MultiDark Galaxies Workshop
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SAG semi-analytic model on the MultiDark simulations

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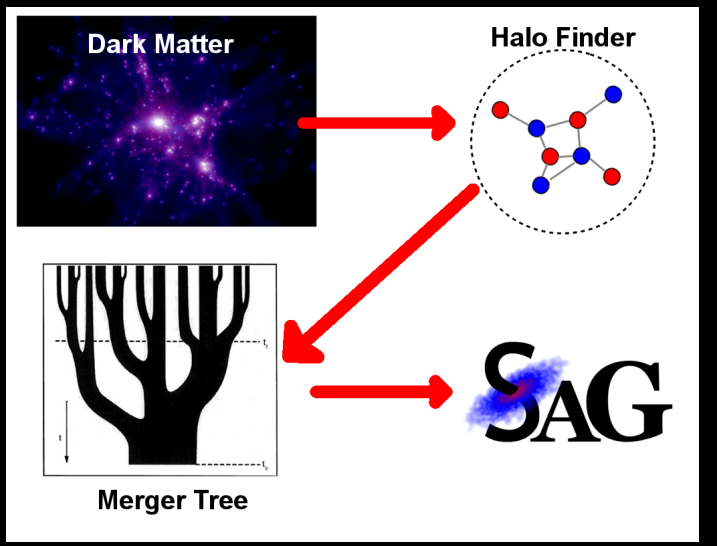
The semi-analytic model **SAG**



- Classic model

  Gas cooling; star formation; mergers; disk instabilities;
  SN feedback chemical enrichment (Cora 2006);
  AGN feedback (Lagos, Cora & Padilla 2008)

- Extended physics model

  Cold gas RPS (Tecce et al. 2010, 2011);
  Disc angular momentum changes (Padilla et al. 2014);
  Orbital evolution of orphan sats. and environmental effects (Cora et al. in prep);
  Galactic fountain and superwinds (Vega-Martínez et al. in prep).

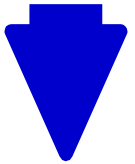
- Extra features

  Emission lines & SEDs (Orsi et al. 2014);
  Integrated Galactic IMF (Gargiulo et al. 2015);
  Calibration using PSO (Ruiz et al. 2015).

First mayor changes in the model

Before nIFTy workshop

- SUBFIND catalogs only
- Two definitions of mass needed: Halos and substructures
- Sequential Code: distribution of calculation by splitting the merger trees.



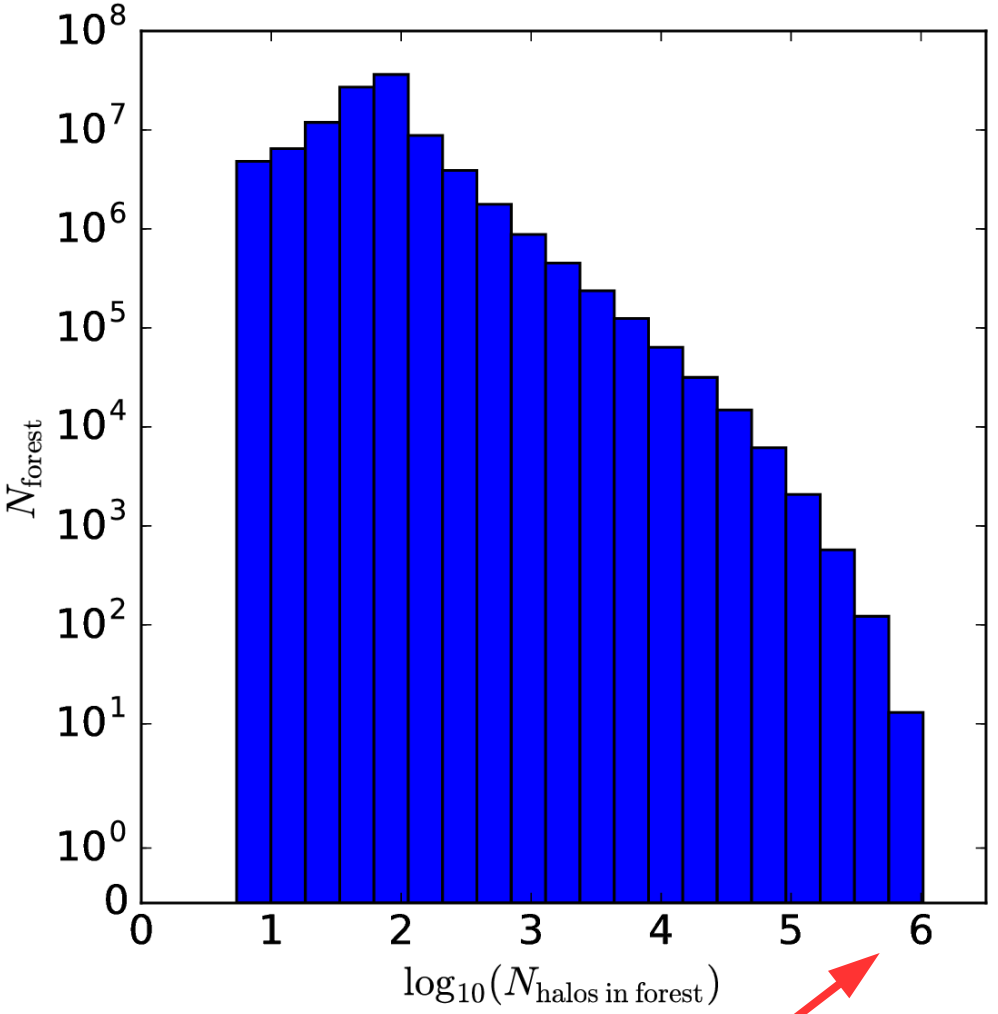
nIFTy and MultiDark Galaxies

- AHF and ROCKSTAR compatibility added through the *sussing* format (ASCII and custom binary)
- Mass definition unified
- Distribution (parallel calculation) naturally by using the forests list.
- Restriction: sub-structure hierarchy collapsed to two (2).

MDPL simulation

- ~ 127 million halos at z=0
- ~ 103 million forests

- ASCII catalogs converted to (custom) binary
- Catalogs divided in 128 parts.
  http://bitbucket.org/cnvega/sussing_scripts



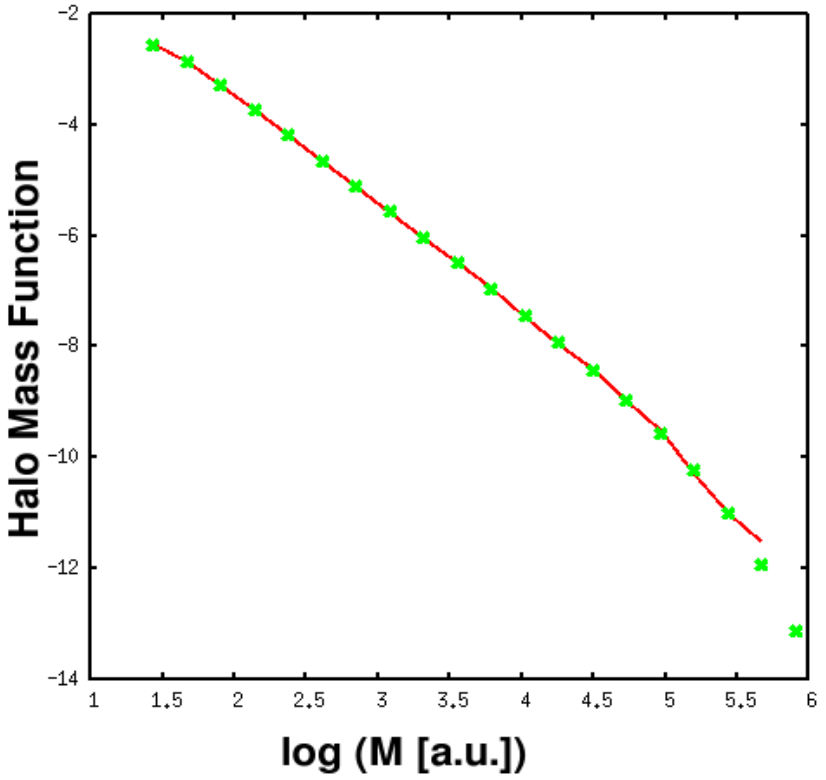
Bottleneck in calculation
Largest forests set the max computational time and memory
Do we need MPI for processing the SMDPL?

Calibration of the code

- Particle Swarm Optimization PSO technique (**Ruiz et al. 2015**): MCMC with crossed communication.
- Parameter search in a selected subbox of the simulation.

