Galaxy simulations: results from FIRE project

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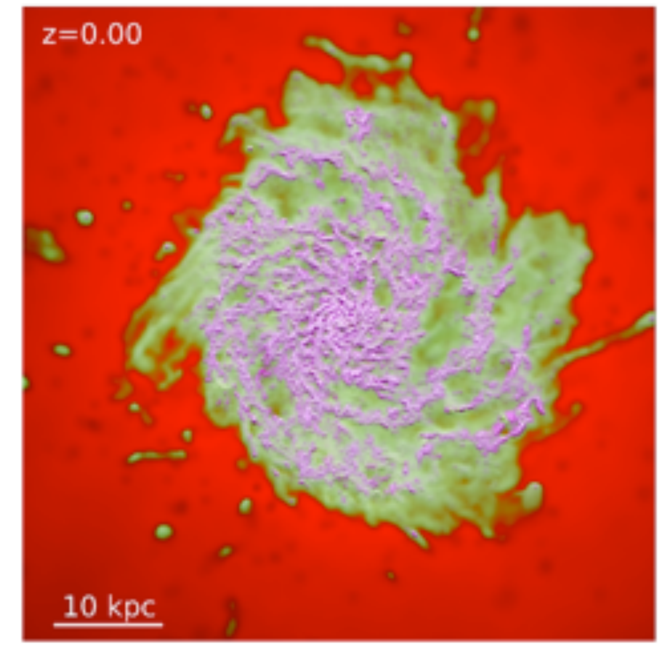
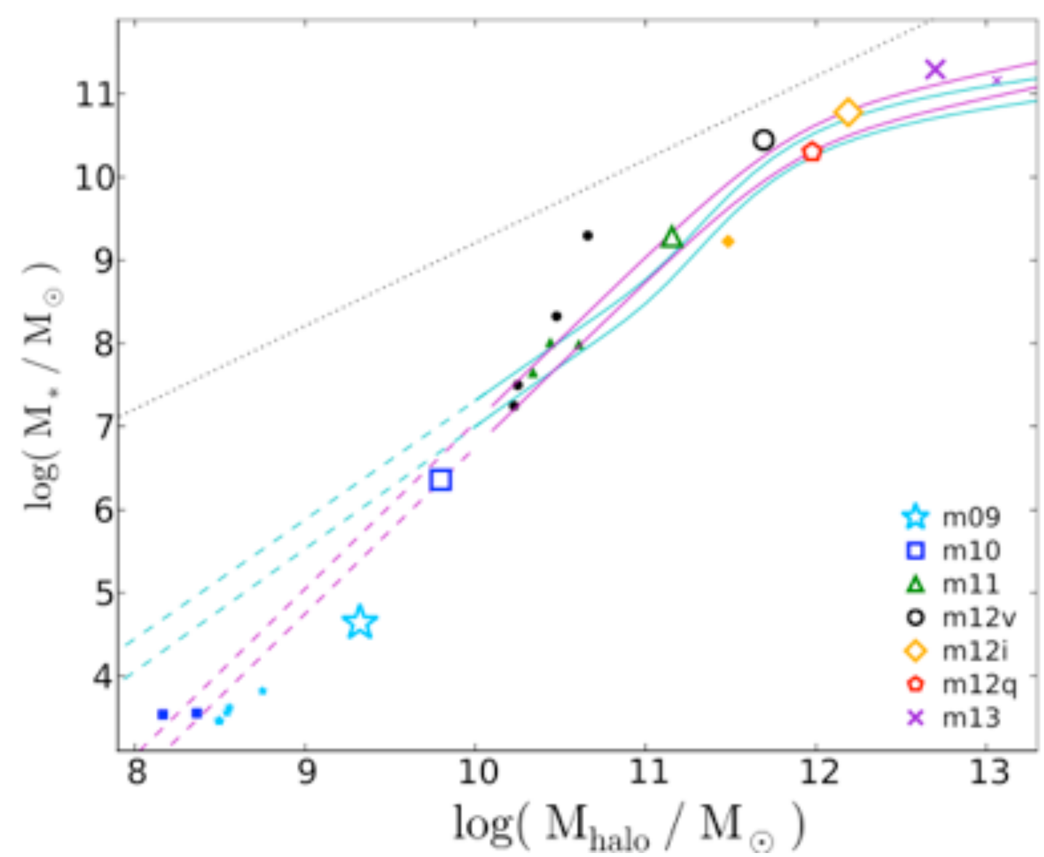
FIRE simulations

- Feedback in Realistic Environments - FIRE!
- Full range of SF driven feedback processes: radiation pressure, stellar winds, HII regions, SN energy and momentum.
- No cooling prevention, no hydrodynamical decoupling; input based on stellar population models in STARBURST 99.
- Fully cosmological simulations with significantly improved P-SPH.
- Spatial resolution typically 10-50pc
- Results: FIRE galaxies are a very good match to observed M_*-M_h relation!

