

PART II:

The Universe in the Cloud

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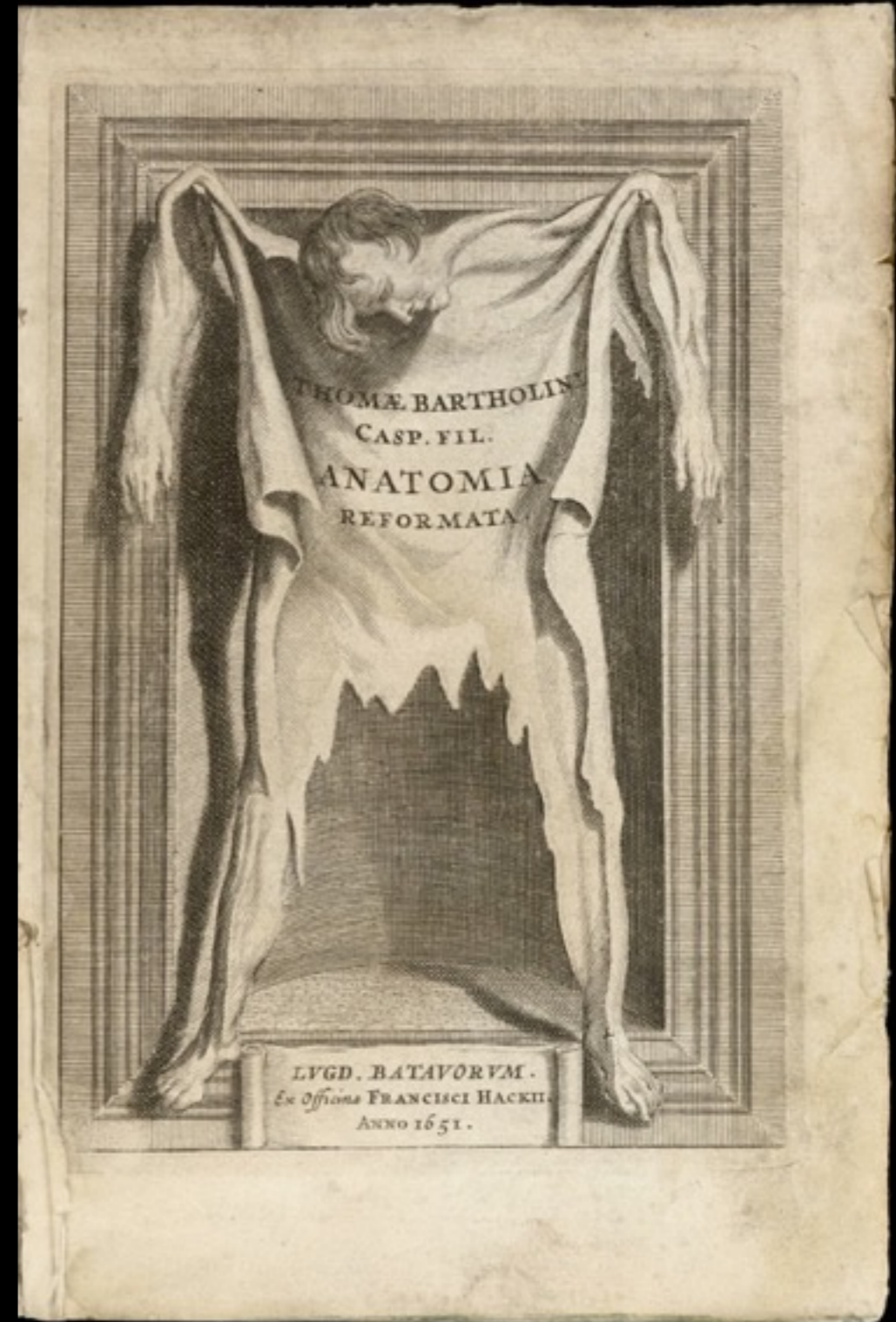
dcroton@astro.swin.edu.au



Let's recap...



