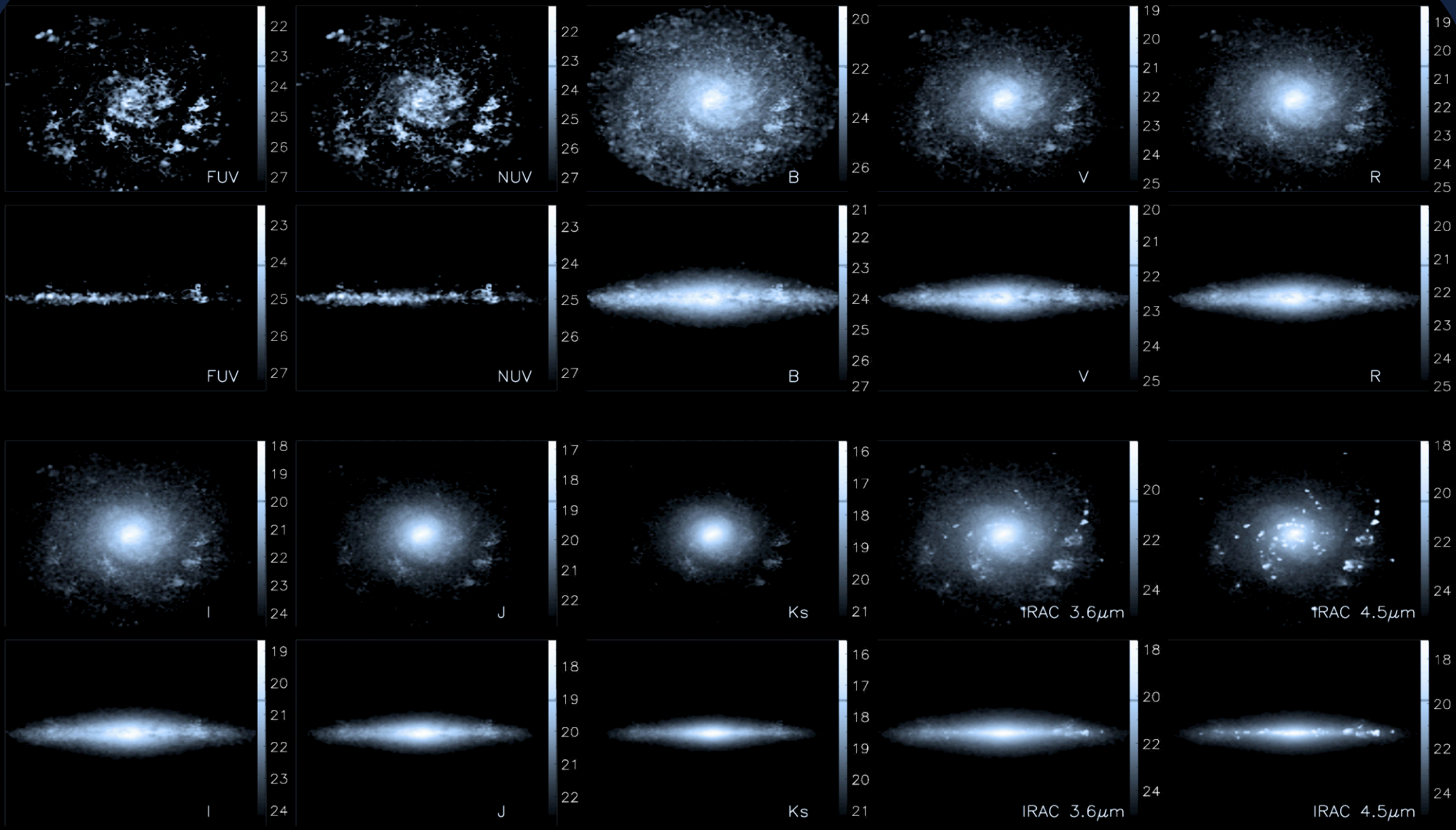
CLUES + ChaNGa+ Gasoline



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CHaNGA

http://librarian.phys.washington.edu/astro/index.php/Research:ChaNGa

Motivation Charm++

* decrease time spent decomposing datasets among processors
* maintain load balancing.
* automatic load balancing framework
* handles application decompositions with uneven granularity
* asynchronous message based system: objects proceed in the computation independently, without waiting for data
* good performance on massively parallel systems

ChaNGa Features

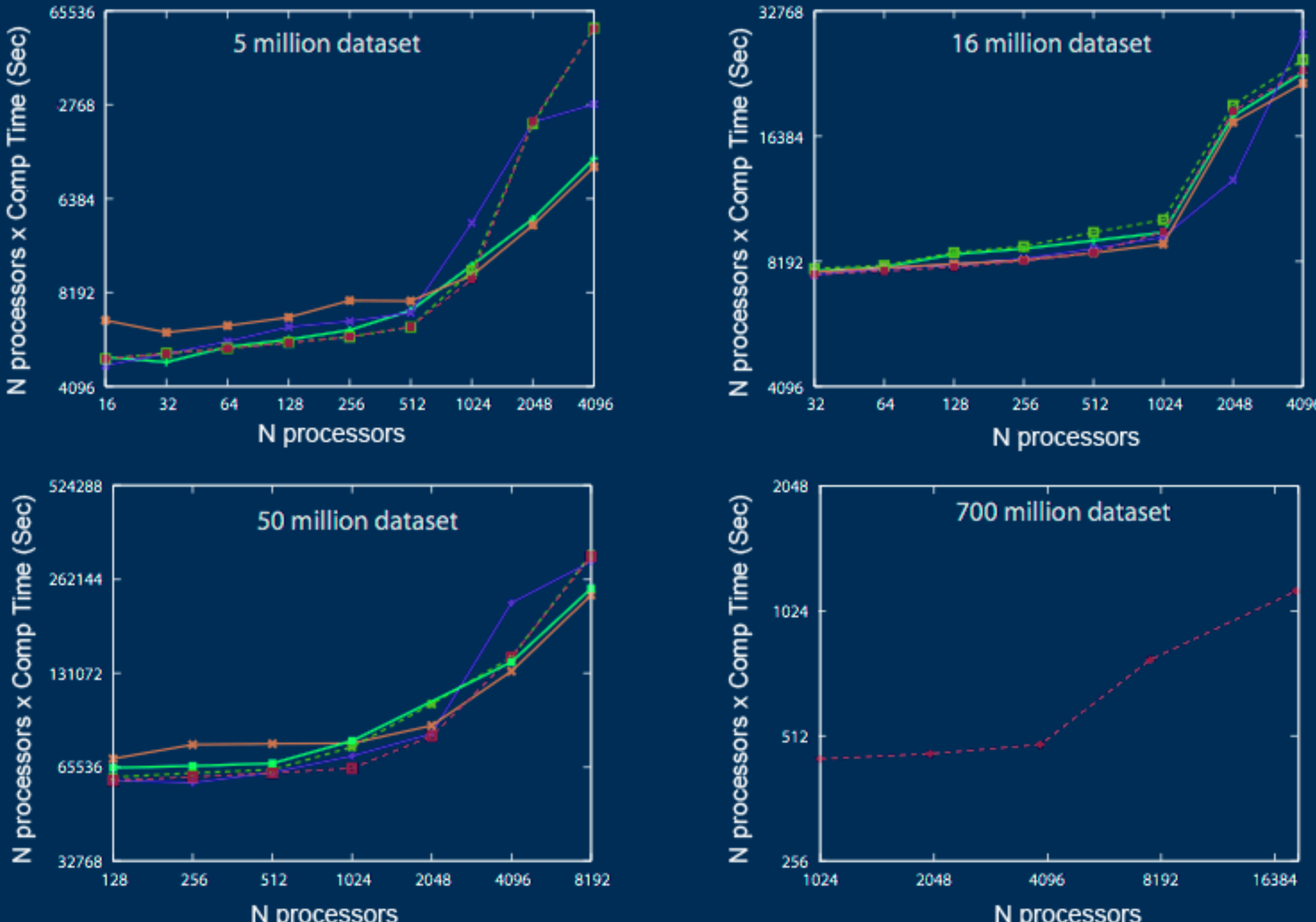
- Tree-based gravity solver
- High order multipole expansion
- Periodic boundaries (if needed)
- Individual multiple timesteps
- Dynamic load balancing with choice of strategies
- Checkpointing (via migration to disk)
- Visualization

Benchmarks

- *Lambs: 3 million particle final state of a cosmological simulation of 70 Mpc .*
- *Lambb: 80 million particle, same 70 Mpc volume.*
- *dwf1: 5 million particle cosmological zoom-in simulation, Mhalo~10^{11}Msun.*
- *dwf1.6144: 50 million particle run of dwf1.*
- *dwf1.ms: same ICs as dwf1, but with multi-stepping capabilities, 64 substeps*