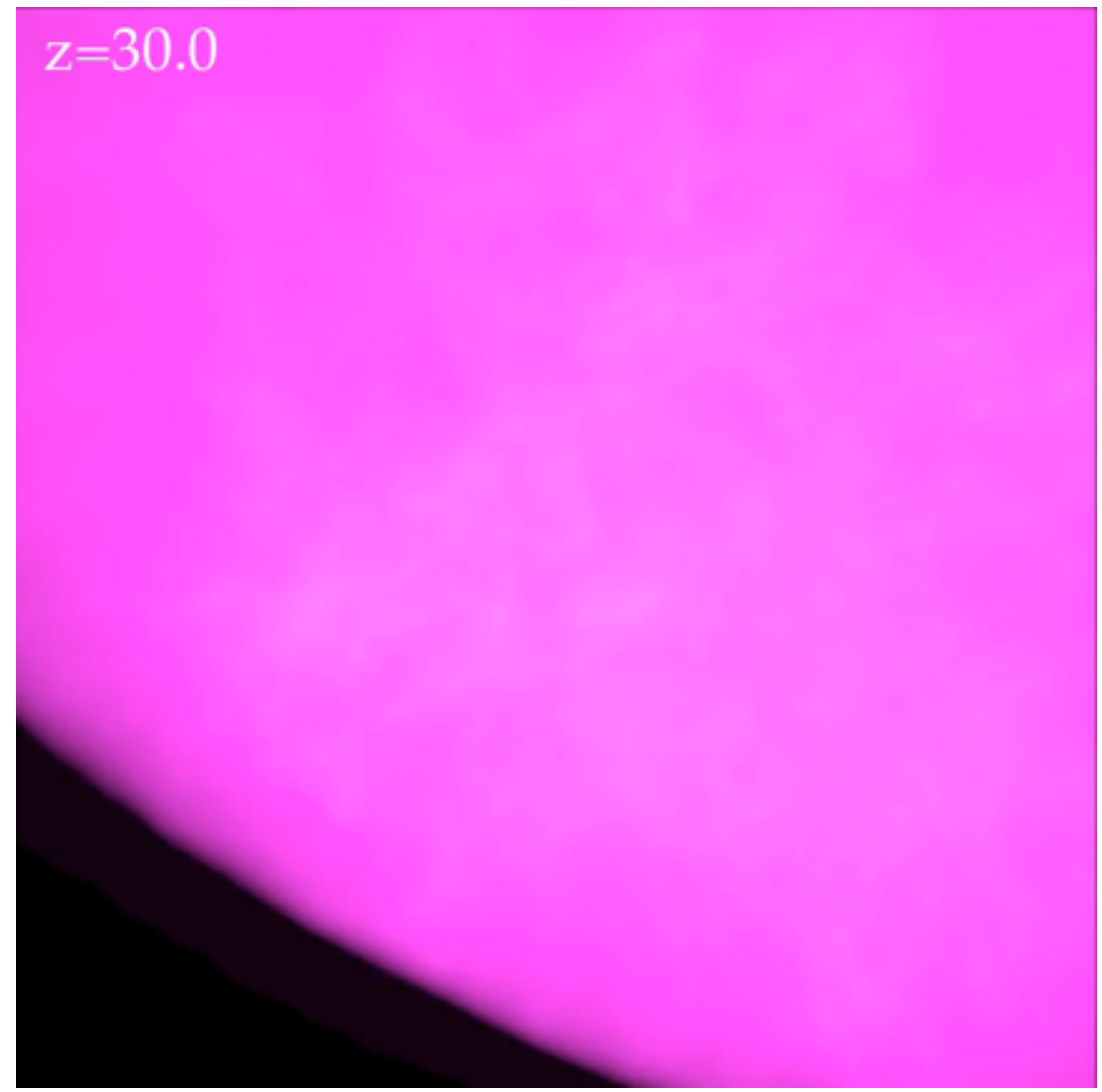




Hopkins, Keres et al., submitted (2013)

What do we do with FIRE?

