1.5 Gyr

New Simulations in Galaxy Evolution

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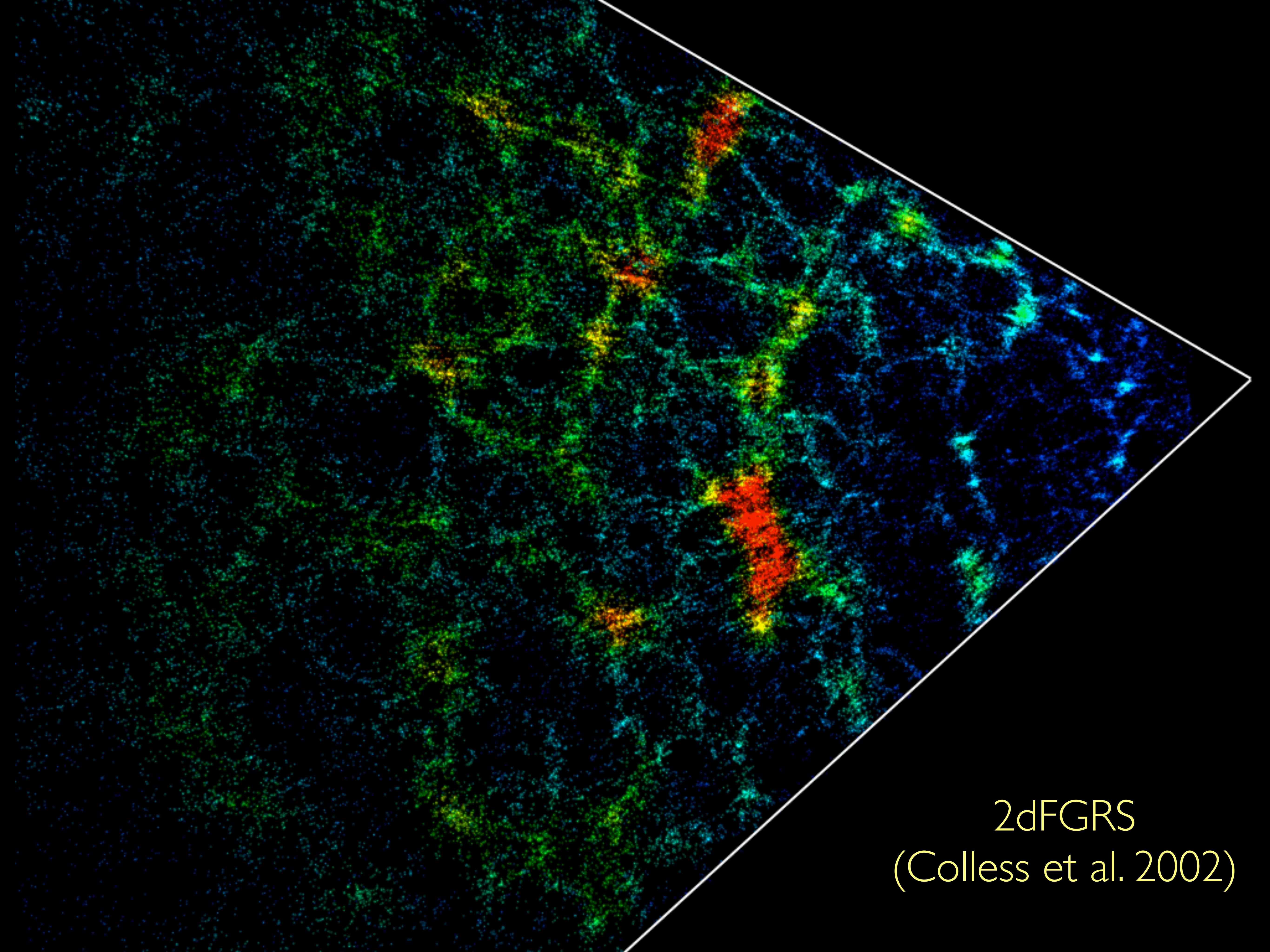
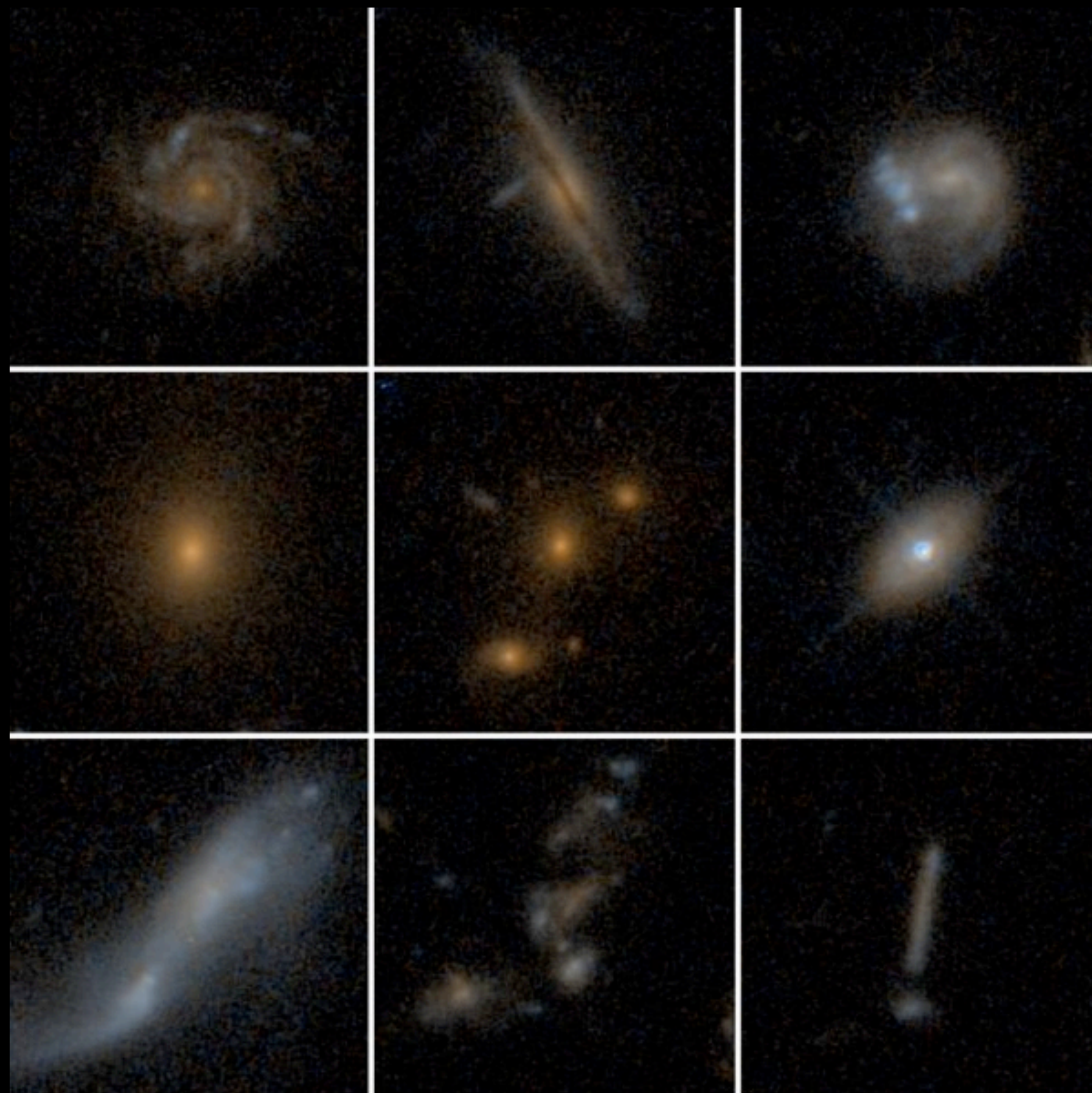
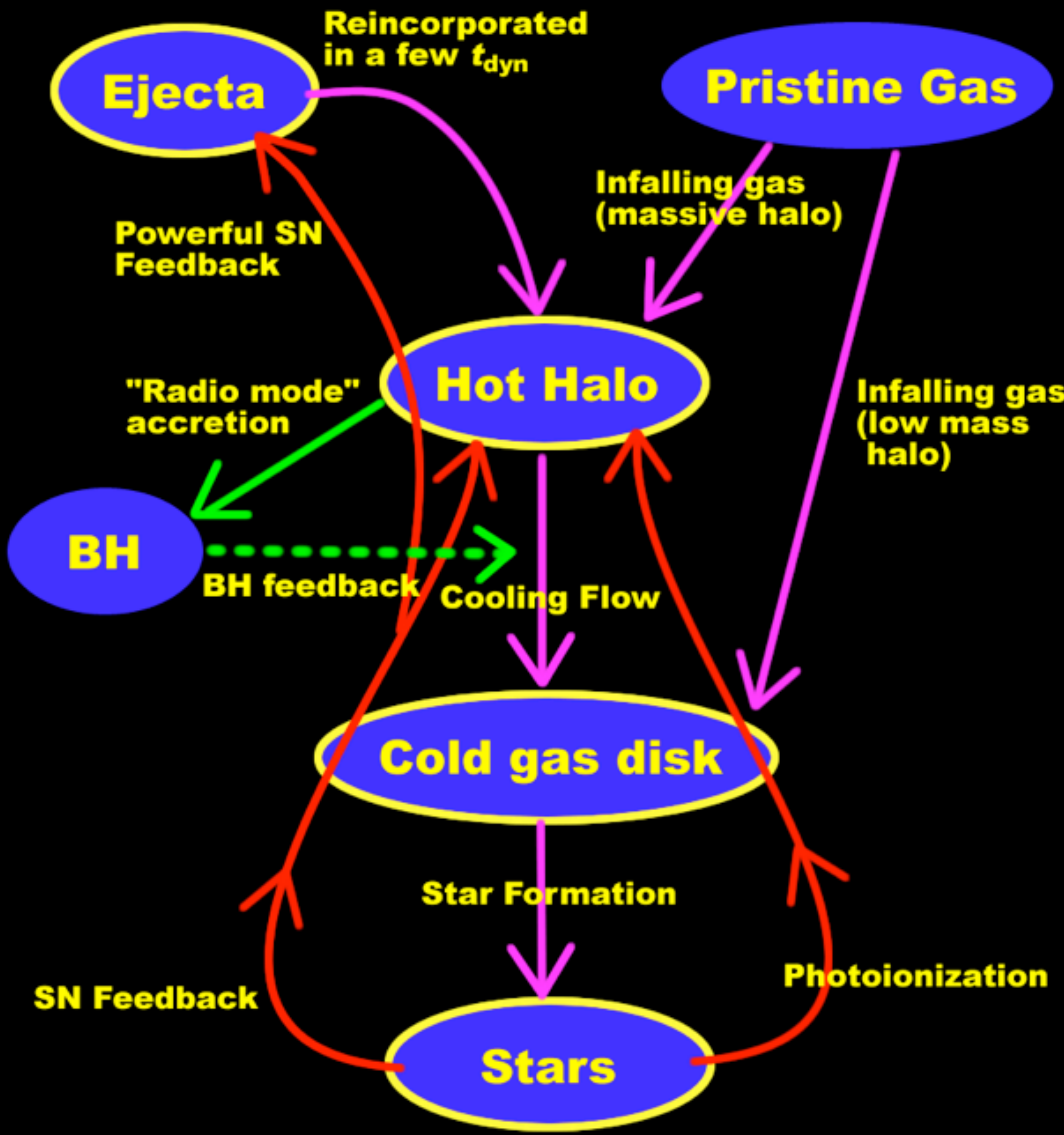

2dFGRS
(Colless et al. 2002)



DEEP2



- 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

morphological transformation

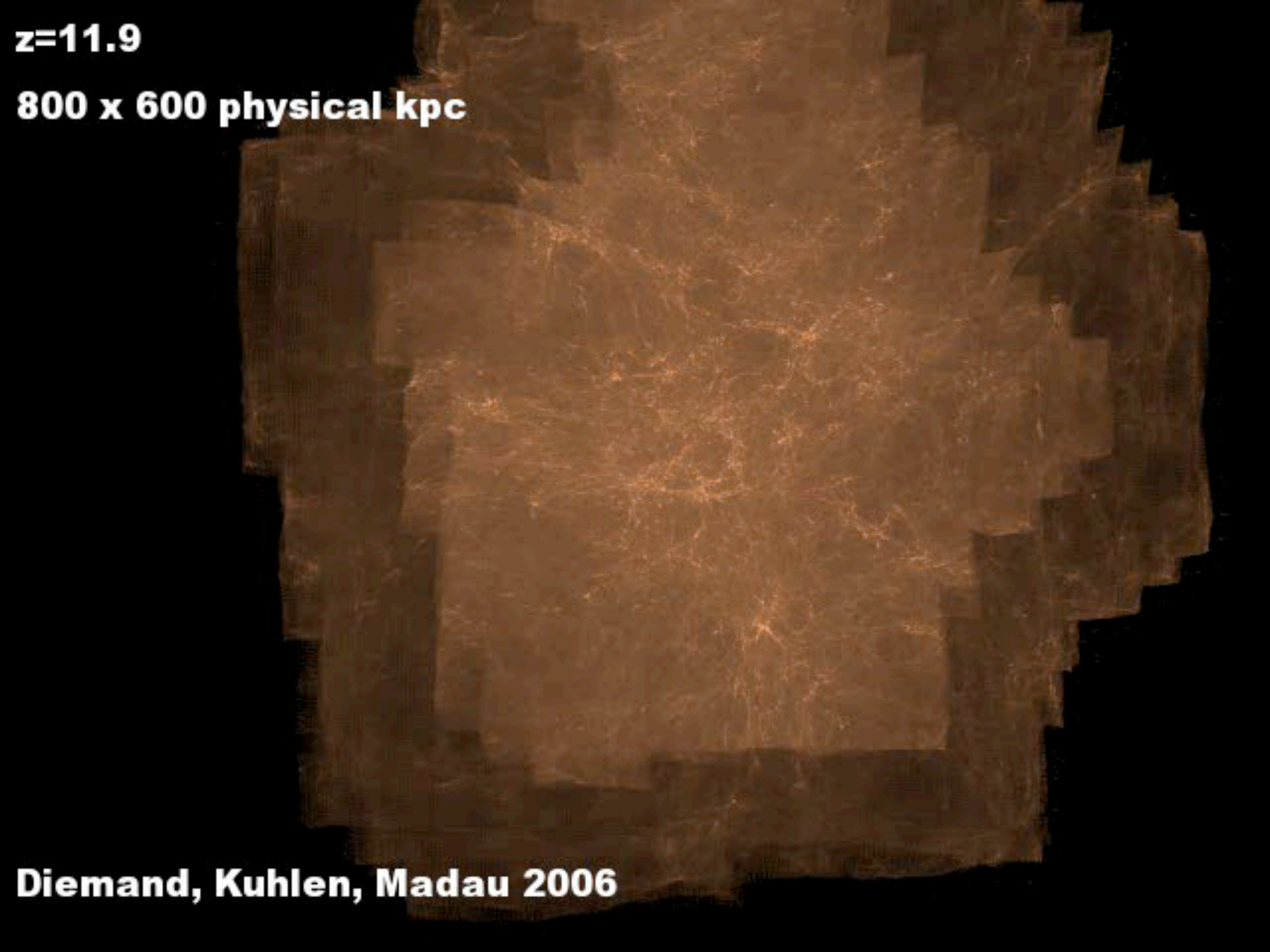
Quescient star formation occurs in the disk

