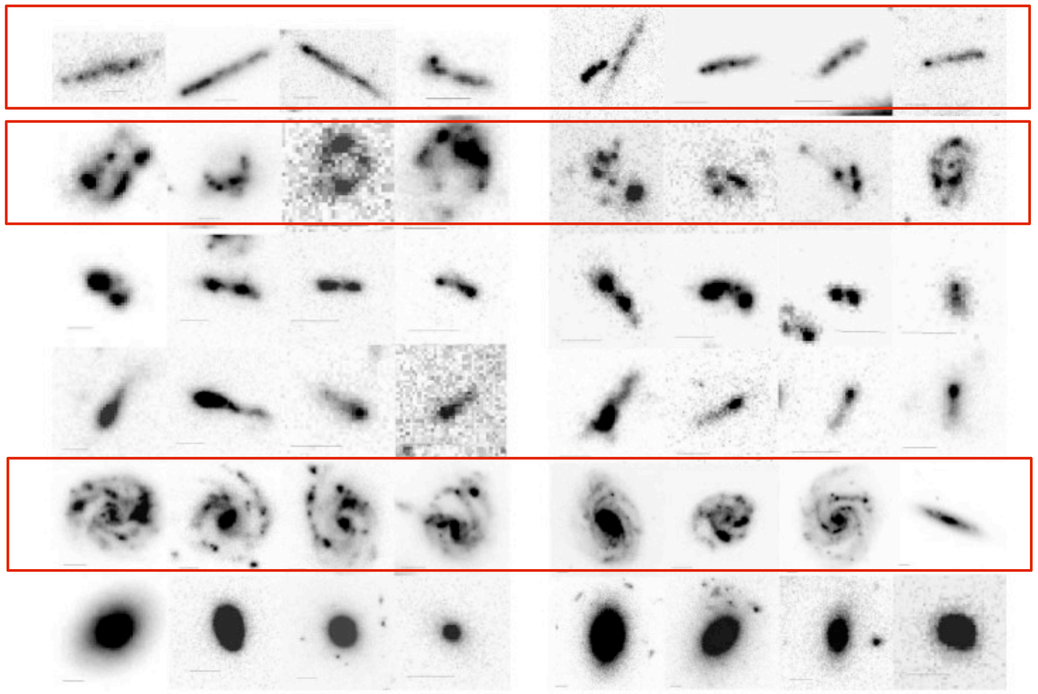
Large Populations of Gravitationally Unstable Galaxies