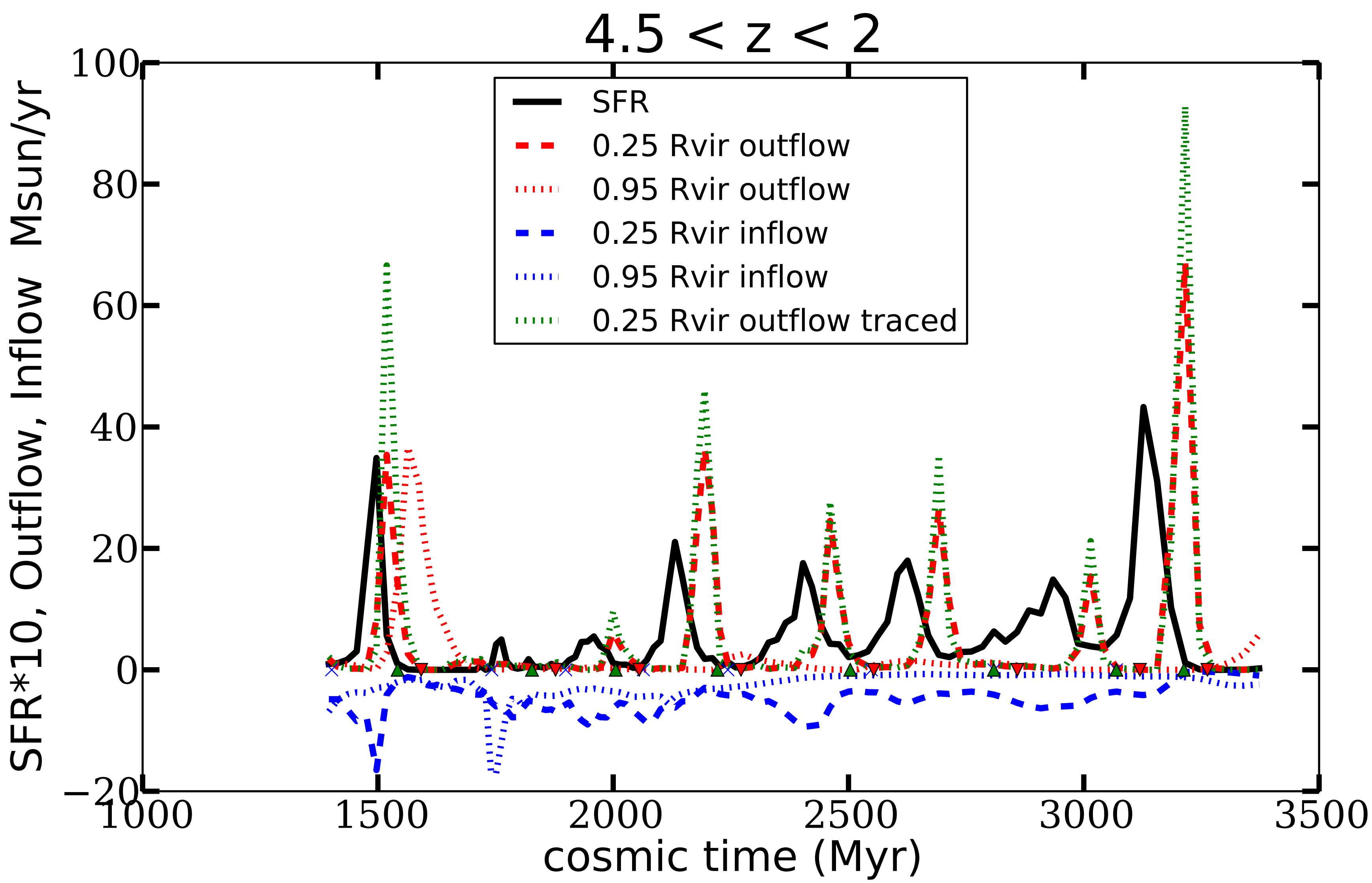
- Progress in several areas where our improved modeling and resolution has advantage over previous models:
  - role feedback in disk formation
  - structure of ISM gas
  - evolution of the CGM gas
  - dwarf galaxy properties
  - central properties of dark matter halos
  - infall and outflow kinematics, phases structure and mass loadings and more...



10^{12}Msun halo, based on AGORA ICs

Star formation driven outflows

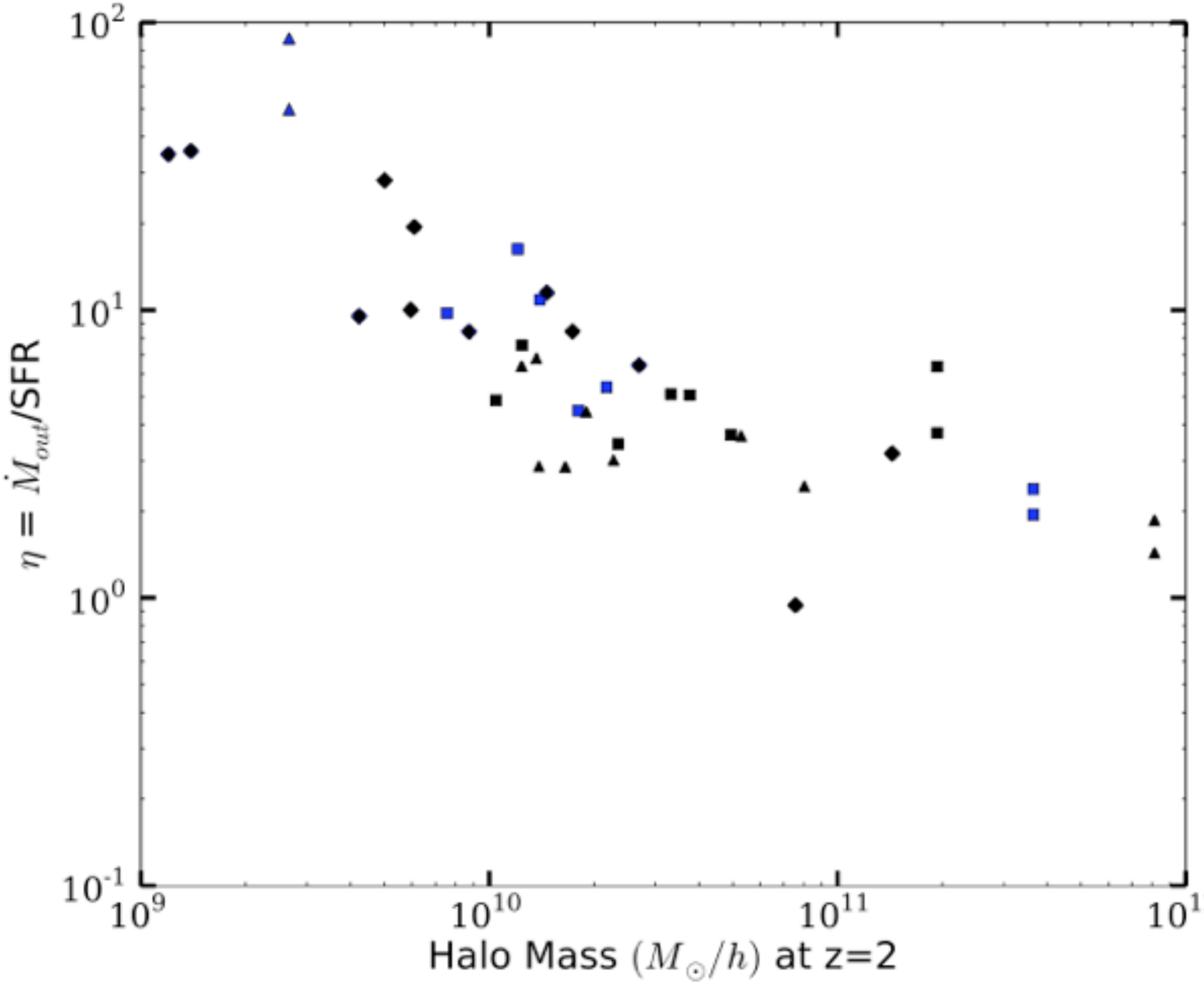
- High-redshift star formation histories are bursty!
- Episodes of star formation drive episodes of winds that push material out of galaxies.



