Zooming in on a Simulated Milky Way-Sagittarius Analog Collision

Benjamin Snyder, Department of Physics and Astronomy
Mentor: Dr. Coral Wheeler
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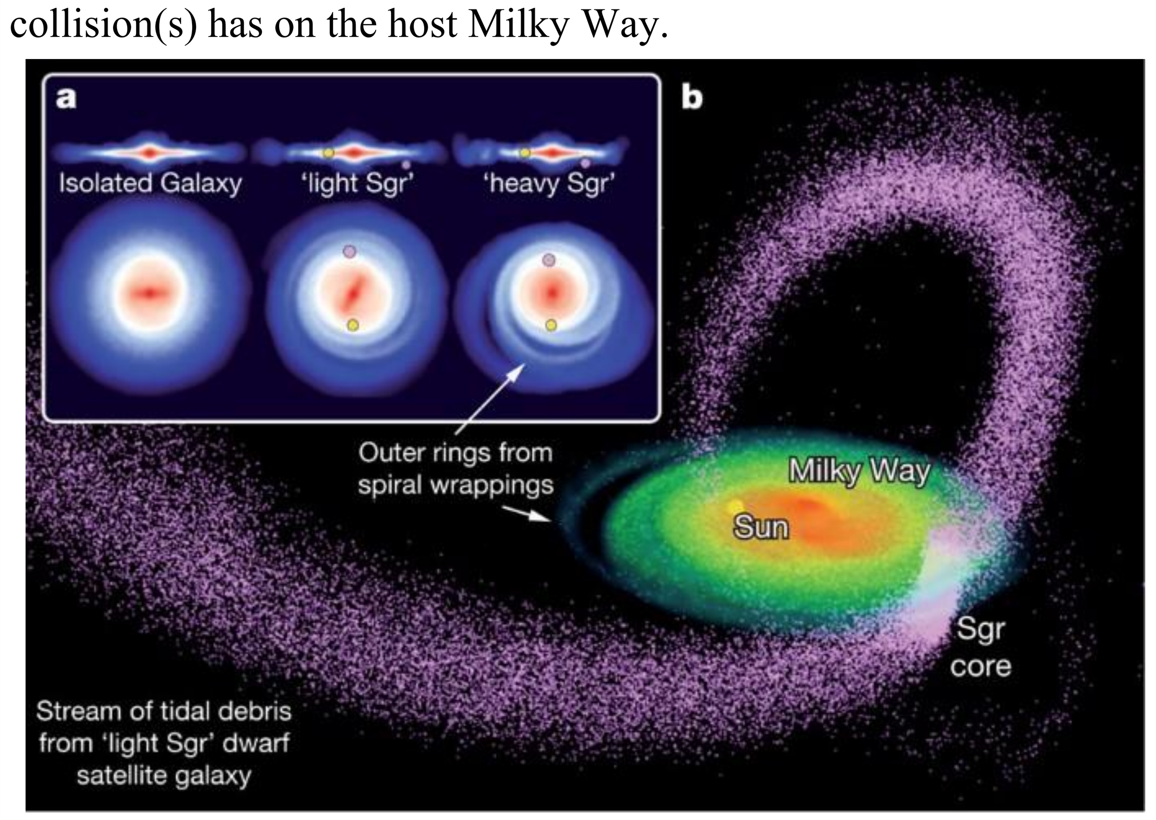
Motivation:

Dwarf galaxies – low-mass galaxies distinct from star clusters by the presence of a dark matter halo – are some of the most intriguing objects in our universe. Interactions between larger host galaxies such as our Milky Way and their dwarf galaxy satellites are thought to play a key role in the evolution of the satellites – affecting everything from stellar structure to star formation. Hydrodynamic cosmological simulations are the perfect playgrounds to develop and test models for these interactions. Most cosmological Milky Way-dwarf collision simulations, however, focus on the effect the collision(s) has on the host Milky Way.



The Milky Way's morphology is dependent on interactions with Dwarf galaxies like Sagittarius (Sgr) (Purcell et. al. 2011)