The skeleton

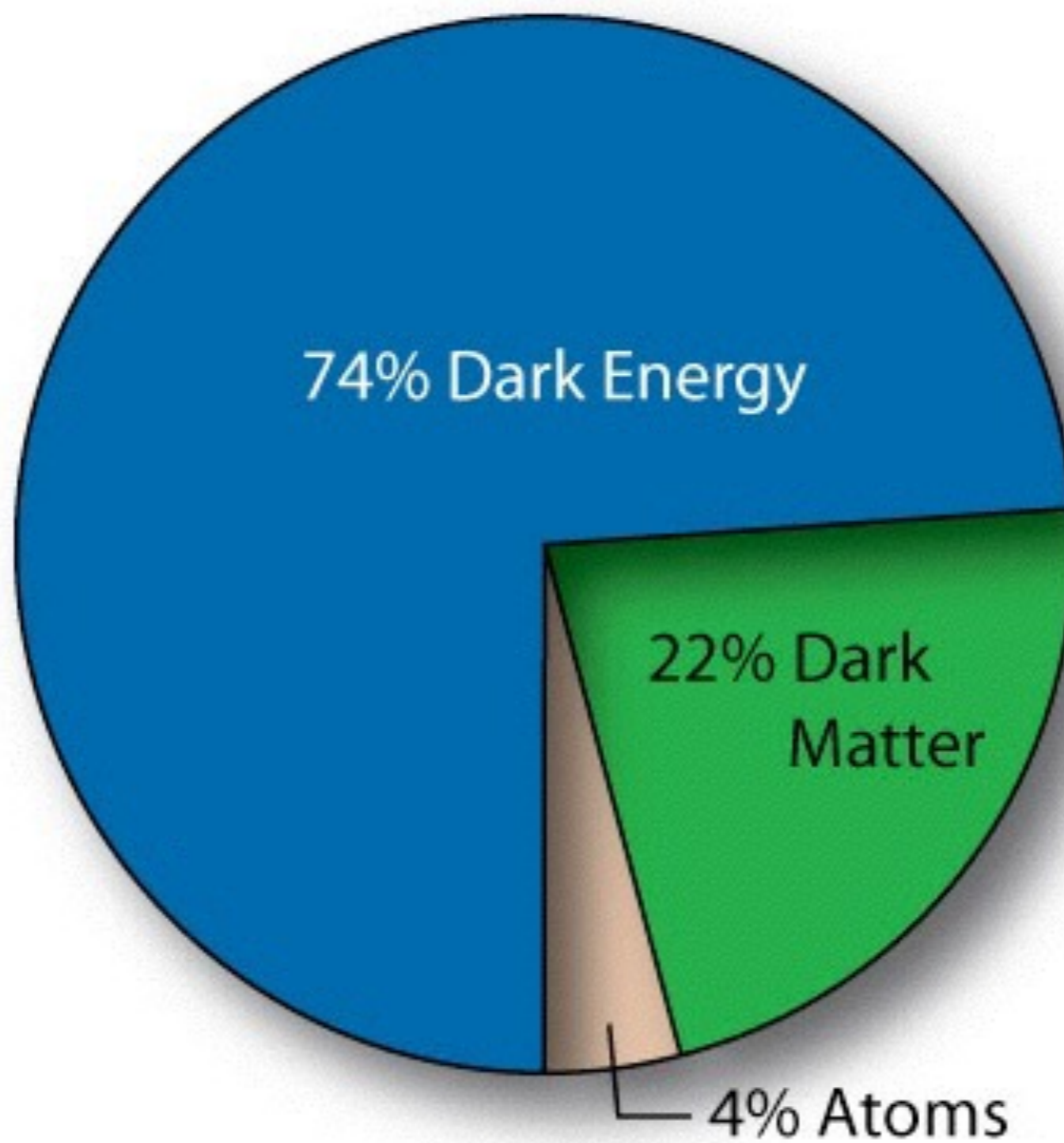


The flesh



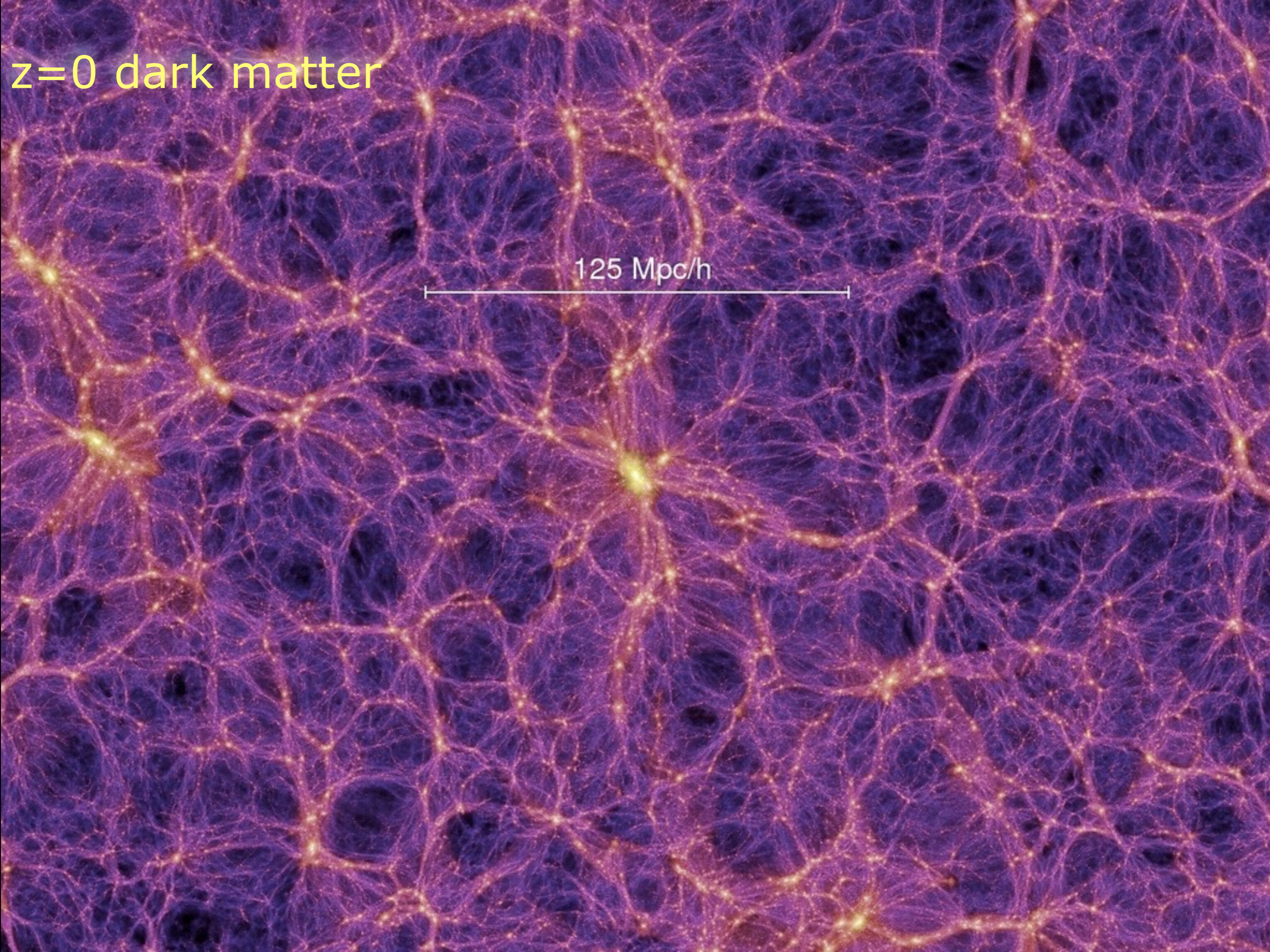


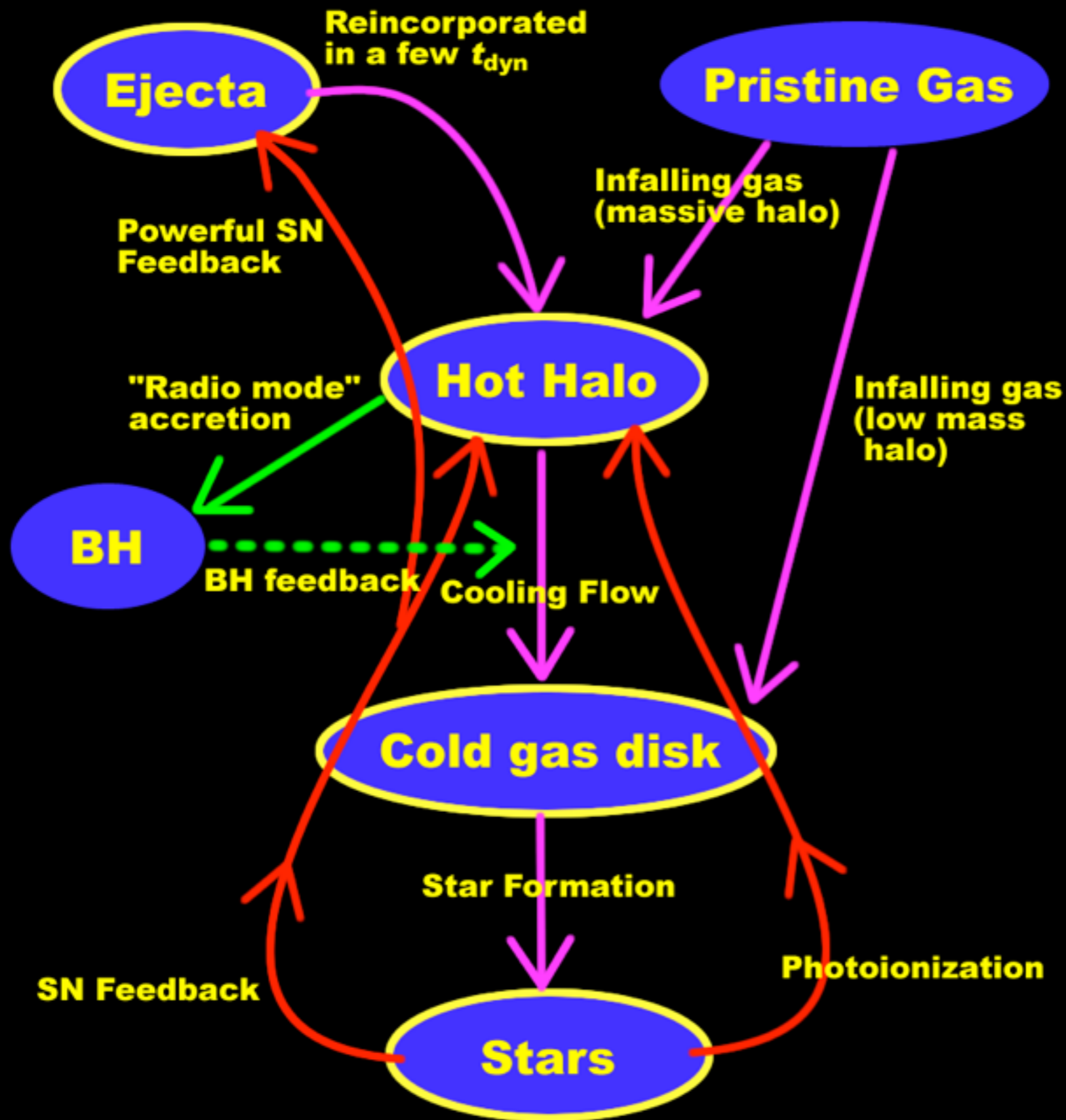
Gordon



$z=0$ dark matter

125 Mpc/h





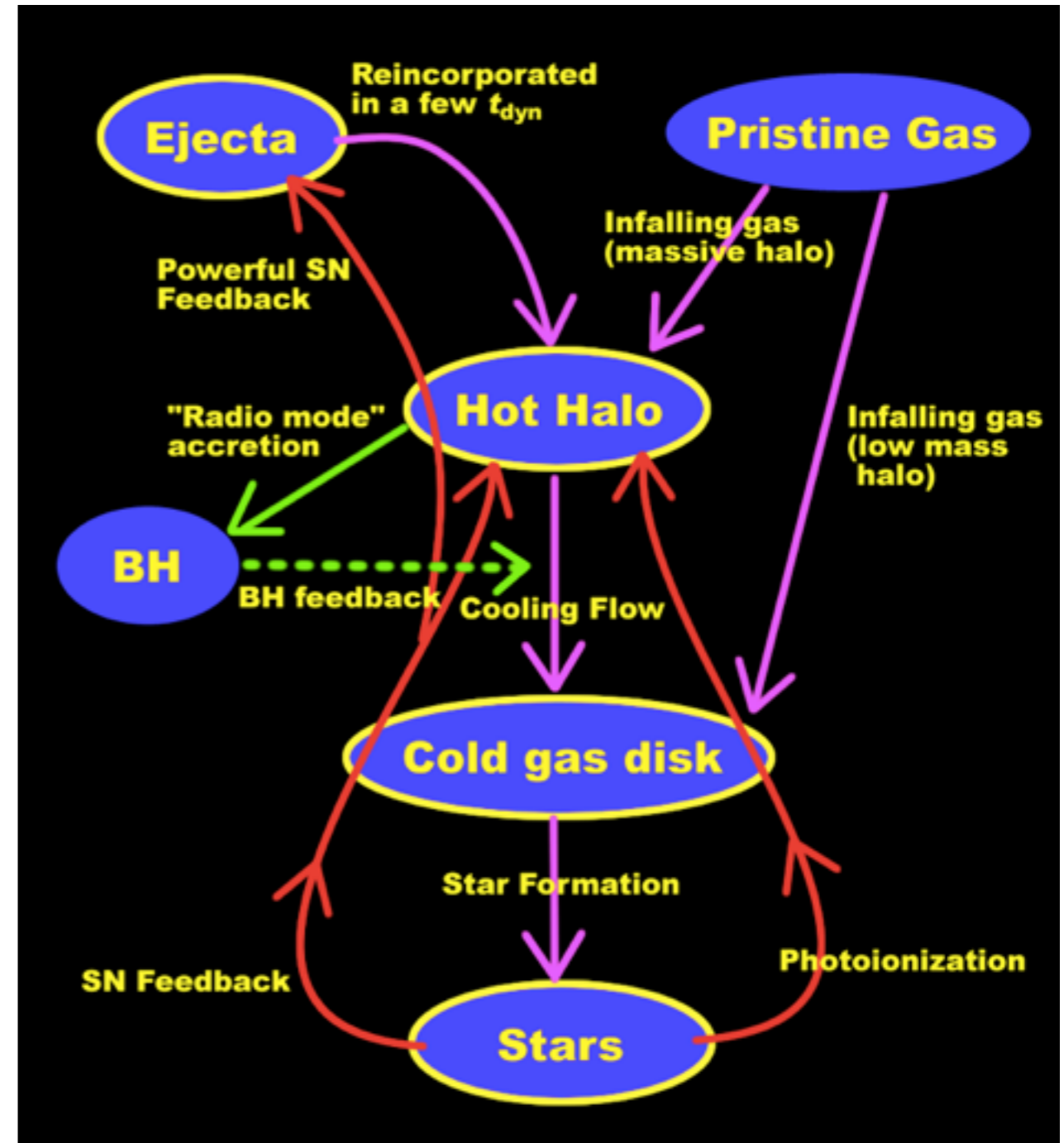
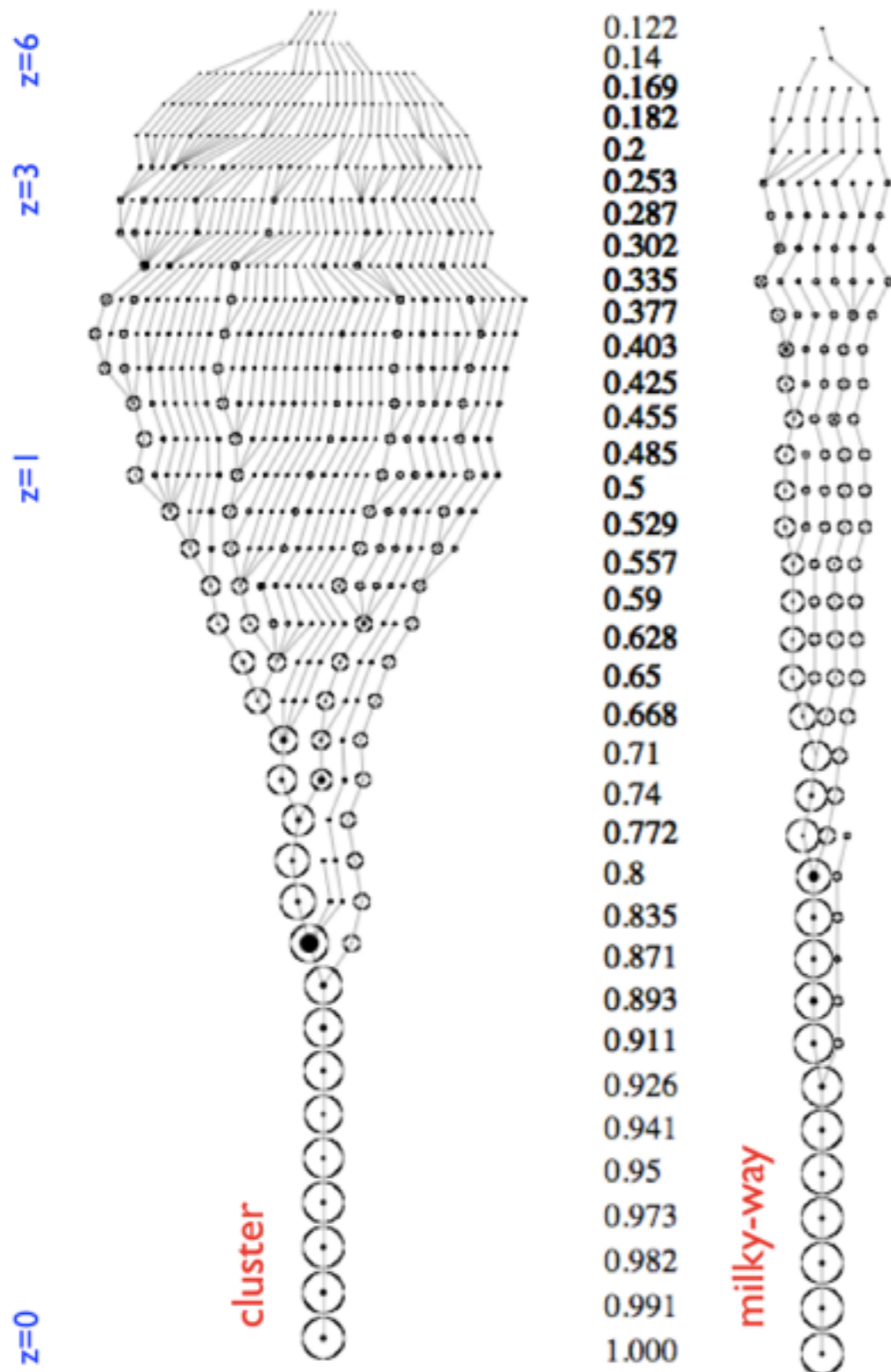
- ▶ Schmidt law star formation
- ▶ SFR dependent SN winds
- ▶ satellite gas stripping
- ▶ morphological transformation
- ▶ assembly through mergers
- ▶ starbursts through mergers
- ▶ Magorrian relation BH growth
- ▶ jet & bubble AGN feedback

Remember:

Numerical Simulation

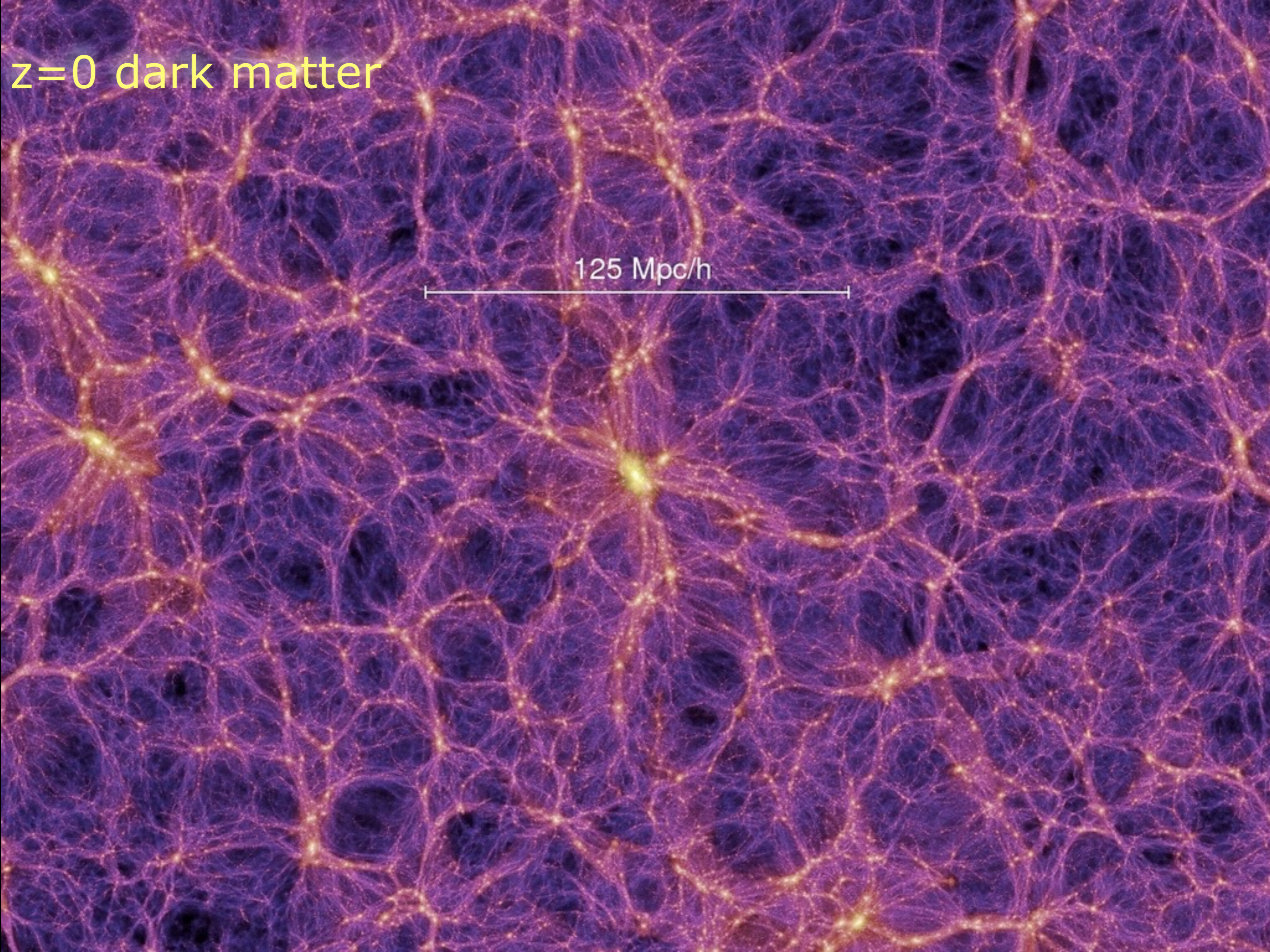
+

Analytic Simulation

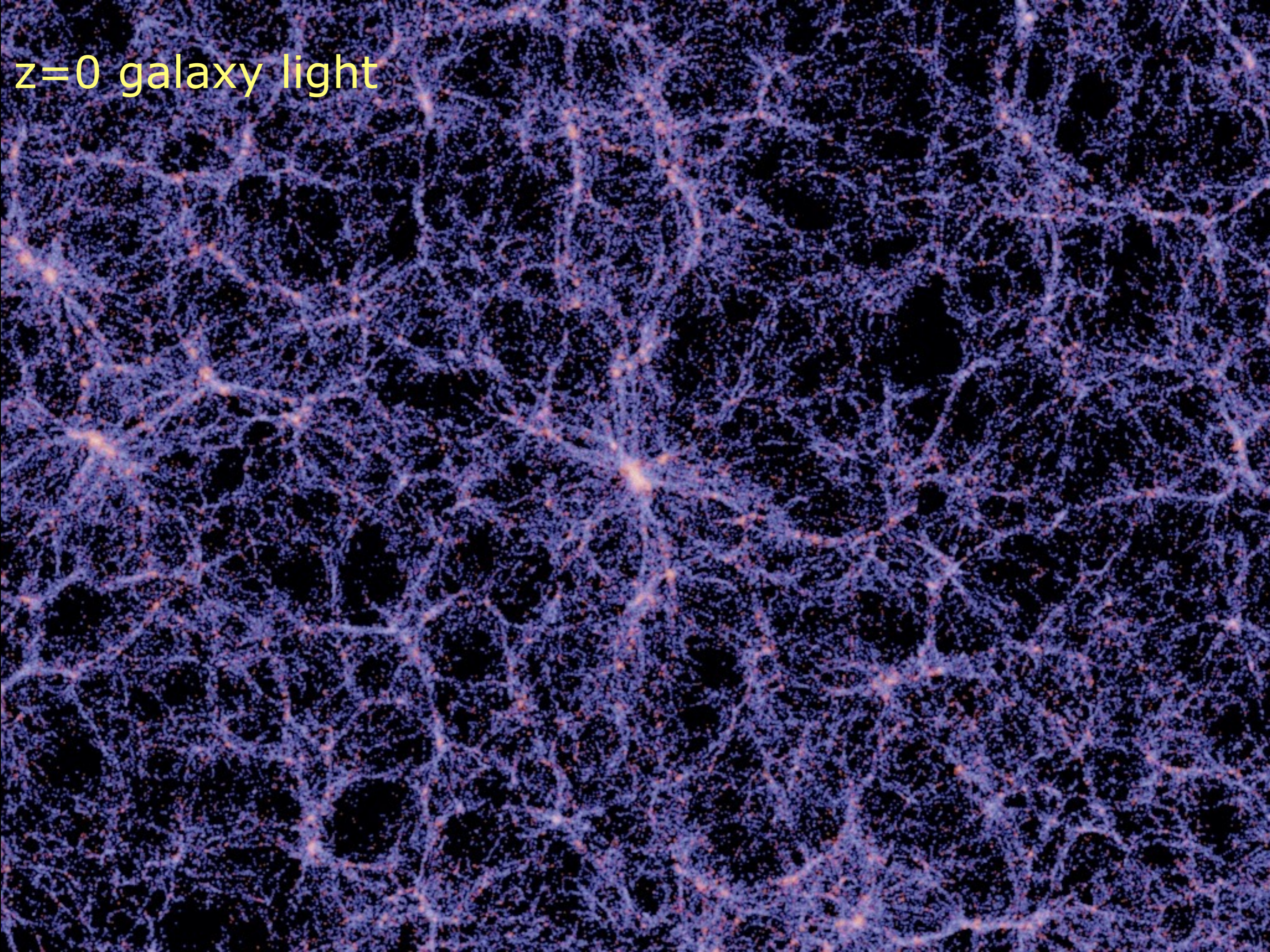


$z=0$ dark matter

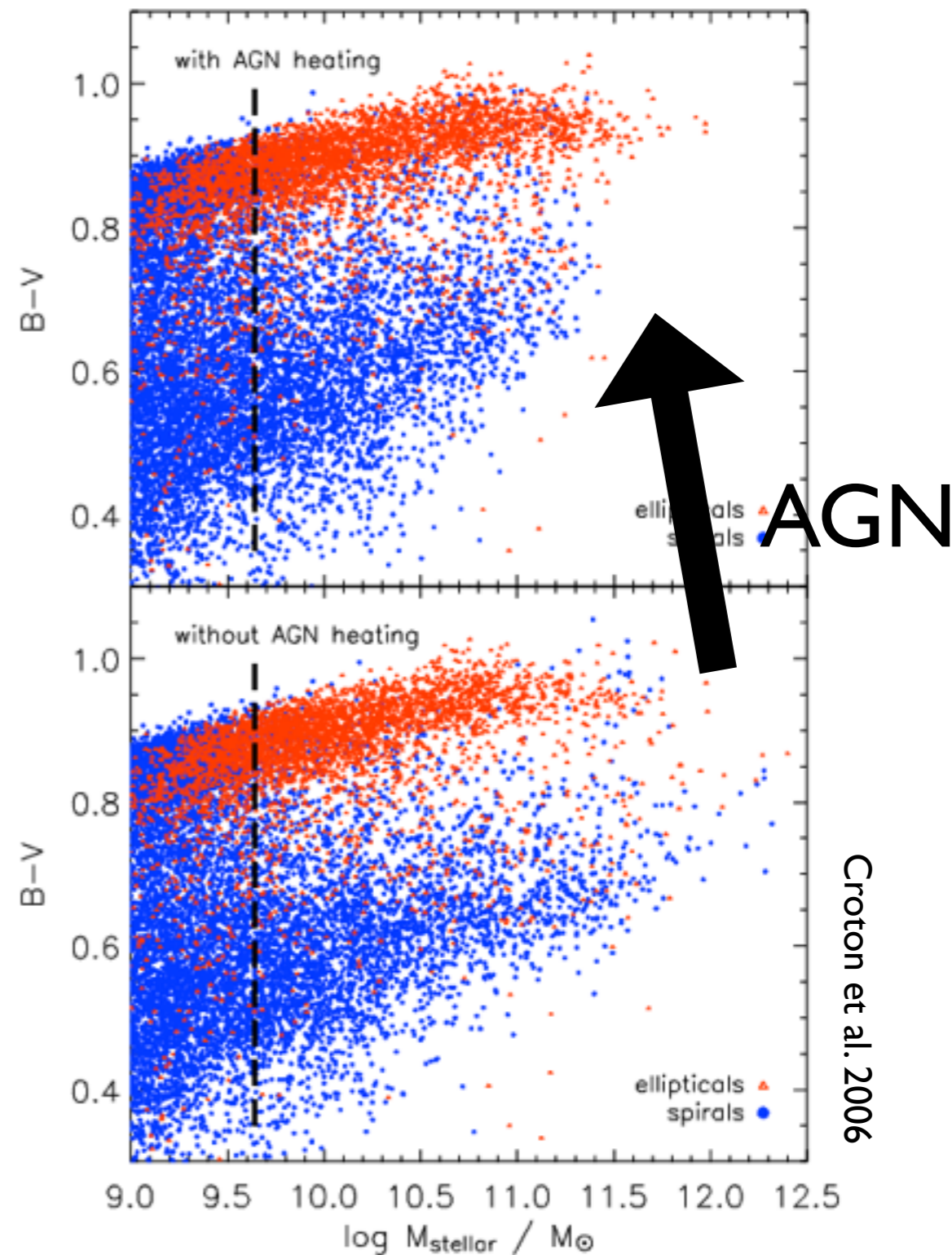
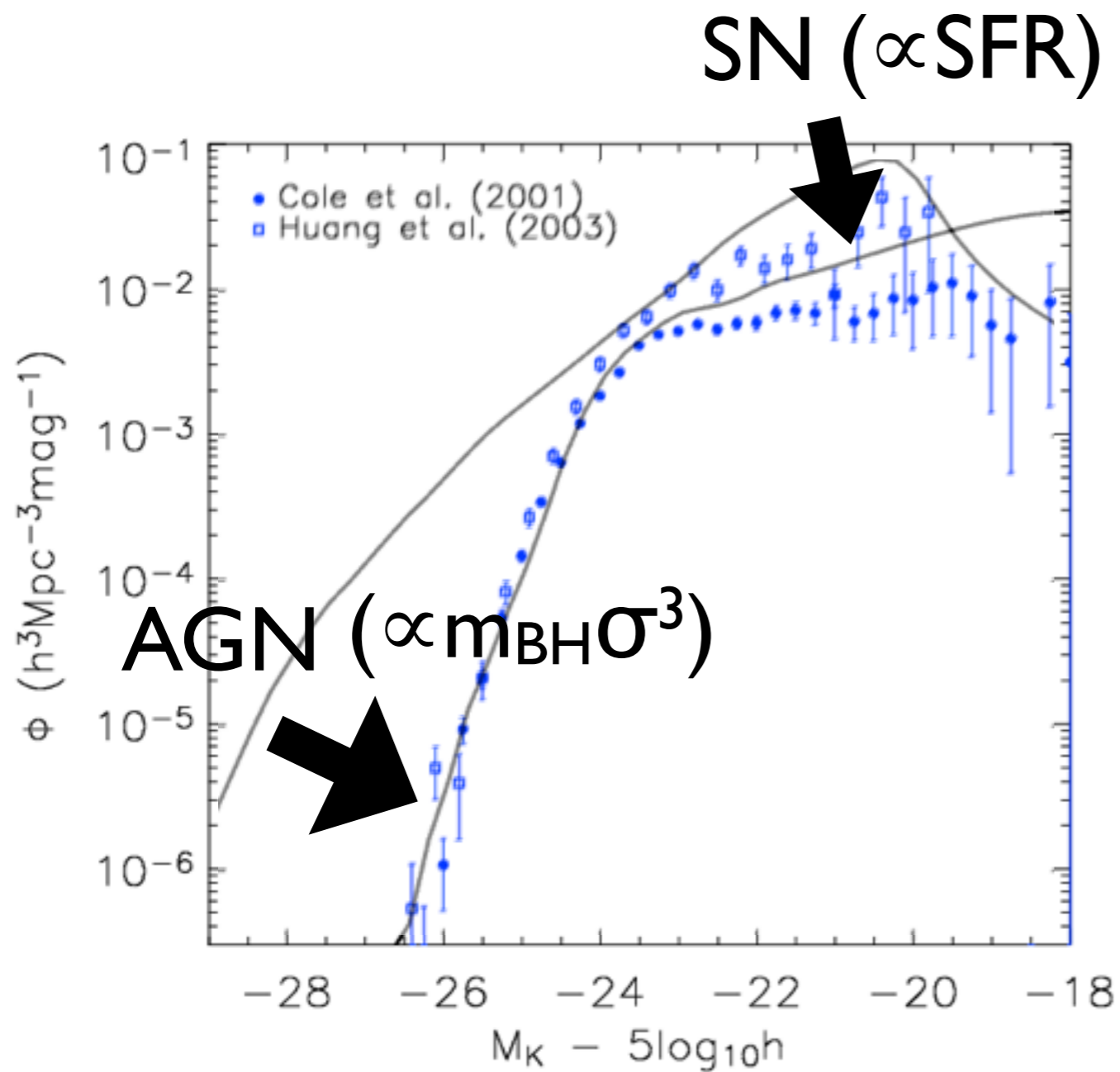
125 Mpc/h

