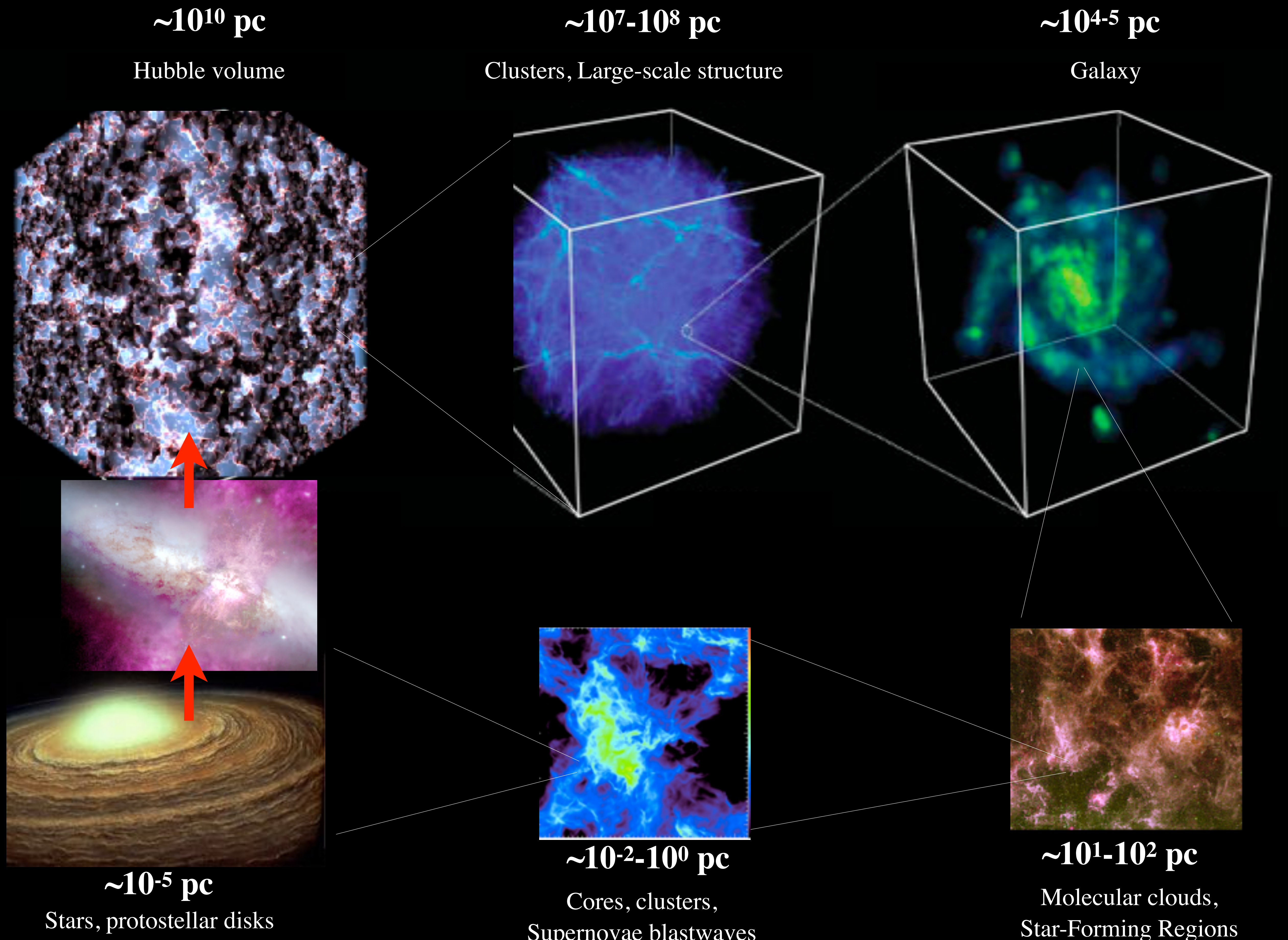
Updates on FIRE & other work



Dust: Actual *Micro*-Physics

The Setup:

SQUIRE & HOPKINS ’17 (SH; arXiv:1706.05020)

Gas equations = (anything that supports a linear mode)

Dust equations = continuity + momentum:

$$\frac{d\mathbf{v}_{\rm dust}}{dt} = -\mathbf{M}_{\rm coupling} \cdot (\mathbf{v}_{\rm dust} - \mathbf{v}_{\rm gas}) + \mathbf{a}_{\rm other}(\ldots)$$

Arbitrary operator

e.g.

$$\frac{d\mathbf{v}_{\rm dust}}{dt} = -\frac{\mathbf{v}_{\rm dust} - \mathbf{v}_{\rm gas}}{t_s(\ldots)} + \mathbf{a}_{\rm other}(\ldots)$$

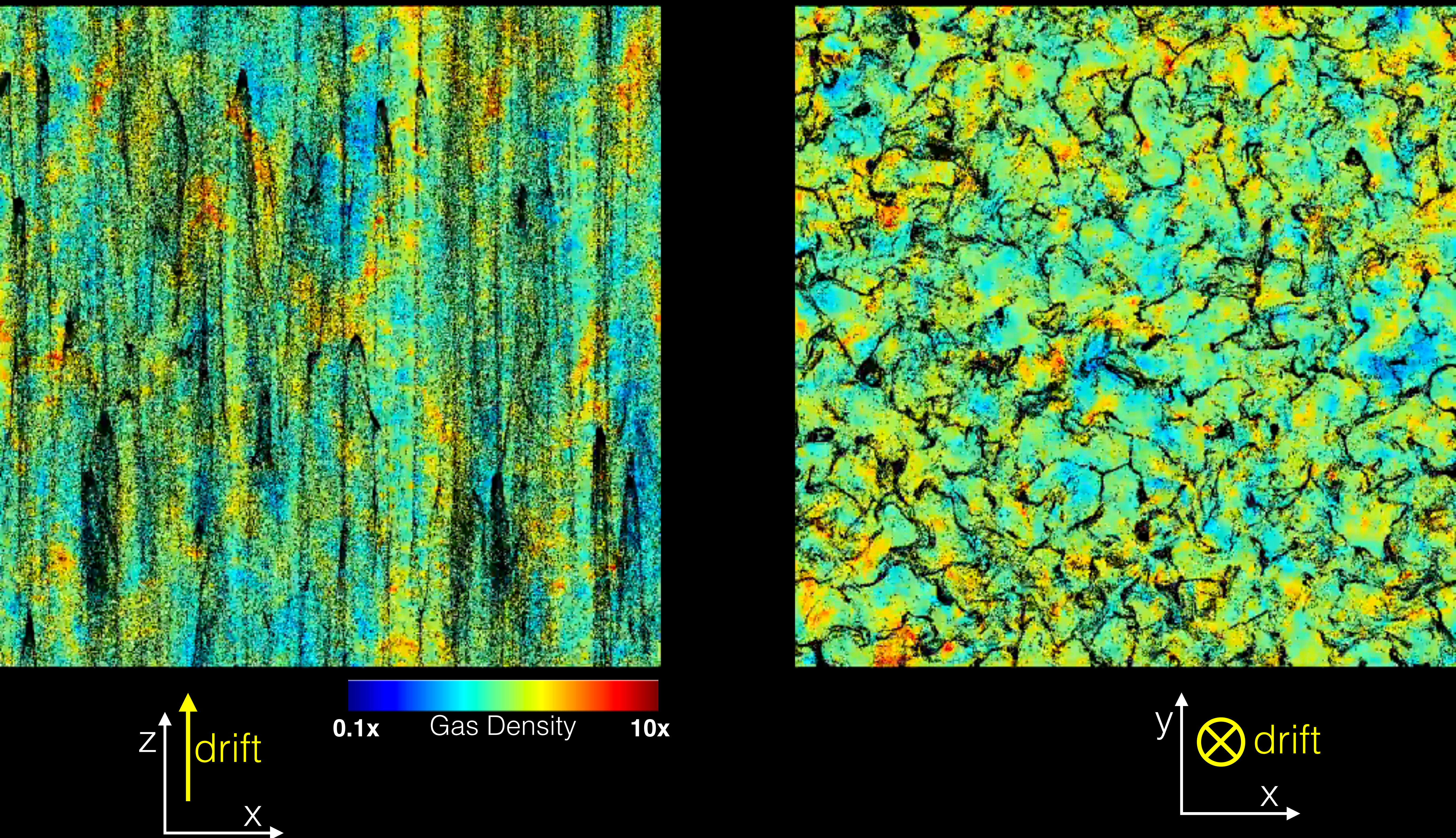
Stopping/drag time

Jono Squire

What Does This Look Like?
(TALK TO ME ABOUT NUMBERS)

$|\mathbf{w}|_{\rm drift} \approx 10\, c_s$

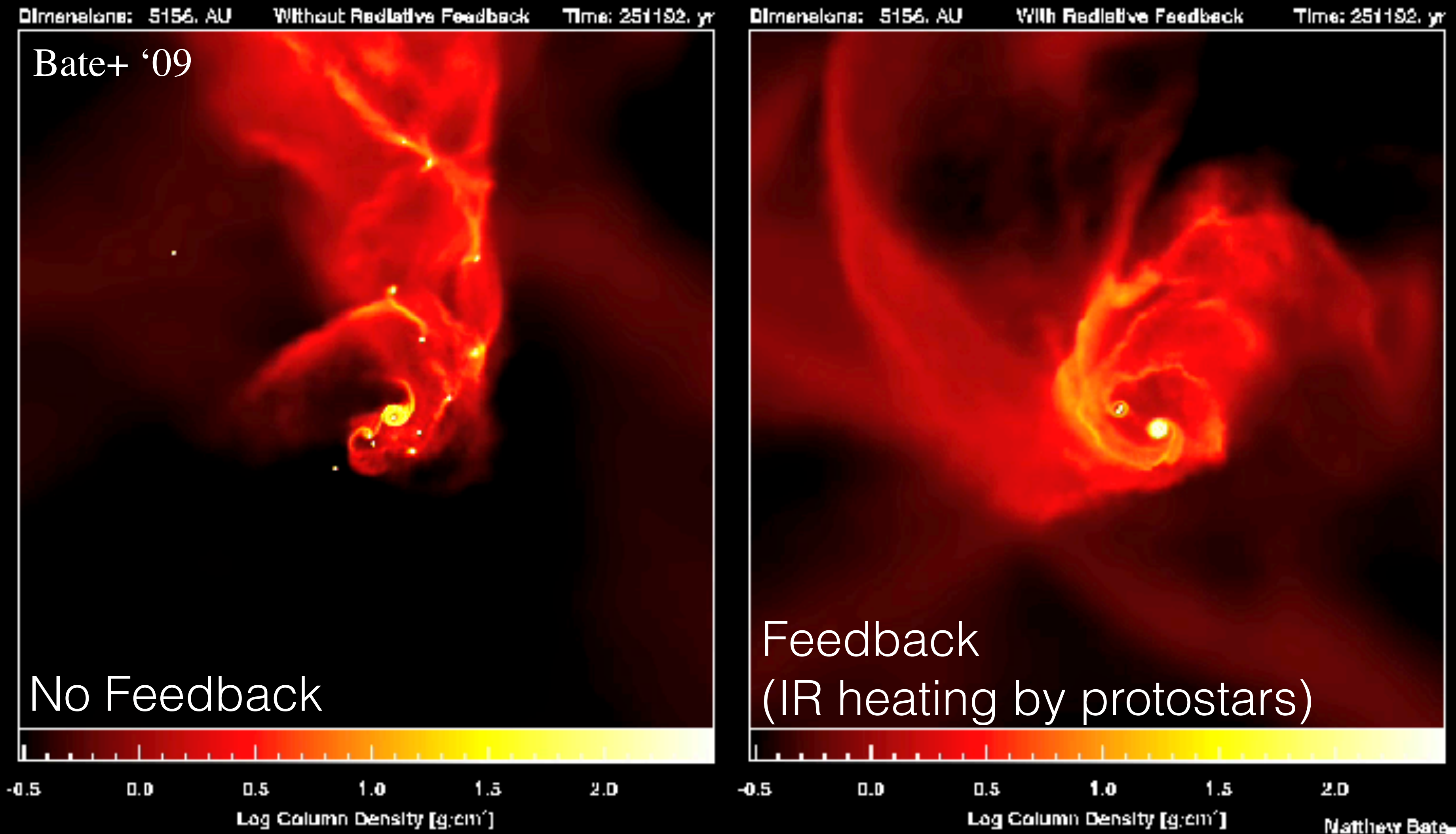
$L_{\rm box} \sim 100\, c_s \langle t_s \rangle$ $\Delta t \sim 80\, \langle t_s \rangle$



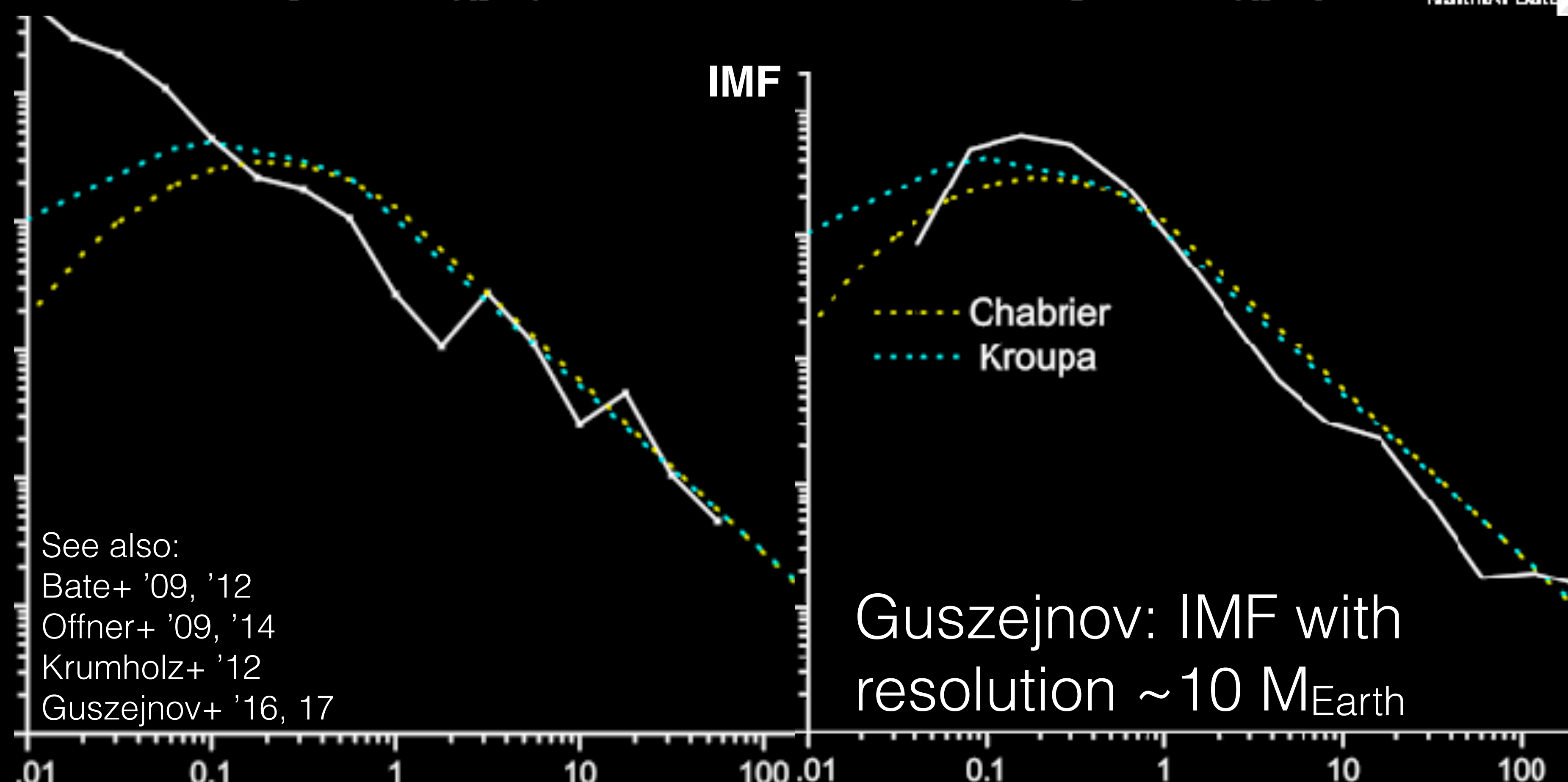
The IMF & Sub-Cloud Scales

Feedback vs. Gravity

Guszejnov, Hopkins, & Krumholz
2015, 2016, 2017

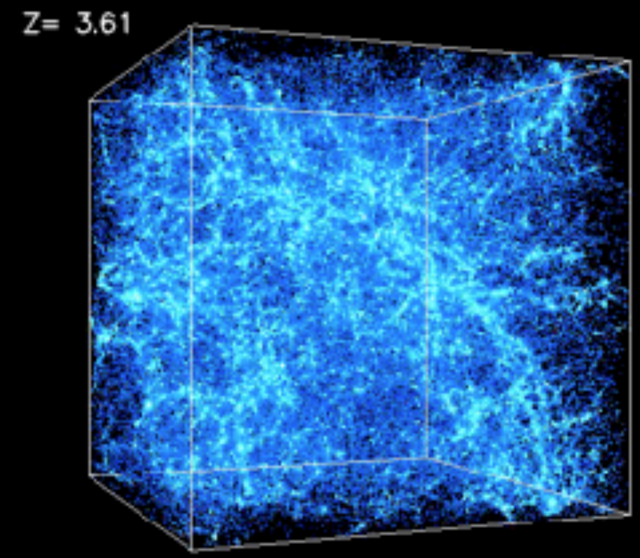


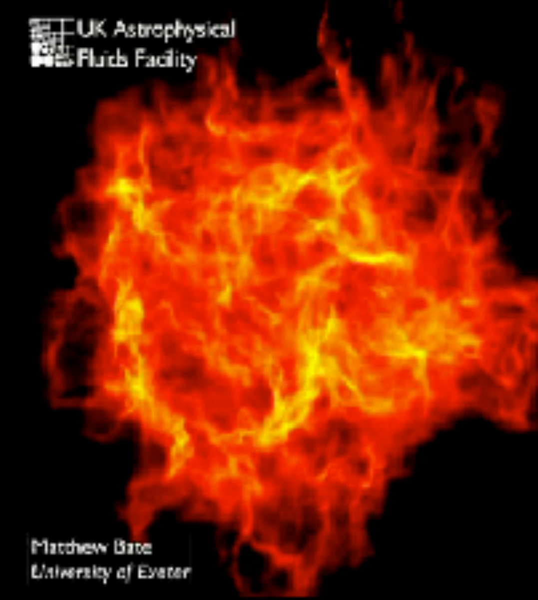
EVERY VARIABLE-IMF MODEL USED EXTRA-GALACTICALLY IS WRONG
(arXiv:1702.04431)



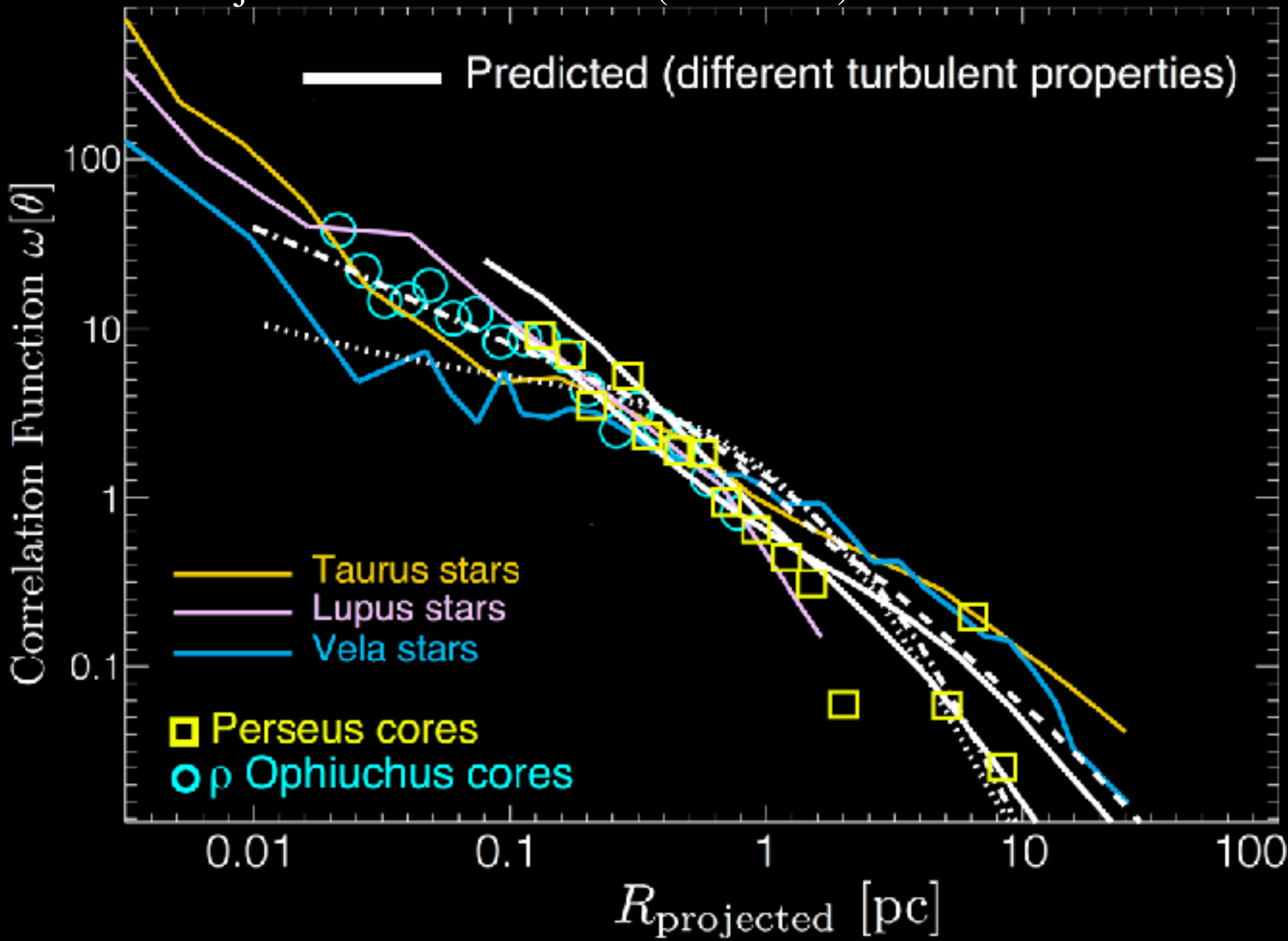
Why Is Star Formation Clustered?

