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Reconstructing the low-mass end of the baryonic Tully-Fisher relation with simulations

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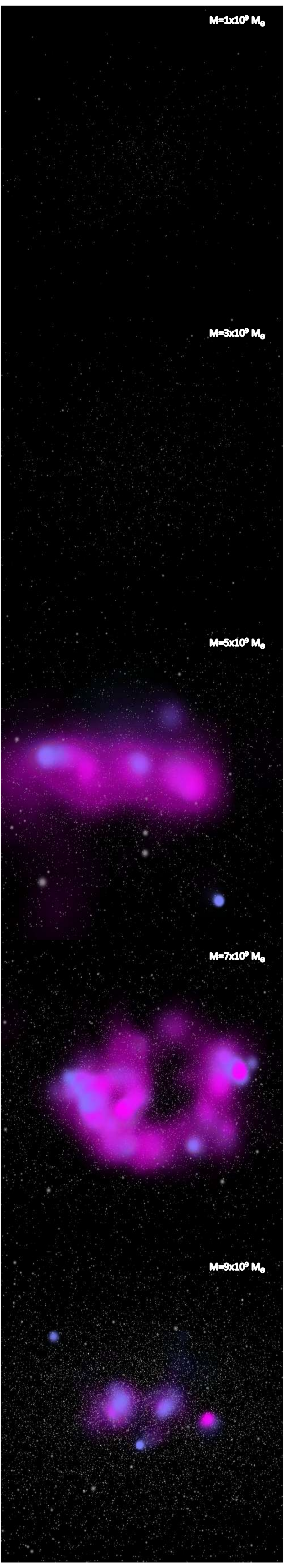


Simulations – The figures above show the stars and gas for the 5 different halo masses of our models at redshift 0. All models shown have an initial rotation velocity of 10 km/s. The gas is plotted using blobs having the size of the SPH smoothing length. The intensity of the blobs is set by their density, while they are color-coded by their temperature (blue is cold, red is warm).

The QR-code below leads to an experimental WebGL-based SPH v... s a live v... ure whic... mani...

http://users.ugent.be/~bwvdnbro/SPHvisualizer/

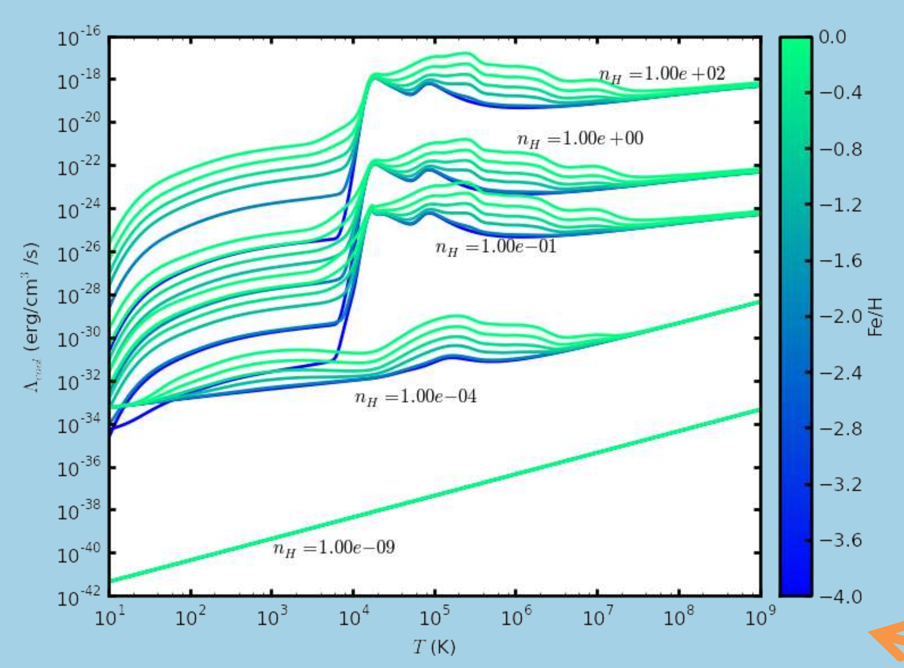
Introduction

The **baryonic Tully-Fisher relation (bTFR)** is an observational relation between the baryonic contents of a galaxy (stars and neutral gas) and the halo potential. It holds for galaxies over many orders of magnitude in mass and implies that a halo of a certain mass will form a certain mass in stars and retain a certain amount of neutral gas.

