Boletim da Sociedade Astronômica Brasileira, **31**, no. 1, 141-142

Effects of supernovae in the central region of dwarf spheroidal galaxies

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Abstract. The total absence of gas is a distinct feature of all the Local Group Dwarf Spheroidal Galaxies (dSph). How this gas was consumed, however, it is still a matter of debate. External physical processes such as ram pressure or tidal stripping could remove a fraction of the gas from the dSphs. On the other hand, galactic winds triggered by supernova explosions can eject material from the interstellar medium of the galaxy. In this work, the effects of supernovae explosions on the dynamics of the gaseous content of a classical Dwarf Spheroidal Galaxy is investigated by means of a 3D hydrodynamic simulation code. Adopting a ratio of baryonic matter-dark matter derived from cosmic background radiation and a static and cored dark matter potential, the gas distribution in the central region of the galaxy (up to 300 pc) is allowed to evolve over 300 million years. The explosion of a single, 10, 100 or 1000 supernovae located at the center of the galaxy at time $t = 0$ yr were considered, and their effects on the gas dynamics were studied.

Resumo. A ausência total de gás é uma característica distinta de todas as galáxias esferoidais anãs do grupo local (dSph). Como este gás foi consumido, no entanto, ainda não se sabe. Processos físicos externos como a pressão de arrasto ou a força das marés poderiam remover uma fração do gás das dSphs. Por outro lado, ventos galácticos desencadeados por explosões de supernovas podem ejetar material do meio interestelar da galáxia. Neste trabalho, os efeitos das explosões de supernovas sobre a dinâmica do conteúdo gasoso de uma galáxia esferoidal anã clássica são investigados por meio de um código tridimensional de simulação hidrodinâmica. Adotando uma razão entre matéria escura e matéria bariônica derivada da radiação cósmica de fundo e um potencial de matéria escura estático e nucleado, a distribuição de gás na região central da galáxia (até 300 pc) é evoluída ao longo de 300 milhões de anos. A explosão de uma única, 10, 100 ou 1000 supernovas localizadas no centro da galáxia no tempo $t = 0$ anos foram consideradas, e seus efeitos na dinâmica do gás foram estudados.

Keywords. Galaxies: dwarf – Galaxies: evolution – Hydrodynamics

1. Introduction

Soon after the discovery of the first dSphs galaxies (Shapley 1938, Wilson 1955), astrophysicists believed they were simple systems, very similar to globular clusters, with a single stellar population and without complex structures. As information about these systems increased, the scenario changed dramatically. It is now known that these galaxies, although structurally simple, are characterized by complex star formations, different stellar populations, chemical enrichment not yet fully explained, and exhibit a large amount of dark matter (Tolstoy, Hill & Tosi 2009). All of them share a common property still unexplained: the total absence of detectable neutral gas (Grcevich & Putman 2009). One fundamental question in the studies of the evolutionary process of the dSph is what type of mechanism is responsible for the removal of the gaseous content of this type of galaxy.

The chemical properties observed in these galaxies indicate that a low efficiency of star formation and the occurrence of intense galactic winds are necessary to explain its evolution (Lanfranchi & Matteucci 2003, 2004, 2010). Several theoretical studies suggest that these winds, triggered by SNe, are not able to completely remove the gas from the dSph medium, and this is only possible for systems with masses up to $\sim 10^5 - 10^6$ $M_\odot$ (Fragile et al. 2003). However, these conclusions strongly depend on the history of star formation adopted (Ruiz et al. 2013): an intense stellar formation with high supernovae (SNe) explosion rate can give rise to an efficient galactic wind, whereas a low SNe rate is not sufficient for the removal of the interstellar gas from the galaxy.

In this work we: investigate the interaction between the energy released by one SNe with the ISM of a dSph galaxy; study the effects of several SNe exploding simultaneously in the central region of the dSph galaxy; analyze the hydrodynamic evolution of the galactic gas in those conditions; evaluate the possible occurrence of galactic winds in different scenarios for the SNe explosions.

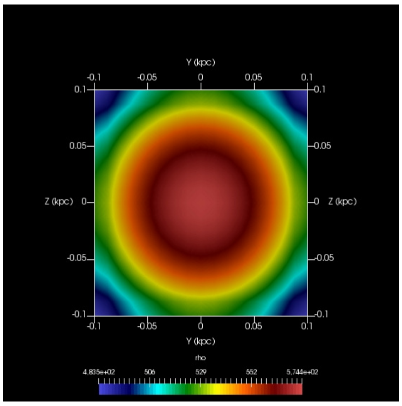

Figure 1. Cut in the yz plane in $t = 0$ yr, for the density profile.

2. Results

The analyses of the interaction between the energy released by SNe with the ISM of a dSph galaxy is performed by means of a 3D hydrodynamic code already fitted to the Ursa Minor dSph galaxy (Caproni et al. 2015, 2017). Two different scenarios were adopted: one with the explosion of 10 SNe in the central point of the galaxy at $t = 0$ yrs and another one with the explosion of 1000 SNe in the central point. The dynamics of the gas in the central region (up to 300 pc) of the galaxy was simulated for 300 Myr, using a computational cube divided in 120^3 cells.

