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Rings of star formation: Imprints of a close galaxy encounter

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Abstract. In this talk, I report results from galaxy merger simulations, which suggest the existence of a ring of star formation produced by close galaxy encounters. This is a generic feature of all galaxy interactions, provided that the disc spins are sufficiently aligned. This signature can be used to identify close galaxy pairs that have actually suffered a close interaction.

Keywords. galaxies: galaxies: formation – evolution – interactions

1. Introduction

Over thirty five years ago, Larson & Tinsley (1978) first recognised interactions as a promising avenue for triggering star formation in galaxies. This has been a subject of intense work by numerical simulators (Barnes & Hernquist 1991, 1996; Cox *et al.* 2006; Di Matteo *et al.* 2007, 2008; Cox *et al.* 2008). With the help of large surveys, such as the Sloan Digital Sky Survey, interactions are now established as a prime driver for igniting star-forming episodes (Ellison *et al.* 2008, 2010, 2011; Patton *et al.* 2011; Scudder *et al.* 2012; Patton *et al.* 2013), active galactic nuclei (Ellison *et al.* 2011, 2013b), and for the creation of tidal tails in galaxies with close companions (Casteels *et al.* 2013).

Indeed, it is common practice to use the presence of tidal tails as an indicator of past interaction (Kartaltepe *et al.* 2012; Hung *et al.* 2013, 2014). However, a problem with this approach is that for many orbits, tidal tails may dissipate long before the two galaxies merge together. Moreover, some orbital configurations may be more conductive to creating tidal tails than others. In other words, it could be the case that visual classification (via the presence of tails) might miss a fraction of truly interacting galaxy pairs.

In this presentation, I report a signature produced by galaxy interactions: a ring of star formation. This feature may serve as an alternative to identifying galaxies that have experienced a close encounter. A more exhaustive study of this ring-like structure is reserved for future work (Moreno *et al.*, in prep).

2. Methods, Results & Discussion

I employ a suite of 75 SPH (smoothed-particle hydrodynamics) merger simulations (Springel 2005), comprised of three disc-spin orientations selected from Robertson *et al.* (2006): the “e”, “f”, and “k” orientations – meant to represent aligned, perpendicular, and anti-aligned spins, respectively. See Torrey *et al.* (2012) and Moreno *et al.* (in prep) for details. For each of the three orientations considered, we focus on five eccentricities ($\epsilon = \{0.85, 0.90, 0.95, 1.0, 1.05\}$) and five impact parameters ($b = \{2, 4, 8, 12, 16\}$ kpc).