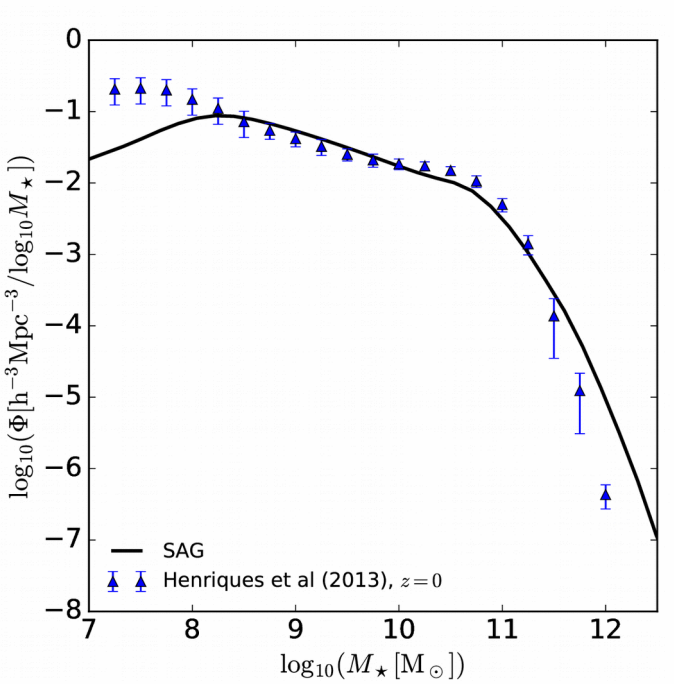
MDPL subbox:

- 1/9 Gpc/h of size
- ~ 176 thousand halos
- ~ 140 thousand forests.

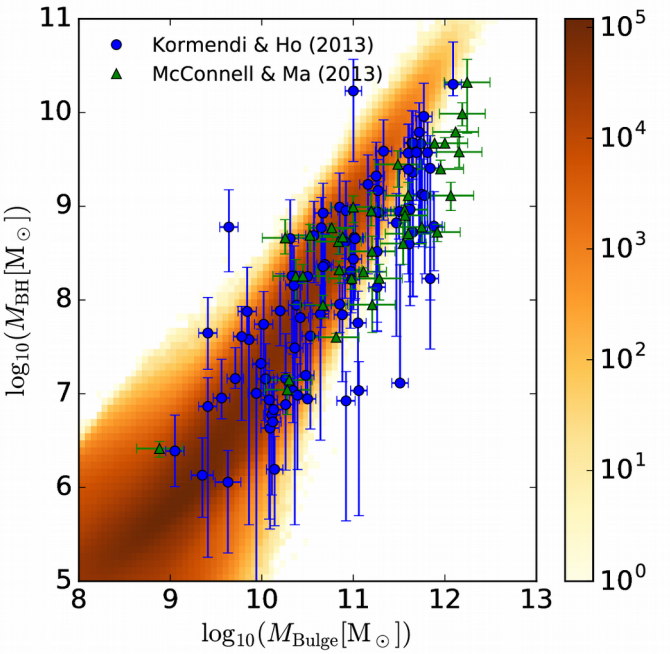


First run

- Classic (basic) model
- One output snapshot (z=0)
- Calibrated (2 constraints)
- ~ 2000 CPU hours.

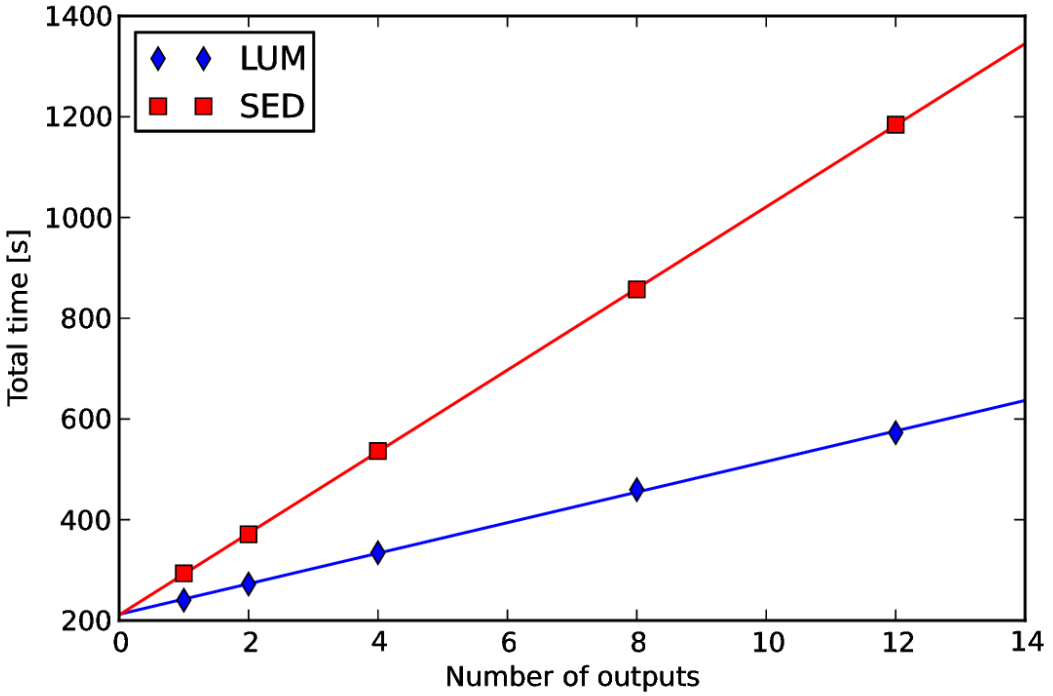


The constraints can be satisfied but the lack hot gas in satellites (strangulation) and environmental effects create a general bad behavior in satellite galaxies.

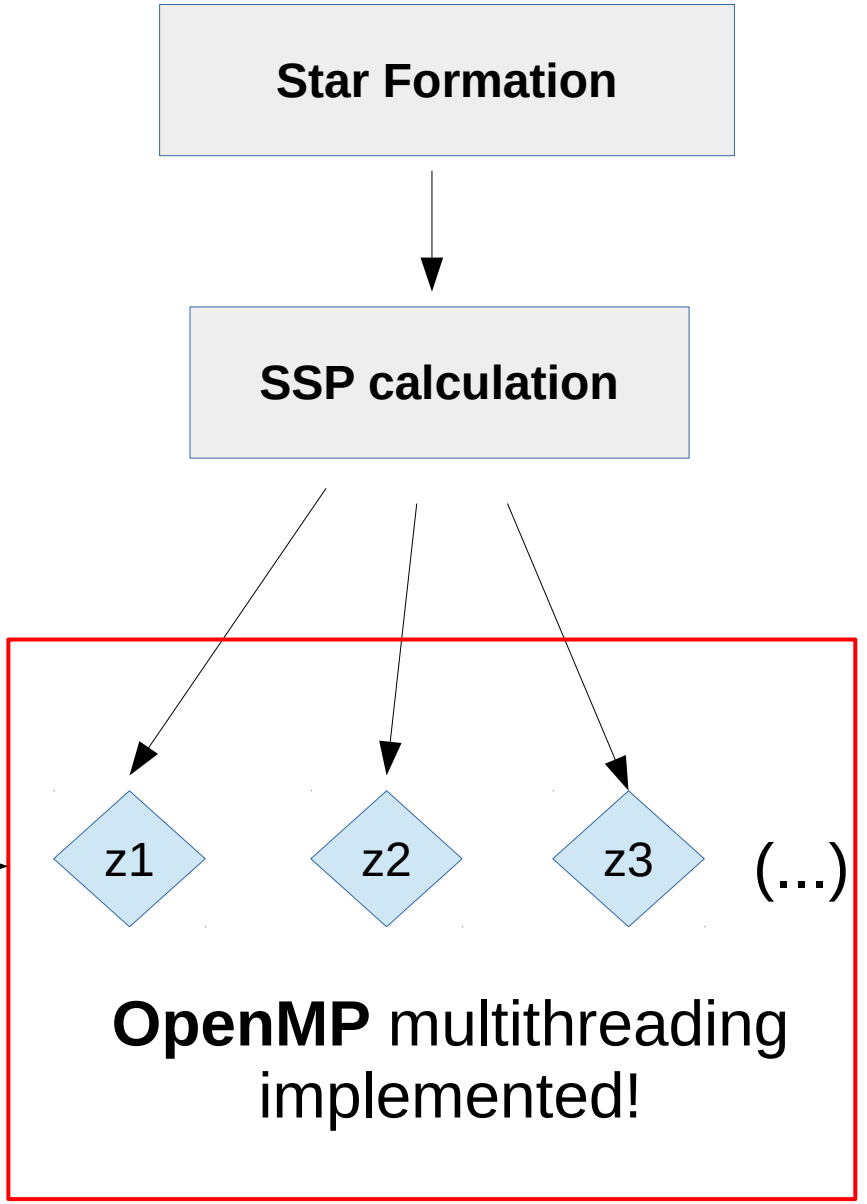


Full physics needed!