INEVITABLE IN GRAVITATIONAL COLLAPSE





Guszejnov: arXiv:1610.00772 (+PFH '12)



Universal

(Guszejnov: 1707.05799):

Stars
Cores
Clumps
GMCs
Star clusters
Galaxies

$$\xi_{\rm 3d} \propto r^{-2}$$

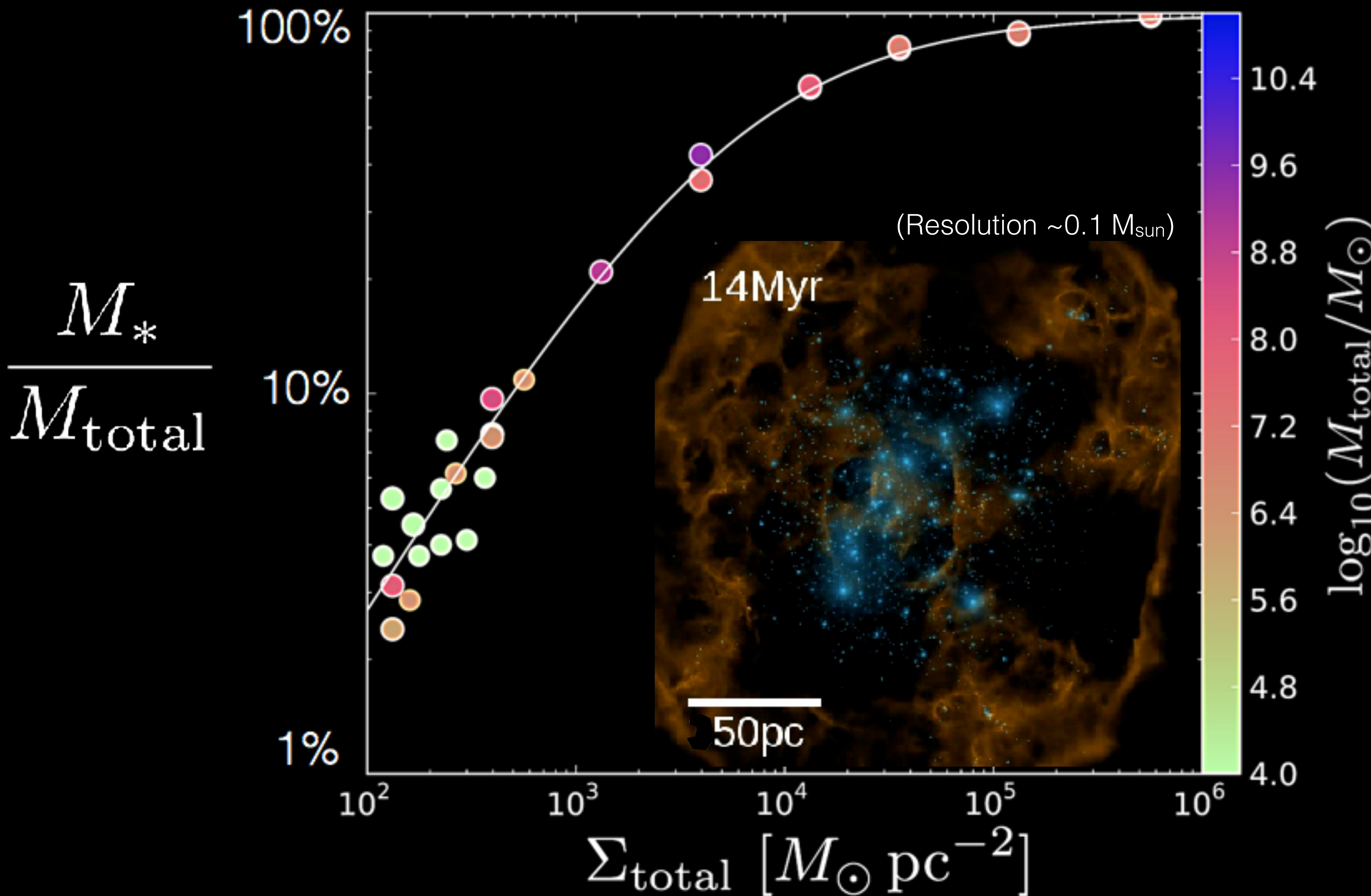
$$(\omega(\theta) \propto \theta^{-1})$$

GMC & Star Cluster Scales

What Determines Cloud Star Formation Efficiencies?

FEEDBACK VS. GRAVITY

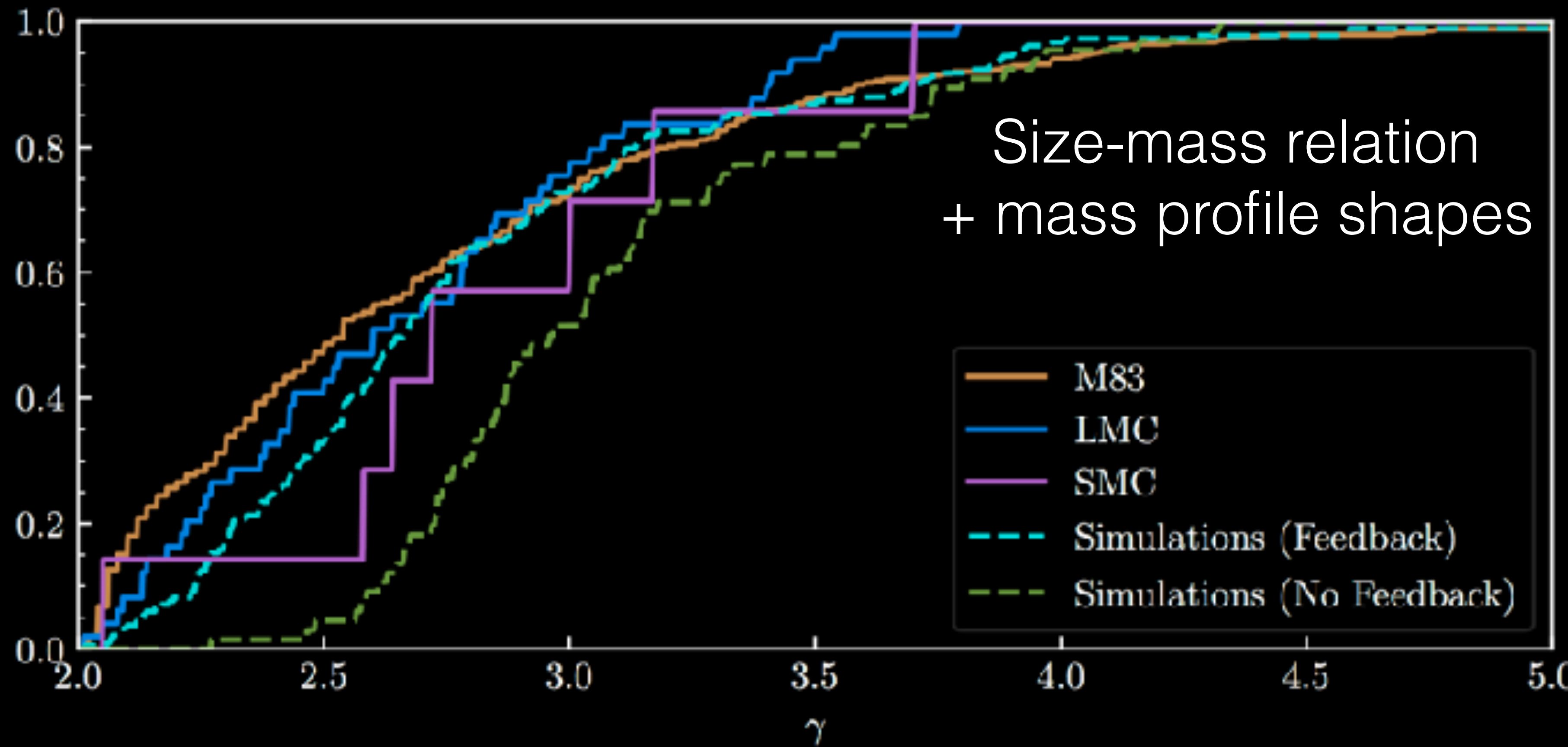
Mike Grudic (arXiv: 1612.05635)



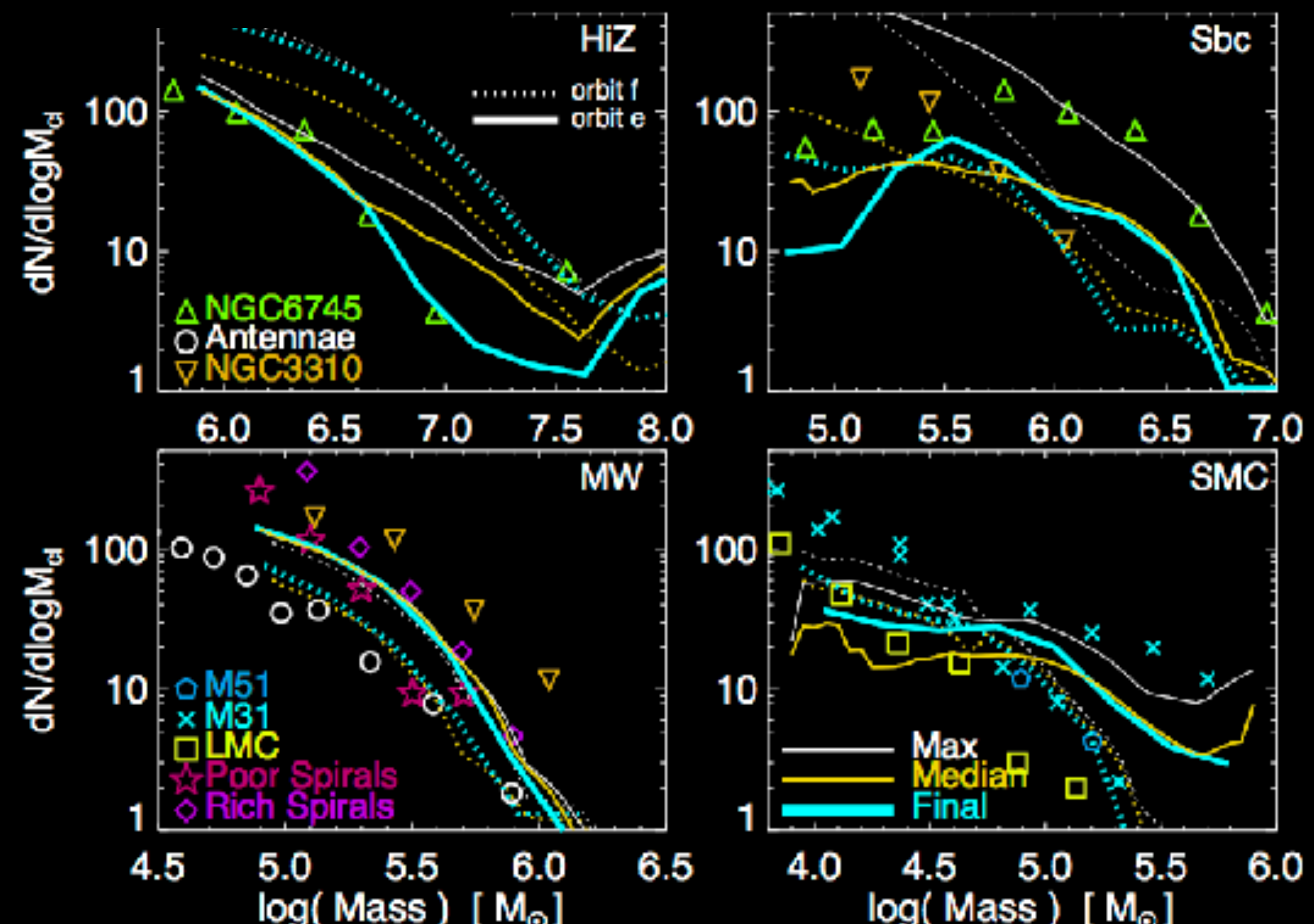
$${\rm Gravity} \sim \frac{G\, M_{\rm tot}\, M_{\rm gas}}{R^2} \propto M_{\rm tot}\, \Sigma_{\rm gas} \quad \text{vs.} \quad {\rm Feedback} \sim \frac{\rm Momentum}{\rm Time} \propto (\ldots)\, M_*$$

Mike Grudic
(in prep)

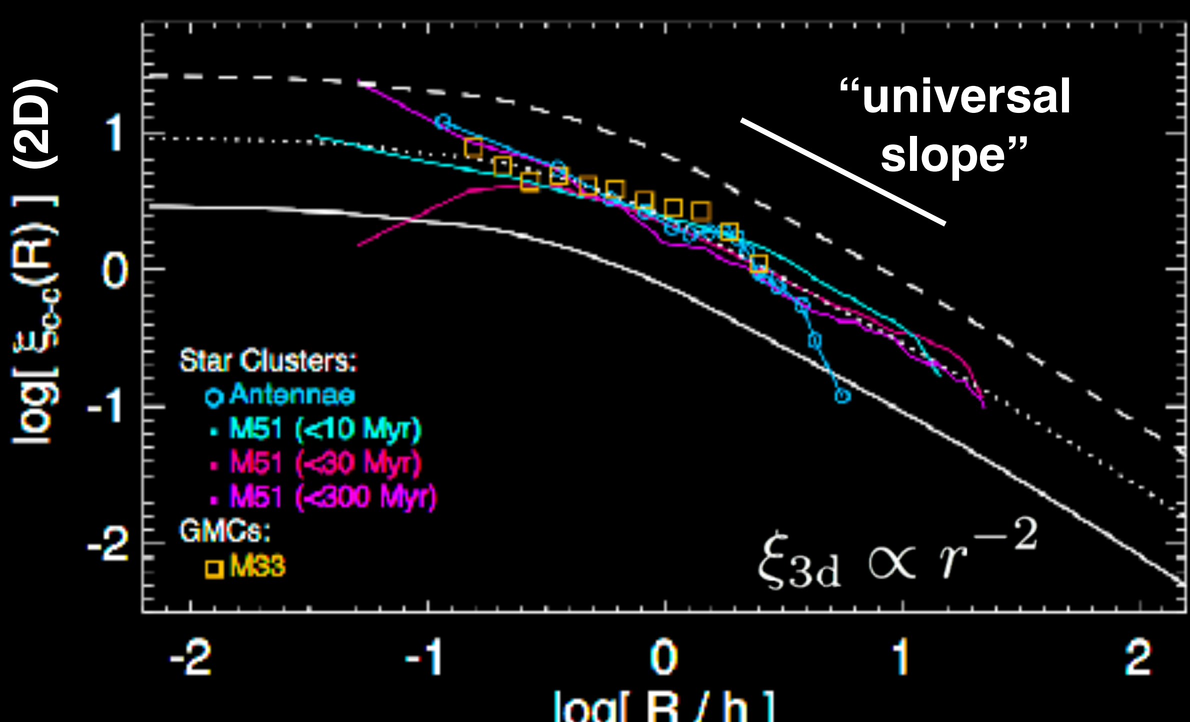
Size-mass relation
+ mass profile shapes

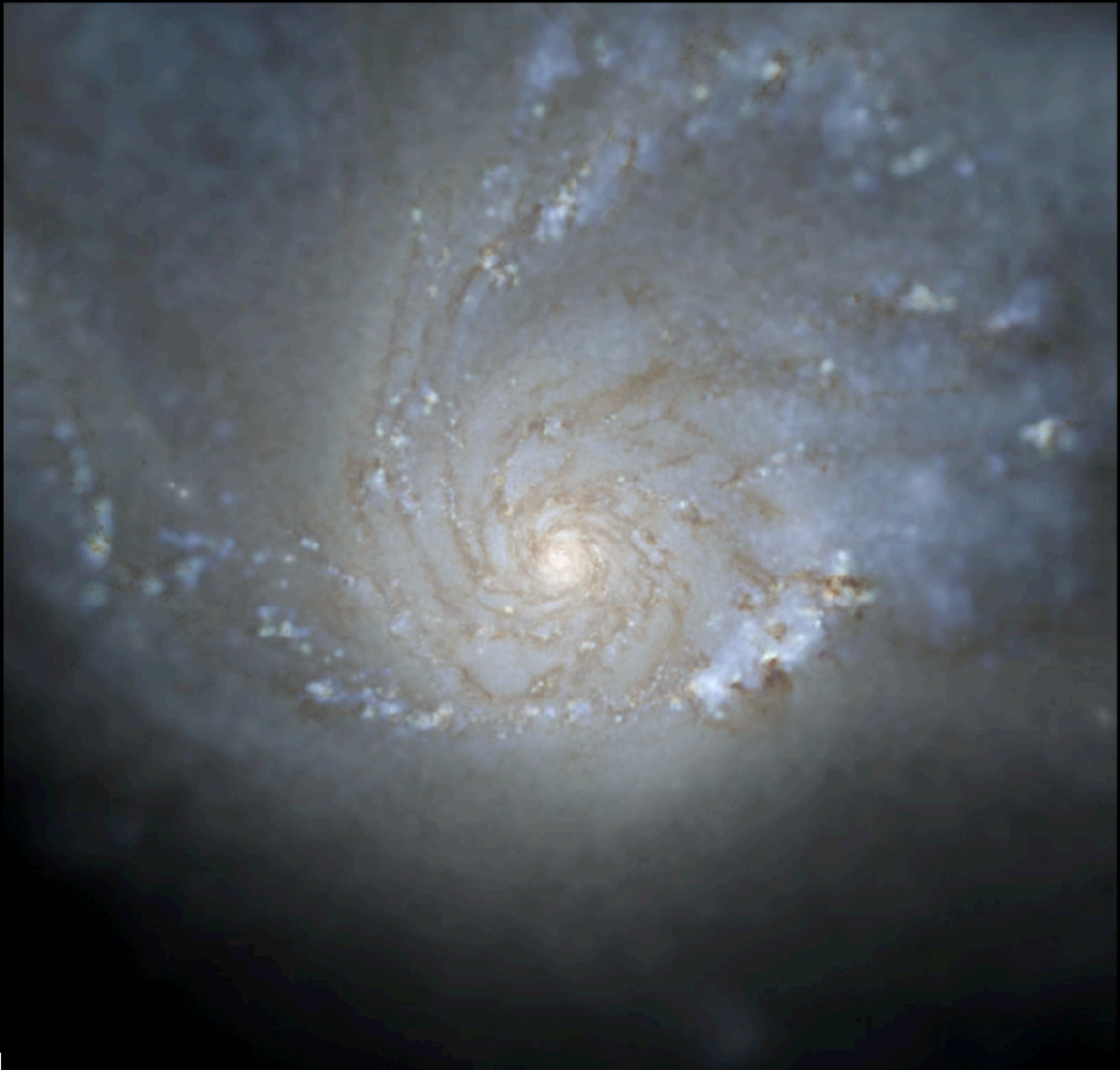


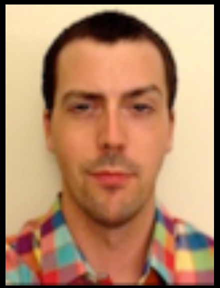
Mass functions (~M^{-2})
vs. environment



Correlation functions







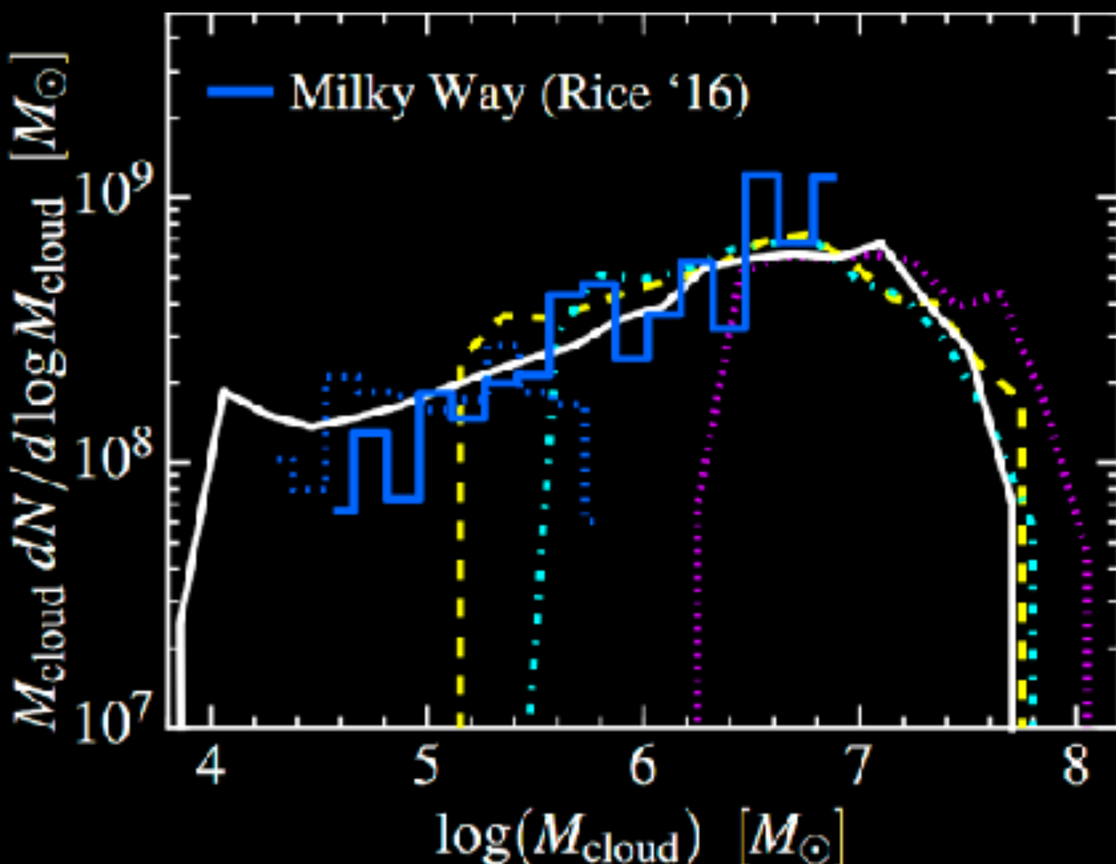
Andrew Wetzel
(arXiv:1602.05957)

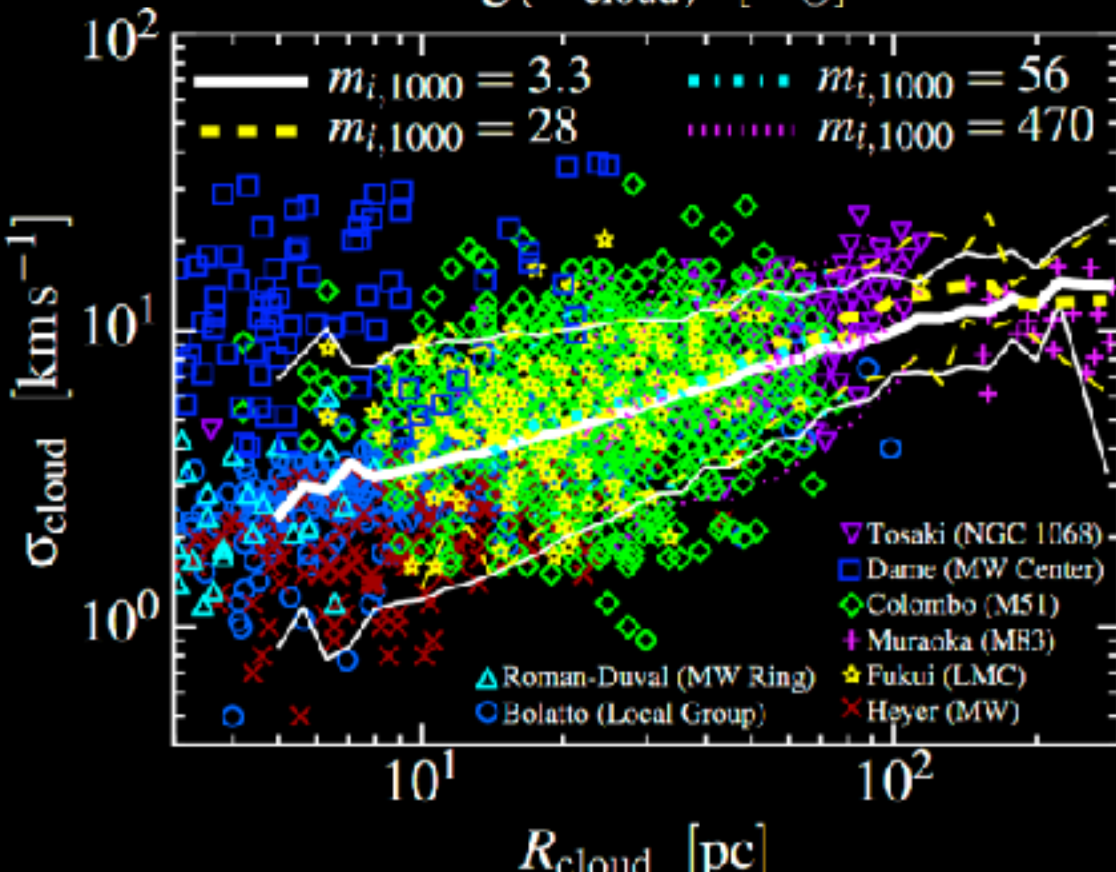
“Triple Latte” (A. Wetzel): Cosmological MW with ~800 M_{sun} , sub-pc resolution

