A NEW STRATEGY WITH UNAVOIDABLE PARAMETERS ONLY

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SIM & SAM

At first glance:

- gravo-hydrodynamical SIMs are based on first principles, while SAMs are a set of recipes with many free parameters
- so much freedom in SAMs that they can fit almost anything, meaning that their predictive power is doubtful

But:

- SIMs include many recipes and free parameters of SAMs
- extremely hard to fit *all* the observables at once, so we could really trust any SIM or SAM able to do so

On the other hand:

- SIMs are at the limit of current computing capabilities, while SAMs can still be substantially improved

Common parameters
in SIMs & SAMs

- Ordinary galaxies
  - Star formation efficiency
  - Yield
  - Reheating and coupling efficiencies
  - IMF
  - Dust extinction
- AGN
  - MBH feeding efficiency
  - Duty cycle
  - Reheating and coupling efficiencies
  - MBH radiation
- Boundary conditions
  - Initial *z* for star formation
  - Initial metallicity
  - Initial MBH mass
  - Ionizing and heating backgrounds

Extra parameters in SAMs

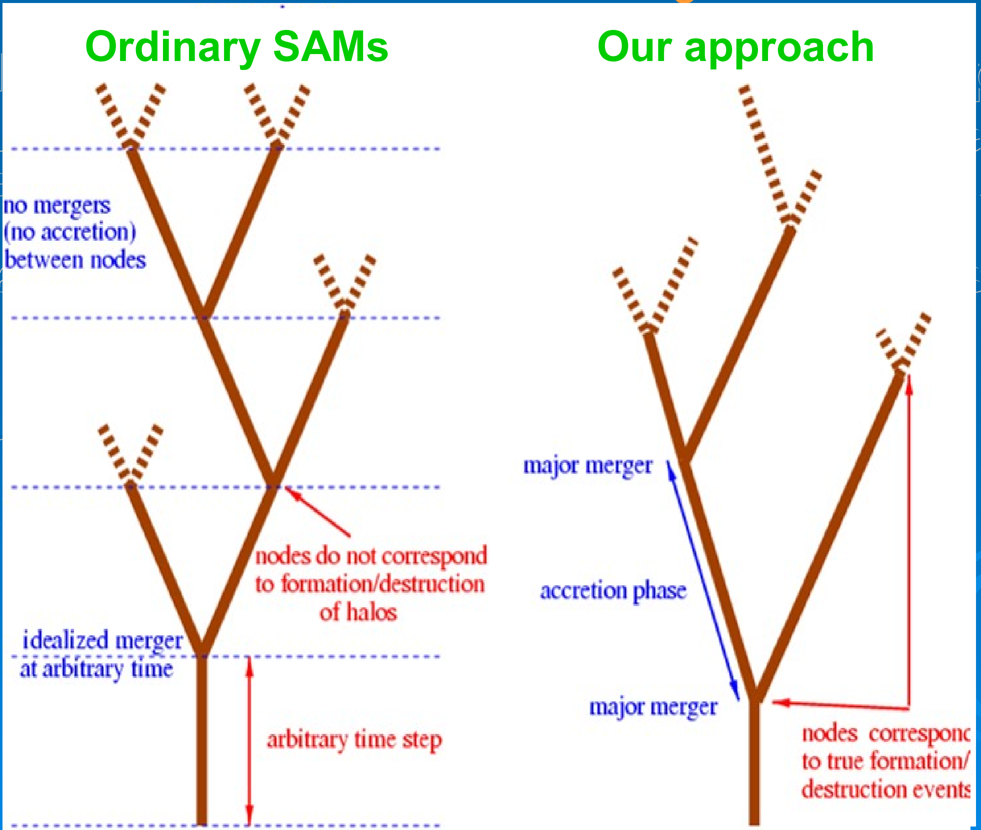
non-hybrid versions

hybrid versions

- DM clustering
  - Halo growth rates
  - Formation times, progenitor masses
- Halo inner structure
  - Mass and time dependence of NFW concentration
  - Velocity dispersion, anisotropy and angular momentum profiles
- Dynamical state of trapped gas
  - Density profile
  - Temperature profile
- Disc properties
  - Scale radius
- Spheroid properties
  - Effective radius and surface density, Sérsic index *n*
- Galaxy interactions
  - Minimum mass for disc destruction, truncation radius, disc-to-bulge mass transfer efficiency