John Forbes

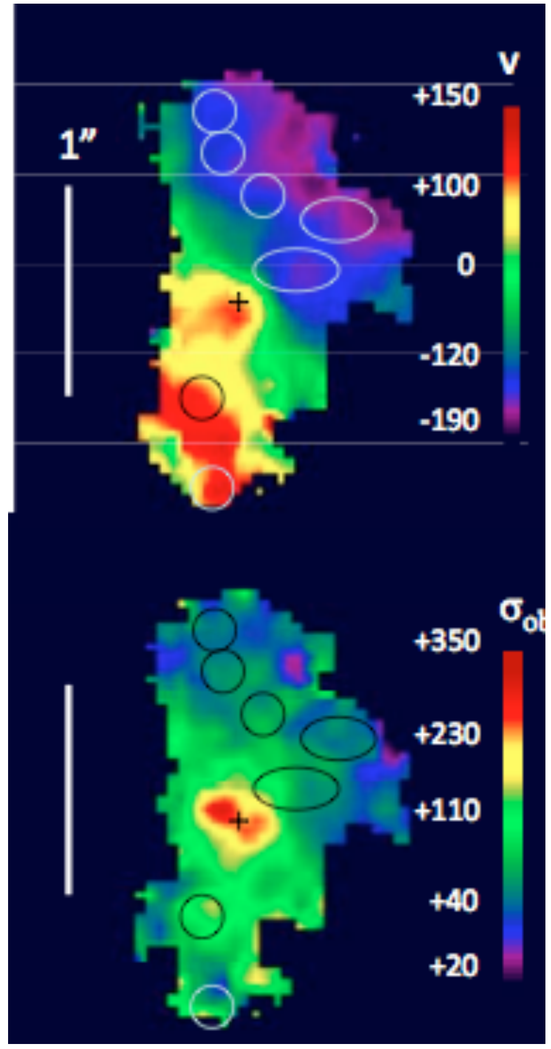
UCSC Galaxy Workshop - August 15, 2012

With Mark Krumholz, Andi Burkert, Avishai Dekel

Disks at high redshift are gravitationally unstable

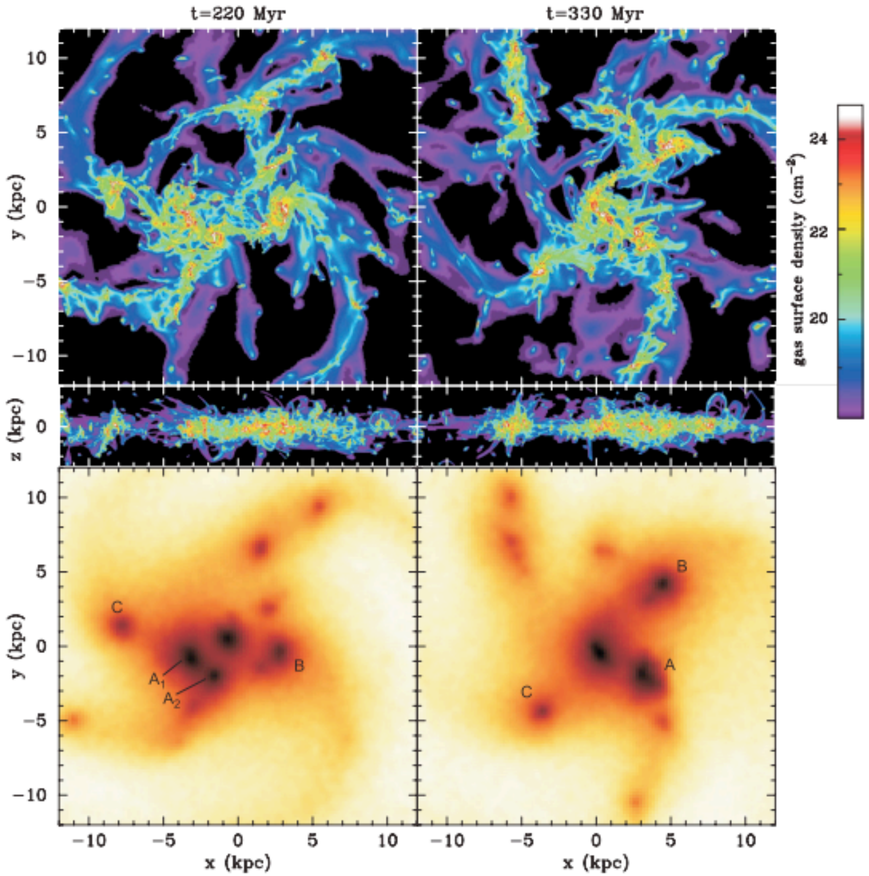


Elmegreen+ 2005

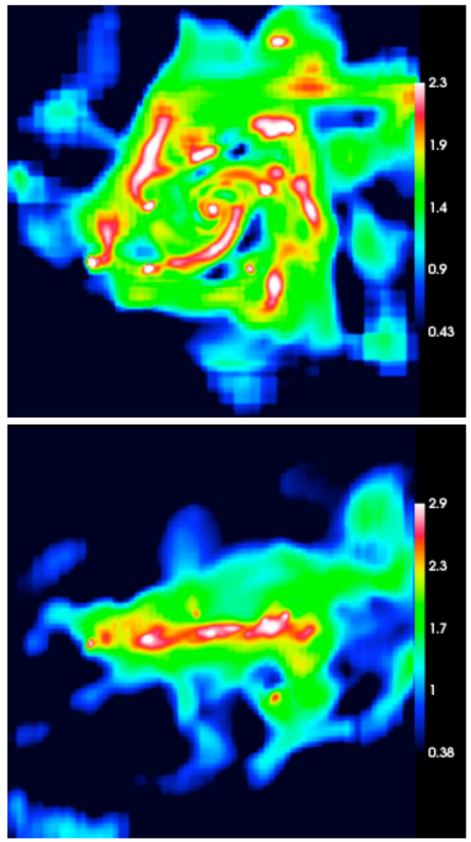


Genzel+ 2011

Disks at high redshift are gravitationally unstable



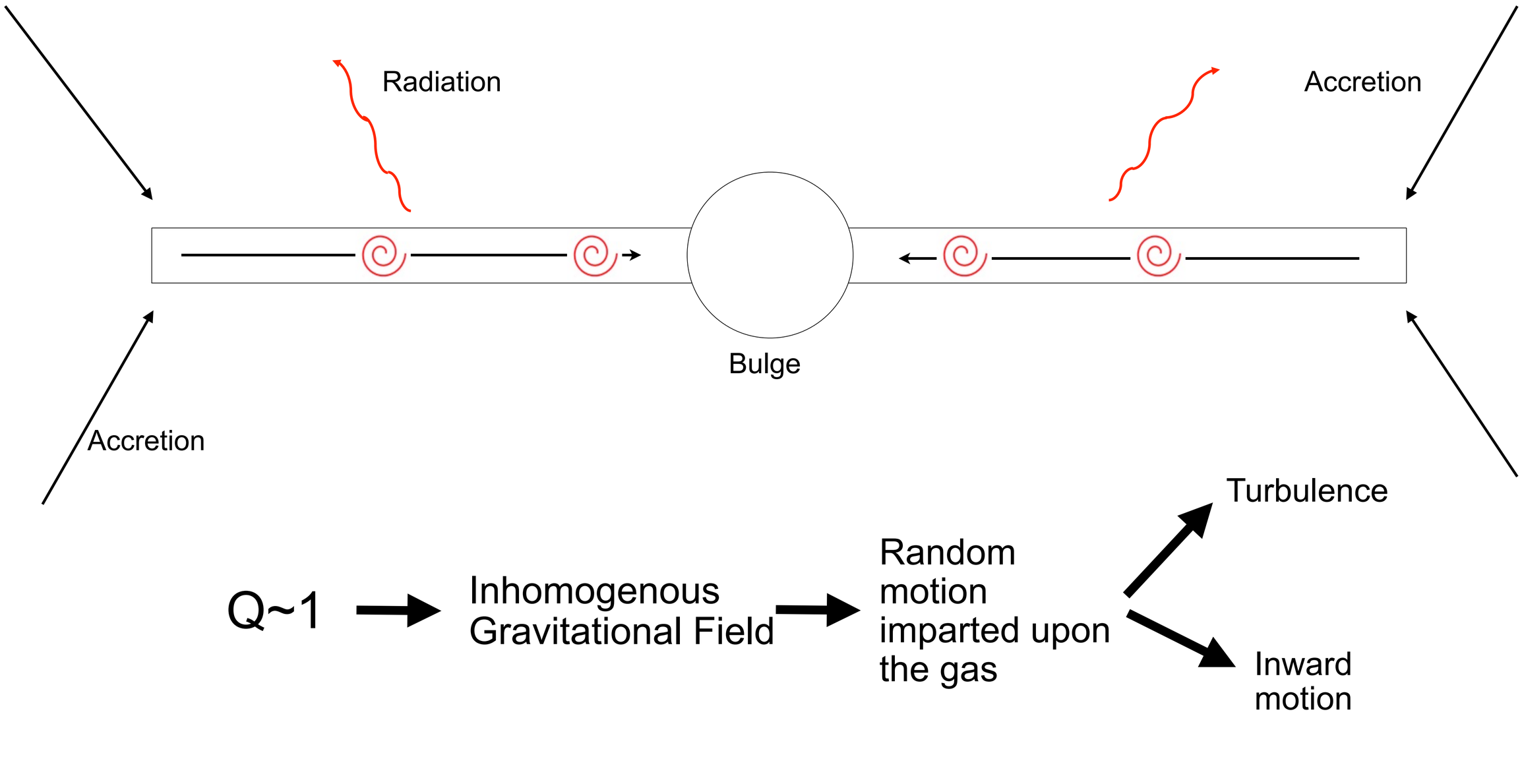
Bournaud+ 2011



Ceverino+ 2009

Galaxies are self-regulated near Q~1.

Dynamics in a Q~1 Disk



Model Overview

- Goal: Efficiently simulate disks self-regulated near Q=1 over cosmological times
- Strategy:
  - Solve hydro equations in the limit of a thin axisymmetric disk
  - Gas: $\Sigma(r,t)$ $\sigma(r,t)$ $Z(r,t)$
  - Stars: $\Sigma_*(r,t,age)$ $\sigma_*(r,t,age)$ $Z_*(r,t,age)$
  - **Set the torque~viscosity so that gas will move to maintain Q=const. if it can**

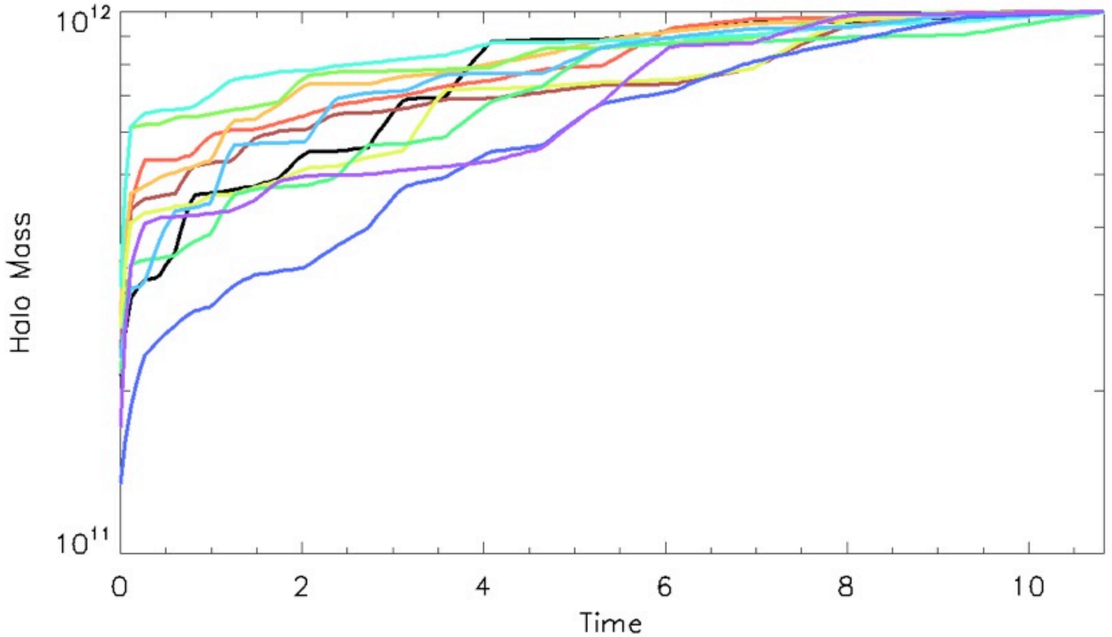
See:
Krumholz & Burkert (2010),
Forbes, Krumholz, & Burkert (2012)

A few more details

- Outflows w/ local mass loading factor = 1
- H_2-regulated star formation
- Metals generated via instantaneous recycling approximation
- Stars heat to specified Q* via spiral instabilities