GMCs: Turbulence+Gravity+Feedback

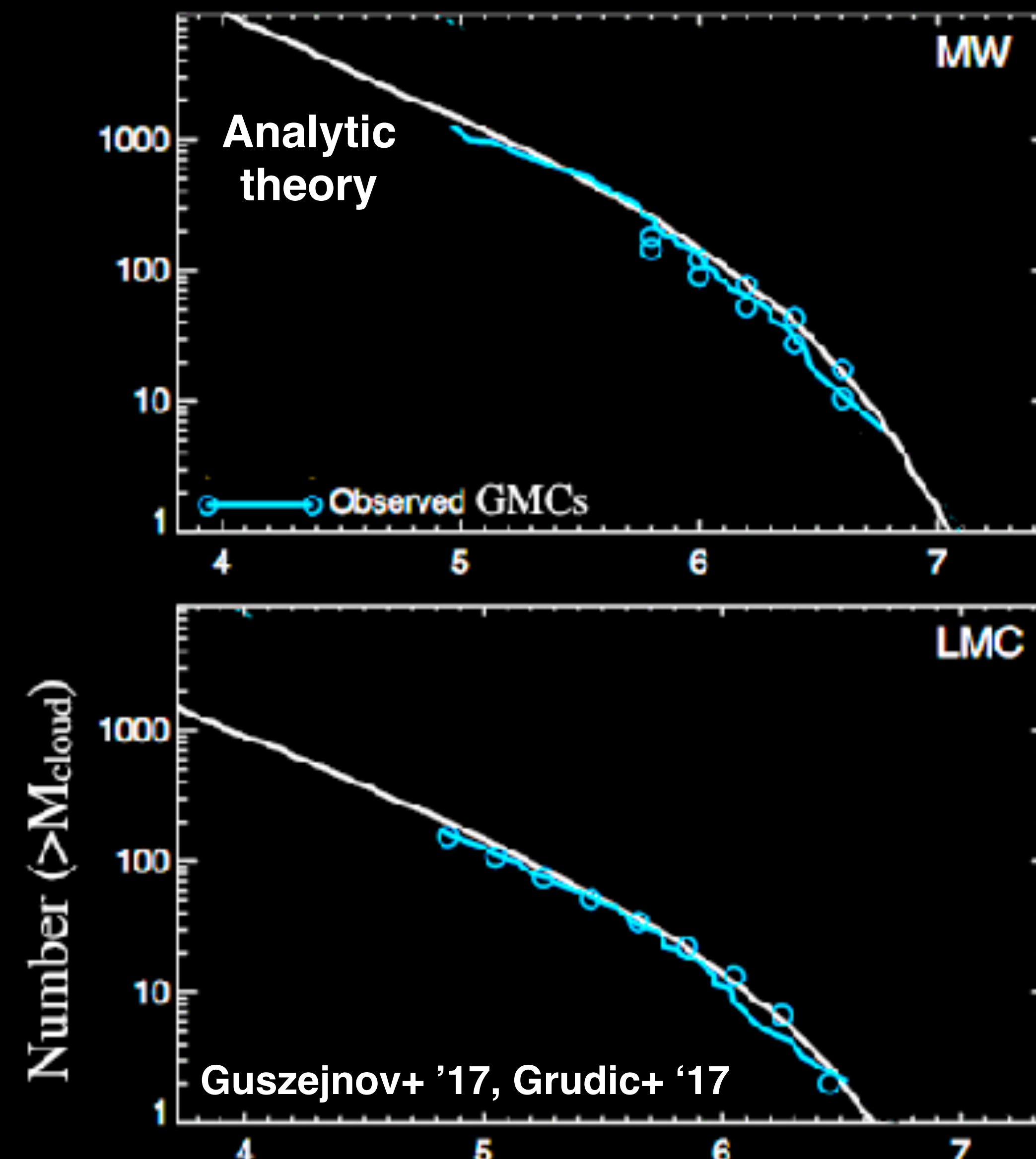
RESOLVING "TOP SCALE" OF FRAGMENTATION

FIRE simulations: Guszejnov (arXiv:1702.04431)

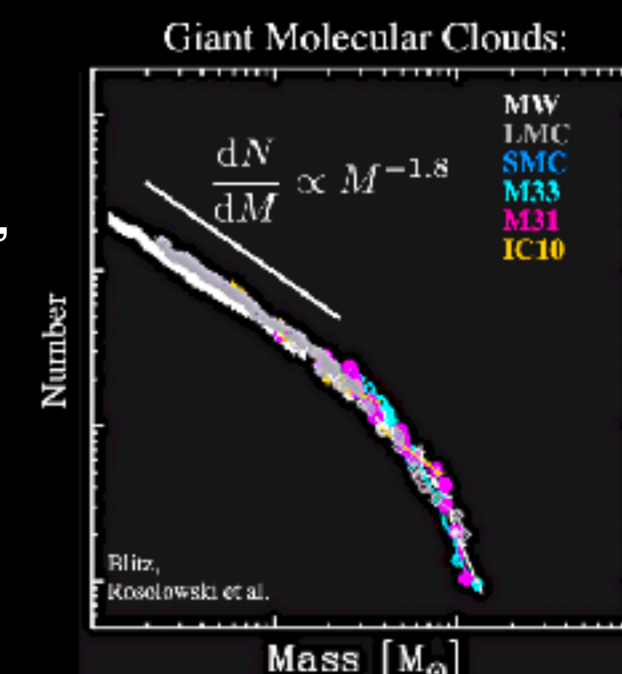




(+cloud lifetimes, SF efficiencies, virial parameters)

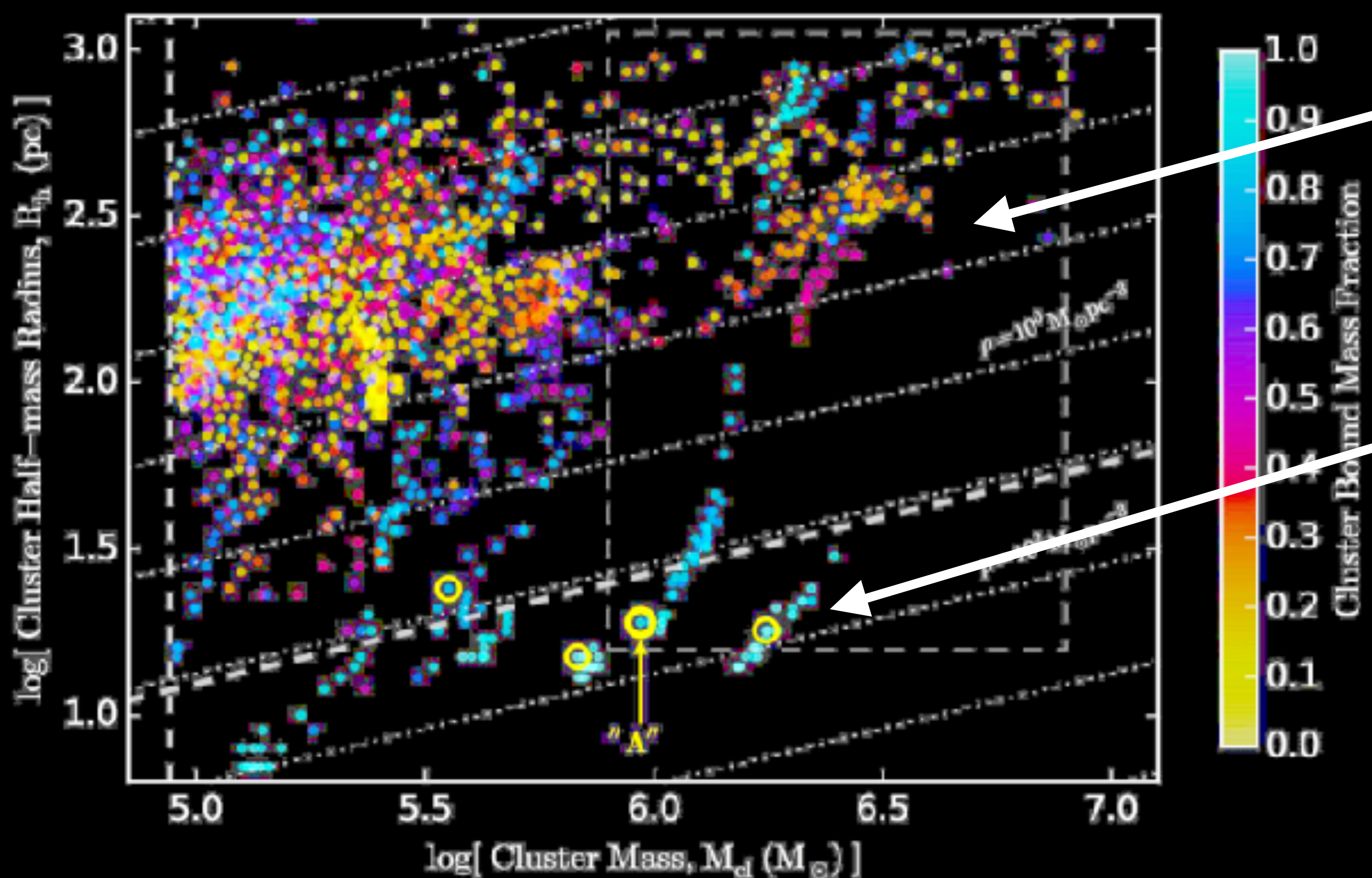


"Universal" Mass Function (GMCs, star clusters, and more!)



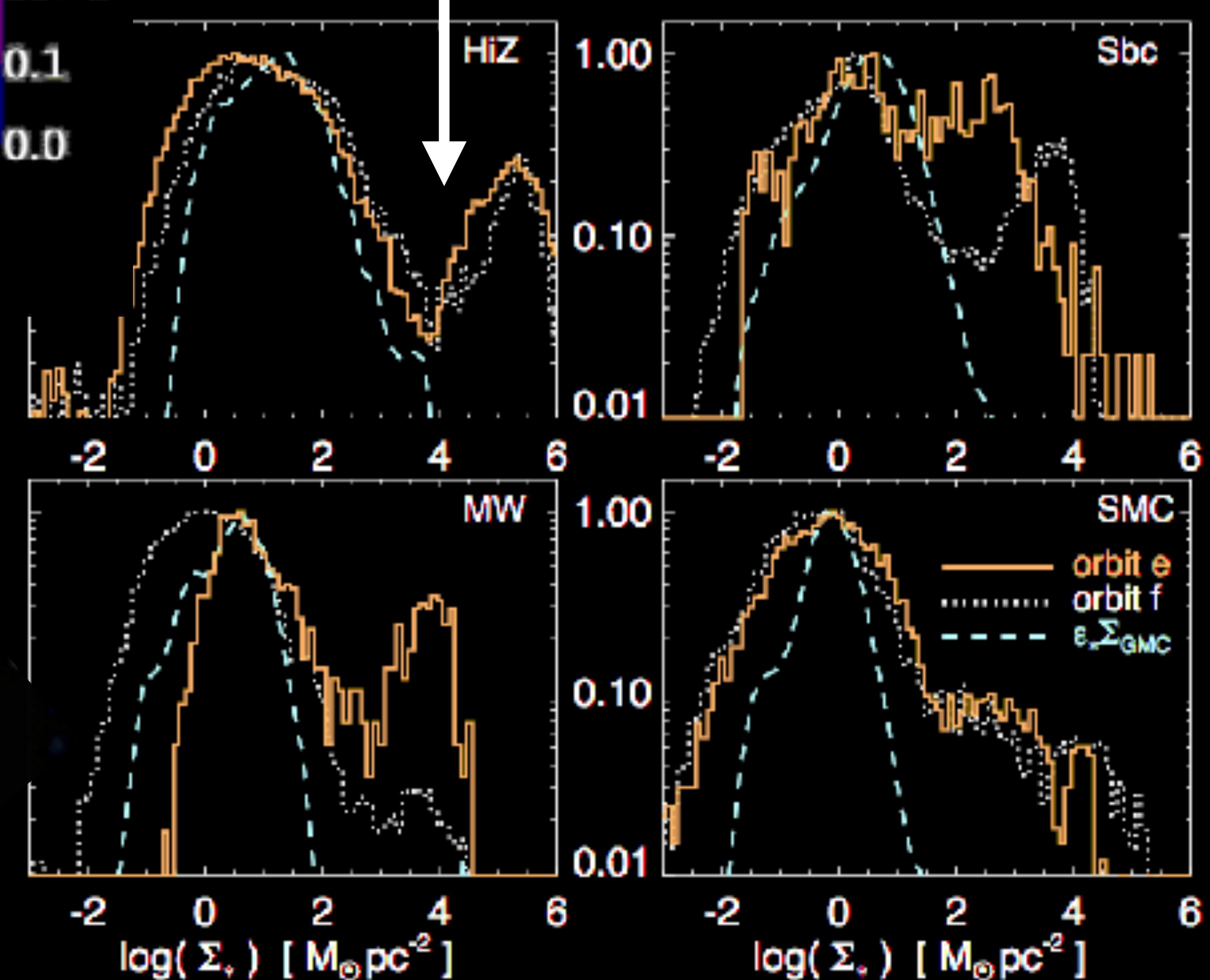
Resolving Globulars in Cosmological Simulations

(KIM '17 + GRUDIC '17)



Most form open clusters

Except long-lived population, around critical $\Sigma_{\rm cloud}$

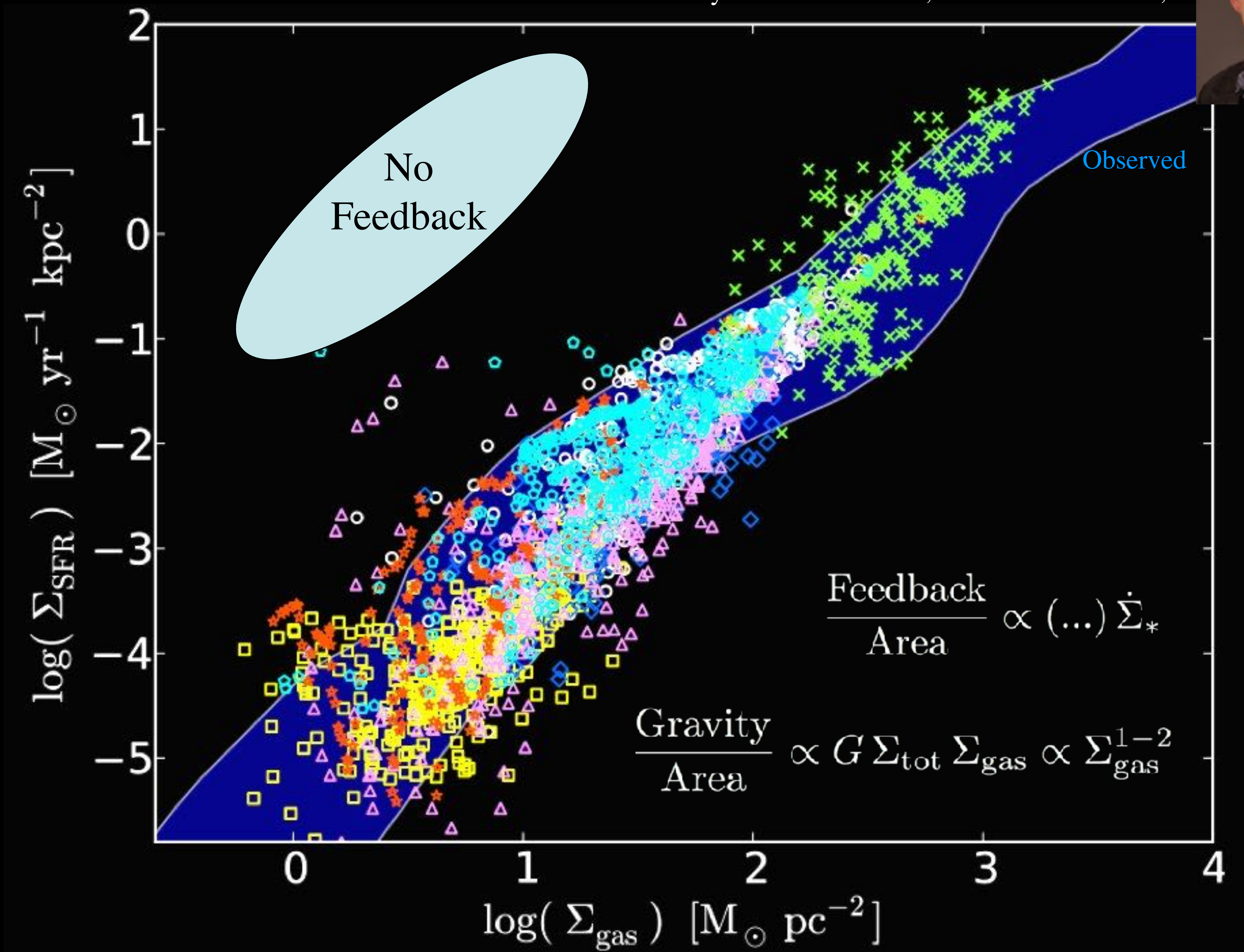


~kpc Scales: Kennicutt-Schmidt

KS Law Emerges Naturally

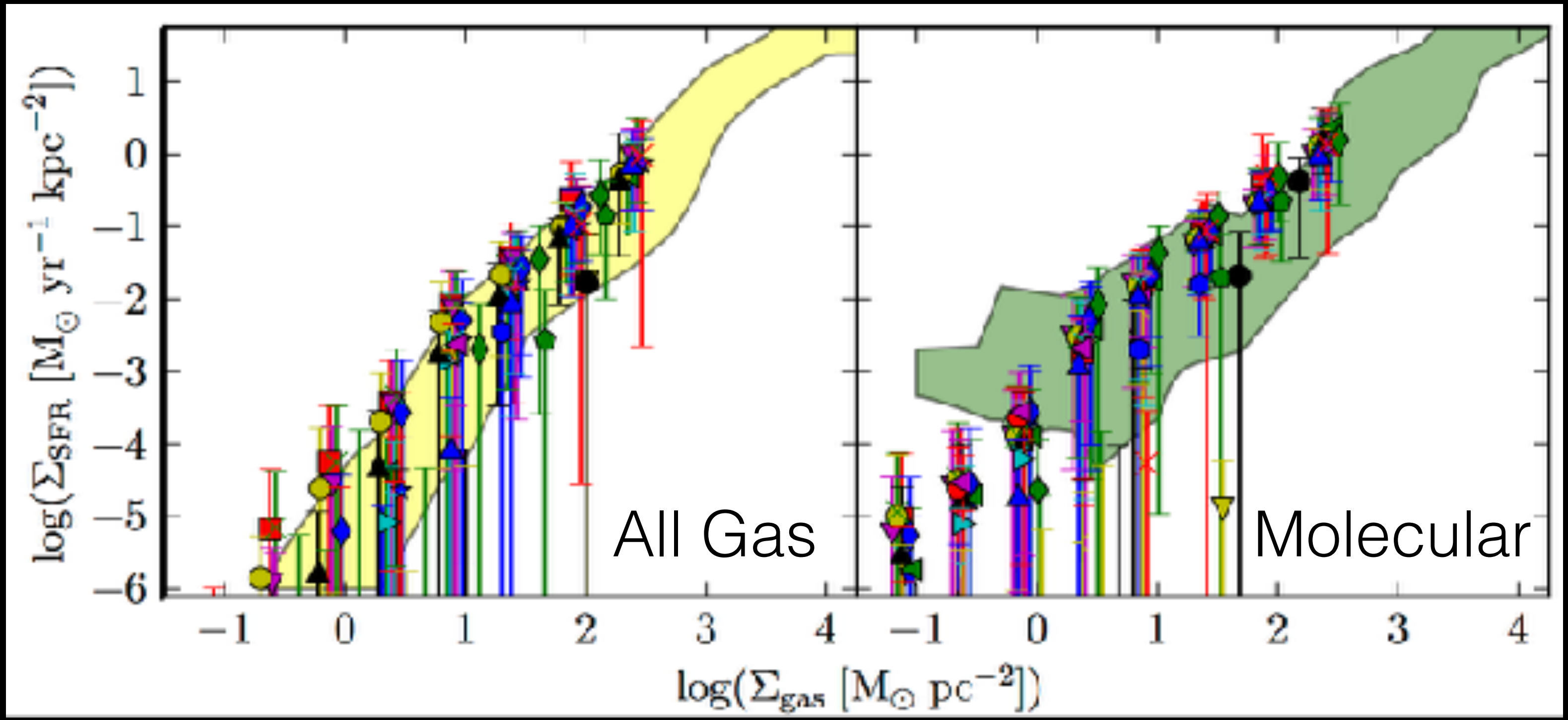
FEEDBACK VS. GRAVITY

Matt Orr (1701.01788)
Agertz+14 , PFH+ 11,12,14
Shetty & Ostriker ’08.11, Kim & Ostriker ’11,13

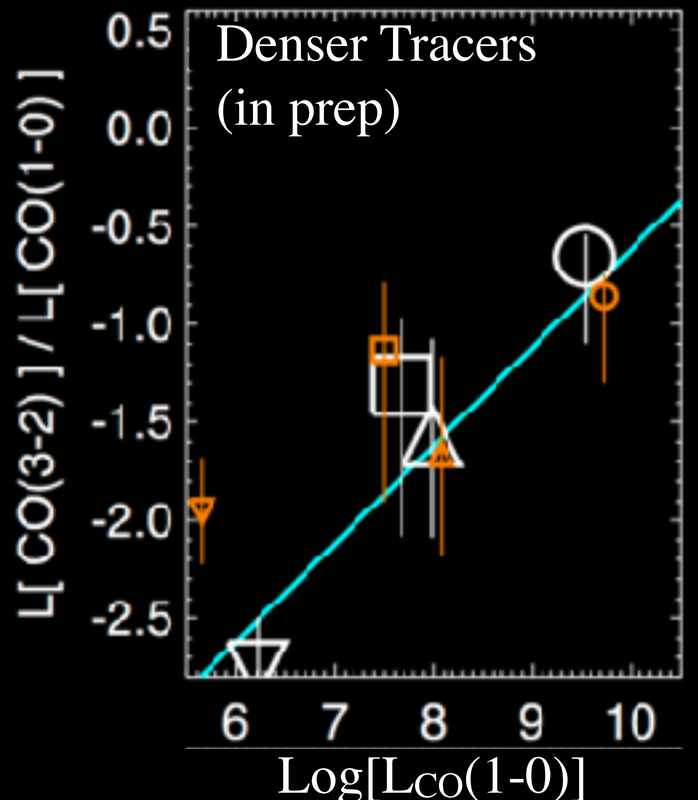


The KS Law: Different Information on Different Scales

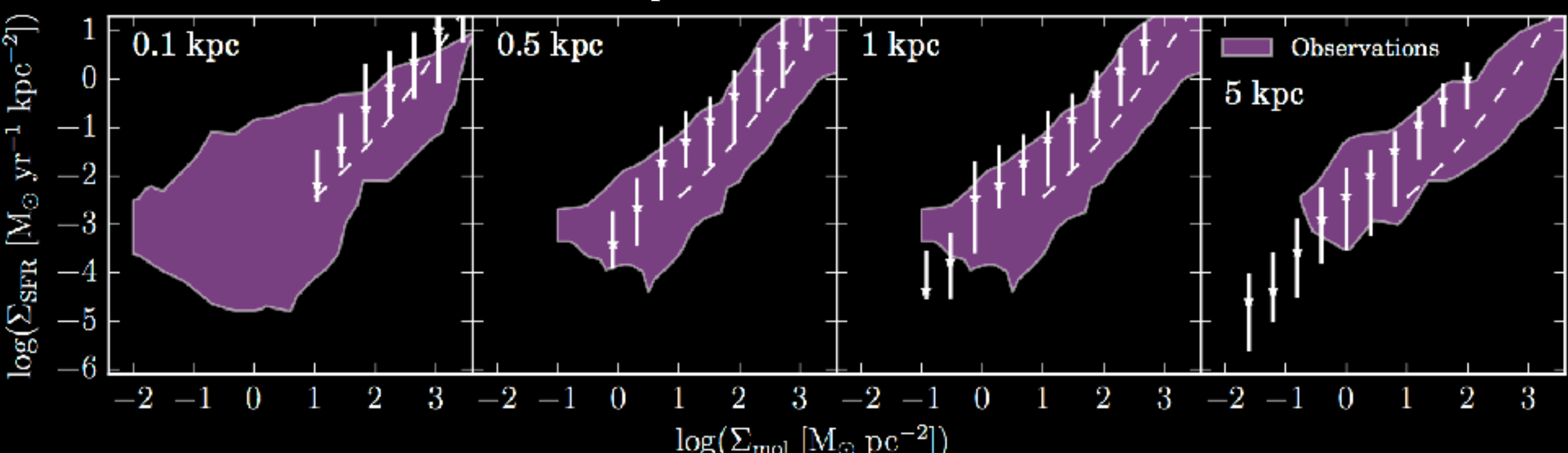
Matt Orr (1701.01788)
+ ’17 (in prep)