More snapshots: high demand in calculation of luminosities

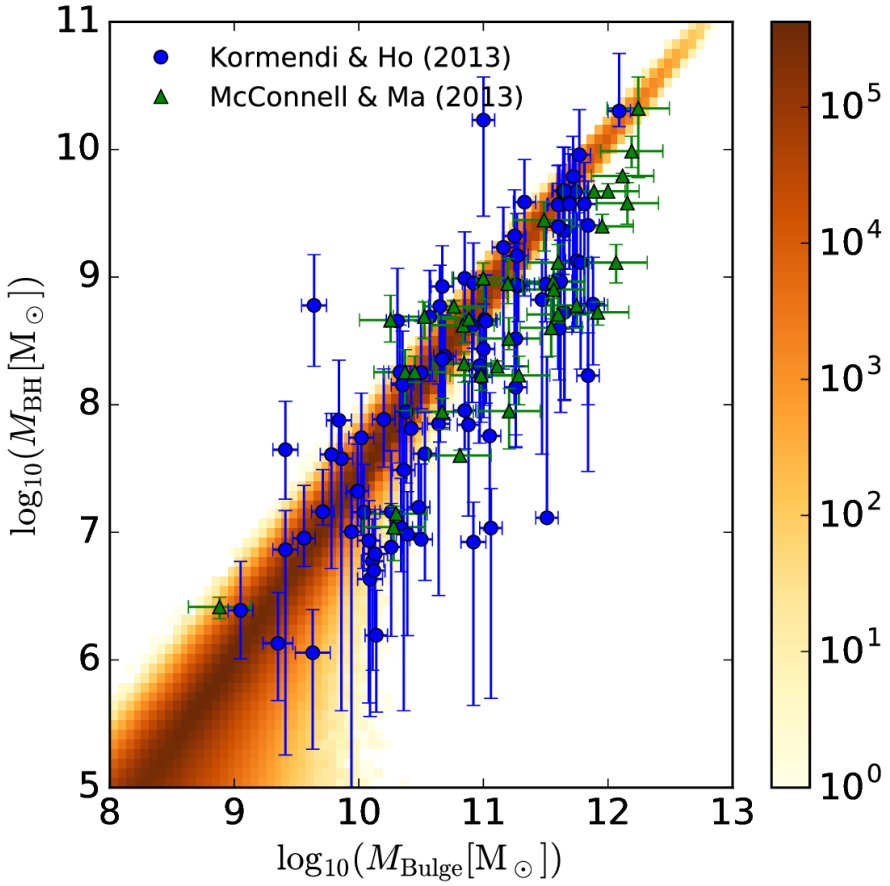


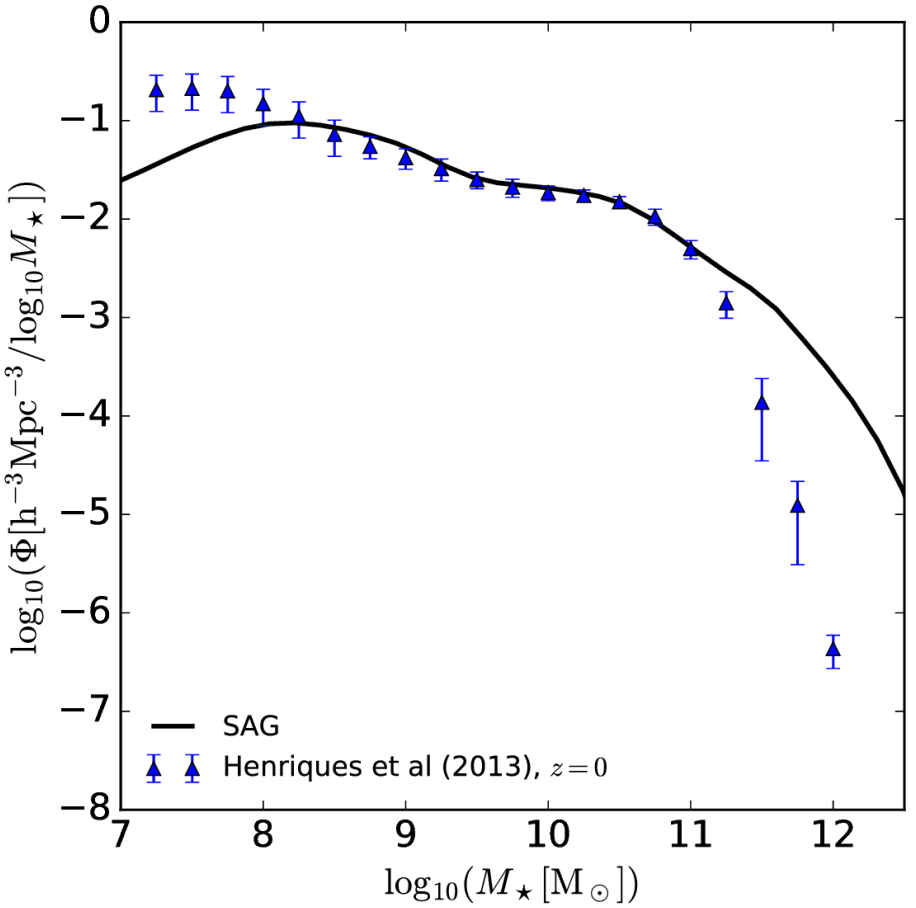
Requested snapshots with magnitudes / SEDs



Second run

- Full physics
- Calibrated (2 constraints)
- But… not good results!



