Morphological Drivers of Milky Way mass galaxies

Insights from the FIRE Simulations

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FIRE-2 MW-mass sample

Fifteen galaxies simulated with the FIRE-2 models for star formation and feedback

Eight galaxies in LG-like pairs; seven isolated galaxies including three from the Latte suite (Wetzel+2016)

Baryonic particle masses

$7 - 55 \times 10^3 \, M_{\odot}$

stellar softening lengths

$\leq 20 \, \text{pc}$

$0.86 \leq M_{\text{halo}} \leq 1.95 \times 10^{12} \, M_{\odot}$

$0.39 \leq M_{\text{star}} \leq 1.5 \times 10^{11} \, M_{\odot}$

$2.5 \leq R_{\text{star}} \leq 17.5 \, \text{kpc}$
Quantifying morphology: \( j_z / j_{circ} \)

- Define: \( f_{\star \text{disk}} = \) fraction of stellar mass with \( j_z / j_{circ} > 0.5 \)
- \( m_{12f} = 0.6 \)

\[ \text{normalized mass} \]

\[ \text{circularity} = j_z / j_{circ}(E) \]

Average age of U when stars in bin formed [Gyr]

Dispersion supported

Anti-rotating

Co-rotating
Sample includes $0.2 \leq f_{\text{disk}}^* \leq 0.8$

Bulge components (almost) uniformly older than disks, consistent with previous results: disks form at late times.
**Define:**  $R^* = 2\text{D radius that contains 90\% of } M_{\text{star}}$
Comparing morphology measures

Kinematic ($f_{\ast}^{\text{disk}}$) and spatial ($R_{\ast}$) correlated, but lots of scatter

=> Study both kinematic morphology and spatial extent
Disks form out of spinning gas

Morphology correlated with gas spin when the galaxy was forming stars.
Growth of the galaxy and its halo

Evolutionary histories

Every galaxy has a story
Every galaxy has a story: Batman

Double merger funnels gas to center at $z \sim 2$ to form bulge; no late-time gas accretion
Every galaxy has a story: Romeo

No direct galaxy mergers after $z \sim 4$
Smooth accretion to $z = 0$
Every galaxy has a story

Sharp, early spikes in the amount of gas in the galaxy disappear as galaxies become disk-dominated.
Morphology scales with $M_{\text{gas}}(z)$

Gas accreted at late times typically has higher angular momentum and forms a disk.
The evolution of stellar morphologies
Differential fraction of stars forming in a disk

Cumulative fraction of stars that have formed in a disk

Instantaneous disk fraction
Galaxies nearly always become more disky with time ($R^*$ also increasing). Nearly all stars forming at late times in MW-mass galaxies form in disks. 60-90% of stars are born in disks overall, even in bulge-dominated systems. Galaxies nearly always become more disky with time ($R^*$ also increasing).

Mergers scramble/destroy disks at early times, but can help build disks if they occur at late times (when they tend to have more $J$).
Summary

• Fifteen MW-mass galaxies on FIRE vary from bulge-dominated to roughly pure disk (defined kinematically)

• Gas spin at high redshift is a good indicator of morphology

• Head-on mergers funnel gas to the center, where it forms massive bulges; galaxies with smoother accretion histories (no direct galaxy mergers; maximize their reservoir of star forming gas at late times) tend to be disk-dominated

• Average amount of cold gas in the halo (i.e., fuel for SF) after $z=1$ well-correlated with morphology

• $\approx 60\%$ of MW stars (+nearly all born at $z\approx 1$) formed in disks (though not necessarily the disk that exists today), consistent with a picture where stars forming primarily from rotation-supported gas, as is the case at $z=0$ in all galaxies
Preview: ELVIS on FIRE

$z \sim 0.2$ (now at $z < 0.1$)

$M_{\text{gas}} \sim 3500 \, M_{\odot}$

(will be) The highest resolution cosmological hydrodynamic simulation of a MW-mass galaxy ever completed
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[the above statement is a lie]