Magellanic-type dwarfs: SPH simulations of stripping, streams, and star formation

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Introduction

Dwarf galaxies (DGs) provide an ideal environment to study interactions in their most extreme form, and to model them at high resolution.

The Magellanic Clouds (MCs) provide a fascinating case study. They show clear evidence of interactions, with distorted morphologies and bar structures, and the large and massive Magellanic Stream (MS) stretching tens of degrees across the sky. However, there is no universal consensus whether these interactions are dominated by interactions between the MCs, or with the MW, and whether by ram-pressure or tidal effects (Hammer et al. 2015, Salem et al. 2015).

Method

We perform a series of smoothed particle hydrodynamics (SPH) simulations using the SPH+N-body chemodynamics code GCD+ (Kawata et al. 2014 and references therein). We model a MW-like halo with an analytic potential and a moving box of gas halo particles. We use idealised initial conditions for our two DGs, with properties in-between those of the Large and Small Magellanic Clouds, with a baryonic mass of 5×10^8 M$_\odot$ and an initial gas fraction of 50%.

In previous work (Williamson et al. 2019) we performed simulations of single DG in a MW-like halo, and found that ram-pressure stripping was not effective (except in extremely plunging orbits), and that thermal pressure *confinement* was a stronger effect, as shown in Fig 1 (see also Du et al. 2019).

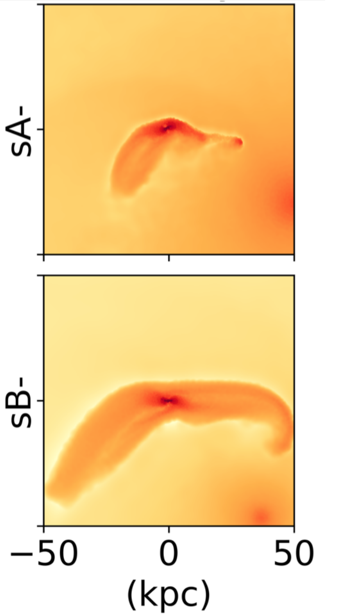

Fig 1: Gas distribution in single DG models. Top: massive host halo. Bottom: less massive host halo

Results

With the dual DG model, we still find that MW ram pressure is weak. Using a variety of orbital configurations (Fig 2), we find that star formation and feedback are the dominant effects. The tidal interactions between the DGs do distort each others morphologies (Fig 3), but also induce starbursts. The starbursts produce outflows that reduce the effective metal yield (Fig 2). These outflows are then shaped by MW tidal effects to produce an MS-like structure. At certain snapshots of some simulations, this can yield a very similar configuration to the observed MCs, with an MS consisting of tails intertwined from both dwarfs, with a mass comparable to the mass of the gas mass of the DGs, and with bar and spiral structure appear in one or both of the DGs (Fig 3).

Conclusion

We find that most of the properties of the MC system can be modelled as a pair of star-forming dwarfs with strong outflows that are shaped by Milky Way tidal forces. Ram pressure does not have a strong effect. Interactions between the clouds also distort their morphologies..

Fig 2 (right): Summary of double DG runs. From top to bottom: projected orbits, distance between DGs, combined star formation rate, warm/cool (T<20,000 K) gas and star masses within DGs (<10 kpc) and outside, effective yield ("new" metals in DGs divided by cumulative star formation mass)

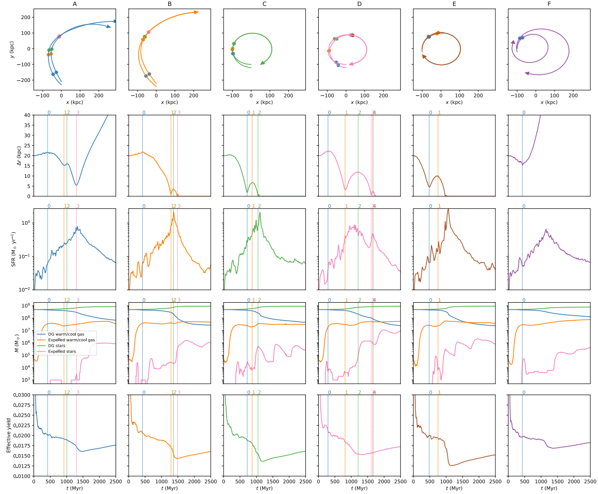

Fig 3 (below): A snapshot of run D. Left two columns: projections of gas mass. Right two columns: projections of stellar mass. Top two rows: zooms on each DG. Bottom row: large scale view of full system.