Redshift-independent, weakly metallicity-dependent



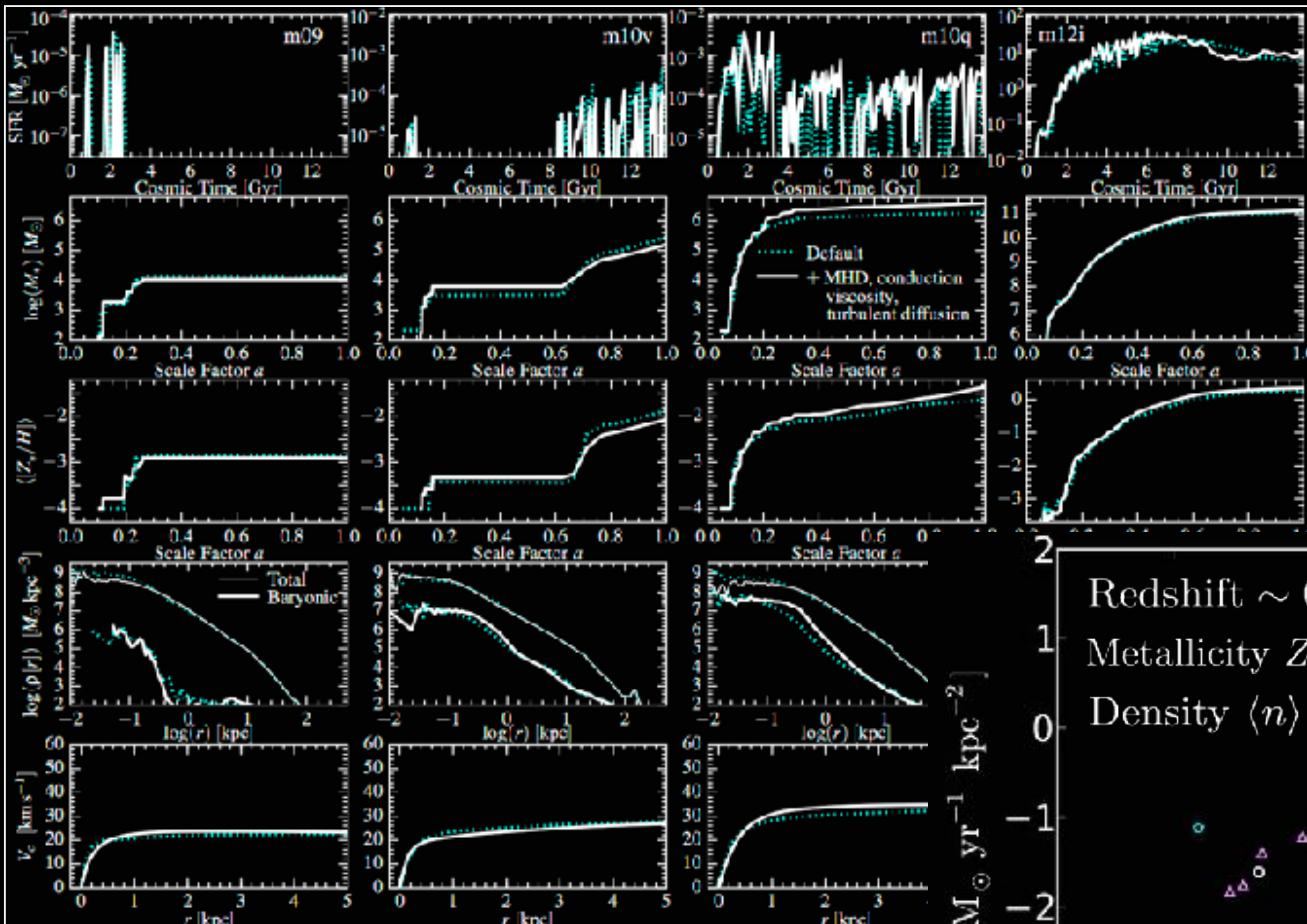
Different “resolved” laws: **no dependence on “numerical” SF law!!!**

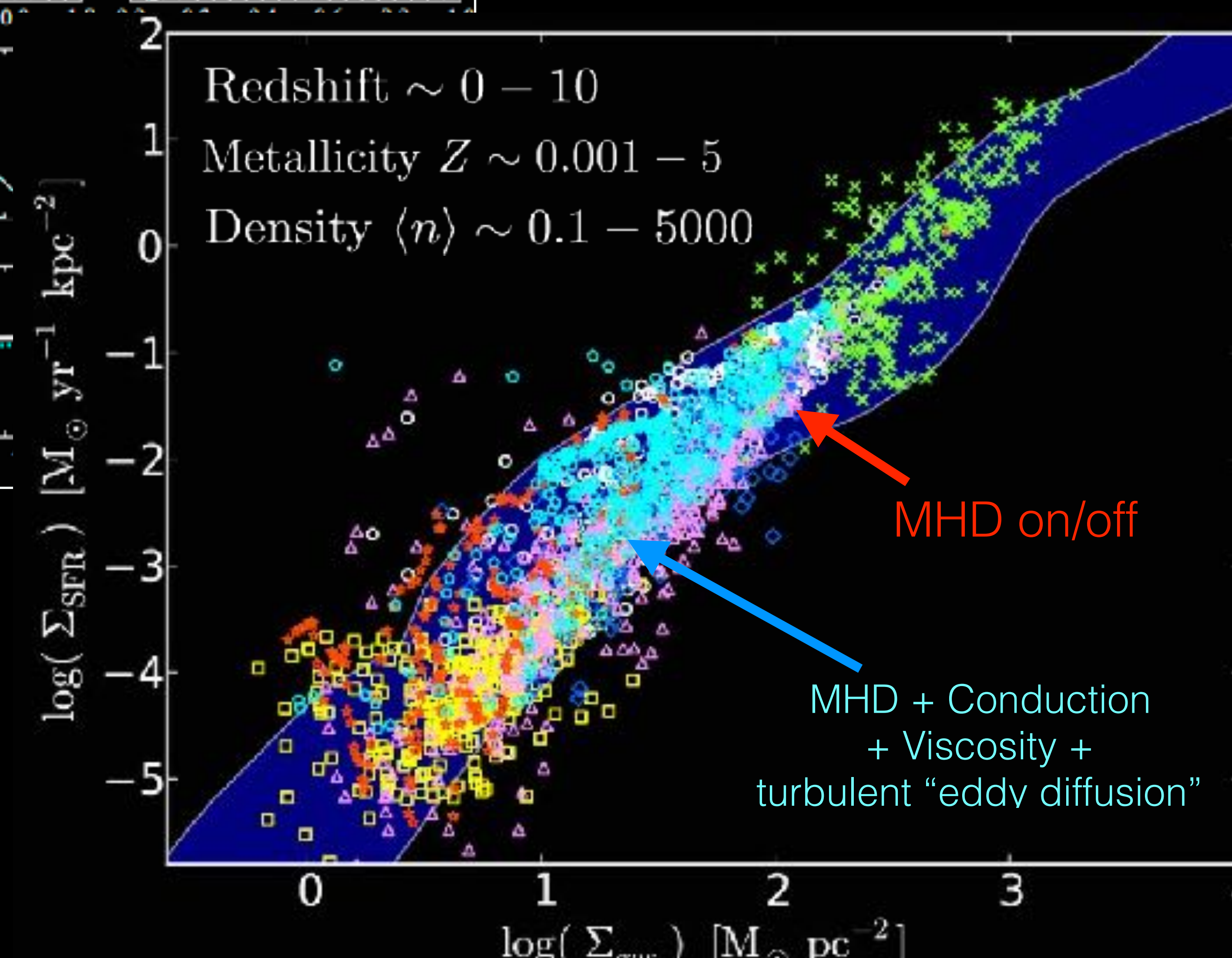


No dependence on MHD, conduction, viscosity, etc.

ONLY SEE IF FEEDBACK IS ARTIFICIALLY WEAK

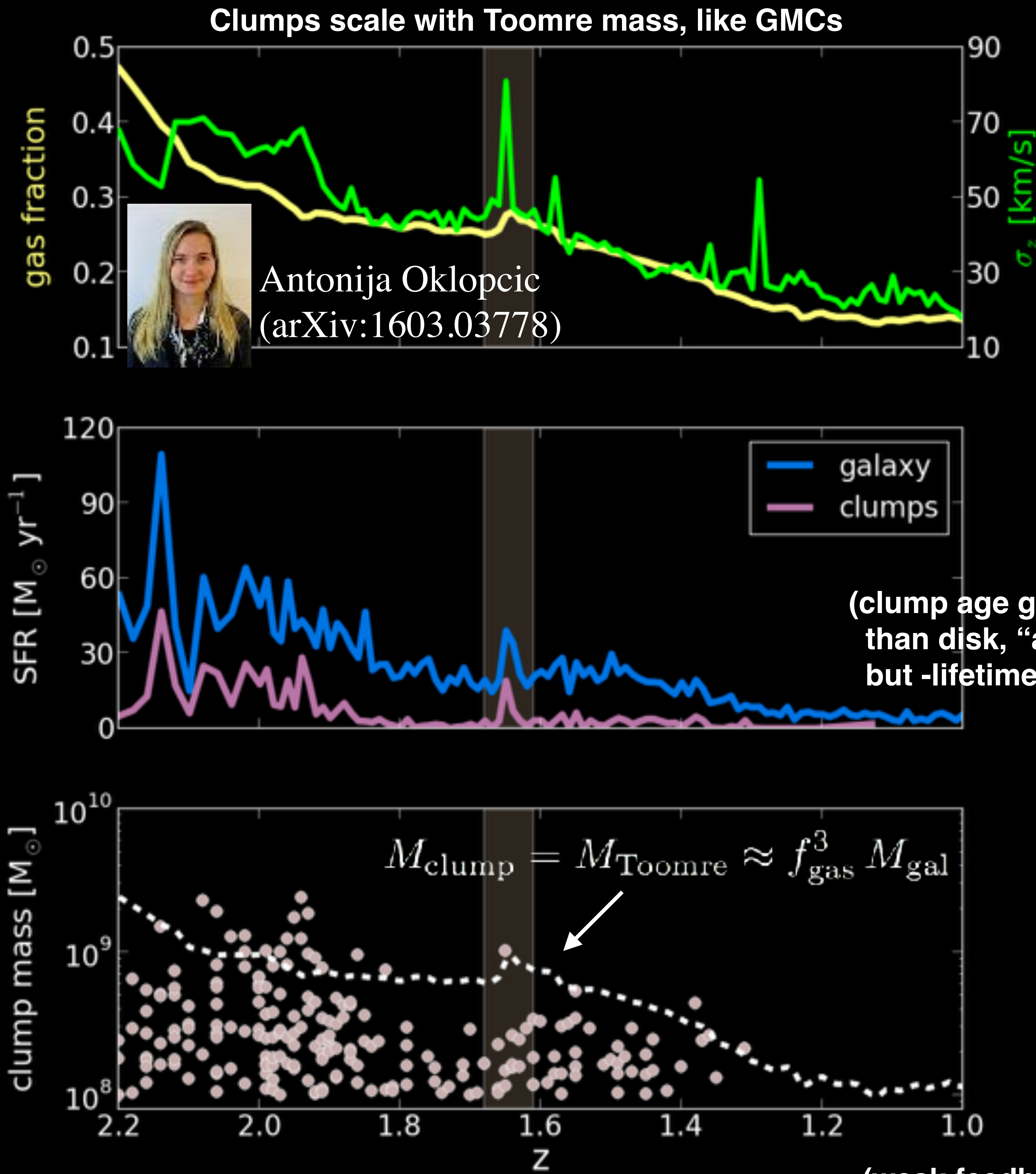
Kung-Yi Su
(arXiv:
1607.05274)

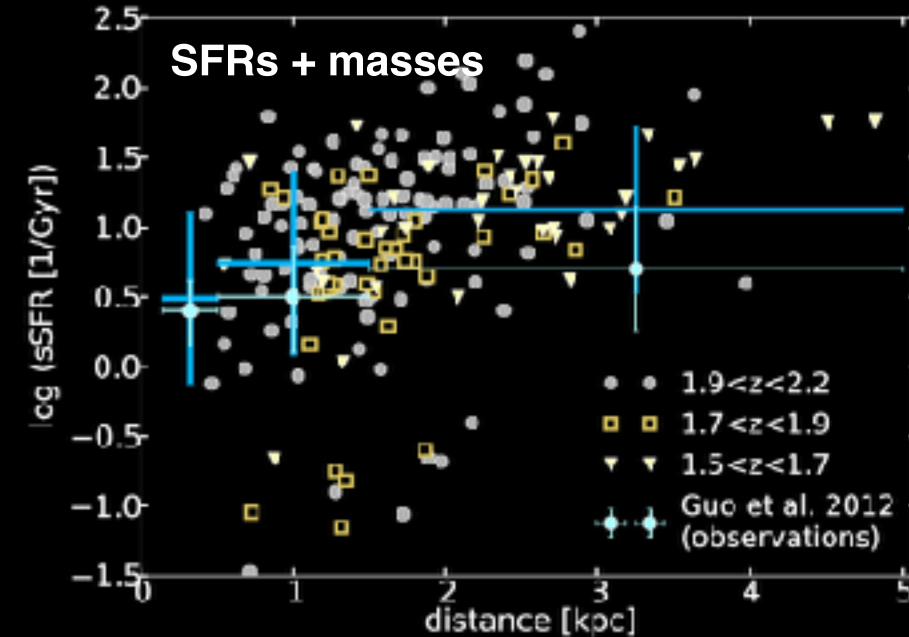


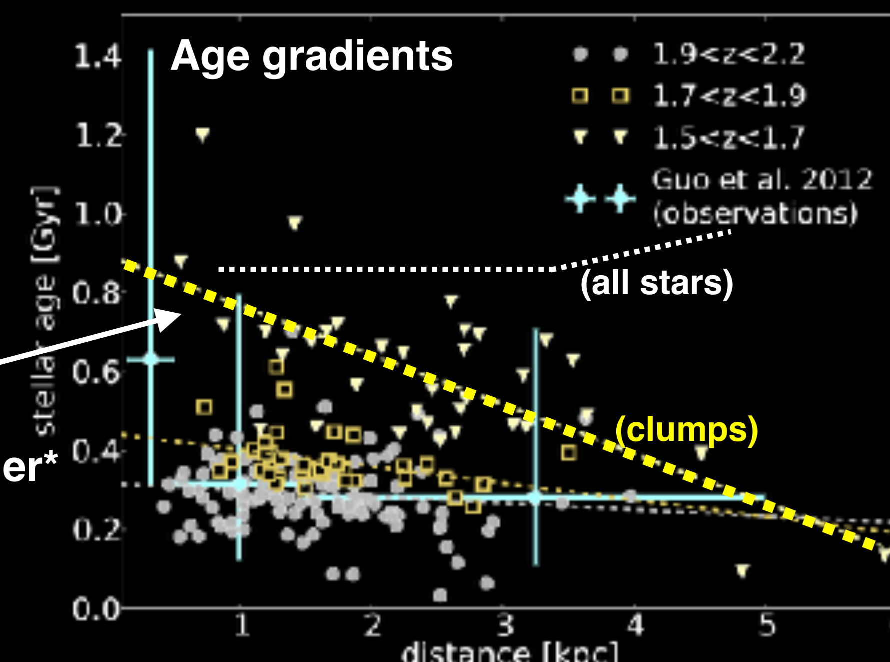


Giant “Clumps”

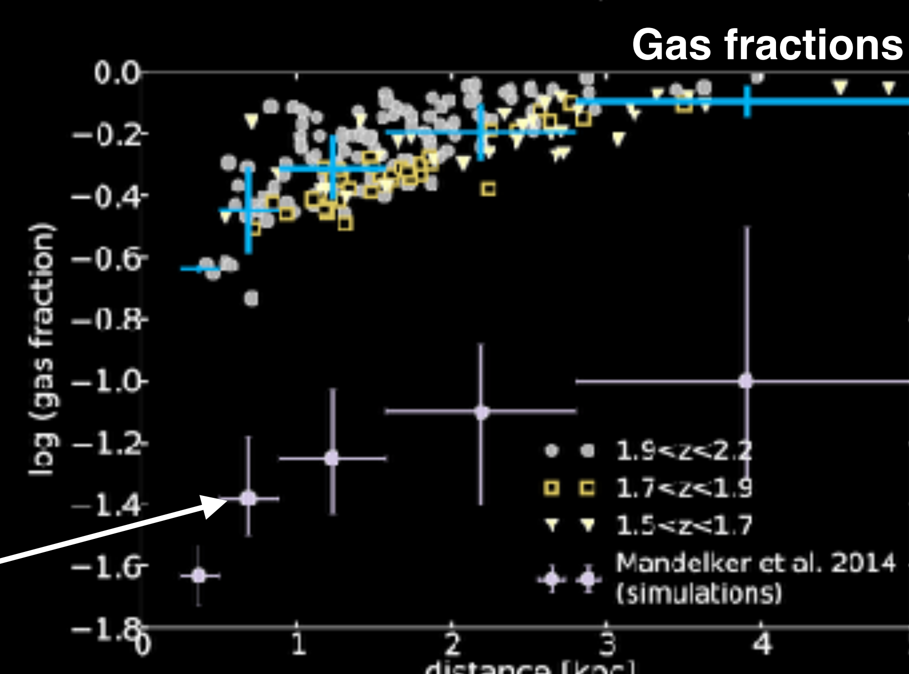
JUST AN EXTENSION OF GMCs







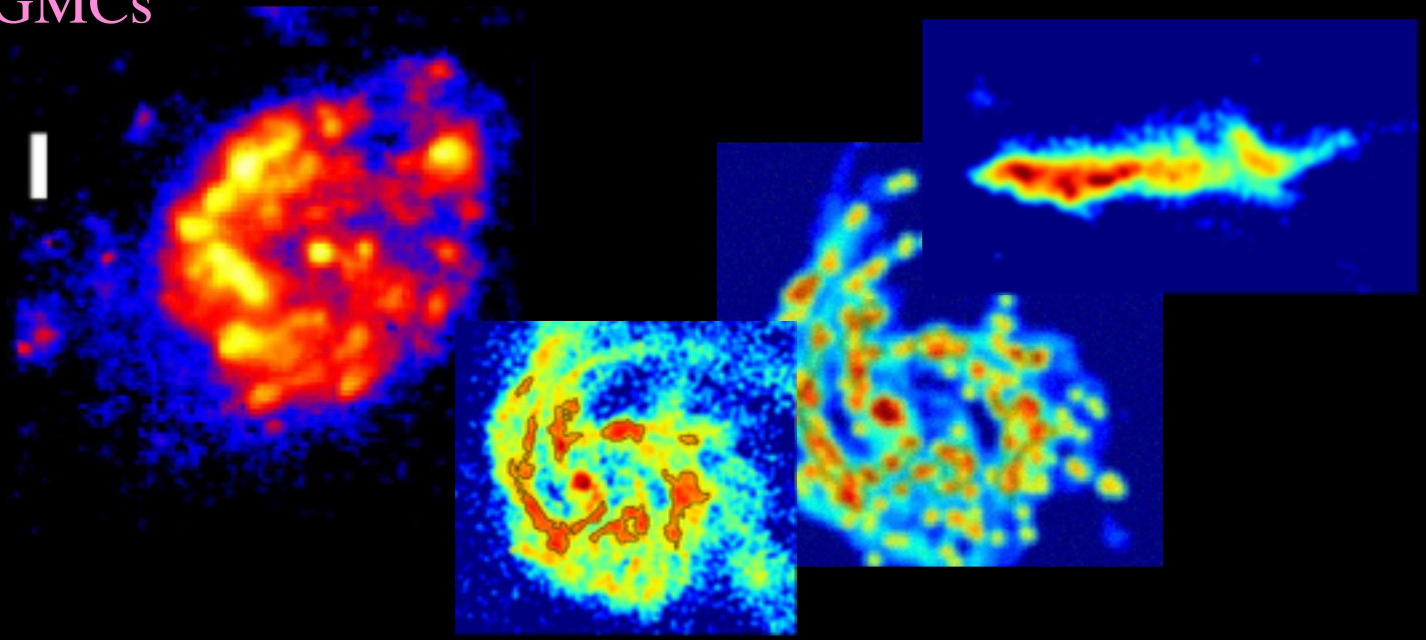
(clump age gradients *stronger* than disk, “ages” >1 Gyr, but -lifetimes- short)



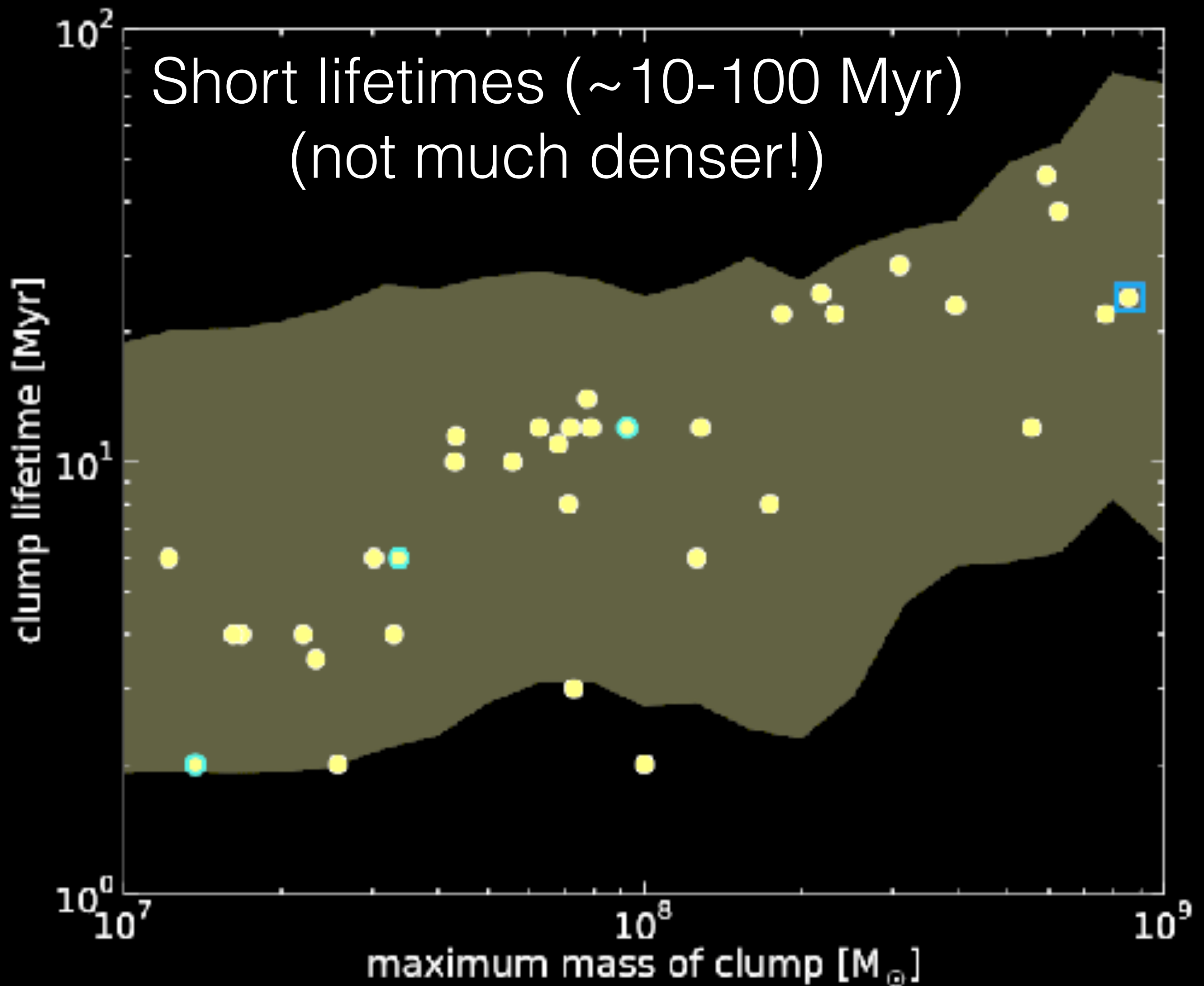
(weak feedback, long-lived clump model)

