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DARK MATTER HALOS IN GALAXY MERGERS

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Abstract. In this paper, we investigated the influence of dark matter in galactic halos on the dynamics of galaxies in merger events, using N-body simulations. In the standard cosmological picture, large massive galaxies are formed by mergers of smaller ones. These mergers are very important for galactic dynamics and evolution. The largest portion of the galactic mass is the dark matter halo. Dark matter has a very important role due to dynamical friction and the formation of observed substructures. Here we investigated how properties of spherical dark matter halos and merger circumstances influence the formation of these morphological structures.

1. INTRODUCTION

Galaxies are building blocks of the Universe. On large scales, we can observe the distribution of galaxies and calculate some cosmological parameters. In the local universe, we can investigate the properties of particular galaxies. In the bottom-up hierarchical model of galaxy formation, large galaxies are formed in mergers of smaller ones. In these mergers, many parameters are important: the mass of the galaxies, their rotation, gas content, and the timescale of the merger event. One of the most important parts of the galaxies is their dark matter halo. The largest portion of the mass of the galaxy is in the dark matter halo and for that reason, a halo is important for galactic dynamics and the formation of the structures in merger events.

There are several morphological types of galaxies. Hubble made the classification known as Hubble's diagram, or Hubble's tuning fork (Fig. 1).

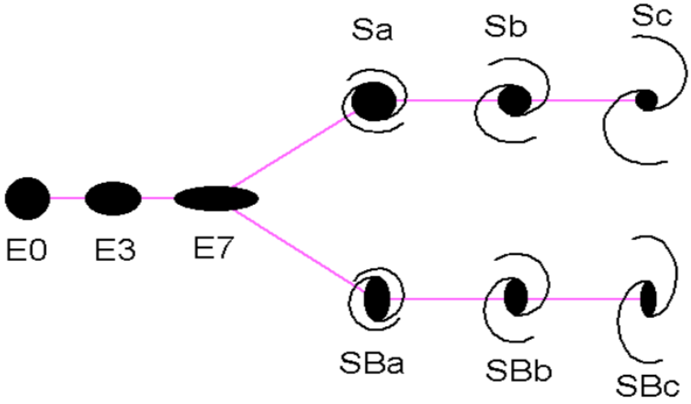

Figure 1: Hubble's "tuning fork" diagram.
(credit: The Ohio State University)

The main morphological types are elliptical galaxies, spiral and irregular galaxies. Elliptical galaxies have several types depending on the observing angle, their ellipticity changes with that angle. Spiral galaxies have disks and they are rotational systems. The velocity of rotation is larger than the velocity dispersion and we have an opposite situation with ellipticals. The large values of the rotational velocity or the flattening of the rotation curves are due to the present of the dark matter halo. Also, we have more gas in spirals then in ellipticals, and younger stars as a consequence. Irregular galaxies are mostly galaxies in interaction and they are tidally disrupted.

In this paper, we are interested in mergers of spiral galaxies and dwarf galaxies. Dwarf galaxies also could be spirals, ellipticals, and spheroidals. These mergers are forming structures in the halos of the spiral galaxies (Amorisco et al. 2013; Atkinson et al. 2015; Karademir et al. 2019) which we call the host and dwarf galaxy we will call progenitor. Examples of these mergers in the Local Group and structures formed in these dynamical processes are the Magellanic Stream in the halo of the Milky Way (Wannier, P., & Wrixon 1972) and Giant Stellar Stream (GSS) in the halo of the Andromeda galaxy. The discovery of the GSS is presented by Ibata et al. 2001. Many theoretical papers investigated the properties of these stellar streams, then shells and other structures, and these papers are based on N-body simulation.

The main influence of dark matter is the stability of the spiral galaxy, dynamical friction, and timescale of forming structures in mergers. In this paper, we present the main result of the N-body simulations of the merger event between the large spiral galaxy and dwarf elliptical galaxy (dSph) and investigate the role of the dark matter halo of the host in the merger event and galaxy dynamics. In Section 2 models of spiral and dwarf galaxies are presented; in Section 3 we present the main results, and in Section 4 we make a brief discussion and conclusions.