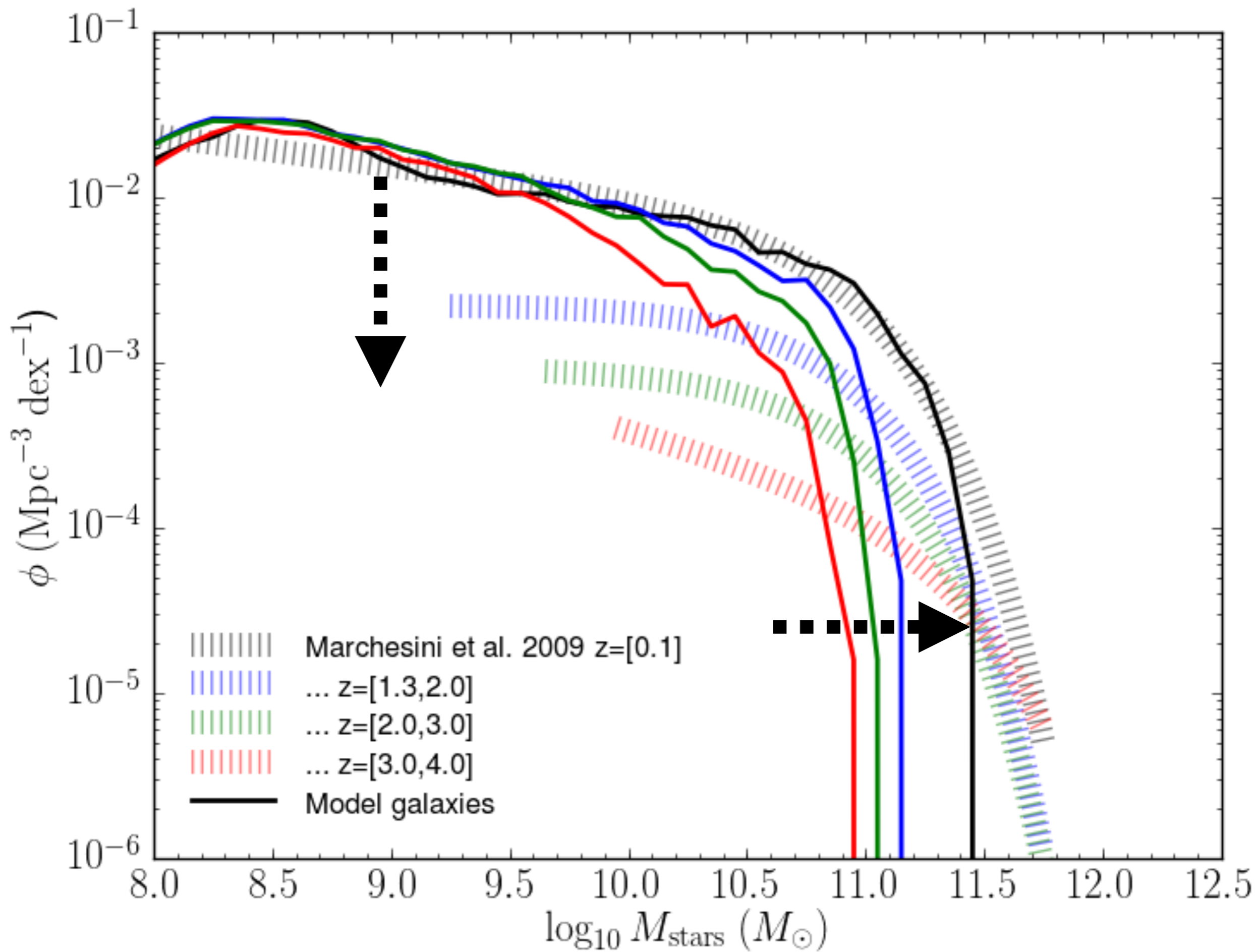


$z=0$ galaxy light



Physical consequences





\$300 $z=1$
\$500 $z=2$
\$1000 $z=3$



Understanding the limitations
of the models

Semi-analytics (mostly) assume:

- ▶ the cosmology is correct
- ▶ local correlations extend to higher redshift
- ▶ the baryon fraction is universal
- ▶ halo properties determine galaxy properties
- ▶ ...

Semi-analytics are at the mercy of:

- ▶ the IMF
- ▶ stellar population models
- ▶ the quality of constraining observations
- ▶ the quality of the underlying simulation
- ▶ ...

The exact values of the
parameter choices are (mostly)
meaningless

Our model is only as good as the
questions we ask

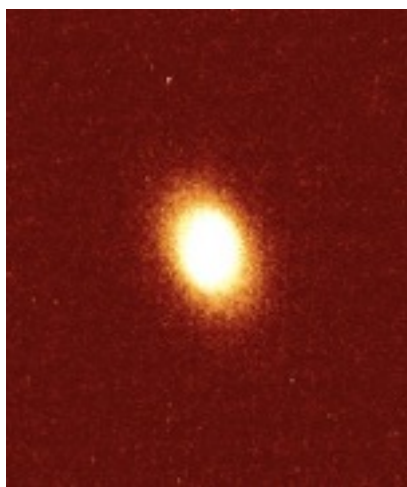
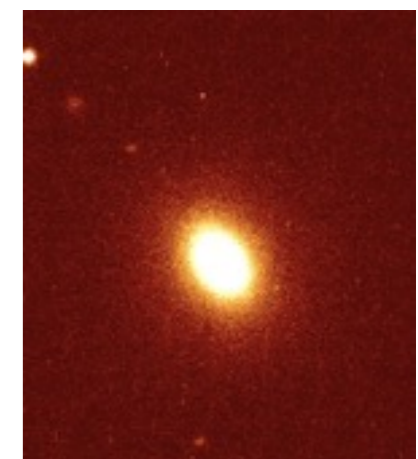
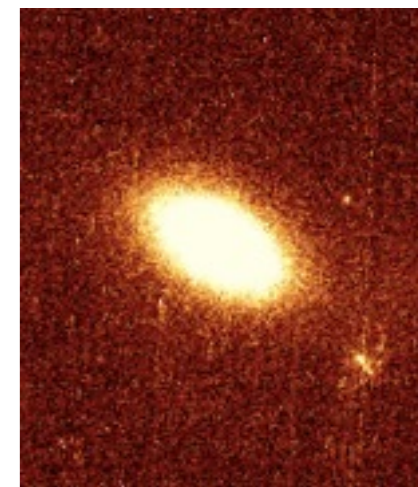
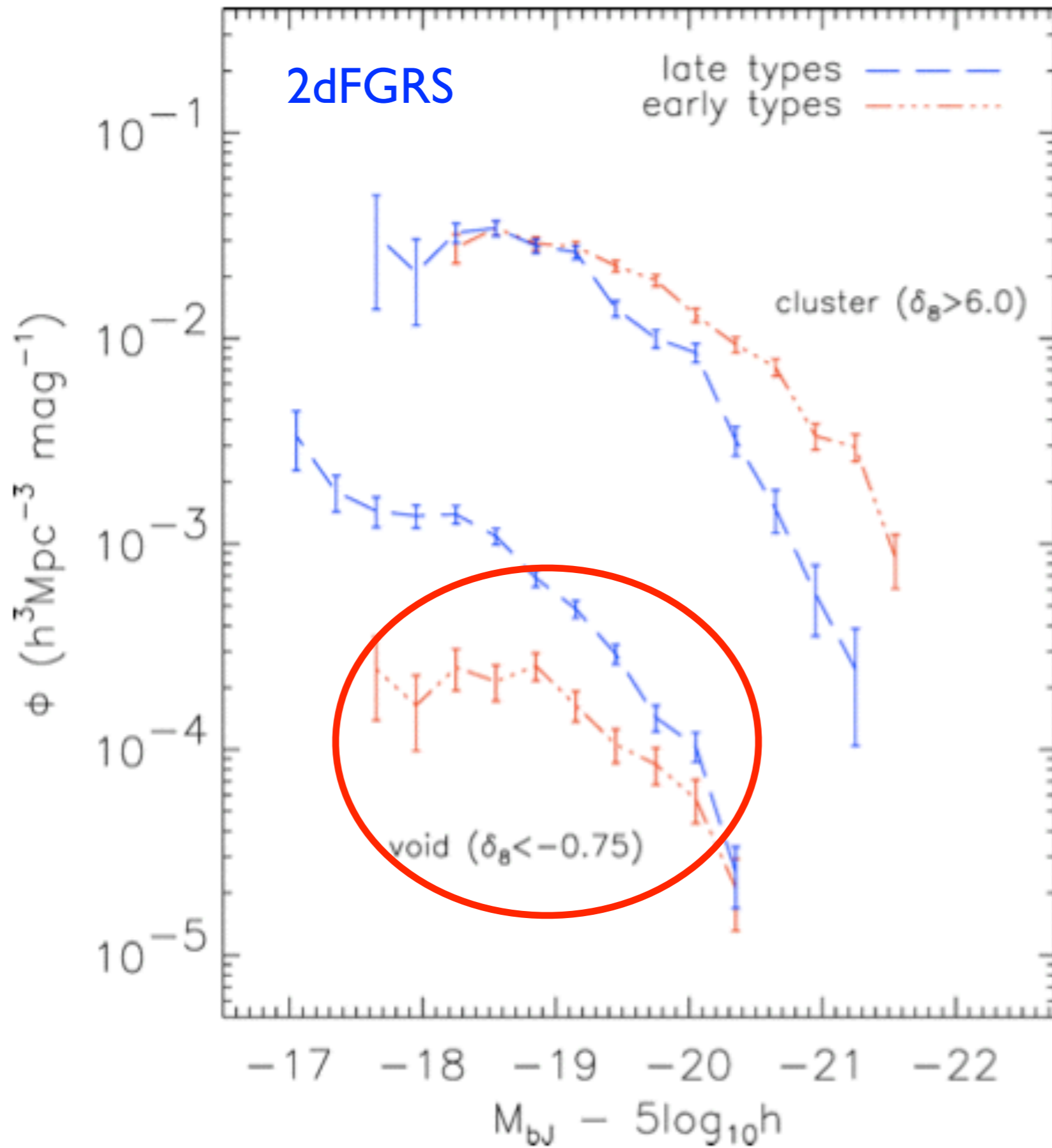


For systems with infinite levels of
complexity, our model can never be
“correct”

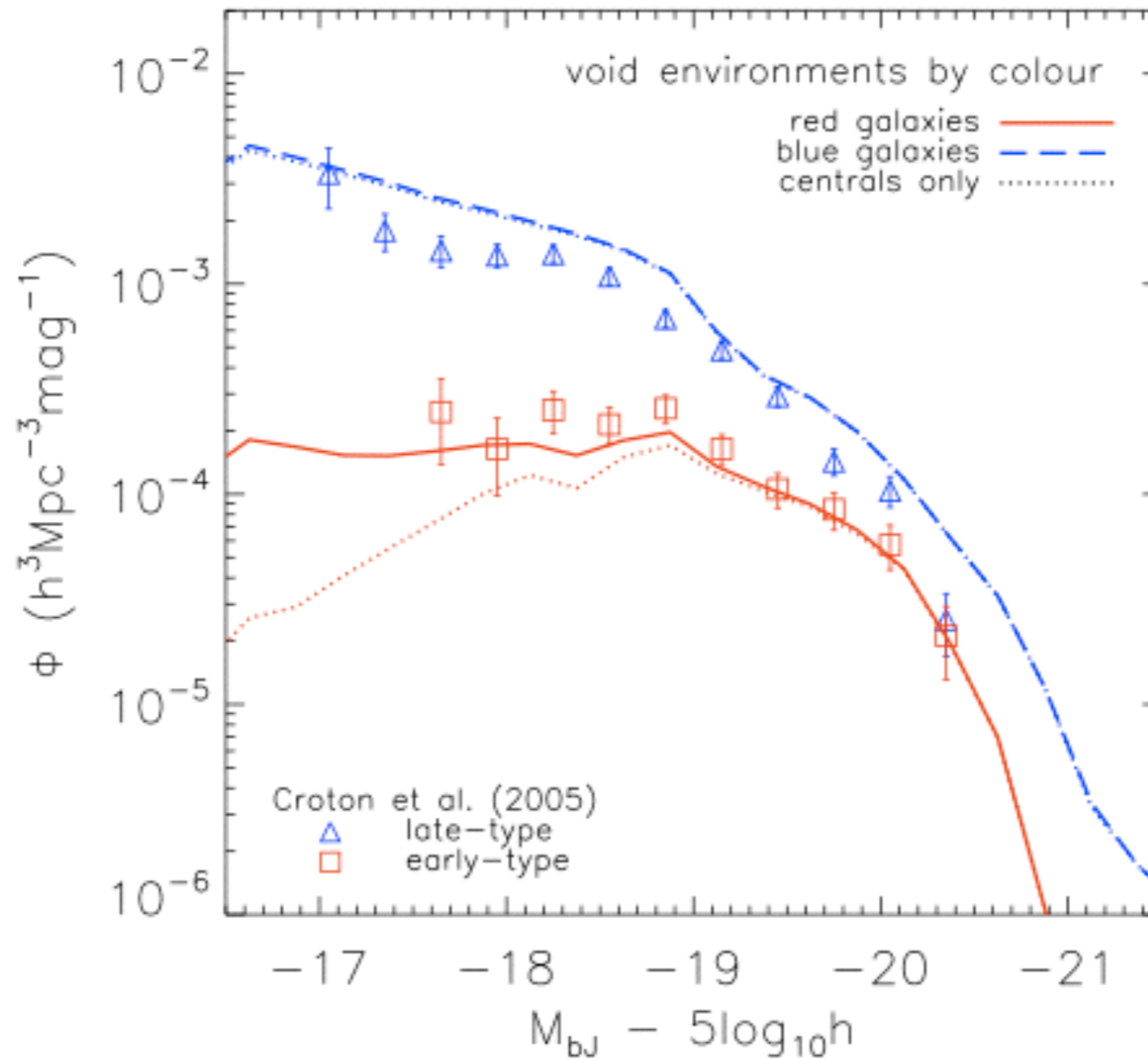
What can semi-analytics
actually tell us
about galaxy formation?

Example 1: Void galaxies

A landscape photograph featuring a vibrant green field in the foreground, a dense line of trees in the middle ground, and a bright blue sky filled with scattered white clouds. The text 'Example 1: Void galaxies' is overlaid in the center of the image.



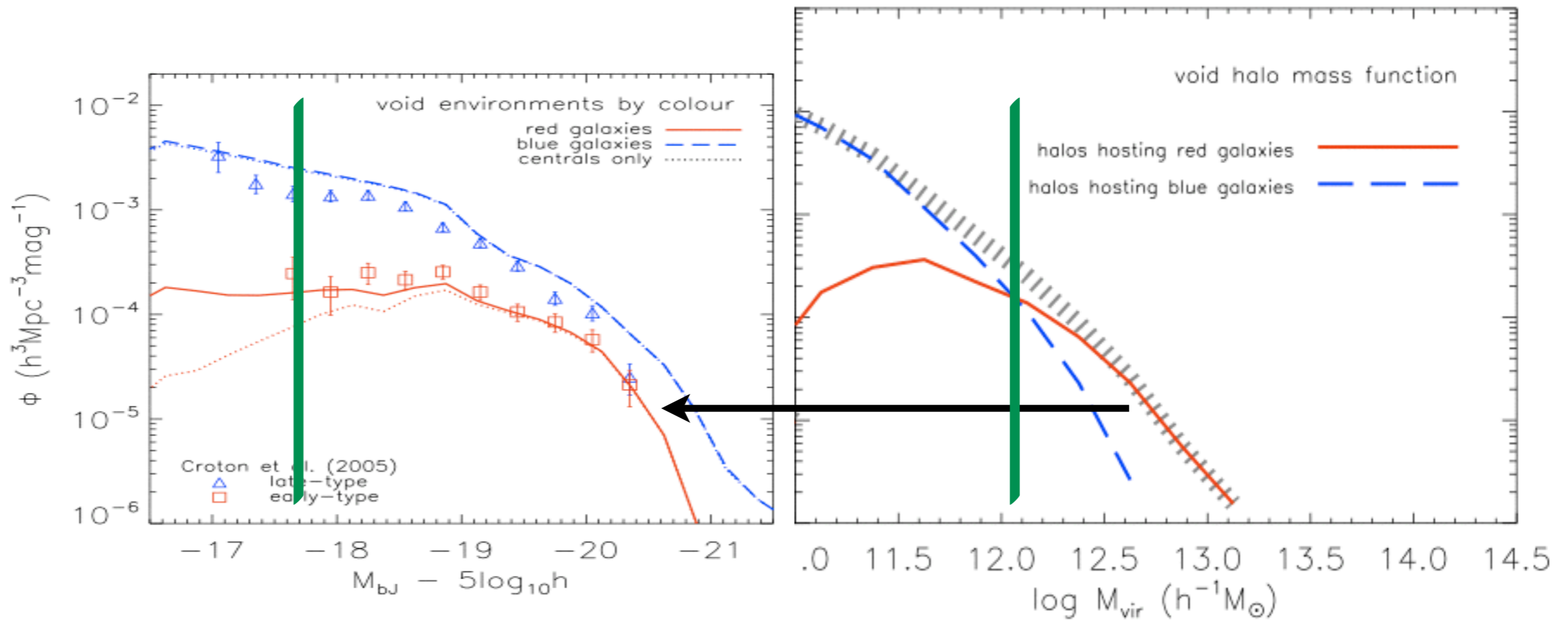
Croton & Farrar (2008)



The Millennium Simulation semi-analytic galaxy formation model

So what's special about early-type void galaxies?