Muratov et al., in preparation

How much material is expelled?

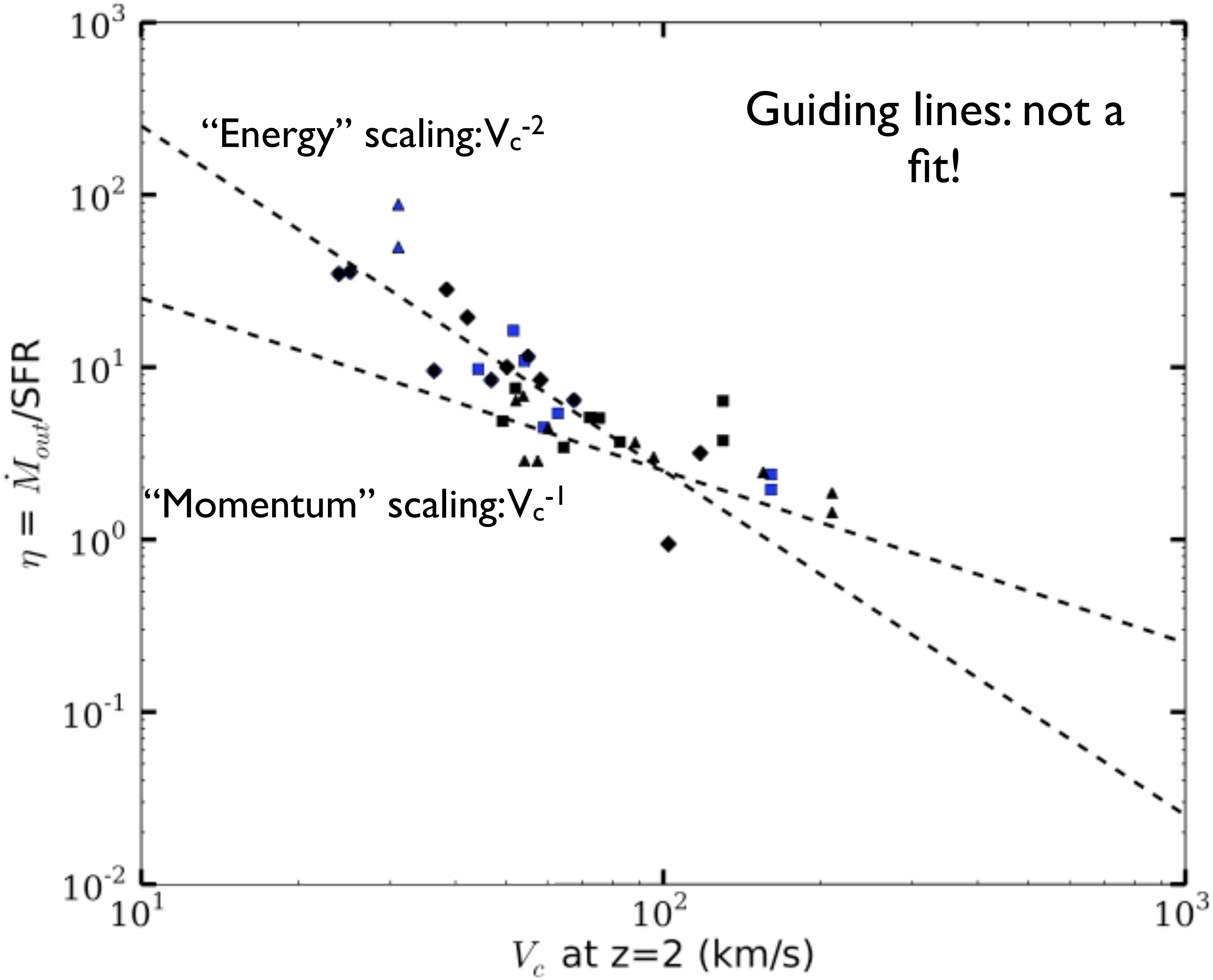
Mass loading of material expelled through a shell in inner halo decreases with increased halo mass!