Recent simulations of low-mass galaxies by e.g. Shen et al. (2013) and Sawala et al. (2010) find that low-mass halos (< 10^9 M$_\odot$) are unable to form stars due to the reionizing UV background. Halos with a higher mass can form stars, but blow away their remaining gas after a few Gyr after which they stop forming stars. This is in striking disagreement with observations of e.g. Hidalgo et al. (2011) and Weisz et al. (2011), which show low mass halos (~ 10^8 M$_\odot$) that do form stars and are able to retain gas and form stars continuously. Also, they find very little effect of the UV background on the star formation histories.

In this work, we will try to compare the observed low-mass end of the bTFR (McGaugh 2012) directly with numerical simulations of isolated dwarf galaxies. Our simulations use an advanced sub-grid model including composition dependent cooling, feedback from SNIa, SNII and stellar winds, and a redshift dependent UV background. We also investigate the effect of different UV backgrounds on the star formation histories of individual dwarf galaxies.

Method



Cooling curves – Small selection of the cooling curves that were used for the simulations. The large increase of the cooling rate at 10^4 K completely disappears at low densities due to ionization of the ISM by the UVB.

Initial conditions:
- Dark matter:
  - NFW profile
  - mass between 1-9x10^9 M$_\odot$
- Gas:
  - pseudo isothermal gas sphere
  - 10,000 K
  - Rotation velocity of 0-10 km/s
  - mass set by Ω_B/Ω_M

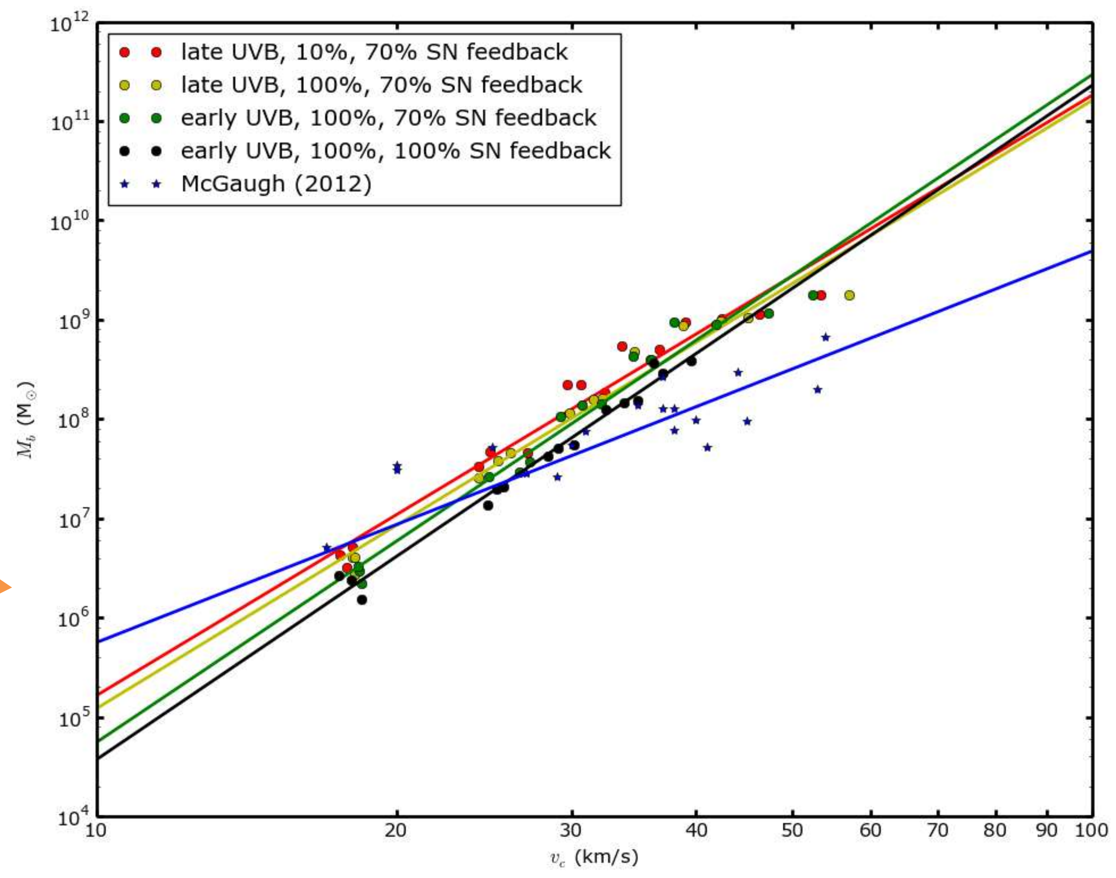
Parameters:
- Start redshift: 12
- End redshift: 0
- SN feedback efficiency 70 or 100% (of 1x10^{51} erg)
- UVB strength 10 or 100% of Faucher-Giguère (2009)
- UVB starts at redshift 11 (early) or 7 (late)
- Resolution: 50,000 particles for each component (convergence tests have shown that this is sufficient for these purposes)

