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DISRUPTION OF DWARF SATELLITE GALAXIES WITHOUT DARK MATTER

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RESUMEN

La evolución de galaxias satélite de la Vía Láctea es estudiada mediante simulaciones numéricas de N-cuerpos. Los satélites iniciales, que contienen 10^6 partículas fueron modelados mediante esferas de Plummer, mientras que el potencial de la galaxia nodriza corresponde a un potencial rígido de tres componentes: disco, esferoide y halo de materia oscura. Se encontró que un conjunto de órbitas del satélite permite la existencia por más de 10^9 años de remanentes fuera del equilibrio que podrían ser interpretados como galaxias dSph de la Vía Láctea. Adicionalmente, mediante el estudio de la evolución de la razón masa luminosidad de los satélites se encontró que es posible que algunas galaxias dSph de la Vía Láctea con razones M/L altas pudiesen no estar dominadas por materia oscura y que dichos valores altos se deban a que se trata de objetos fuera del equilibrio.

ABSTRACT

The evolution of a satellite galaxy of a Milky Way like galaxy has been studied using N-Body simulations. The initial satellites, containing 10^6 particles, have been simulated by a Plummer sphere, while the potential of the host galaxy is a three component rigid potential: disc, bulge and dark matter halo. It has been found that several orbits of the satellites allow for the existence, for about 1 Gyr or more, of an out-of-equilibrium body that could be interpreted as a dSph satellite galaxy of the Milky Way. In addition, from the study of the evolution of the mass-to-light ratios of satellites that show a disrupted phase it has been found that it is possible that some dSph galaxies of the Milky Way with large M/L ratios might not be dark matter dominated and that their high mass to light ratios are observed because they are out of equilibrium objects.

Key Words: galaxies: dwarf — galaxies: evolution — galaxies: formation — galaxies: interactions

1. INTRODUCTION

Dwarf spheroidal galaxies (dSph) are stellar ellipsoidal, gas poor and with low surface brightness systems. For some dSph satellites mass-to-light (M/L) ratios as large as a few hundred are inferred. A M/L ratio larger than 10 is usually associated with a dark matter dominated system. Nevertheless, an alternative possibility to explain large M/L ratios relying on Newtonian physics, is that some of the observed dSph satellites may not be in virial equilibrium. That such systems may exist is shown by the simulations of the long-term evolution of initially spherical satellite galaxies with 3×10^5 particles and typical masses of 10^7 $M_\odot$ (Kroupa 1997).

In this paper we present the evolution of a couple of initially in equilibrium spherical satellites with 10^6 particles orbiting a galaxy that resembles the Milky Way.

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2. N-BODY SIMULATIONS

The evolution of the satellites orbiting the Milky Way has been simulated using the tree-code feature of the Gadget-2 N-body code (Springel 2005). Each simulation has been run for 12 Gyr and the evolution of some quantities of the satellites like their Lagrange radii, number of bound particles, central surface brightness, half light radius and the M/L ratio have been studied. The last three quantities have been obtained projecting the remnant object as it would appear to an observer on earth.

The host galaxy has been modeled using a three component rigid potential: a Miyamoto-Nagai potential for the disk, a Hernquist potential for the bulge and a logarithmic potential for the dark matter halo. The parameters of the model are the ones appearing in Johnston et al. (1995).

The initial satellites are modeled as Plummer spheres with 10^6 particles, plummer radius of 0.3 kpc and cuttof radius of 1.5 kpc. Their initial masses are 10^7 and 10^8 $M_\odot$ respectively, and intrinsically dark matter free. For the construction of the spheres the algorithm proposed by Aarseth et al. (1974) has been used.