Muratov et al., in preparation

How much material is expelled?

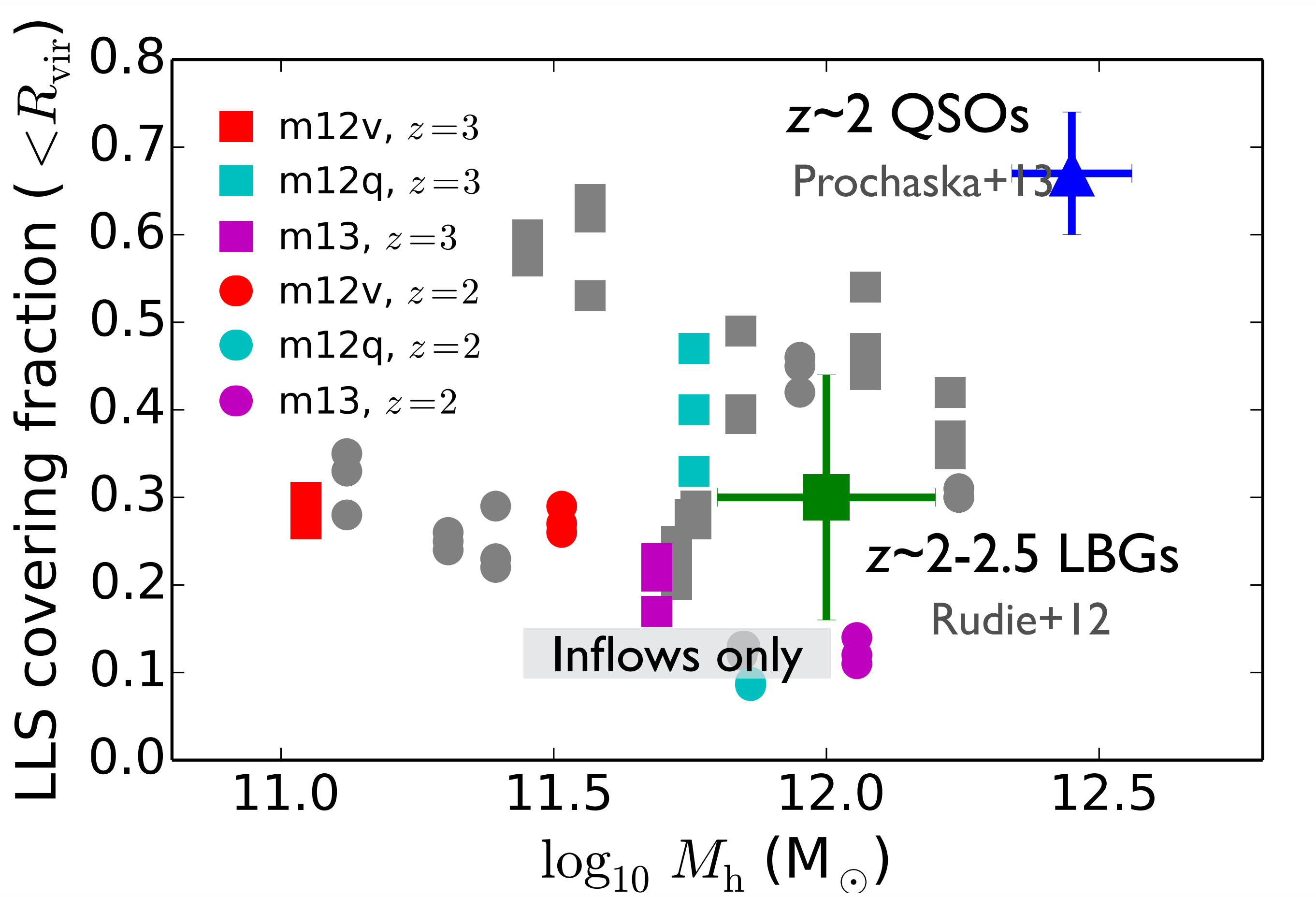
Steeper scaling at low Vc, comprehensive interpretation needed.