Machine	Date	Compiler	Charm build	benchmarks (ncores:time)				
				lambs	lambb	dwf1	dwf1.6144	dwf1.ms
gordon	5/2013	GCC	net-linux-x86_64-ibverbs	16:18.2s 128:2.8s	128:79.9s 1024:12.3s	16:28.4s 128:4.2s	128:45.9s 1024:6.9s	16:1105s 128:300s
gordon	5/2013	Intel	net-linux-x86_64-ibverbs	16:18.3s 128:2.7s	128:80.5s 1024:12.3s	16:29.4s 128:4.2s	128:47.6s 1024:7.0s	16:1247s 128:323s
gordon	5/2013	GCC	mpi-linux-x86_64	16:18.6s 128:3.0s	128:87.1s 512:24.8s	16:29.5s 128:4.5s	128:51.1s 256:27.1s	
bluewaters	5/2013	GCC	gemini_gni-crayxe-hugepages-smp	32:17.3s 256:2.5s	256:72.9s 2048:10.2s	32:26.0s 256:3.3.7s	256:41.3s 2048:6.2s	32:401s 256:91.3s
stampede	6/2013	GCC	net-linux-x86_64-ibverbs	16:15.6s 128:2.8s	128:66.7s 1024:10.1s	16:25.1s 128:4.2s	128:39.4s 1024:6.5s	16:392s 128:98.2s
kraken	6/2013	GCC	mpi-crayxt	12:32.4s 96:5.1s	96:140s 768:20.7s	12:49.8s 96:7.5s	96:78.4s 768:14.3s	12:753s 96:186s

Scaling to 10,000+ Processors



Hydro version also publically available: GASOLINE

ChaNGa GASOLINE publically available which includes:

- Smoothed Particle Hydrodynamics
- Gas Cooling
- Star Formation
- Blast Wave Supernova Feedback (Stinson 2006)

Note: Gasoline currently undergoing major changes to the implementation of hydrodynamics e.g. heat diffusion

Treatment of viscosity is currently being updated

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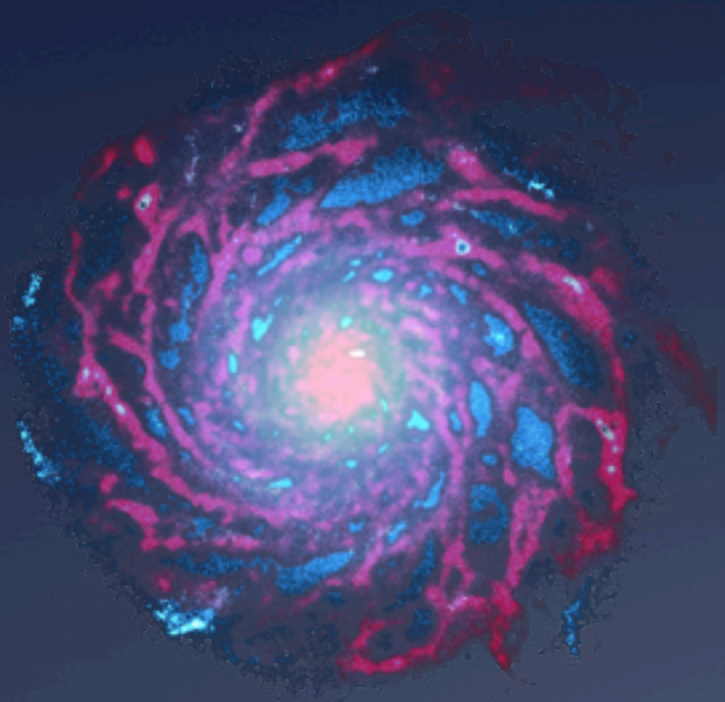
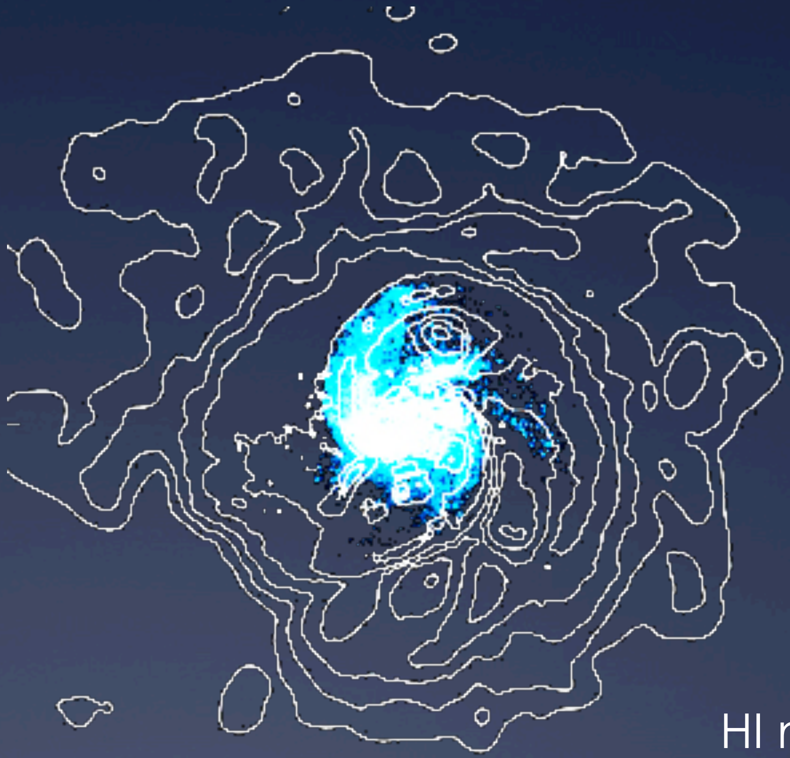
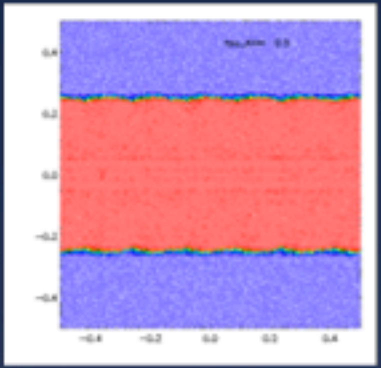


Eris simulation
Guedes et al. 2011



Bulgeless Dwarfs
Governato, Brook et al. 2010
Brook et al. 2011, 2012

SPH Kelvin Helmholtz fixes

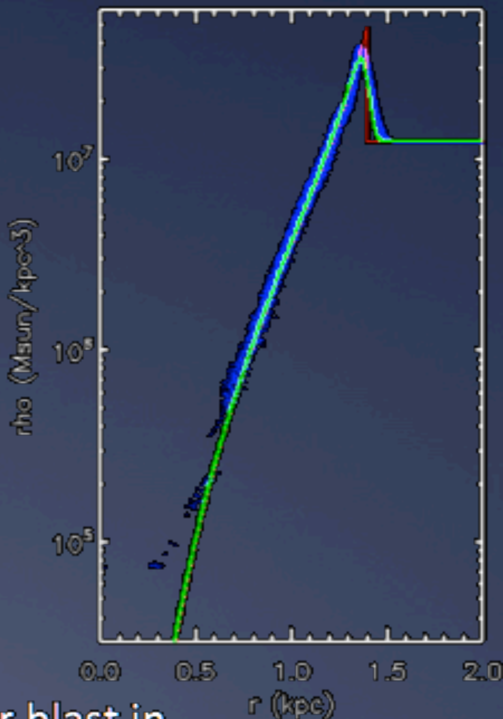


- Ritchie & Thomas (2001) – smooth pressure not density and Geometric Density Average in Force: remove surface tension (pressure errors at density jump)
- Price (2008) – smear density jumps
- Read, Hayfield & Agertz (2010), Read & Hayfield (2011), Abel (2011), Murante et al (2011) … modified SPH
- Pressure-Entropy SPH (Hopkins 2013)

Gasoline

Current Version (2013):

- Fixed number of neighbours (e.g. 64 for Wendland C_2 kernel, Dehnen & Aly 2012)
- Single SPH smooth (no iterations)
- Standard density, geometric density forces
- Turbulent Diffusion (Shen, Wadsley & Stinson 2010)
- f correction to PdV work
- Multistepping power of 2 KDK plus Saitoh & Makino (2009) timestep adjustment



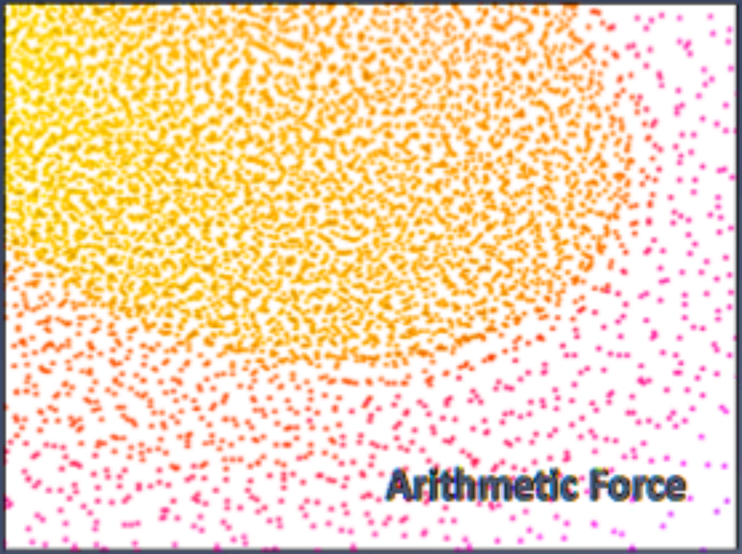
good integrator test: Sedov-Taylor blast in T=0 K gas (128^3) 0.08 % Energy error