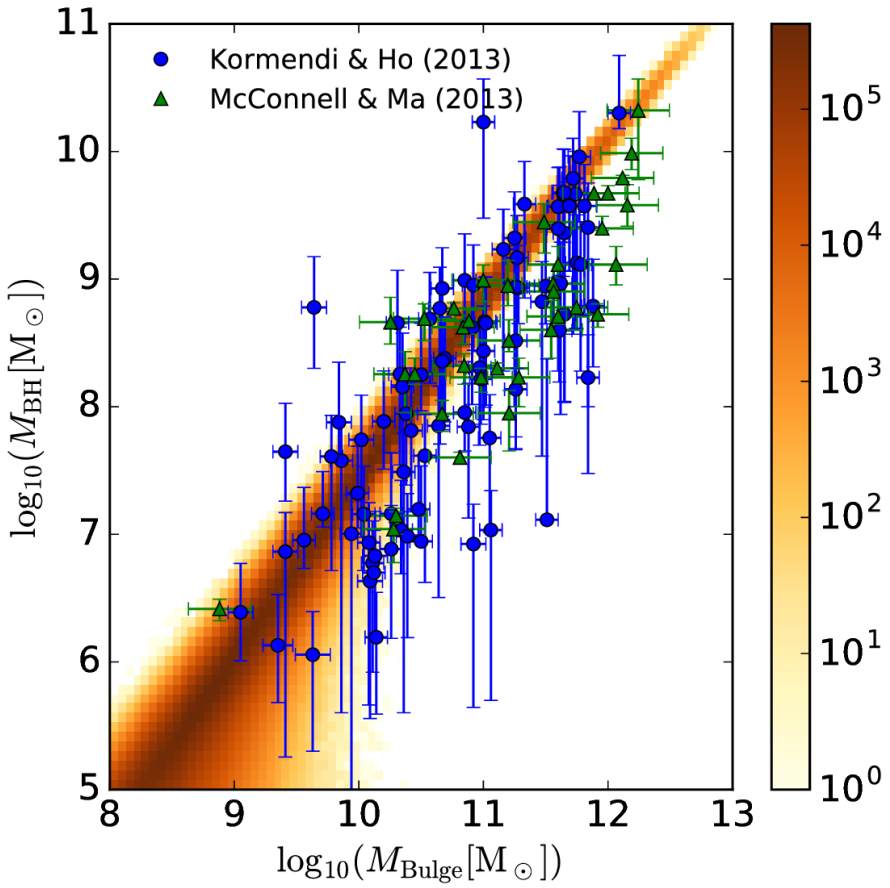


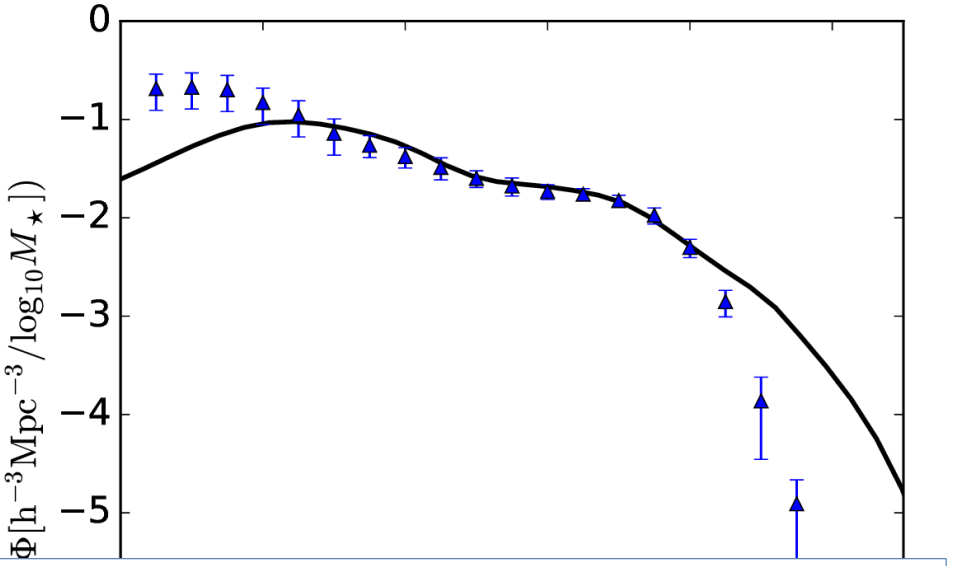
Constraints

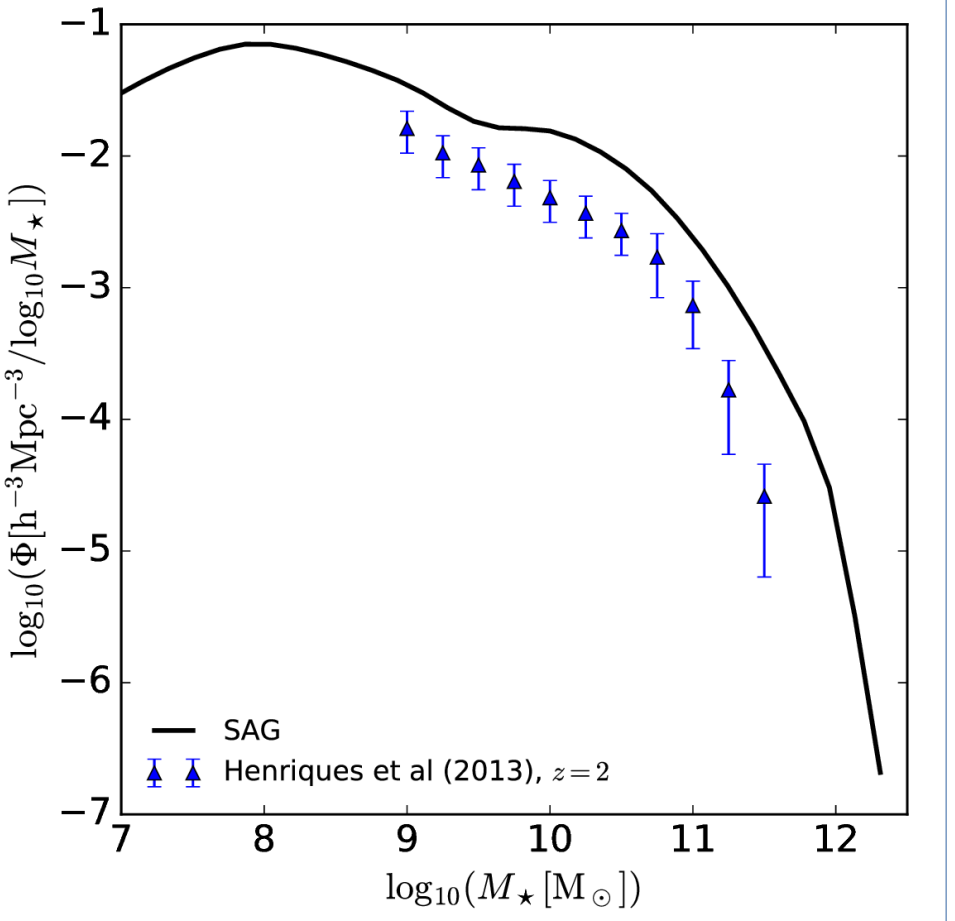
- SED calculation included
- *Only* 51 output snapshots
- ~ 200 million CPU hours needed

Second run

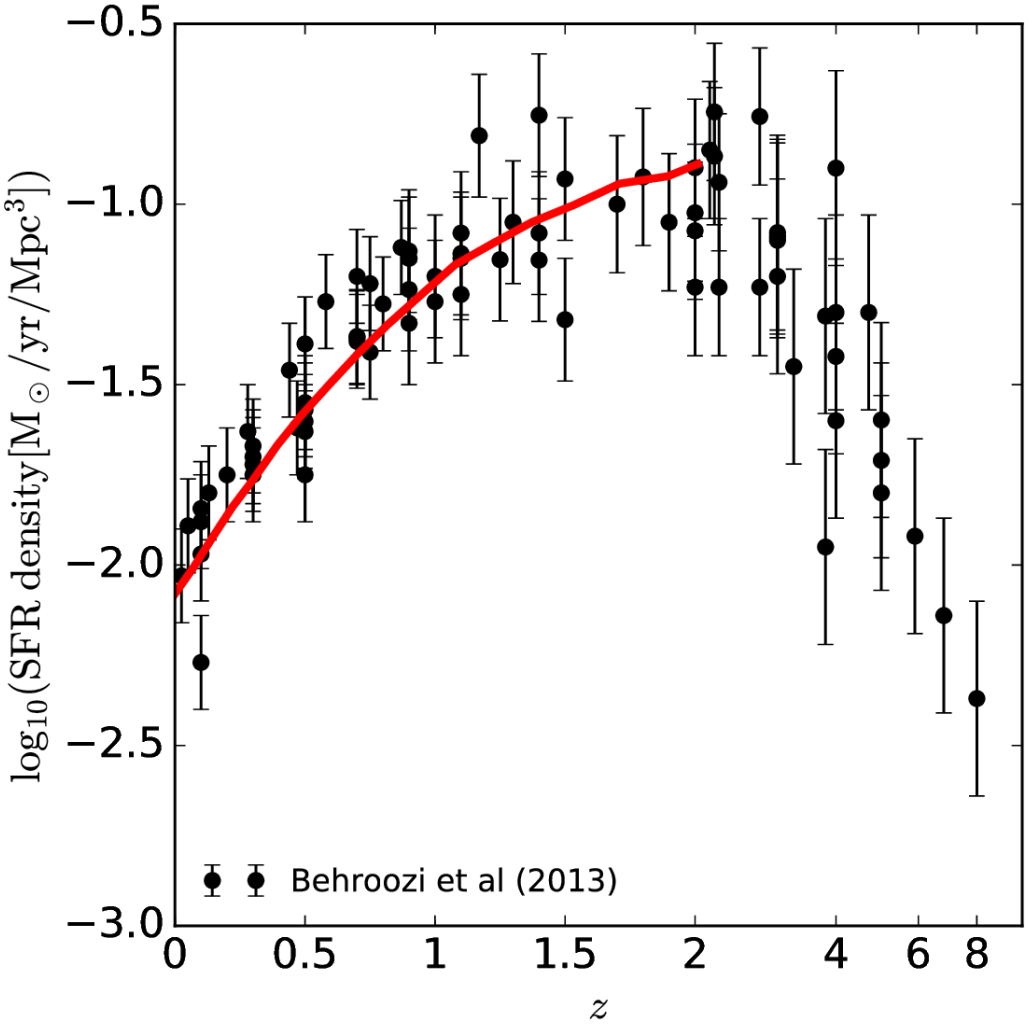
- Full physics
- Calibrated (2 constraints)
- But… not good results!