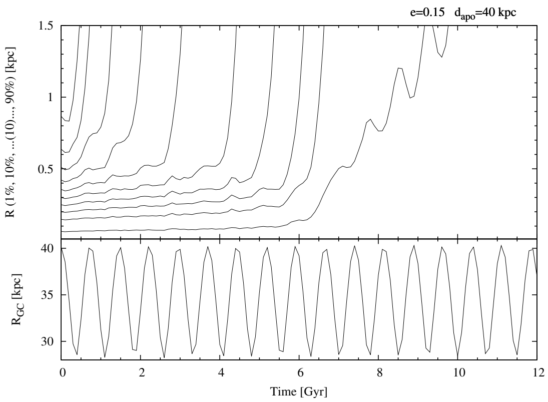

Fig. 1. Lagrange radii containing (bottom to top) 1%, 10%, 20%,..., 90% of the initial mass of a satellite with 10^7 $M_\odot$. Bottom panel: galactocentric distance of the density maximum. The parameters of the orbit are given in the upper right corner.

3. SATELLITE EVOLUTION

Satellites in very eccentric orbits are completely depopulated in a very short time interval, usually in a single perigalactic passage. On the other hand, satellites on orbits with very low eccentricity can retain more than 90% of their initial mass over a Hubble time. These kind of orbits lead to an object that does not reach an out-of-equibrium state. The intermediate case corresponds to satellites that loose more than 90% of their initial mass but retain more than 1% of the mass for about 1 Gyr or more (see Figure 1). These satellites present an out-of-equilibrium phase and are the objects we are more interested in.

4. MASS-TO-LIGHT RATIOS

In Figure 2 we plot the evolution of the M/L ratio for two out-of-equilibrium satellites obtained using the core fitting formula (Richstone & Tremaine 1986, and references therein). The M/L ratio remains relatively constant as the satellite is being smoothly depopulated. After the satellite enters the disrupted phase the M/L ratio rises considerably, reaching values of hundred and more. The values of the M/L ratios of the satellites during the disrupted phase show large oscillations. Thus, depending on the time of observation a satellite might show very different values of the M/L ratio. Values much larger than the intrinsic M/L ratio of the satellites can only be obtained during the disrupted phase.

5. CONCLUDING REMARKS

It is possible to obtain disrupted remnants of initially spherical bound objects, that survive as out-of-equilibrium systems for times longer than 1 Gyr,

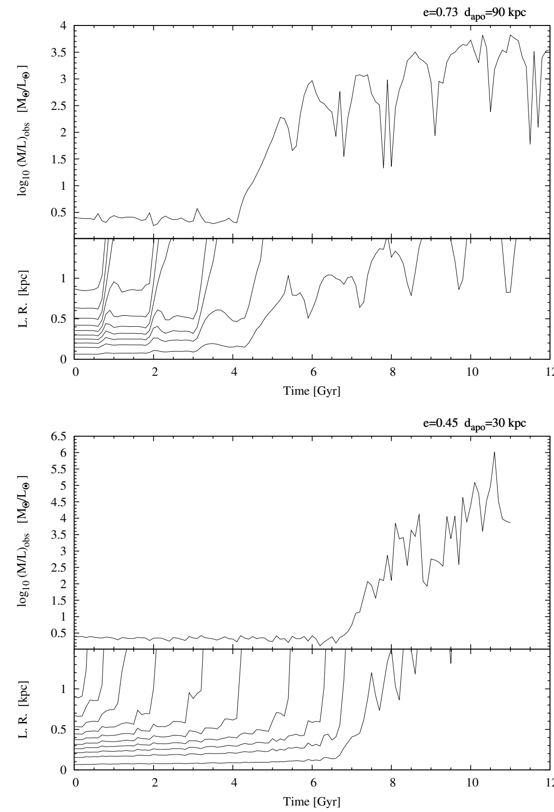

Fig. 2. Mass-to-light ratios for satellites with initial mass of 10^7 $M_\odot$ (top) and 10^8 $M_\odot$ (bottom). For both satellites the Lagrange radii, as in Figure 1, have been included to locate start of disrupted phase.

confirming and extending the results from Kroupa (1997). The disrupted satellites show a high M/L ratio, similar to that of some dSph galaxies. Those remnants are candidates to be interpreted by an observer on earth as dSph-like galaxies. Hence, it is possible that some dSph galaxies of the Milky Way with large M/L ratios might not be dark matter dominated and that their high M/L ratios are observed because they are out of equilibrium systems.

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