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Simulations on the survivability of Tidal Dwarf Galaxies

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Abstract. We present detailed numerical simulations of the evolution of Tidal Dwarf Galaxies (TDGs) after they kinematically decouple from the rest of the tidal arm to investigate their survivability. Both the short-term (500 Myr) response of TDGs to the stellar feedback of different underlying stellar populations as well as the long-term evolution that is dominated by a time dependent tidal field is examined. All simulated TDGs survive until the end of the simulation time of up to 3 Gyr, despite their lack of a stabilising dark matter component.

Keywords. galaxies: dwarf - galaxies: evolution - galaxies: formation

1. Introduction

The formation of TDGs, as actively star-forming gaseous over-densities embedded in the tidal arms of interacting galaxies, is studied with observations in various wavelengths and their formation is modelled within large-scale simulations of galaxy interactions (see Duc & Renaud 2013, for a review). Whereas they are easily identifiable when they are still connected to the tidal arm, their typical lifetimes remain under discussion. The contribution of ancient TDGs to the population of low-mass galaxies depends on both their formation rate as well as on their survivability. The estimates of dwarf galaxies (DGs) with a tidal origin cover a wide range from 6% (Kaviraj *et al.* 2012) to 100% (Okazaki & Taniguchi 2000). Long-term chemo-dynamical simulations of TDGs do not only allow for a better estimate of their typical lifetimes but can also constrain the physical and chemical properties of ancient TDGs.

2. Results

Early response to stellar feedback: The initial conditions of the simulated TDGs represent a spherical, pressure supported gas cloud with cold over-densities that serve as the seeds for immediate star formation (SF). Within 20 Myr after the simulations start, the total SF rate of the TDGs reaches $5 \times 10^{-2} \mathrm{M}_{\odot} \mathrm{yr}^{-1}$. We study the response of dark matter (DM)-free DGs to different stellar feedback scenarios. In the low feedback case, the initial mass function (IMF) of each star cluster is truncated at a maximal star mass up to which at least a single star can be formed and that is dependent on the mass of the star cluster ($m_{\max} - M_{\mathrm{ecl}}$ relation and IGIMF theory, for details see Kroupa & Weidner 2003; Weidner *et al.* 2013). For the high feedback case the IMF is assumed to be

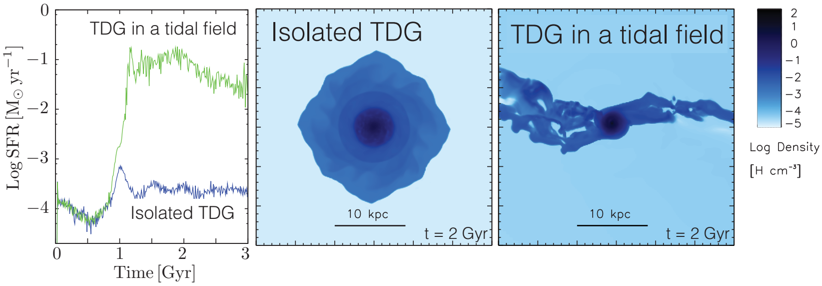

Figure 1. Comparison of the SFRs of initially identical TDGs with and without a tidal field (left panel). A face-on density slice is shown for the isolated TDG (middle panel) as well as the TDG in a tidal field (right spanel) at the peri-center passage of the orbiting TDG (t = 2 Gyr).

completely filled up to a maximal star mass of $120 M_\odot$ for every star cluster. In the first 300 Myr, the stellar feedback regulates the SF significantly stronger in the high feedback case, resulting in a 6 times lower stellar mass after 500 Myr than in the low feedback case ($8.35 \times 10^5 M_\odot$ and $5.73 \times 10^6 M_\odot$, respectively). After 300 Myr, both simulated TDGs regulate their SF to a constant rate below $10^{-4} M_\odot \mathrm{yr}^{-1}$. In both cases, the initially high SF does not lead to a disruption of the TDG (Ploeckinger *et al.* 2014a).

Long term evolution: Starting from a smooth, warm, rotating gas cloud in the tidal field of a massive galaxy, we simulate the long-term evolution of TDGs. In order to carve out the effect of the tidal field, a comparison simulation of an identical but isolated TDG is performed. In the first Gyr the SF is comparable. After 1 Gyr, as the TDG in the tidal field is approaching the peri-center of its orbit, the TDG is compressed and subsequently the SF increases by more than 2 orders of magnitude, but both TDGs survive until the end of the simulation time at t = 3 Gyr (see Fig. 1 and Ploeckinger *et al.* 2014b, subm.).

3. Conclusions

We simulate pressure supported and rotating TDGs, with low and high stellar feedback, and exposed them to ram pressure and a tidal field. All simulated TDGs ($Z = 0.1{-}0.3 Z_\odot$) survive until the end of the simulation (up to 3 Gyr). This serves as an additional sign that TDGs can turn into long-lived objects, complementary to indications from observations (Dabringhausen & Kroupa 2013; Duc *et al.* 2014) and simulations of galaxy interactions (e. g. Bournaud & Duc 2006; Hammer *et al.* 2010; Fouquet *et al.* 2012).

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