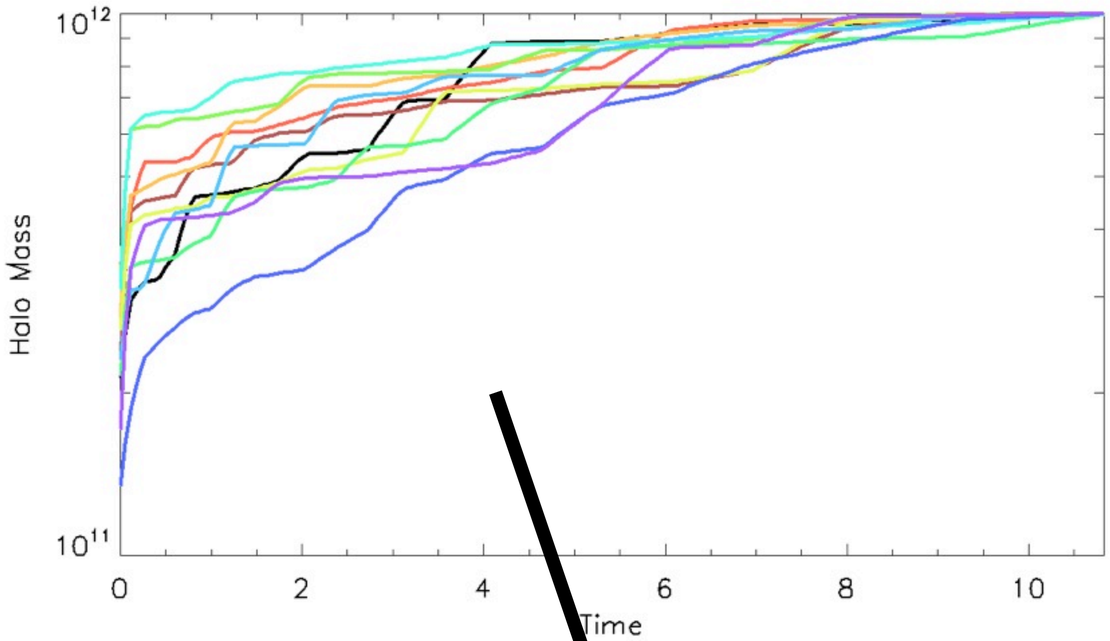
See:
Forbes, Krumholz, & Burkert (2012)

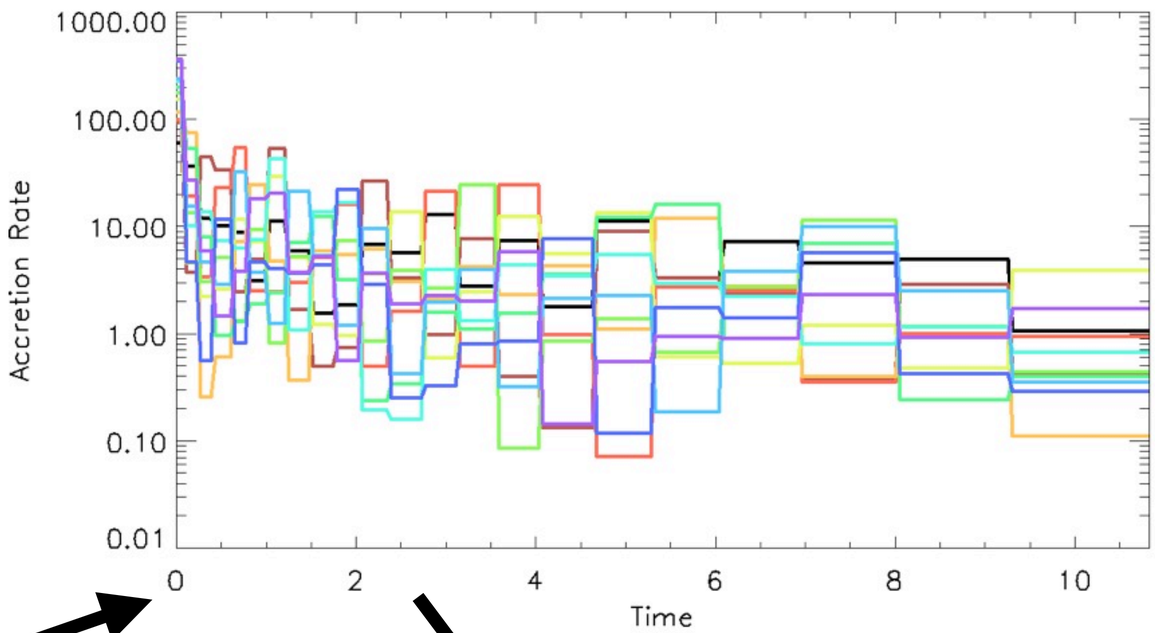
Accretion histories are generated stochastically from Neistein & Dekel (2008)



z=2 **z=0**

Accretion histories are generated stochastically from Neistein & Dekel (2008a)





differentiate, multiply by baryon fraction

multiply by efficiency(z) ~ .7 -> .35

The resulting galaxies:

Elapsed time since z=2 (Gyr)

Gas arrives from the IGM

Gas Column Density: Solar Masses / pc^2

Radius (kpc)

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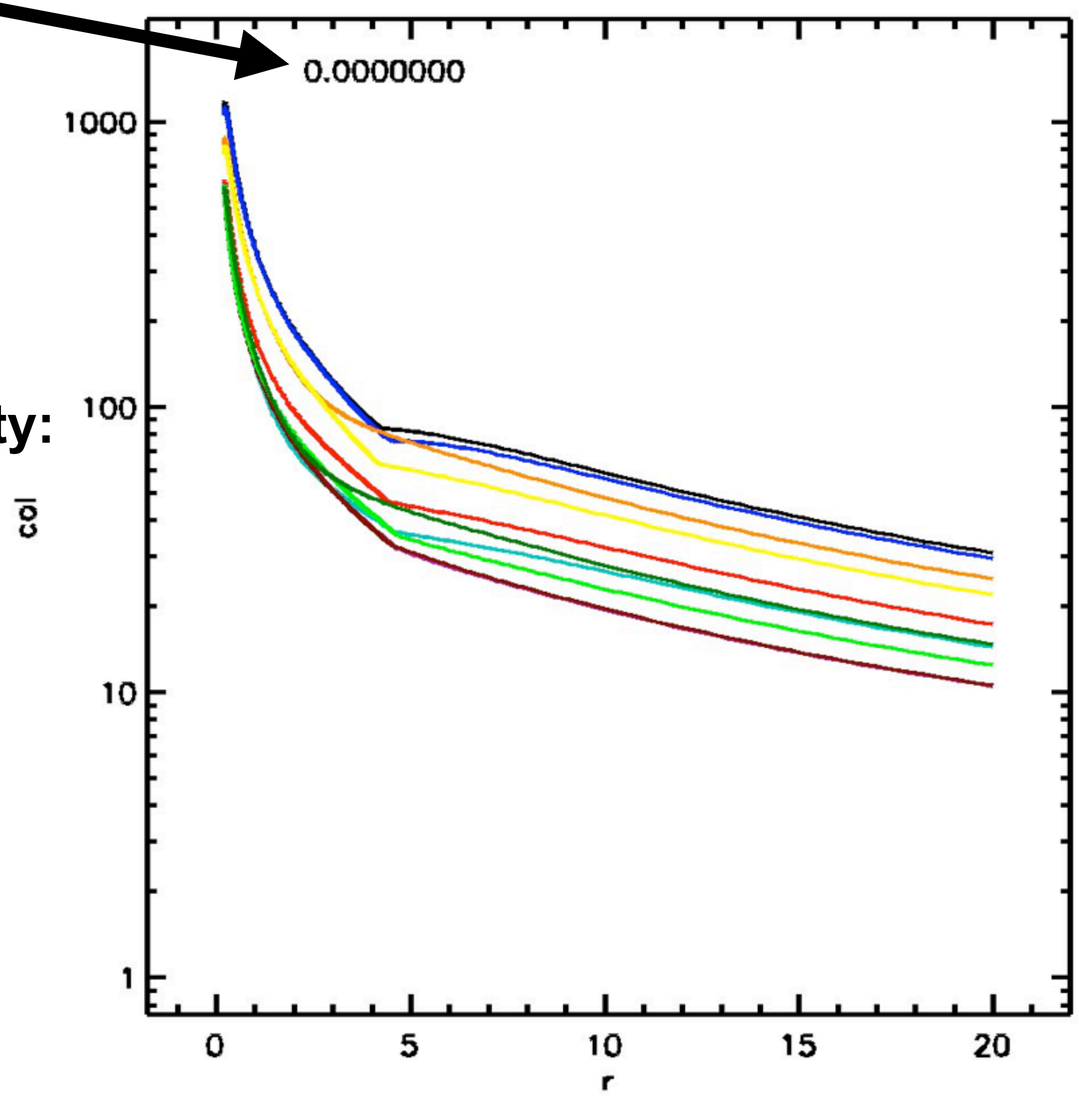
Elapsed time since z=2 (Gyr)