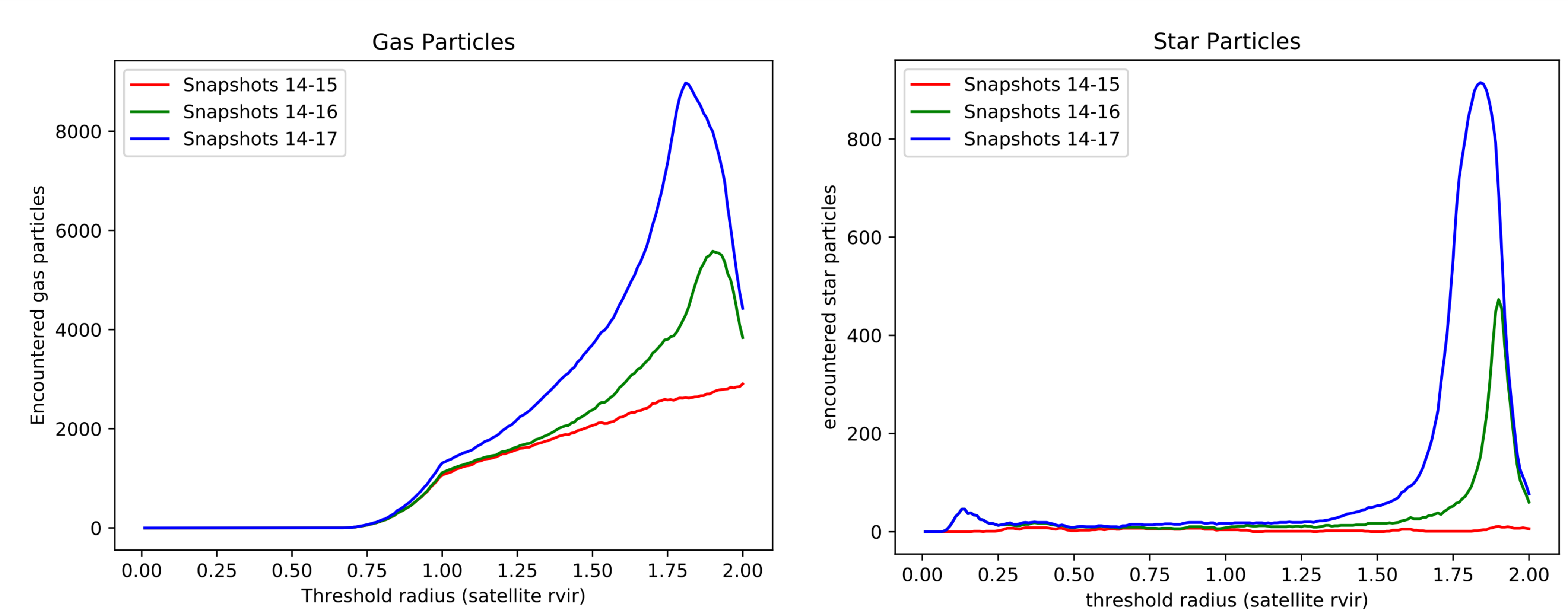
While studying the effects these collisions have on the host is a worthwhile pursuit, understanding the effects on the dwarf itself in these mergers will help us better understand the nature of these smaller, dark matter dominated galaxies. For example:

1. What happens to any satellites of the dwarf? Do they survive the merger? This may help explain the overabundance of Milky Way satellites compared to observations (Missing Satellites Problem)
2. Does the ratio of the dwarf's circular velocity to its velocity dispersion change? Shocks from the interaction could cause the galaxy to become more dispersion-supported (lower ratio)
3. Does the dwarf retain its gas? Ram-pressure stripping could cause gas to be lost, shutting down star formation.