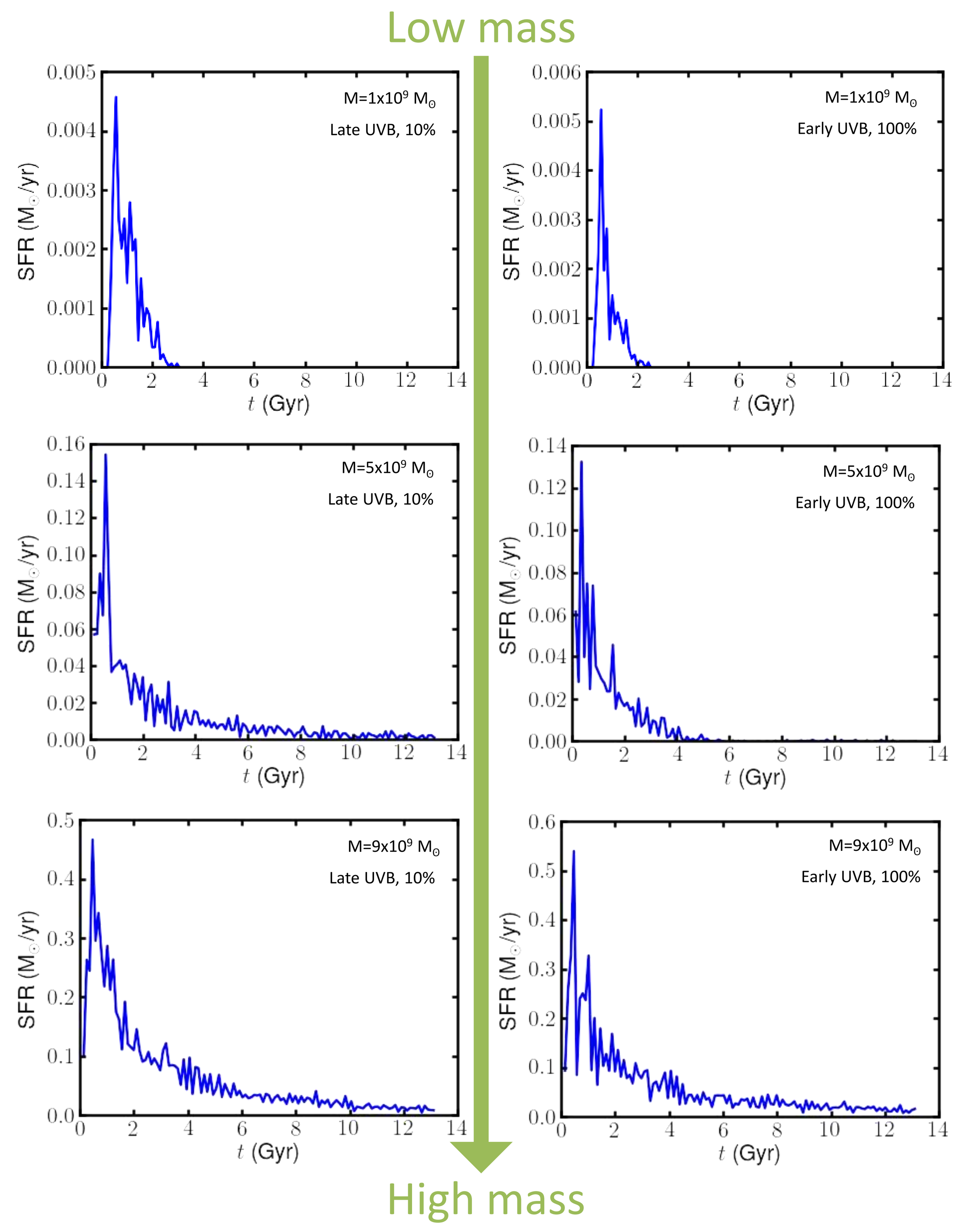
Simulation code:
Gadget2
+ advanced cooling and heating (De Rijcke et al. 2013)
+ advanced gas physics (Vandenbroucke et al. 2013)
+ star formation, metal enrichment…