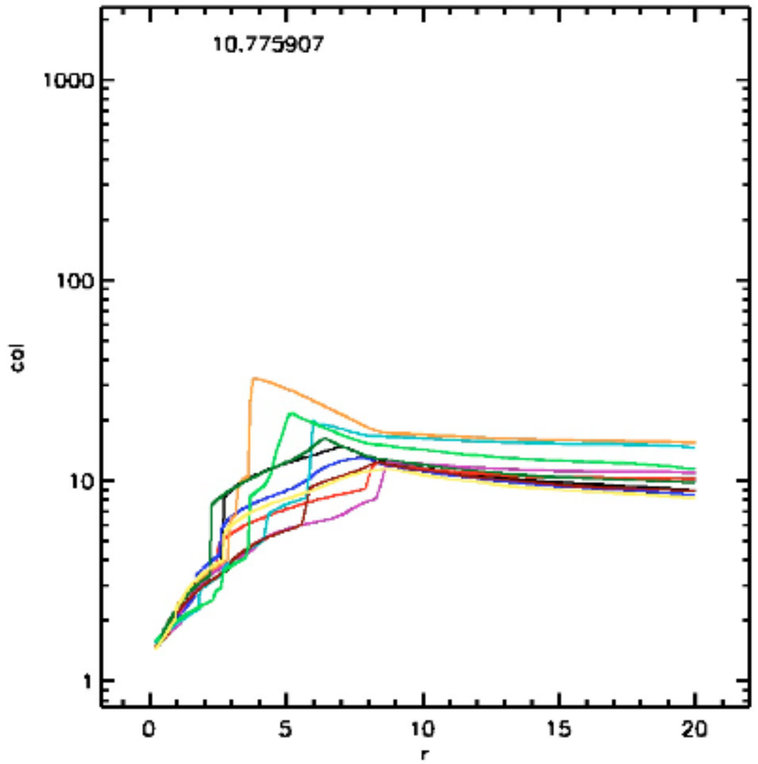


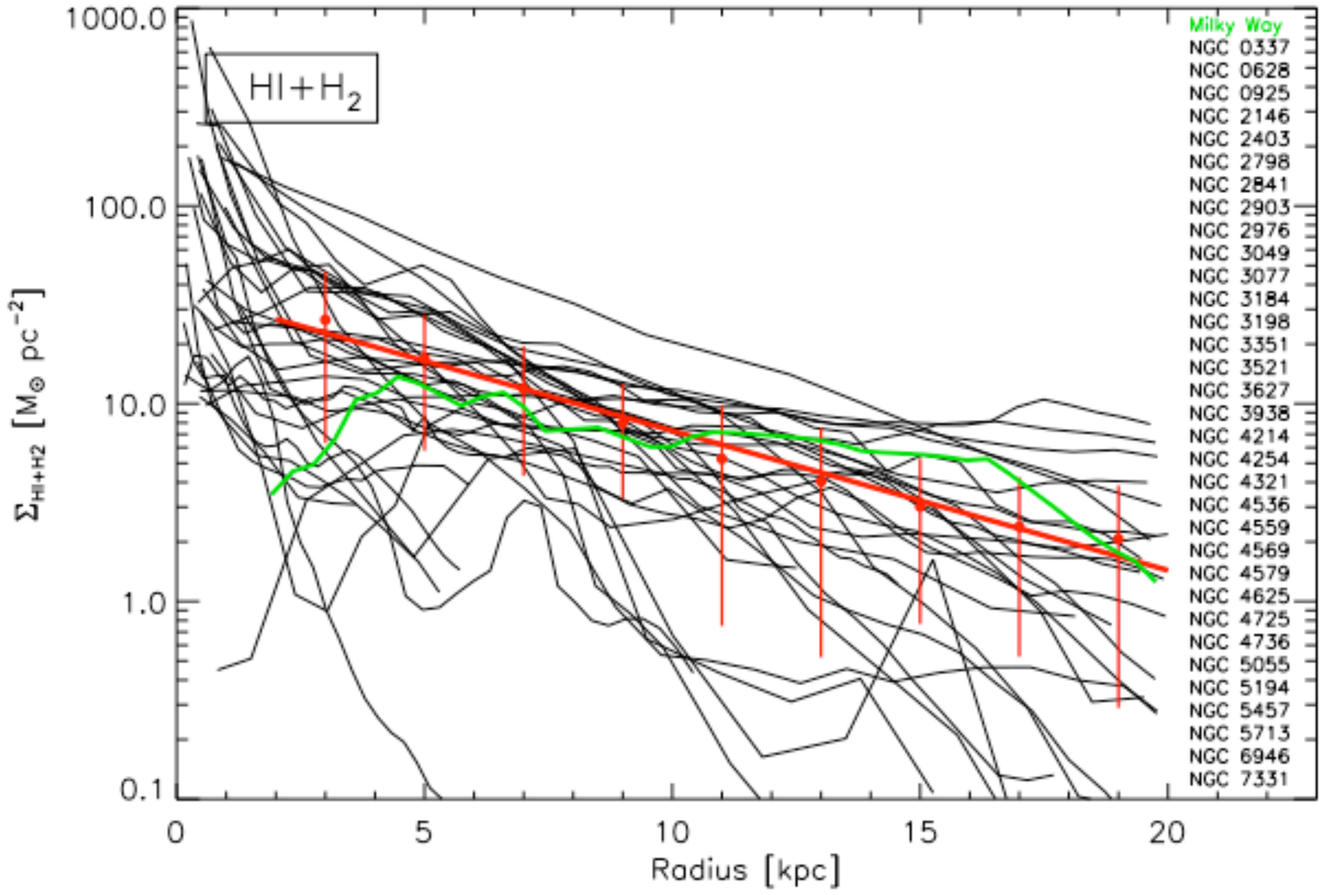
Gas arrives from the IGM

Gas Column Density: Solar Masses / pc^2

Radius (kpc)

A rough comparison with observations:





Bigiel & Blitz (2012) (last week)