2. METHODS

We assume three components for the N-body model of the spiral galaxy: bulge, disk, and dark matter halo. For the model of the spherical bulge we took a density profile that is described with equation (Font et al. 2006; Fardal et al. 2007; Sadoun et al. 2014; Milošević et al. 2022):

$$\rho_b = \rho_0 (r / r_b) \exp(r / r_b)^{(-1/n)}.$$

The central density is ρ_0, and r_b is the bulge scale length. The density profile of the disk is modeled as two components profile. The exponential is in the radial direction:

$$\Sigma(R) = (M_d / 2\pi R_d^2) \exp(-R / R_d).$$

Here, M_d is the mass of the disk and R_d is the disk scale length in the radial direction. When we add the density profile in the z-direction which is sech^2, the density profile of the disk is given with:

$$\rho(R, z) = (\Sigma(R) / 2 z_0)\, sech^2(z / z_0),$$

where z_0 is the scale height of the disk. Dark matter halo is presented with Navarro-Frenk-White (NFW) profile (Navarro et al. 1996):

$$\rho_h(r) = \frac{\rho_0}{r / r_h (1 + r / r_h)^2},$$

where r_h is the scale radius of the dark matter halo. Values of the parameters are given in previous works cited above. The N-body model of the dwarf galaxy contains a spherical bulge and spherical dark matter halo presented with the same equations as for the spiral galaxy, but with different values of the parameters. To generate N-body models we used GalactICs package (Widrow, et al. 2008).

We run a large number of N-body simulations to find the influence of the orbits orientation on structure formation in the halo of the host and how,the dark matter halo influences the timescale of the merger event. Dark matter in the galaxy is very important for the dynamics, and the N-body representation of the halo is very important for calculating dynamical friction. For running simulations, we used Gadget2 cosmological code (Springel 2005).

3. RESULTS

In a galaxy merger between a large spiral host and a dSph galaxy, structures are formed in the halo of the host due to tidally disruption. In the first stage, the dark matter halo of the dSph galaxy starts to disrupt and baryonic particles are still bounded. These situations are presented in Fig. 3 and Fig. 4.

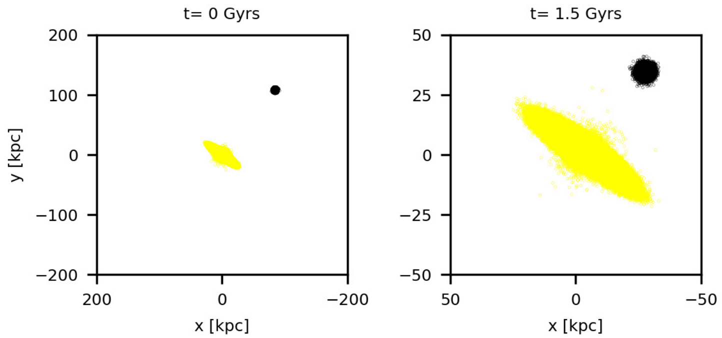

Figure 2: The baryonic matter particles of the dwarf galaxy are in black and the spiral galaxy is in yellow at the beginning of the simulation (left panel) and after 1.5 Gyrs (right panel). The baryonic part of the dSph galaxy isn't yet tidally disrupted.

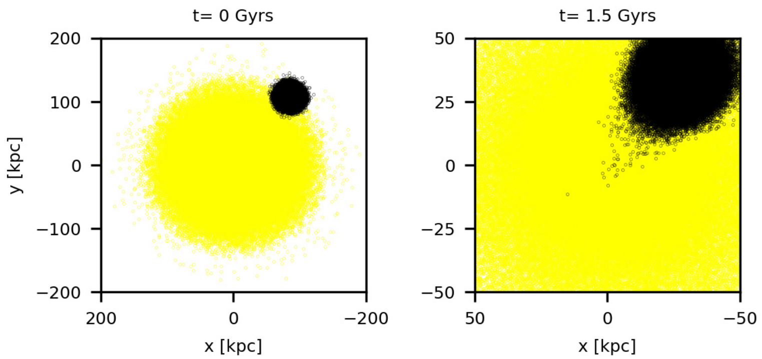

Figure 3: The dark matter halo particles of the dwarf galaxy are in black and the halo of the spiral galaxy is in yellow at the beginning of the simulation (left panel) and after 1.5 Gyrs (right panel). The dark matter halo of the dwarf is "pilling off" in the potential of the host.