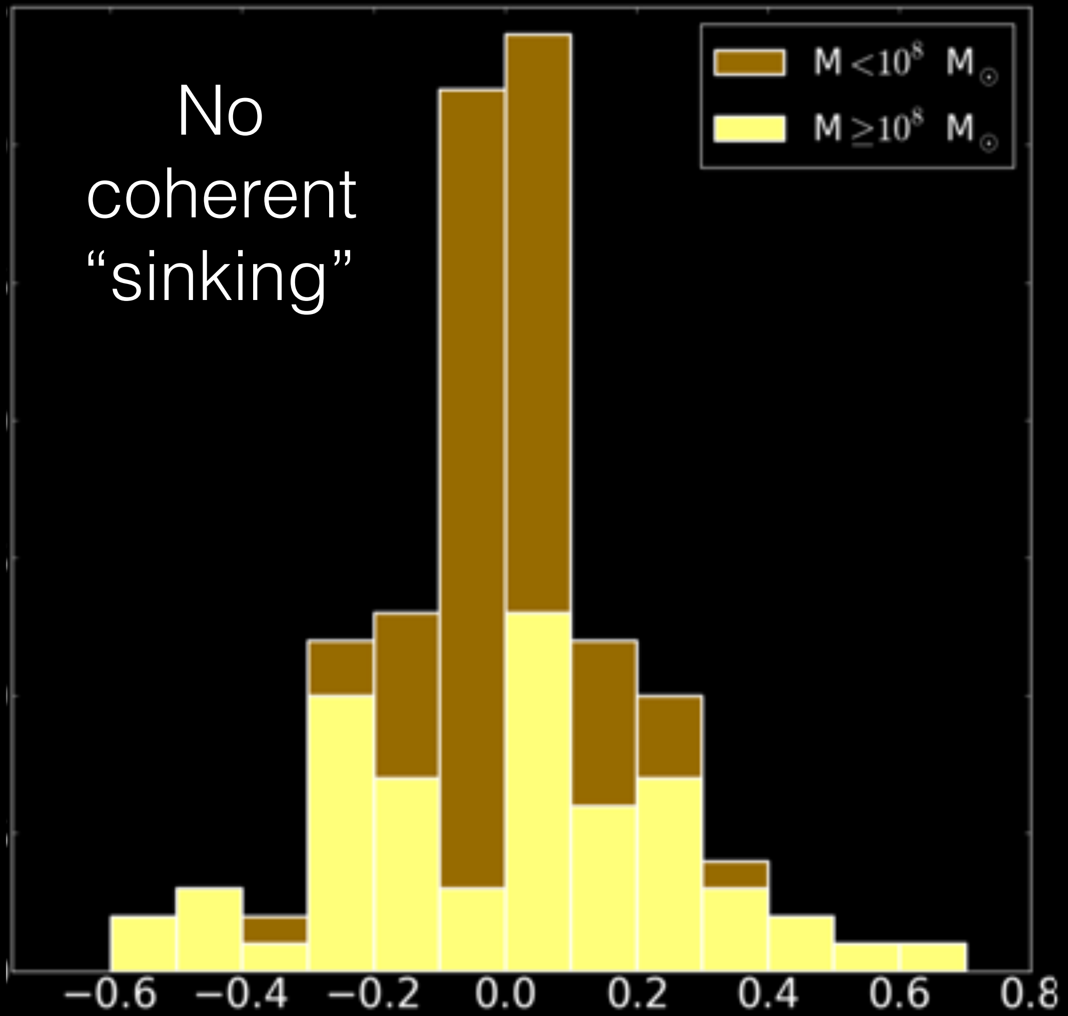
Giant "Clumps" Blow Up, Don't Sink

JUST AN EXTENSION OF GMCs



Antonija Oklopcic
(arXiv:1603.03778)





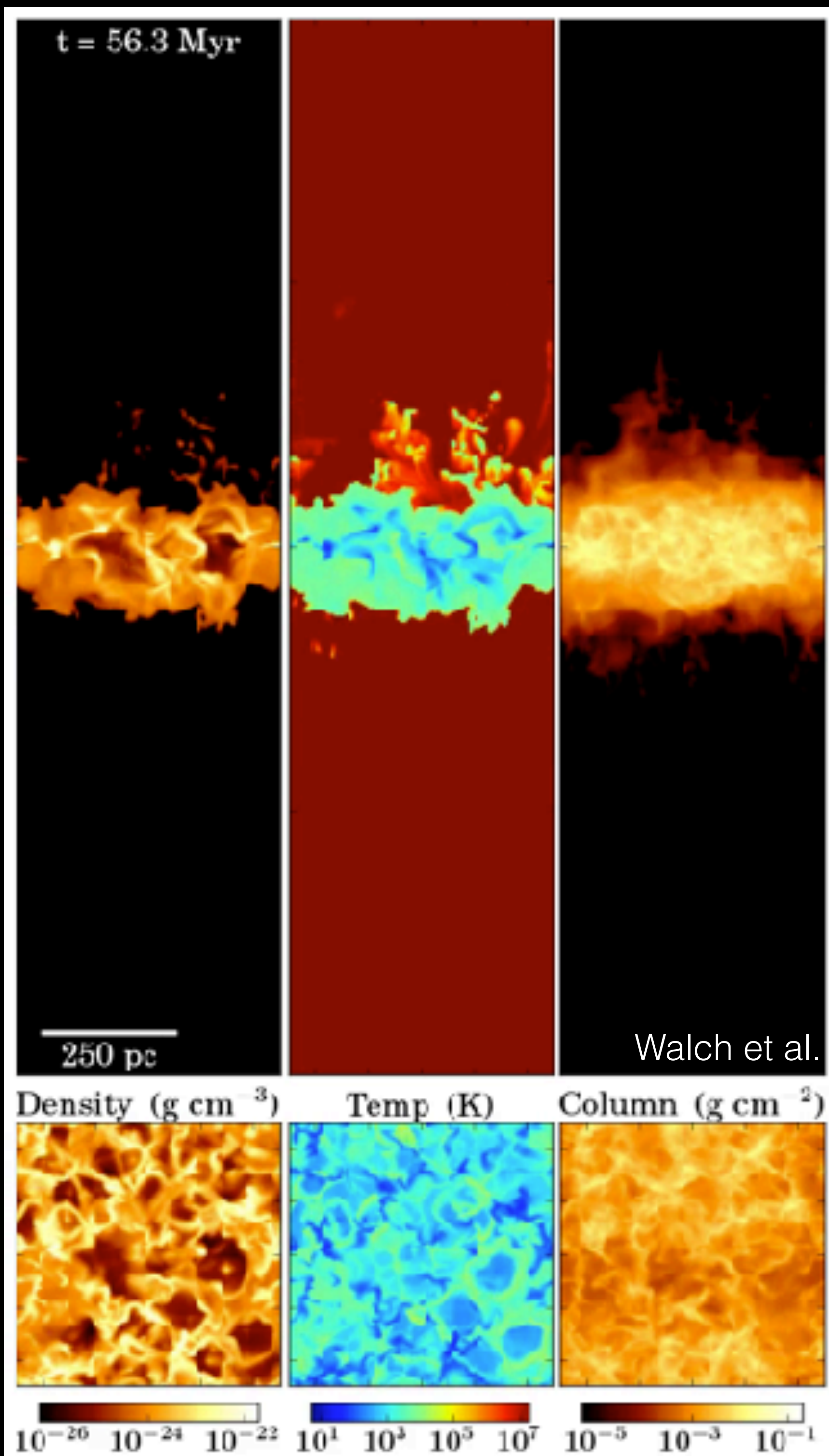
Fractional Change in Clump Orbital Angular Momentum

Galactic/Cosmological SFRs:
Driving Winds

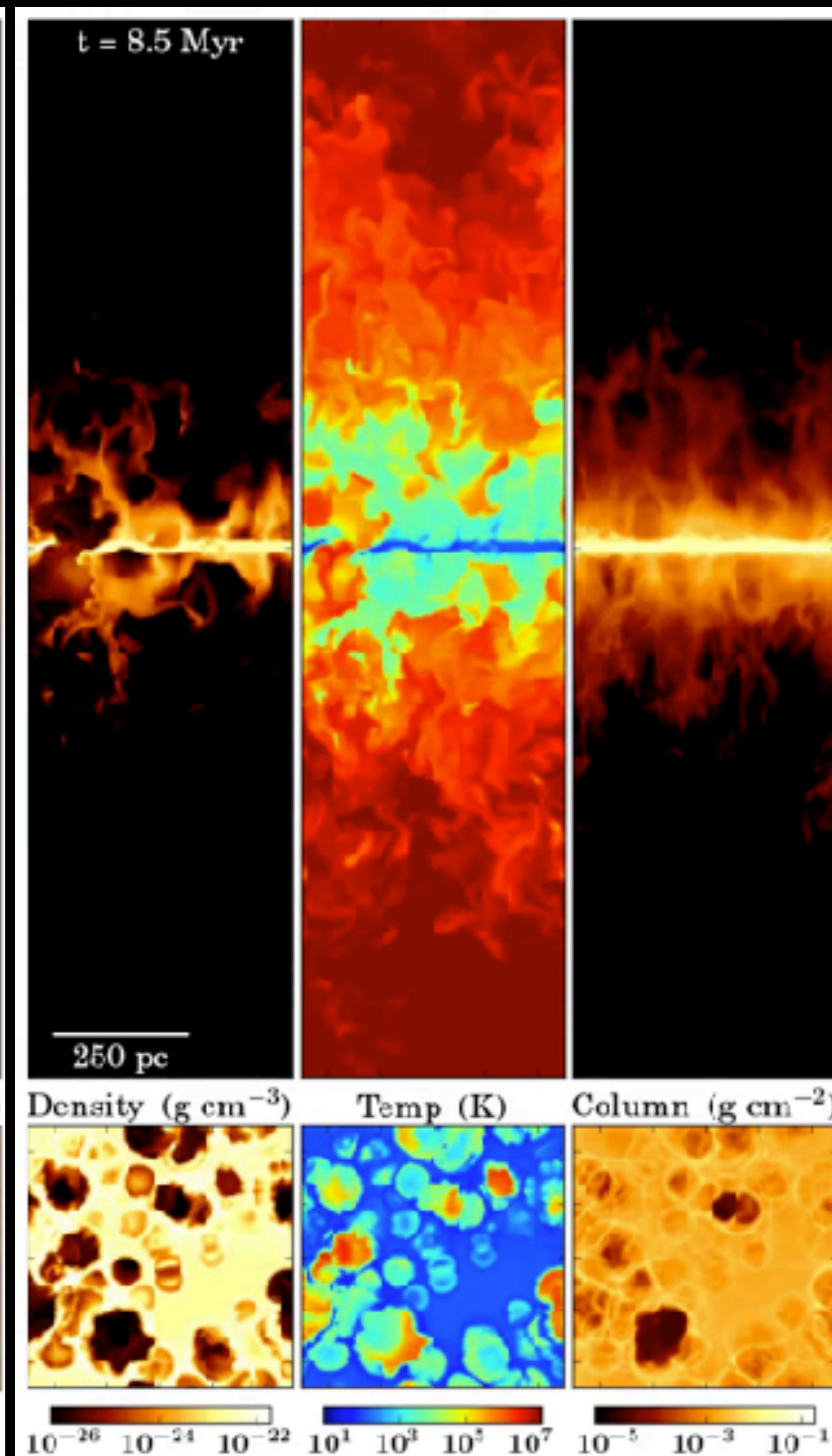
Remember Stellar Clustering?
THIS MATTERS, A LOT!

Martizzi+ '16
Walch+, Kimm+,
many others

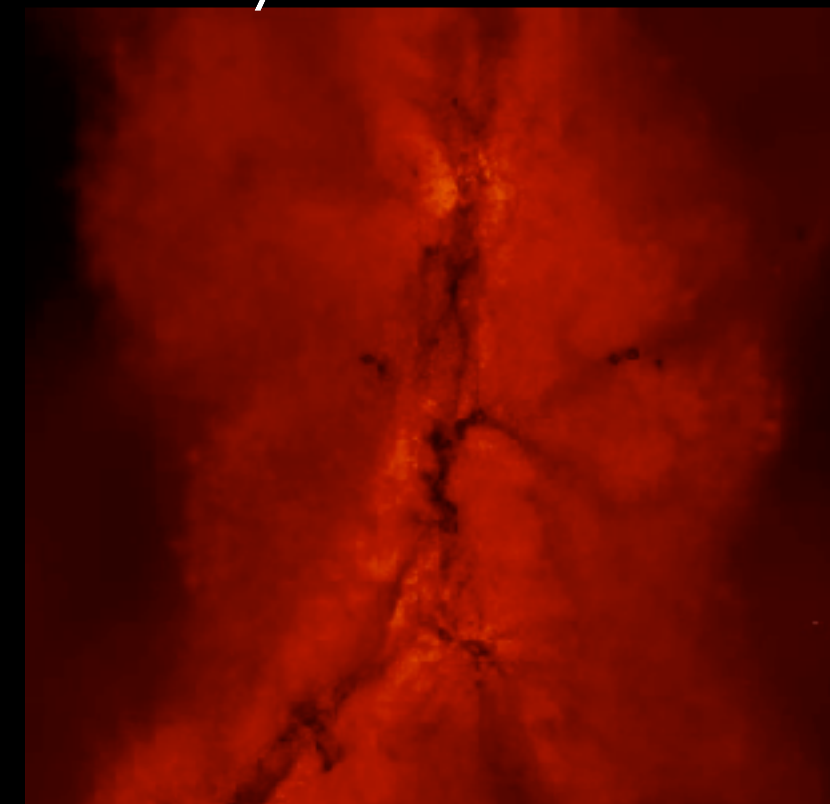
SNe Explode in Density Peaks (no radiative feedback)



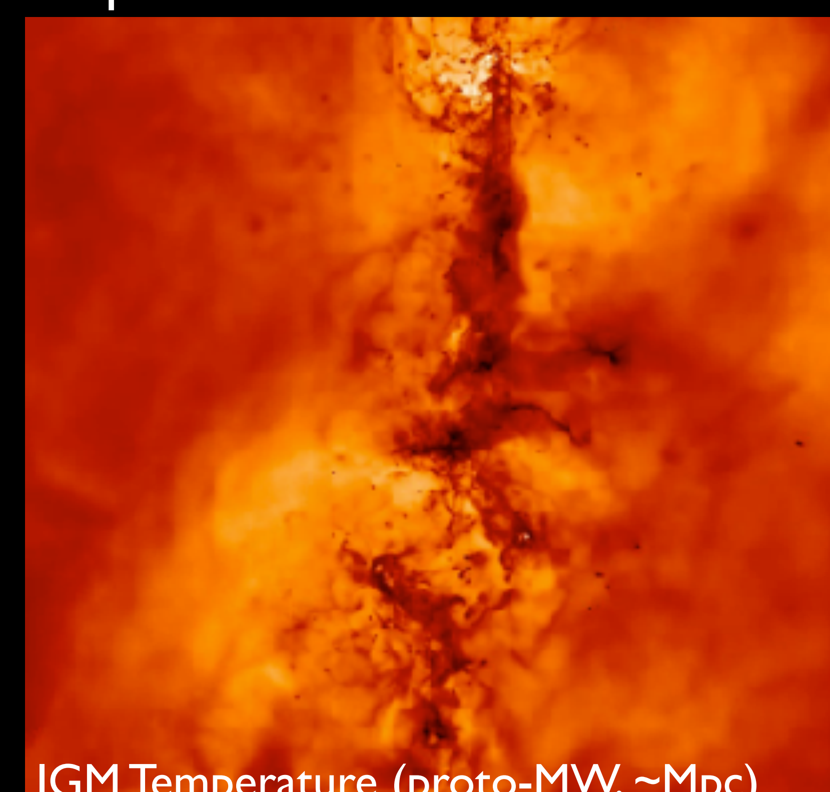
SNe Clustered & Off-Peak (radiative feedback/pre-processing)



Winds "by hand" ~SFR



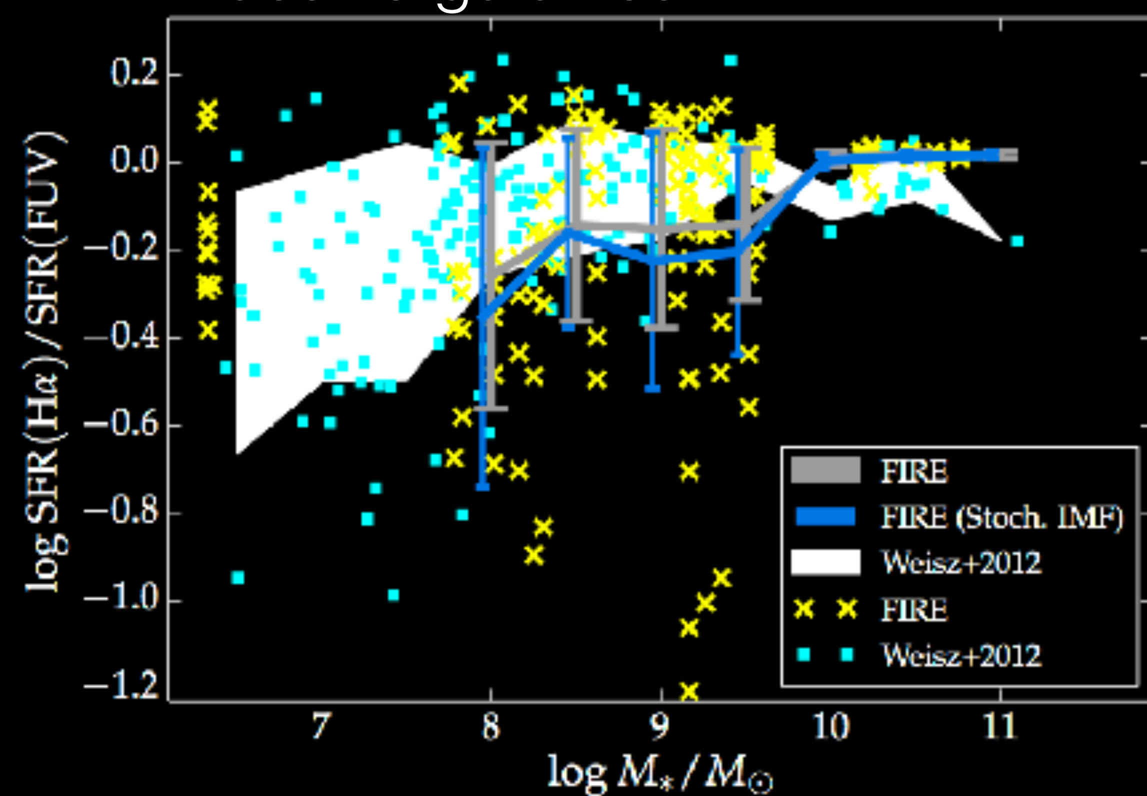
Explicit ISM/Feedback



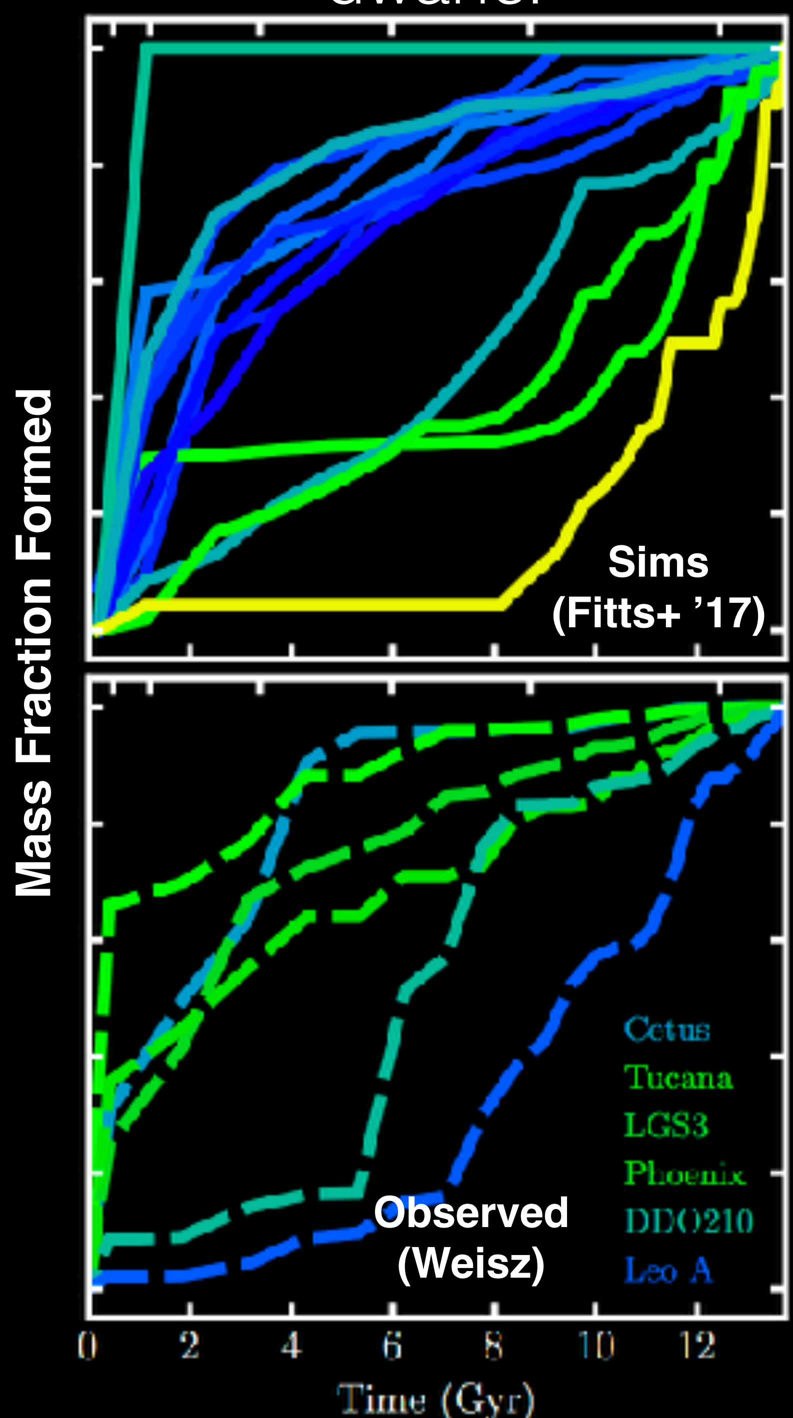
Burstiness & SFR-M_{stars} Relation

M. Sparre
arxiv:1510.03869

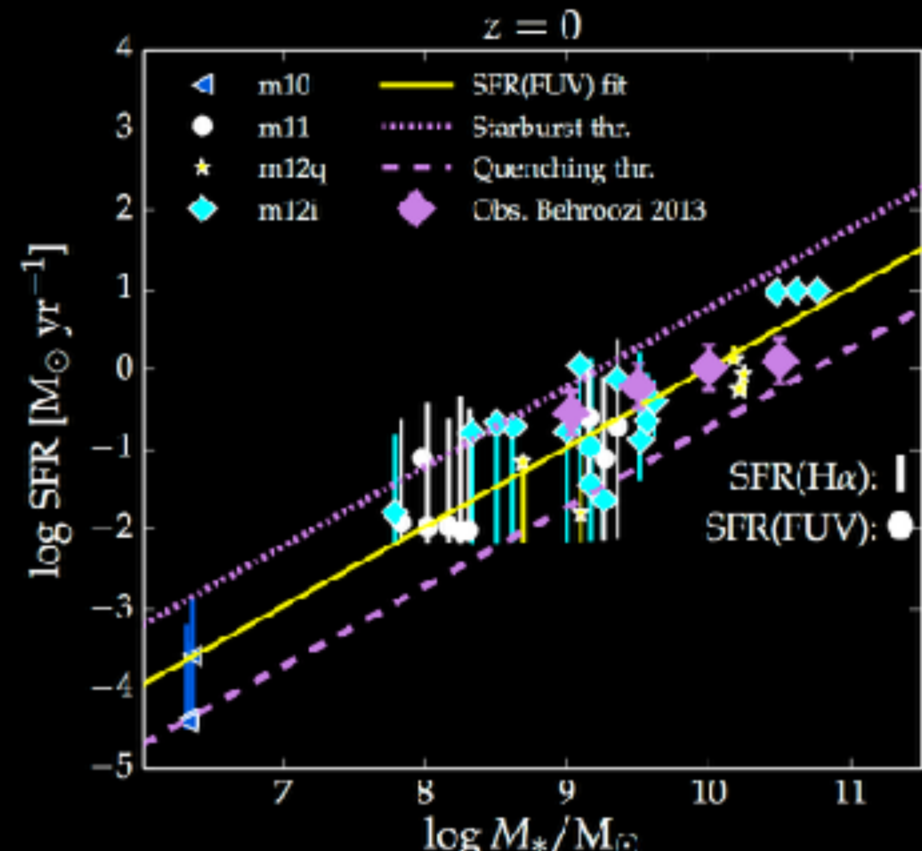
massive galaxies:

