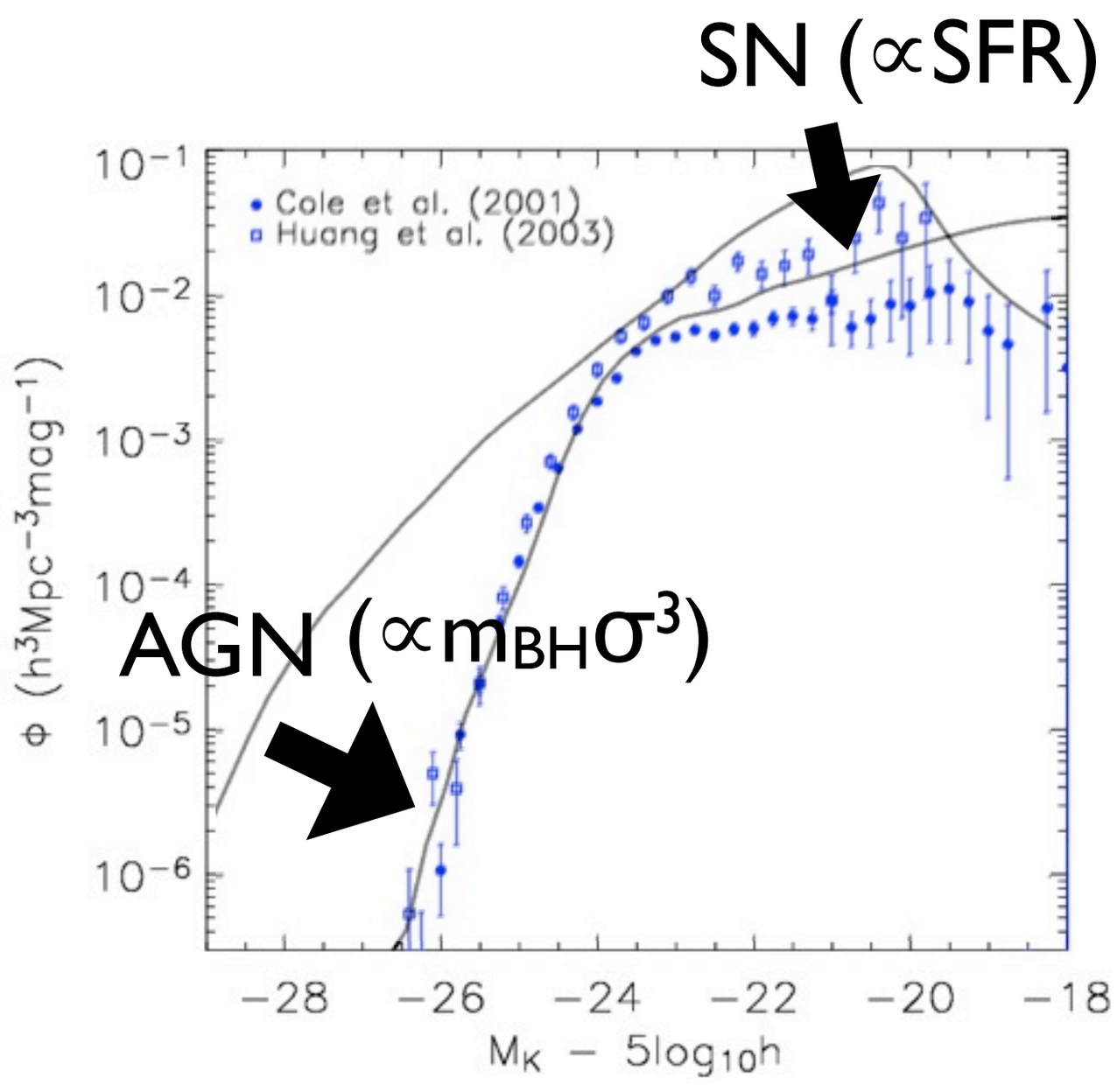
-model-

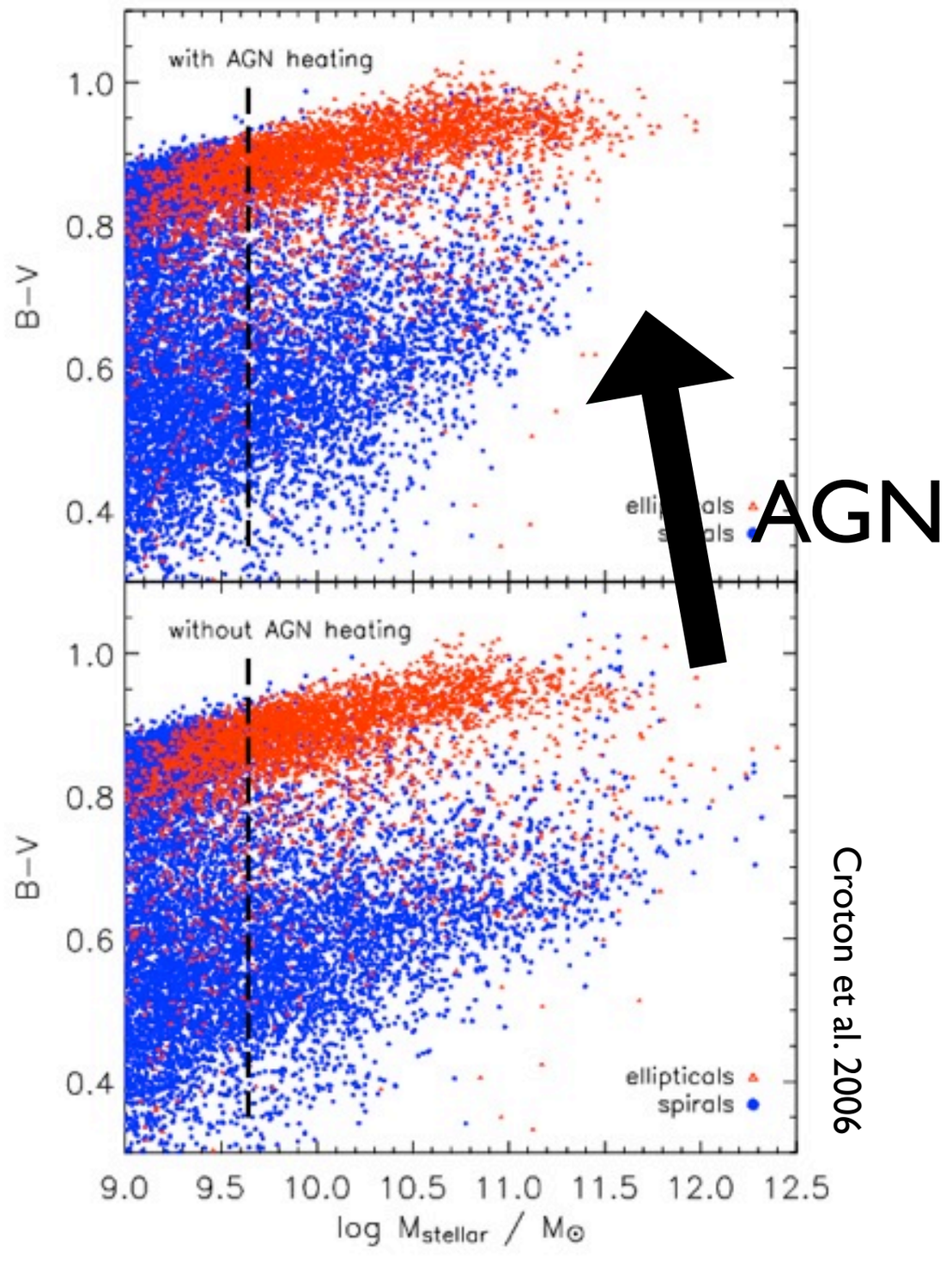
Baldry et all. 2005

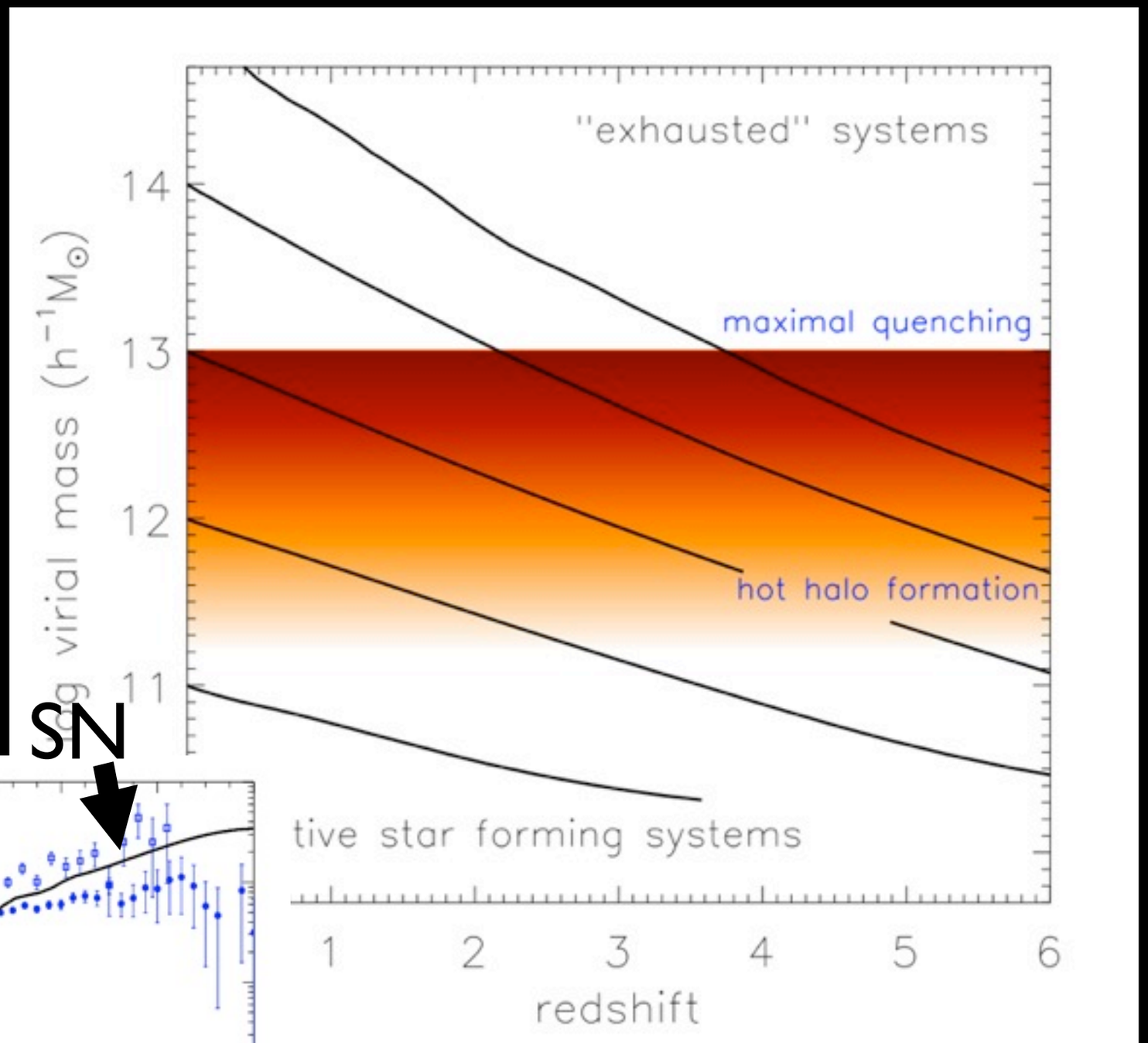


-SDSS-

Physical consequences

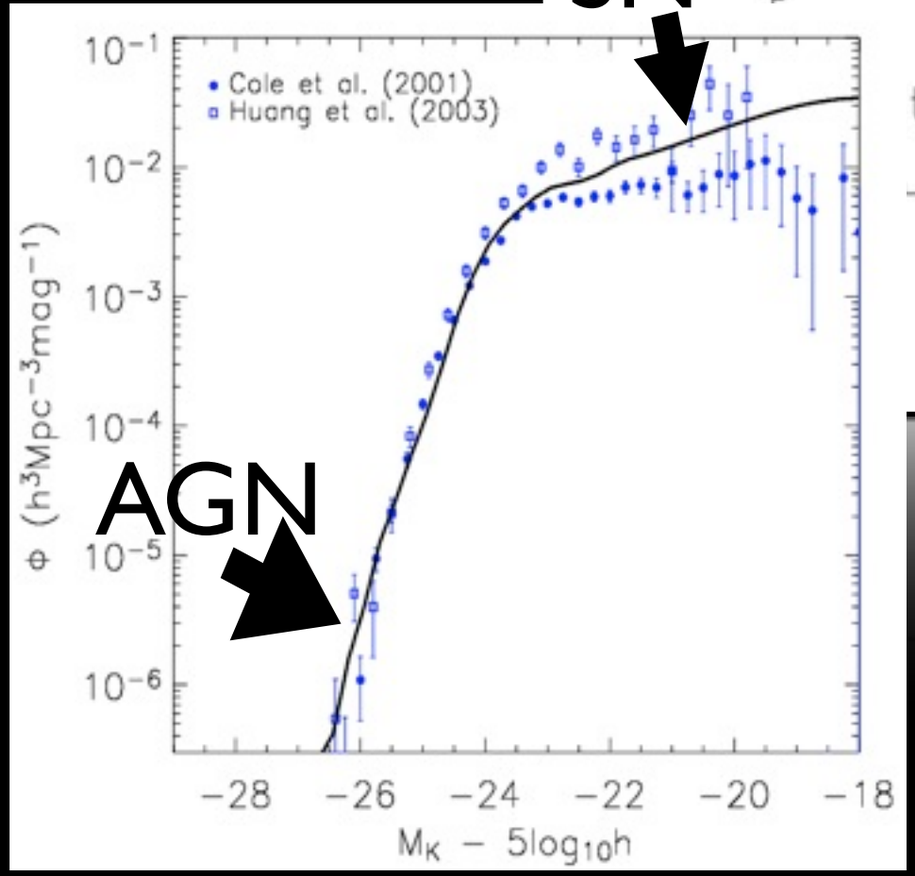