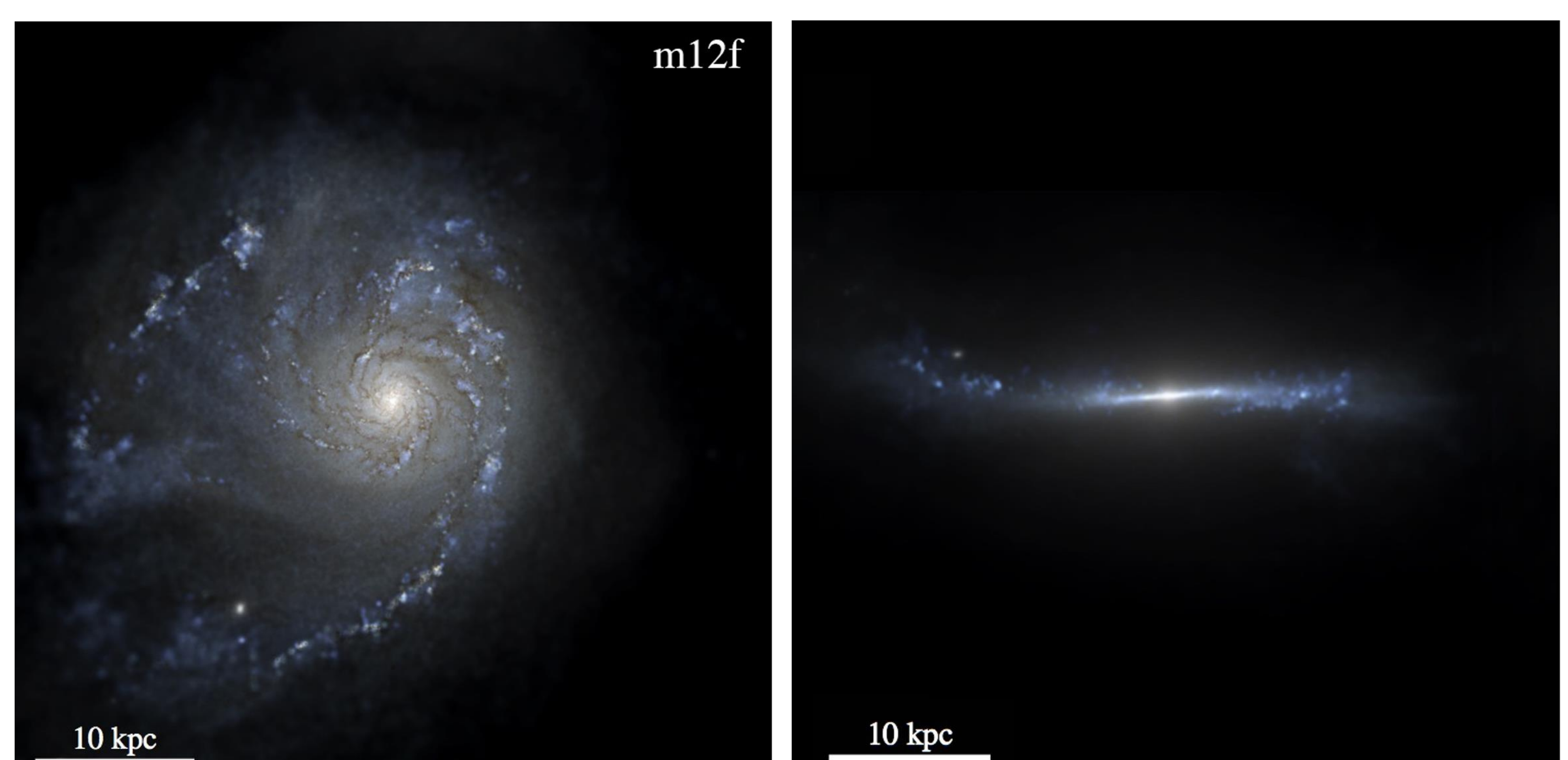
These simulated collisions have either been too low in resolution to study the dwarf in much detail, or idealized as opposed to cosmological in nature. By performing particle splitting on a FIRE (Feedback in Realistic Environments) cosmological zoom-in simulation of a Milky Way-Sagittarius analog collision, we can make predictions for what effects mergers like these have on the satellite dwarf galaxy.

Project Description:

The goal of this project is to determine whether or not it is computationally feasible to use particle-splitting to achieve high resolution locally at the collision site. In order to achieve this, we need to determine how many star, gas, and dark matter particles from the Milky Way analog interact with the dwarf and will need to be split. First, I use the m10r dwarf-dwarf simulated collision ($250M_{\odot}$ resolution) to develop a particle-counting algorithm that I can use on the Milky-Way dwarf simulation. This algorithm takes in the simulation snapshots over which the merger takes place. It works by tagging each particle that lies within a certain distance of the satellite galaxy's center (the relevant distance will change based on the type of particle we're considering). For each subsequent snapshot, it counts any particles that move within the threshold radius. Then, I will use this algorithm on the m12f Milky Way-Sgr analog collision simulation.



Encountered gas (left) and star (right) particles for 200 threshold radii over four snapshots for the m10r dwarf-dwarf merger test simulation. Particles initially within the threshold radius are not counted.



The m12f Milky Way analog face-on (left) and edge-on (right) (Hopkins et. al. 2018). $M_{halo} = 1.6 \times 10^{12} M_{\odot}$. Mass resolution: 7100 $M_{\odot}$.

Initial Results:

After running the counting algorithm over 12 snapshots for the m12f simulated merger, we find that the following numbers of particles come within one Sgr virial radius of the dwarf:

- Star Particles: 17,087
- Gas Particles: 91,256
- Dark Matter Particles: 553,322

The ratio of gas to star particles is much less than what we observe in the m10r merger with a threshold radius of one satellite viral radius.

Next Steps:

The next step for this project will be running this algorithm at multiple threshold radii, and producing plots much like the ones on this poster for the Milky Way-Sgr analog. Based on these results, we will determine if it is computationally feasible to use particle-splitting to achieve high resolution locally at the collision site, and if so, what resolution we can achieve. We will determine the appropriate simulation parameters, and I will learn how to run the simulation myself.

Potential avenues for further investigation include:

1. Splitting the particles to different resolutions based how close they come to the satellite, resulting in a gradient of resolutions Computing resources would be used to provide the most resolution where we care about it the most
2. Investigation of the three scientific inquiries described in the Motivation section. Comparing what we see at different resolutions is a good way to tell what properties are affected the most by resolution.

References:

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