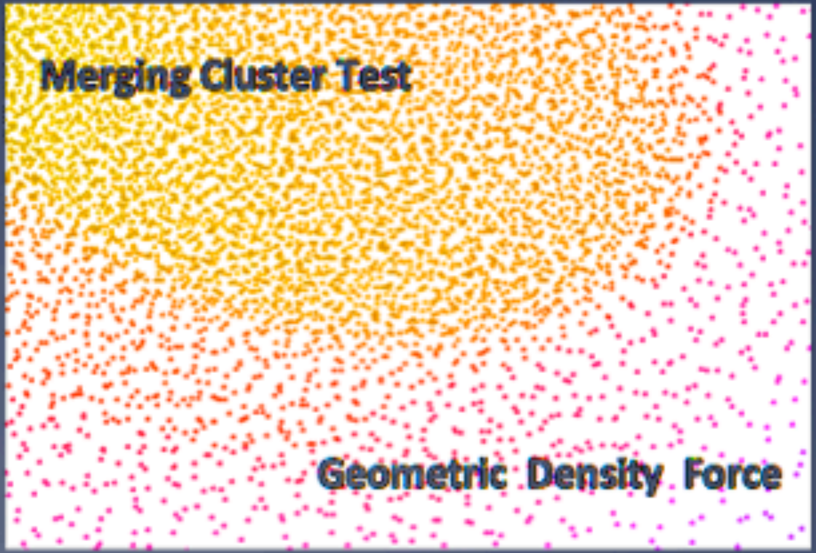
Common element in relieving SPH surface tension:

- Geometric Density Average in Force (GD Force):

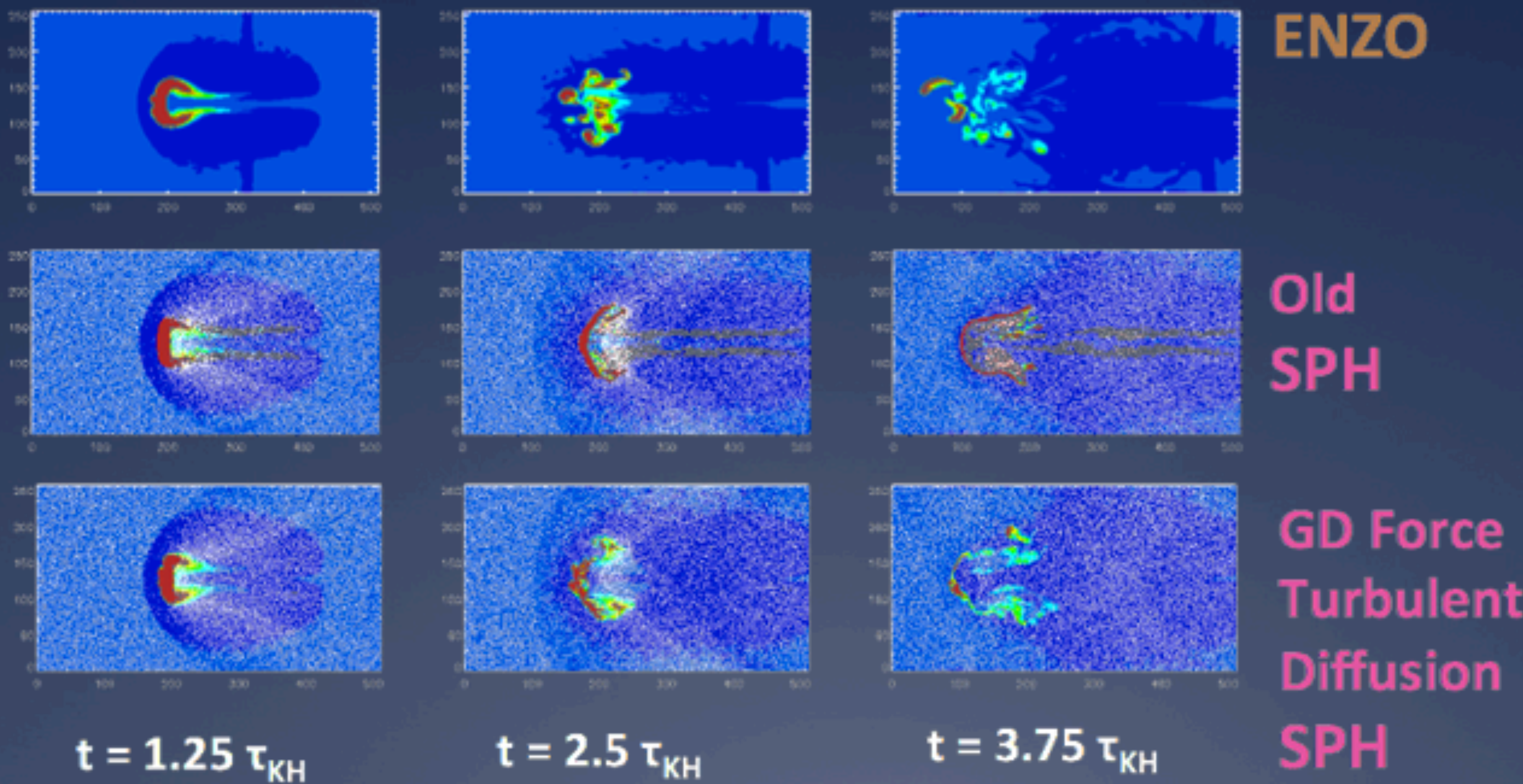
$$\frac{dv_a}{dt} = -\sum_b m_b \left(\frac{P_a + P_b}{\rho_a \rho_b} \right) \nabla_a W_{ab}$$

Morris (1996), Monaghan (1992)
Ritchie and Thomas (2001),
Can be derived from a Lagrangian:
Monaghan & Rafiee (2012)
see also Abel (2011), Hopkins (2013)

