The effect of feedback and reionization on low-mass dwarf galaxy halos

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Goals

• Understand the physics regulating star formation in low-mass halos ($M_{\text{halo}} \sim 10^9 \, M_\odot$)

• Test the relative importance of reionization and supernova feedback

• Use high resolution zoom-in AMR simulations to explore these issues
Simulation Set-up

- Enzo - Adaptive Mesh Refinement (AMR) code
- $1.55 \times 10^9 \, M_\odot$ at $z = 0$ in isolated environment
- 4 comoving Mpc $h^{-1}$ cosmological box with 2 nested refinement grids ($m_{dm} = 5353 \, M_\odot$)
- Adaptive refinement based on dm & gas density (12 levels, $\Delta x_{\text{min}} = 11$ comoving pc)
- Metal line cooling & heating rates (Smith et al. 2008)
- Cosmic UV backgrounds (photoionizing & photodissociating) (Hardt & Madau 2001, 2011)
- Self-shielding prescription from photoionization & photodissociation (Simpson et al. 2012 in prep, Shang, Bryan & Haiman 2010)
- Star formation ($m^* = 100 \, M_\odot$) (Cen & Ostriker 1992)
- Thermal supernova feedback (assume 150 $M_\odot$ stars make $10^{51}$ ergs injected over 10 Myrs) (Cen & Ostriker 1992)
<table>
<thead>
<tr>
<th>Dark Matter Density</th>
<th>Gas Density</th>
</tr>
</thead>
<tbody>
<tr>
<td>$150 \text{kpc}/(1+z)$</td>
<td>Temperature</td>
</tr>
</tbody>
</table>
Gas Density

Temperature

Dark Matter Density

Stellar Mass Density

150 kpc/(1+z)
Multiphase ISM

before reionization

after reionization

Gas with $r_{200}$ of a progenitor
Reionization vs. SN feedback

No UV Background

black: full physics
red: No UV bg
Reionization vs. SN feedback

No UV Background

Simulation Ends

black: full physics
red: No UV bg

No Thermal Feedback

black: full physics
red, yellow: No SN feedback
Comparison to MW dSphs

Kirby et al. 2008 & Kirby et al. 2011

Reionization

\[ z=6-7 \]

\[ z=8-8.9 \]

<table>
<thead>
<tr>
<th></th>
<th>R10</th>
<th>R10-earlyUV</th>
</tr>
</thead>
<tbody>
<tr>
<td>( M_{\text{tot}}/M_{\odot} )</td>
<td>( 1.55 \times 10^9 )</td>
<td>( 1.55 \times 10^9 )</td>
</tr>
<tr>
<td>( M_*/M_{\odot} )</td>
<td>( 1.43 \times 10^6 )</td>
<td>( 1.16 \times 10^5 )</td>
</tr>
<tr>
<td>( r_{200} ) (kpc)</td>
<td>23.7</td>
<td>23.9</td>
</tr>
<tr>
<td>( r_{1/2} ) (pc)</td>
<td>704</td>
<td>213</td>
</tr>
<tr>
<td>( M_{1/2}/M_{\odot} )</td>
<td>( 3.05 \times 10^7 )</td>
<td>( 3.86 \times 10^6 )</td>
</tr>
<tr>
<td>( M_{300}/M_{\odot} )</td>
<td>( 7.53 \times 10^6 )</td>
<td>( 7.41 \times 10^6 )</td>
</tr>
<tr>
<td>( \sigma_{1/2} ) (km/s)</td>
<td>7.83</td>
<td>8.30</td>
</tr>
<tr>
<td>( \langle Z/Z_{\odot} \rangle ) (median)</td>
<td>0.51</td>
<td>0.06</td>
</tr>
</tbody>
</table>

Data from Walker et al. 2009, Kirby et al. 2008 & Kirby et al. 2011
Comparison to MW dSphs
Comparison to MW dSphs

Data from Walker et al. 2009, Kirby et al. 2008 & Kirby et al. 2011
Comparison to MW dSphs

- Full Model
- No Feedback
- No UV Background

Graphs showing comparisons of various parameters such as $\sigma$ (km s$^{-1}$), Log($r_{1/2}$/pc), Log($L/L_\odot$), and $\langle [Fe/H] \rangle$.
Why? an old story

We assume 150 M☉ of stars produce $10^{51}$ ergs in thermal energy.
Spatial resolution

Black: $\Delta x_{\text{min}} = 11 \text{ pc}/(z+1)$

Magenta: $\Delta x_{\text{min}} = 43 \text{ pc}/(z+1)$
Conclusions

- We have performed a series of high resolution, cosmological simulations of the formation of a low-mass dwarf halo.
- We find that our halo forms hierarchically, with multiple star forming progenitors at high redshift.
- The timing of reionization can produce a difference in stellar mass of an order of magnitude.
- The UV background and SN feedback work together to suppress star formation; the UV background by suppressing the overall gas fraction, and SN by destroying self-shielded dense gas.
- We form an object consistent in mass and luminosity to MW dwarfs.
- We do not find good agreement with stellar metallicities for such objects, indicating the need for a more realistic feedback model.
- The low masses of dwarfs make them attractive laboratories for simulators to tackle these types of issues at high resolutions.