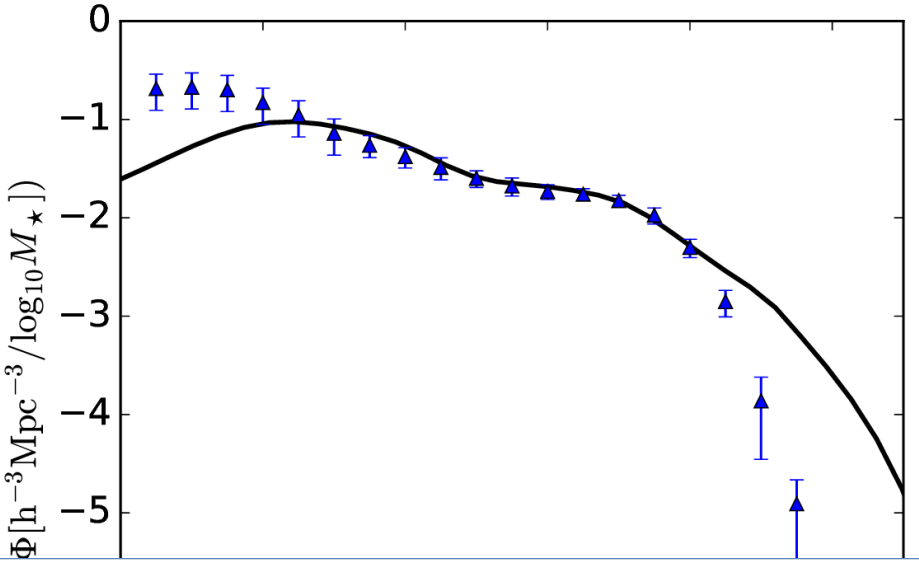


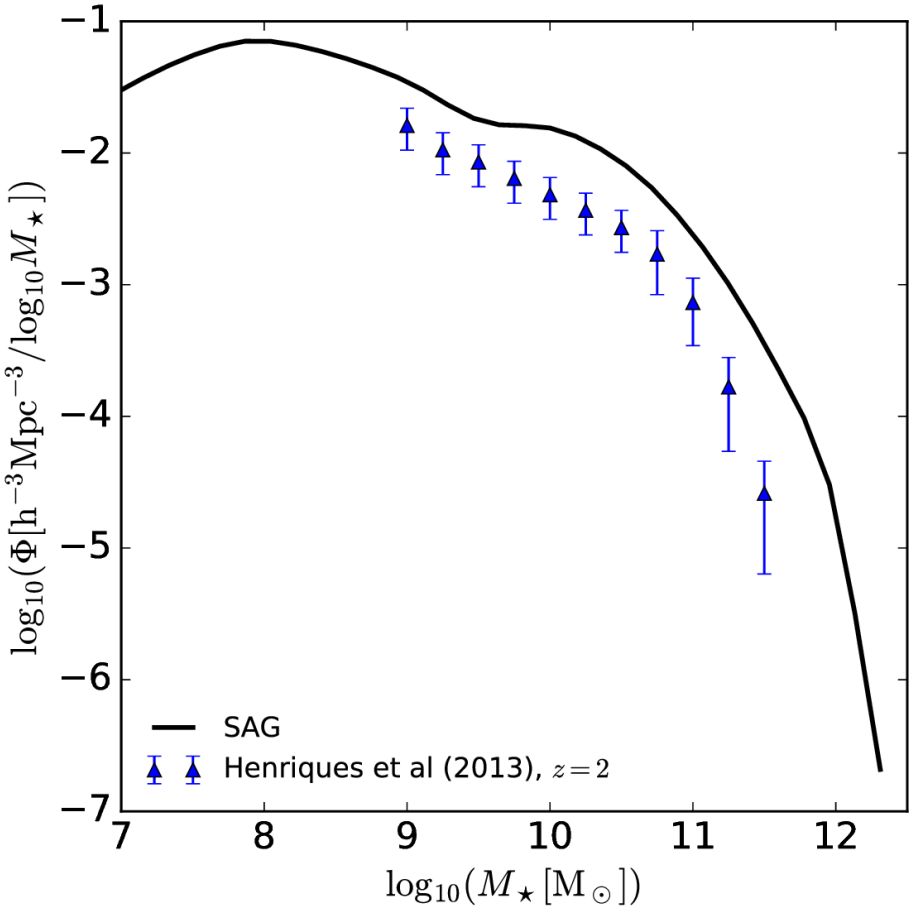


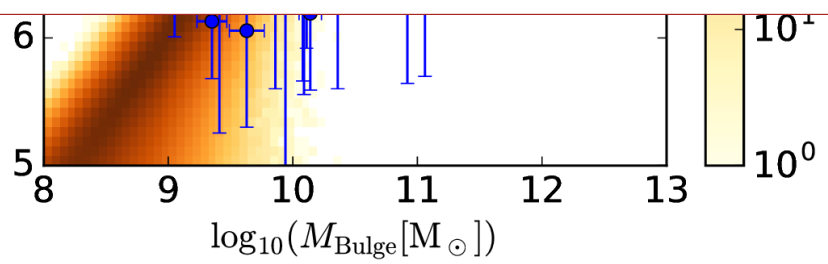


Second run

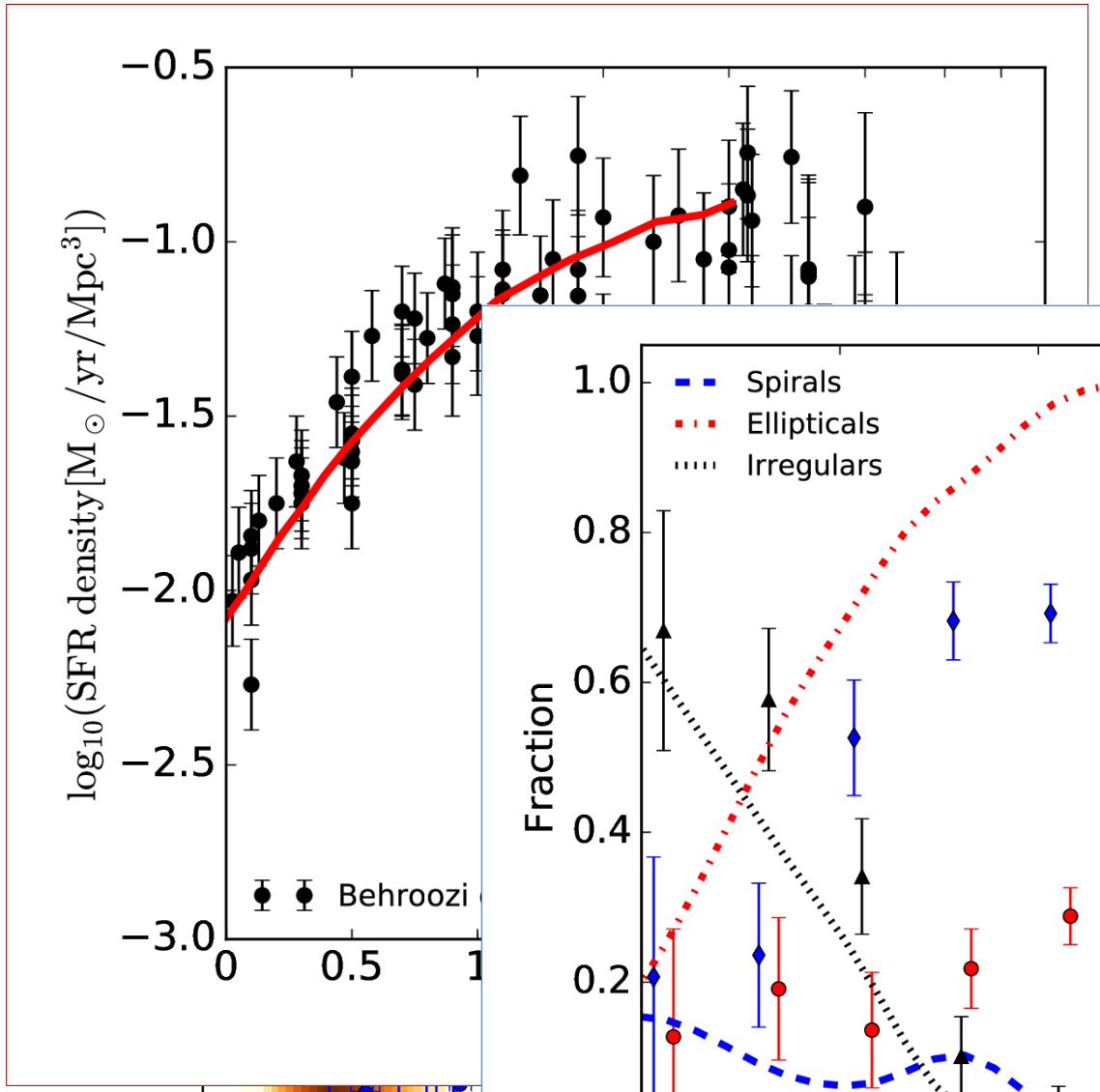

$\log_{10}(\mathrm{SFR\ density}[\mathrm{M}_\odot/\mathrm{yr}/\mathrm{Mpc}^3])$
z
Behroozi et al (2013)