Croton & Farrar (2008)



Halo mass function in different environments

A black hole with a glowing accretion disk is shown in the lower right. A bright orange star is in the upper left, with a white arrow pointing from it towards the black hole. The background is a dark space filled with stars and nebulae.

Example 2:

BH growth -
mergers or secular?

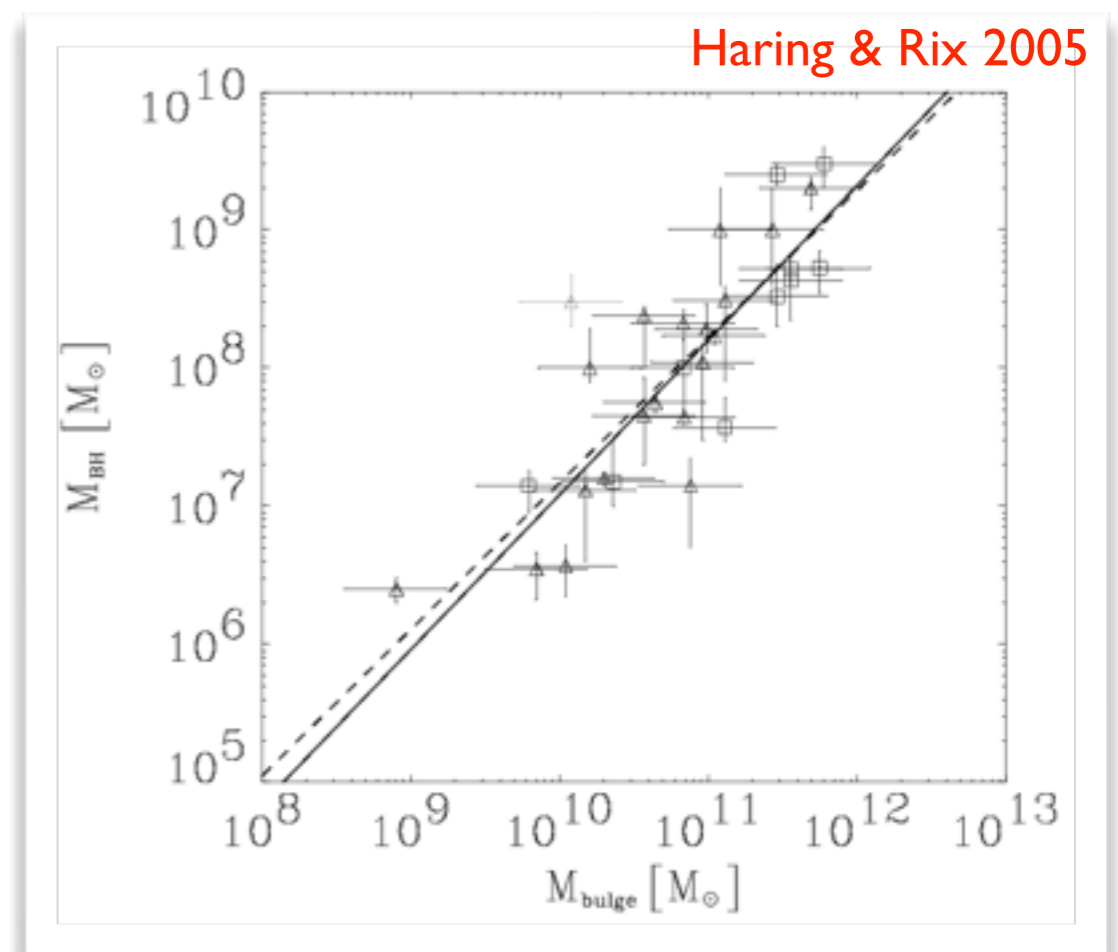
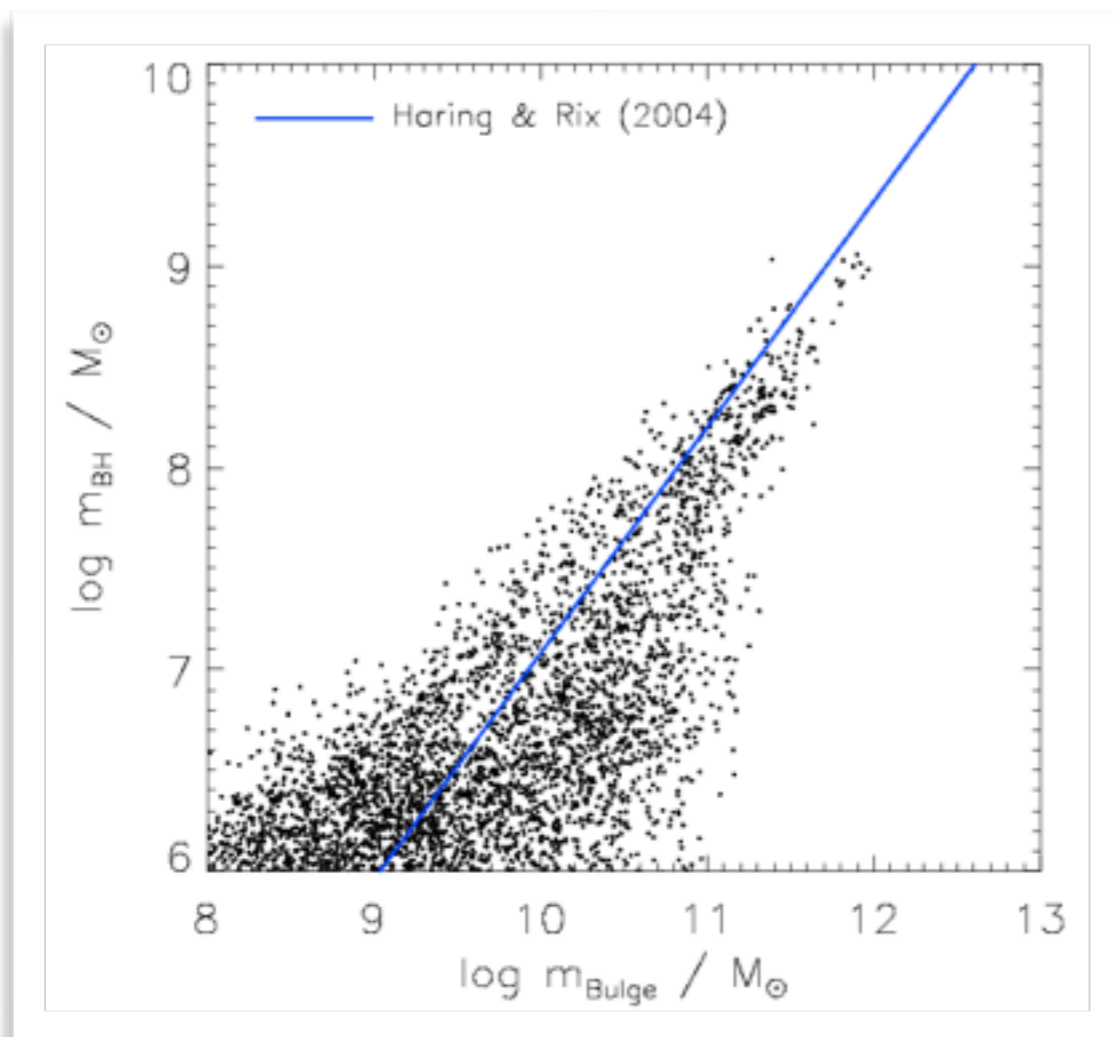
Merger driven growth

During the merger some fraction of the cold gas is driven onto the black hole

$$\Delta m_{\text{BH}} \sim 0.03 m_{\text{R}} m_{\text{cold}}$$

black hole-bulge

merger driven growth



Secular driven growth

As the stellar disk becomes unstable, some fraction of the cold gas is dragged inward to accrete onto the black hole

$$\Delta m_{\text{BH}} \sim 0.01 m_{\text{cold}}$$

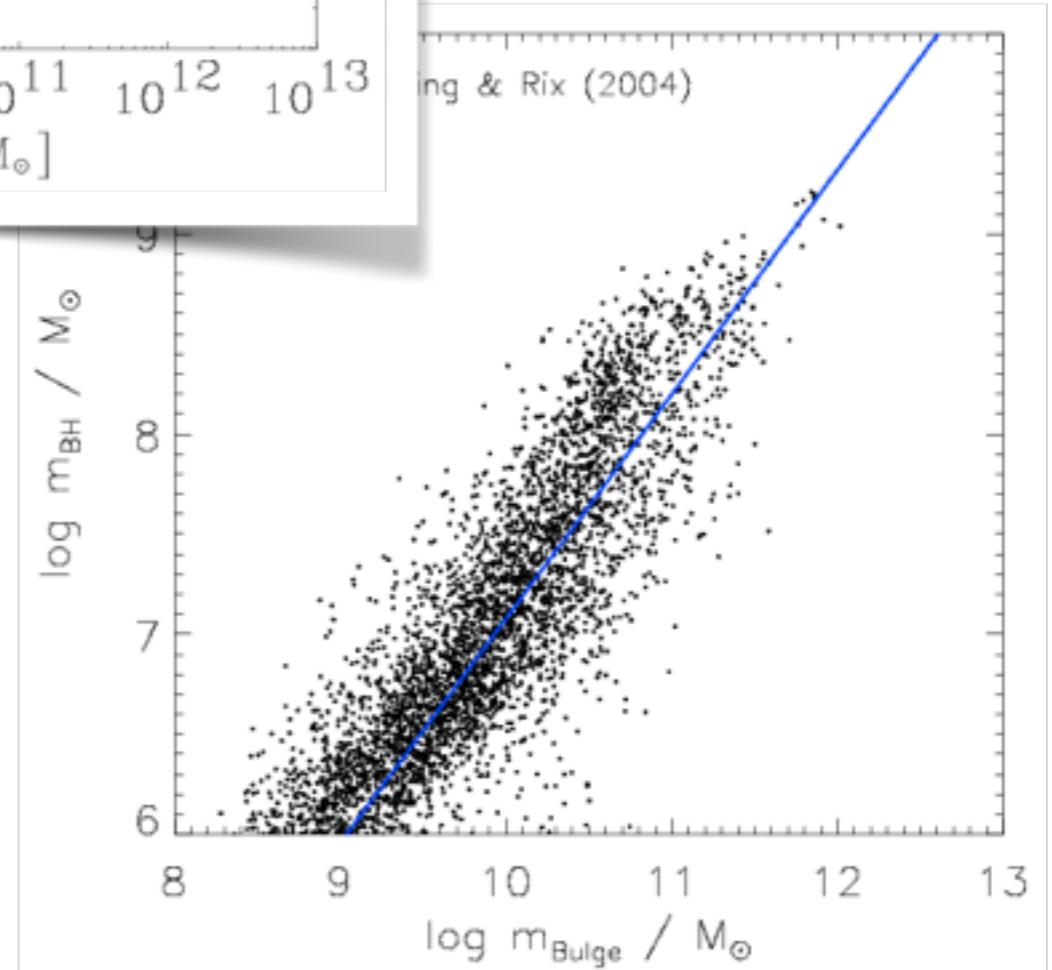
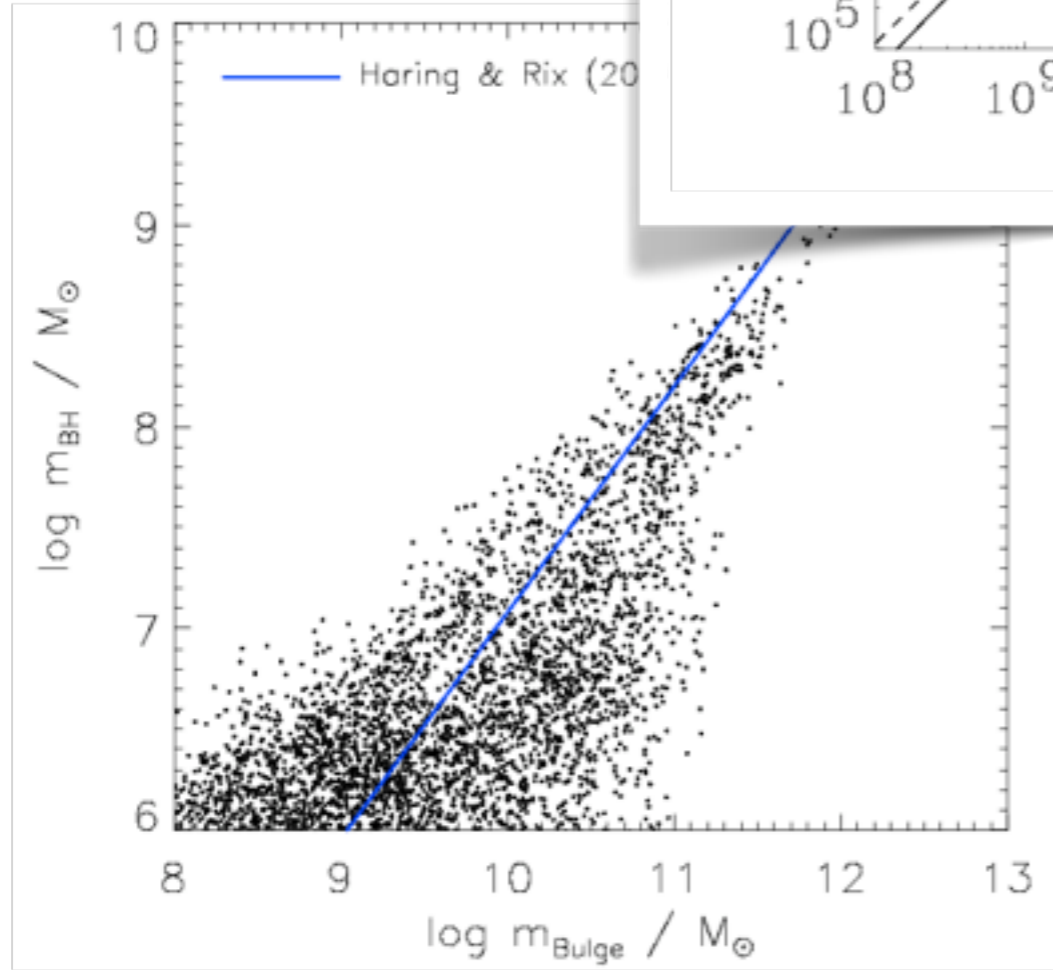
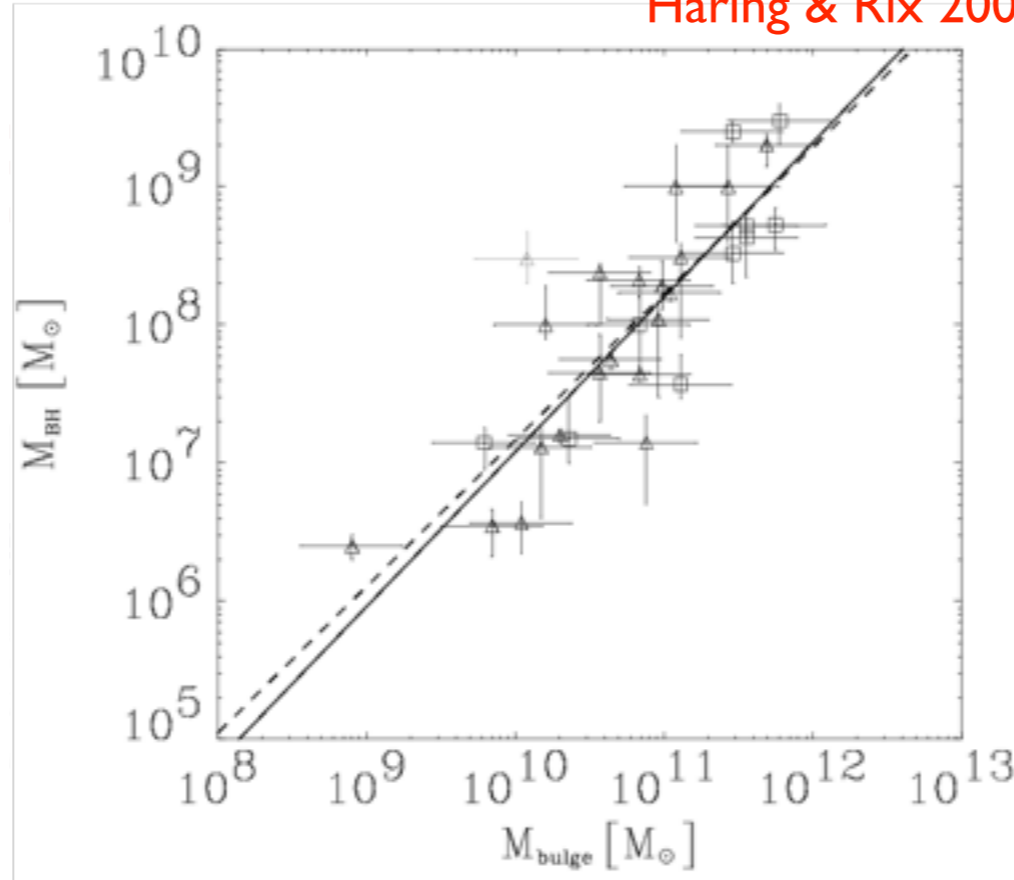
black hole