Burst star formation adds to the bulge

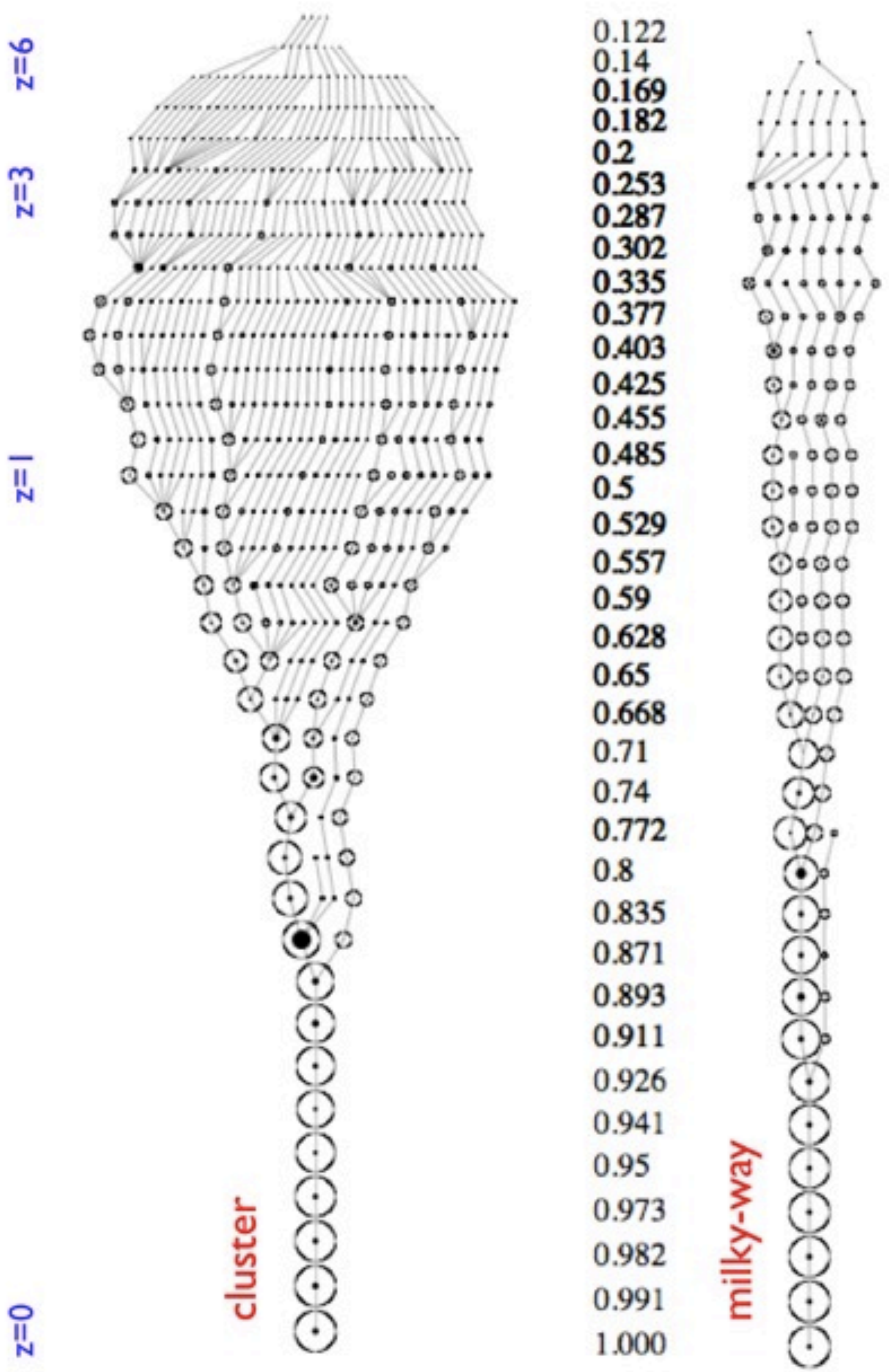
Disk instabilities move disk stars to the bulge

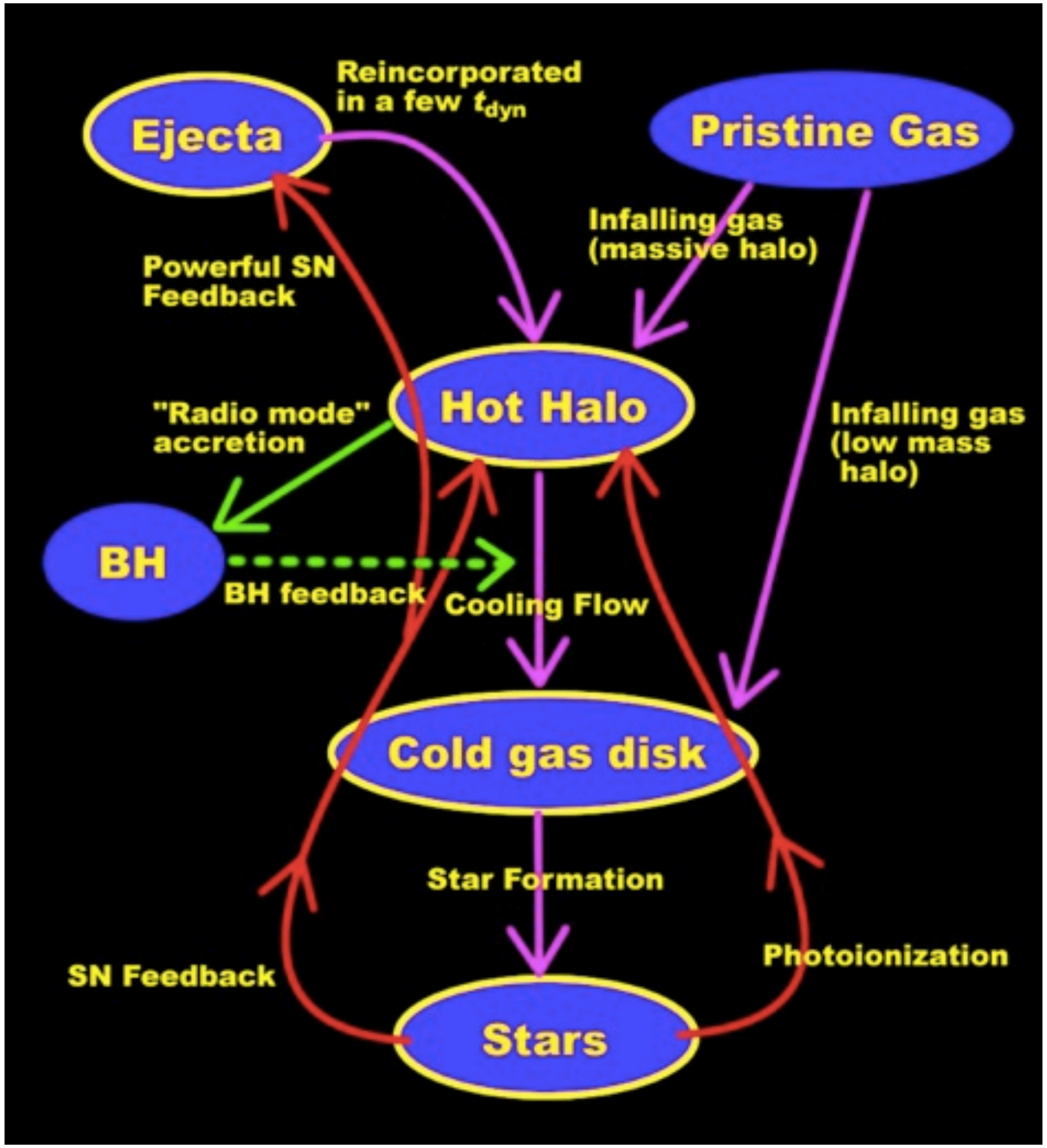
Minor galaxy mergers add satellite stars to the disk

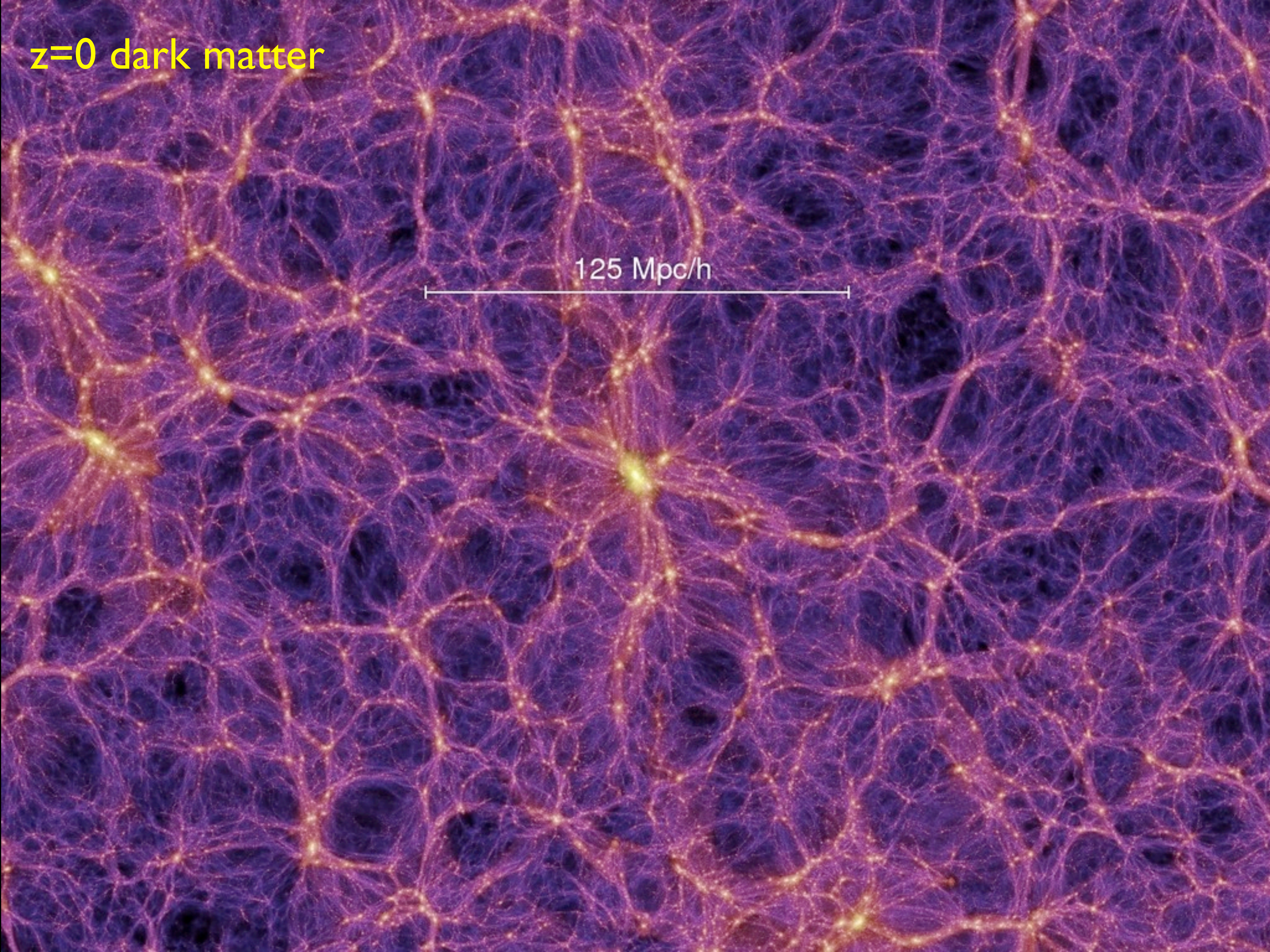
Major galaxy mergers move disk stars to the bulge