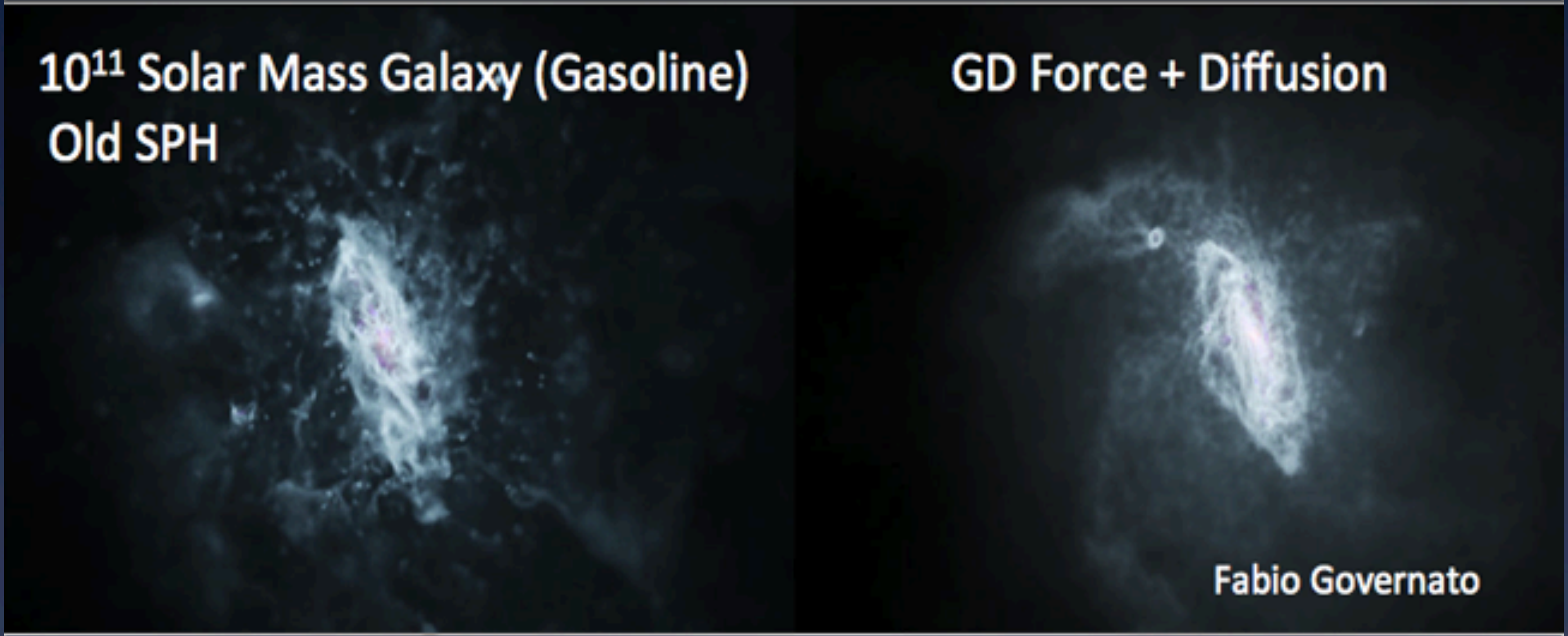




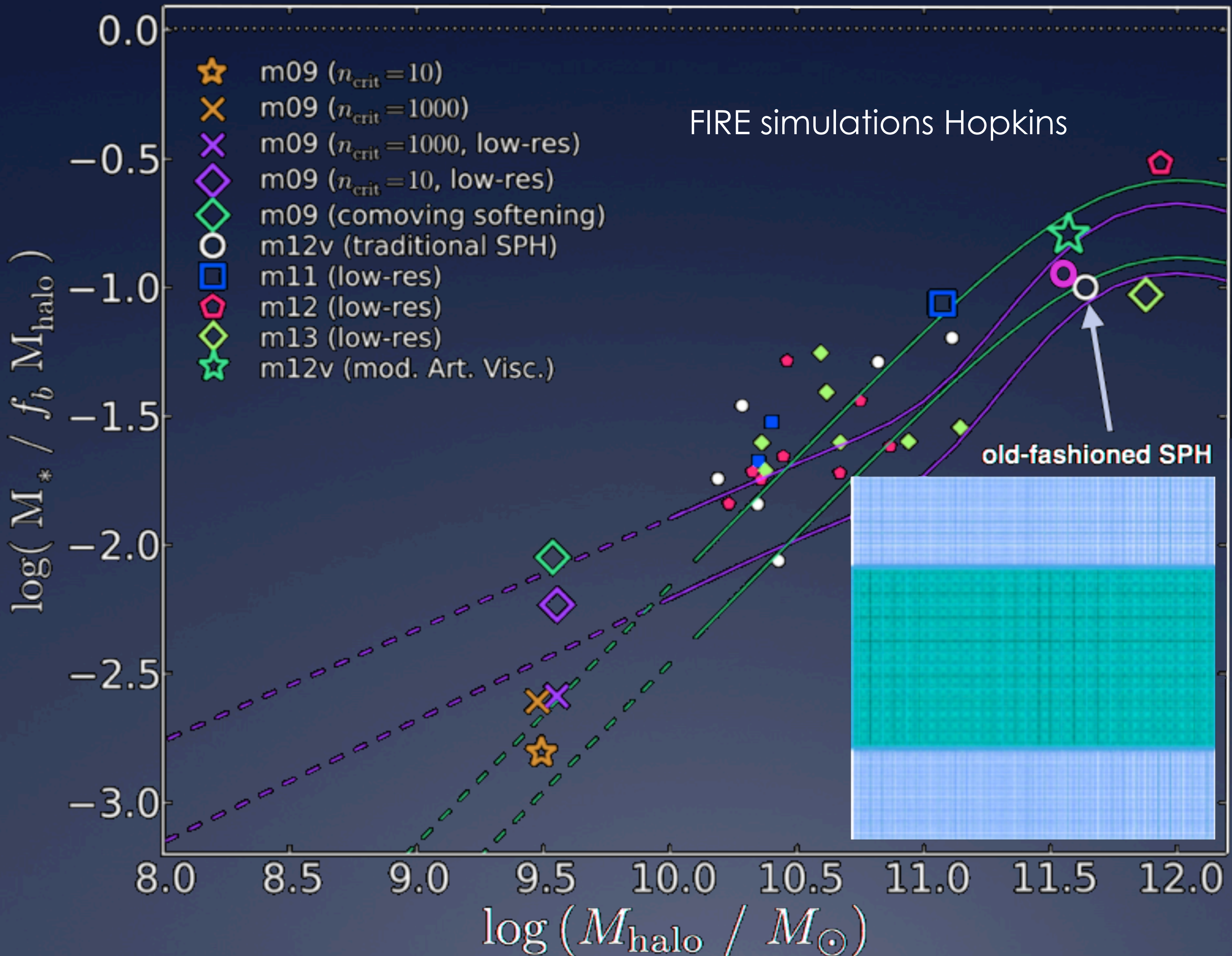
Blob Test in Entropy ($T^{3/2}/\rho$)