Post-processing using the same ionization equilibrium used for the cooling , heating and gas physics. Gas is considered neutral if the neutral fraction > 90%.

Results

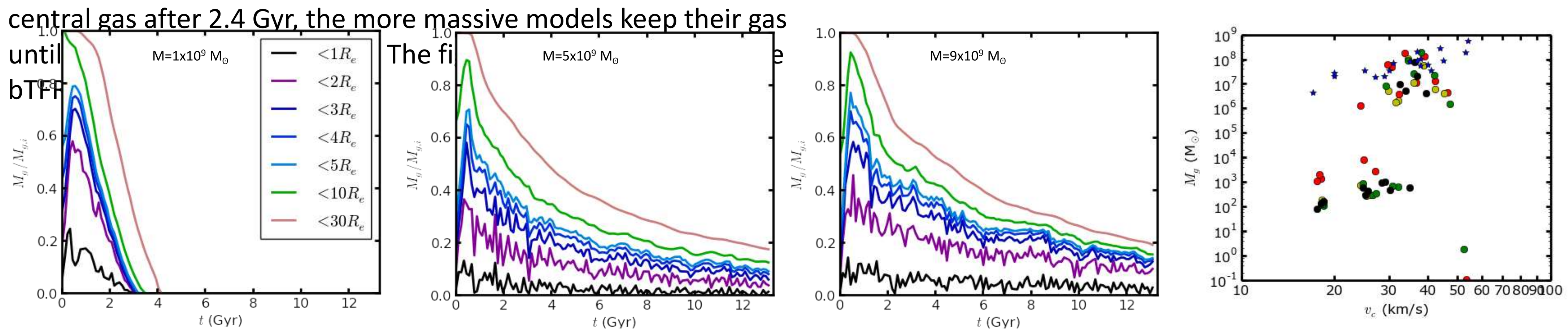
- Star formation histories:
  - Initial strong peak
  - Peak shut down by SN feedback
  - Subsequent star formation suppressed partly or completely by UV background heating
- bTFR:
  - Linear relation BUT: offset to observations of McGaugh (2012)
  - Slope differs from observational slope
  - Shifts downwards for higher SN feedback, but slope is not affected
- UV background:
  - Timing and strength hardly influence bTFR
  - Do have an influence on individual star formation histories





bTFR – The baryonic Tully-Fisher relation for our simulations. The lines represent linear fits to the points, they clearly have a different slope than the observational slope of McGaugh (2012). The figures on the right show six star formation histories for individual models with an initial rotation of 10 km/s, to demonstrate the suppression of star formation for the low mass models and the effect of a varying UV background on the star formation history.

Missing gas – The figures below show the fraction of the initial gas mass within different radii of the galaxy as a function of time, for the models with a low, late UVB. The lightest halo loses its central gas after 2.4 Gyr, the more massive models keep their gas until ... The fi... bTFR...



Problems

- Need to suppress initial star formation peak to obtain lower total stellar mass
- Need to be able to keep gas longer to match observed star formation histories

Already tried:
- Different stellar IMF
- Lower/higher SN feedback strength
- Different SN feedback mechanism
- Lower/higher star formation rate

BUT star formation is self-regulating

➔ Suggestions are welcome

References

- De Rijcke, S. et al., MNRAS, 433, 3005 (2013)
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- Weisz, D.R. et al., ApJ, 739, 5 (2011)