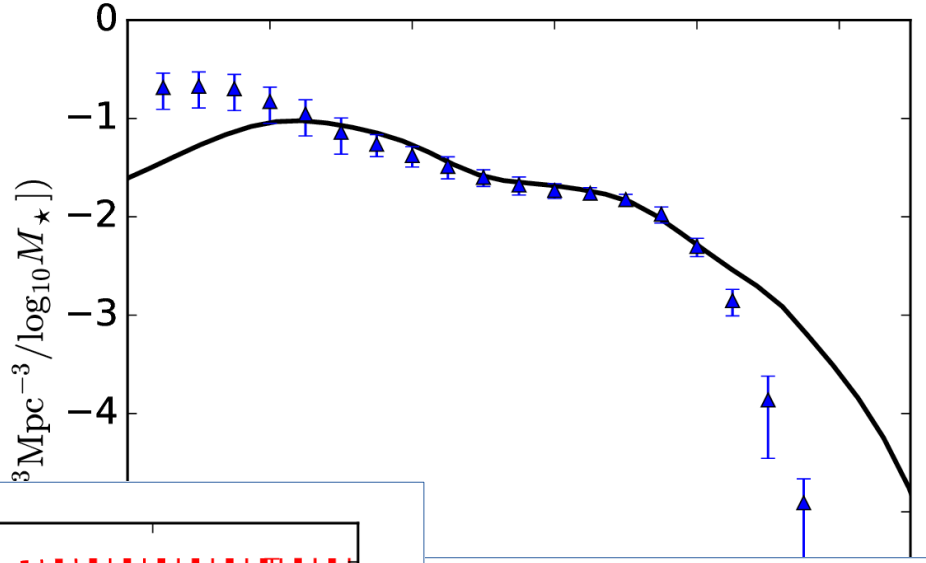

$\Phi[\mathrm{h}^{-3}\mathrm{Mpc}^{-3}/\log_{10}M_\star])$

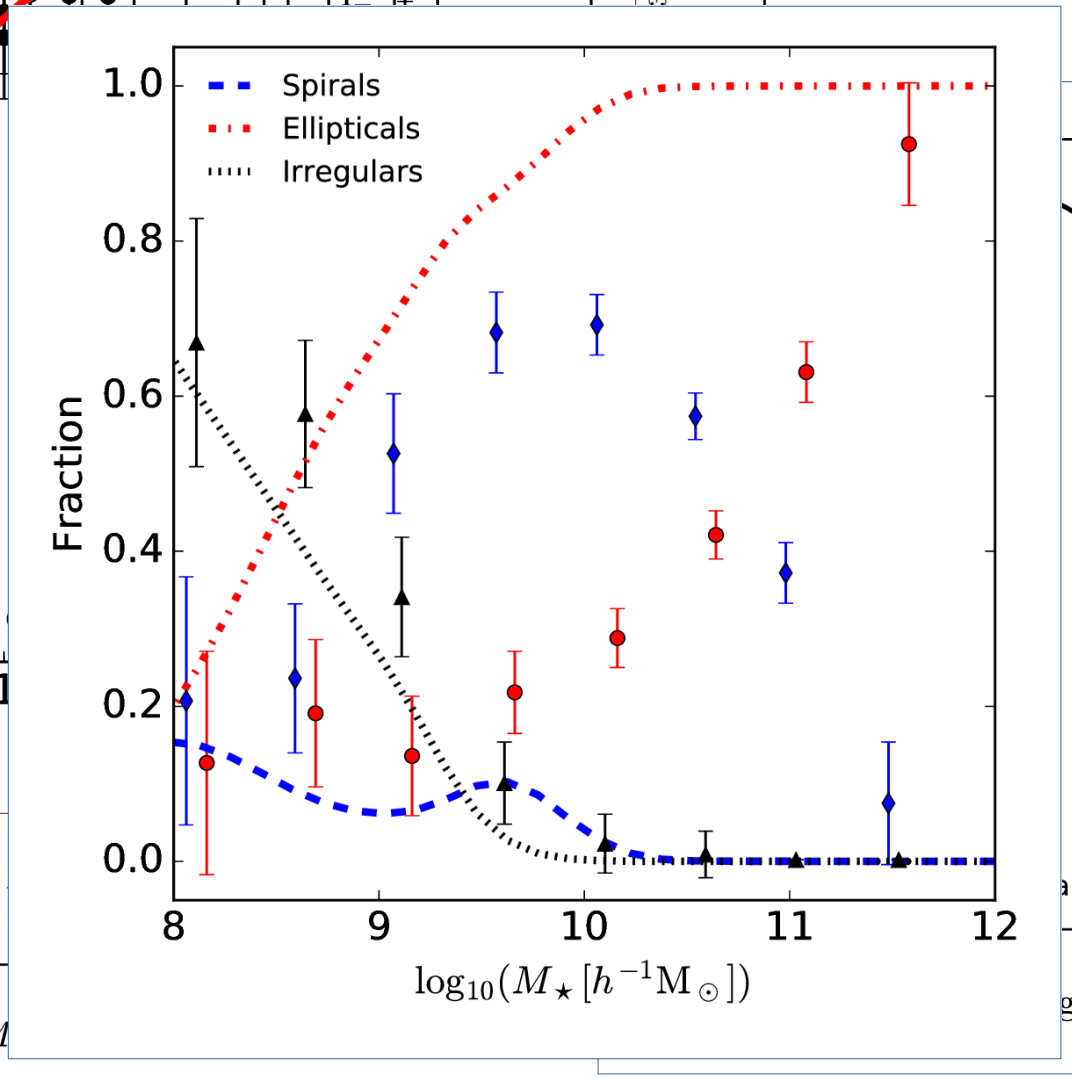

$\log_{10}(\Phi[\mathrm{h}^{-3}\mathrm{Mpc}^{-3}/\log_{10}M_\star])$
SAG
Henriques et al (2013), $z=2$
$\log_{10}(M_\star[\mathrm{M}_\odot])$

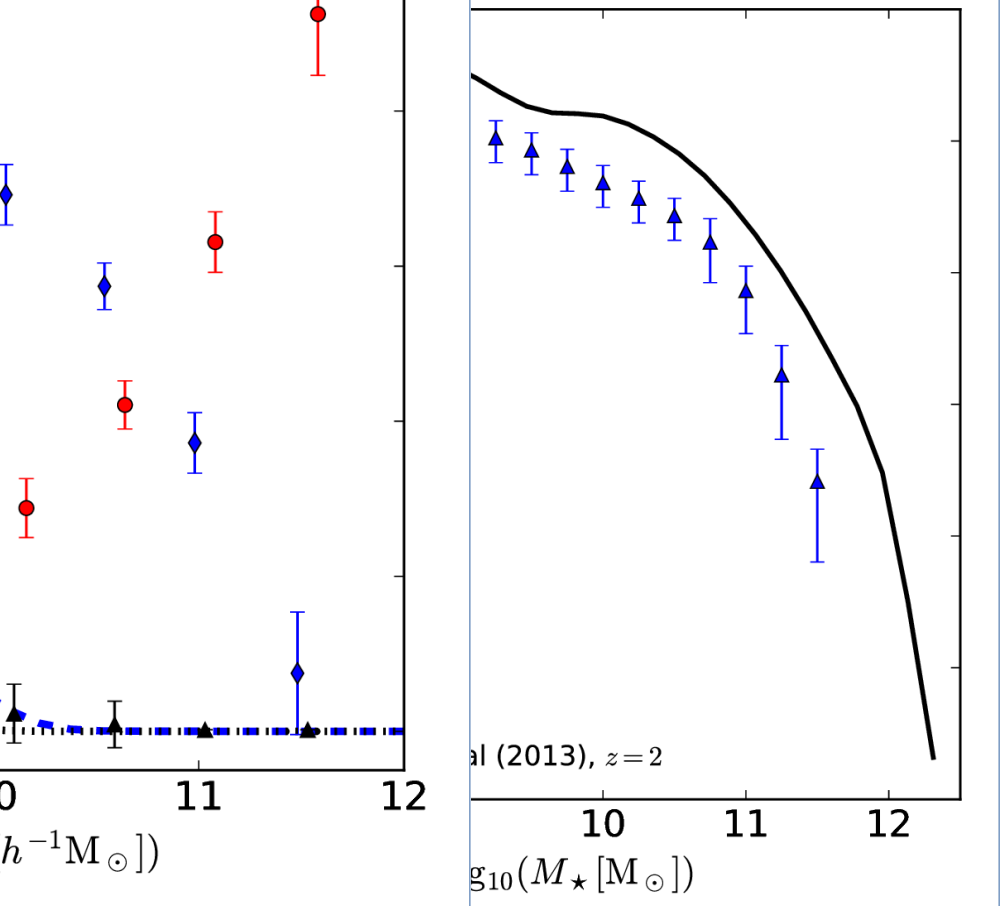

$\log_{10}(M_{\mathrm{Bulge}}[\mathrm{M}_\odot])$

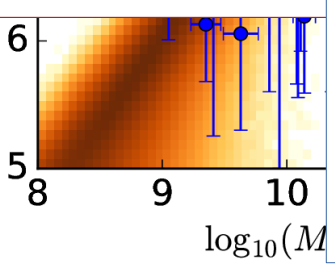
Second run


$\log_{10}(\mathrm{SFR\ density}[\mathrm{M}_\odot/\mathrm{yr}/\mathrm{Mpc}^3])$
Behroozi


$^3\mathrm{Mpc}^{-3}/\log_{10}M_\star])$


Spirals
Ellipticals
Irregulars
Fraction
$\log_{10}(M_\star\,[h^{-1}\mathrm{M}_\odot])$