growth

merger driven

instability
driven growth

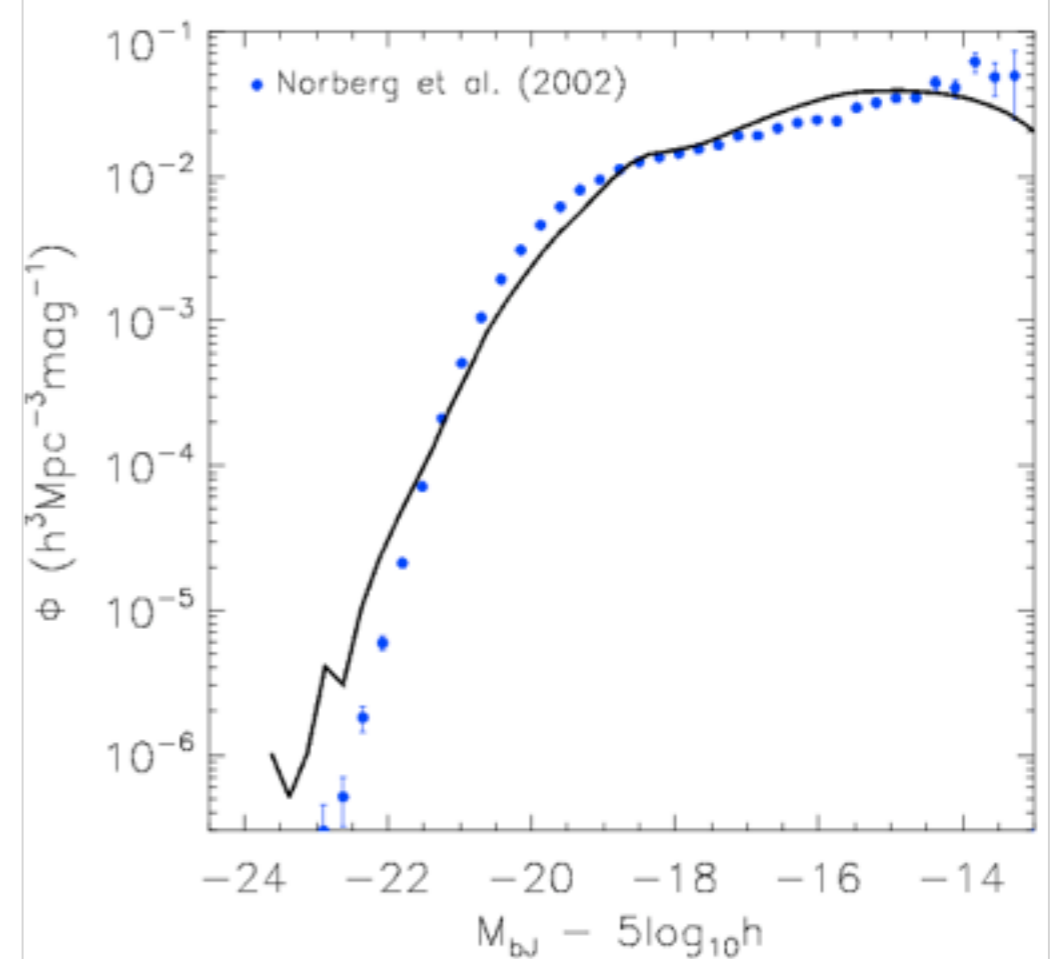
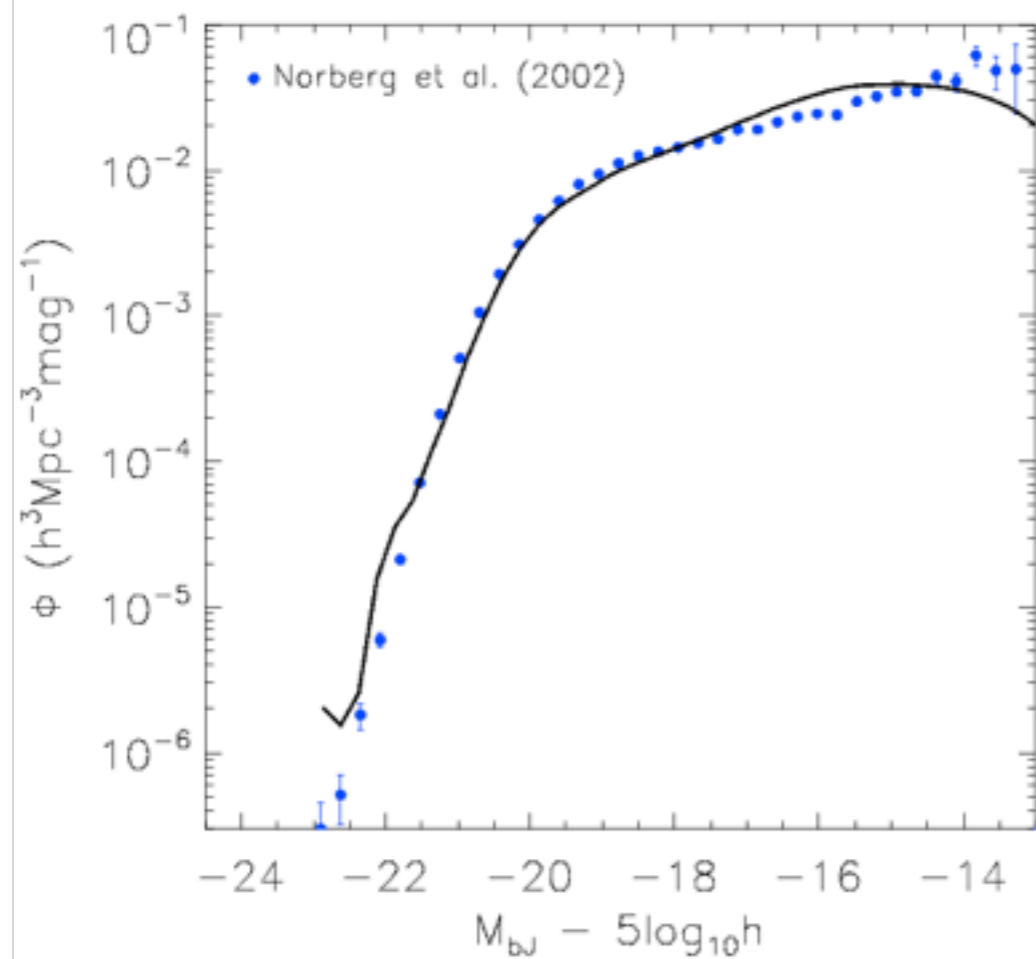
Haring & Rix 2005



luminosity function

merger driven growth

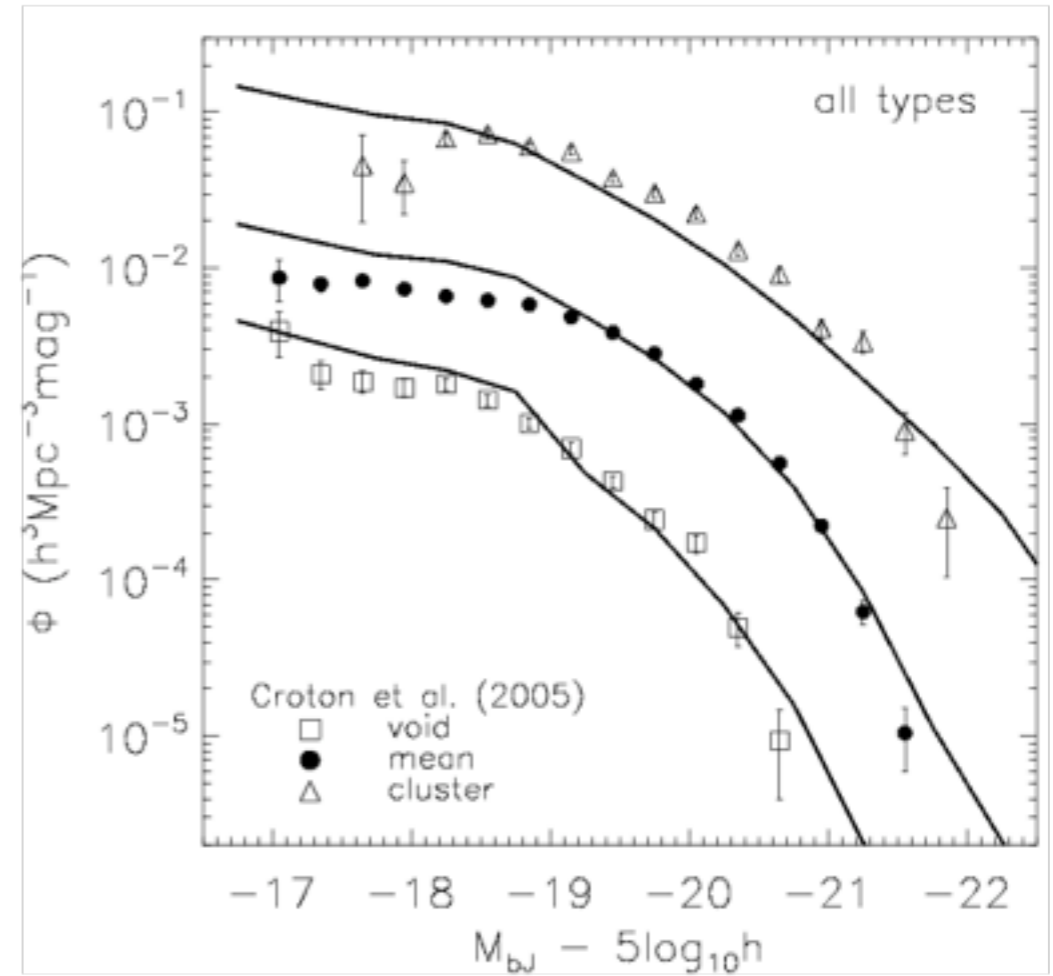
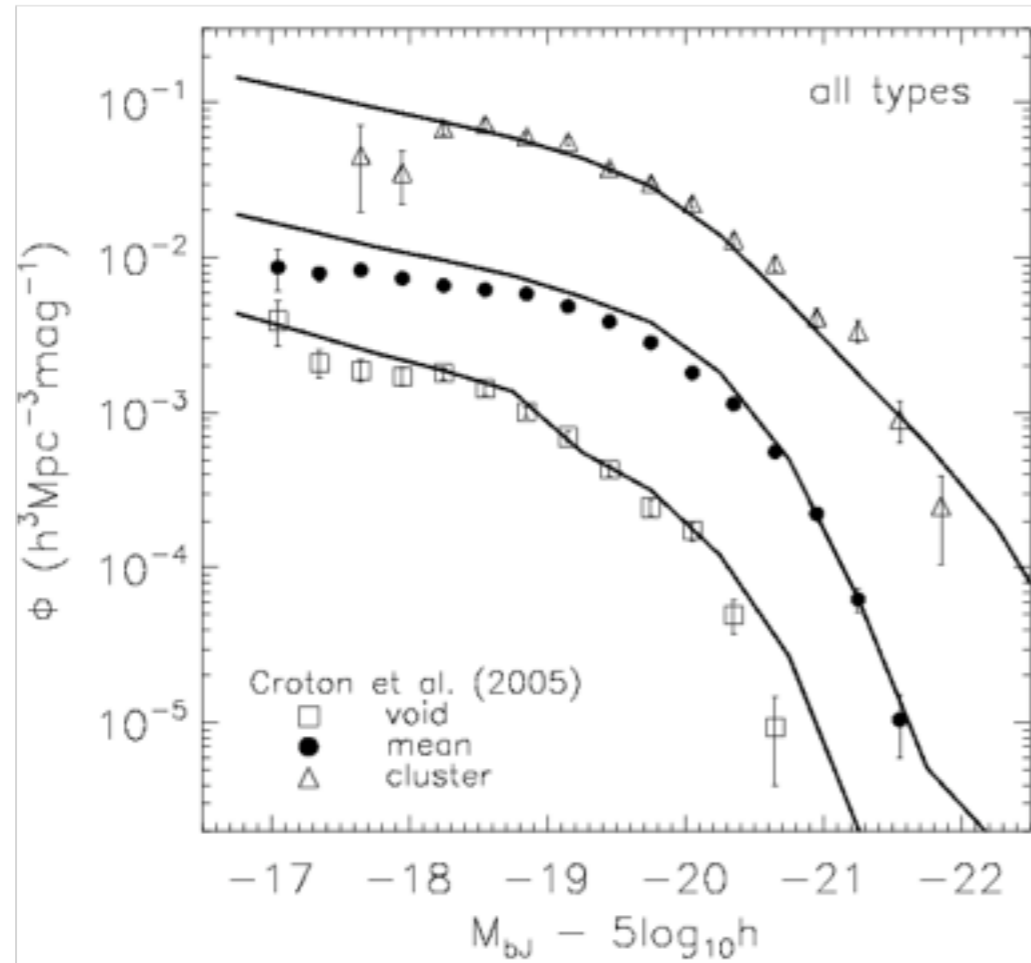
disk instability
driven growth



environment LFs

merger driven growth

disk instability
driven growth

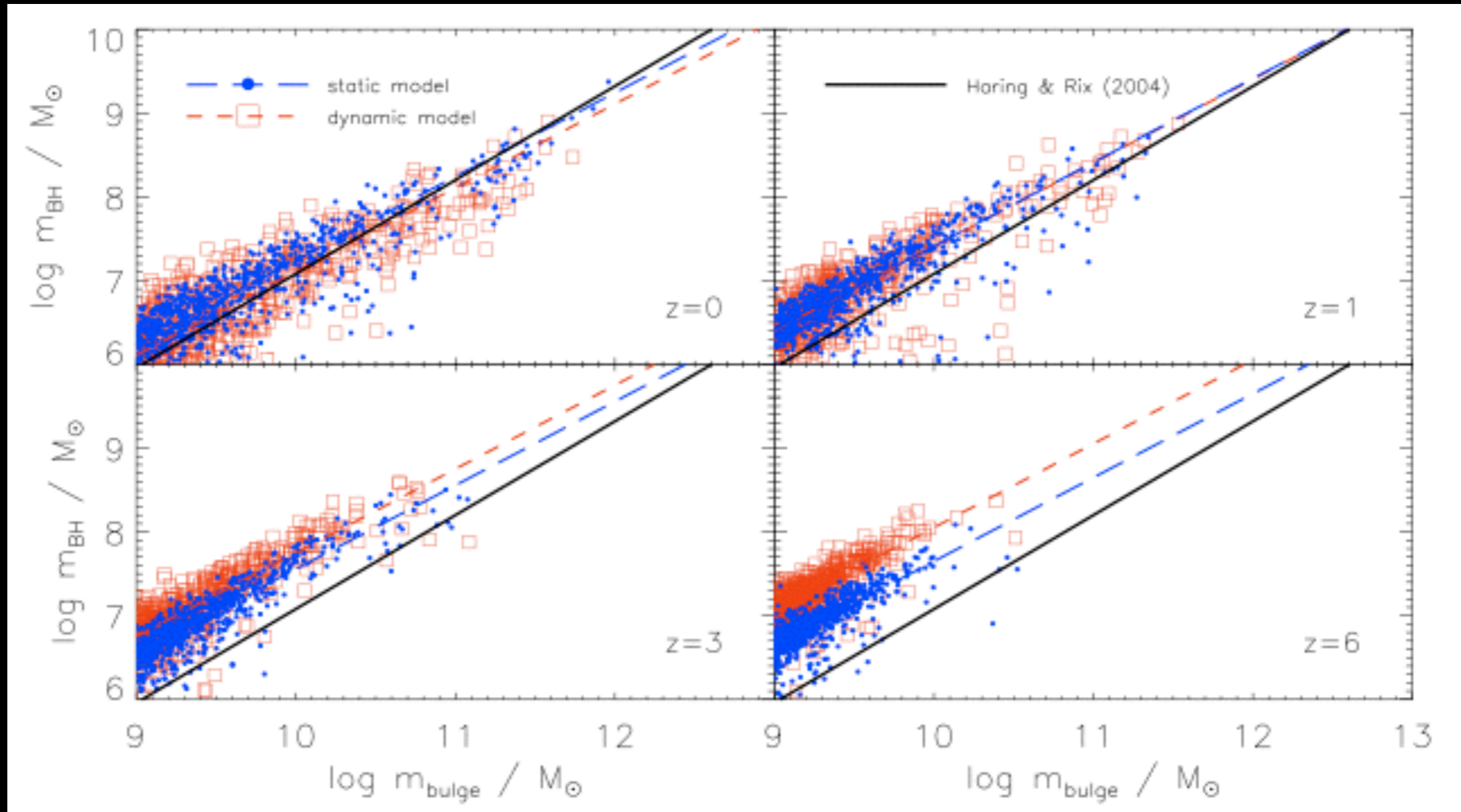




Example 3:

Evolution in the
 $m_{\text{BH}}-m_{\text{bulge}}$ relation

BH-bulge Mass Evolution



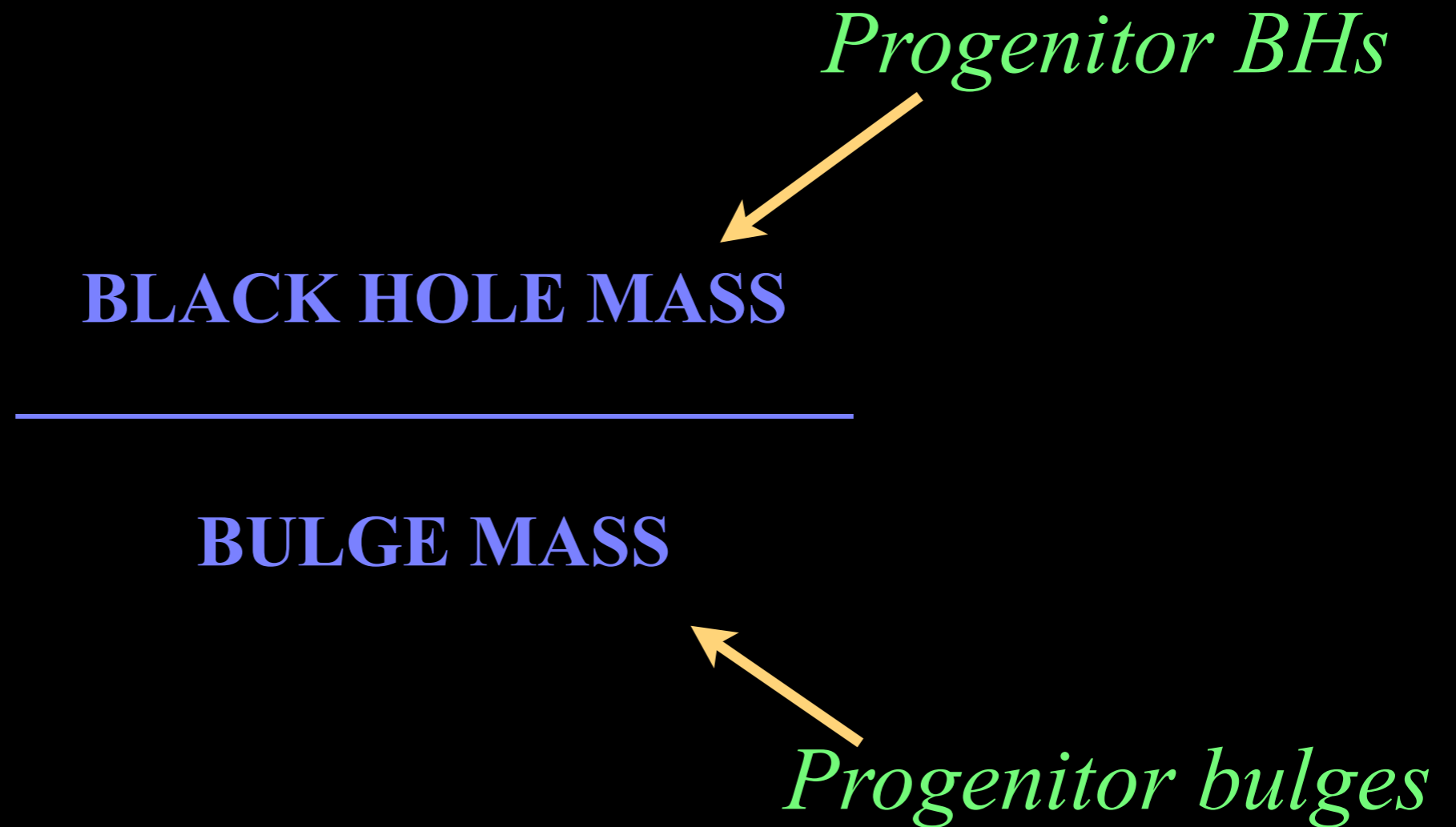
Can we isolate the source of this evolution?
(Croton 2006)

BH-bulge Mass Evolution

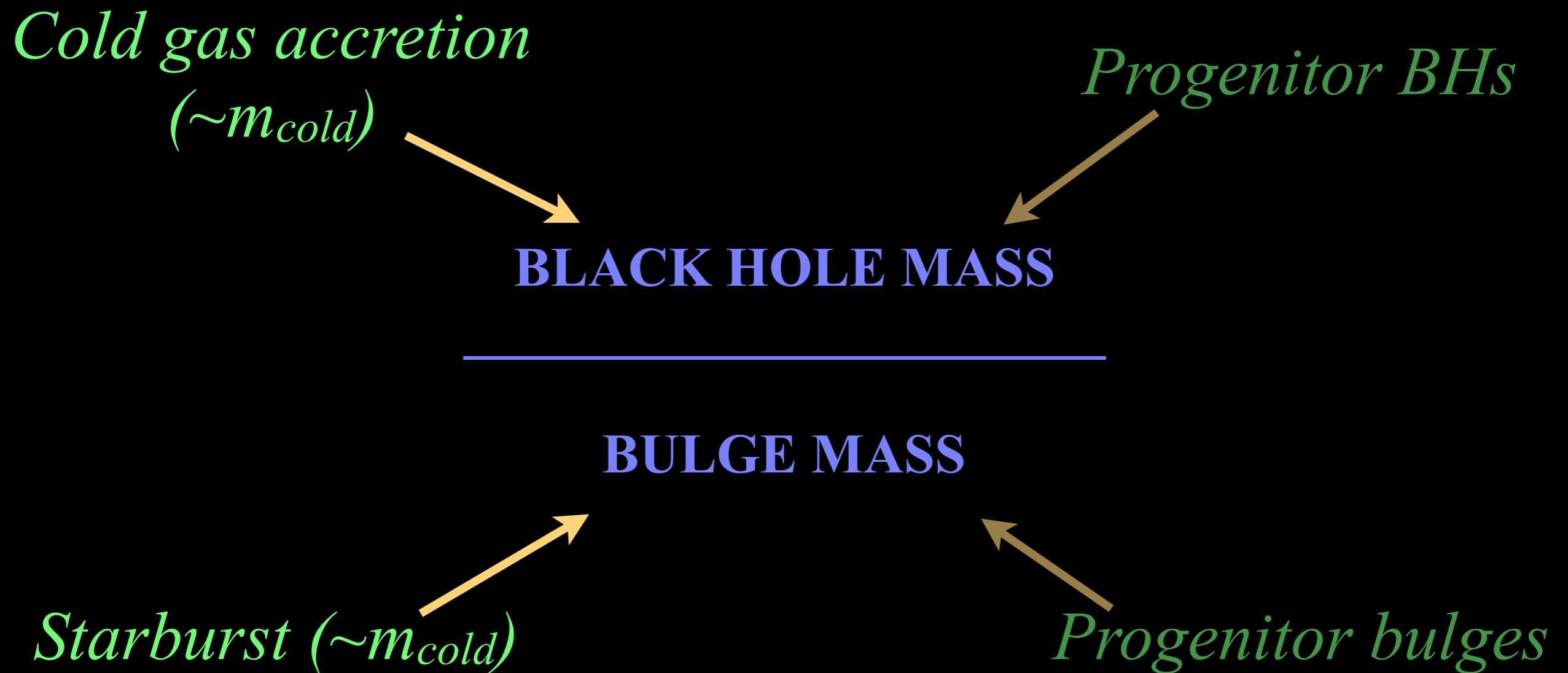
BLACK HOLE MASS

BULGE MASS

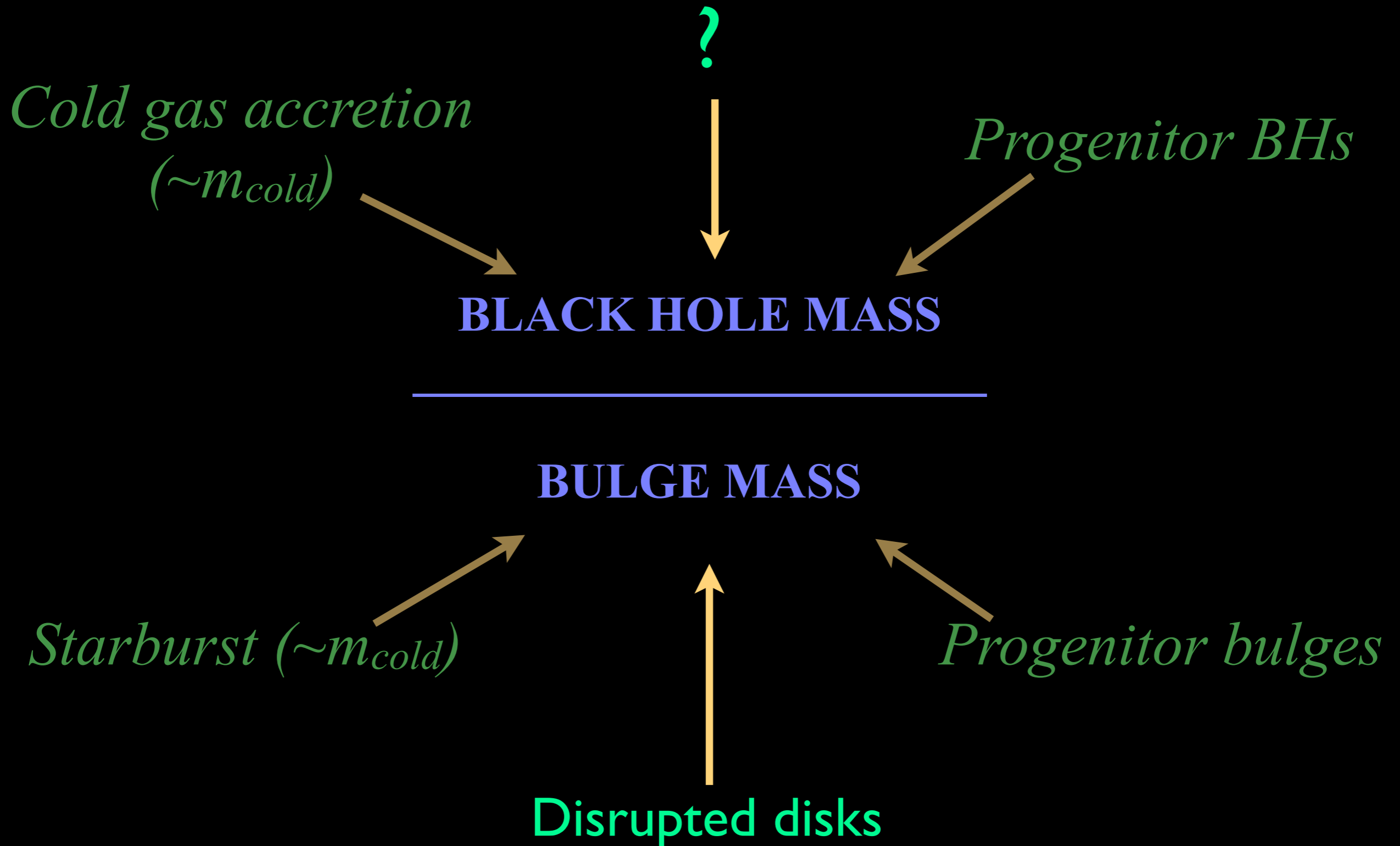
BH-bulge Mass Evolution



BH-bulge Mass Evolution



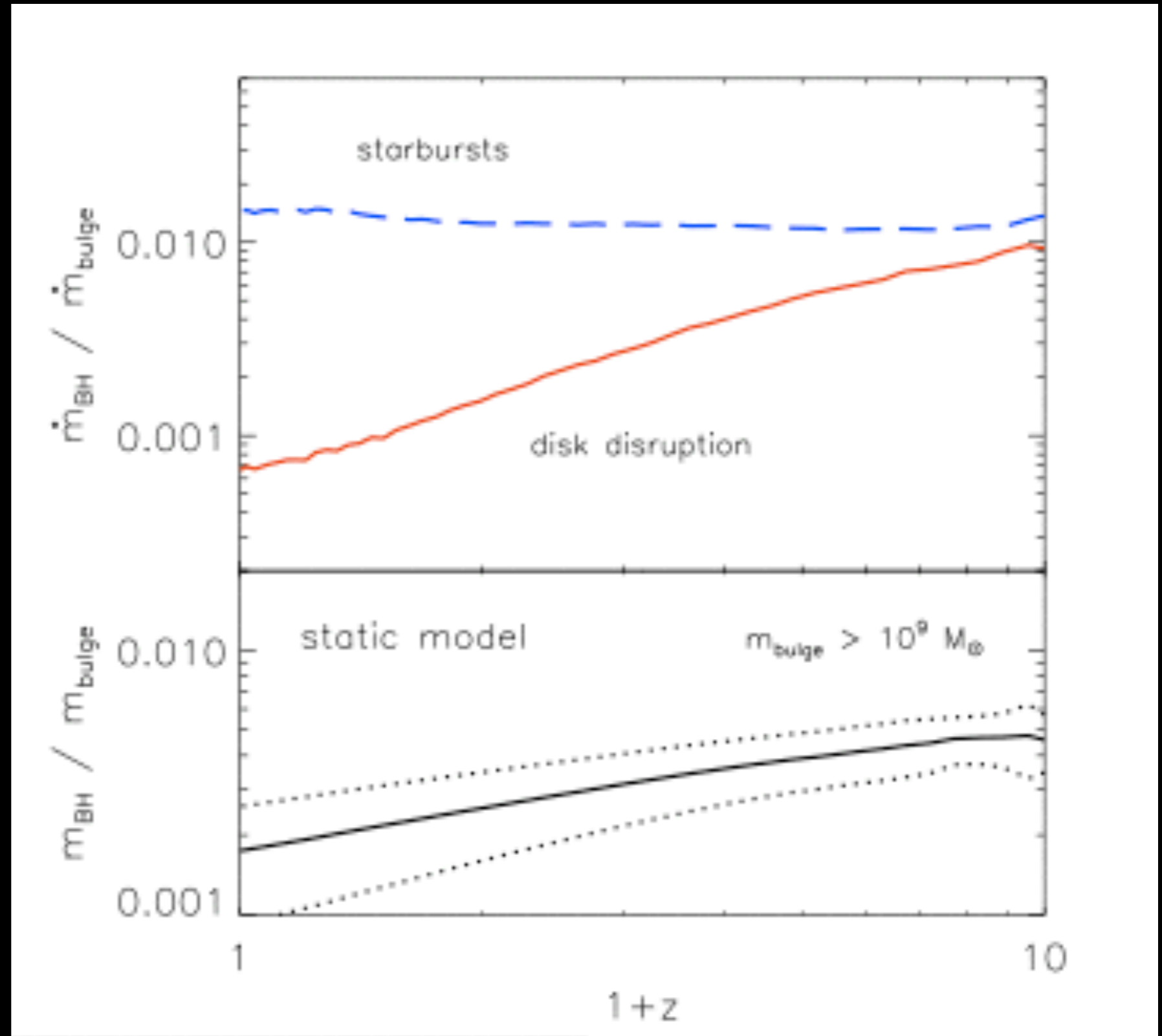
BH-bulge Mass Evolution



BH-bulge Mass Evolution

Madau plot: star formation increases until $z \sim 1$
-> galaxy disks

Λ CDM: merger rate increases until low redshift
disks -> bulges



TAO:

Theoretical Astrophysical Observatory

Bernyk, Croton et al., ApJS, 2016

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

Virgo - Millennium Database

Documentation

CREDITS/Acknowledgments

Registration

News

FAQ

Public Databases

+ DGalaxies

+ DHalotrees

+ Guo2010a

+ MField

+ MillenniumII

+ millimil

+ miniMilII

+ MMSnapshots

+ MPAGalaxies

+ MPAHaloTrees

+ MPAMocks

Private (MyDB) Databases

darren_db (rw) (context)



Welcome Darren Croton.

Streaming queries return unlimited number of rows in CSV format and are cancelled after 420 seconds.

Browser queries return maximum of 1000 rows in HTML format and are cancelled after 30 seconds.

Query (stream)

Query (browser)

Help

Maximum number of rows to return to the query form:

Demo queries: click a button and the query will show in the query window.

Holding the mouse over the button will give a short explanation of the goal of the query. These queries are also available on [this page](#).

Mainly Halos:

Mainly Galaxies:

Metadata queries: The SQL statements under these buttons provide examples for querying and managing the state of a private database. Holding the mouse over the button will give a short explanation of the goal of the statement.