SPH Galaxies: No more blobs

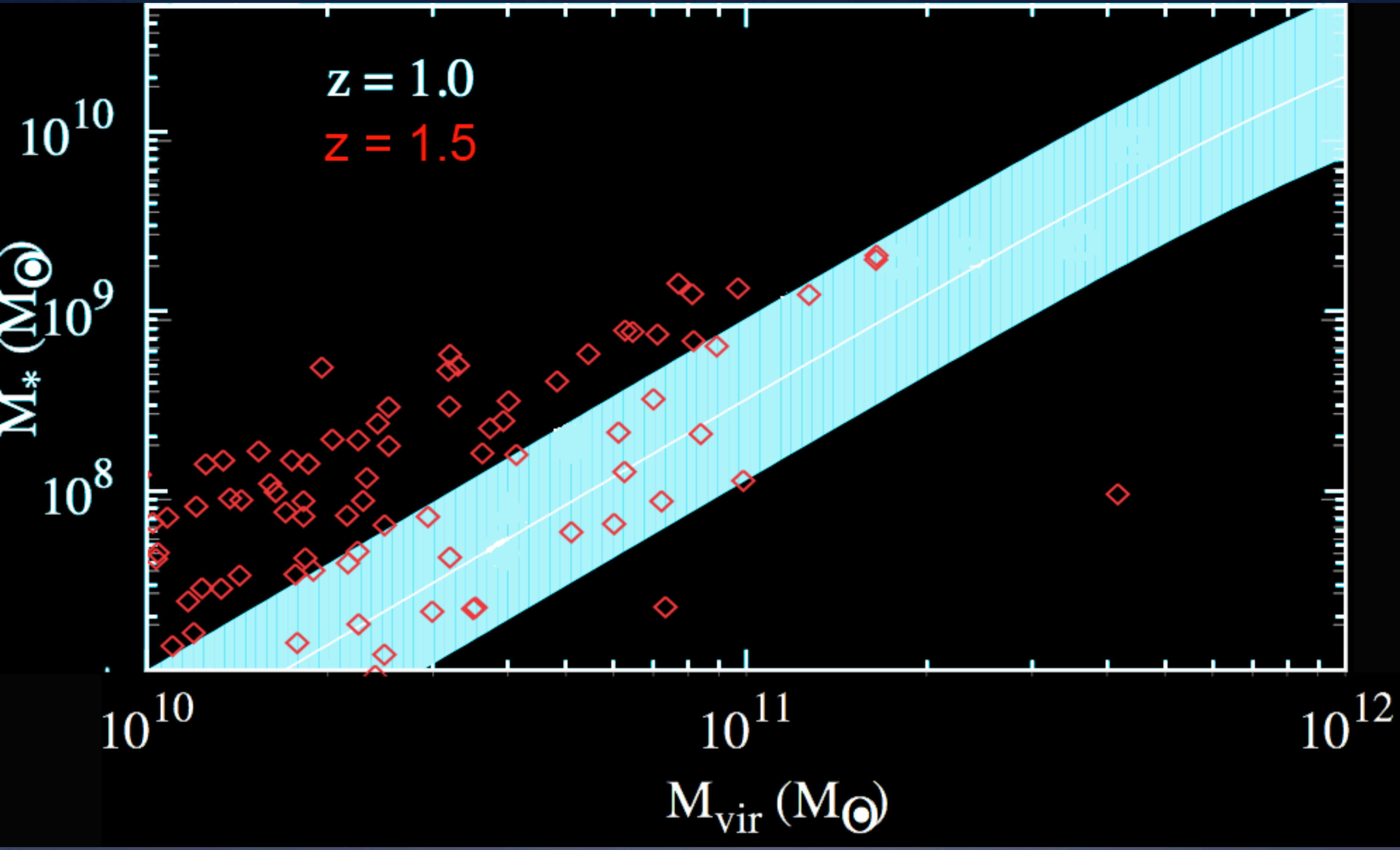


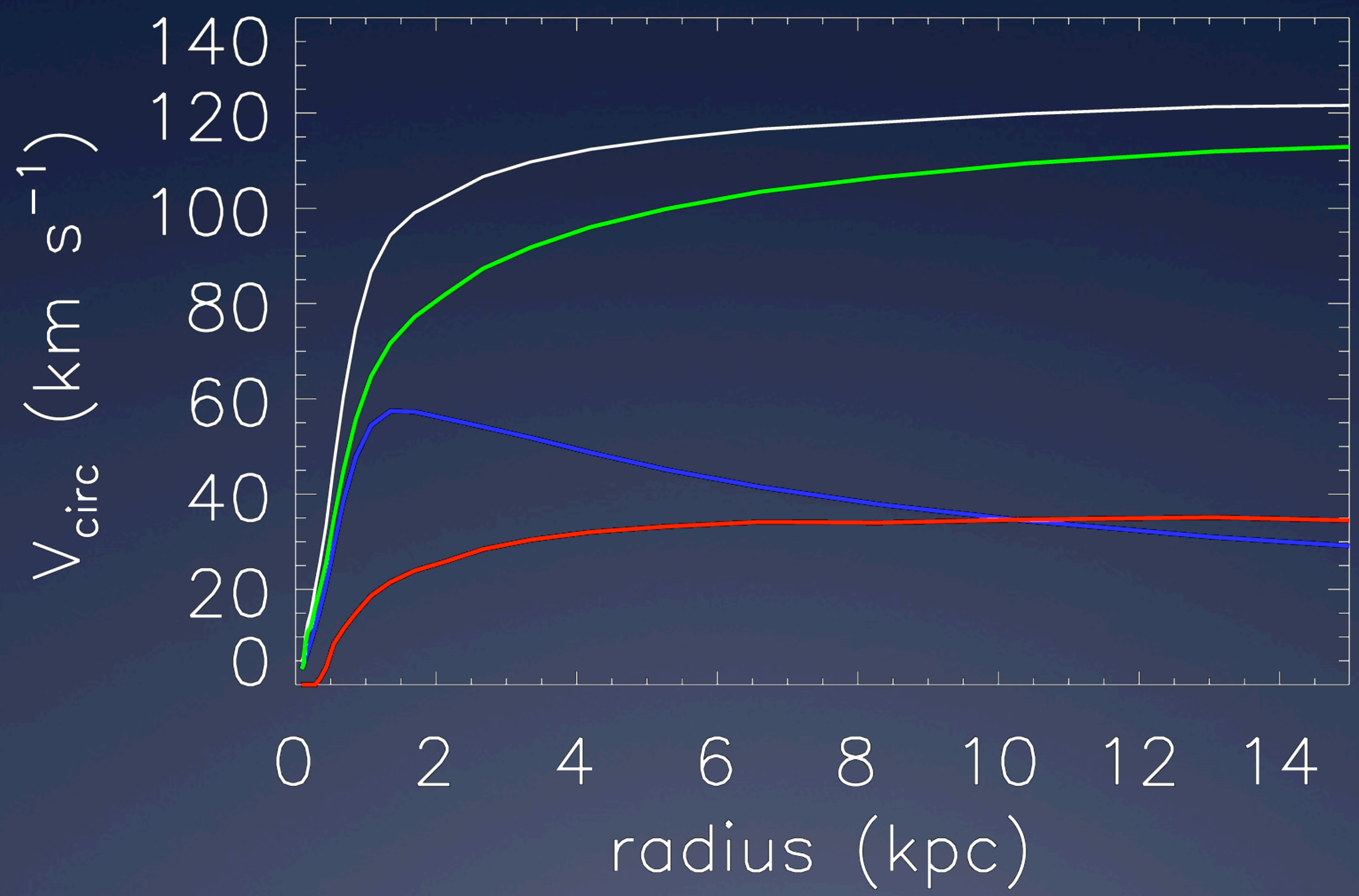
- Large scale gas accretion similar, but overall star formation higher
  - feedback less effective
- Mixing → More gas at intermediate Temperatures → more cooling (cf. Eagle, Illustris, Teyssier – strong 300% SN FB)



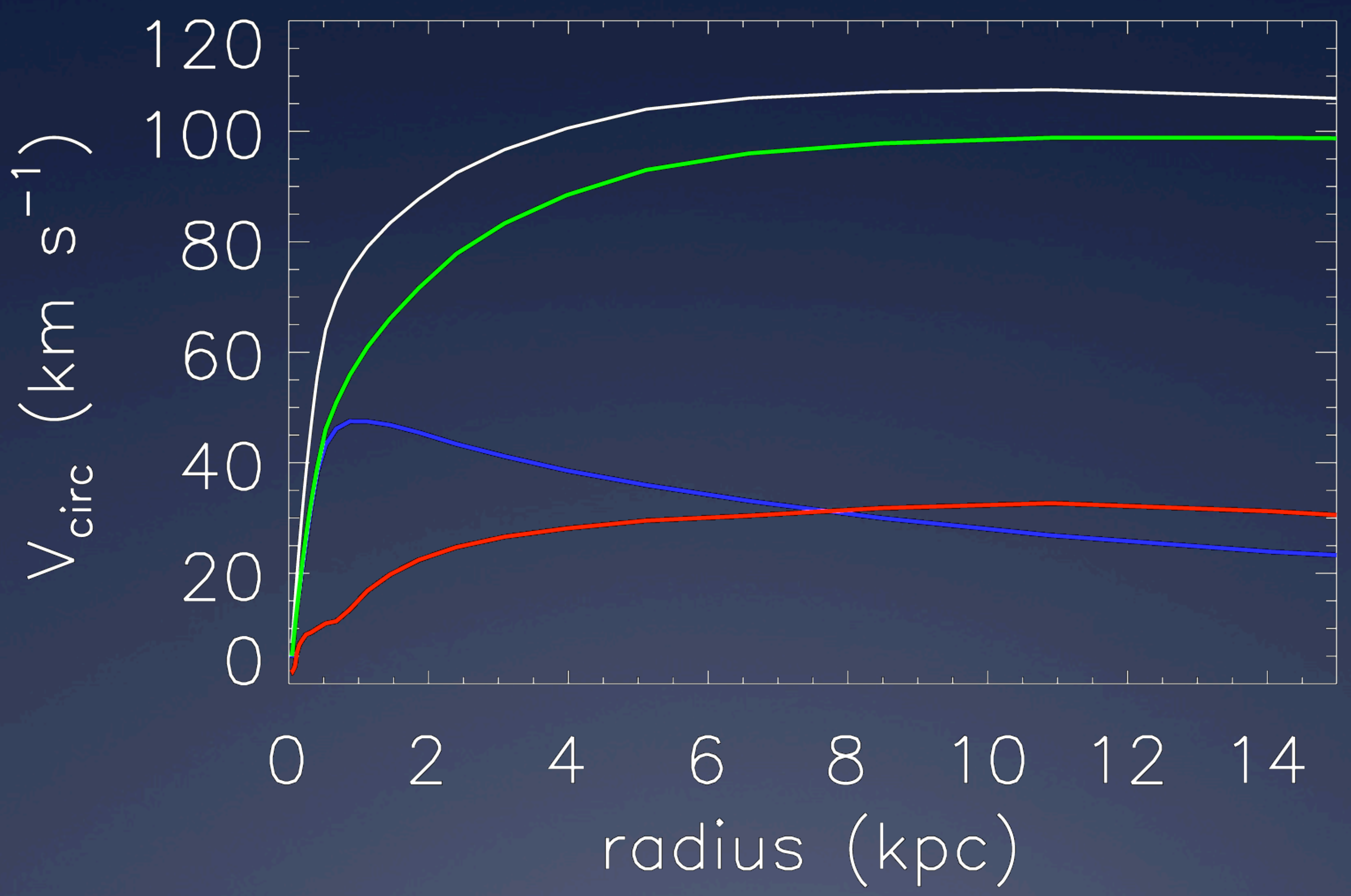
FIRE simulations Hopkins
m09 ($n_{crit}=10$)
m09 ($n_{crit}=1000$)
m09 ($n_{crit}=1000$, low-res)
m09 ($n_{crit}=10$, low-res)
m09 (comoving softening)
m12v (traditional SPH)
m11 (low-res)
m12 (low-res)
m13 (low-res)
m12v (mod. Art. Visc.)
old-fashioned SPH
$\log(M_* / f_b M_{halo})$
$\log(M_{halo} / M_\odot)$
0.0
−0.5
−1.0
−1.5
−2.0
−2.5
−3.0
8.0
8.5
9.0
9.5
10.0
10.5
11.0
11.5
12.0

CLUES WMAP3 HR + PUBLIC GASOLINE/ChaNGa





140
120
100
80
60
40
20
0
V_{circ} (km s^{-1})
0
2
4
6
8
10
12
14
radius (kpc)