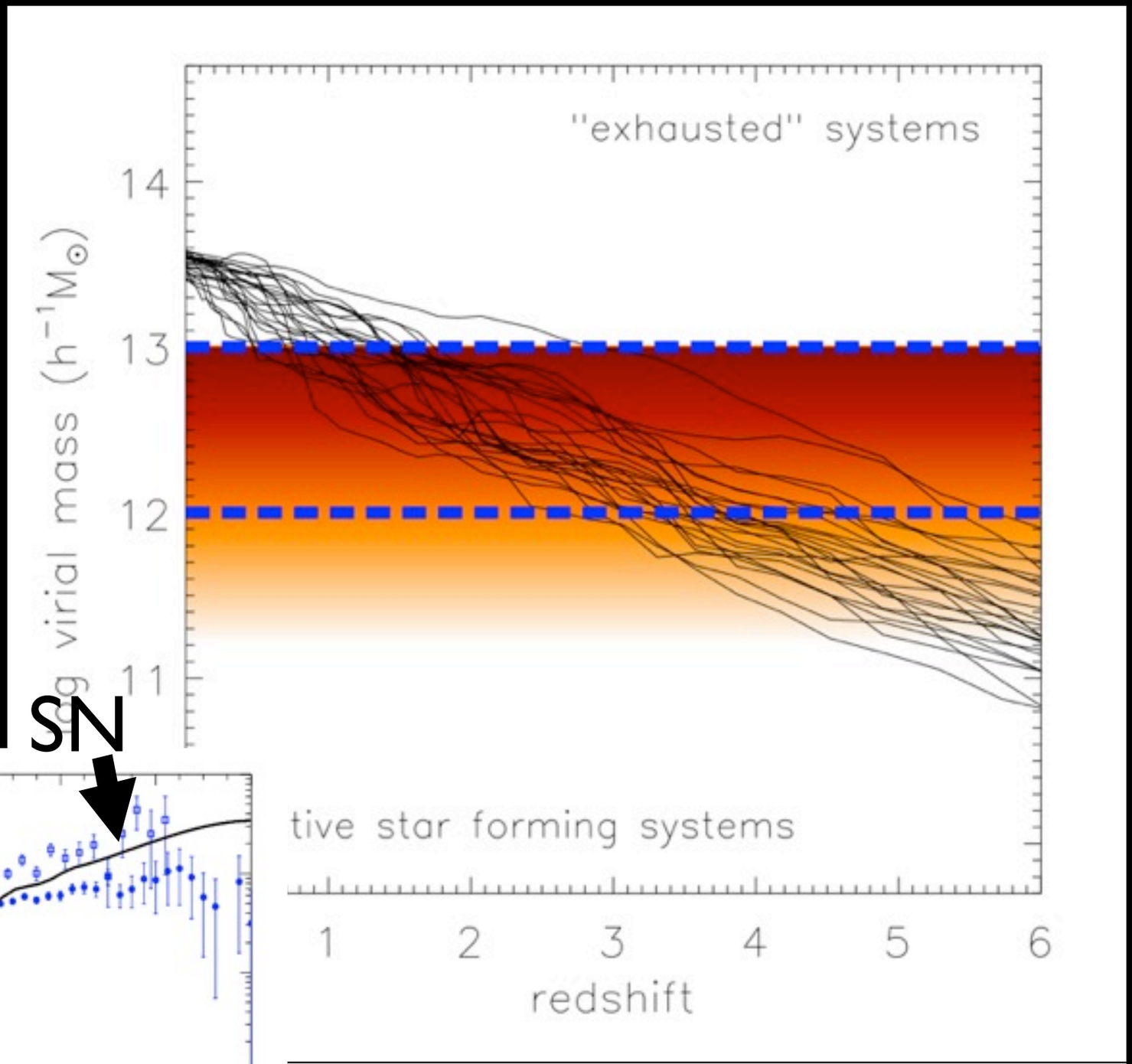



"exhausted" systems
maximal quenching
hot halo formation
tive star forming systems
14
13
12
11
g virial mass ($h^{-1}M_\odot$)
1
2
3
4
5
6
redshift

SN

AGN


Cole et al. (2001)
Huang et al. (2003)