PROPOSED STRATEGY

- Fully analytical approach using sampled PDFs
  reaching very high-z and low-M → accurate (trivial) boundary conditions
  distinguishing between accretion & major mergers → accurate merger trees
  accounting for all M at each z → accurate integrals over M and evolution over z



- Keep unavoid… procedures
  by adding mo… ary conditions
  → realistic me… heating backgrounds
- Minimize extr… sical processes
  less freedom
- Adjust as mar…
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- Keep unavoidable parameters only and improve usual procedures
  by adding molecular cooling and avoiding unjustified boundary conditions
  → realistic metal enrichment, MBH seeds, and ionizing and heating backgrounds
- Minimize extra parameters by causally connecting physical processes
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- Adjust as many observables as possible
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Unavoidable parameters

- boundary conditions + molecular cooling

- Ordinary galaxies
  - Star formation efficiency
  - Yield
  - Reheating and coupling efficiencies
  - IMF
  - Dust extinction
- AGN
  - MBH feeding efficiency
  - Duty cycle
  - Reheating and coupling efficiencies
  - MBH radiation
- Boundary conditions
  - Initial z for star formation
  - Initial metallicity
  - Initial MBH mass
  - Ionizing and heating backgrounds
- New
  - Critical metallicity
  - Pop III IMF (equivalent to yield and mass fraction locked into MBH)
  - Fraction of escaping UV photons from ordinary galaxies

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Connected physics: no extra parameters
(except a few)

- DM clustering: EPS + frontier between minor and major mergers
  - Growing rates
  - Formation time pdf, progenitor mass pdf
- Halo inner structure
  - Mass and time dependence of NFW concentration
  - Velocity dispersion, anisotropy and angular momentum profiles
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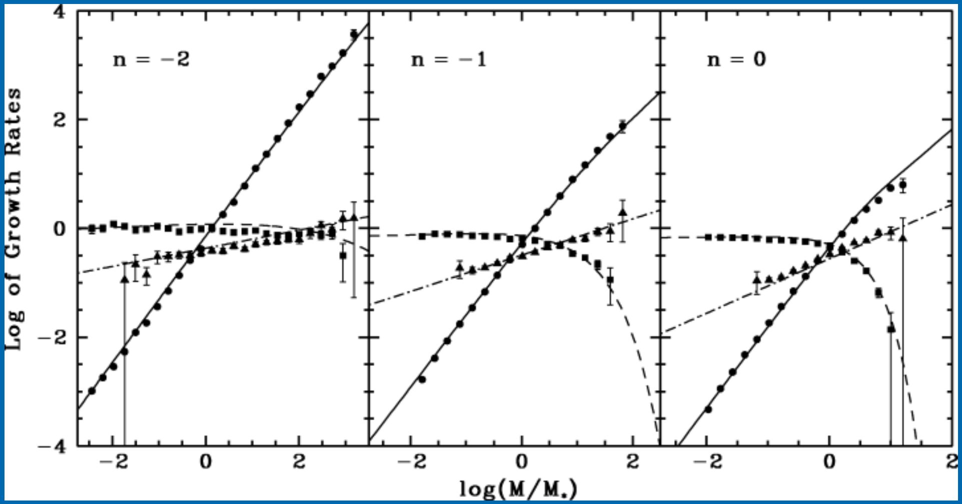
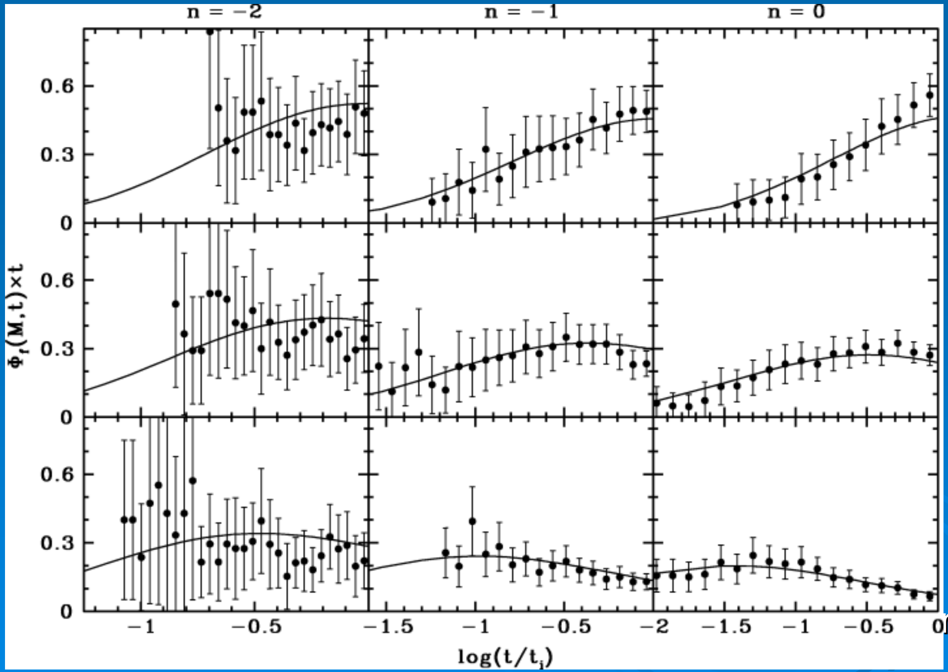
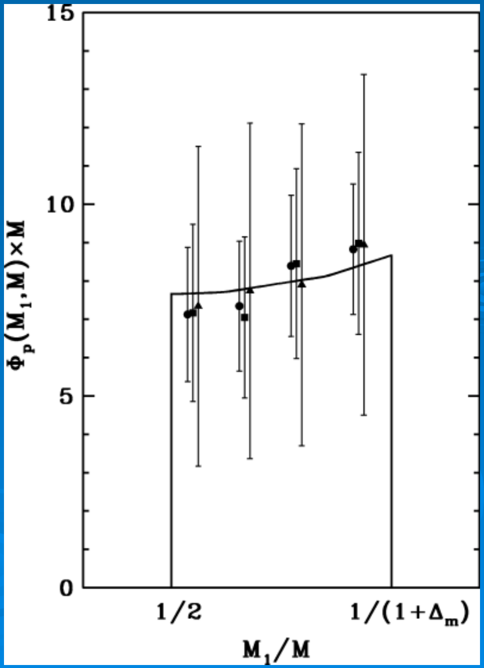
DM clustering (EPS + frontier minor/major mergers)