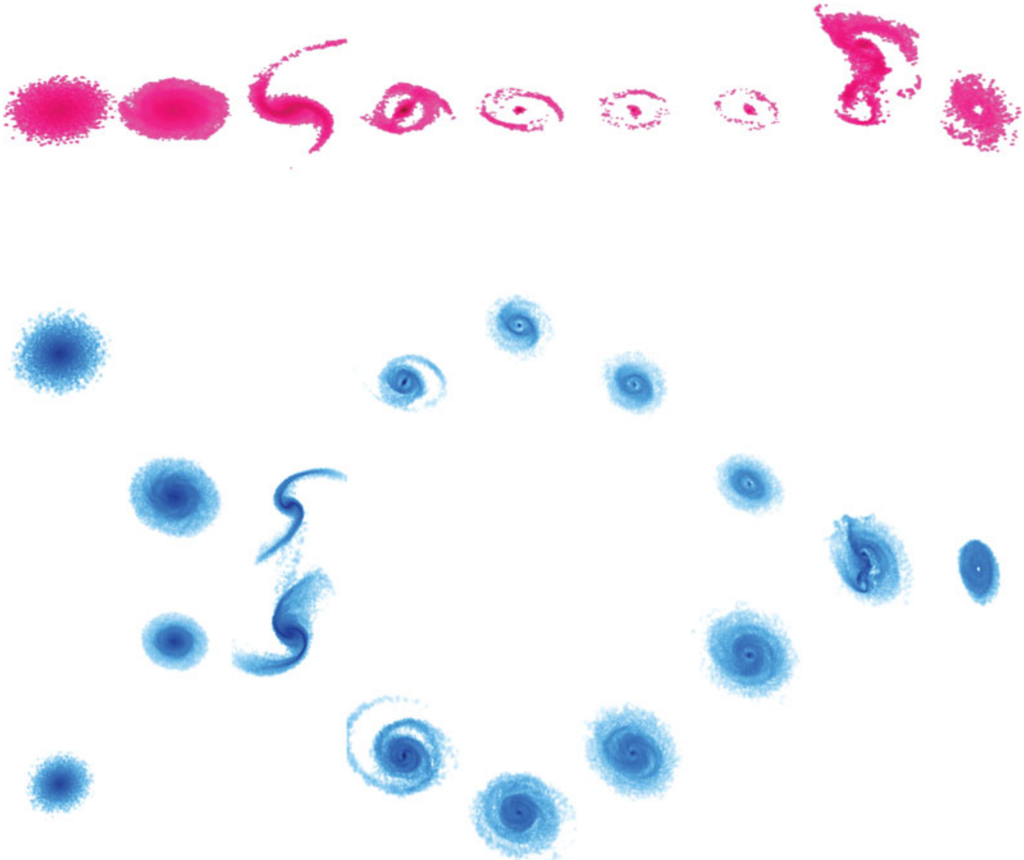

Figure 1. Interacting galaxies with strongly-aligned disc-spin orientation. *Left-to-right:* Various stages of interaction and merging: incoming, close pericentric passage, receding, re-approaching, and merging. *Top:* The morphology of star formation in the secondary (smaller) galaxy (in pink). *Bottom:* The gas-morphology of the two interacting galaxies (in blue – zoomed-out scale).

Figure 1 shows the results for one of our orbits ($\epsilon = 1.05$, $b = 16$ kpc, "e" orientation). In blue (bottom), we show the morphology of the gas component for both galaxies. From left-to-right, each stage of the merger sequence is presented: incoming (1-2), first pericentric passage (3), receding (4-5), re-approaching (6-7), merging (8-9). Tidal tails are only evident briefly (3). In pink (top), we show the morphology of star formation (zoomed-in scale). After first pericentric passage, tidal tails wrap around into a ring of off-nuclear dense gas. This accumulation of material triggers a stable star-forming ring-like structure, which survives for a prolonged period.

This feature takes $\sim$0.2-1 Gyr after first pericentric passage to appear. It is triggered for all orbits in the "e" and "f" orientations (aligned and perpendicular spins), regardless of ϵ and b. However, when the disc spins are anti-aligned ("k" orientation), this ring-like feature is absent (with the exception of a few anomalous orbits where the two disc interpenetrate one another).

Figure 2. Interacting galaxies with anti-aligned orientation. Same format as in Figure 1.

3. Conclusions

In this talk, I report the existence of ring-like off-nuclear star formation produced by close galaxy interactions. If the two discs are sufficiently aligned, a ring-like feature is triggered on the secondary galaxy soon after first passage.

In principle, this is a promising way of identifying those galaxy pairs that have actually experienced a close encounter in the past – which, in turn, would allow more refined calculations of the galaxy merger rate (Patton *et al.* 1997; Bluck *et al.* 2012; López-Sanjuan *et al.* 2013) – but see Moreno (2012) and Moreno *et al.* (2013) for caveats.

One could argue that, if observed, there might be other causes for the existence of this ring. For instance, a ring-like structure is detected in M31 (Gordon *et al.* 2006). However, based on its off-centre nature, simulations suggest that this was caused instead by a direct off-nuclear collision (Block *et al.* 2006; Dierickx *et al.* 2014).

It is my hope that these findings motivate observational investigations by integral-field spectroscopic surveys, such as CALIFA (Sánchez *et al.* 2014), SAMI (Croom *et al.* 2012), MaNGA (Bundy *et al.*, in prep), and the future HECTOR survey (Lawrence *et al.* 2012).

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