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
10^{-6}
Φ (h^3Mpc^{-3}mag^{-1})
−28
−26
−24
−22
−20
−18
$M_K - 5\log_{10}h$


"exhausted" systems
14
13
12
11
log virial mass ($h^{-1}M_\odot$)
tive star forming systems
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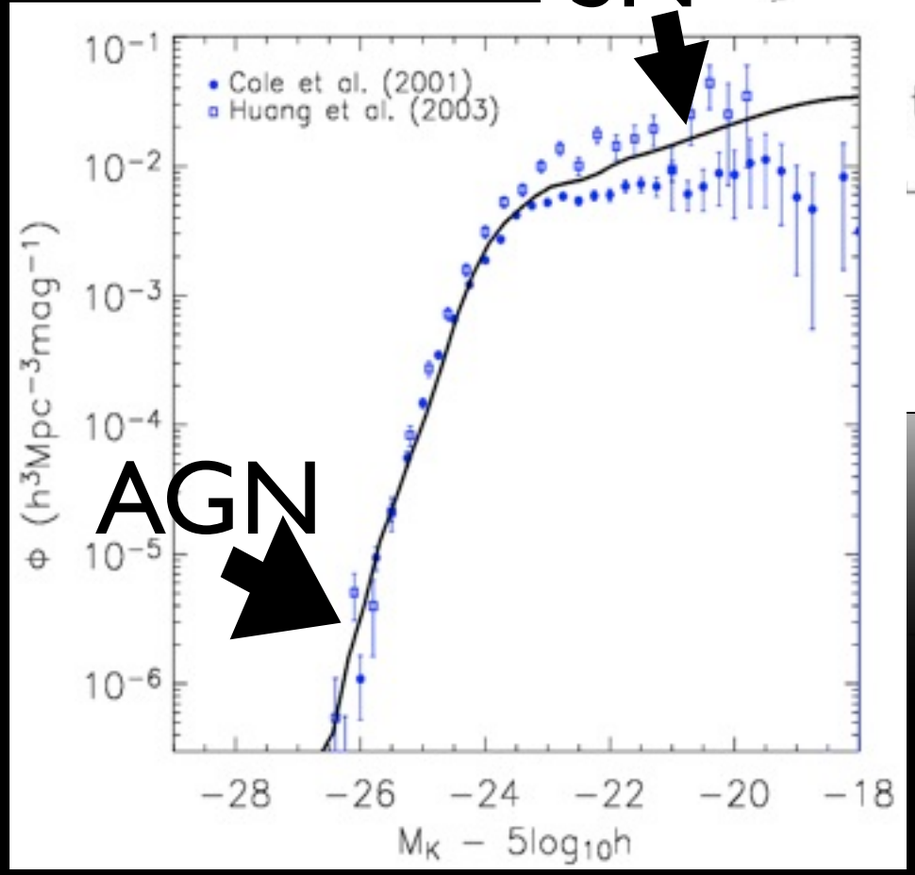
redshift

SN

AGN


Cole et al. (2001)
Huang et al. (2003)
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
10^{-6}
Φ ($h^3Mpc^{-3}mag^{-1}$)
−28
−26
−24
−22
−20
−18
$M_K - 5\log_{10}h$

Our model is only as good as the questions we ask

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

...and the story continues in the next lecture with "Model parameterisation"...