Halo accretion, formation and destruction rates (Raig et al. 2001)



Formation time and main progenitor mass PDFs (Raig et al. 2001)

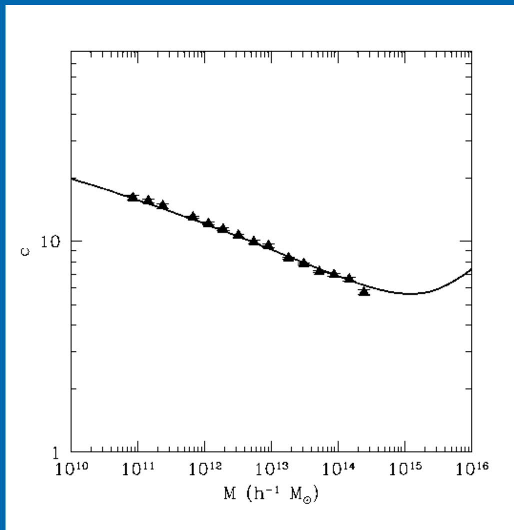


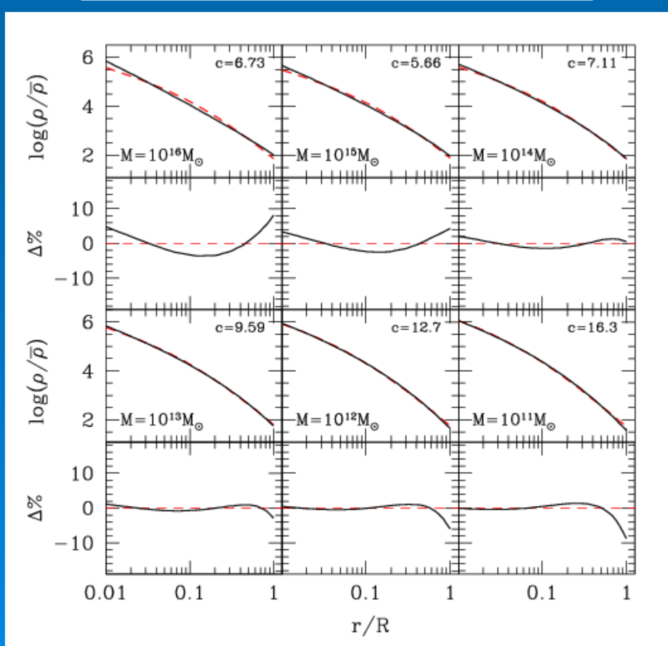


ngham Extra

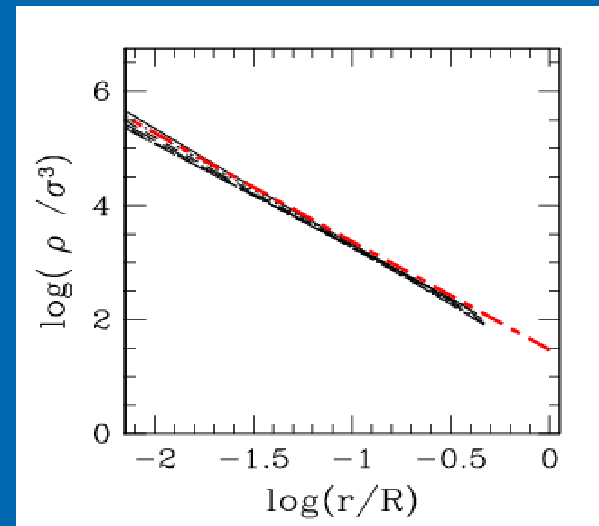
Halo inner structure (collapse time increasing function of turnarround radius)

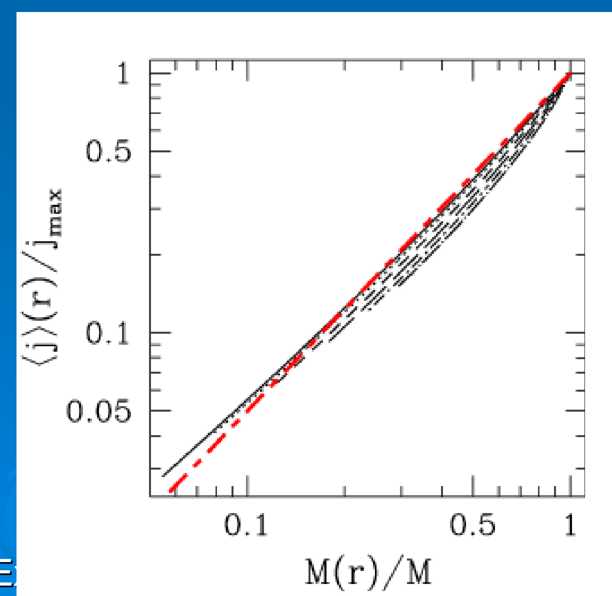
Density (Salvador-Solé et al. 2007)





Kinematics (González-Casado et al. 2007)

