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Stripping of satellites on prograde and retrograde orbits

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Abstract. We derived a revised expression for the tidal radius, which is a theoretical boundary of a satellite orbiting a host. Our expression properly takes into account possible rotation of the satellite. We verified our predictions against simulations and obtained satisfactory agreement.

Keywords. galaxies: dwarf – galaxies: interactions – galaxies: kinematics and dynamics – galaxies: structure

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Satellites (e.g. dwarf galaxies) orbiting around a host (e.g. Milky Way) are influenced by tidal forces. Their internal structure is altered and the outer parts are stripped down. The satellites on prograde orbits (i.e. rotating in the same direction as they orbit) are affected much more strongly than the ones on retrograde orbits (i.e. rotating in the opposite sense to the orbital motion).

The tidal radius, r_{t}, is a theoretical boundary of a satellite in the host potential. Within this radius, the motion of the stars is governed mostly by the potential of the satellite itself. When a star crosses r_{t}, it can be considered as stripped and its motion is determined by the potential of the host. The only strict theoretical formula for r_{t}, valid for the circular orbit of the satellite, is the so-called Jacobi radius $r_{\mathrm{t}} = R[(m/M)/3]^{1/3}$, where R is the distance from the satellite to the host, m is the mass of the satellite and M is the mass of the host galaxy. It is identical to the expression for the Lagrange points L1/L2. Improving the approach of Read *et al.* (2006), we derived an expression valid in the case of an arbitrary rotation of the satellite: $r_{\mathrm{t}} = R[(m/M)/(2\Omega_{\mathrm{s}}/\Omega_{\mathrm{orb}}+1)]^{1/3}$ where Ω_{orb} is the orbital angular velocity of the satellite and Ω_{s} is the angular velocity of the satellite rotation. In the case of the prograde orbit $\Omega_{\mathrm{s}} > 0$ and for the retrograde one $\Omega_{\mathrm{s}} < 0$. The formula predicts the tidal radius to be significantly larger for a satellite on a retrograde orbit.

We analysed two N-body simulations of a dwarf galaxy orbiting a Milky-Way-like host. The dwarf on the prograde orbit was stripped much more severely than the retrograde one. We introduced a kinematic radius which differentiates between stars following the potential of the dwarf and of the host. The tidal radii calculated from our formula correctly characterize the sizes of both dwarfs, as well as their regions of influence. In comparison with previous formulae for r_{t}, in the prograde case the difference is small but noticeable. However, in the retrograde case our r_{t} is significantly larger, in agreement with the results of the N-body simulations.

The full derivation of the new tidal radius formula, along with a comprehensive discussion of the results, and the analysis of the simulations is available in Gajda & Łokas (2016).

References

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