Exploring dwarf galaxy evolution around Milky Way mass galaxies

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Understanding galaxy evolution
Key Challenges

• Understanding galaxy evolution requires:
  – large volume
  – high spatial resolution
  – long time span
  – good time resolution
  – following of dark matter particles
  – creation of stars and treatment of feedback
  – following gas flows
• Understanding dwarf galaxy evolution requires:
  – even higher spatial resolution
  – large, well resolved volumes
Why it Matters

• Still are discrepancies between theory predictions and observations on small (galaxy) scales
• Gain a better understanding of:
  – how dwarf galaxies build up their mass
  – how many satellite dwarf galaxies there are
  – morphological types of dwarf galaxies as evolution
  – how satellite and isolated dwarf galaxies differ
  – what dwarf galaxies central densities depend on
  – how dwarf galaxies impact their host galaxy
  – where the other 50% of gas mass is around our galaxy
  – what observations are required to find this gas
Project Goals

• Create galaxies that are:
  – realistic - match observations on a variety of tests
  – high resolution - able to examine these small scales

• Use them to learn about dwarf galaxies
  – isolated and satellite galaxies
  – abundances
  – star formation rates
  – central densities
  – morphological changes
  – tidal disruption and mass loss
  – influence on gas around galaxies
Simulations

Run by Daniel Ceverino
hydrodynamical ART code

Box length = 20 /h Mpc
DM mass = 8x10^4 M_{sun}
Resolution = 17 pc

N cells = 67 million
N particles = 30 million

Stellar winds
Supernovae feedback
Radiation pressure (τ_{IR}=0)
Simulations

10 VELA host galaxies
Possible MW progenitors
No specific environmental selection
Range of merger histories and $M_{\text{vir}}$

Results from redshift one

$M_{\text{vir}} = 2 \times 10^{11} - 1.2 \times 10^{12} \ M_{\text{sun}}$

$M_{\text{star}} = 6 \times 10^{9} - 8 \times 10^{10} \ M_{\text{sun}}$

$R_{\text{vir}} = 92 - 147 \ \text{kpc}$
Distribution of galaxies around main halo

• **Red “x”** marks the center of main halo

• **Red circle** marks the ‘edge’ of the main galaxy

• **Blue dots** are luminous dwarf galaxies

• **Black dots** are dwarf galaxies without any stars (dark galaxies)
Stellar Mass Functions

• All normalized to a halo mass of $10^{12} \, M_{\odot}$

• Half of the halos are similar to observations
• There is lots of scatter in $M_*$ and $M_{\text{vir}}$
• In agreement with other simulations, observations, and expected low-mass abundance matching relations
Star Formation Histories (SFH)

Cumulative SFH of dwarf galaxies
- Gray area is range of SFHs
- Black line is the average SFH

Weisz 2014 observations of Local Group dwarfs in the same mass range

$10^5 \, M_{\text{sun}} < M_* < 10^6 \, M_{\text{sun}}$

$10^6 \, M_{\text{sun}} < M_* < 10^7 \, M_{\text{sun}}$
New initial conditions run with ART by Anatoly Klypin and Kenza Arraki

All implemented physics is included: Supernovae Radiation Pressure Photoionization

Box = 100 /h Mpc
DM mass = 2x10^5 M_{sun}
Resolution = 60 pc

No specific environmental selection

Run down to z=0
Conclusions

• Vela simulations are high-resolution hydro runs of MW-mass galaxies and their satellites down to redshift one

• Including Radiation Pressure (RP) and Photoionization (PH) physics produces a realistic dwarf galaxy population

• Slightly over produces luminous satellites

• Stellar-Mass Halo-Mass function has a large spread in $M_*$

Upcoming:
  Vela4 simulations including SNe, RP, & PH
  New ICs, larger box, run down to $z=0$

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