120
100
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0
V_{circ} (km s^{-1})
0
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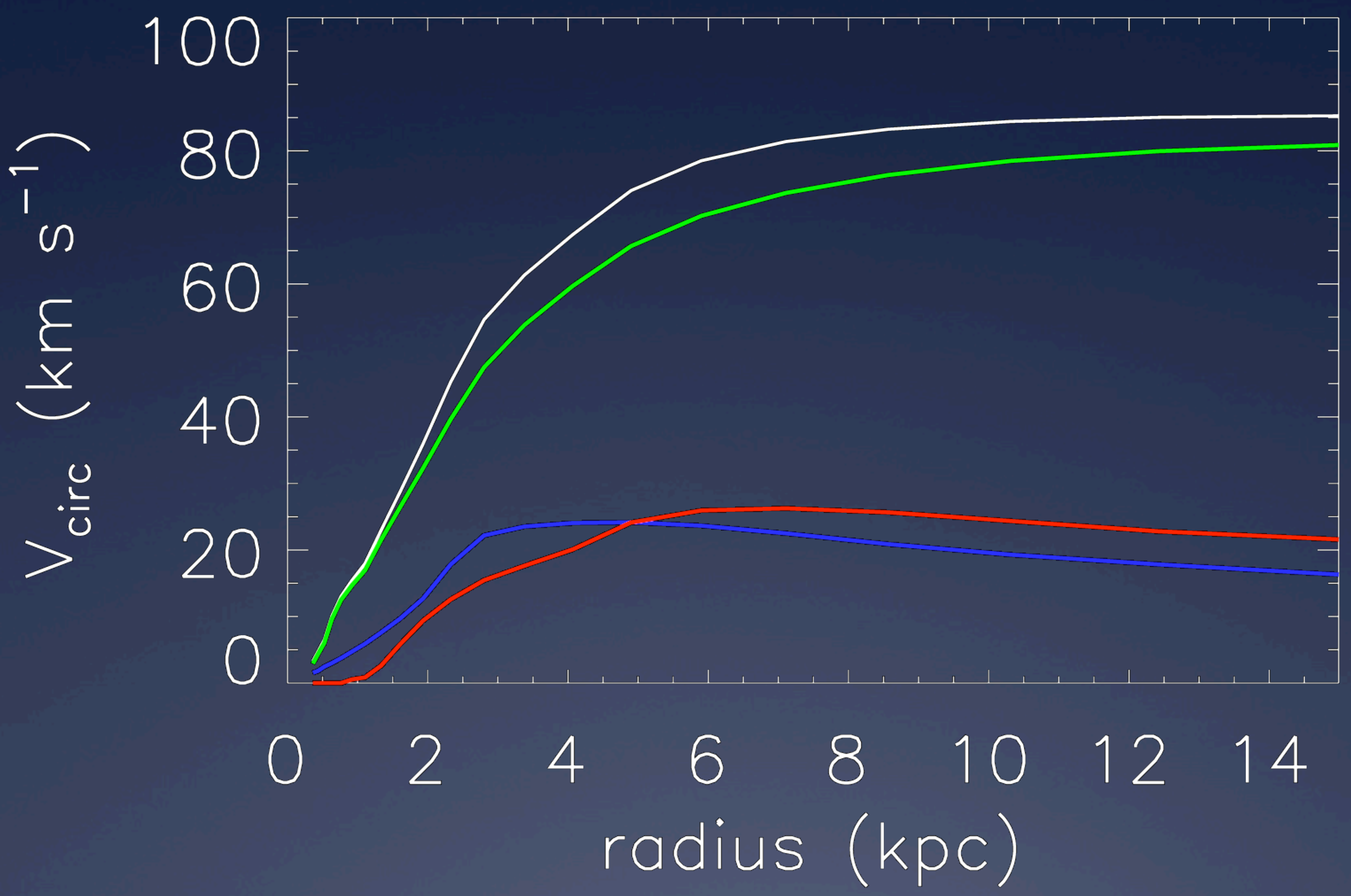
radius (kpc)



100
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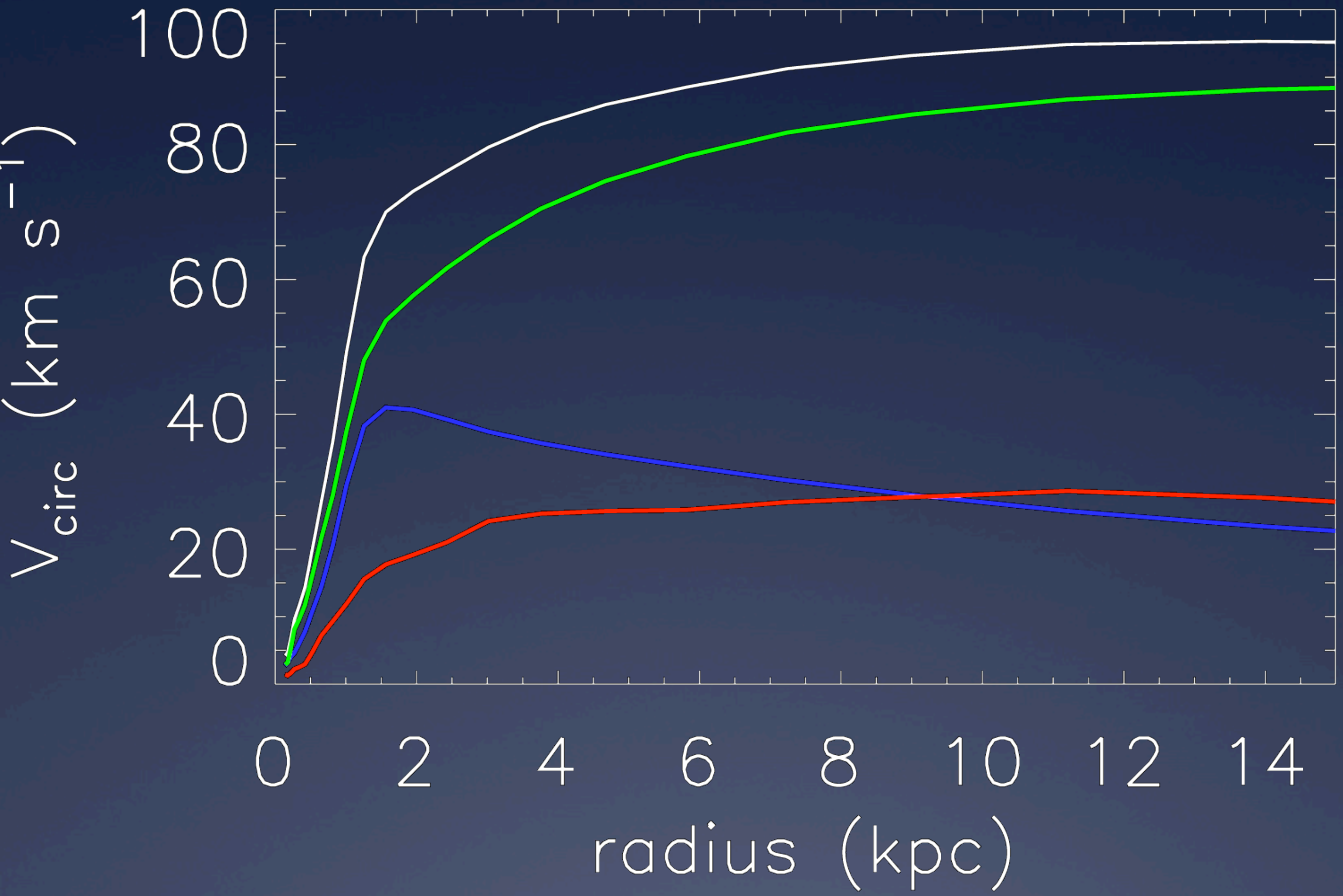
V_{circ} (km s^{-1})
radius (kpc)