ShowTables

Show Views

Show Columns

Show Indexes

MyDB Size

MyDB Table Size

Create View

Drop Table

Create Index

TAO

Telescope simulator

Image generation

Light cone generation

SEDs + Filters

Web form data query

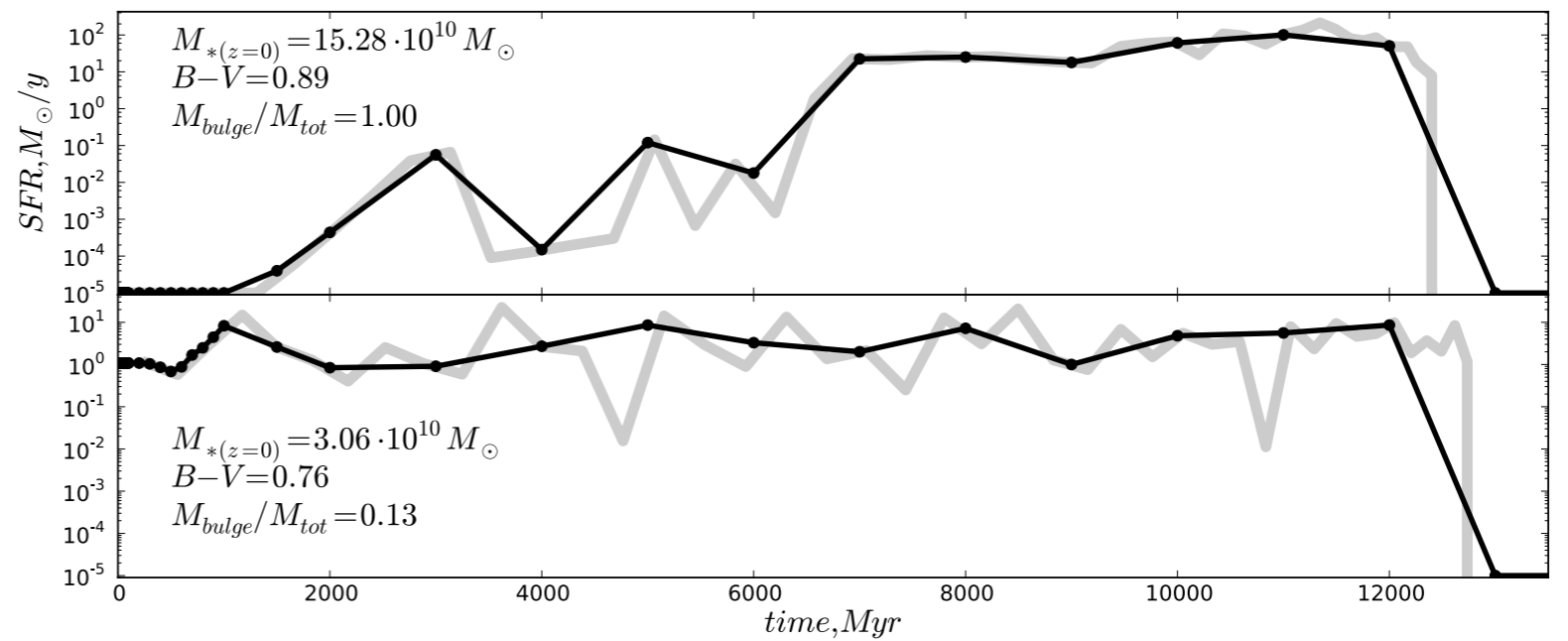
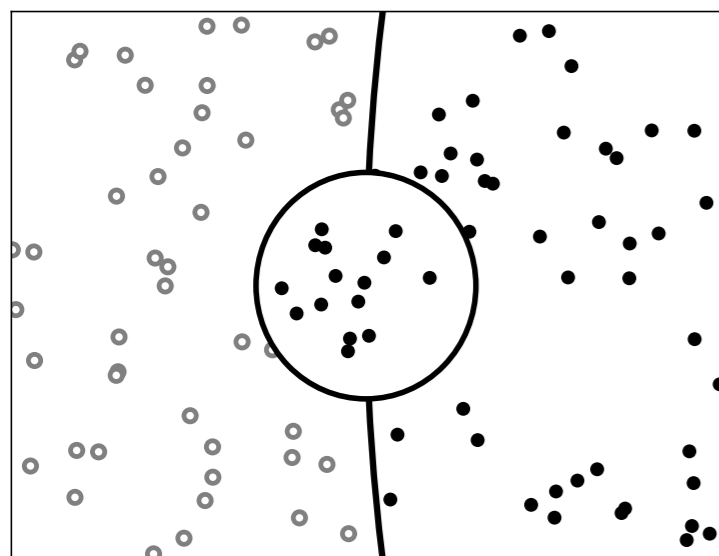
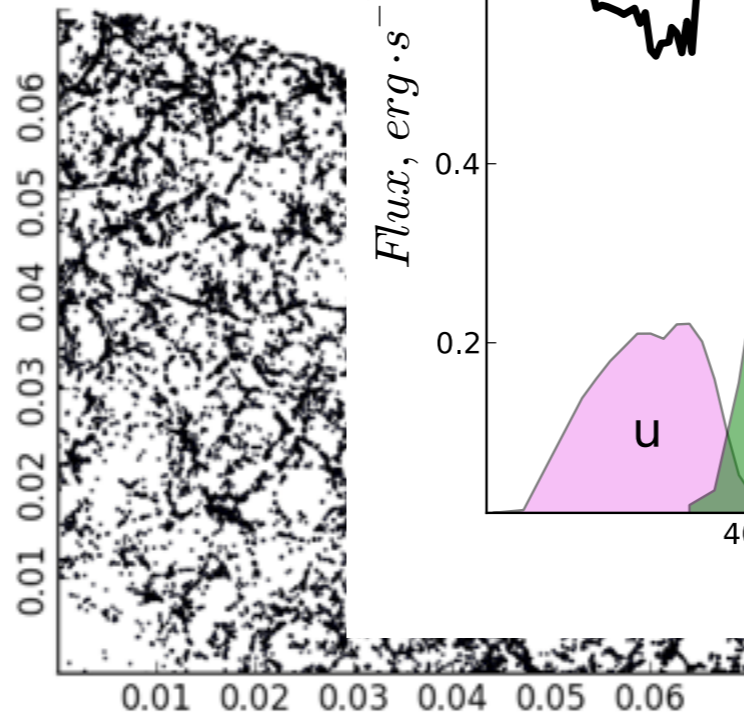
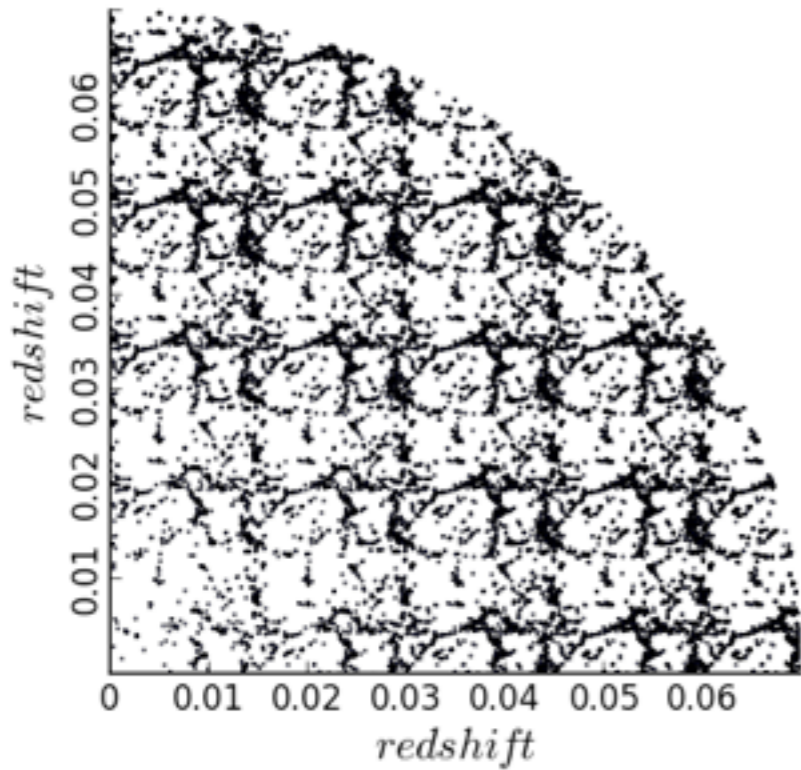
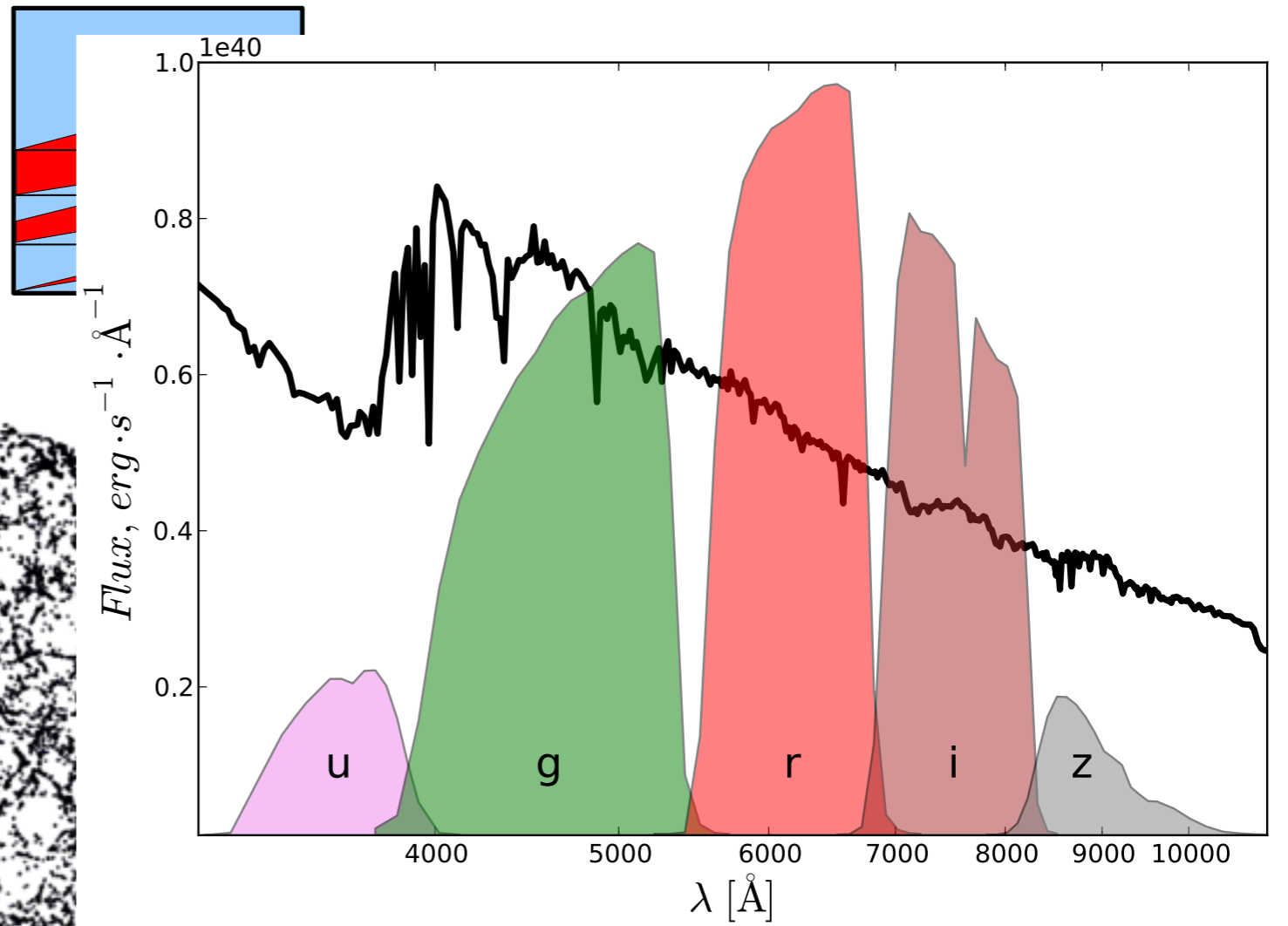
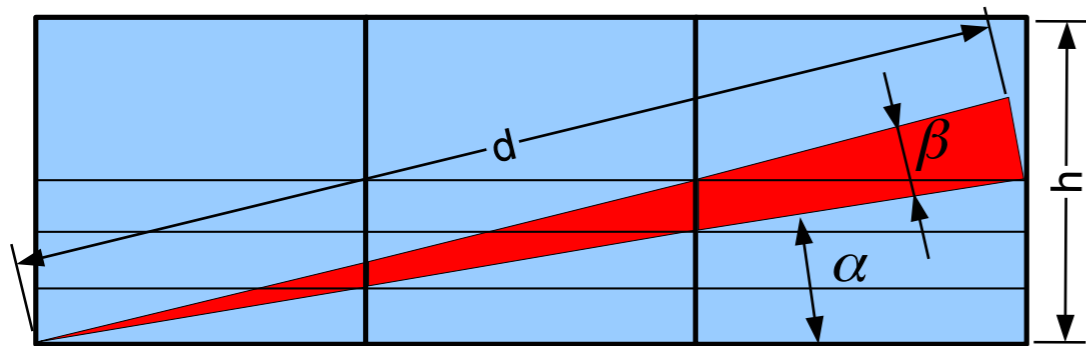
Simulation database

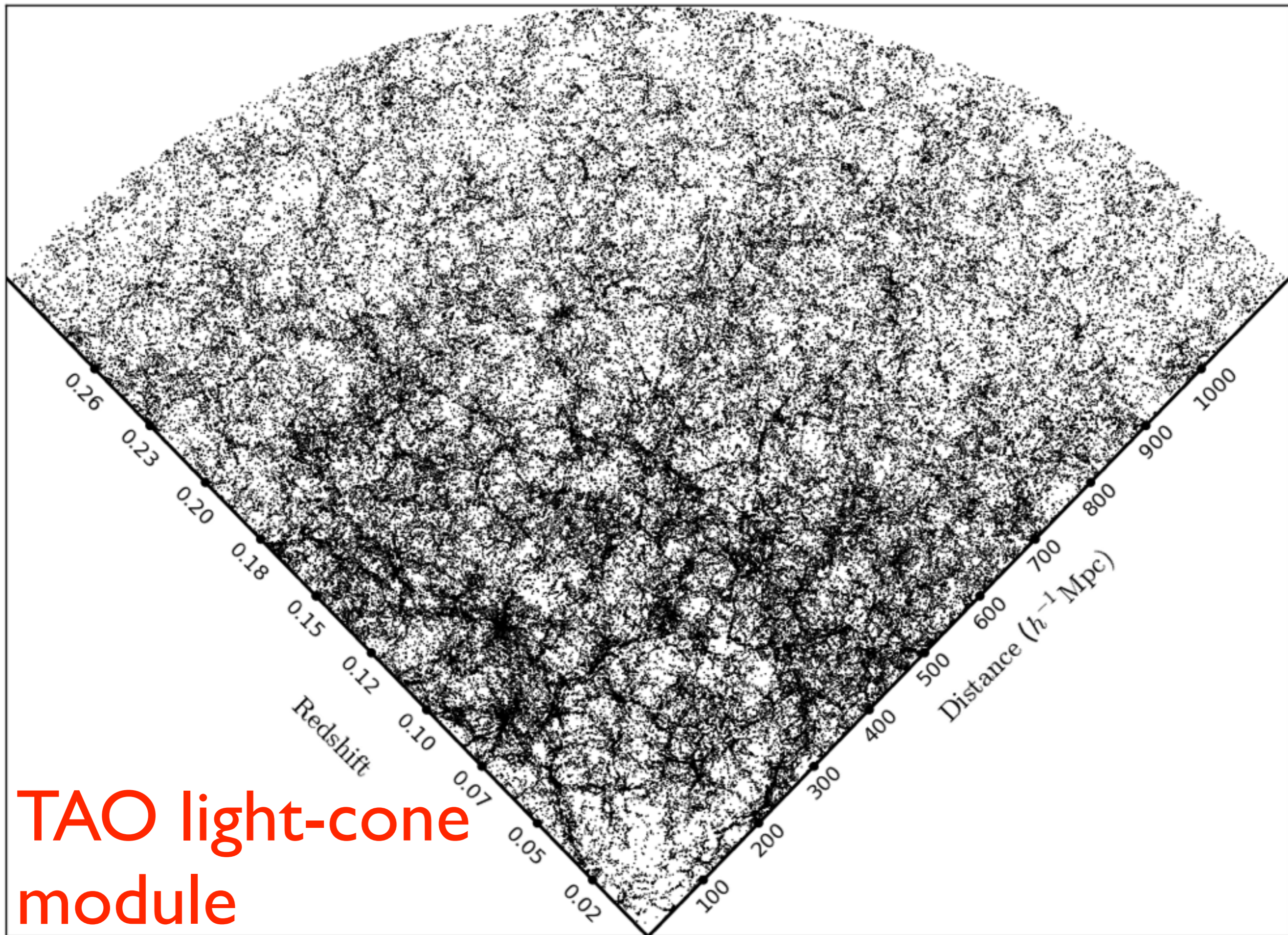
GAVO

SQL data query

Simulation database

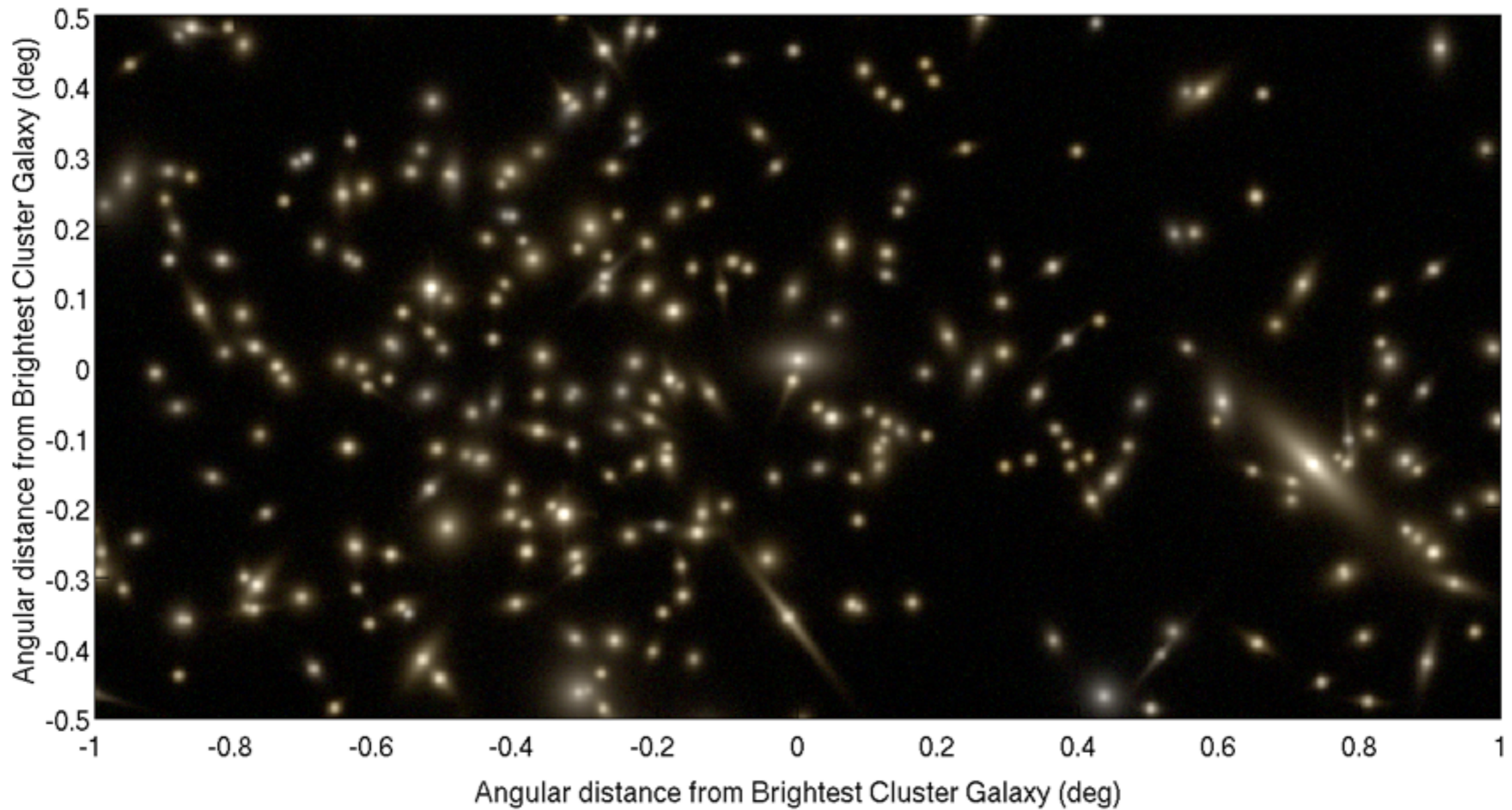
<https://tao.asvo.org.au>





**TAO light-cone
module**

TAO image module



Usage Case:

The “Wide Area VISTA Extra-galactic Survey” (WAVES)

- ✦ 4MOST Consortium Design Reference Survey.
- ✦ Will use the VISTA/4MOST facility to spectroscopically survey ~ 2 million galaxies.
- ✦ TAO used for predictions and to argue the science case.