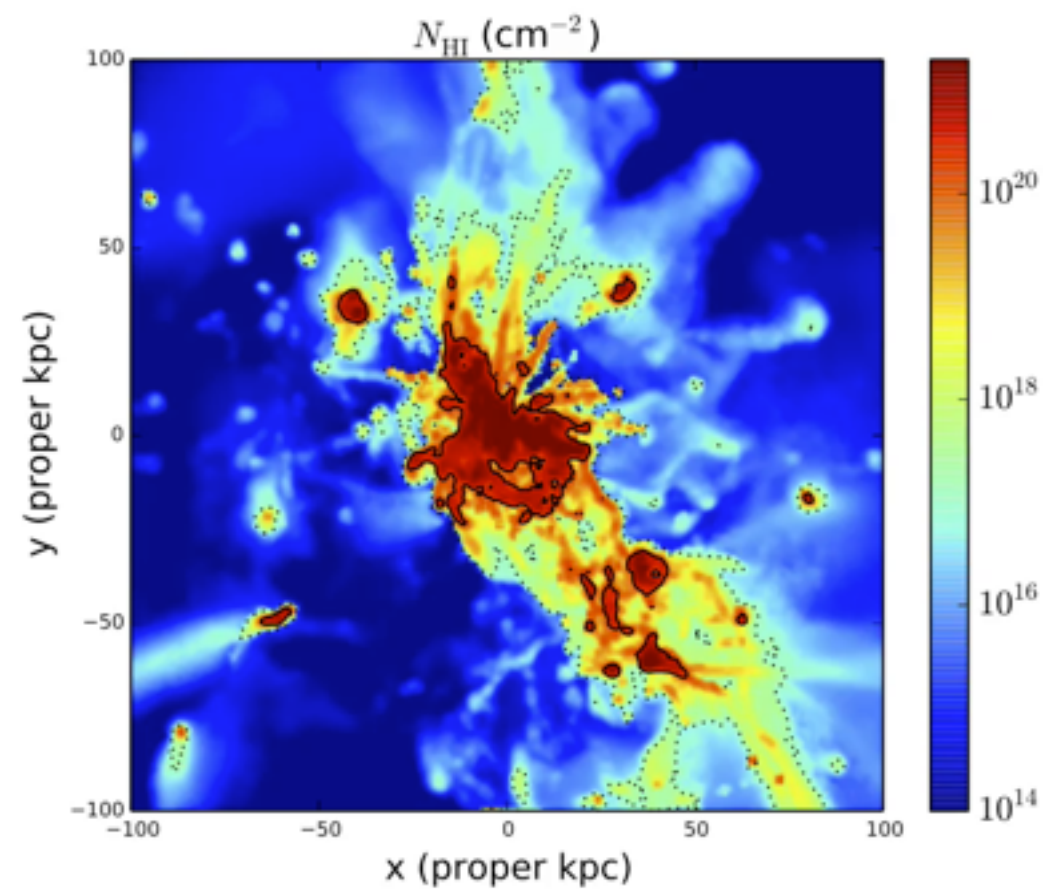


Muratov et al., in preparation

Test: LLS covering factor

- Winds increase the amount of neutral hydrogen in galactic halos and change its covering factor.
- Simulations with SF-driven winds consistent with data around LBGs! Time variable: larger observational+simulated samples needed to test this quantitatively.



