A Pilot Survey of Stellar Tidal Streams in Nearby Spiral Galaxies

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Abstract Within the hierarchical framework for galaxy formation, merging and tidal interactions are expected to shape large galaxies to this day. While major mergers are quite rare at present, minor mergers and satellite disruptions—which result in stellar streams—should be common, and are indeed seen in both the Milky Way and the Andromeda Galaxy. As a pilot study, we have carried out ultra-deep, wide-field imaging of some spiral galaxies in the Local Volume, which has revealed external views of such stellar tidal streams at unprecedented detail, with data taken at small robotic telescopes (0.1 – 0.5 m) that provide exquisite surface brightness sensitivity. The goal of this project is to undertake the first systematic and comprehensive imaging survey of stellar tidal streams, from a sample of ∼ 50 nearby Milky Way-like spiral galaxies within 15 Mpc, that features a surface brightness sensitivity of ∼ 30 mag/arcsec². The survey will result in estimates of the incidence, size/geometry and stellar luminosity/mass distribution of such streams. This will not only put our Milky Way and M31 in context but, for the first time, also provide an extensive statistical basis for comparison with state-of-the-art, self-consistent cosmological simulations of this phenomenon.
1 Introduction

Within the hierarchical framework for galaxy formation (e.g. [29]), the stellar bodies of galaxies are expected to form and evolve through dark-matter-driven mass infall and successive coalescence of smaller, distinct sub-units that span a wide mass range. Mergers of initially bound sub-halos (which we refer to as satellites; they consist of dark matter, gas, and, in most cases, stars) are effected by dynamical friction, either through gradual orbital decay or by a single encounter (depending on the initial orbit), its eccentricity and the satellite-to-main-galaxy mass ratio. It is likely that a satellite becomes disrupted by the tidal forces of the larger companion before its orbit spirals all the way to the center. If such a tidal disruption is complete, and no bound satellite is left, dynamical friction ceases to act. If the disruption is only partial at this epoch, the surviving satellite fragment displays extensive tidal tails, leading and trailing its current position in the galactic halo.

While in $\Lambda$-Cold Dark Matter ($\Lambda$CDM) the interaction rate is expected to drop to the present-day epoch, such disruption of satellites should still occur around normal spiral galaxies. The fossil records of these merger events may be detected nowadays in the form of distinct coherent stellar structures in the outer regions of massive systems. The most spectacular cases of tidal debris are long, dynamically cold, stellar streams from a disrupted dwarf satellite, which have wrapped around the host galaxy’s disk and roughly trace the orbit of the progenitor satellite. The now well-studied Sagittarius tidal stream surrounding the Milky Way [12] and the giant stream in Andromeda galaxy [8] are archetypes of these satellite galaxy merger fossils in the Local Group. They provide sound qualitative support for the scenario that tidally disrupted dwarf galaxies are important contributors to stellar halo formation in the Local Group spirals.

State-of-the-art, high-resolution numerical simulations of galaxy formation, built within the $\Lambda$CDM context (e.g. [21, 27]), can guide the quest for observational signatures of such star-streams (e.g. [4, 9]). Recent simulations have demonstrated that the characteristics of substructure currently visible in the stellar halos are sensitive to the last (0–8 Gyr ago) merger histories of galaxies, a timescale that corresponds to the last few to tens of percent of mass accretion for a spiral galaxy like the Milky Way. While stellar streams in the Milky Way and Andromeda can be studied in detail, comparison with cosmological models is limited by cosmic variance. However, the current models imply that a survey of 50–100 parent galaxies reaching to a surface brightness of 30 mag/arcsec$^2$ would reveal many tens of tidal features, perhaps nearly one detectable stream per galaxy [9]. However, a specific comparison of these simulations with observations is missing because no suitable data sets exist. Such a comparison, which could quantify the present sub-halo merger rate, is not only important as a test of $\Lambda$CDM models, but also as a more direct probe of how resilient disks are to minor mergers.