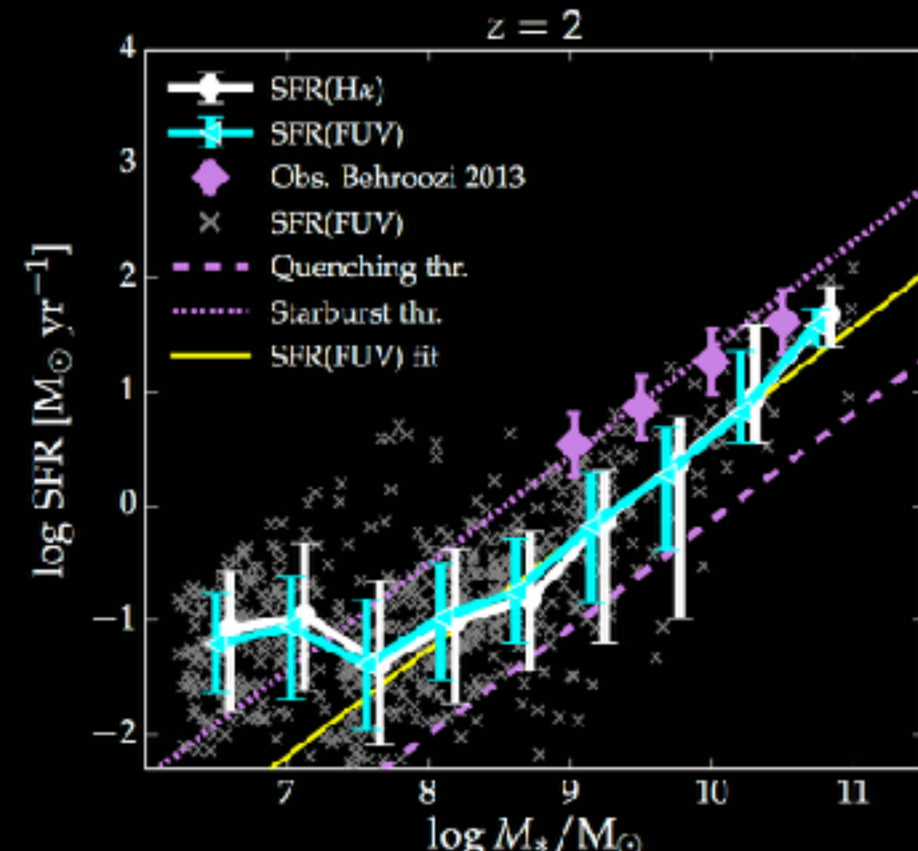


dwarfs:



Low-mass scatter is *not* a "hidden variable"



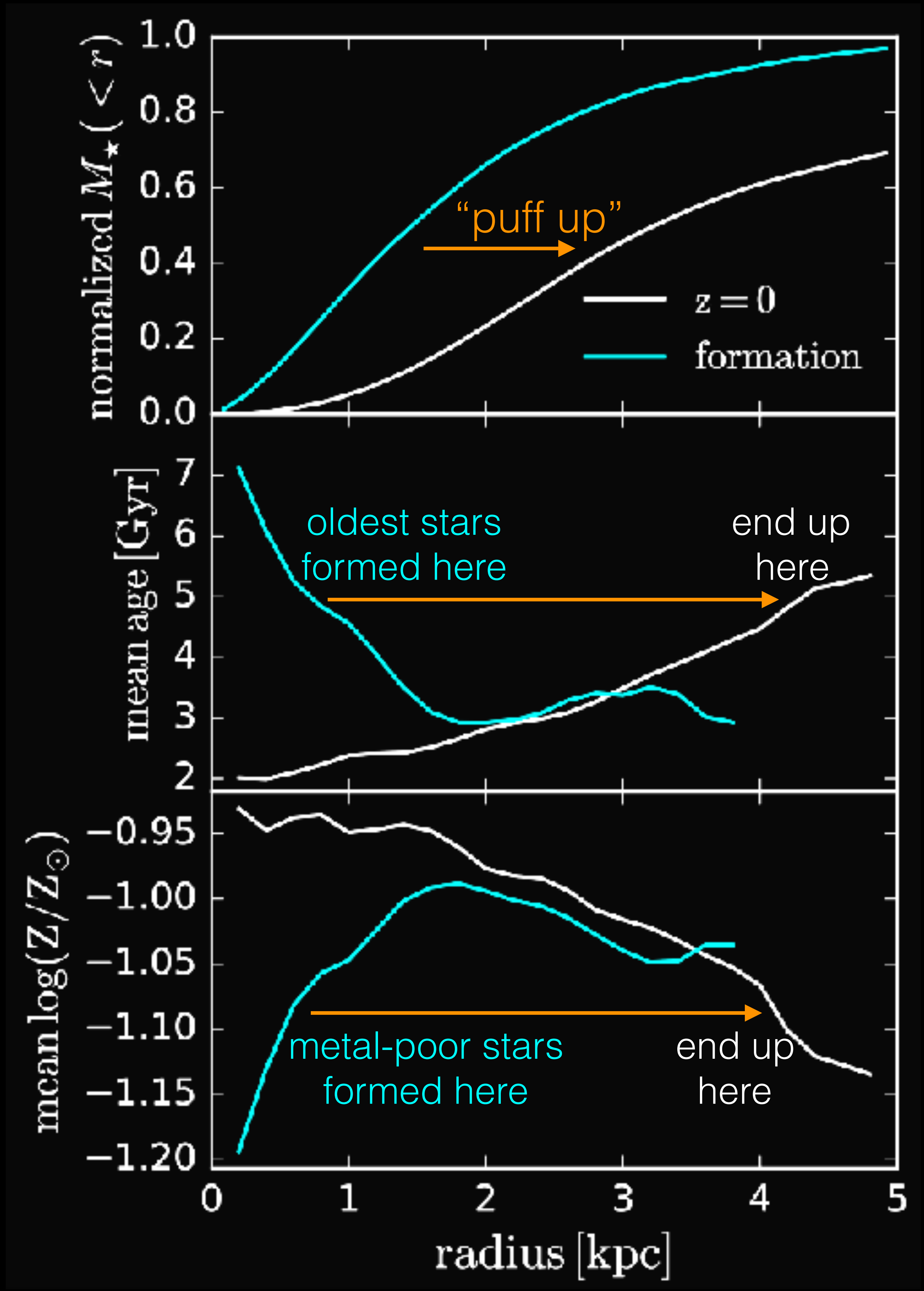


Bursty/Calm Star Formation
& Galactic Structure

Direct Consequences for Structure

BURSTY SF = STARS MIXED, JUST LIKE DM

- If DM orbits perturbed, stars are too!
  - Radial anisotropy
  - Gradients "wiped out"
  - Galactic radii *oscillate*

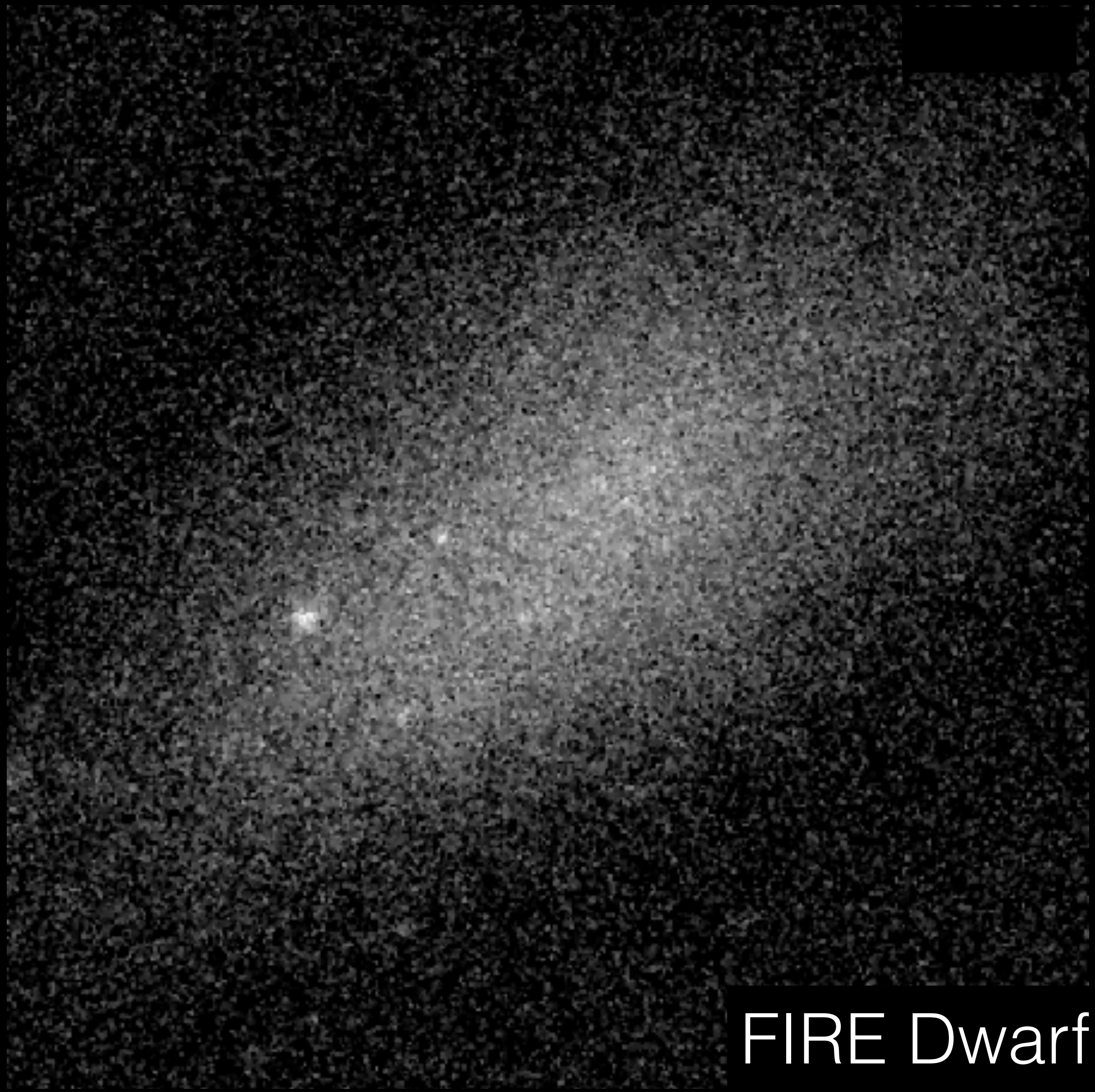


Kareem El-Badry
arXiv:1512.01235

New Classes of Galaxies

ULTRA-DIFFUSE SYSTEMS: THE NEW “NORMAL”

TK Chan (prep)

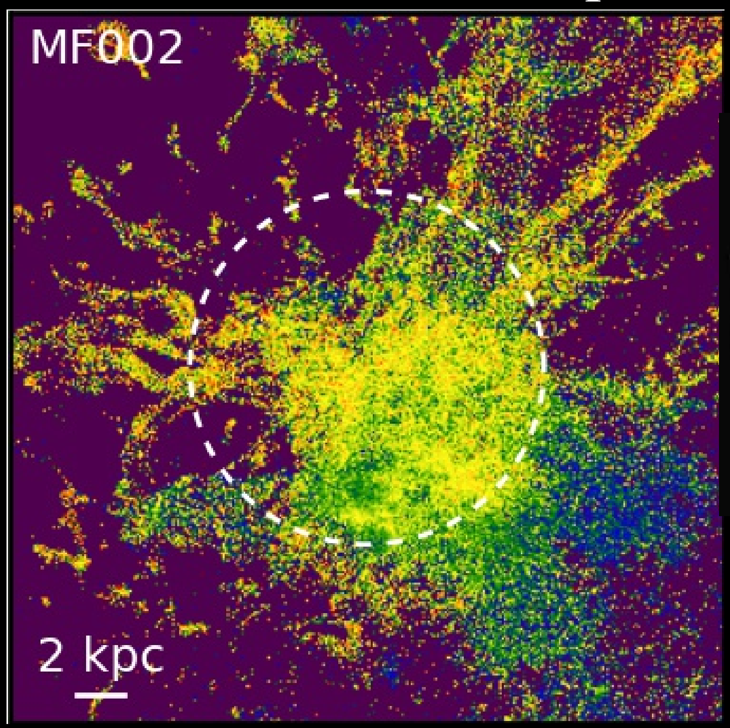


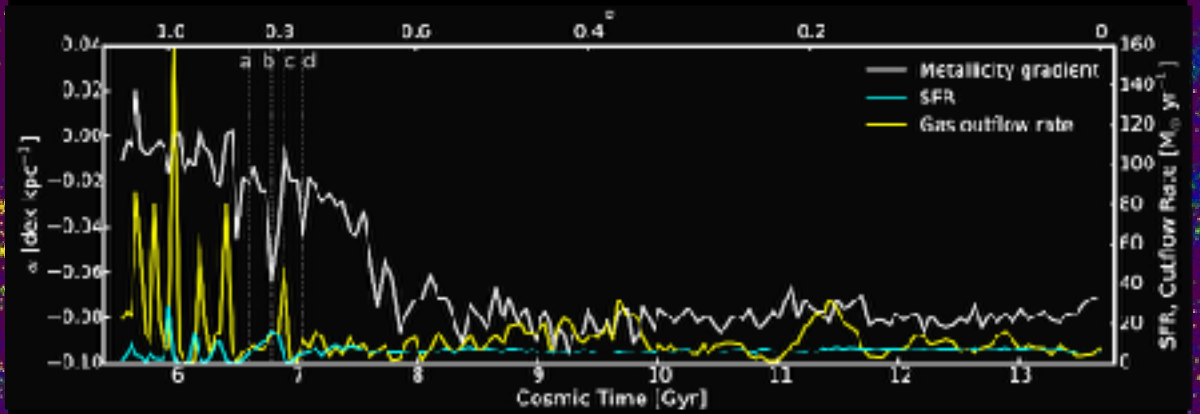
Transition from Feedback-Dominated to “Calm” (Gravity-Dominated)

BUILDUP OF METALLICITY GRADIENTS

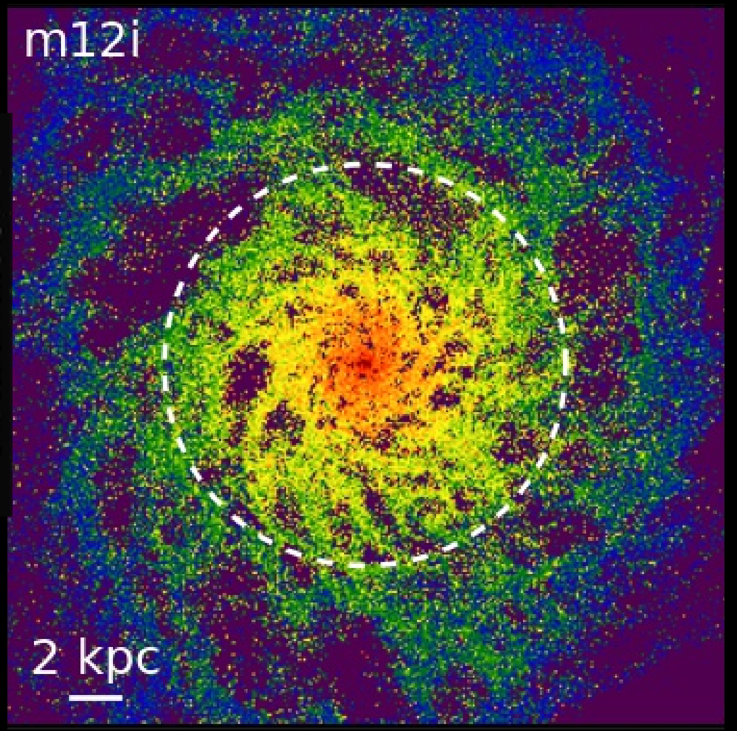
Xiangcheng Ma
(arXiv:1610.03498)

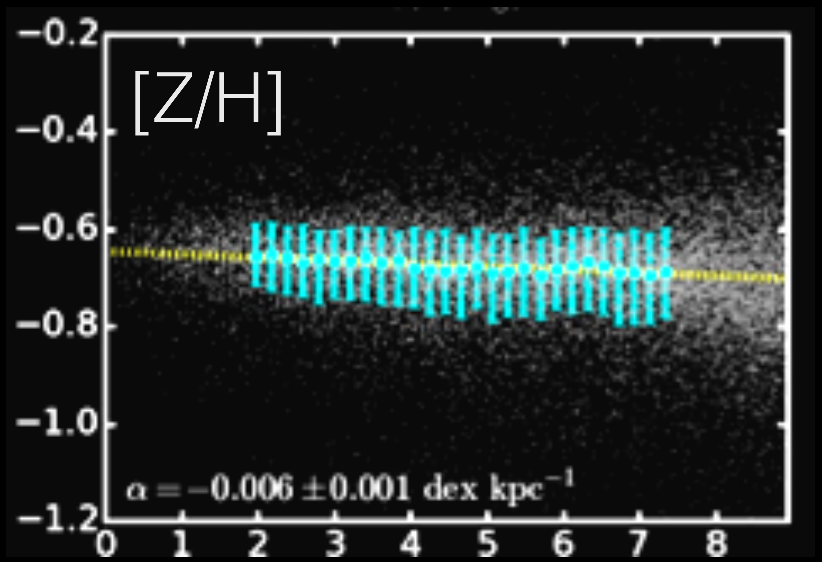
“feedback-dominated” phase



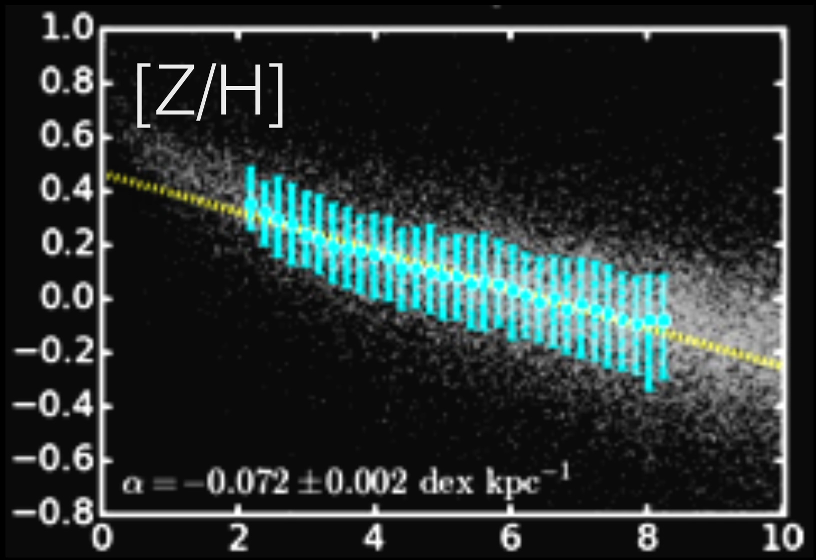


“gravity-dominated” phase





R [kpc]