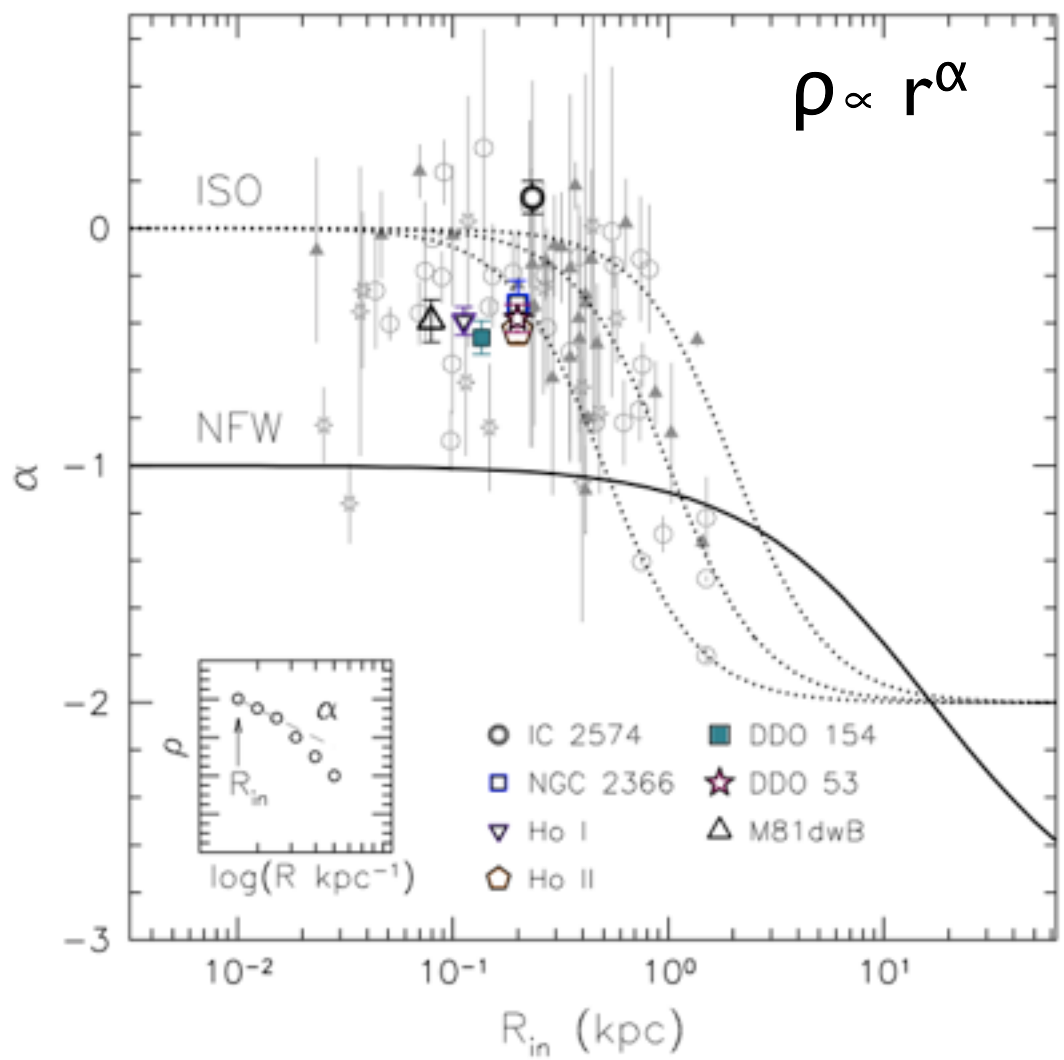


Faucher-Giguere et al. in preparation,
see also Fumagalli+13 and CAFG &Keres 2011

Cusp or core?

- Observations of central parts of larger number of dwarf galaxies suggest flatter central profiles than what is predicted by CDM: cores.
- Recent work suggested that cores are created as a consequence of rapid changes in central potential caused by gas outflows (Pontzen, Governato et al.).