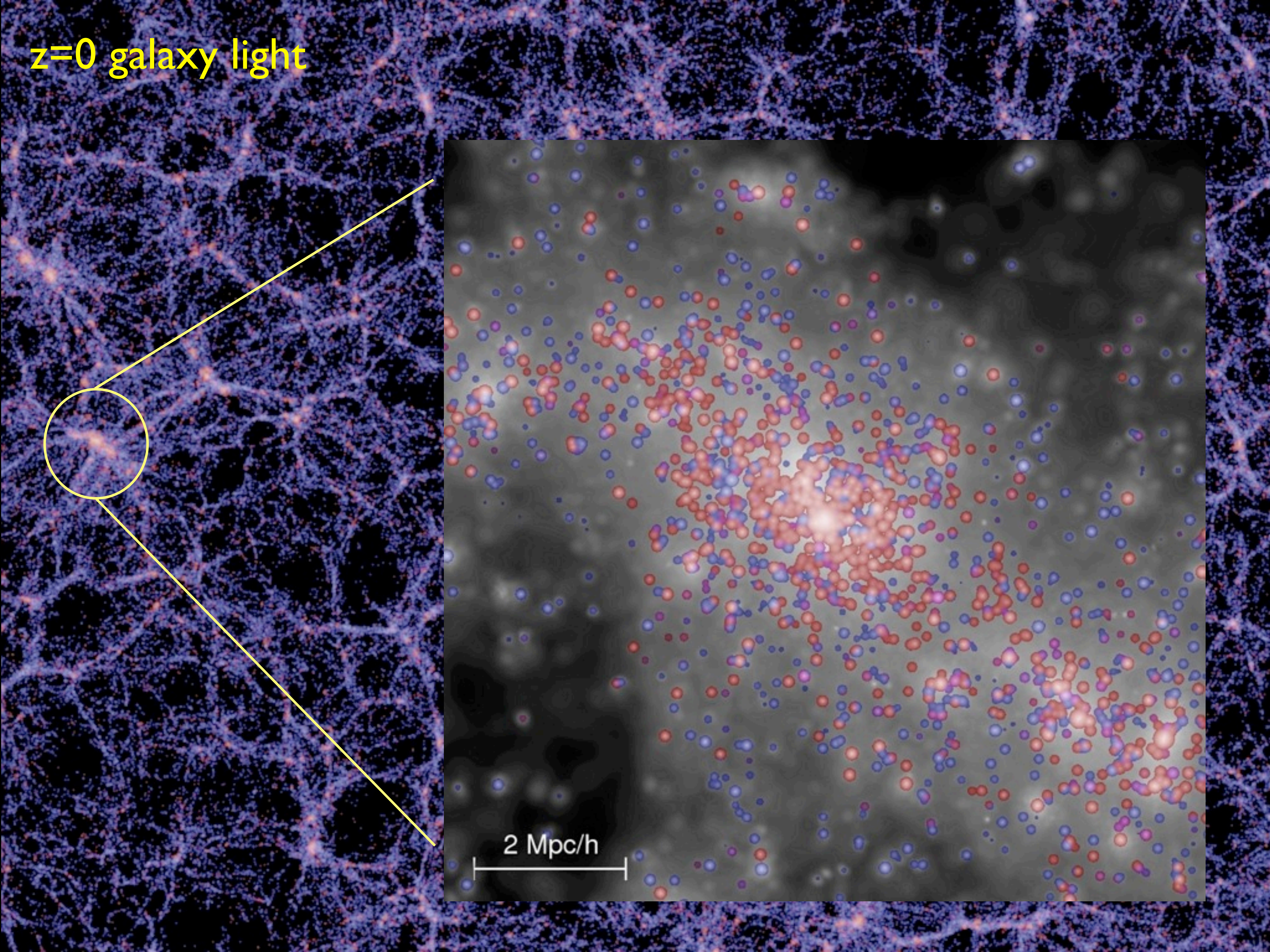

z=11.9
800 x 600 physical kpc
Diemand, Kuhlen, Madau 2006

Numerical Simulation + Analytic Simulation

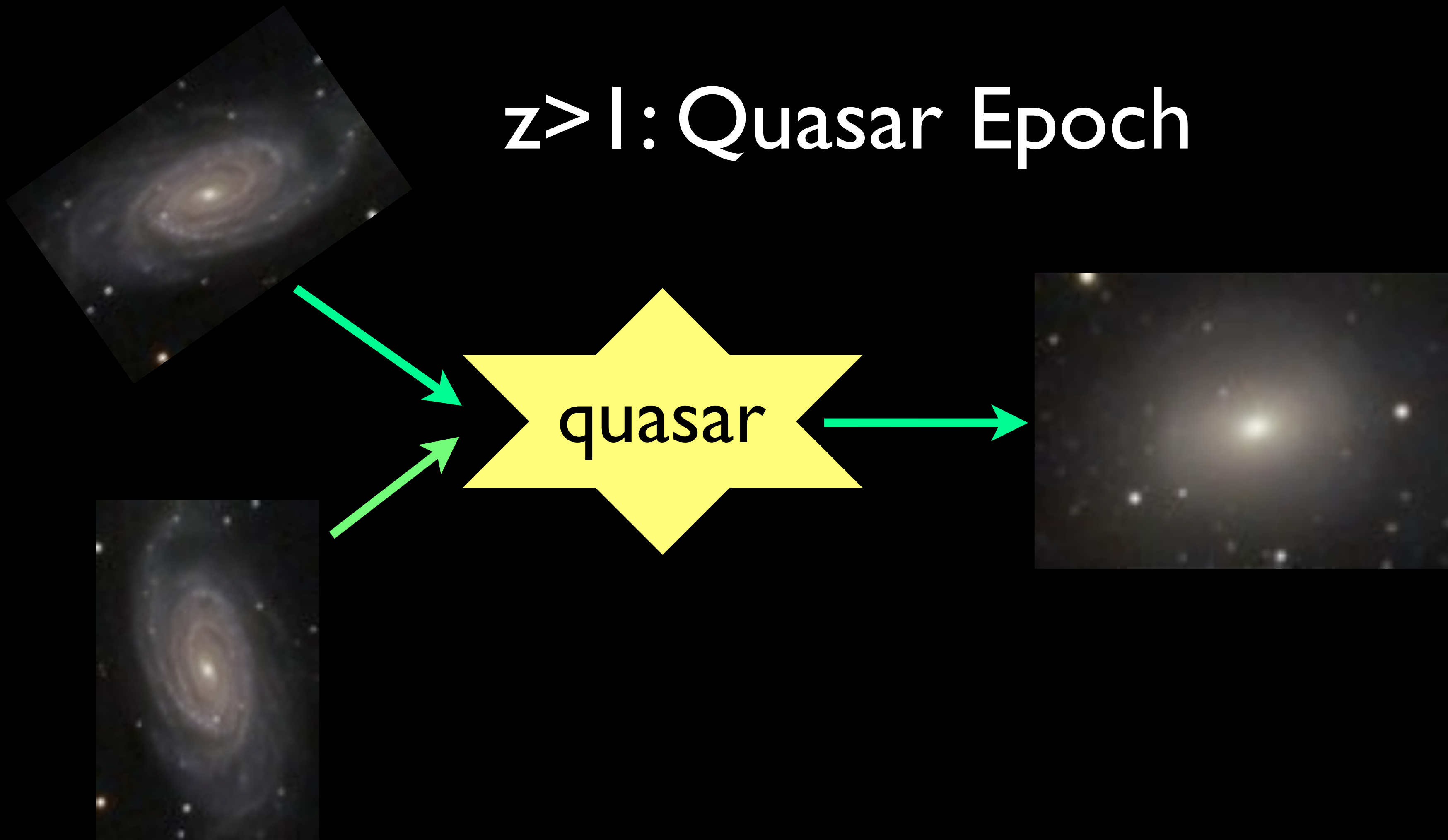


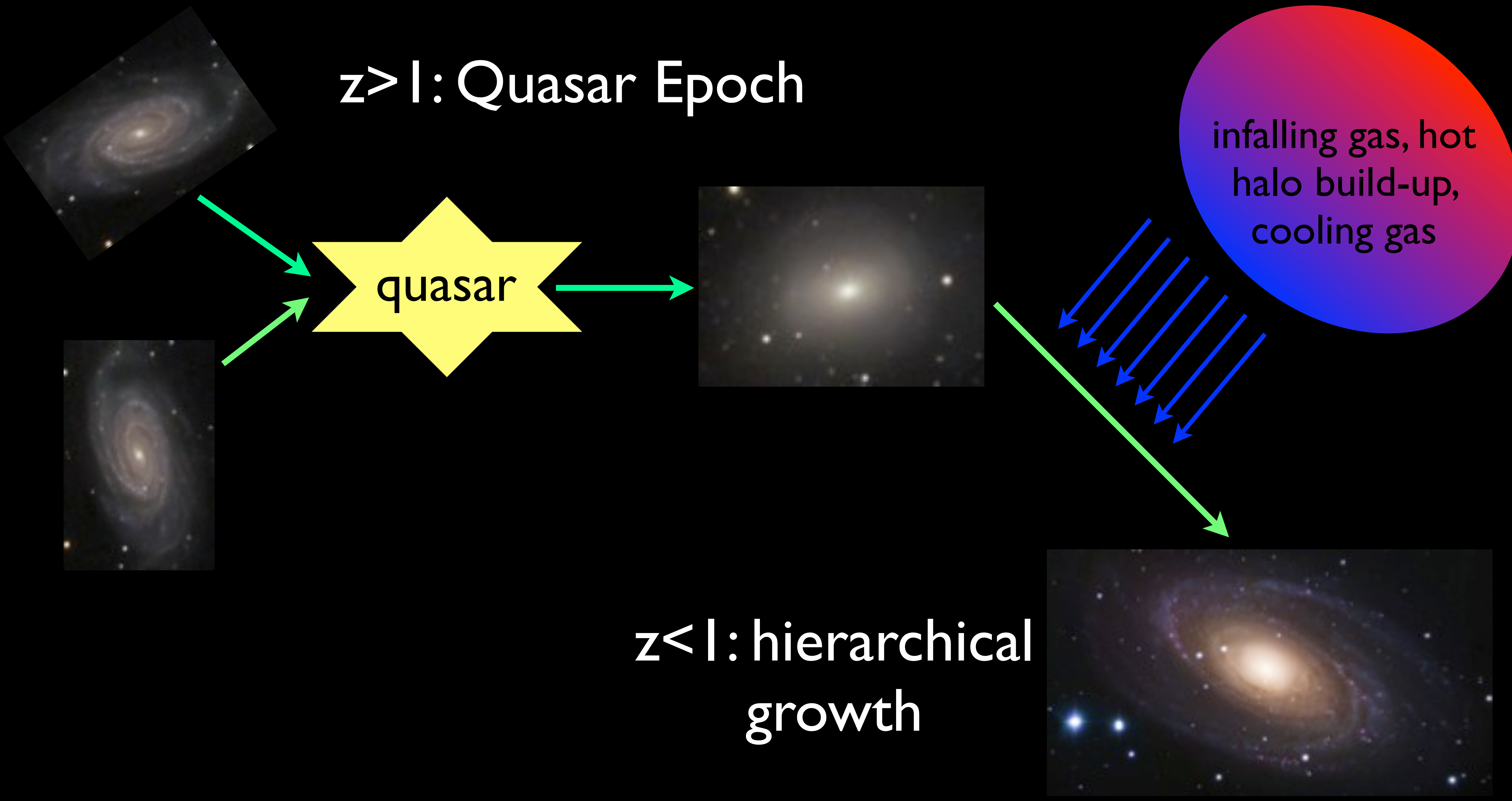



z=0 dark matter
125 Mpc/h


z=0 galaxy light
2 Mpc/h

z>1: Quasar Epoch




z>1: Quasar Epoch
quasar
infalling gas, hot halo build-up, cooling gas
z<1: hierarchical growth

black hole accretion toy model (radio mode)

assumption: the hot gas around the black hole is static and has uniform density

assumption: maximal cooling flow - at the Bondi radius, the gas density is determined by equating the cooling time to the free fall time

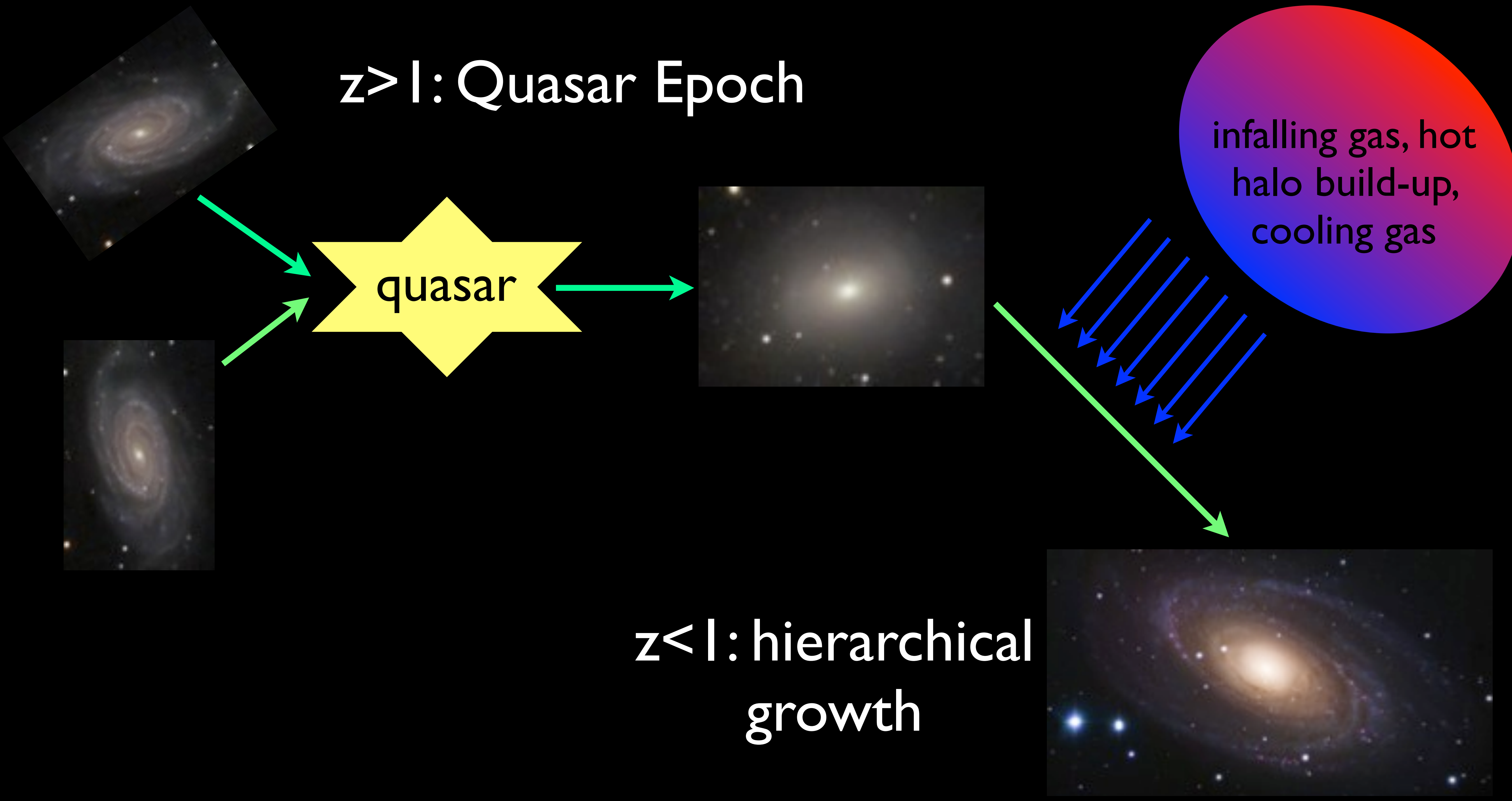
$$\dot{m}_{\rm Bondi} = 2.5\pi G^2 \frac{m_{\rm BH}^2 \rho_0}{c_{\rm s}^3}$$

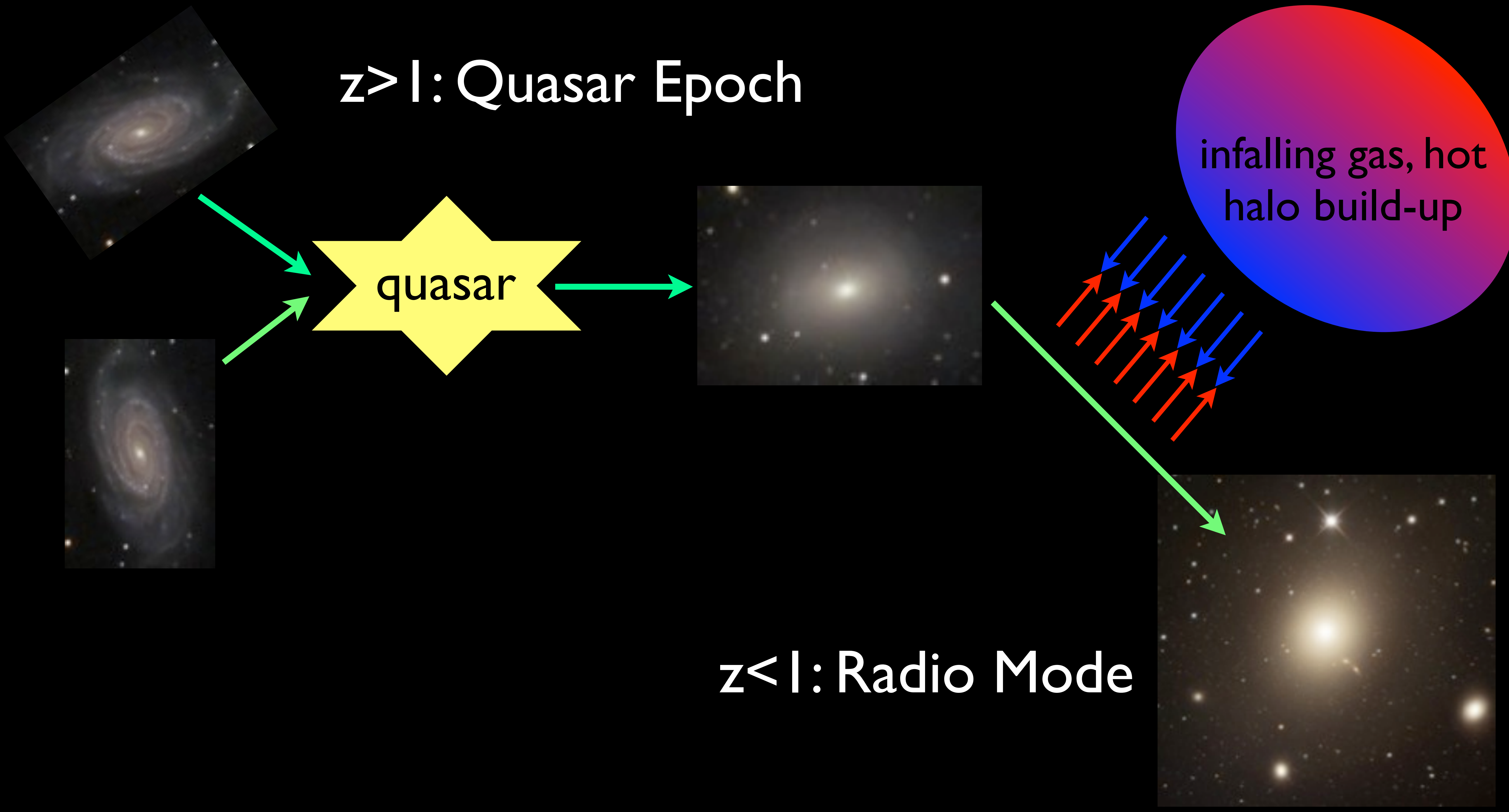
$$\frac{2r_{\rm Bondi}}{c_{\rm s}} \approx \frac{4Gm_{\rm BH}}{V_{\rm vir}^3} = \frac{3}{2} \frac{\bar{\mu} m_{\rm p} kT}{\rho_{\rm g}(r_{\rm Bondi}) \Lambda(T, Z)}$$

