Explaining the Velocity Dispersion of Dwarf Galaxies by Mass Loss during the First Collapse

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Probes of Dark Matter on Galaxy Scales, Monterey, July 2013
Problem:

- Too big to fail: The observed phase-space density of Dwarf Galaxies (e.g. Fornax) is much smaller than predicted by ΛCDM (dark matter only) simulations (e.g. Boylan-Kolchin et al. 2011, 2012)
Caveat I: Feedback

- Simulations with more realistic baryonic physics and feedback mitigates the problem (e.g. Brooks & Zolotov 2012)
Caveat II: Mass of the MW

- The mass of the Milky Way might be smaller than previously assumed.

- Deason et al. 2012: we infer that the mass within 150 kpc is less than $10^{12} \, M_\odot$ and suggest it probably lies in the range $(5-10) \times 10^{11} \, M_\odot$. 
Caveat III: Resolution

New high resolution simulations seem to alleviate the problem e.g. the ERIS simulation (Guedes et al. 2011) with a SF-threshold of 10 g/cm³ produces a MW-like disk

**Annalisa Pillepich** (The Physical Link between Galaxies and their Halos, Garching, 2013) – ERIS features:

- MW Halo contraction and a small core
- No missing satellite problem according to Eris(Dark) only 5 luminous satellites survive to z=0
- No too big to fail issue in Eris (nor in Eris Dark) - smaller host mass, bigger scatter in N(>V_{max})
Caveat IV: Cosmology

- The too big to fail problem is based on the Aquarius/Millennium simulations (Springel et al. 2008)

All our simulations follow halo formation within a periodic cube of side $100 \, h^{-1} \text{Mpc} \simeq 137 \, \text{Mpc}$ in a cosmology with parameters $\Omega_m = 0.25$, $\Omega_\Lambda = 0.75$, $\sigma_8 = 0.9$, $n_s = 1$ and Hubble constant $H_0 = 100 \, h \, \text{km s}^{-1} \, \text{Mpc}^{-1} = 73 \, \text{km s}^{-1} \, \text{Mpc}^{-1}$. These cosmological

- Via Lactea (Diemand et al. 2007):

  WMAP 3-year data release (Spergel et al. 2006): $\Omega_M = 0.238$, $\Omega_\Lambda = 0.762$, $H_0 = 73 \, \text{km s}^{-1} \, \text{Mpc}^{-1}$, $n = 0.951$, and $\sigma_8 = 0.74$. The simulation was centered on an iso-

- WMAP 9:

  $\Omega_M = 0.233$, $\Omega_\Lambda = 0.721$, $H_0 = 70 \, \text{km s}^{-1} \, \text{Mpc}^{-1}$, $\sigma_8 = 0.82$
Caveat V

During the first collapse a massive burst of star formation is to be expected

Our approach:

- SEREN N-body simulation, placed at Hubble turnaround.
- Feedback is parameterized by instantaneous mass loss (very crude)
- Similar to the work on stellar clusters by Aarseth et al. 1988
‘in time to shine’

**Our solution:** The timely loss of about 10% of baryonic matter by feedback during the first collapse leads to a significant puff-up.

Unperturbed
Central Mass Loss of 10%
Amount and Region of Loss

Core vs Cusp

also Pontzen & Governato 2012
The Initial Density Profile

Comparison to Observations

Observations of Fornax (Jardel & Gebhardt 2012)

Energetics

\[ E_{\text{req}} = \frac{GM}{R_b} \Delta m = \left( \frac{GM}{R_{\text{hm}}} \right) \left( \frac{R_{\text{hm}}}{R_b} \right) \left( \frac{\Delta m}{M_{\text{tot}}} \right) M_{\text{tot}} = \]

\[ = \sigma^2 \left( \frac{R_{\text{hm}}}{R_b} \right) \left( \frac{\Delta m}{M_{\text{tot}}} \right) M_{\text{tot}} = \]

\[ = 10^{11} \cdot 20 \cdot 0.1 \cdot 10^{8-9} \cdot 10^{33} \text{ erg} \approx \]

\[ \approx 10^{52-53} \text{ erg} \]

Supernova-Feedback: \( E_{\text{SN}} \approx 10^{51} \text{ erg} \) about 10-100 supernovae (assuming ideal coupling)

Even before, the ionization might have a strong influence
(see also Noriega-Crespo et al. 1989)

\[ E_{\text{ion, O-star}} \approx 10^{52} \text{ erg} \]
Ionization

Gritschneder et al., 2009a, b, 2010
Future Work: ‘SIREN’

Monte Carlo ray casting implemented into the tree-SPH code SEREN
Particle ray intersection test
Two sweeps, one depositing photons, one calculating ionization
Photo-ionization (currently, photo-dissociation pending):

\[ \eta = \frac{\gamma_{\text{deposited}}}{\gamma_{\text{required}}} \]

Gritschneder et al. in prep
Ionization of multiple sources
Conclusions

• Early feedback (mass loss) significantly alters dwarf galaxies (phase space density, cusp versus core)

• The ΛCDM-‘approximation’ does not fail here

• The various ΛCDM-‘crises’ might be mainly related to the approximative implementation of ΛCDM into simulations