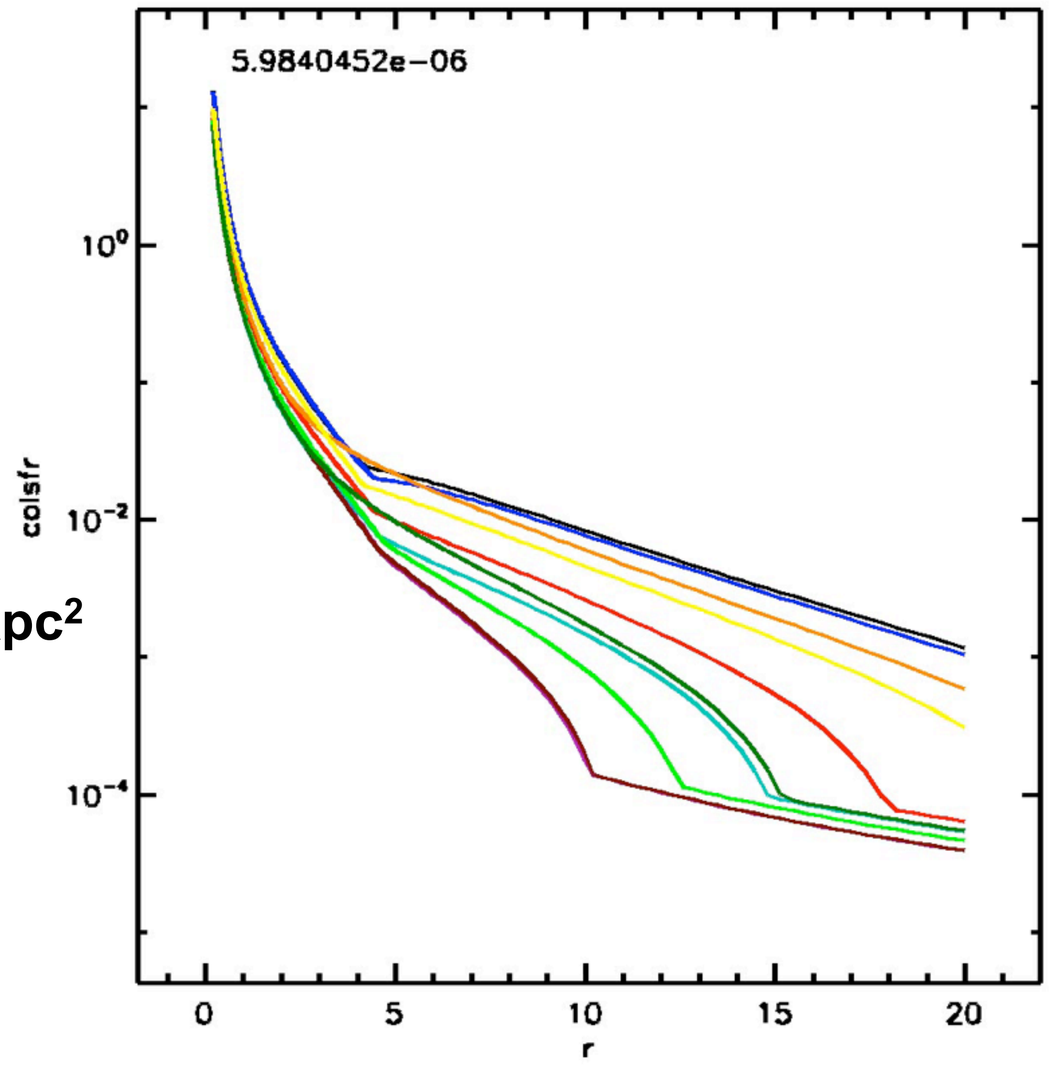
SFR Density: Highly peaked at small radii at z=2

$$\dot{\Sigma}_*^{SF} = \epsilon_{\rm ff}\,\frac{f_{H_2}\Sigma}{t_{\rm ff}}$$

SFR Density
Solar Masses / yr / kpc^2

Radius (kpc)

SFR Density: Highly peaked at small radii at z=2

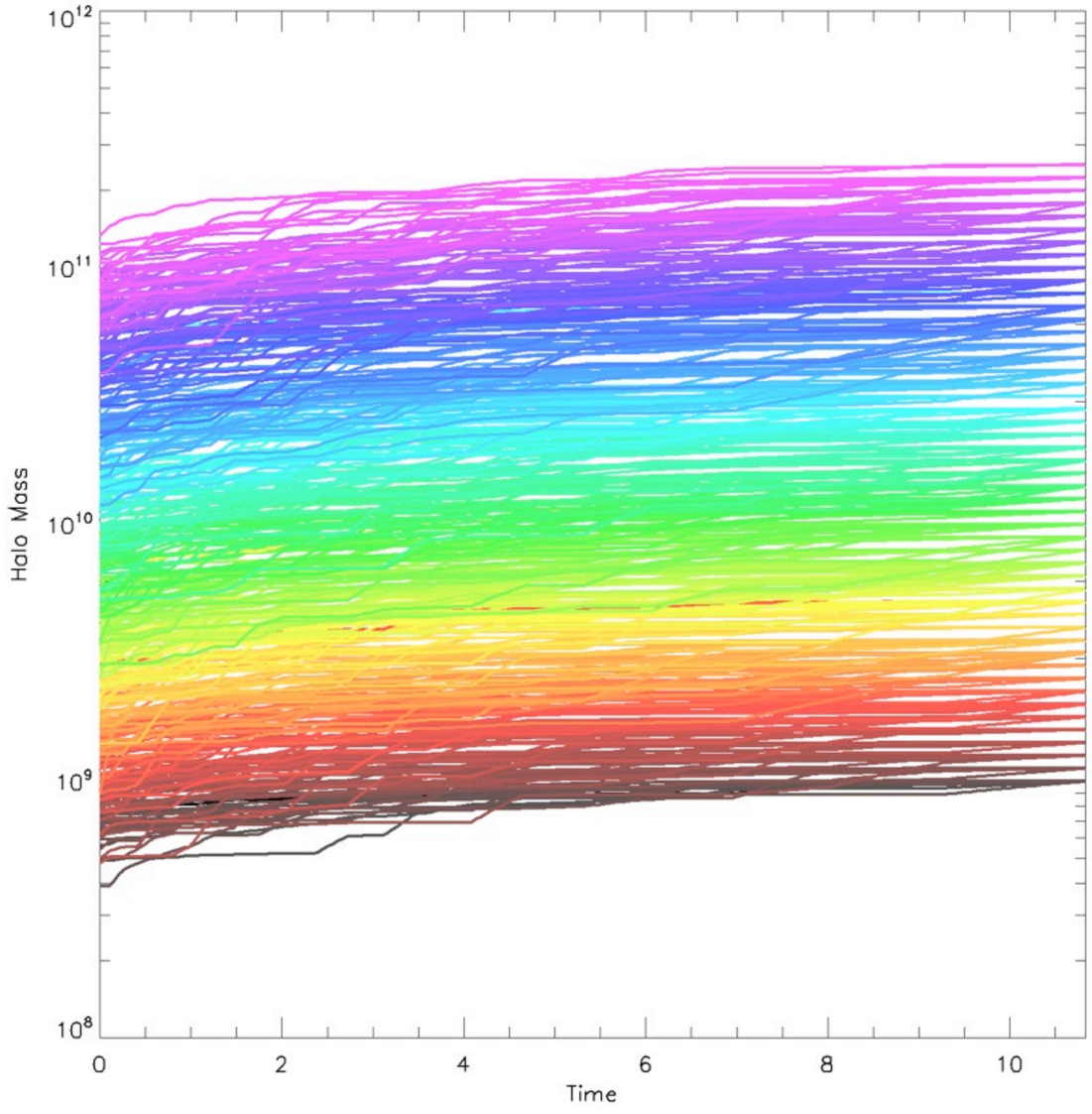


$$\dot{\Sigma}_*^{SF} = \epsilon_{\rm ff} \frac{f_{H_2}\Sigma}{t_{\rm ff}}$$

SFR Density
Solar Masses / yr / kpc^2

Radius (kpc)