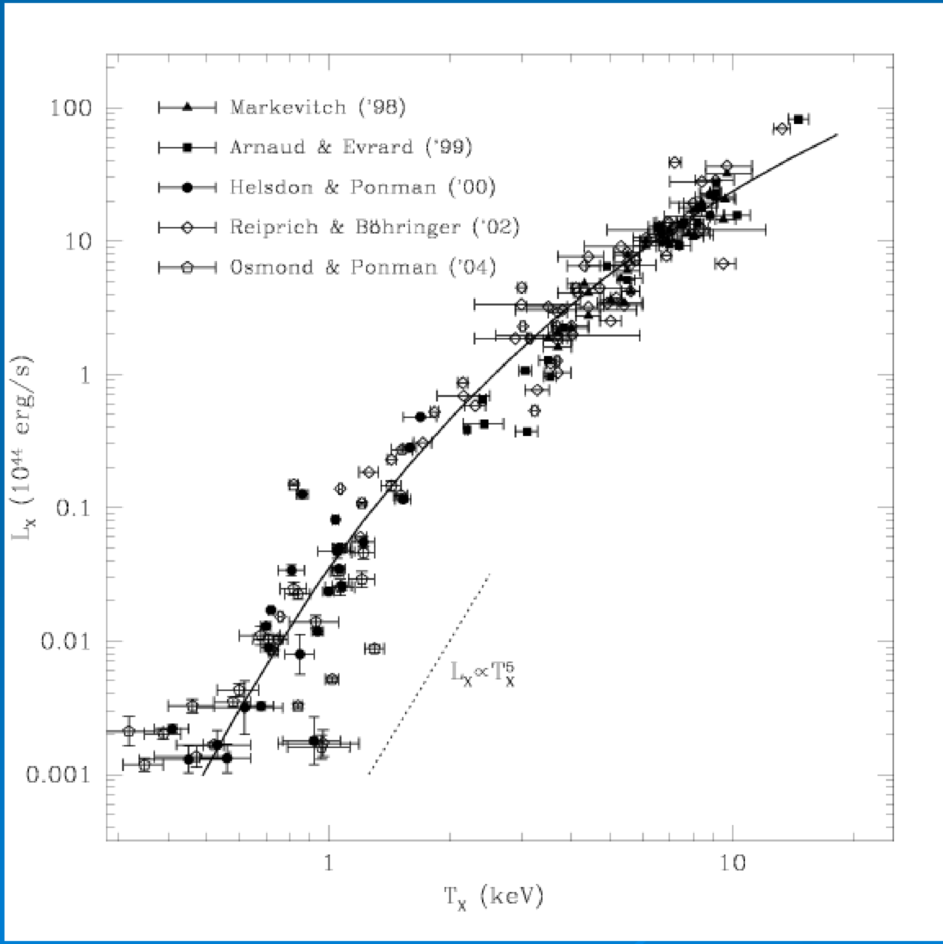




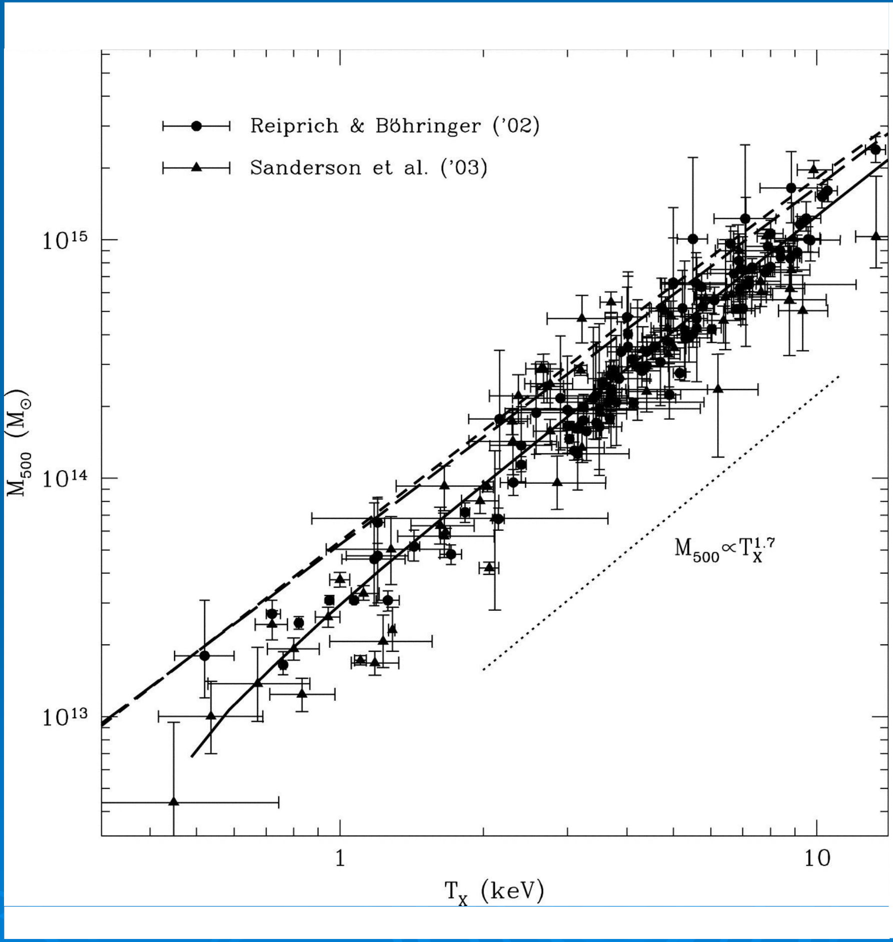
Dynamical state of trapped gas (polytropic approximation, self-consistent γ)

(Solanes et al. 2005; see also Ostriker et al. 2005)