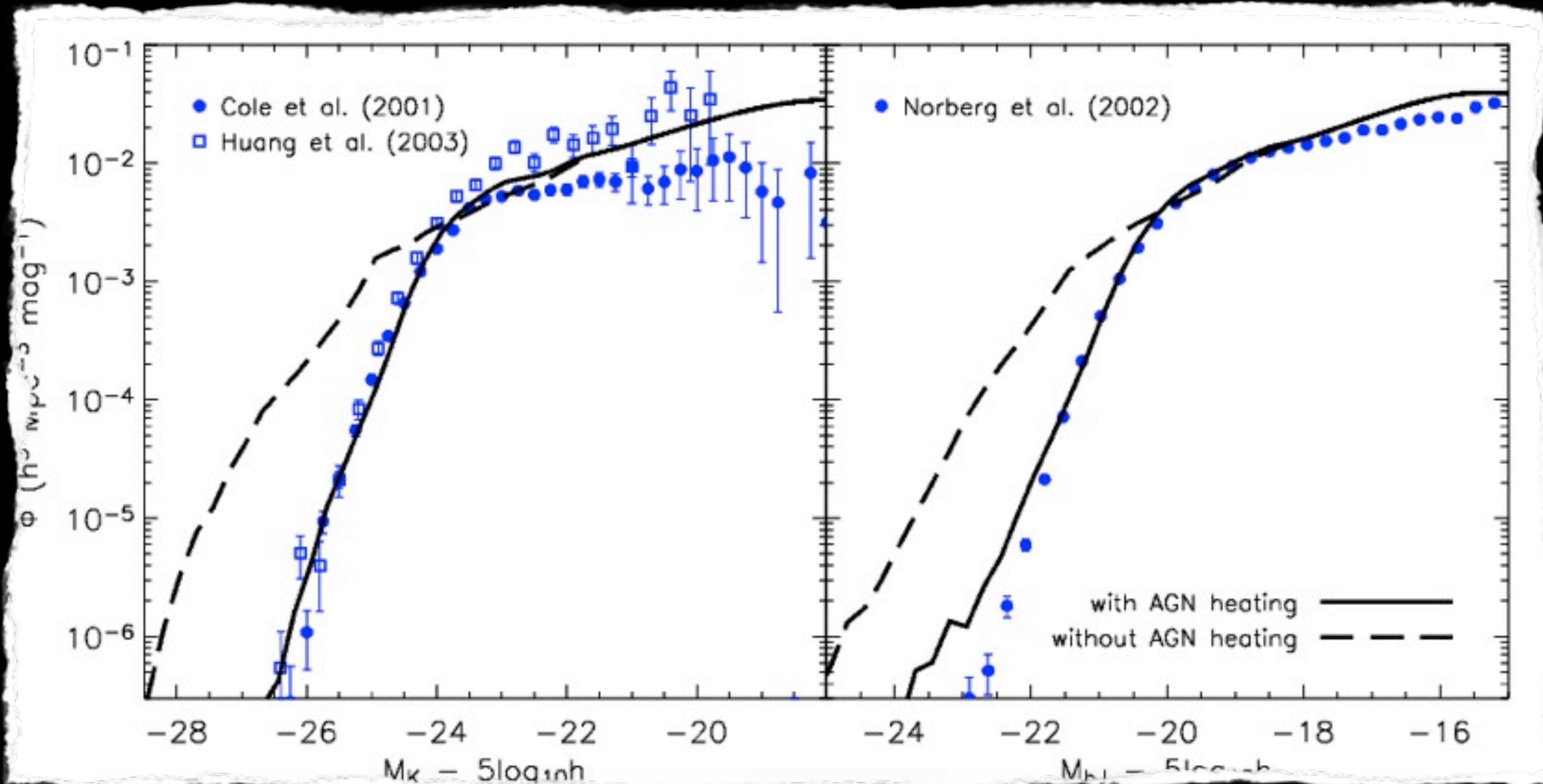
$$\rho_0 = \rho_{\rm g}(r_{\rm Bondi}) = \frac{3\mu m_{\rm p}}{8G} \frac{kT}{\Lambda} \frac{V_{\rm vir}^3}{m_{\rm BH}}$$

$$\dot{m}_{\rm Bondi} \approx G\mu m_{\rm p} \frac{kT}{\Lambda} m_{\rm BH}$$

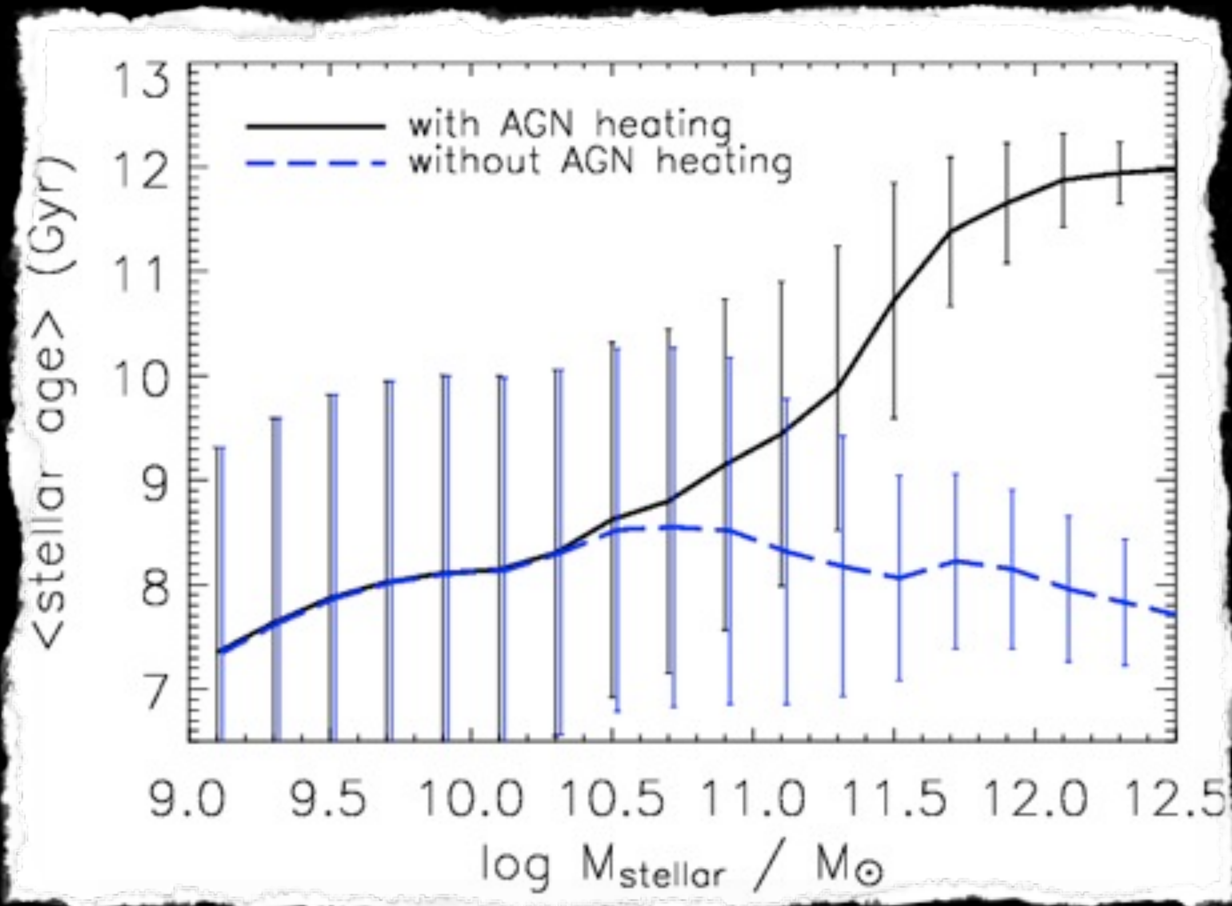
Croton et al. 2006


z>1: Quasar Epoch
quasar
infalling gas, hot halo build-up, cooling gas
z<1: hierarchical growth

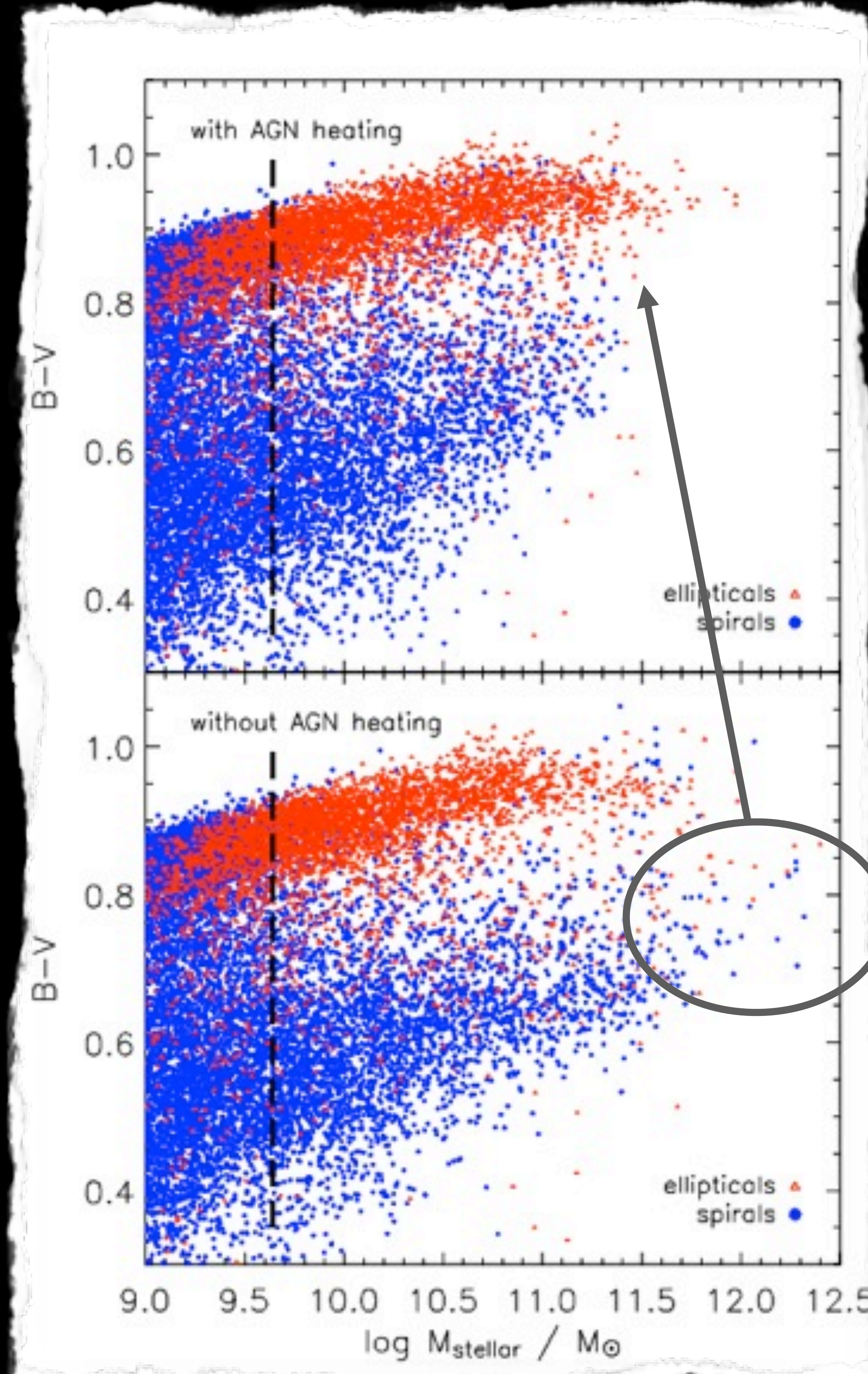

z>1: Quasar Epoch
quasar
infalling gas, hot halo build-up
z<1: Radio Mode



Cole et al. (2001)
Huang et al. (2003)
Norberg et al. (2002)
with AGN heating
without AGN heating



with AGN heating
without AGN heating
<stellar age> (Gyr)
log $M_{stellar}$ / $M_{\odot}$



with AGN heating
without AGN heating
B−V
ellipticals
spirals
log $M_{stellar}$ / $M_{\odot}$

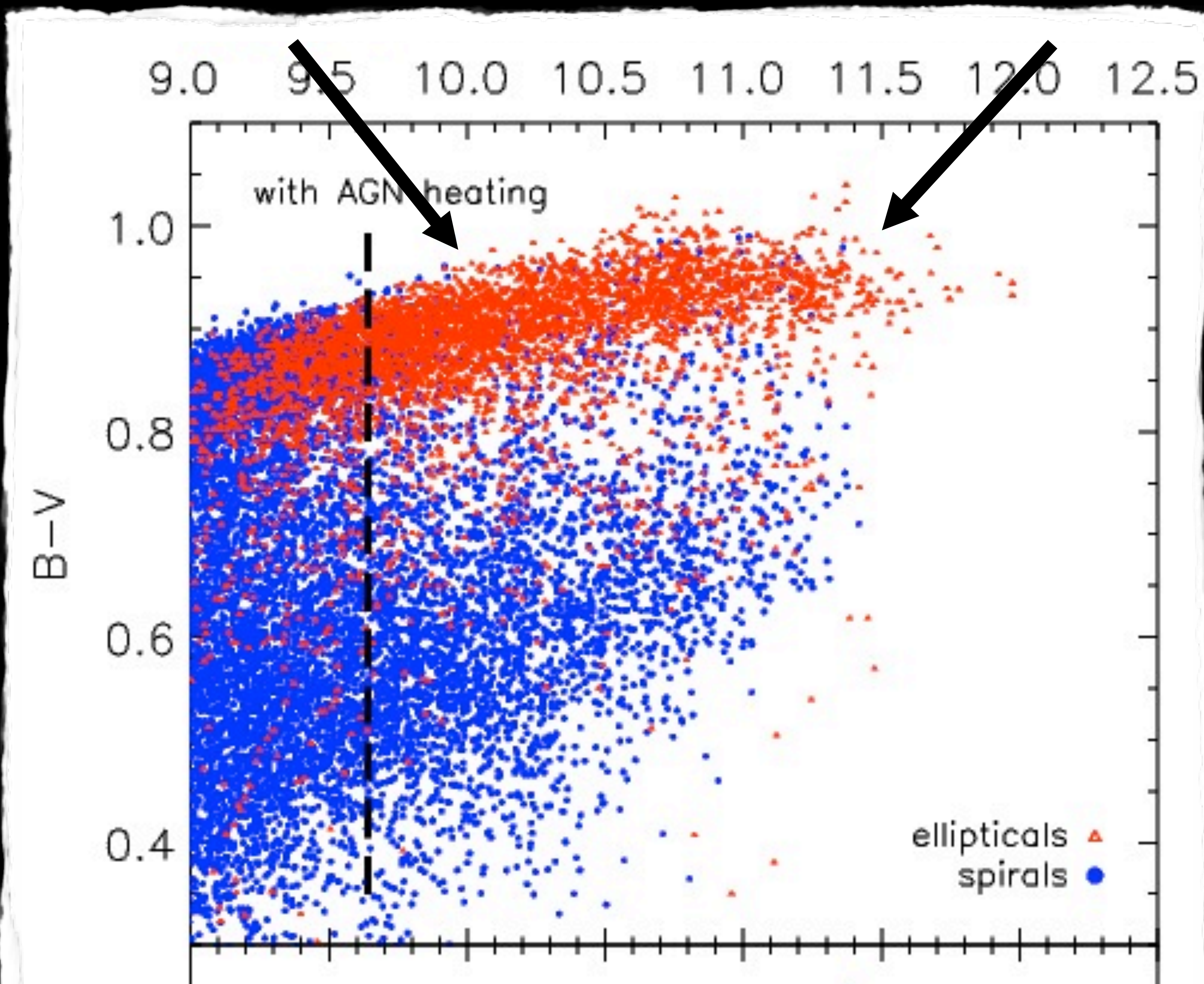
Croton et al. 2006

	When?	Trigger?	Feeding?	Consequence?
Quasar Mode	at early times	gas rich mergers	cold gas	BH growth, sets properties of ellipticals
Radio Mode	at late times	BH & hot halo large enough?	hot gas? stellar winds?	suppresses cooling gas, shuts down SF

Importantly, some kind of quenching is needed to get the low-z morphologies right

environment quenching
(satellite galaxies)