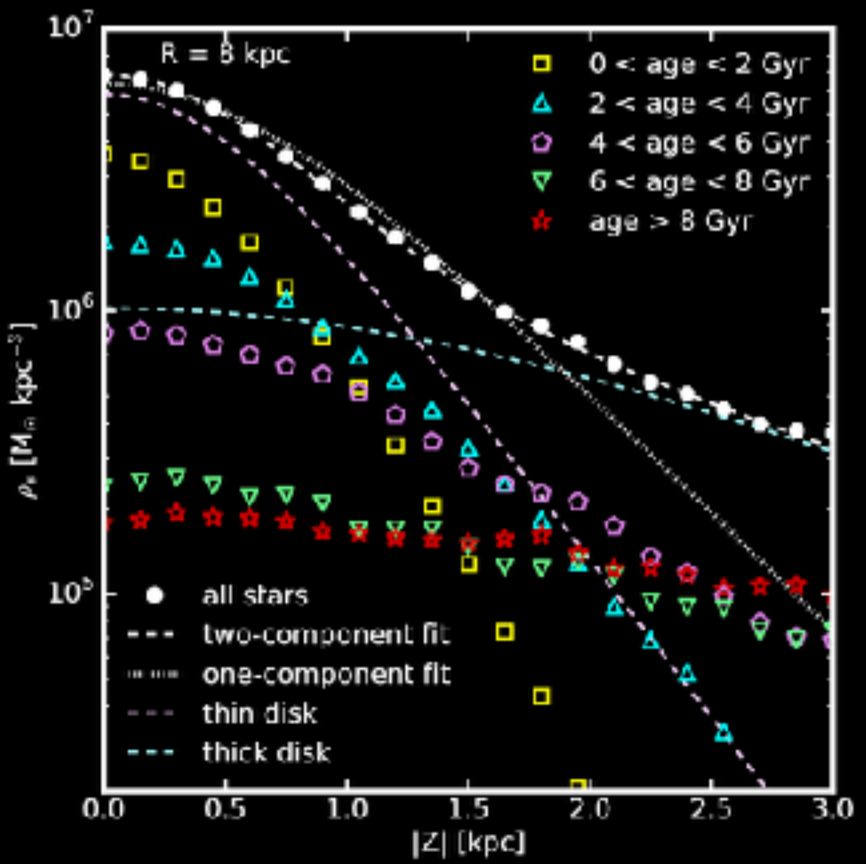


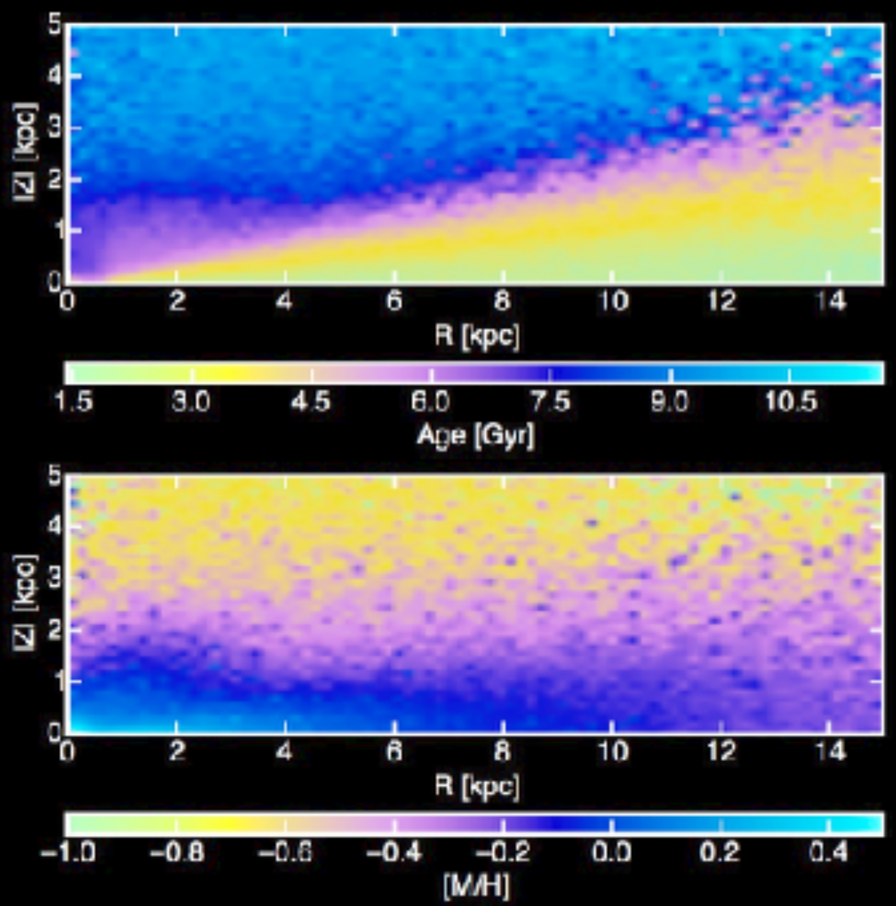
R [kpc]

Transition from Feedback-Dominated to “Calm” (Gravity-Dominated)

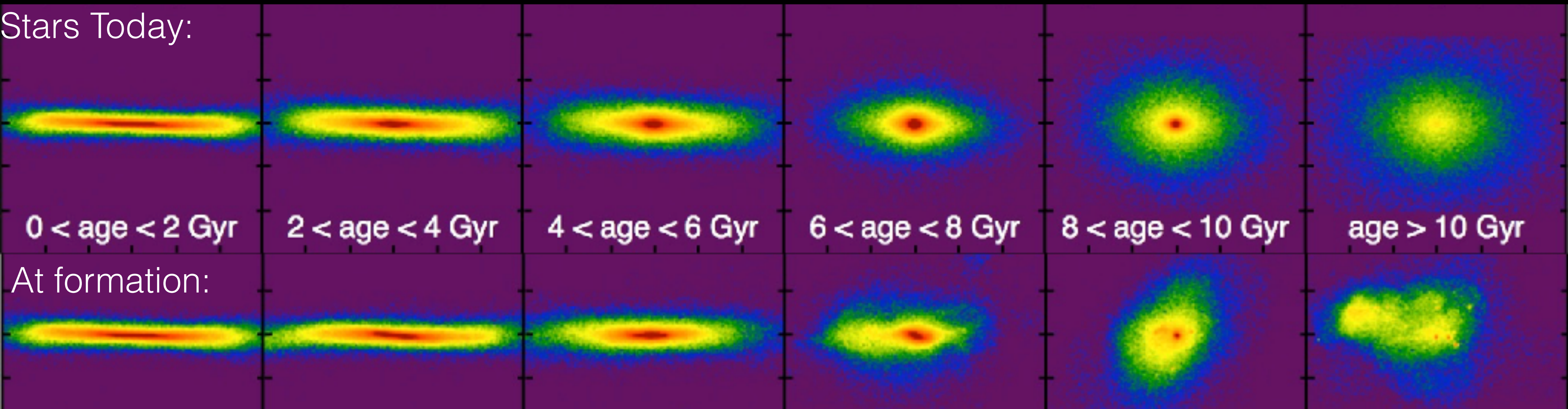
THICK -> THIN DISK

Xiangcheng Ma
(arXiv:1608.04133)
Ana Bonaca
(arXiv:1704.05463)

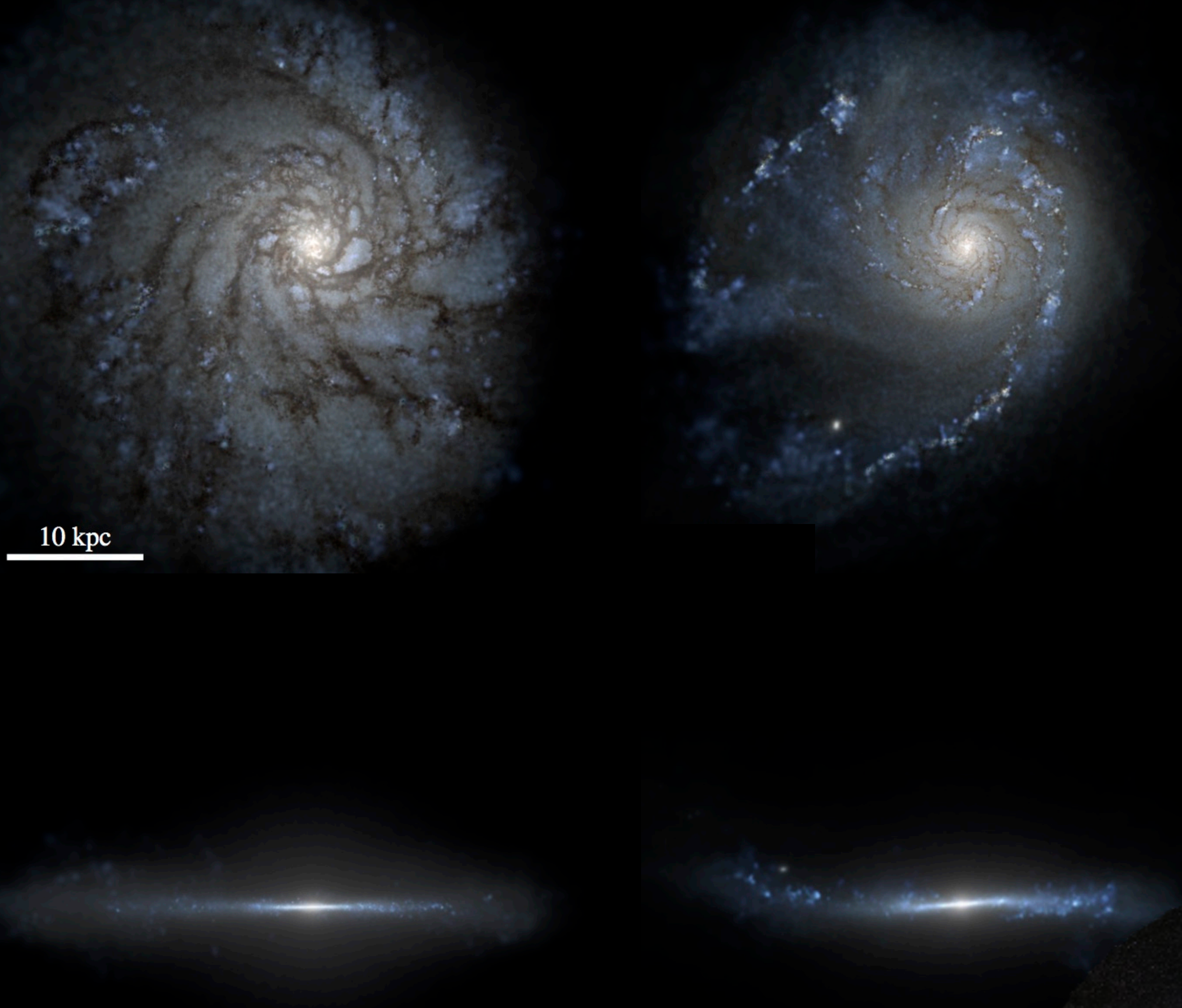




Detailed vertical+radial abundance gradients & kinematics of thin/thick disk populations



Thin Disks Emerge Naturally…
but when/where?

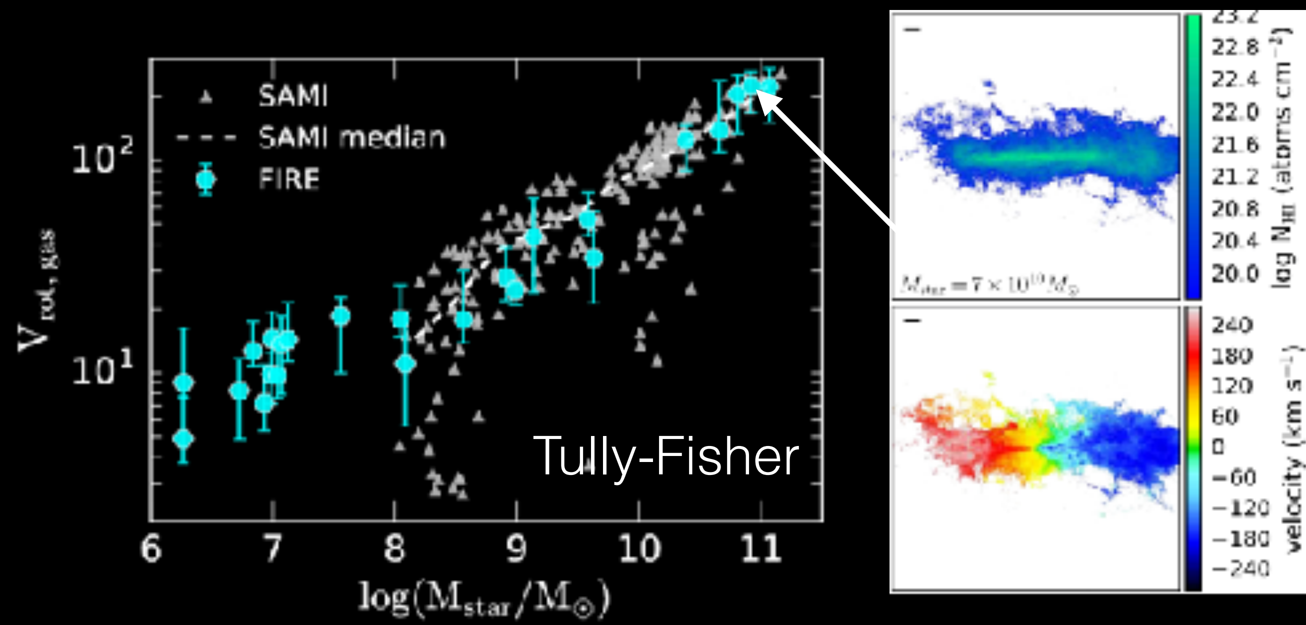


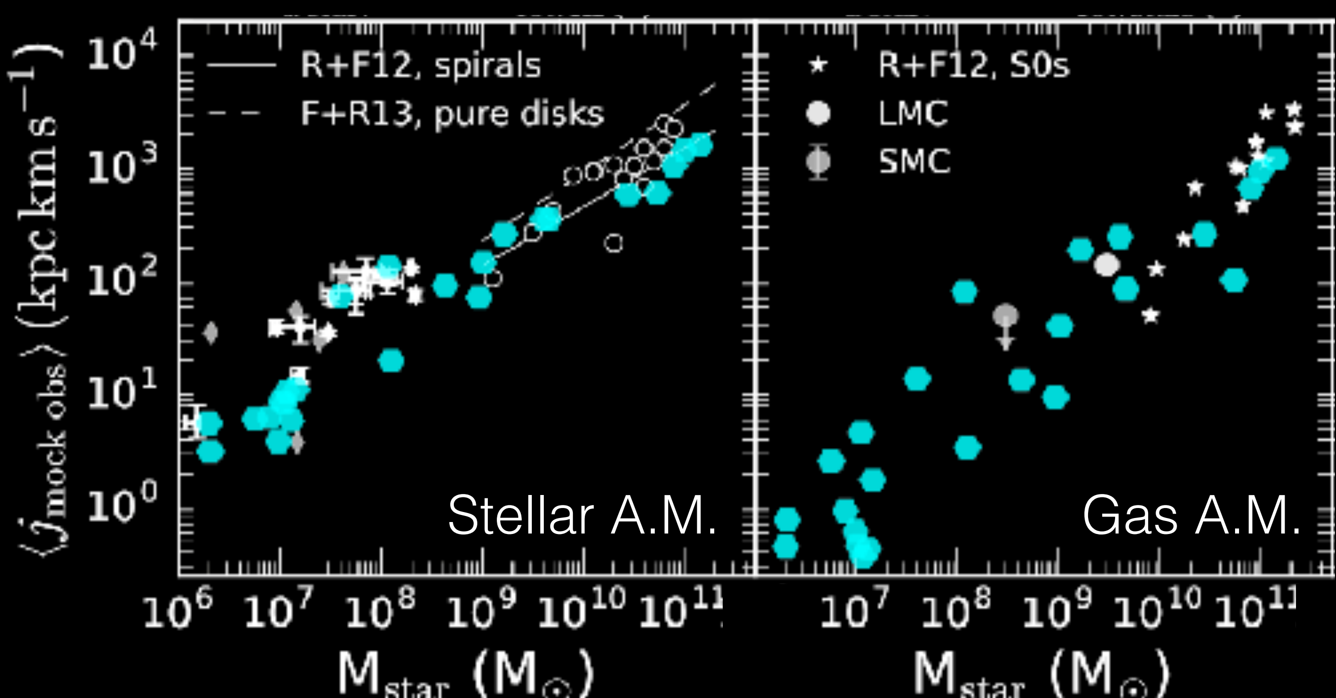
Garrison-Kimmel
et al., in prep

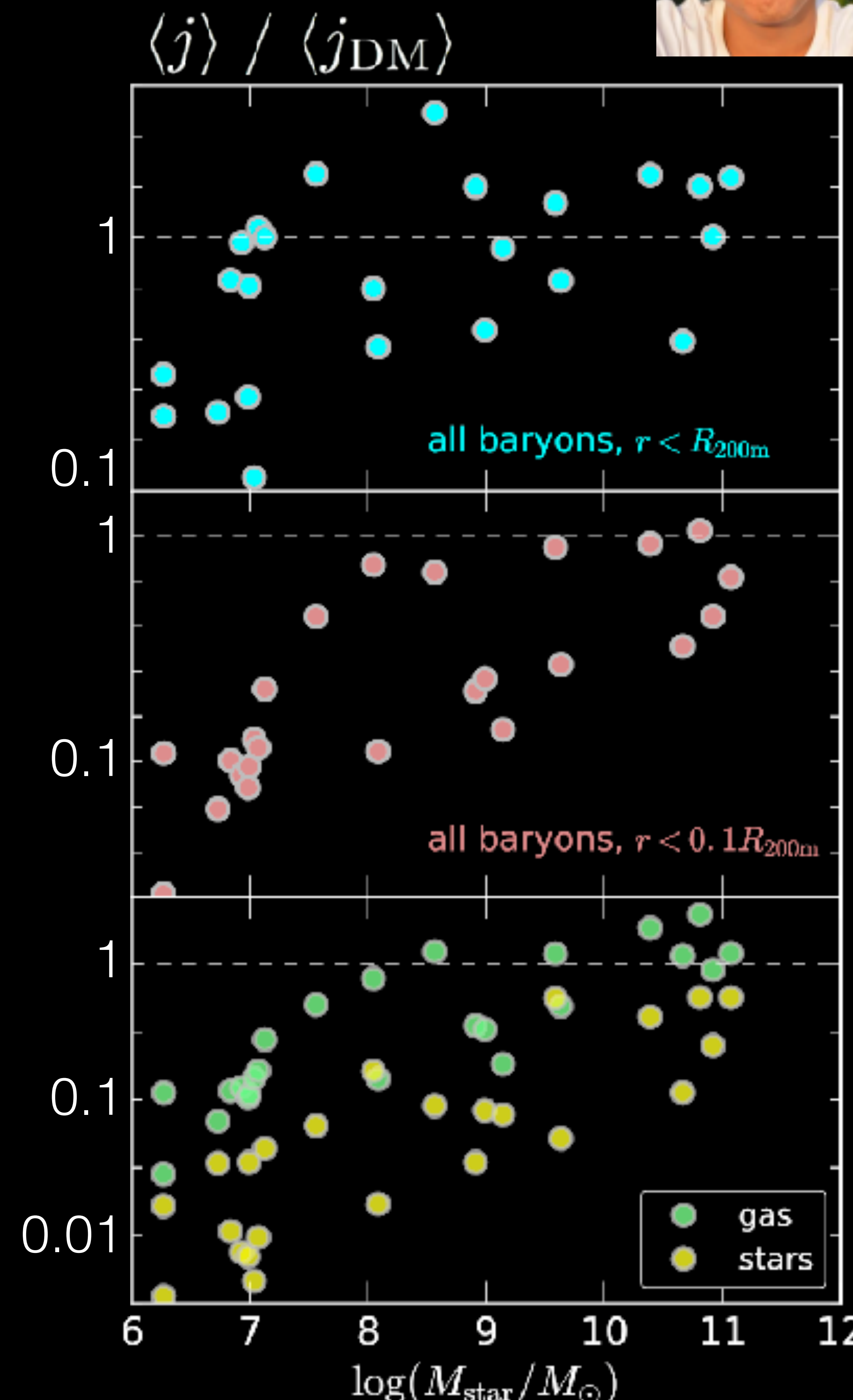
Angular Momentum of Gas+Stars

WHY DO DWARFS NOT HAVE (THIN) DISKS?

Kareem El-Badry
(arXiv:1705.10321)



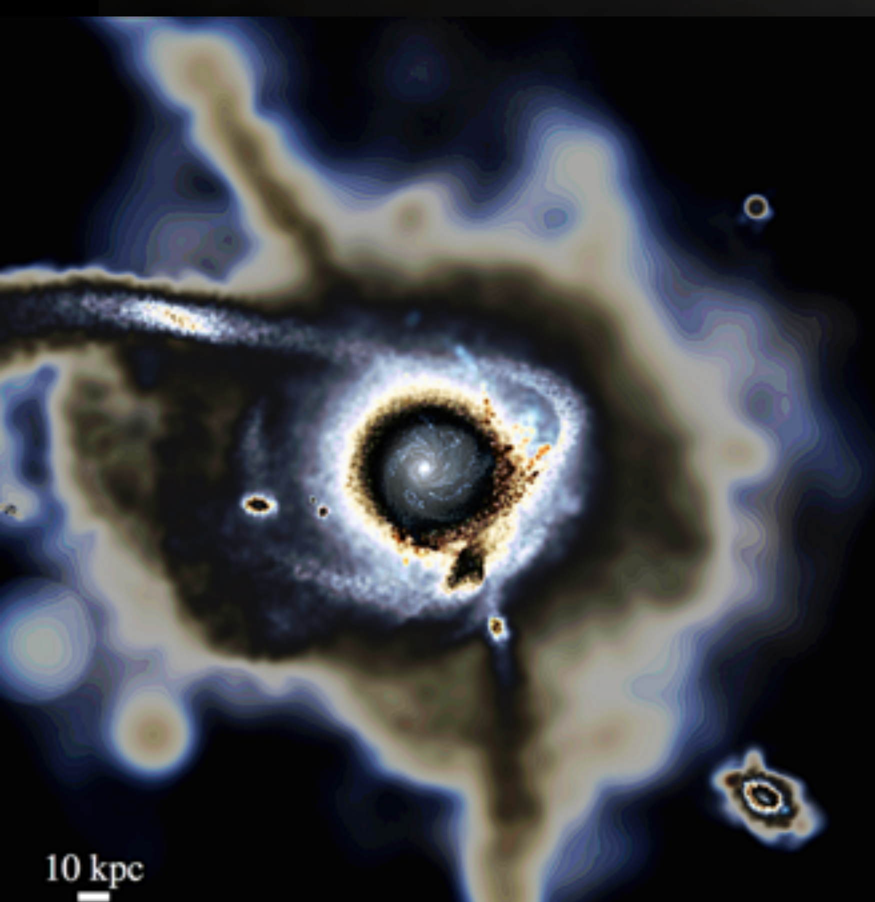


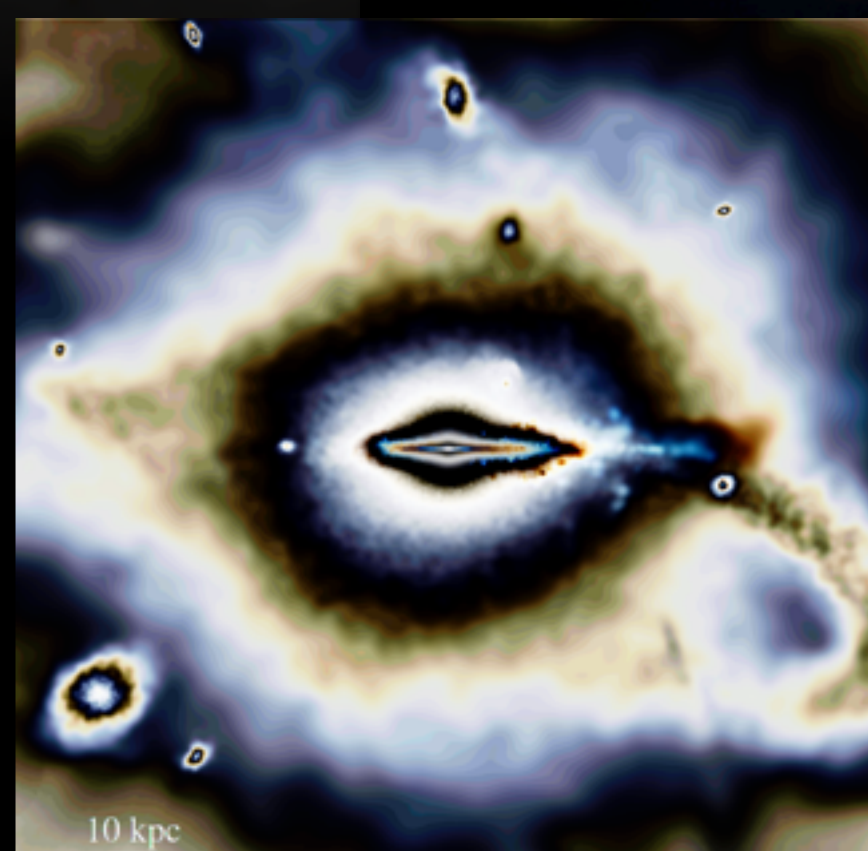


- Thick/irregular [clumpy+bursts+pressure]
- Suppressed late-time accretion [UVB+FB]

Halo Structure

Mock GAIA Catalogues with ~100,000,000 Stars in the (Simulated) Galaxy

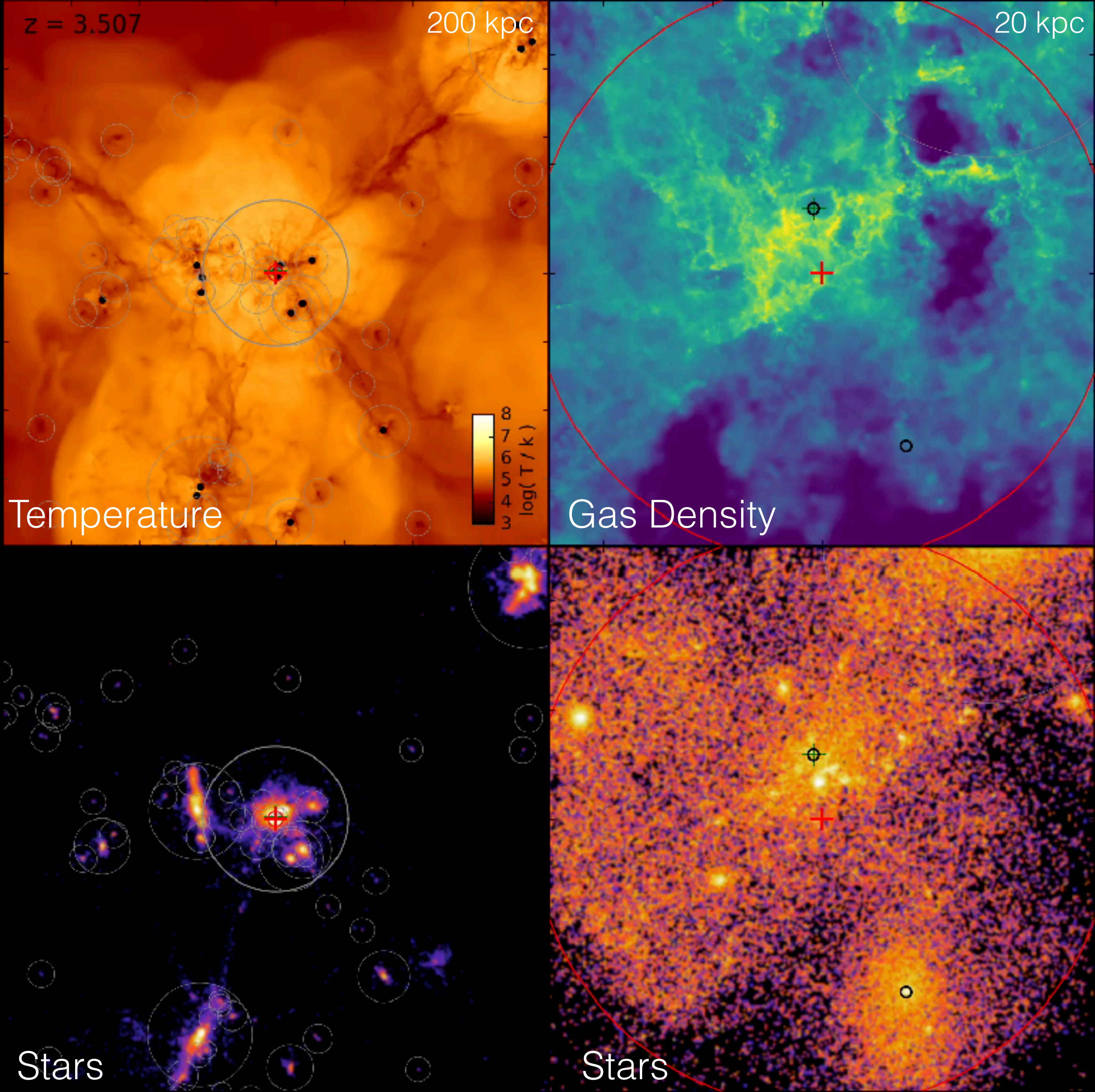




Sanderson et al. (in prep)

What About AGN?