A preliminary study in halo mass



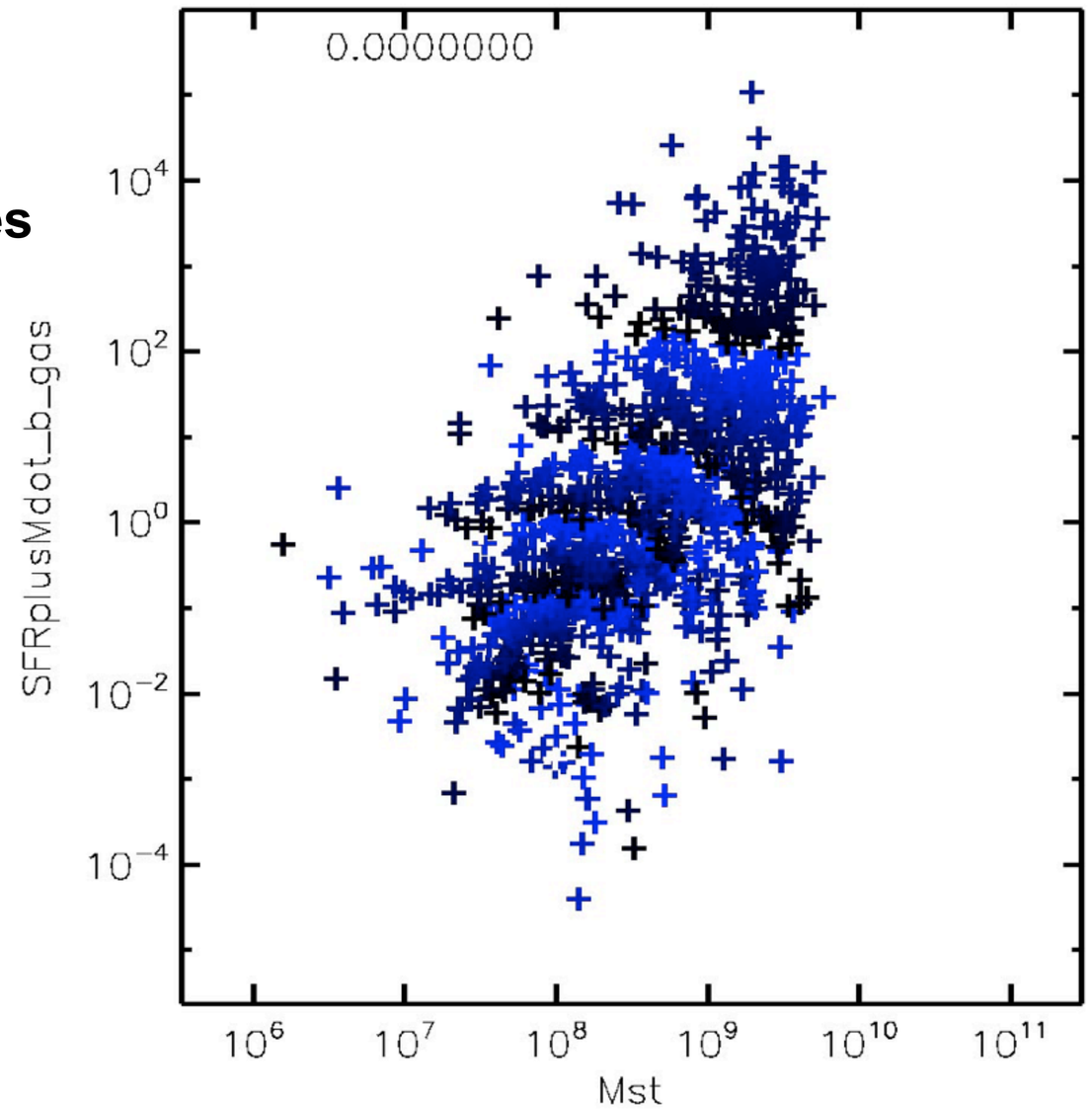
M* - SFR relation

**SFR
(Solar Masses
per year)**

**Stellar Mass
(Solar Masses)**

M* - SFR relation

SFR (Solar Masses per year)



Stellar Mass (Solar Masses)

How much does a galaxy know about its accretion rate?

SFR (Solar Masses per year)

Accretion rate (Solar Masses per year)

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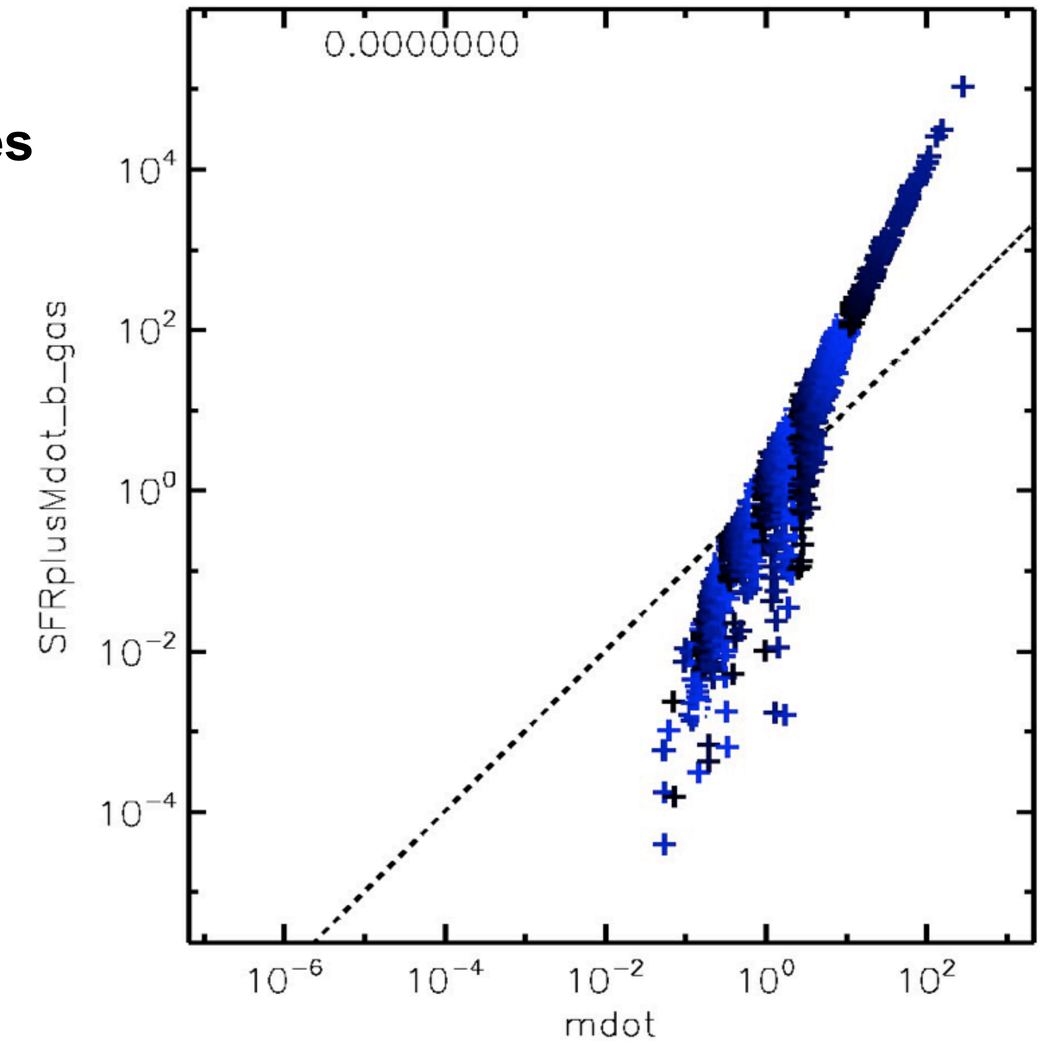
SFR (Solar Masses per year)



Accretion rate (Solar Masses per year)

To conclude...