100
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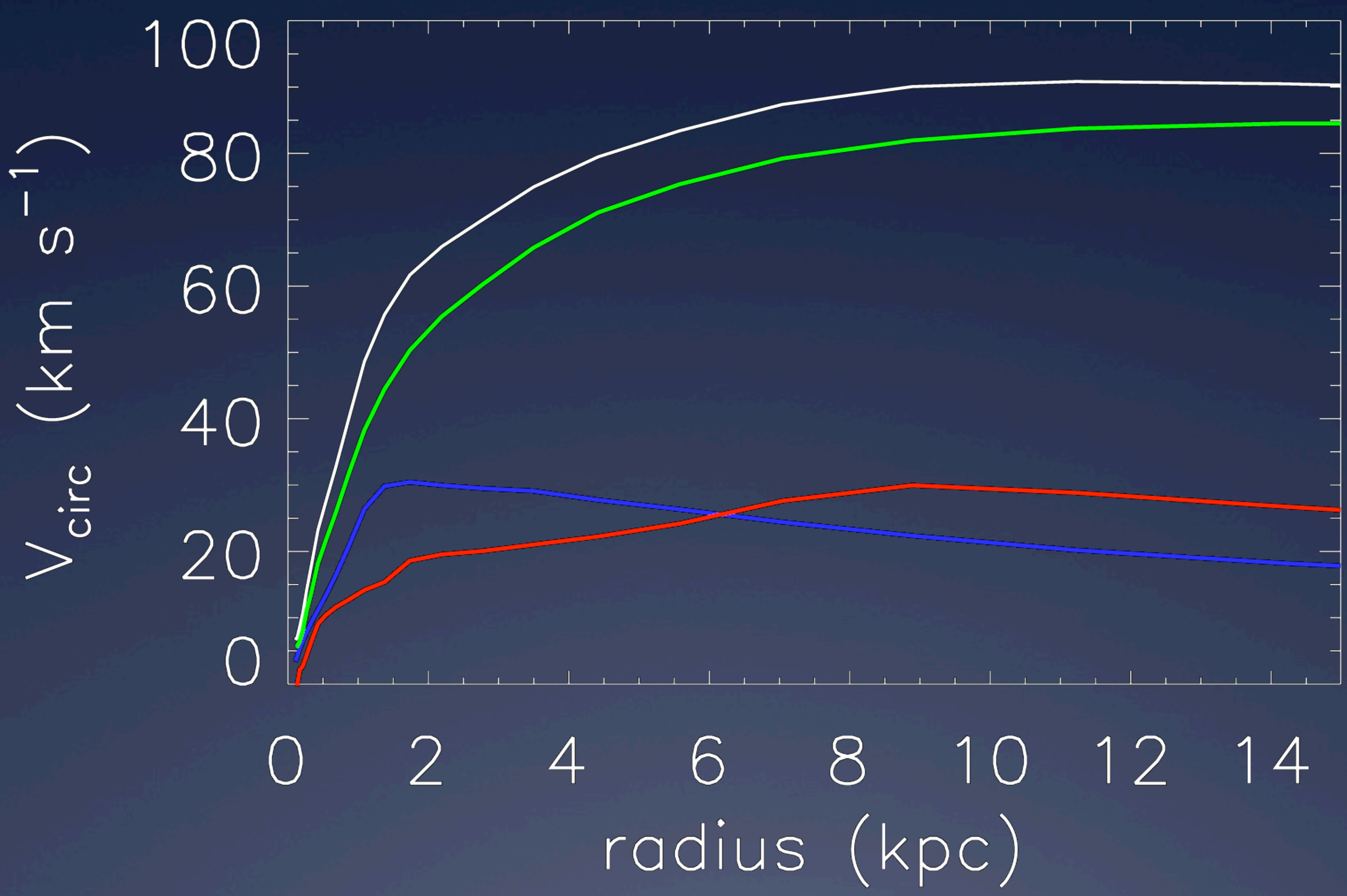
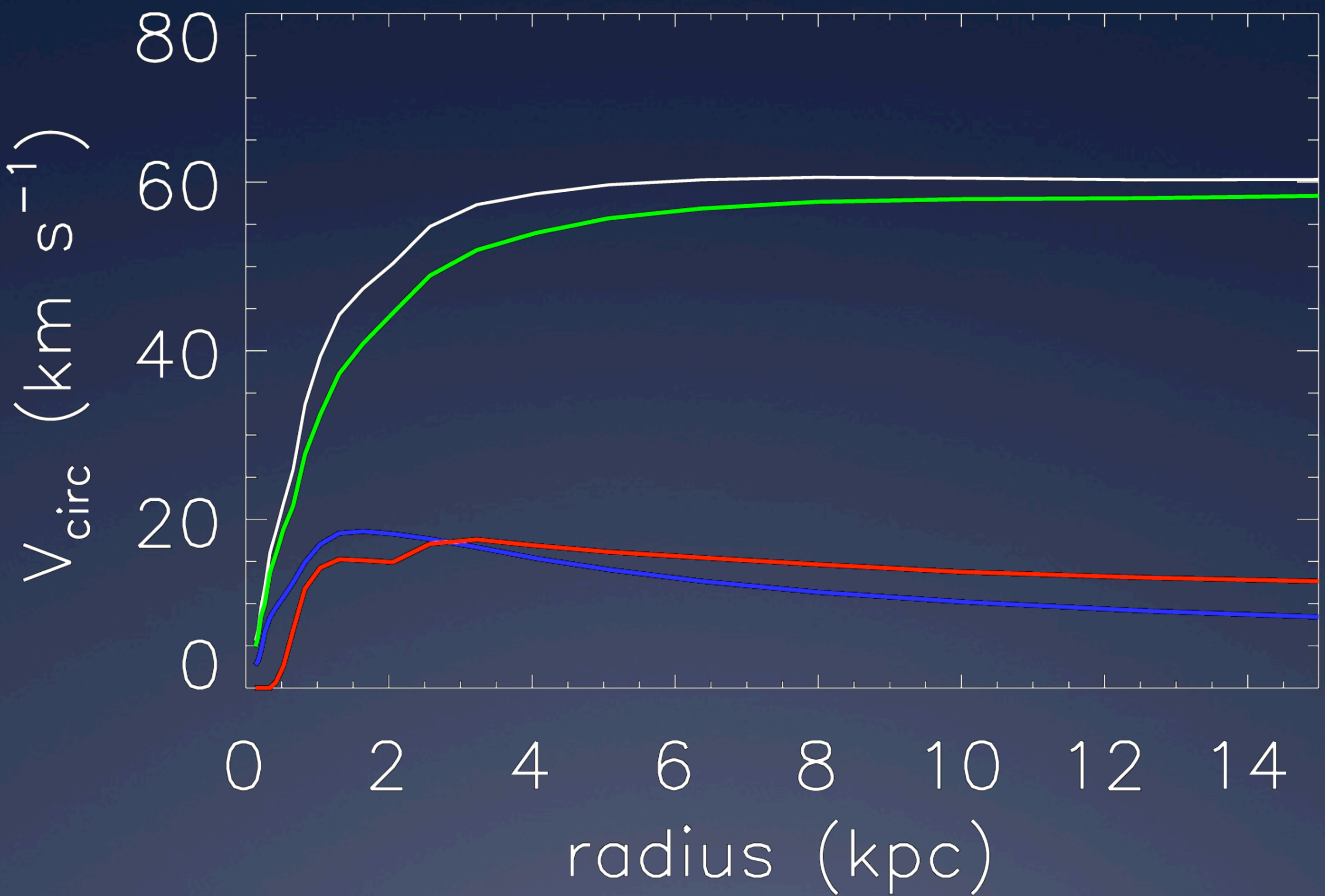
14
radius (kpc)
V_{circ} (km s^{-1})


100
80
60
40
20
0
V_circ (km s^-1)
0
2
4
6
8
10
12
14
radius (kpc)



80
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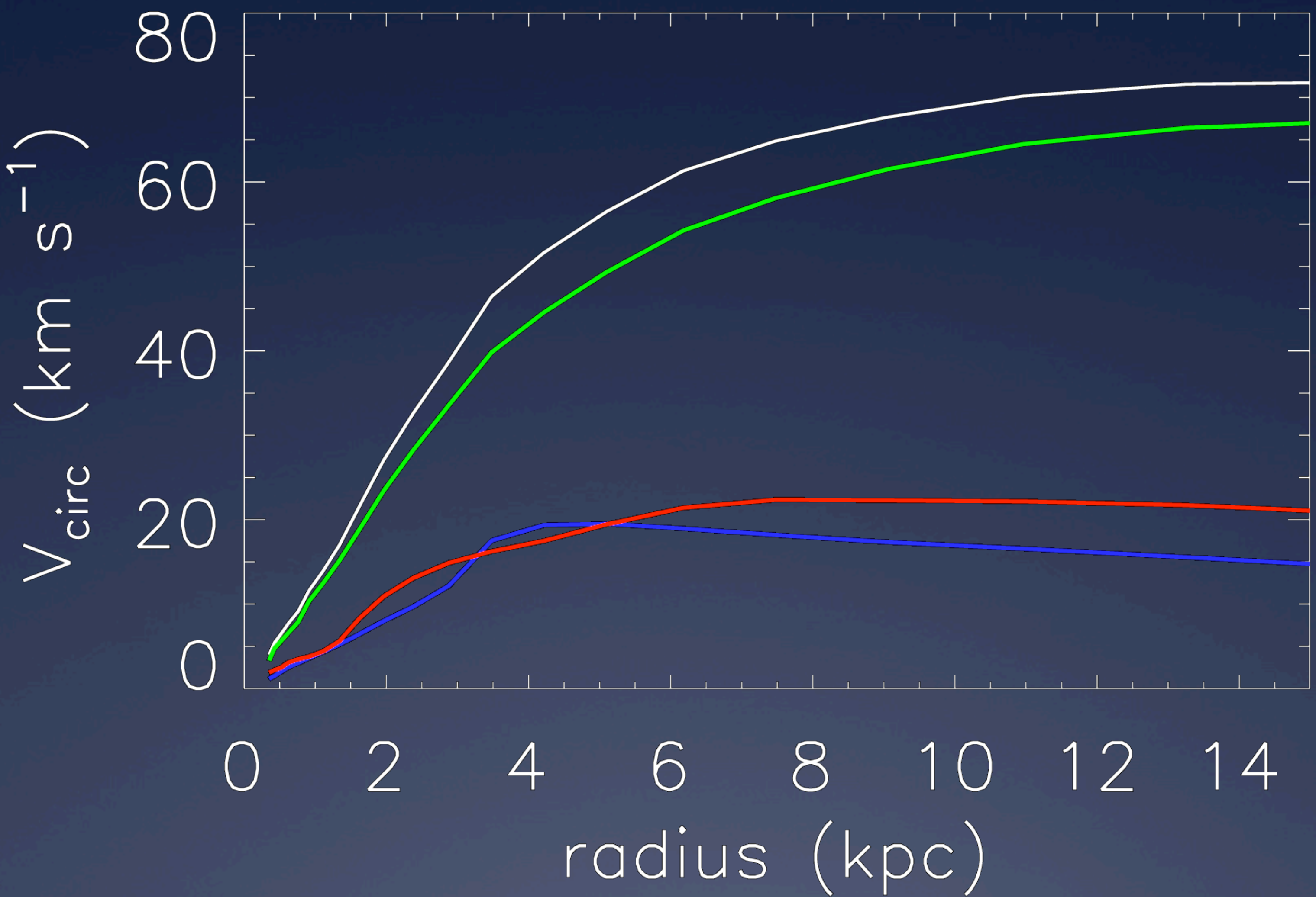
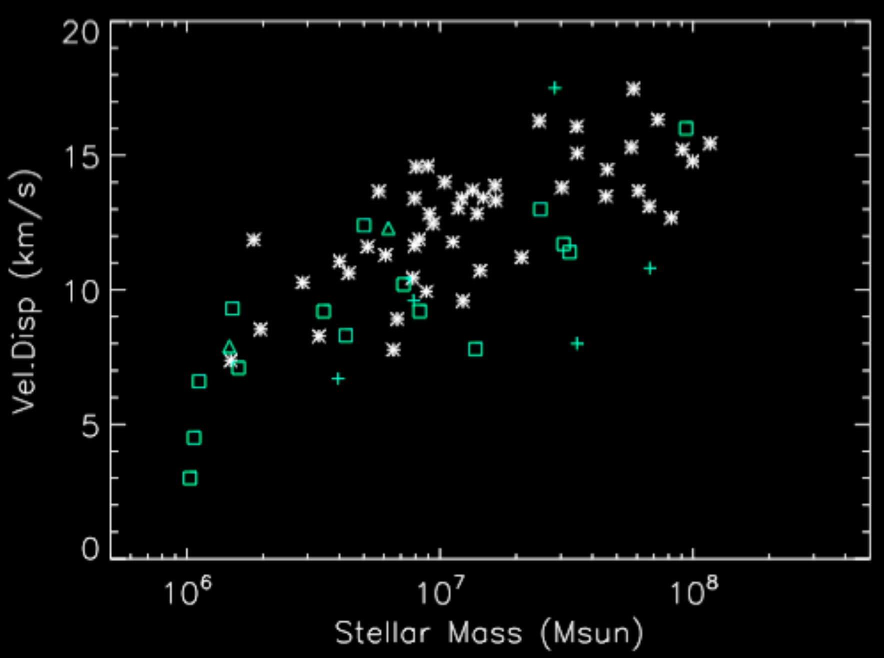
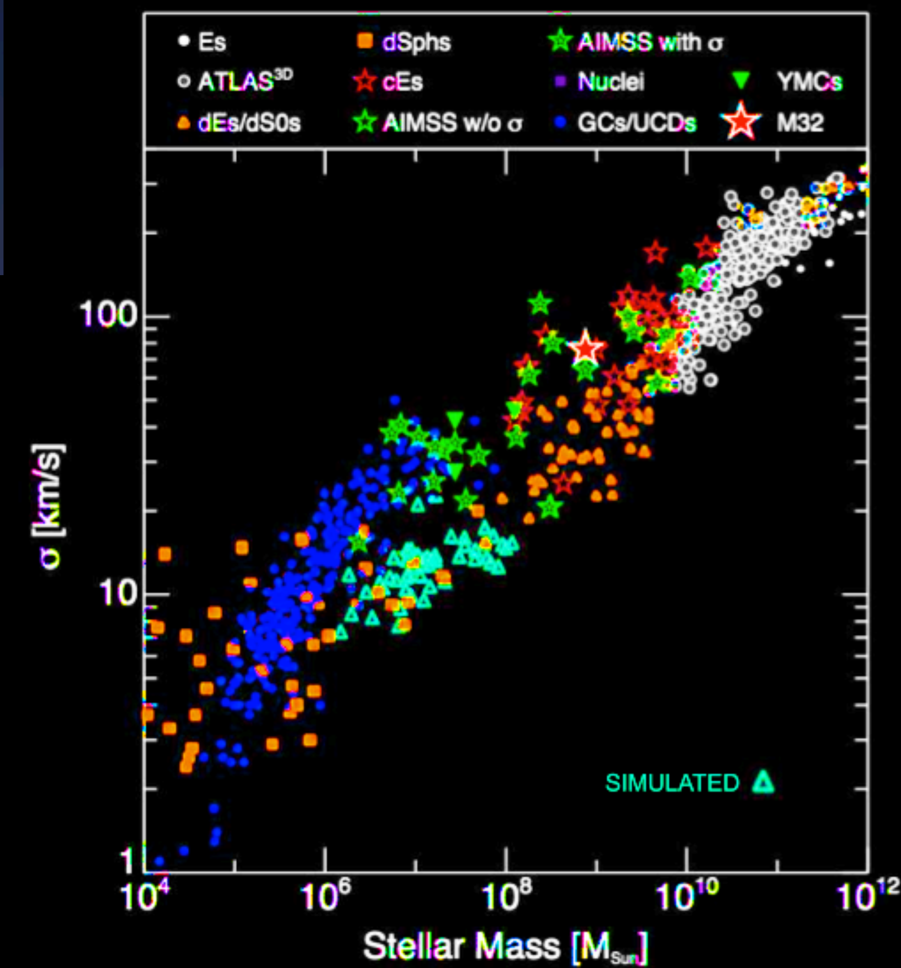
20
0
V_{circ} (km s^{-1})
0
2
4
6
8
10
12
14
radius (kpc)