L_X vs T_X



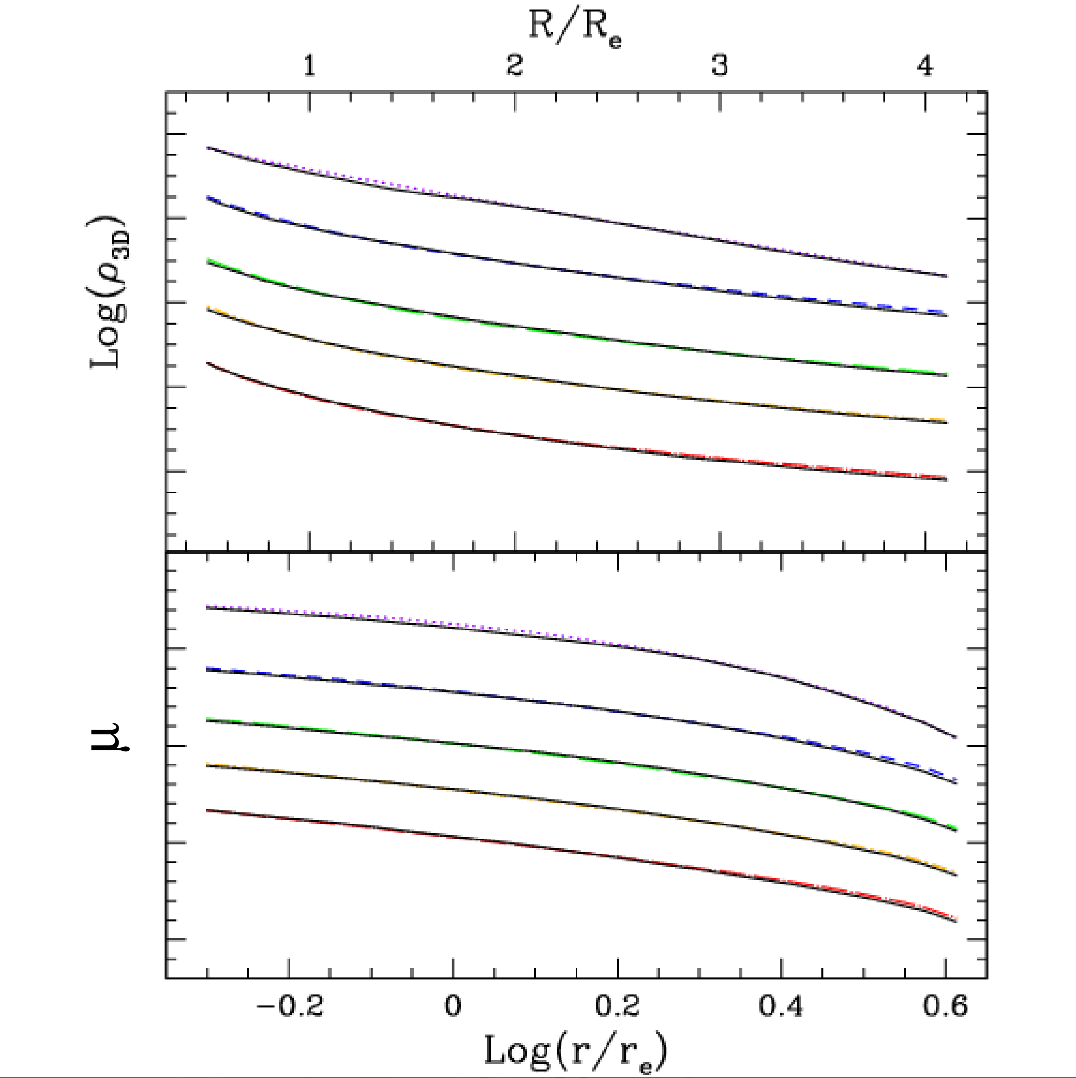
M_X vs T_X



Spheroid properties (major mergers of two galaxies)

2D and 3D density profiles compared to typical 2D and 3D Sérsic profiles for ellipticals of $3\cdot10^9$, 10^{10}, $3\cdot10^{10}$, 10^{11} and $3\cdot10^{11}$ $M_\odot$

(Serra et al. 2008, in preparation)



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Adjusted parameters:

$Z_{crit} = 10^{-4}\, Z_{\odot}$

Pop III top-heavy IMF

$(Y_{PIII} = 0.25;\ M_{BH}/M_{PIII} = 0.5)$

$f_{esc} = 0.17$

Observed values used:

$\Omega_{cg}(z{\sim}3) \sim 1.8 \cdot 10^{-3}$

SFR(z=3) ~ 0.34 $M_{\odot}\ yr^{-1}\ Mpc^{-3}$

\# ion/baryon (z=4) $\leq$ 7

$Z_{IGM}(z{=}4) > 3.54 \cdot 10^{-4}\, Z_{\odot}$

$z_{ion} \sim 6.0$ & 9–11

Conclusions

SAMs have SIMs as guideline, but...

They are not only more practical, but also more easy to improve than SIMs.

E.g., one can include molecular cooling and connect physical processes.

Doing so, SAMs become even more predictive and reliable than SIMs.

THE END