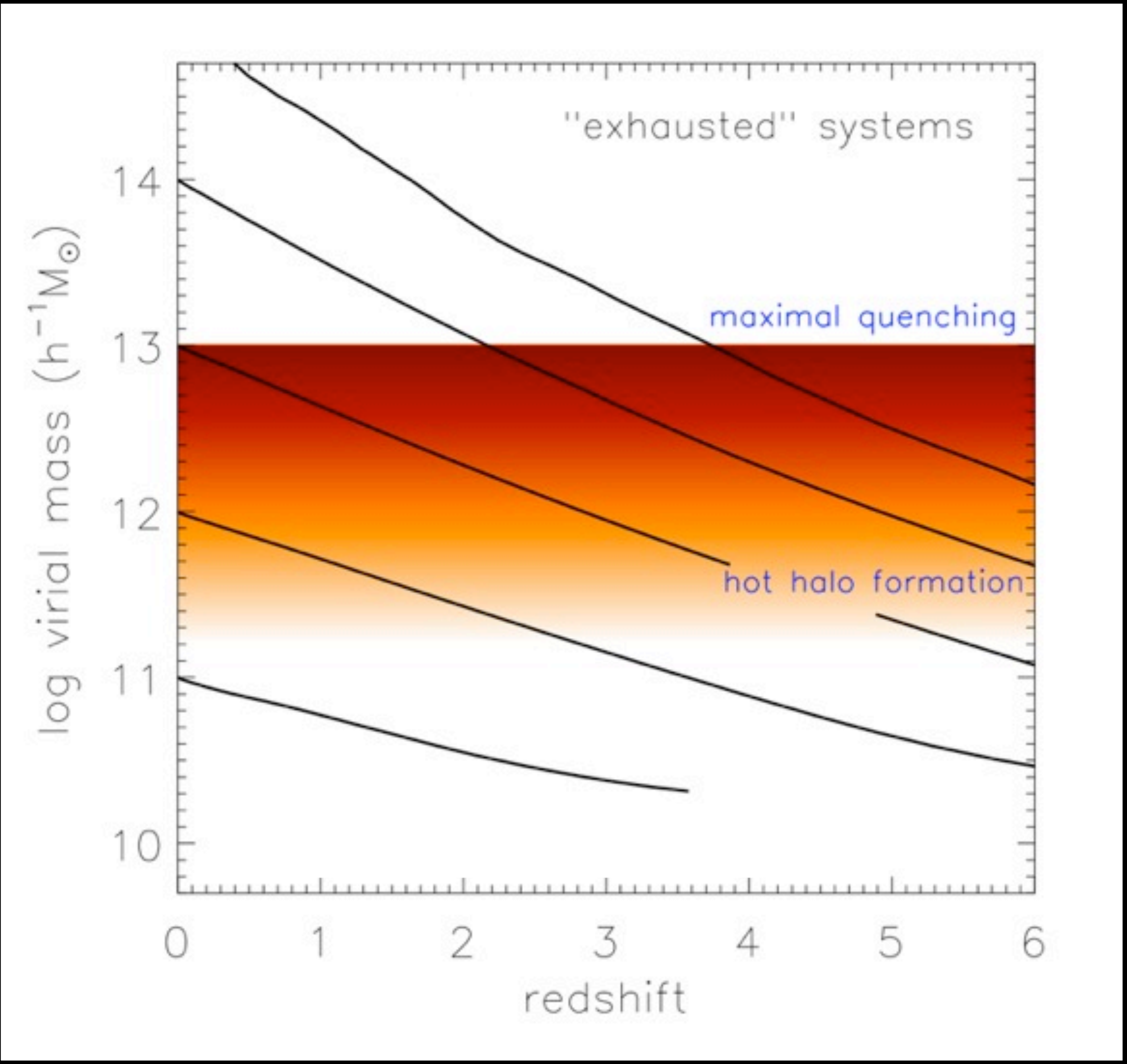
AGN quenching
(central galaxies)



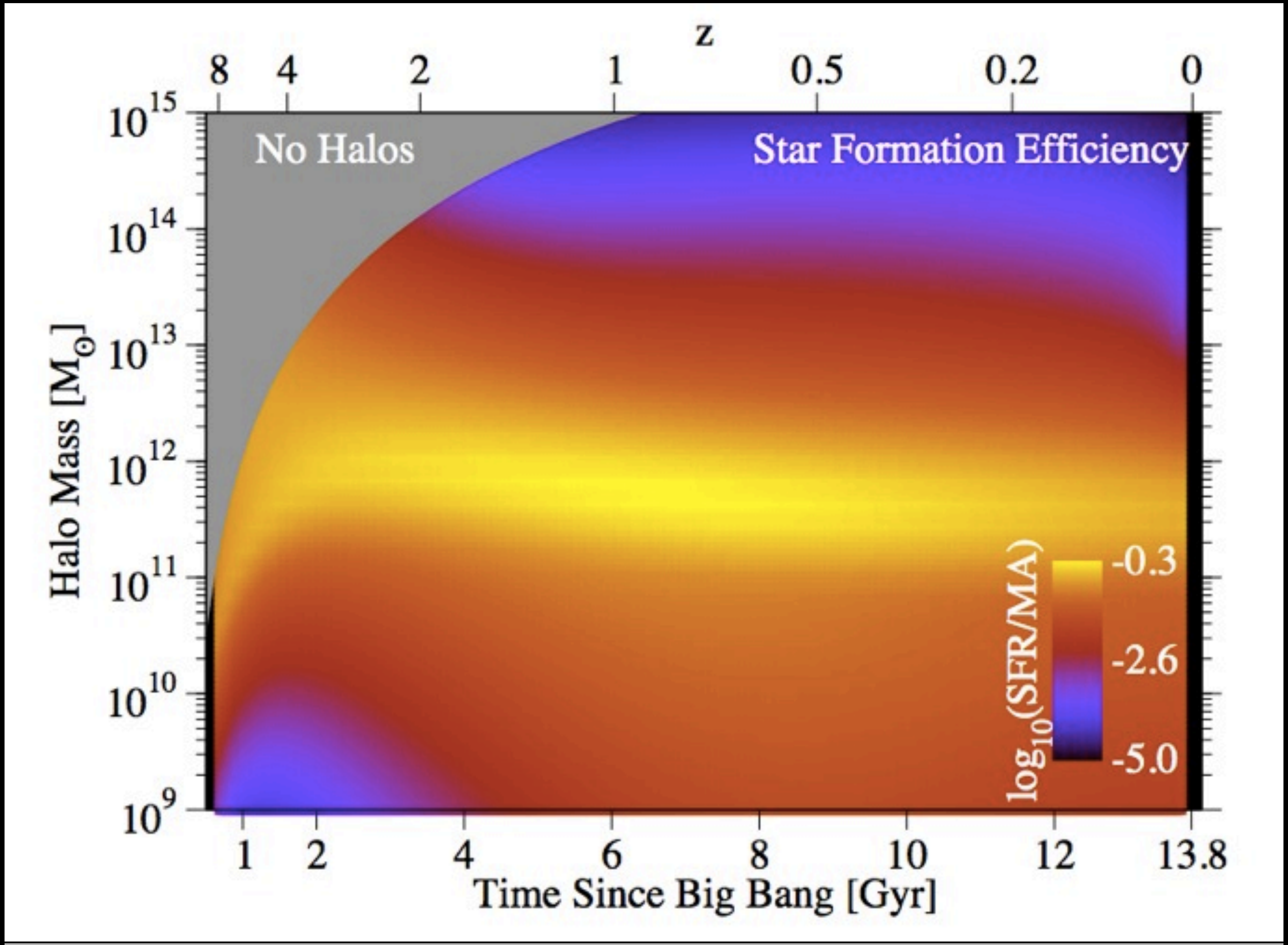

GALAXY ZOO
SYDNEY 2013
RUNNING RINGS AROUND
URANUS
SYDNEY 2013


CLEARWAY
SPECIAL EVENTS
1AM TO 10AM
22 SEPTEMBER 2013
BLACKMORES
110min
110min
asics
The Sydney Morning Herald

Amanda Bauer, Kelly Borden, Darren Croton, Sara Ellison, Amit Kapadia, Amy Kimbal, Naomi McClure-Griffiths, Bob Nichol, Jenna Ryon, Chris Snyder, Christopher Usher, Anna Weigel.

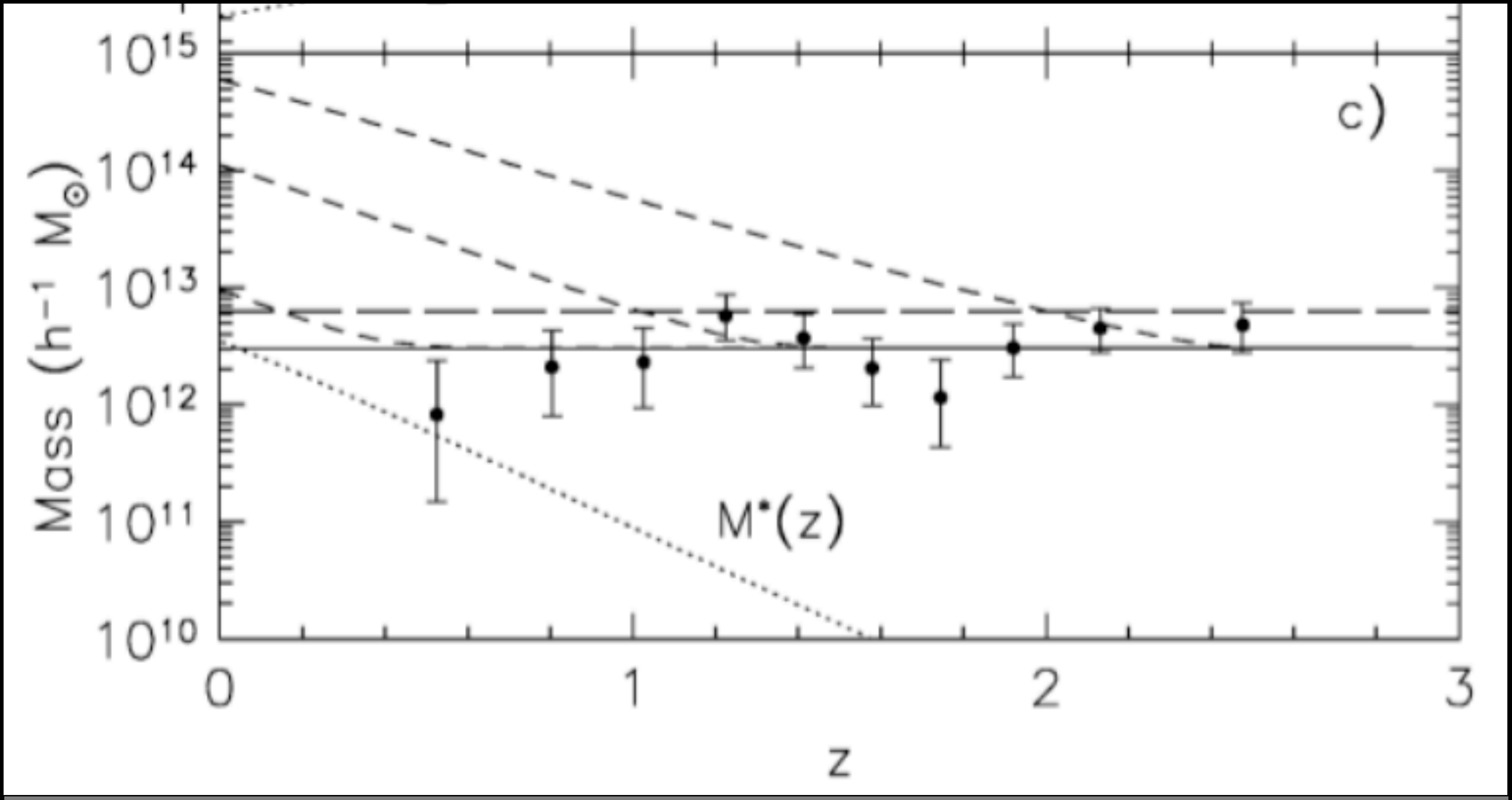

"exhausted" systems
maximal quenching
hot halo formation
log virial mass ($h^{-1}M_{\odot}$)
14
13
12
11
10
0
1
2
3
4
5
6
redshift

Galaxies



Behrozzi et al. 2012

Quasars



Croom et al. 2005

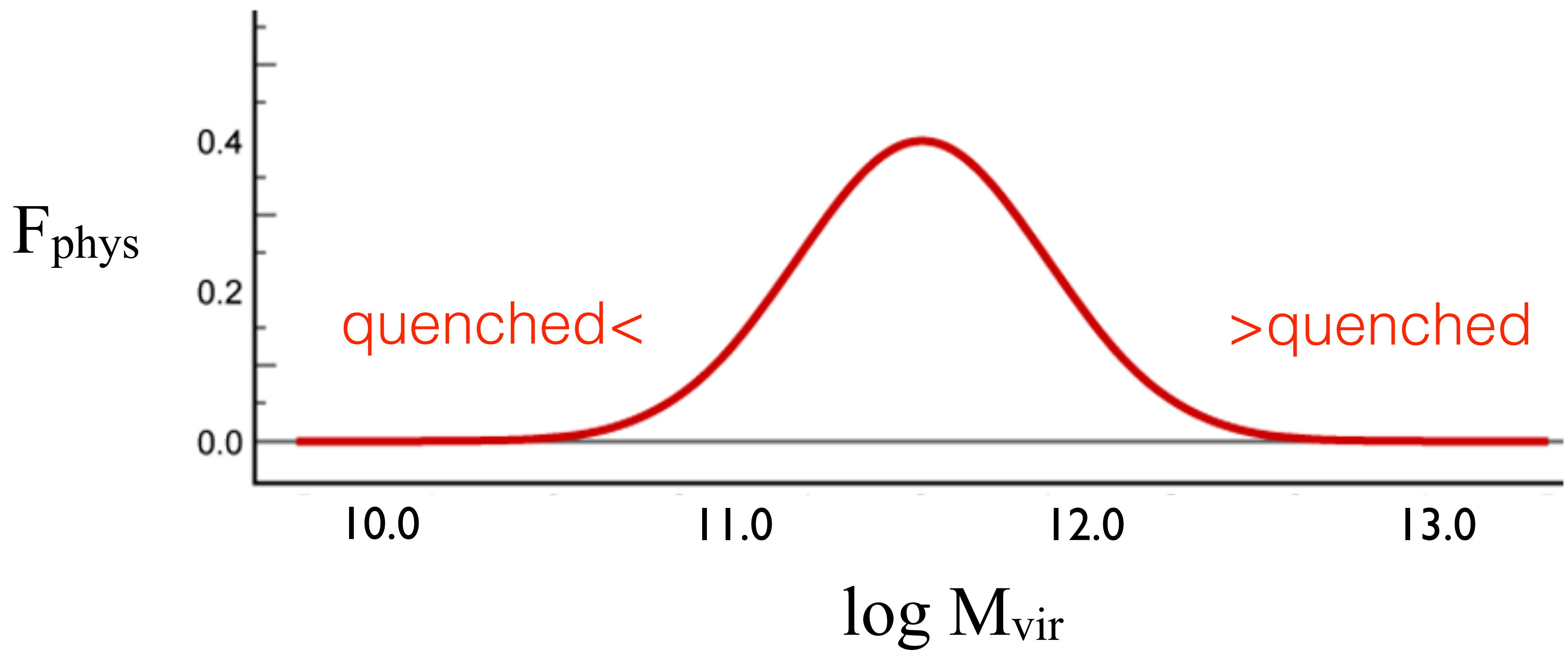
The simplest model of galaxy formation I: A formation history model of galaxy stellar mass growth

Simon J. Mutch[1,2*], Darren J. Croton[2] and Gregory B. Poole[1]
[1] *School of Physics, The University of Melbourne, Parkville, Victoria 3010, Australia*
[2] *Centre for Astrophysics & Supercomputing, Swinburne University of Technology, PO Box 218, Hawthorn, VIC 3122, Australia*