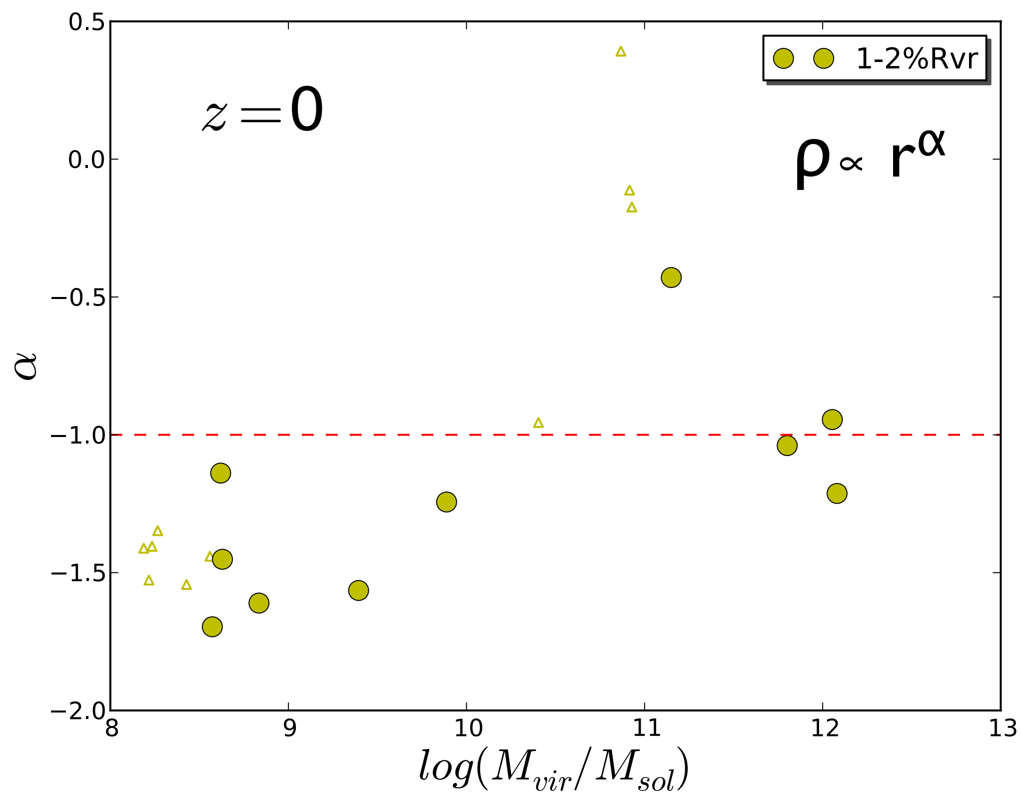
Observations

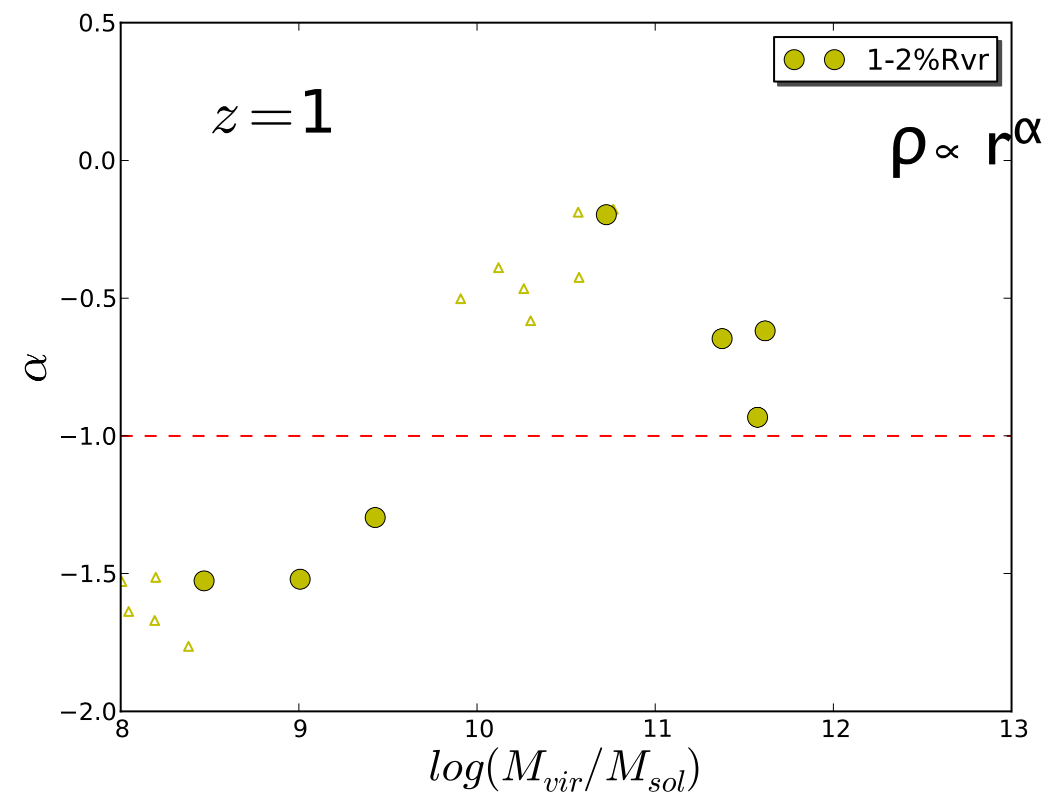


Oh et al 2011, ~10^8Msun galaxies

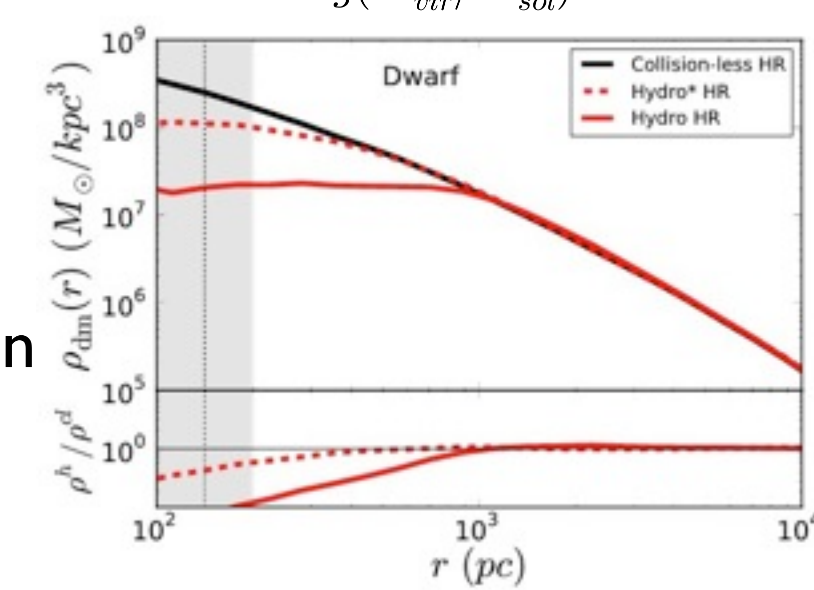
Cusp or core?

Overall in FIRE cores form only in a limited range of halos masses: ~10^{10}-10^{11}Msun, halos hosting M_*~10^8Msun galaxies.





T.-K. Chan et al., in preparation



For dwarfs around 10^{10}Msun this process seems to be very sensitive to star formation history (Onorbe et al., in preparation)!

Future plans

- Analysis with a range of projects with current simulations.
- Increase statistics!
  - Increasing number of simulated halos at dwarf and MW masses at low-z and reach higher masses at high-z (quasar hosts, quenching, accretion etc).
- Adding new physics:
  - Improvement in stellar winds: metal diffusion, addition of cosmic ray pressure, magnetic fields (MHD already implemented by P. Hopkins, tests needed) etc.
  - Improved SMBH accretion and related feedback (now when central regions are better resolved)
- Next generation of models likely in the next year or two.

HiPACC's role

- Special thanks to HiPACC: seed funding for mini-workshops helped us organize two FIRE related workshops: May and October 2013 at UC San Diego where we brainstormed many issues.
- Great way to discuss technicalities, make decisions, fix the codes.
- I hope similar workshop funding opportunities will exist in the future!