- Simulations performed using GIDGET, the **G**ravitational **I**nstability-**D**ominated **G**alaxy **E**volution **T**ool, available here:

http://www.ucolick.org/~jforbes/gidget.html

To conclude...

- Simulations performed using GIDGET, the **G**ravitational **I**nstability-**D**ominated **G**alaxy **E**volution **T**ool, available here:

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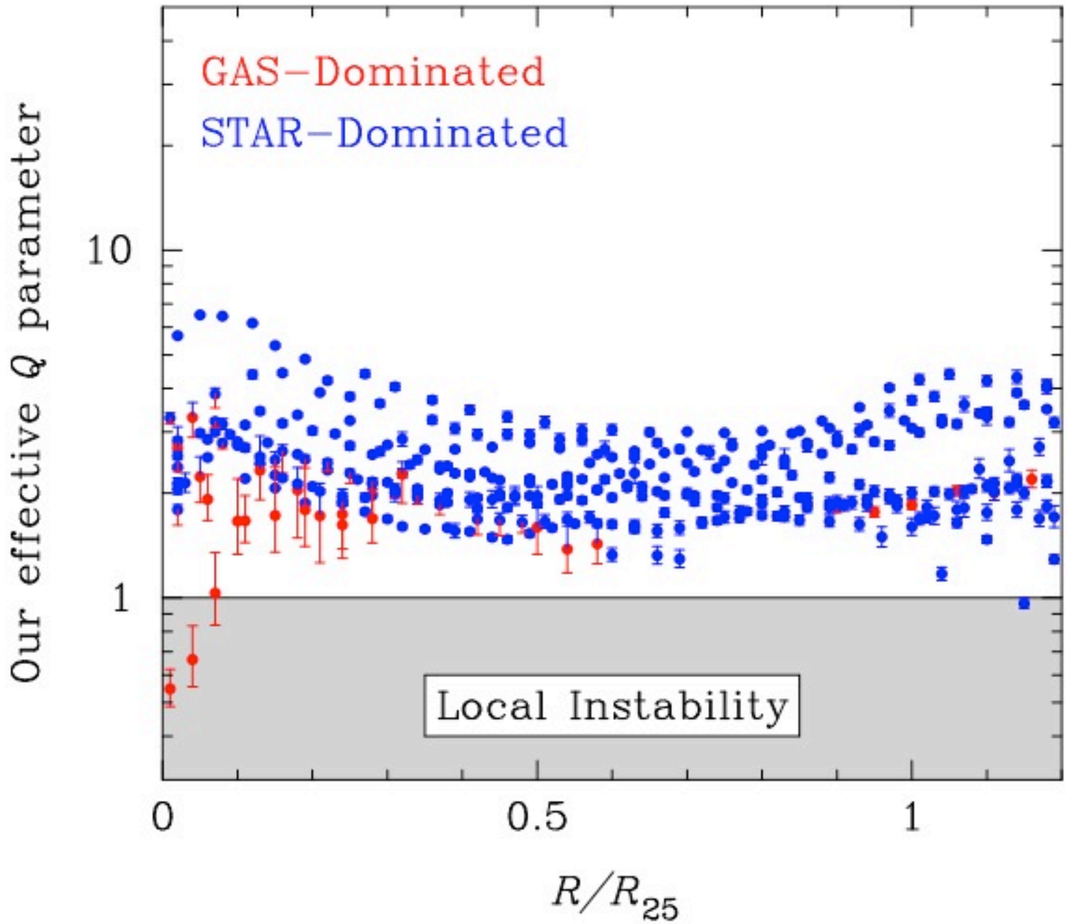
- Galaxies can be **centrally quenched** without AGN, mergers, or bars.
- The intrinsic **scatter in the SFR-M*** relation may be explained by variable accretion rates + physics of gravitational instability

Is Q=1 in nearby galaxies?



Romeo and Wiegert (2011)

Stellar ages (caution: no outward stellar migration)

Mass-weighted age (yrs)

Radius (kpc)

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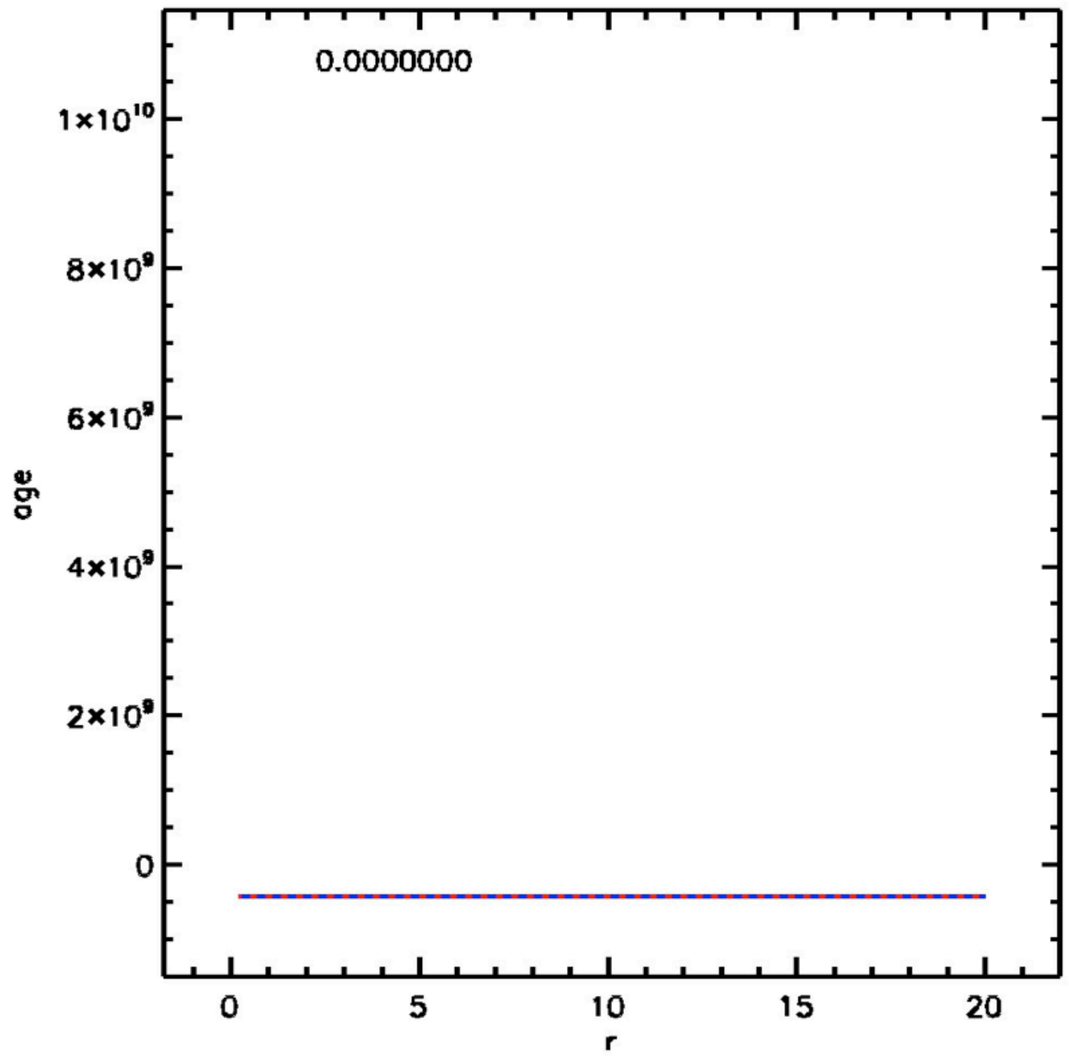