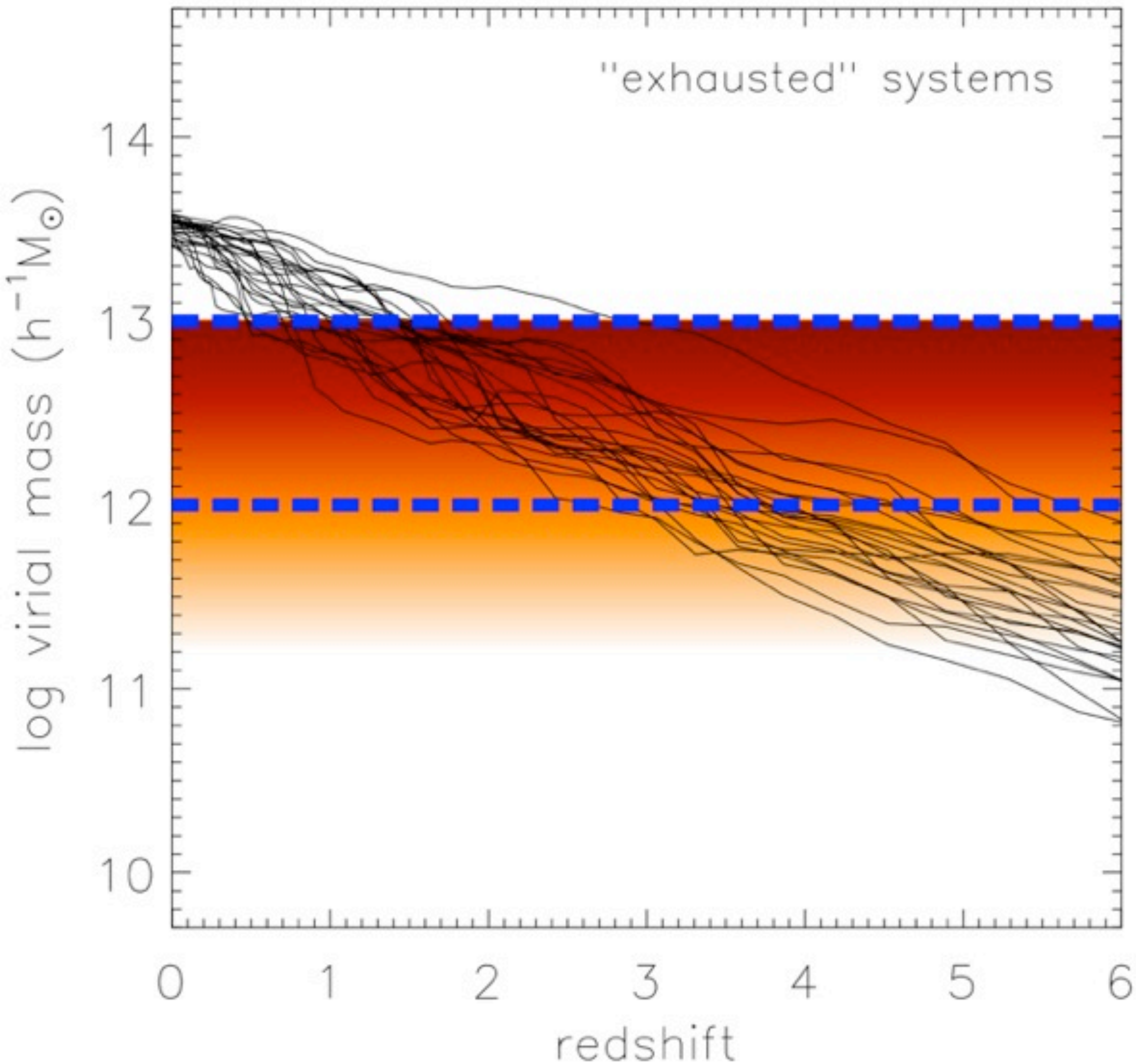
See also:
Peng et al. 2010 (Schechter function)
Driver et al. 2013 (morphology/SFR)

Mutch, Croton & Poole 2013

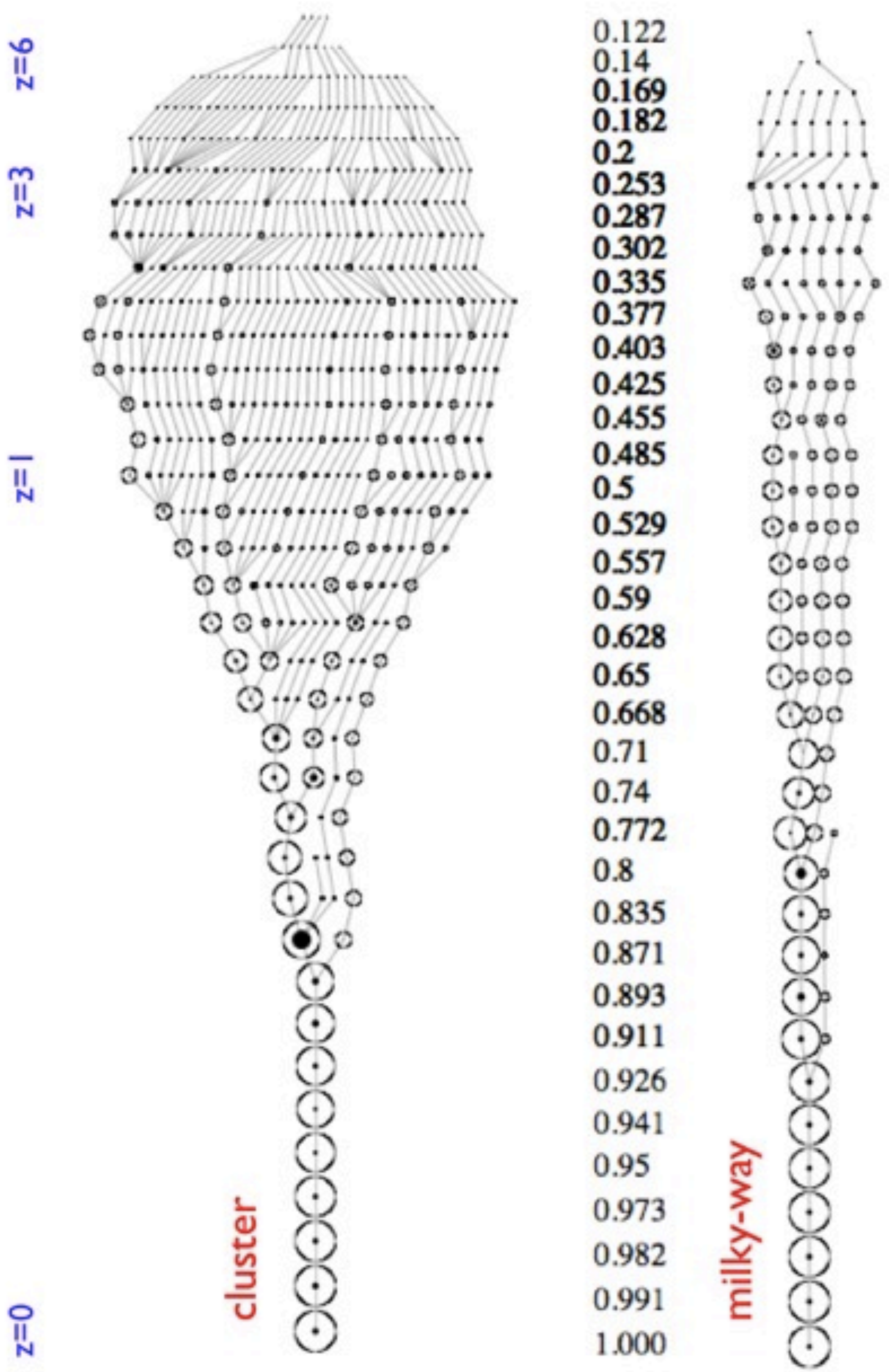
$$\dot{M}_* = f_\mathrm{b} \frac{dM_\mathrm{vir}}{dt} F_\mathrm{phys}$$