Without the dark matter halo, the timescale would be different and the baryonic part of the dwarf would make structures in the halo of the host much earlier. Some of the formed structures are presented in Fig. 4:

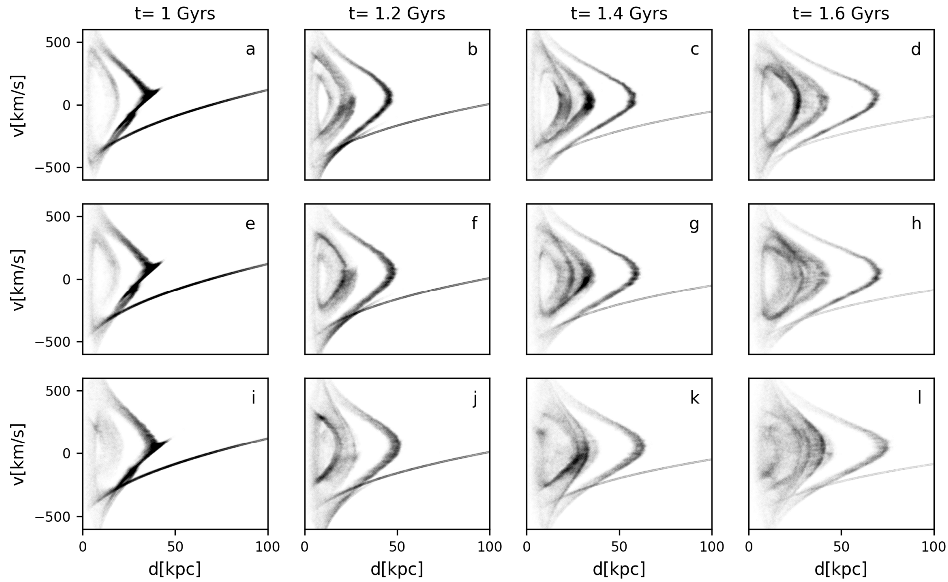

Figure 4: Structures in the halo of the host formed in a merger event, where progenitor is dSph for different infalls. We can see shells and stream, for the presented timescale which is between 1 and 1.6 Gyrs. This timescale of the formation of these shells and streams depends on the content of the dark matter. This graph is made as a continuation of research presented in Milošević 2022.

In Fig. 4 we can see formed structures in the halo of the host, from different infall angles of the dSph progenitor. These panels represent the baryonic matter of the dwarf in space d-v, where d is the distance from the center of the host, and v is radial velocity. In each simulation, we can see formed at least two stellar shells and one stellar stream. The properties of these structures are very dependent on the properties of the dwarf and the dark matter in the halo of the dwarf.

4. DISCUSSION AND CONCLUSIONS

We used pure N-body simulation to describe the dynamical history of galaxies. In particular, we were interested in the merger between a large spiral galaxy and its satellite, a dwarf spheroidal galaxy.

In merger events dark matter halo plays important role in the determination of the orbit of the dwarf in the potential of the host and the timescale of structure formation in the halo of the host.

Due to dynamical friction, the baryonic matter of the dwarf later starts to disrupt, because of the disruption of the halo of the dwarf.

Determination of the orbits of galaxies unlocks the possibility to determine the masses of the galaxies and makes constraints on the masses of the halos of both galaxies. In merger events, we found that stellar shells and streams are formed, and that is in agreement with previous works. In future work, it would be important to investigate gas dynamics in the mergers due to the important role that gas has in galaxy evolution.

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