Searching for tidal tails in Galactic dwarf spheroidal satellites

D. Martínez-Delgado
Instituto de Astrofísica de Canarias, 38200 La Laguna, Spain

A. Aparicio
Instituto de Astrofísica de Canarias, 38200 La Laguna, Spain

M. A. Gómez-Flechoso
Geneva Observatory, CH-1290 Sauverny, Switzerland

August 15, 2000

Abstract. We present preliminary results of a long-term project to investigate the process of accretion and tidal disruption of dSph satellites in the Galactic halo and, in particular, to search for new tidal tails in a sample of nearby dSph satellites of the Milky Way. Here we present our finding of extra-tidal debris in the Ursa Minor dSph and discuss the detection by the Sloan Digitized Sky Survey team of what could be a tidal stream associated to the Sagittarius dSph.

Keywords: sample, \LaTeX

1. Introduction

The formation of the Galactic halo is currently best explained by the combination of two scenarios which were previously regarded as competing models. Based on the kinematics of metal-poor halo field stars, Eggen, Lynden-Bell & Sandage (1962) proposed that the halo formed during a rapid, smooth collapse from a homogeneous primordial medium. Searle & Zinn (SZ, 1978) argued halo formation via the gradual merging of many sub-galactic fragments.

Although recent evidence shows that the inner region of the Galactic halo ($R < 20$ kpc) has mostly been formed in a fast process (Rosenberg et al. 1999), several results indicate at least a part of the outer halo originated in a process similar to the SZ scenario. The discovery of the Sagittarius dwarf galaxy (Ibata, Gilmore & Irwin 1994), in the process of dissolving into the Galactic halo, argued in favour of the hypothesis that accretion events can take place in the Milky Way, whose full formation history (through satellites merging into it) might not have finished yet. On the basis of this discussion, it is very important to investigate whether Galactic dSph satellites display tidal tails beyond their tidal limits. The availability of a new generation of wide-field...
CCD cameras offer for the first time a good opportunity of successfully addressing this issue.

2. Methodology

The detection of tidal tails in dSphs is very challenging due to their large angular sizes and low surface brightness. This requires using wide field observations and a careful analysis of the foreground contamination. We use a technique based in B,R photometry survey of selected wide fields of the galaxy to obtain deep color-magnitude diagrams (CMDs) that reveal the main sequence (MS) turnoff of its old population. In moderate foreground contaminated fields, it is also possible to trace the tidal debris by means of the blue horizontal stars (BHB) or blue stragglers (BS) members of the dSph, due to the almost absence of Galactic foreground stars for $(B - R) < 0.5$.

3. Results

3.1. Ursa Minor

Ursa Minor (UMi) is one of the closest satellites of the Milky Way (d=69 kpc) and a strong candidate to be a disrupted dSph interacting with the external Galactic halo. Figure 1 shows the $[(B - R), V]$ CMD for three selected elliptical annuli centered in UMi: a) the central region; b) the elliptical area beyond the tidal radius ($r_t$) given by Kleyna et al. (1995) ($R = 34'$); and c) the elliptical region beyond the $r_t$ obtained by Irwin & Haztzidimitriou (IH, 1995) ($R = 50.6'$). For comparison, the CMD of a control field situated $\sim 3$deg S from the center of UMi is shown in Figure 1d. BHB as well as old MS turnoff stars are detected in these extra-tidal fields (Figure 1b and 1c) indicating the presence of a tidal extension in Ursa Minor even beyond the $r_t$ given by IH.

The existence of tidal tails in UMi suggests that this satellite is undergoing a tidal destruction process. This is also supported by the presence of substructure in the main body of UMi reported by Olczewski & Aaronson (1985) and more recently by IH (1995) and Kleyna et al. (1998). We confirm this lumpiness and asymmetry in the stellar distribution of UMi from our deeper data, although we are currently carrying on an analysis to test its statistical significance. In this context, it is possible a tidal origin for the UMi’s high observed mass-to-light ratio, as it is suggested by Kroupa (1997). If this substructure is real, more elaborated models including details of the substructure and the
presence of tides will be needed to estimate the real dark matter content of UMi.

3.2. Sagittarius

There is general agreement that the Sagittarius (Sgr) satellite is being disrupted by the Milky Way. Theoretical simulations of the encounter (Gómez-Flechoso et al. 1999) predict tidal streams emerging from the main body of Sgr and extending along its projected major axis, and possibly even encircling the sky.

Recently, the Sloan Digital Sky Survey (SDSS) have found two clear, \( \sim 45 \) deg long stripes of blue, A-type stars, with magnitudes 19 and 21 (Yanni et al. 2000). They could be respectively formed by BHB and BS stars at 45 kpc from the Sun belonging to an old stream in the outer galactic halo, possibly associated to a tidally disrupted dwarf galaxy.

The best of all known candidates is Sgr, due to the SDSS slice overlaps the area where the models predict the presence of the Sgr northern stream. To check this possibility we have computed a model of Sgr assuming that the two streams found by the SDDS are tidal debris of this galaxy. The result is shown in Figure 2. The agreement is very good (see Figure 3 in Yanni et al. 2000) and suggests we are likely seeing the apocenter of Sgr, although the possibility of an unknown tidal disrupted galaxy cannot be rejected. We are carrying on a photometry survey in this region to spatially trace the stream.
Figure 2. A polar wedge diagram with Right Ascension and $V$ magnitude for our model of Sgr (see Yanni et al. 2000 for details of this representation).

References

Eggen, O. J.; Lynden-Bell, D.; Sandage, A. R. Evidence from the motions of old stars that the Galaxy collapsed. Astrophysical Journal, 136:748–766, 1962.

Gomez-Flechoso, M. A., Fux, R., Martinet, L., Sagittarius, a dwarf spheroidal galaxy without dark matter?. Astronomy & Astrophysics, 347:77–91, 1999.

Ibata, R., Gilmore, G. & Irwin, M. J. A dwarf satellite galaxy in Sagittarius. Nature, 370: 194–196, 1994.

Irwin, M.; Hatzidimitriou, D. Structural parameters for the Galactic dwarf spheroidals. Monthly Notices of the Royal Astronomical Society, 277: 1354–1378, 1995.

Kleyna, J. T.; Geller, M. J.; Kenyon, S. J., Kurtz, M. J.; Thorstensen, J. R. A V and I CCD Mosaic Survey of the Ursa Minor Dwarf Spheroidal Galaxy. Astronomical Journal, 115, 2359-2368, 1998.

Olszewski, E. W.; Aaronson, M. The Ursa Minor dwarf galaxy - Still an old stellar system. Astronomical Journal90: 2221–2238, 1985.

Pavel, K. Dwarf spheroidal satellite galaxies without dark matter. New Astronomy, 2, 139–164, 1997.

Rosenberg, A., Saviane, I., Piotto, G., Aparicio, A. Galactic Globular Cluster Relative Ages. Astronomical Journal, 118, 2306–2320, 1999.

Searle, L.; Zinn, R. Compositions of halo clusters and the formation of the galactic halo. Astrophysical Journal, 225:7 357–379, 1978.

Yanny B. et al. Identification of A-colored stars and Structure in the Halo of the Milky Way from SDSS Commissioning Data. Astrophysical Journal, 540, 825–841, 2000.