Mutch, Croton & Poole 2013

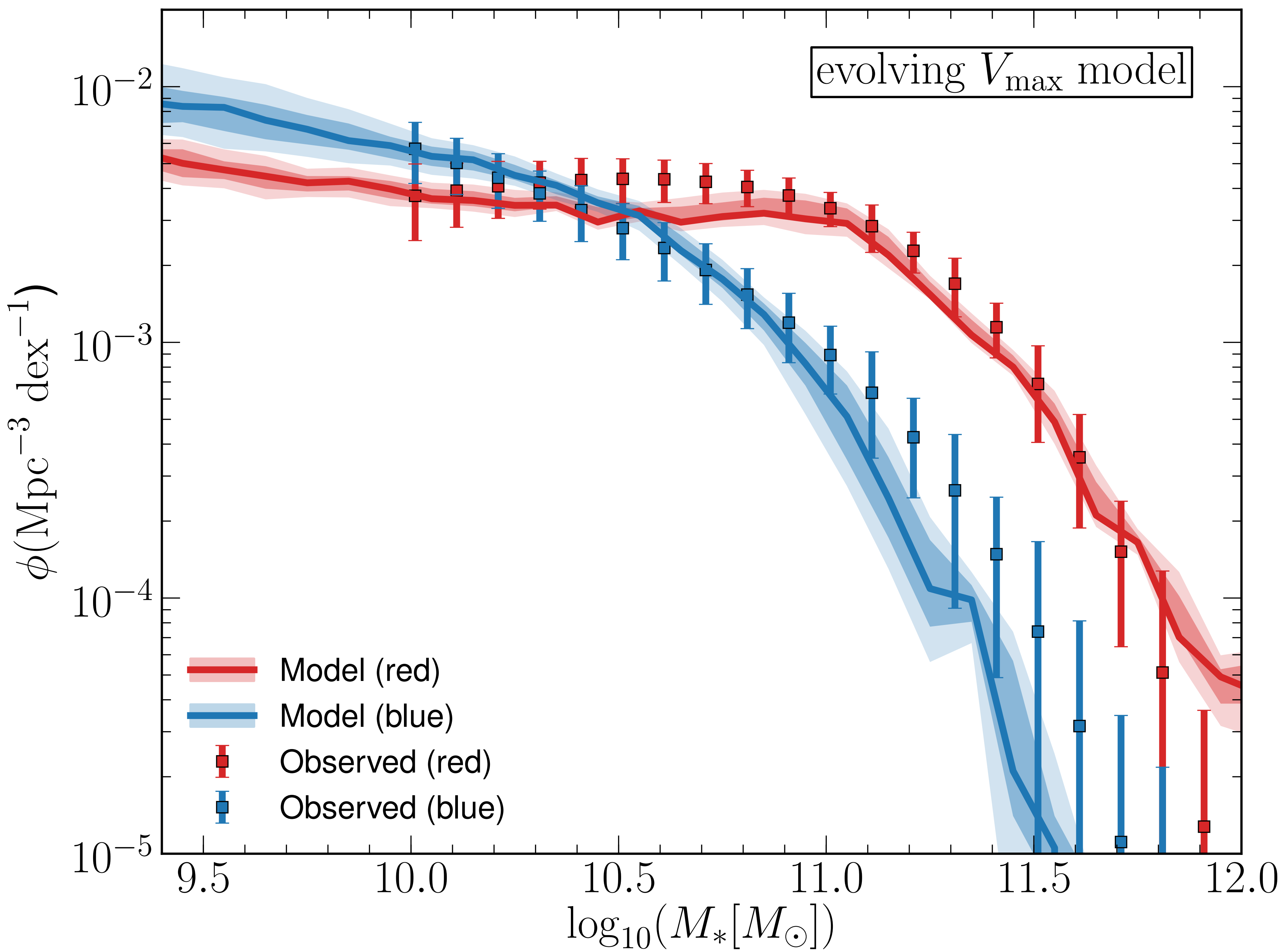


Numerical Simulation + Analytic Simulation

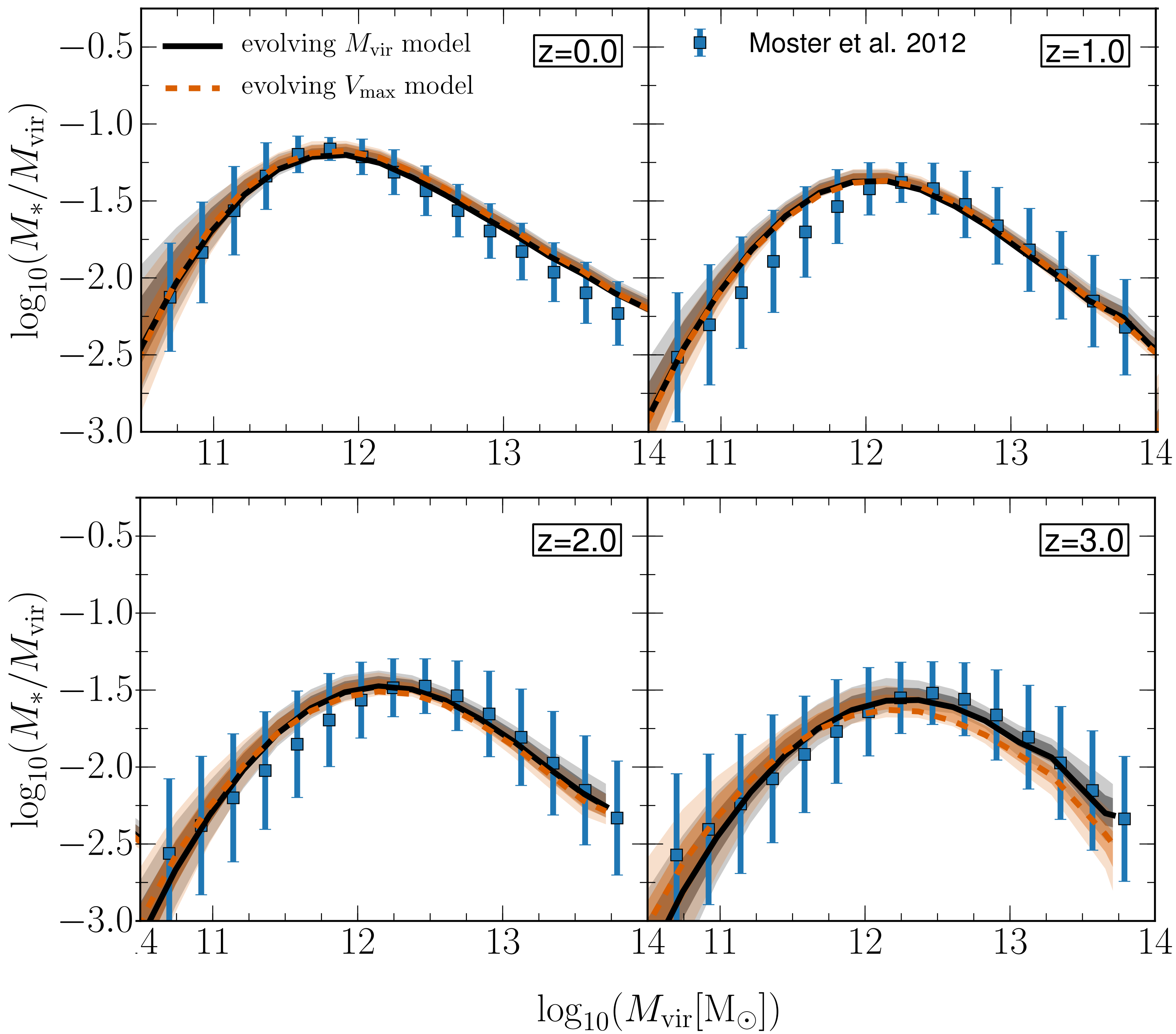


$$\dot{M}_* = f_\mathrm{b} \frac{dM_\mathrm{vir}}{dt} F_\mathrm{phys}$$

Mutch, Croton & Poole 2013



Mutch, Croton & Poole 2013



Mutch, Croton & Poole 2013

$$\dot{M}_* = f_\mathrm{b} \frac{dM_\mathrm{vir}}{dt} F_\mathrm{phys}$$

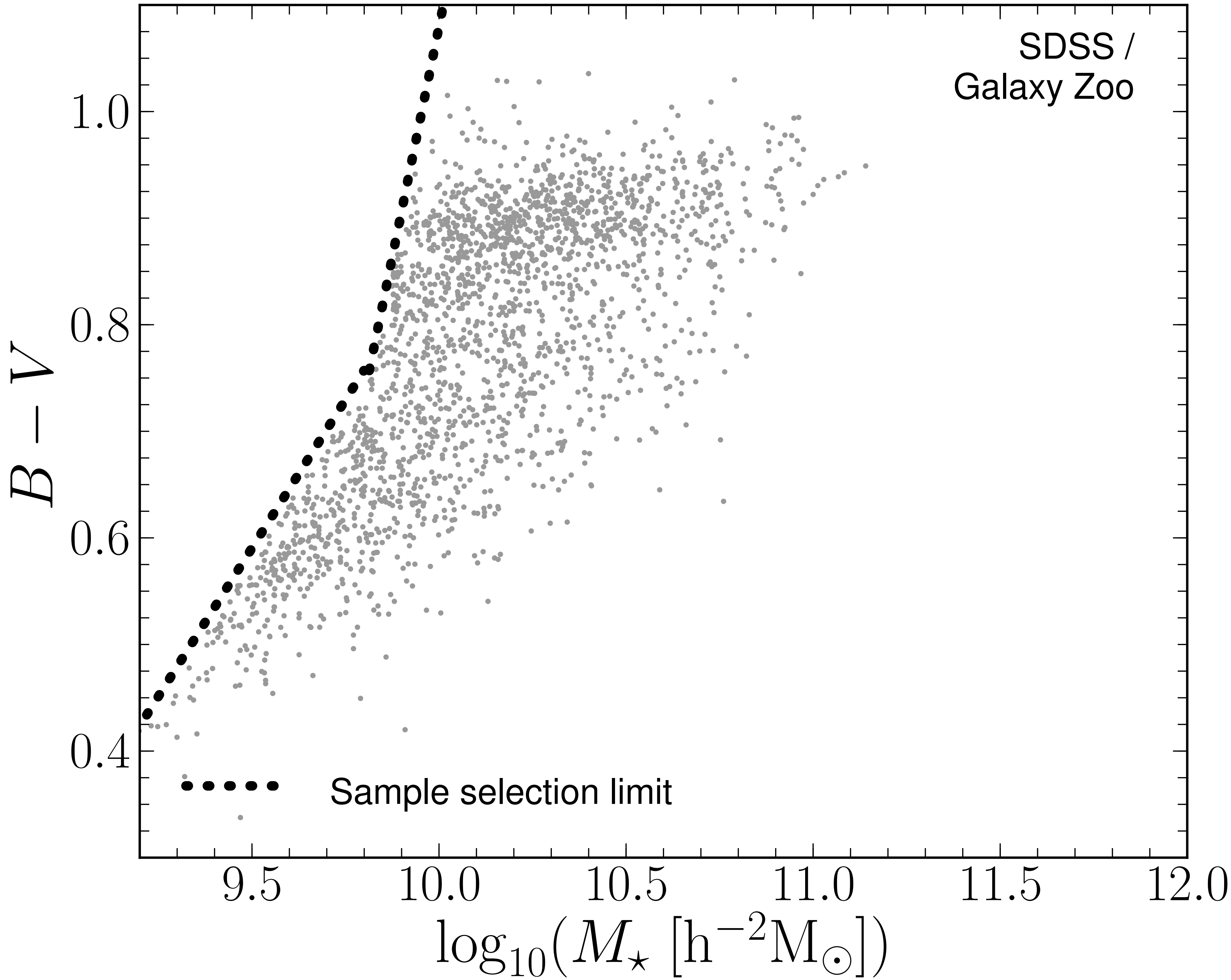
1. Can be applied to any simulation
2. Physics function can be arbitrarily complex
3. Statistically constrained
4. Full formation histories

the mid-life crisis of the Milky Way?

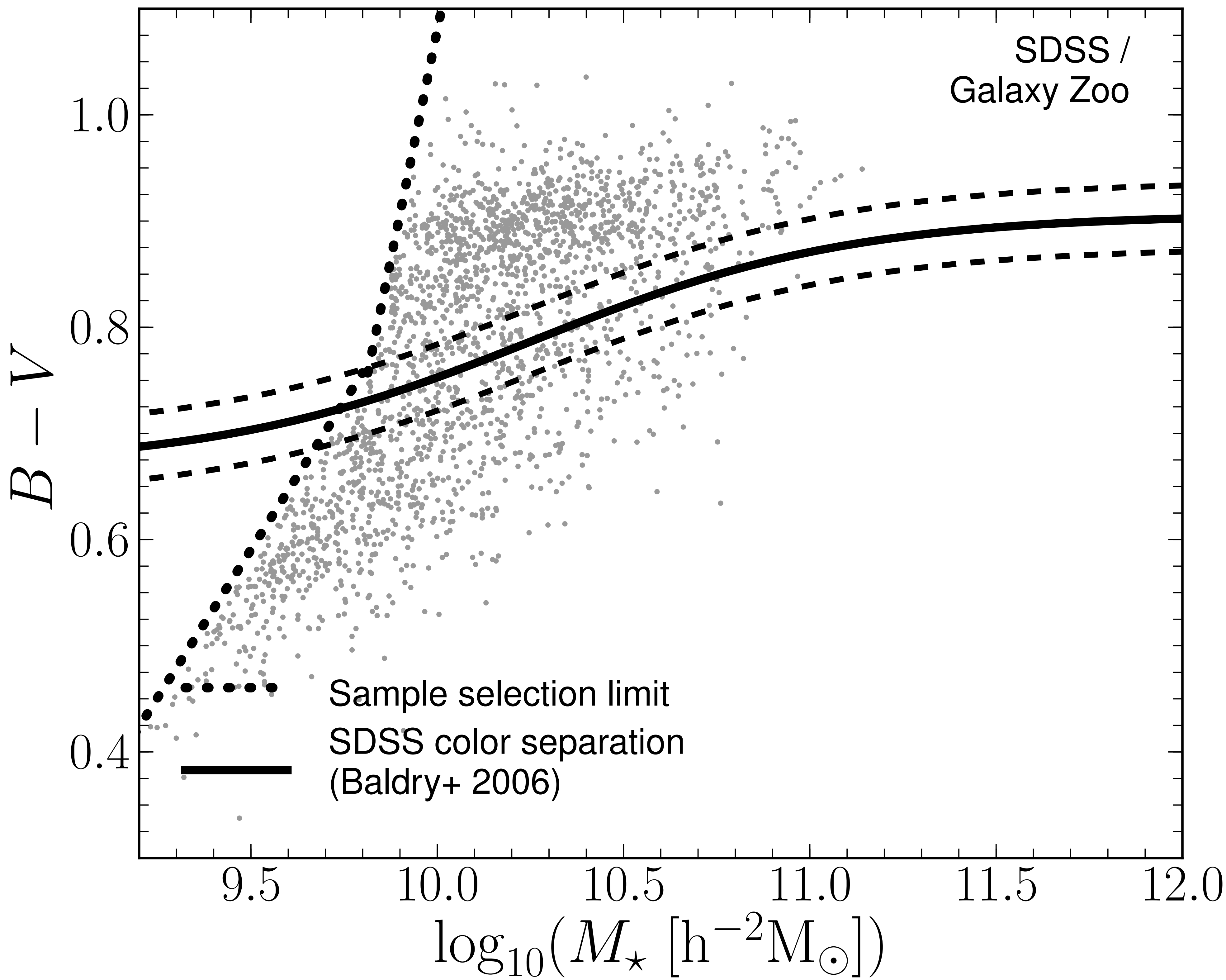
QUESTION: Where does the Milky Way and M31 lie in the traditional colour-magnitude diagram?

QUESTION: How would we intrepret the MW if we were an alien race and included it in one of our galaxy surveys?