80
60
40
20
0
V_{circ} (km s^{-1})
0
2
4
6
8
10
12
14
radius (kpc)



20
15
10
5
0
Vel.Disp (km/s)
10^6
10^7
10^8
Stellar Mass (Msun)



Es
ATLAS^{3D}
dEs/dS0s
dSphs
cEs
AIMSS w/o σ
AIMSS with σ
Nuclei
GCs/UCDs
YMCs
M32
100
10
1
σ [km/s]
SIMULATED
10^4
10^6
10^8
10^{10}
10^{12}
Stellar Mass [M_{Sun}]

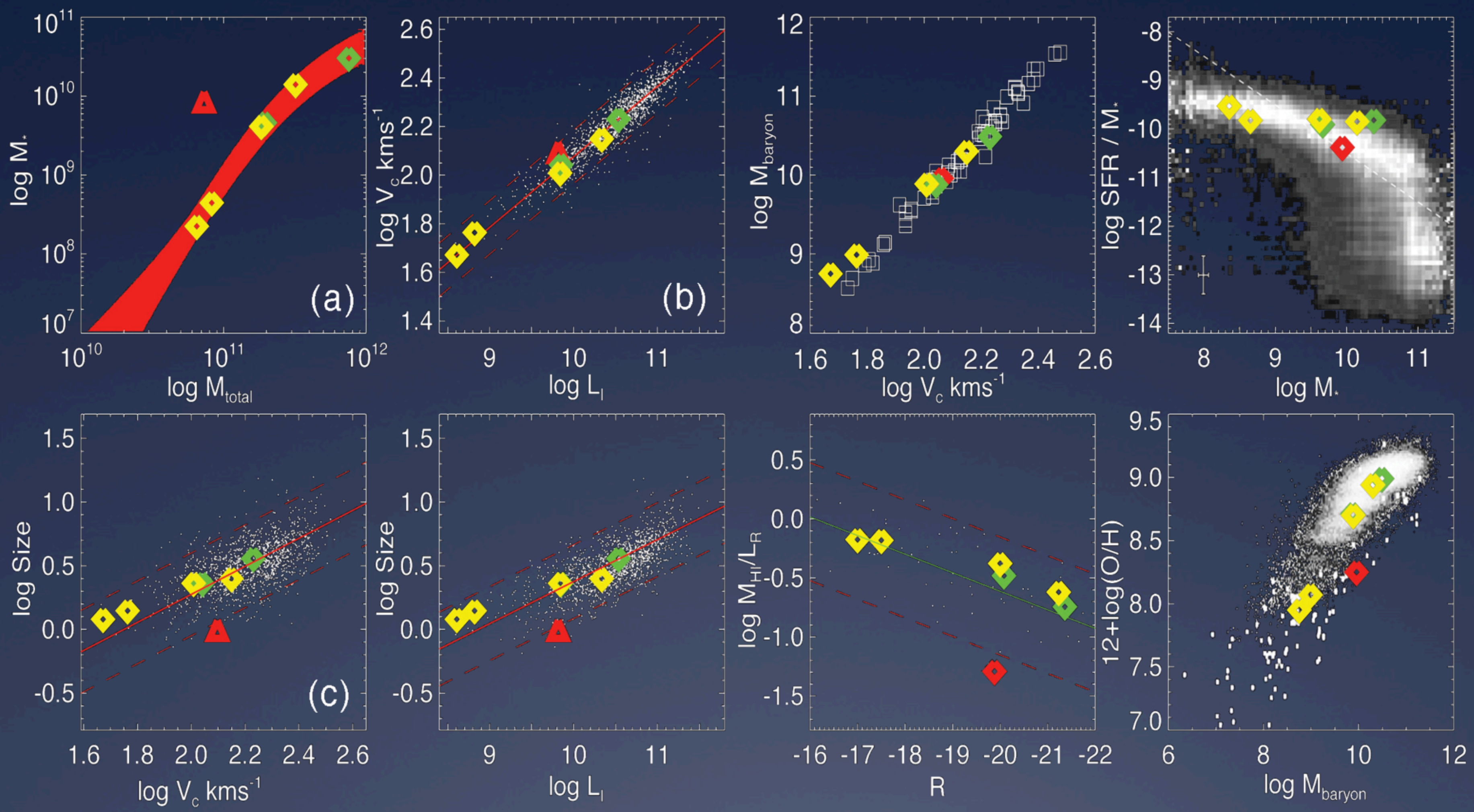
MaGICC: Making Galaxies in a Cosmological Context

: Chris Brook Universidad Autónoma de Madrid & Greg Stinson (MPIA)

High-resolution galaxy formation simulations of isolated galaxies

Goal : match a wide range of galaxy properties

- Gasoline: parallel SPH galaxy evolution code Wadsley + 2004
- Cosmological Initial Conditions
- Star Formation Rate ~ $\rho_{gas}^{1.5}$ Kennicut-Schmidt law
- UV background radiation Haardt & Madau 96
- Compton & Radiative cooling
- Metal Line Cooling Shen+10
- Metal and Heat Diffusion
- Feedback from supernovae (blastwaves) and massive stars Stinson+06,+13
- metal enrichment: H, He, C, O, Fe, Si, N, Mg



Brook et al. 2012