Lumpiness + SNe
Need big seeds
or “anchors”



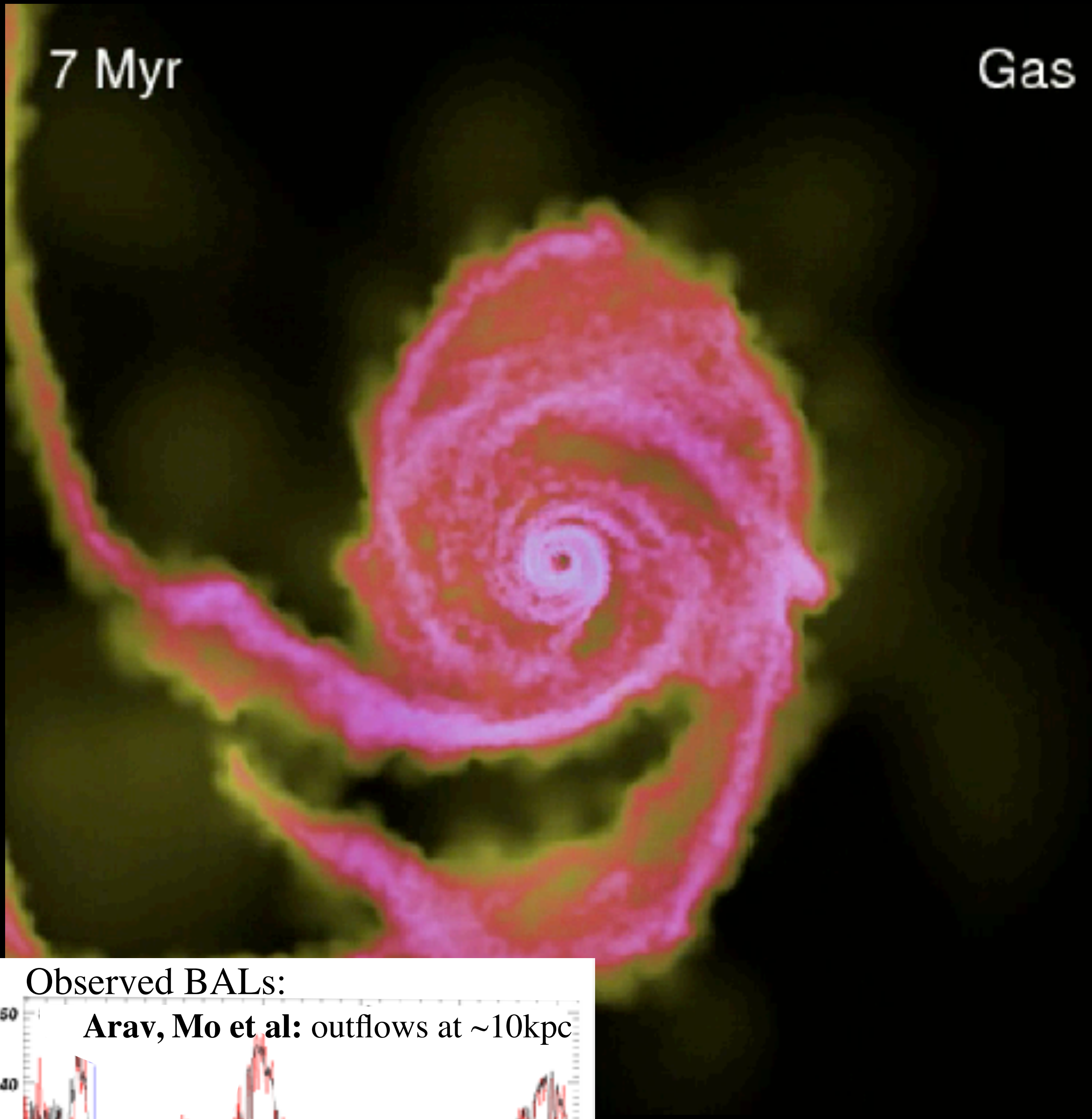
D. Angles-Alcazar
arXiv:1707.03832

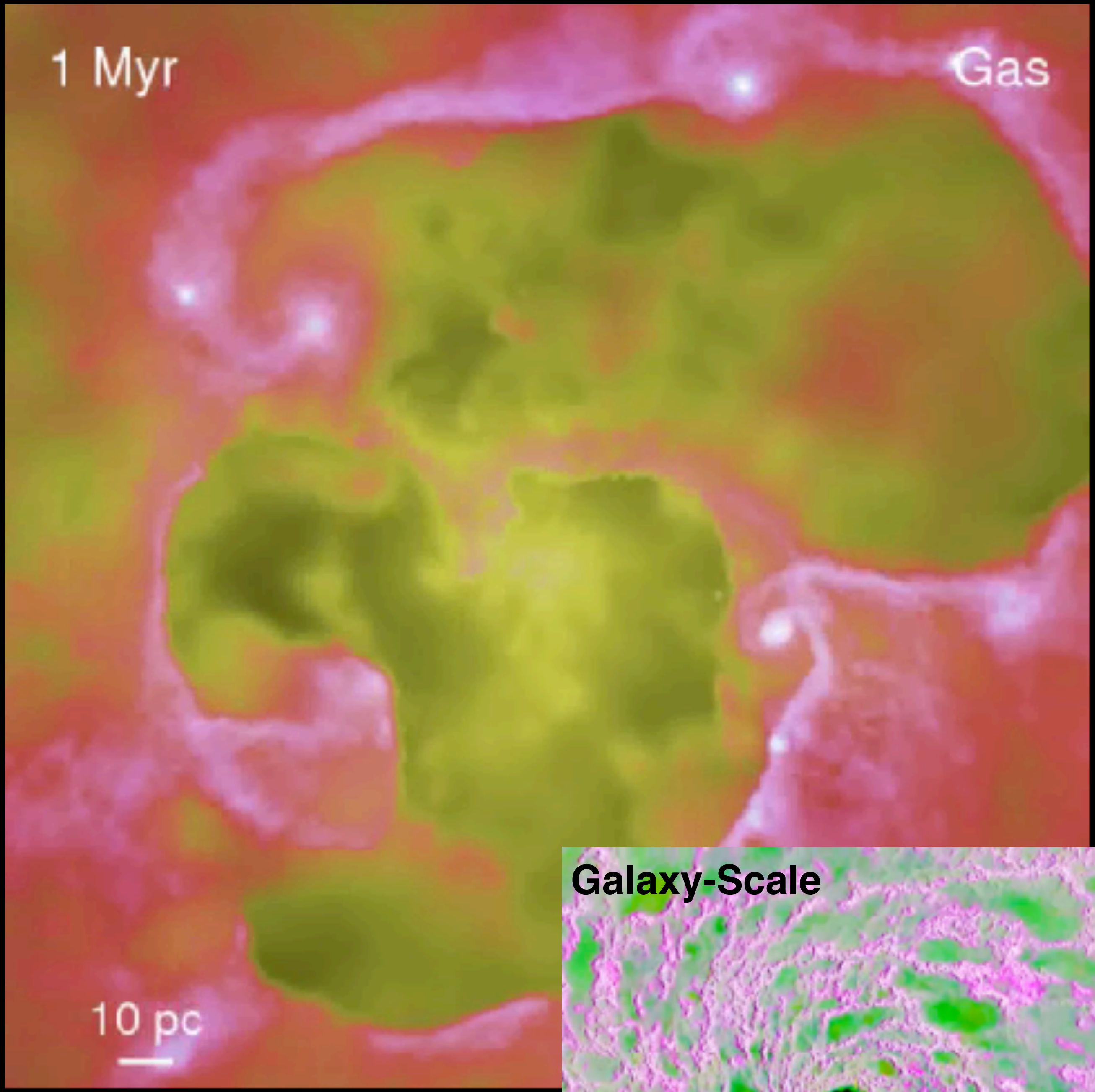
Accretion Disk Winds: 0.01-10,000 pc

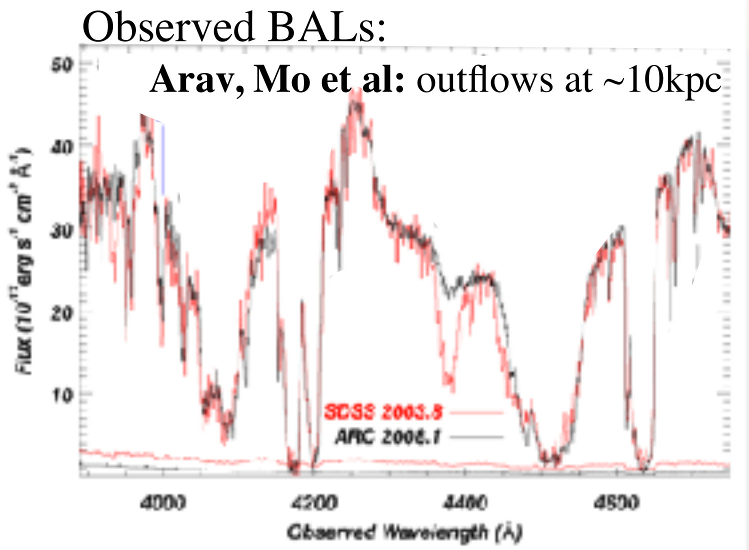
Torrey et al.
in prep

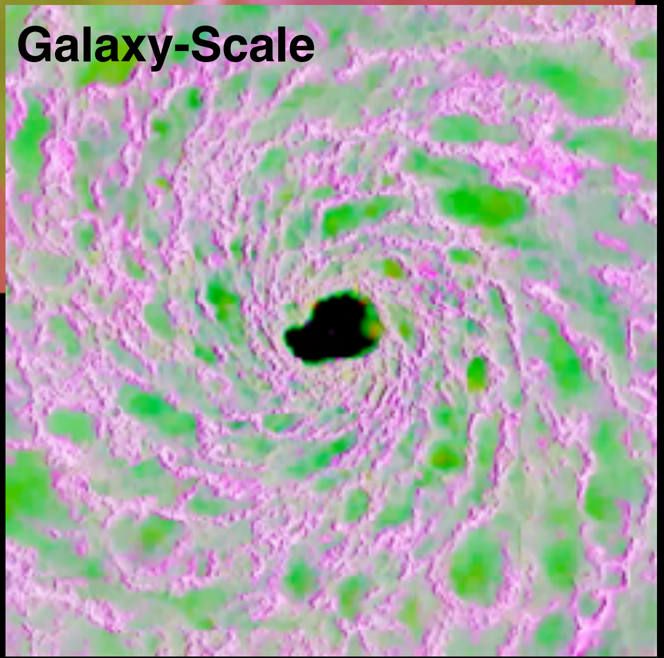
No BAL Winds

With BAL Winds





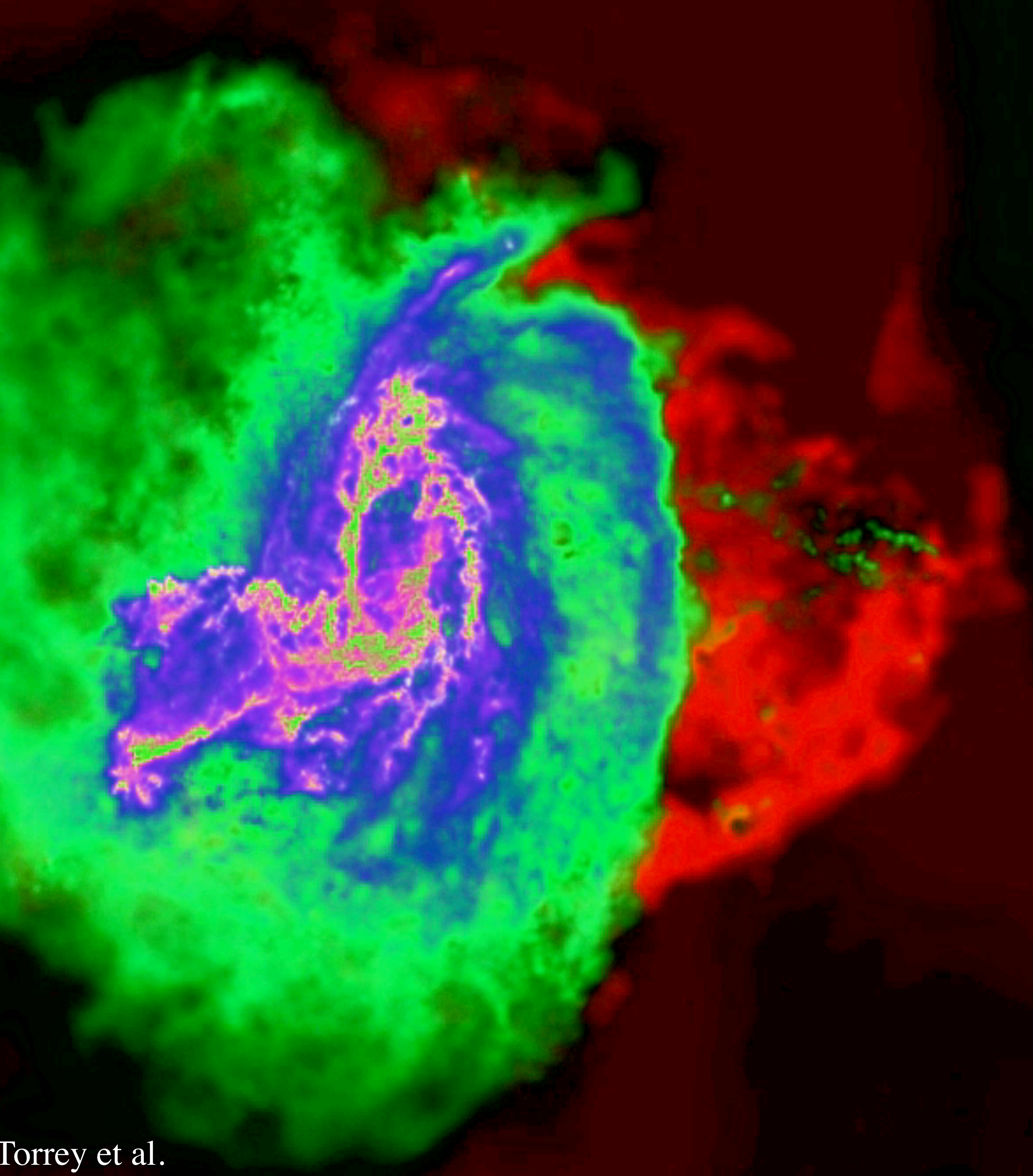




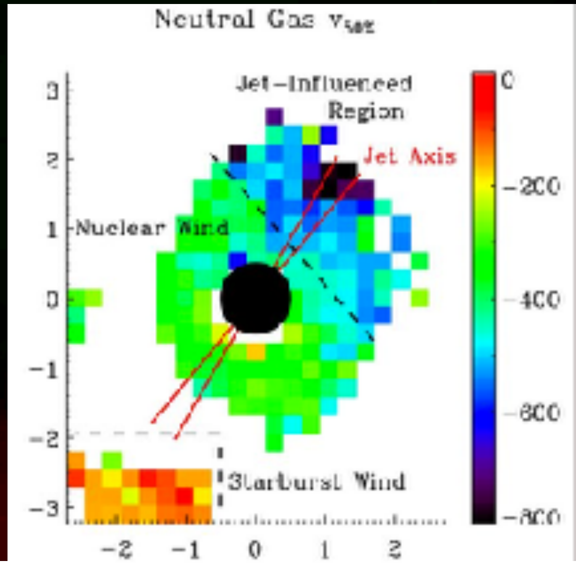
$$\dot{M}_{\rm launch}(0.1\,{\rm pc}) = 0.5\,\dot{M}_{\rm BH}$$

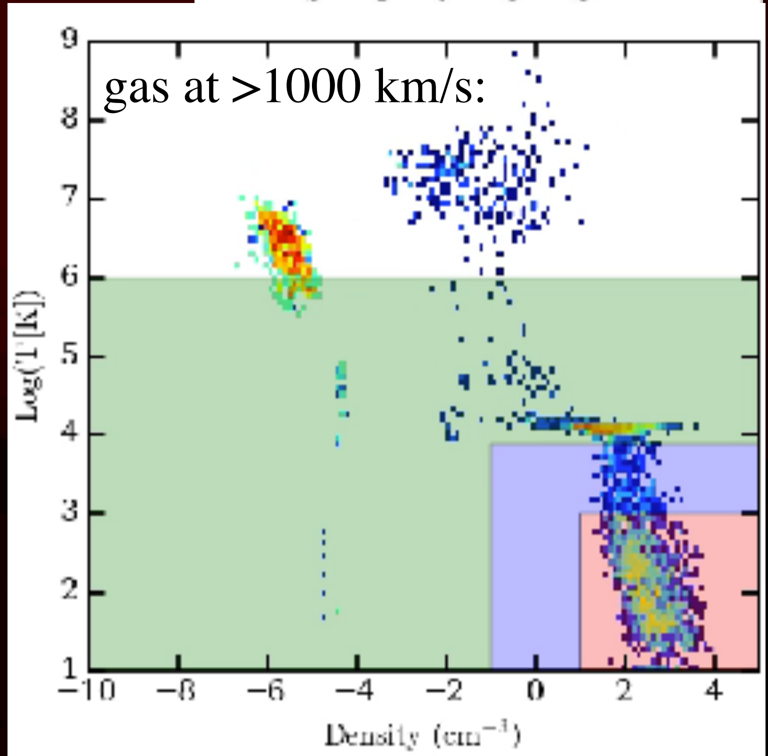
$$v_{\rm launch}(0.1\,{\rm pc}) = 10,000\,{\rm km/s}$$

Accretion Disk Winds: 0.01-10,000 pc

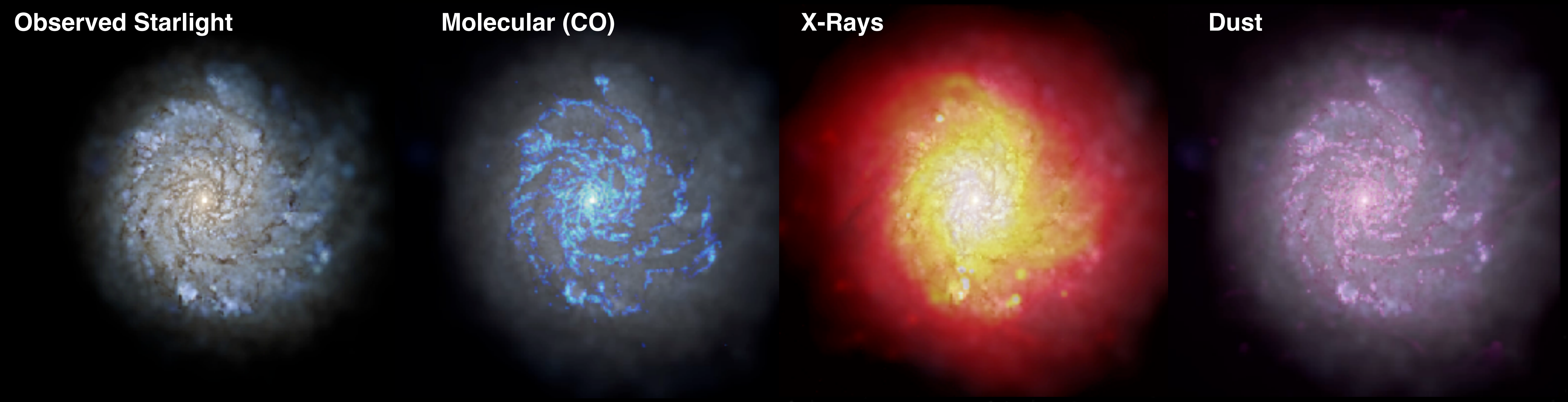


Mrk 231
(+all other warm ULIRGs)





Torrey et al.
in prep



- Dust-Gas Mixtures Inherently Unstable (Squire+ 17)
- IMF: Feedback or Galaxy-Scale Models are Wrong (Guszejnov+ 17)
- Stellar clustering is Universal (Guszejnov+ 17)
- Realistic clusters: Cloud surface density determines properties (Grudic+ 17)
- Globulars resolved(?) (Kim+ 17)
- KS=feedback: dense laws; SF 'starts' with instability (Orr+17)
- Weak dependence of ISM/SF on MHD, etc (Su+ 17)
- Giant clumps ~ scaled GMCs (Oklopcic+ 17)
- Bursty SF important to observed SFR relations (Sparre+ 16)
- Bursty SF perturbs dwarfs (El-Badry+ 16), disk settling key (Ma+16)
- Halo structure (Sanderson+) & AGN (Torrey, Angles-Alcazar) in prep…