FIRE IN THE FIELD

SIMULATING THE THRESHOLD OF GALAXY FORMATION

ALEX FITTS - UT AUSTIN

MIKE BOYLAN-KOLCHIN – UT AUSTIN
JAMES BULLOCK – UCI
OLIVER ELBERT – UCI

JOSE OÑORBE – MAX PLANCK
PHIL HOPKINS – CALTECH
AND THE FIRE TEAM

SANTA CRUX GALAXY WORKSHOP 2016
MOTIVATION

• Dwarf galaxies challenge ΛCDM theory
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• Interesting scale at $M_{\text{vir}} \sim 10^{10} \, M_\odot$, $M_\star \sim 10^6 \, M_\odot$
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  • Core/cusp (Moore et al. 1994, Flores & Primack 1994)
  • Too Big to Fail (Boylan-Kolchin et al. 2011)
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  • Scale of faintest observed isolated dwarfs
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  - Too Big to Fail (Boylan-Kolchin et al. 2011)
  - Scale of faintest observed isolated dwarfs
  - Sensitive to reionization
SIMULATION DETAILS

- GIZMO code + MFM hydro (Hopkins 2015)
- 12 isolated dwarfs at $M_{\text{vir}} \sim 10^{10} \ M_{\odot}$ selected from $35^3 \ \text{Mpc}^3$ boxes
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- GIZMO code + MFM hydro (Hopkins 2015)
- 12 isolated dwarfs at $M_{\text{vir}} \sim 10^{10} M_\odot$ selected from $35^3 \text{ Mpc}^3$ boxes
- $\varepsilon_{\text{gas}} \sim 1.4 \text{ pc}$, $\varepsilon_{\text{dm}} \sim 25 \text{ pc}$
- $M_{\text{gas}} \sim 500 M_\odot$, $M_{\text{dm}} \sim 2500 M_\odot$
MASS ASSEMBLY HISTORIES

\[ M_{\text{vir}} (M_\odot) \]

Time (Gyr)

0 2 4 6 8 10 12 14
MASS ASSEMBLY HISTORIES

Simulations

Mean Assembly History
(Fakhouri et al. 2010)
A GLANCE AT $M_\star$
A GLANCE AT $M_*$

Note narrow range of halo masses
MASS ASSEMBLY HISTORIES

The diagram shows the mass assembly histories over time, with the y-axis representing the virial mass ($M_{\text{vir}}$) in solar masses ($M_\odot$) and the x-axis representing time in Gyr. The colors indicate different log masses. The curves illustrate the growth of mass over time for various scenarios.
$V_{\text{MAX}}$ THROUGH TIME
$V_{\text{MAX}}$ THROUGH TIME
COMPARISON TO OBSERVATIONS

Kirby et al. 2013, 2014
COMPARISON TO OBSERVATIONS

Kirby et al. 2013, 2014
Variations in observed SFRs can be strongly affected by time.

Cumulative Stellar Mass Fraction

Comparison between the SFHs of the LCID galaxies shown as a function of time.

Skillman et al. 2014

Observed Star Formation Histories
COMPARISON TO OBSERVATIONS

Skillman et al. 2014

Observed Star Formation Histories

Simulated Star Formation Histories
Radial Density Profiles

\[ M_\star = 4.68 \times 10^5 \, \text{M}_\odot \]
\[ M_\star = 4.25 \times 10^6 \, \text{M}_\odot \]
\[ M_\star = 1.07 \times 10^7 \, \text{M}_\odot \]

\( \rho (\text{M}_\odot / \text{kpc}^3) \)

Radius (kpc)

- Dark matter only
- Hydro
All galaxies have **same** halo mass of $\sim 10^{10} \, M_\odot$

- No cores for halos with $M_\star < \sim 10^6 \, M_\odot$ (Governato et al. 2012, Di Cintio et al. 2014, Dutton et al. 2016)
RADIAL DENSITY PROFILES

$M_\star = 4.68 \times 10^5 \, M_\odot$

$M_\star = 4.25 \times 10^6 \, M_\odot$

$M_\star = 1.07 \times 10^7 \, M_\odot$

Increasing $M_\star$
Decreasing Central Density
RADIAL DENSITY PROFILES
RADIAL DENSITY PROFILES

Increasing $M_*$

$\frac{\rho_{\text{hydro}}}{\rho_{\text{dm0}}}$ vs. $\frac{r}{r_{1/2}}$
CONCLUSIONS

• 12 high-resolution gizmo + FIRE simulations of isolated dwarf galaxies, all with $M_{\text{vir}}(z=0) \sim 10^{10} \, M_\odot$

• Good agreement between simulations and observed isolated dwarfs for $M_\star(z=0)$, SFH, $R_{1/2}$, $M_{\text{dyn}}/M_\star$

• Strong correlation between early dark matter mass assembly and present-day stellar mass
  • higher concentration, higher $V_{\text{max}}$ halos build up more stellar mass earlier

• $M_\star(z=0)$ correlates well with density reduction
  • No modification from dark-matter-only simulations below $M_\star \sim 10^6 \, M_\odot$, increasingly large density reduction and dark matter cores at higher stellar masses

• Future work: dwarfs in WDM, SIDM (including hydrodynamics; see talk by V. Robles)
THANK YOU!