Radius (kpc)

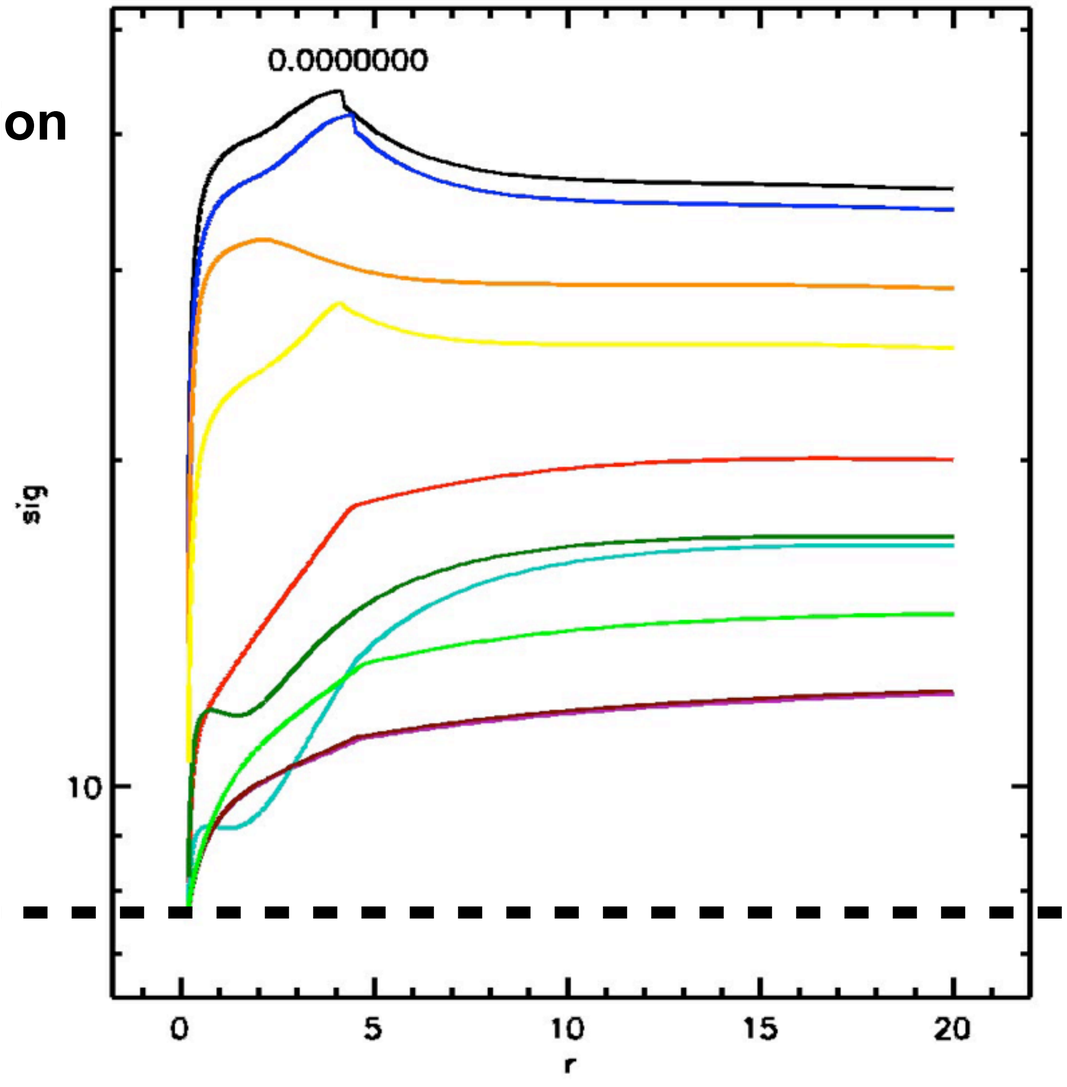
Velocity Dispersions

Velocity Dispersion (km/s)

7000 K

Velocity Dispersions

Velocity Dispersion (km/s)



7000 K

Stellar Column Density

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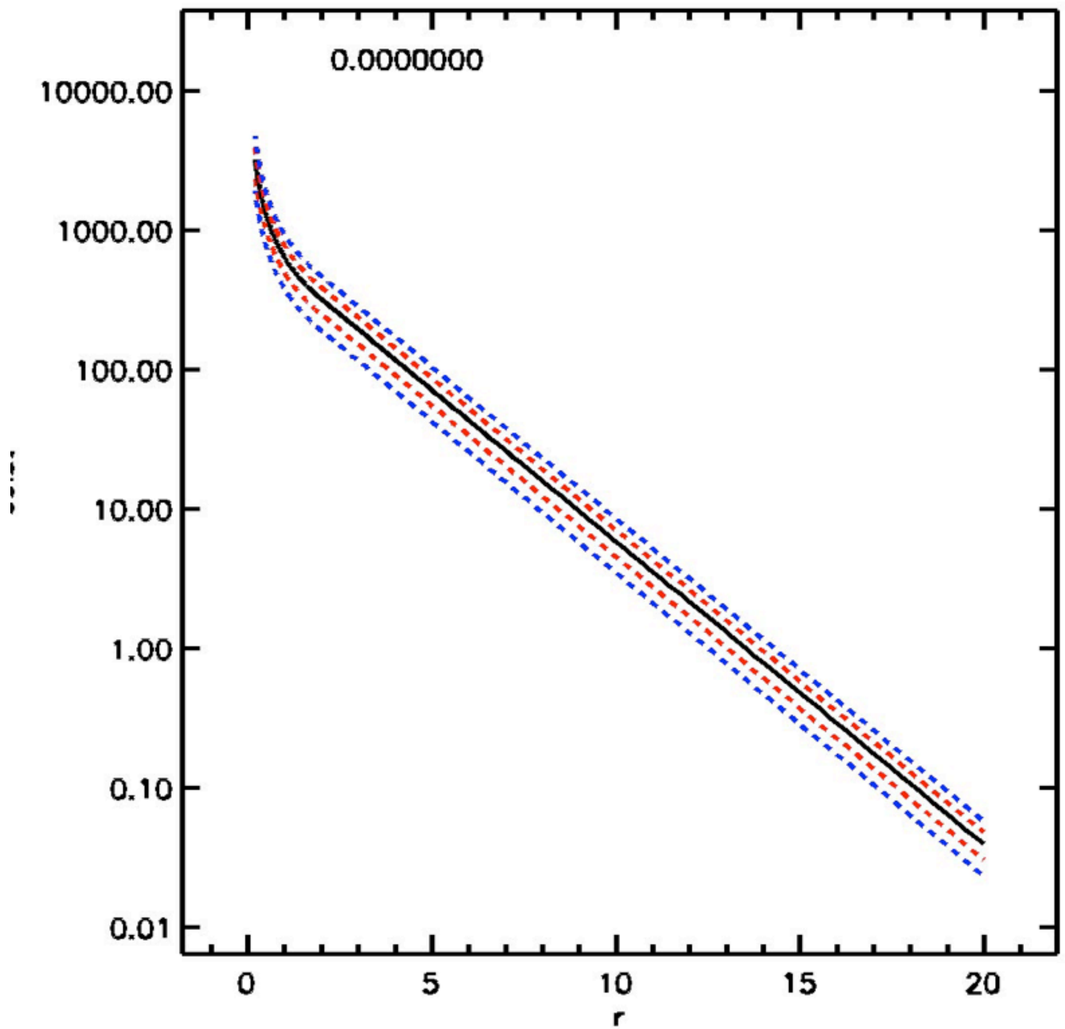

H2 Fraction

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