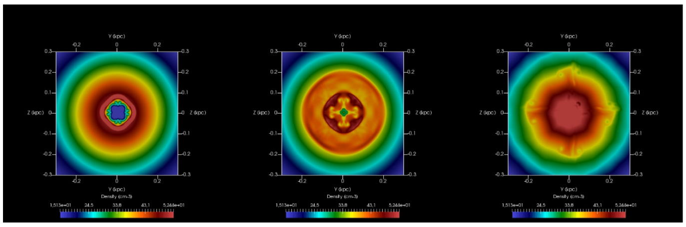

Figure 2. Cut in the yz plane for the density of the gas at t = 2 Myr (left), 10 Myr (center), and 200 Myr (right).

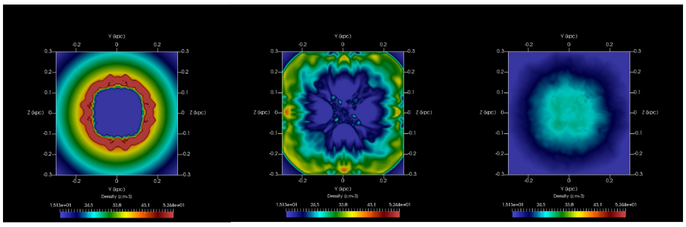

Figure 3. Cut in the yz plane for the density of the gas at t = 2 Myr (left), 10 Myr (center), and 200 Myr (right)

Initially (t = 0 yr), the interstellar gas is in hydrostatic equilibrium with the gravitational potential. The density, pressure and temperature distribution profiles of the gas are all homogeneous at the beginning of the simulation (Figure 1). Starting from this point, the energy of the SNe (10^{51} erg per SN) is injected in the central cell of the cube.

2.1. 10 Supernovae

When the energy of 10 SNe is injected in the central point at t = 0 yr, almost instantaneously a shock wave is created (left panel Figure 2). The shock wave propagates spherically toward outer regions. At the same time is formed a thin region of high pressure and high temperature that follows the shock wave. This pushes initially a fraction of the gas (> 20%) outward to external regions. However, after a few hundreds Myr, the gas falls back and the density in the central region increases again (right panel Figure 2).

2.2. 1000 Supernovae

The situation changes drastically when the energy of 1000 SNe is injected in the central cell at t = 0 yr. The effect seen in previous case is amplified by the higher number of SNe: the shock wave is more intense (left panel — Figure 3), the velocity gained by the gas is higher, and a region with a higher pressure is created. The shock wave carries away all the gas to external regions instantaneously. However, at the end of the simulation, almost 45% of the initial mass returns to the 300 pc volume (right panel — Figure 3).

2.3. Mass fraction

The mass fraction as a function of time inside two volumes (100 pc and 300 pc) is estimated in both cases. In the case of 10 SNe, in the 100 pc region, the mass fraction drops fast below 80 % but increases again soon, and remains varying between 90 and 100%, whereas in the 300 pc volume, it is almost constant, with no change (Figure 4 — left). For 1000 SNe the mass fraction drops fast to 0% in the 100 pc volume, but increases again, remaining varying between 50 and 60%. In the 300 pc region it

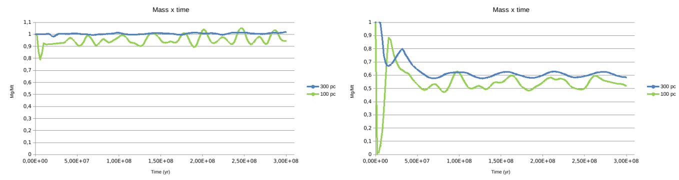

Figure 4. Mass fraction vs. time in the case of 10 SNe (left) and 1000 SNe (right).

decreases to 60% during the first 100 Myr, and then remains constant (Figure 4 — right).

3. Conclusion

Different SNe configurations affect the ISM of a dSph galaxy in different manners: the higher the energy inserted in the interstellar medium the faster the gas moves and the higher the amount of gas that is pushed outward to external regions of the galaxy. When 10 SNe are considered, a small fraction of the gas (~ 10 %) is blown away from the central region at the beginning of the simulation, but almost all gas (~ 90 %) returns at the end of 300 Myr. When the energy of 1000 supernovae is injected into the central region of the galaxy at t = 0 yr, virtually all gas is initially removed from the central region and almost 45% returns at the end of the simulation.

Acknowledgements. This work has made use of the Sistema de Computação Petaflópica do SINAPAD - Laboratório Nacional de Computação Científica (LNCC). The authors thank the Brazilian agency CNPq (grant 304928/2015-1) and FAPESP (grants 2014/11156-4, 2017/25651-5 and 2017/25799-2).

References

Caproni A., Lanfranchi G. A., da Silva A. Luiz, Falceta-Gonçalves D., 2015, ApJ, 805, 109
Caproni A., Lanfranchi G. A., Baião G. H. C., Kowal G., Falceta-Gonçalves D., 2017, ApJ,
Fragile, P. C., Murray, S. D., Anninos, P., Lin, D. N. C., 2003, ApJ, 590, 778
Grcevich J., & Putman M. E., 2009, ApJ, 696, 385
Lanfranchi G. & Matteucci F., 2003, MNRAS, 345, 71
Lanfranchi G. & Matteucci F., 2004, MNRAS, 351, 1338
Lanfranchi G. & Matteucci F., 2010, A&A, 512, A85
Ruiz, L.O., Falceta-Gonçalves, D.A., Lanfranchi, G.A., Caproni A. 2013, MNRAS, 429, 1437
Shapley, H.. 1938, "Two Stellar Systems of a New Kind". Nature, 142, 715
Tolstoy, E., Hill, V., Tosi, M., 2009, ARA&A, 47, 371
Wilson, A. G.. 1955, PASP, 67, 27