- Ensemble of Milky-Way sized systems to test CDM
- The low surface brightness and dwarf domains
- The evolution of galaxy structure (with Euclid)
- The evolving HI universe (with ASKAP/SKA)

WAVES Survey

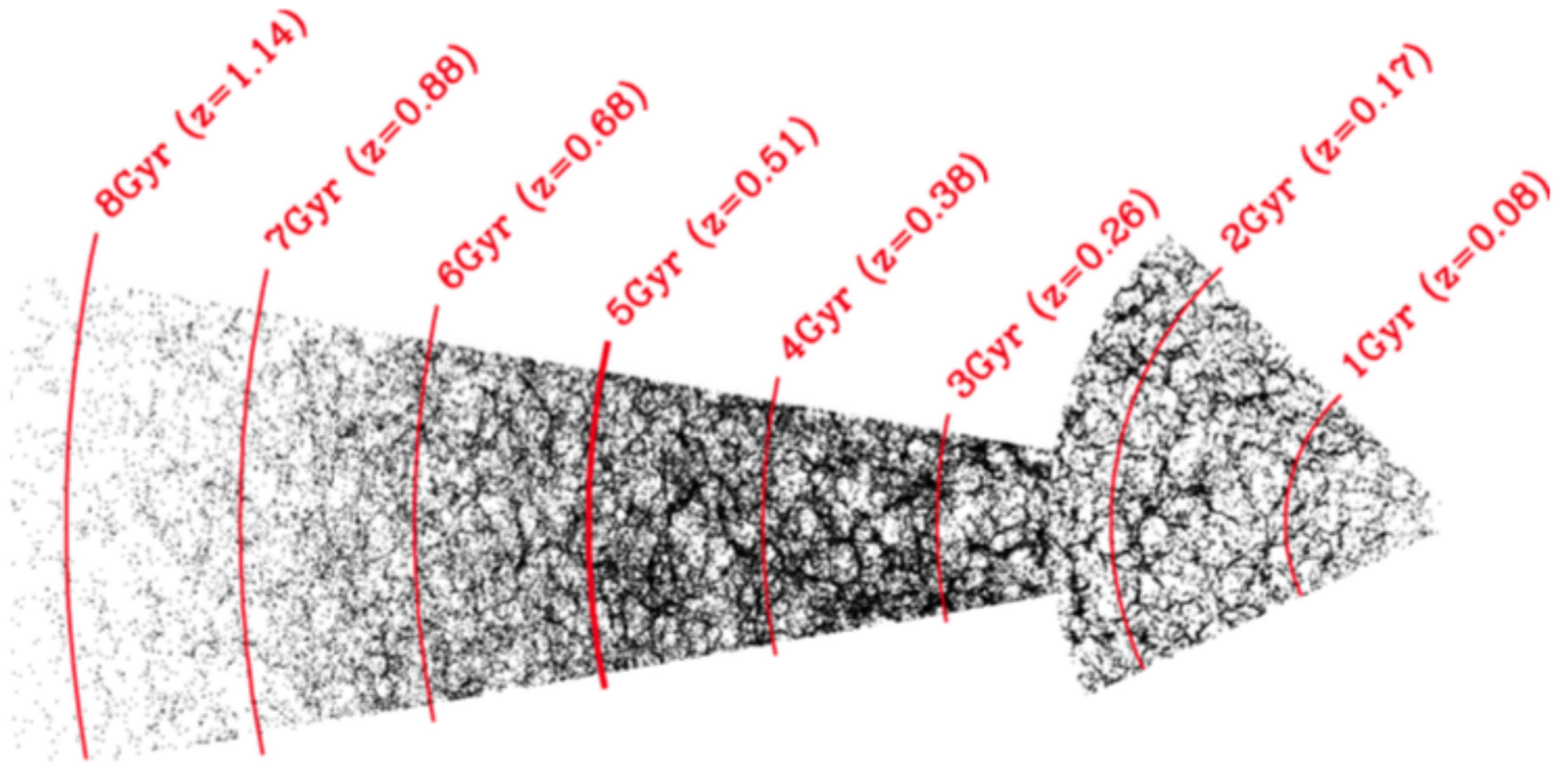


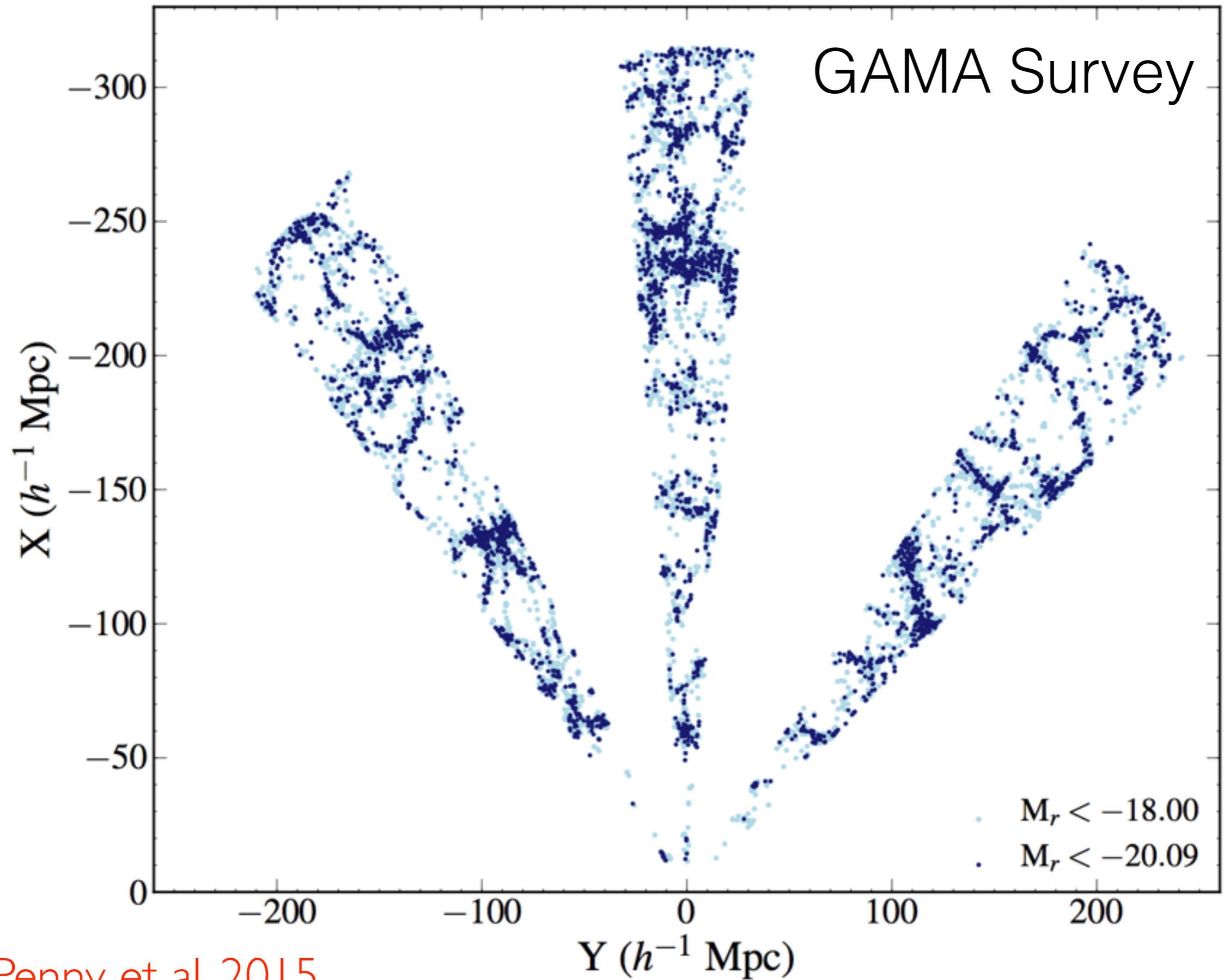
Fig. 1 A representation of the RA geometry of the WAVES survey (derived from the Theoretical Astrophysical Observatory), highlighting the complexity of structures that will be sampled.

Usage Case:

Cosmological-scale holes in the local Universe - (GAMA)

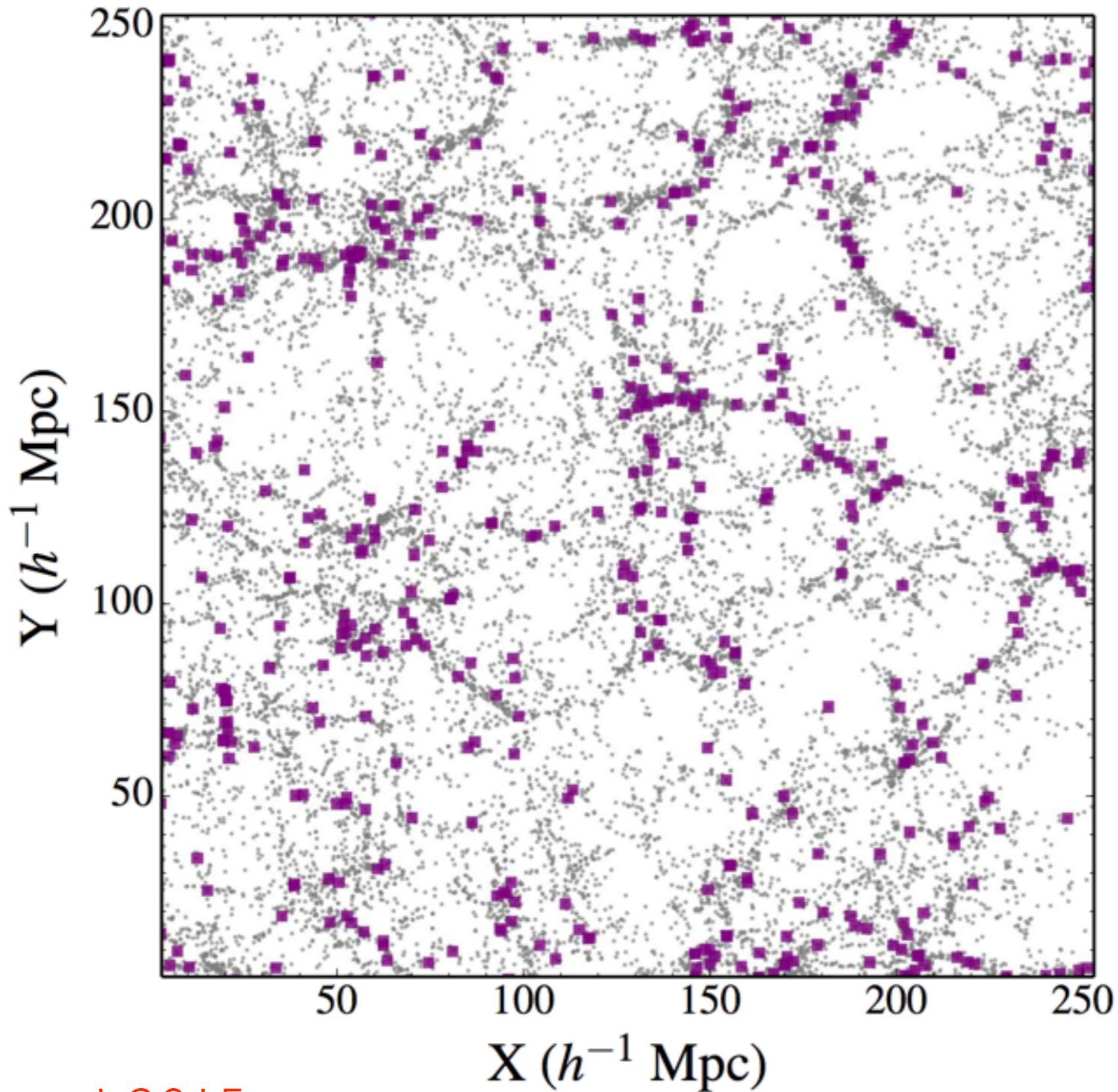
- ✦ There are massive regions of the Universe *almost* totally devoid of galaxies.
- ✦ Where do the “lost” galaxies that do live there come from?
- ✦ TAO allows access to the latest theoretical modelling.

GAMA Survey



Penny et al. 2015

TAO Galaxies

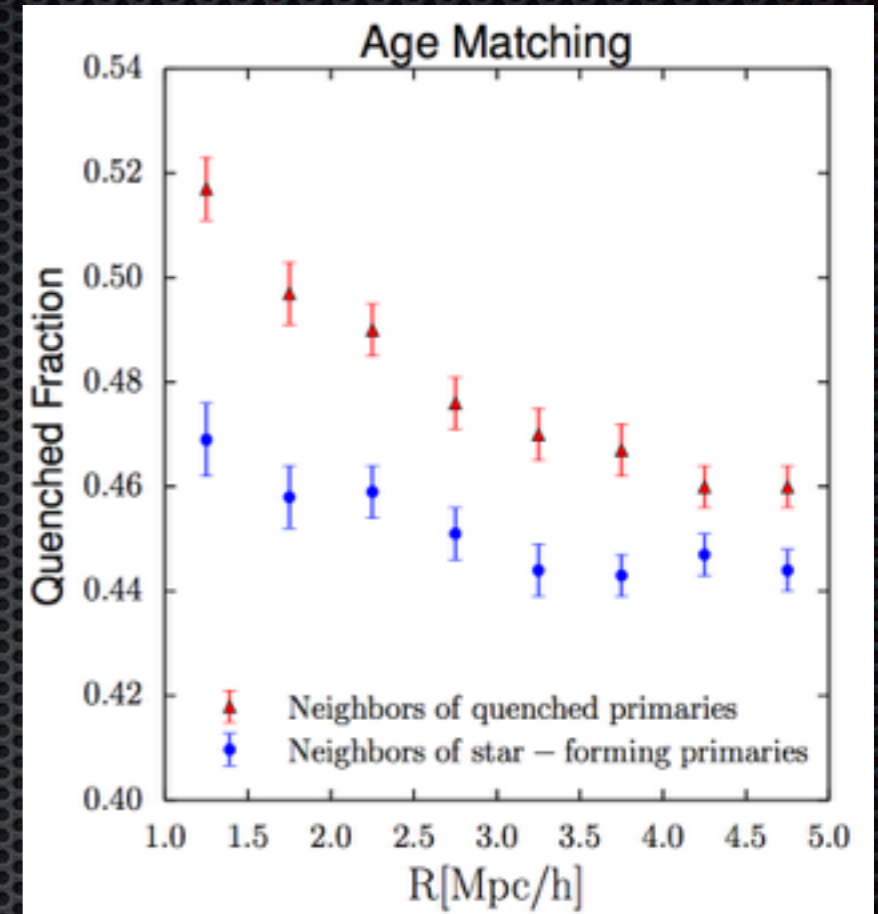


Purple =
recent
galaxy-galaxy
collision

Grey =
all TAO
galaxies

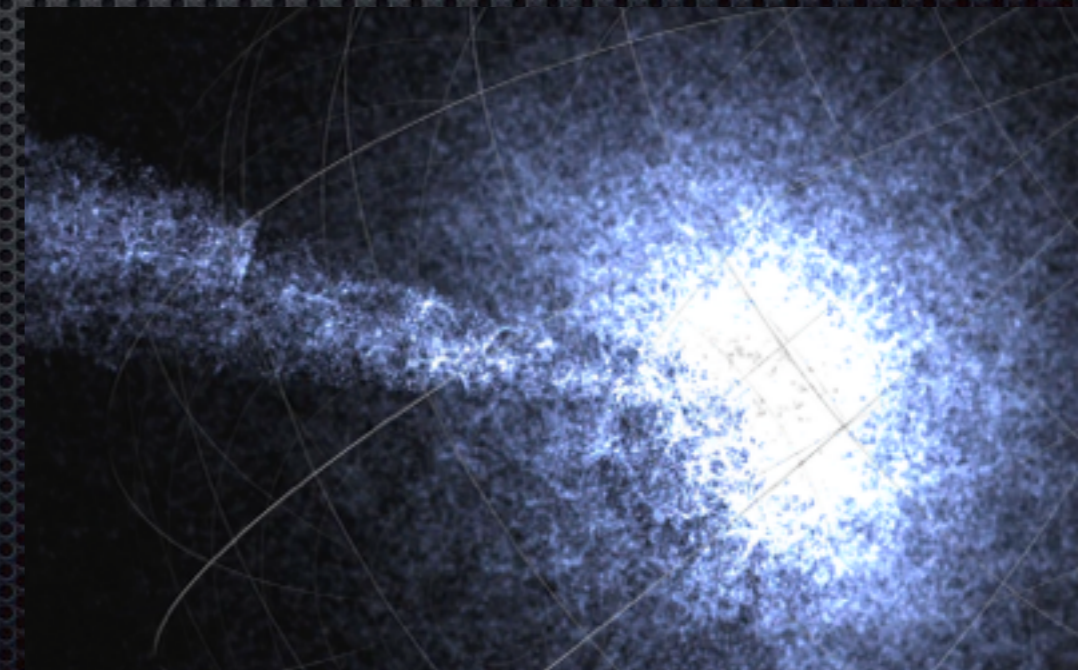
Usage Case: SDSS Cosmic conformity

- Galaxies “conform” over scales much larger than their local physics can impact. Why? (Hearin et al. 2014)



Usage Case: ASKAP Radio Surveys

- How many galaxies will ASKAP see?
What kinds of galaxies? (Duffy et al. 2012)



The Australian Square Kilometre Array Pathfinder [**ASKAP**]
radio telescope will expand our understanding of the Universe ...

CODE:

git clone <https://github.com/darrencroton/sage.git>

TREE FILES:

<http://supercomputing.swin.edu.au/data-sharing-cluster/mini-millennium-simulation/>