al (2013), $z=2$
$g_{10}(M_\star\,[\mathrm{M}_\odot])$



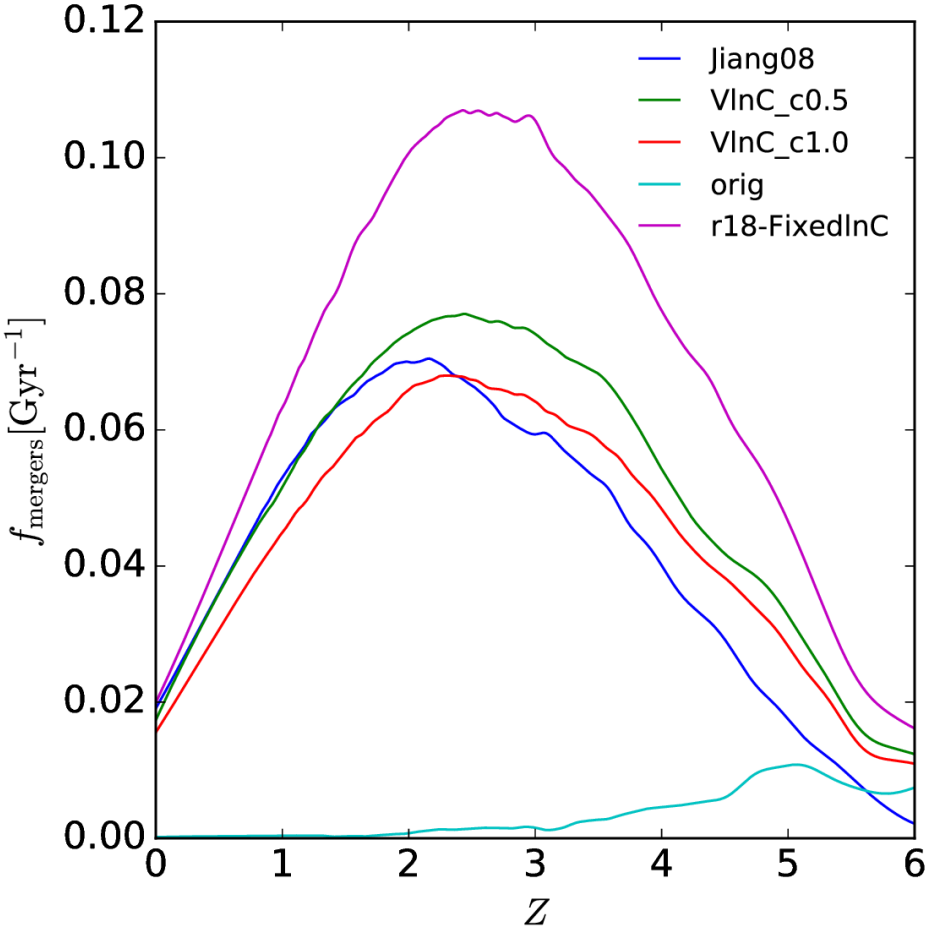
Model refinements

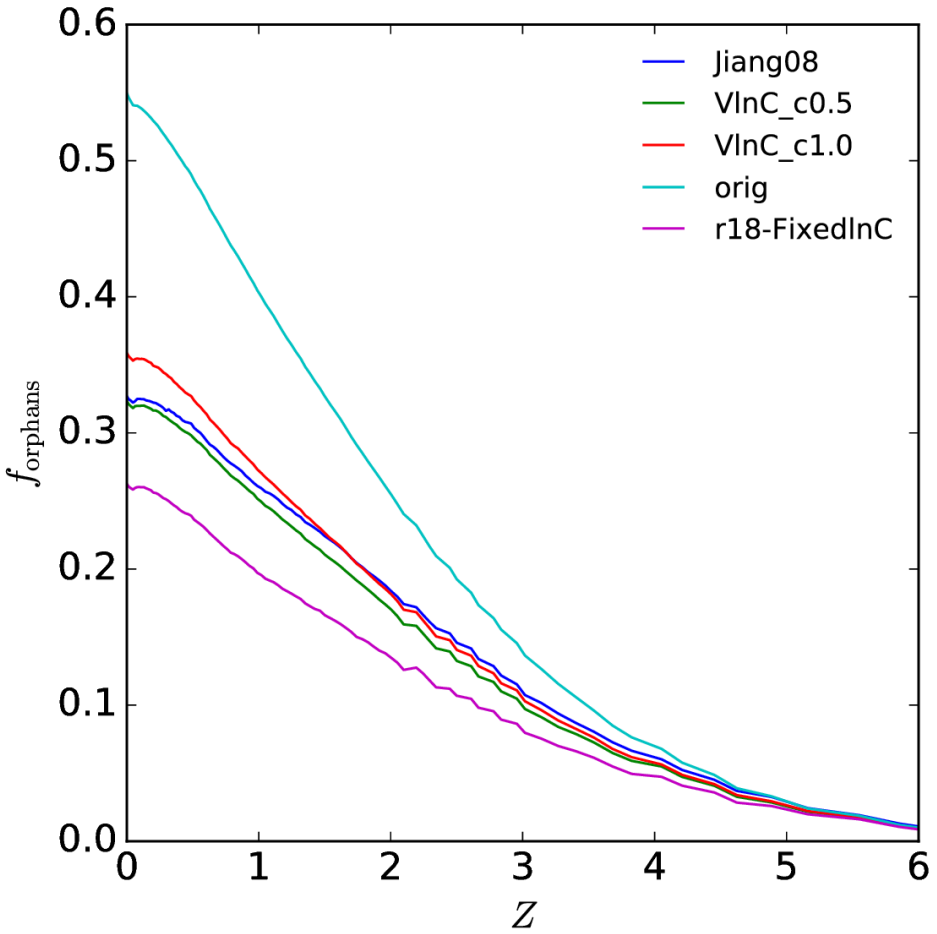
- Improved treatment of Cold Gas (bulge) in bursts.
- Moved from retention to ejection scheme.
- New prescriptions for reheated mass, ejection and reincorporation by following the Hirschmann et al. (2015) FIRE's model.
- Refinements in the definition of galactic mergers in the analytical integration of orphan's orbits.

Model refinements

- Orbit integration of orphan galaxies needs a consistent dynamical friction:

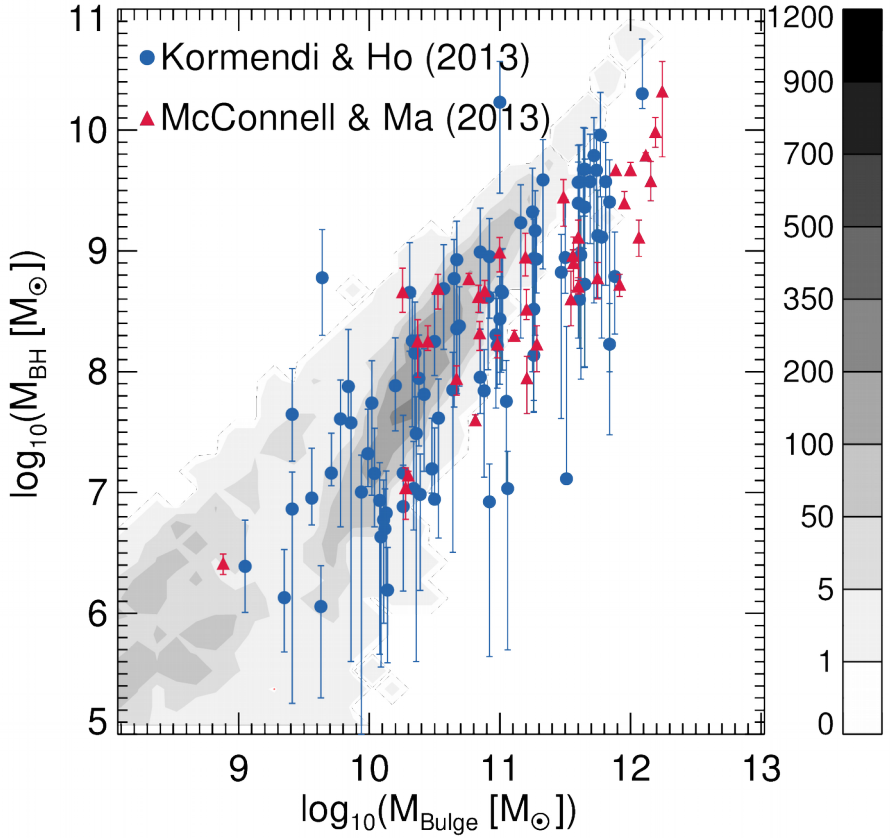
$$F_{df} \sim \ln(\Lambda)\, f(M_{sat}, v_{sat}, r_{sat})$$

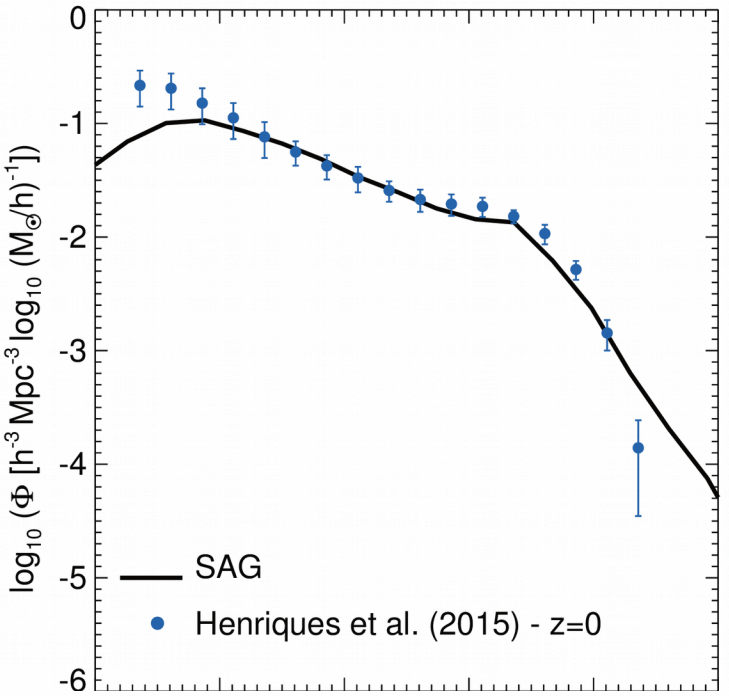


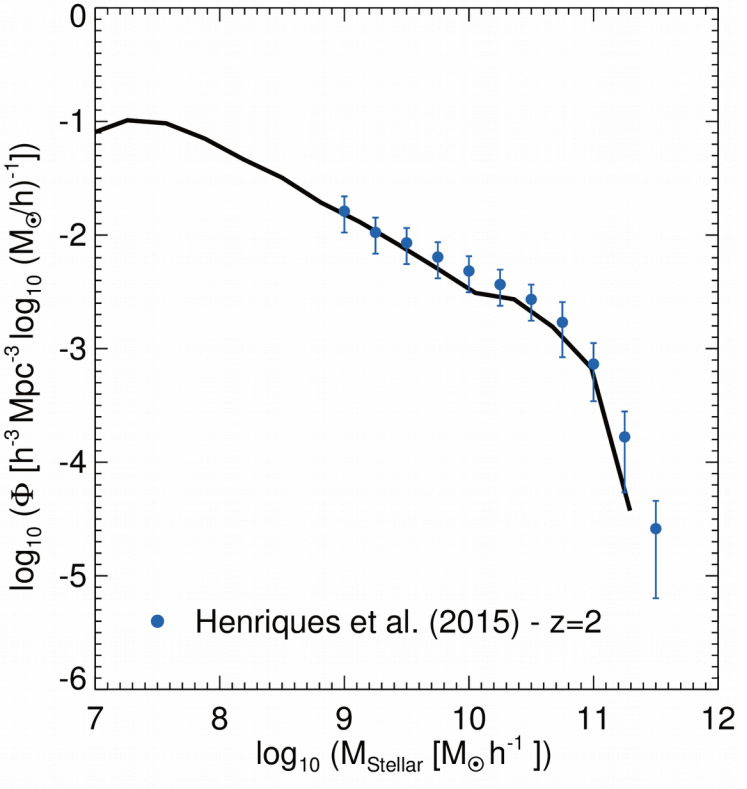


Third run

- Calibrated using 5 constraints: SMF(z=0, z=2), SFRF, BHBM, CGMF.
- Full simulation in process.