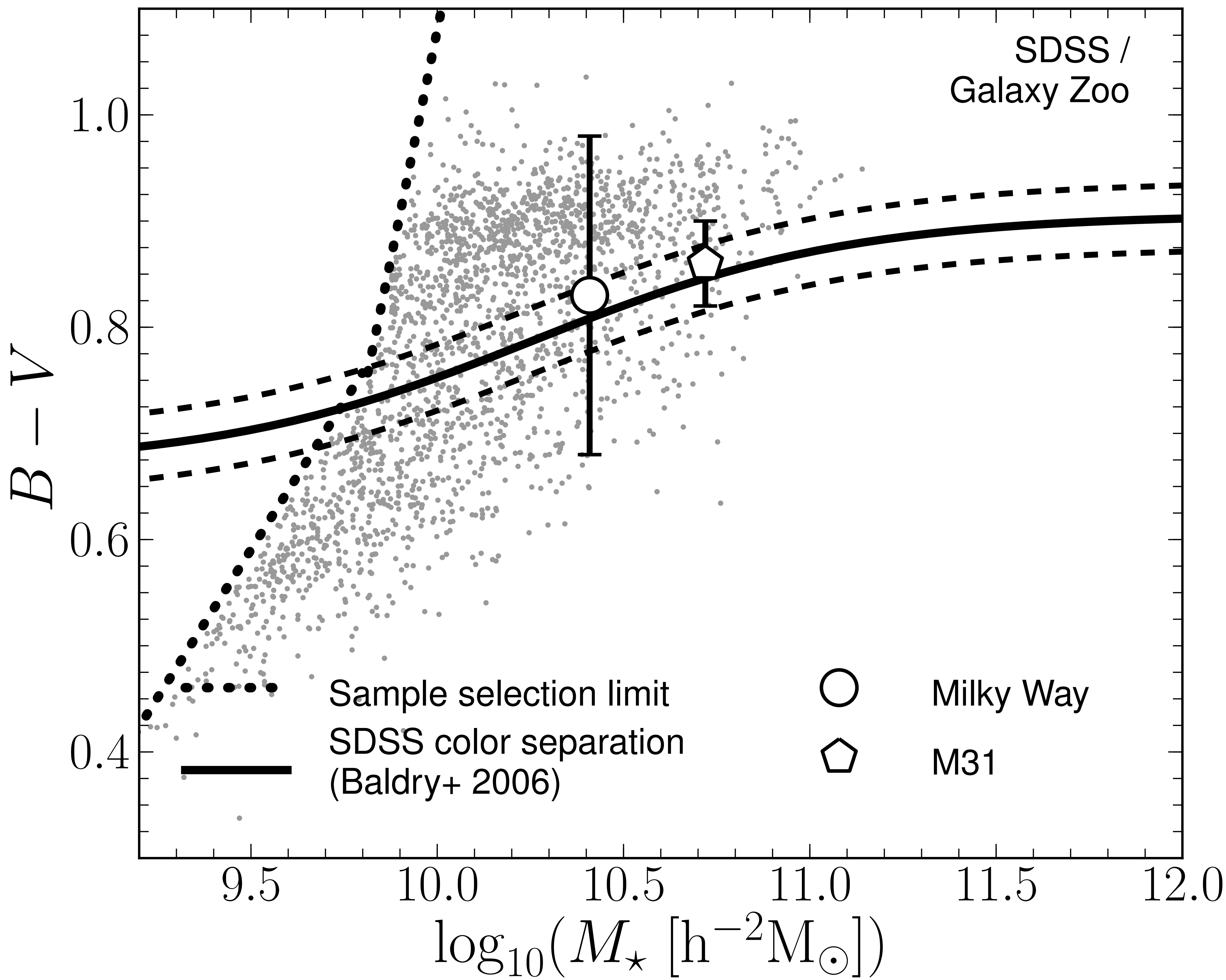
Mutch, Croton & Poole 2013



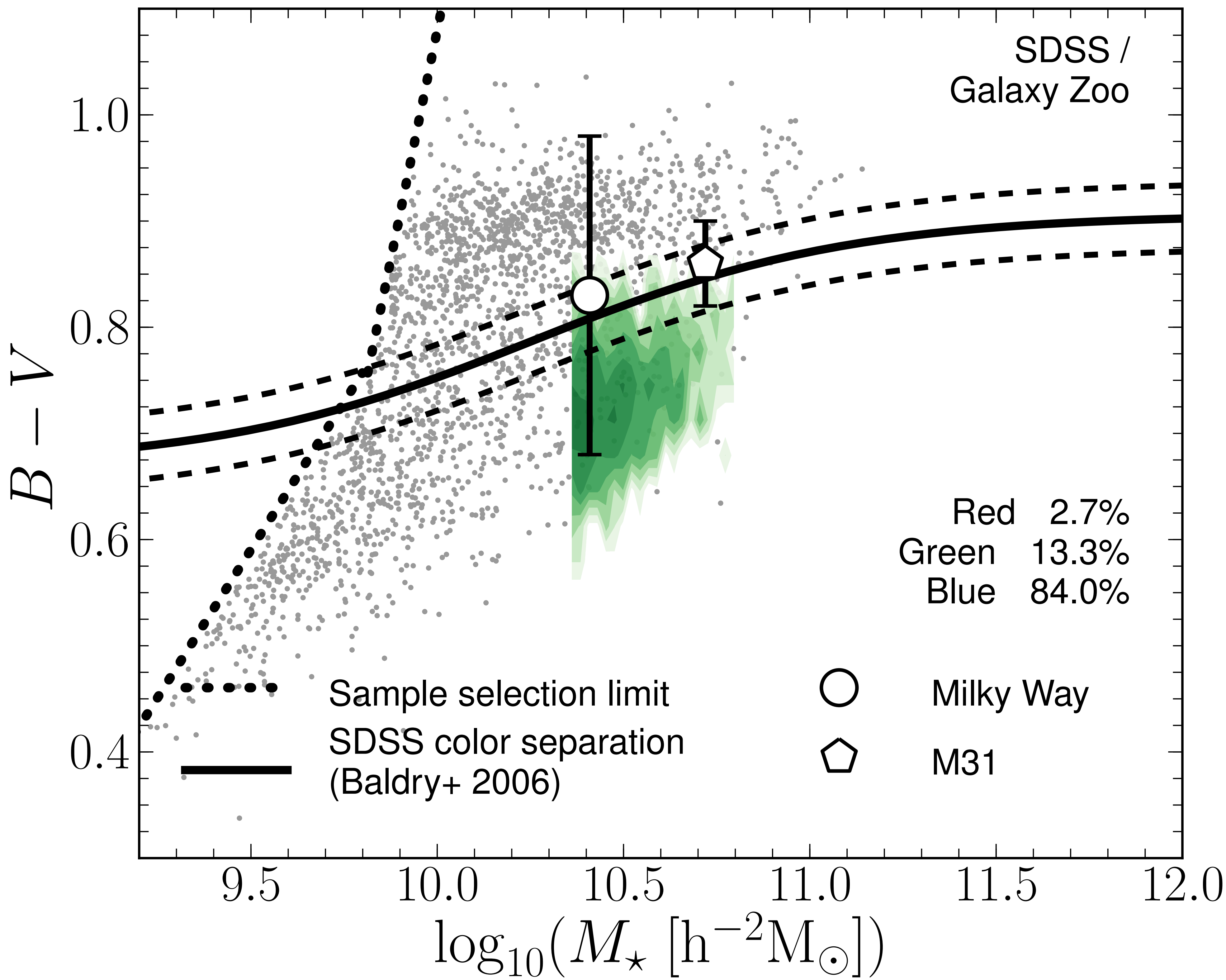
Mutch, Croton & Poole 2013



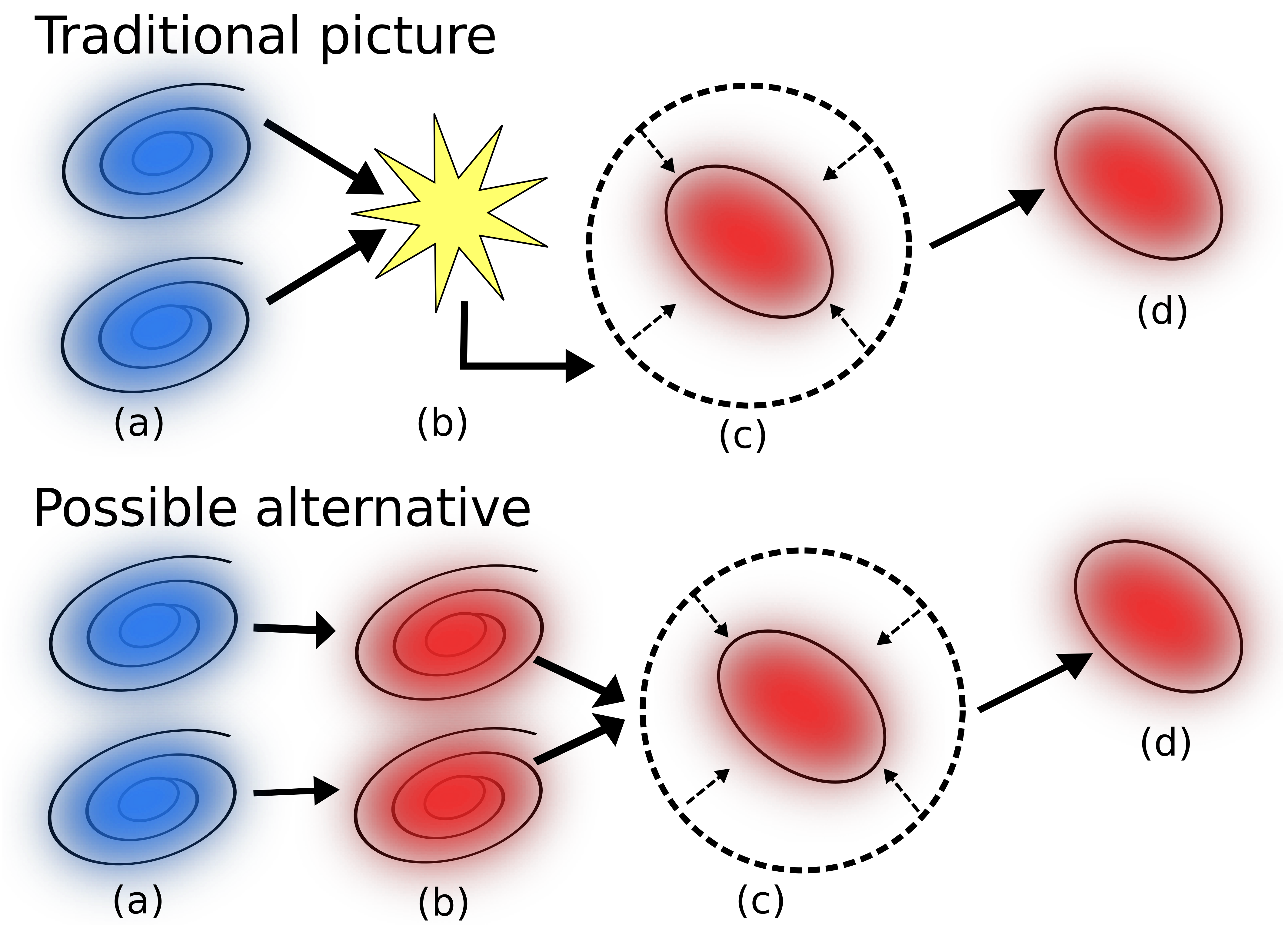
Mutch, Croton & Poole 2013



Mutch, Croton & Poole 2013



Mutch, Croton & Poole 2013



...and finally

https://www.nectar.org.au/all-sky-virtual-observatory

nectar

connecting • sharing • collaborating

home programs RFP news researchers documents about NeCTAR

The All Sky Virtual Observatory

Search

What is the All-Sky Virtual Observatory

New telescopes and facilities coming online in the next three to five years will produce data in volumes never previously experienced in Australian astronomy. To gain maximum scientific benefit from this data flood, the federation of datasets from all types of astronomical facilities in Australia will be needed. This will involve creating the hardware, tools and services to bring together data from radio telescopes, optical telescopes and supercomputers, covering all parts of the southern sky, under a Virtual Observatory.

After extensive consultation with the entire astronomy community, two Australian astronomical facilities were chosen to form the first pillar of the All-Sky Virtual Observatory:

The primary observational dataset will come from the SkyMapper facility, an optical telescope located at Siding Spring Observatory, NSW, built by the Australian National University. SkyMapper is producing the most detailed and sensitive digitized map of the southern sky at optical wavelengths. This nationally significant dataset will be a fundamental reference for astronomers in Australia, and internationally, for many decades.

The Theoretical Astrophysical Observatory (TAO), being developed at Swinburne University of Technology, will house the growing ensemble of Australian theory data sets and galaxy formation models, with value-add tools that will allow astronomers to observe each virtual universe as if it was real. This will be achieved by mapping the simulated data onto an observer's viewpoint and the application of custom telescope simulators, beginning with SkyMapper. TAO provides a direct and vital link between the theoretical and observational aspects of data collection and analysis.

Who is Astronomy Australia?

Astronomy Australia Ltd (AAL) is a not-for-profit company whose members are all the Australian universities and research organisations with a significant astronomical research capability.

Our vision is that astronomers in Australia will have access to the best astronomical research infrastructure. AAL will achieve its

VLs in project negotiation

The All Sky Virtual Observatory

Climate and Weather Science Laboratory

Humanities Networked Infrastructure (HuNI) unlocking and uniting Australia's cultural data

The Genomics Virtual Laboratory

The Characterisation Virtual Laboratory: research environments for exploring inner space

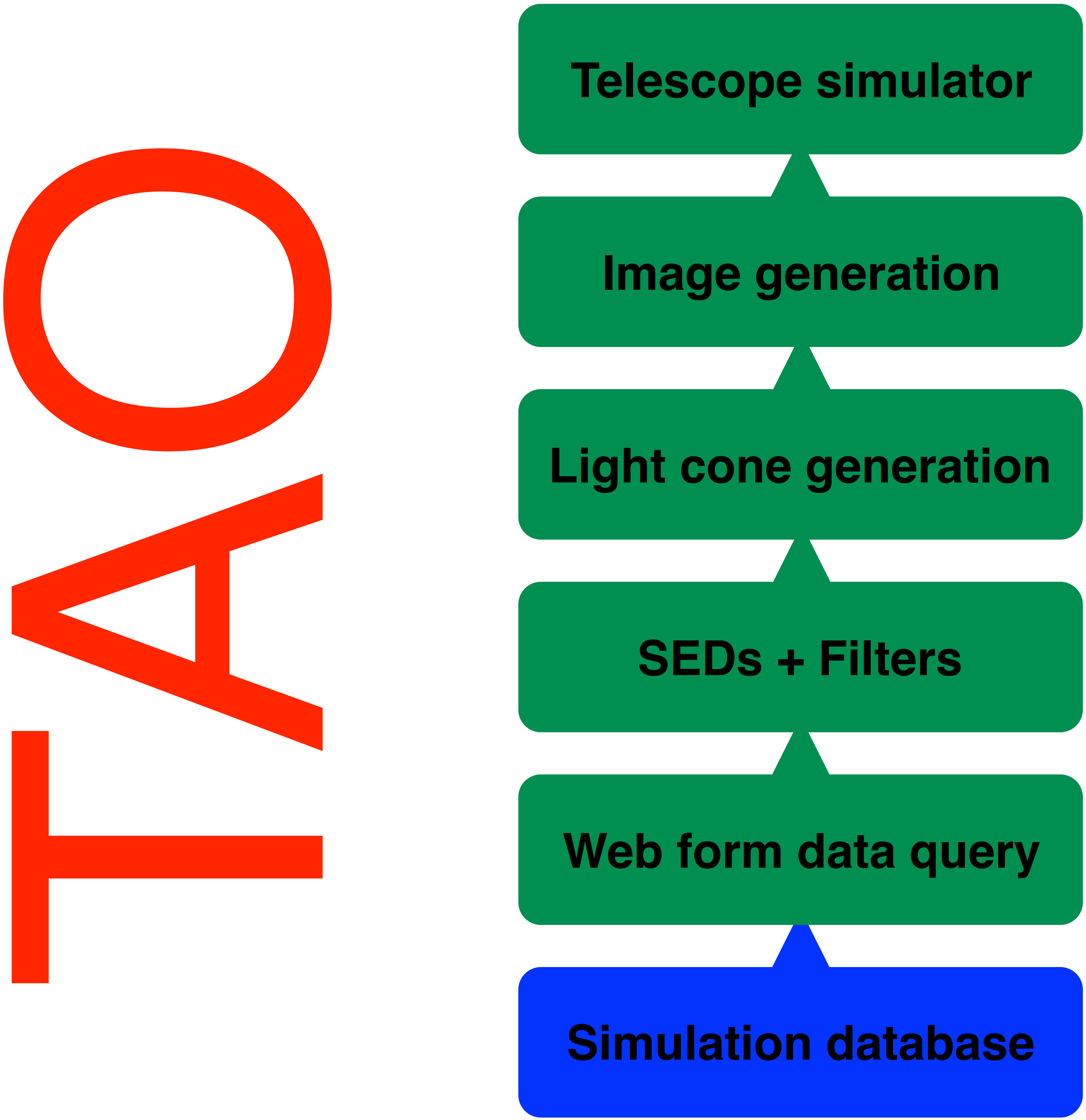
Early Activities

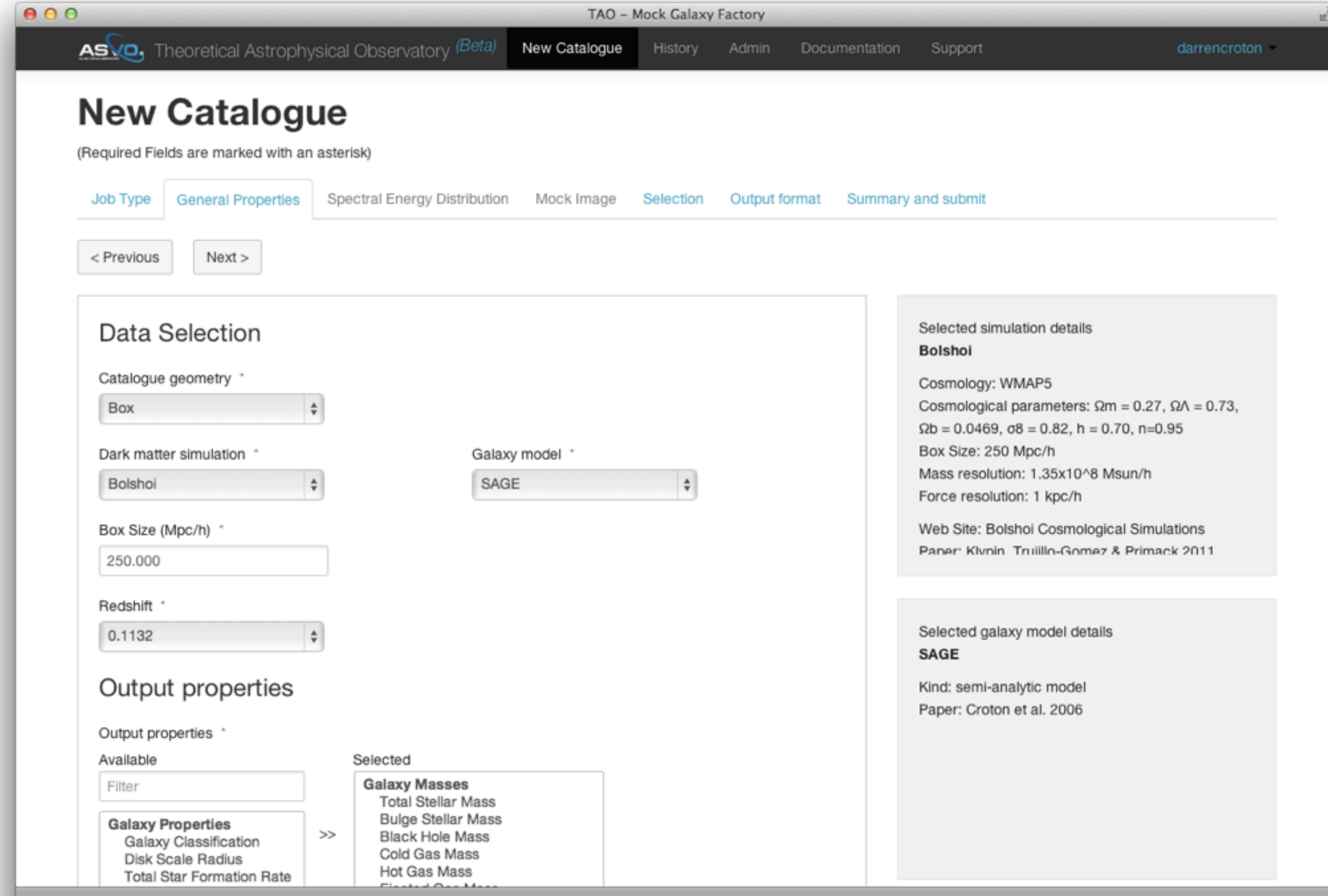
CSIRO - Virtual Geophysics Laboratory

University of Queensland - Virtual Genomics Laboratory

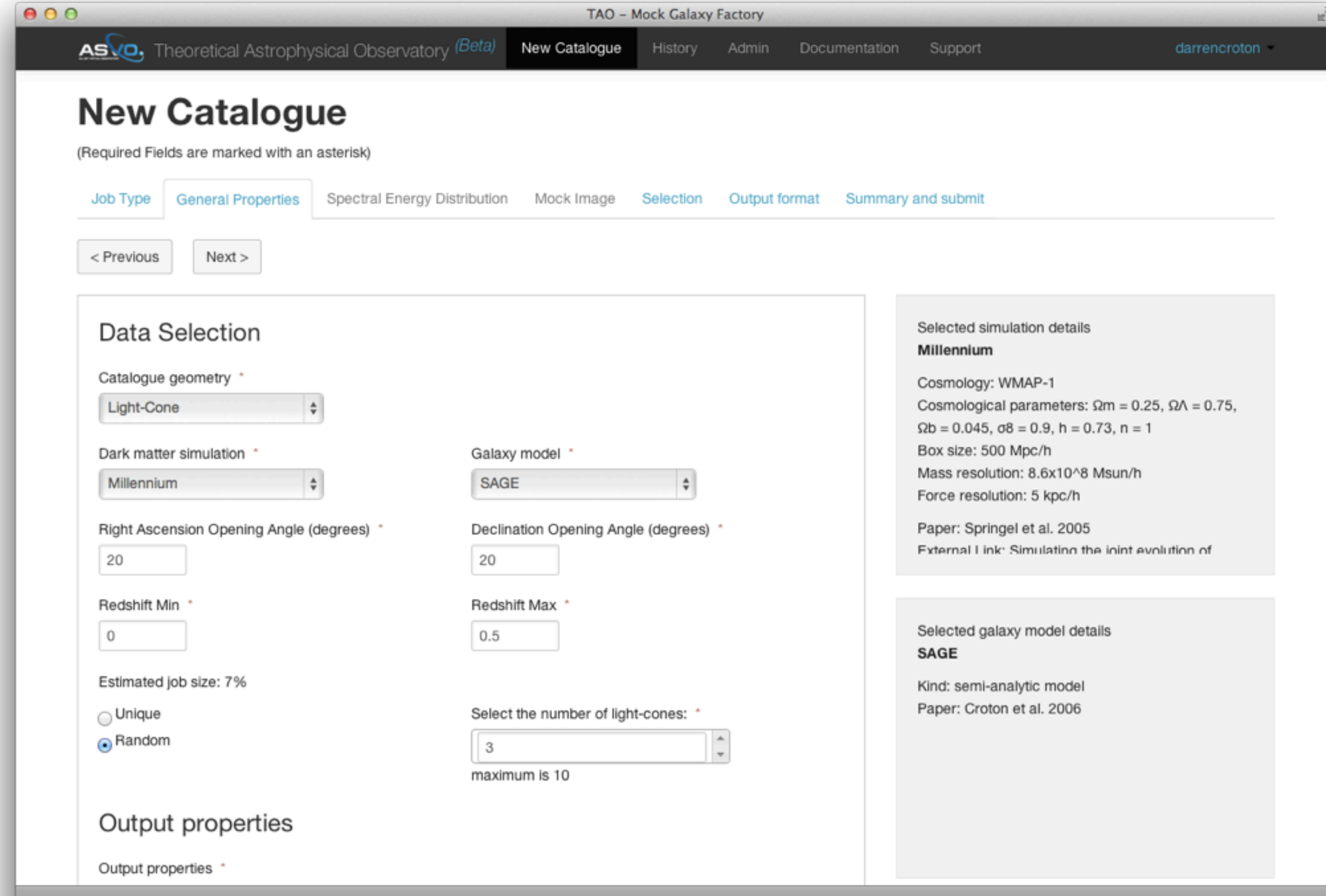
University of Tasmania - Marine Virtual Laboratory

Latest News ...


TAO
Telescope simulator
Image generation
Light cone generation
SEDs + Filters
Web form data query
Simulation database



https://tao.asvo.org.au/tao/



https://tao.asvo.org.au/tao/

The Future

1. Toy AGN heating models work, but how can we know the actual quenching mechanism(s)?

2. Quenching shapes morphology.

3. How simple is too simple when it comes to modelling galaxies?

4. Is the MW a green valley galaxy? What does this mean?