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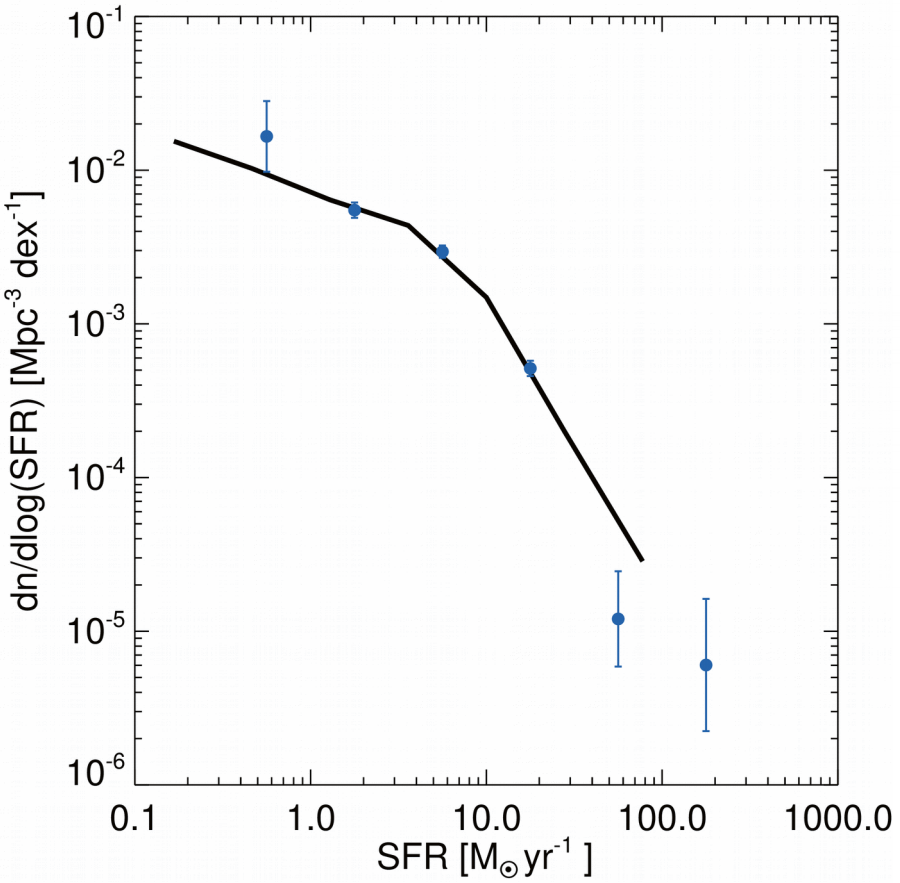
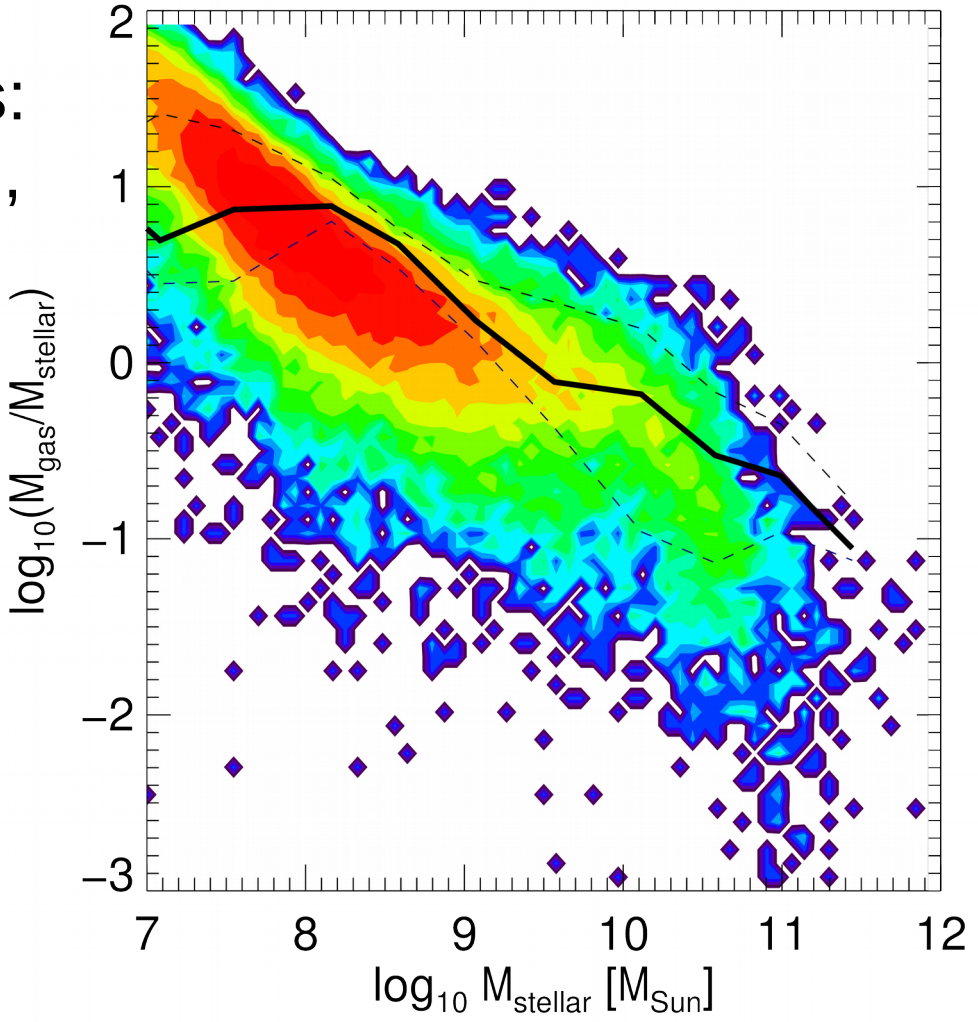
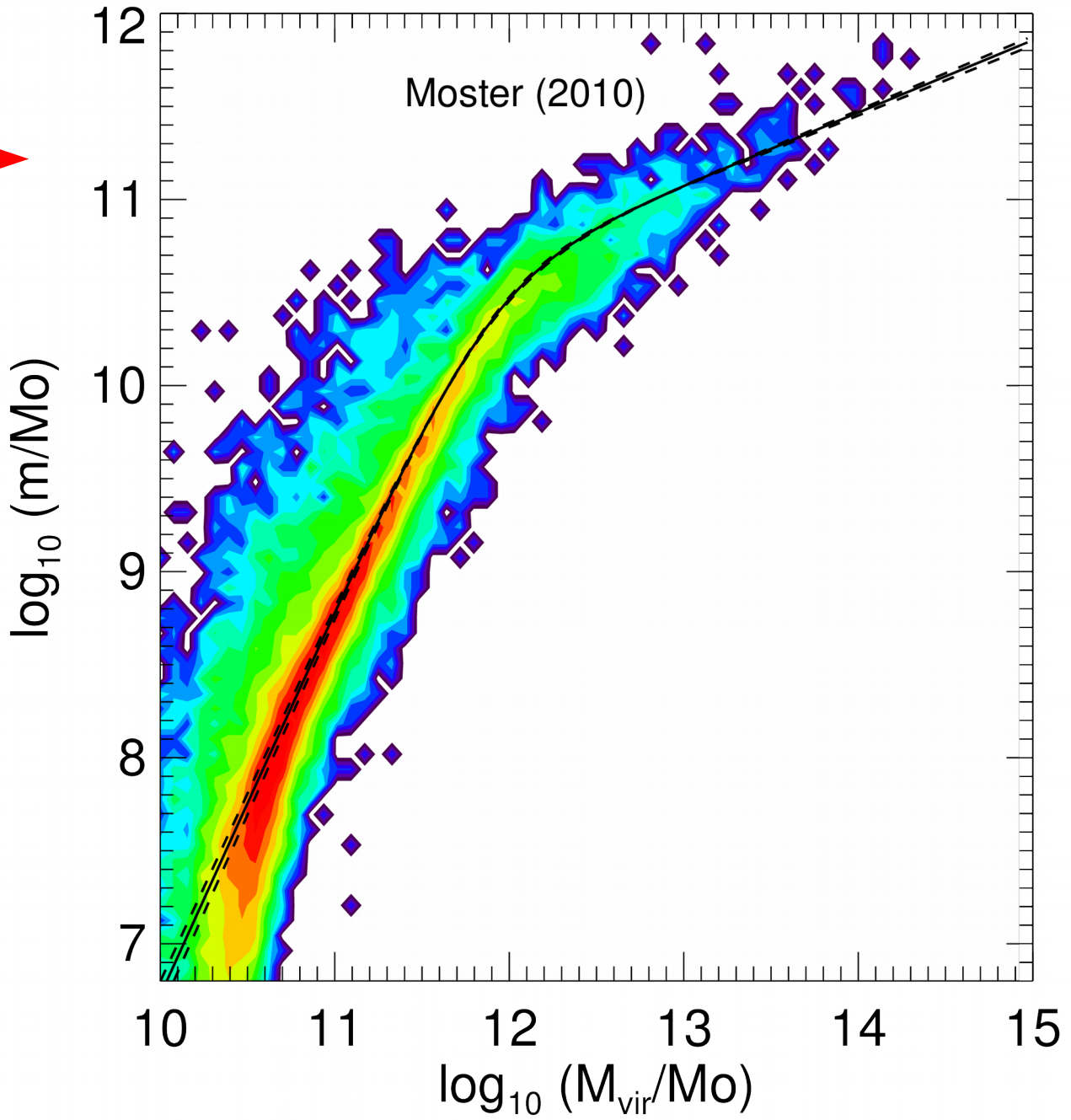




Third run

- Prediction



- More results in the next talks!