A two micron all-sky survey view of the Sagittarius dwarf Galaxy.
IV. Modeling the Sagittarius tidal tails

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A summary by Gergő Popping

Introduction and motivation

The Sagittarius dwarf spheroidal galaxy (Sgr) was discovered only in the mid 90’s. Totten & Irwin (1998) were the first to suggest that tidal tails of the disrupting Sgr extend full across the sky. M giants from the Two Micron All-Sky Survey (2MASS) verified this conclusion. Nowadays Sgr is the best example of a satellite being eaten by our Milky Way (MW). The properties of Sgr and its interaction with the MW provide a great laboratory for finding the shape and strength of the Galactic potential, as well as for exploring the dynamics of a satellite under tidal influence of a galaxy.

Helmi (2004) showed that leading debris velocity trends of Sgr are best described by a prolate halo. However, Johnston et al. (2005) have demonstrated that the observed orbital pole precession of leading versus trailing debris is best described with oblate halo.

This paper has two main goals:

1. Resolve this conflict using a single-component model for Sgr traveling along a single orbit in a nonevolving potential

2. Constrain the current mass and orbit of Sgr

In the paper these goals are approached by modelling Sgr for different parameters. The Milky Way is described by a three component potential (disk, halo, spherical) and Sgr by a Plummer model. 11 observed properties were adopted as constraints on the simulated MW-Sgr system.

Results

Galactic parameters

In this section the paper presents the best fit compared to M giant star data for the leading and trailing velocity data using a single component orbit. The trailing velocity data have a slight preference for oblate model halos, although the difference in goodness of fit for oblate and prolate halos is not much $\Delta \chi^2_{\text{trail}} \sim 0.1$. The leading velocity data strongly prefer prolate halo models, such that this preference dominates the combined leading and trailing data (fig 3 in the paper).

However, this still does not describe the sense of precession suggested by the offset of the planes of the leading versus trailing debris. Therefore the paper
implies that no single orbit/or potential can fit all the data. This conclusion implies that some evolution of Sgr’s orbit has occurred over time since debris in the leading side were released.

Galactic rotation curve

The paper shows that rotation curves of the MW are flat out to large radii with circular velocities in the range 180 - 220 km s$^{-1}$ at 50 kpc. For this results they used modeled orbits with a goodness of fit of $\chi_{\text{trail}} < 1.1$. This velocity range corresponds to a MW mass of $3.5 - 5.6 \times 10^{11} M_\odot$.

Sgr properties

Mass of Sgr

For different potentials (oblate (O) $q = 0.9$, spherical (S) $q = 1.0$ and prolate (P) $q = 1.25$) the paper plots the mass of Sgr as a function of velocity and spacial distribution of trailing debris (fig 7 in the paper). The results are compared with values found from the 2MASS M giants. In all potentials this leads to a mass range of $M_{\text{Sgr}} = 2 - 5 \times 10^8 M_\odot$.

Velocity of Sgr

The trailing arm velocities must match the velocities for M giants. In the paper the offset of trailing debris velocities from the fiducial Sgr stream M giant velocities is plotted as a function of tangential velocity in each potential (fig 9 in the paper). This leads to best choices for the tangential velocity for the model dwarf of $v_{\text{tan}} = 275-280$ (O), 265-270 (S) and 250-260 (P) km s$^{-1}$.

Best fit model

Using previous results Law et al. created best fit models. These models have a maximum extent of bound material $r_{\text{bound}} \sim 500'$ along the semimajor axis, within which a luminosity for Sgr of $L_{\text{Sgr}} = 1.4 \times 10^7 L_\odot$ is found. Other results are presented in table 1

<table>
<thead>
<tr>
<th>$M_{\text{Sgr}}/L_{\text{Sgr}} (M_\odot/L_\odot)$</th>
<th>Oblate</th>
<th>Spherical</th>
<th>Prolate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Period (Gyr)</td>
<td>0.85</td>
<td>0.88</td>
<td>0.87</td>
</tr>
<tr>
<td>U (km s$^{-1}$)</td>
<td>238</td>
<td>235</td>
<td>231</td>
</tr>
<tr>
<td>V (km s$^{-1}$)</td>
<td>-42</td>
<td>-40</td>
<td>-37</td>
</tr>
<tr>
<td>W (km s$^{-1}$)</td>
<td>222</td>
<td>213</td>
<td>198</td>
</tr>
<tr>
<td>pericenter (kpc)</td>
<td>10-16</td>
<td>14</td>
<td>14-19</td>
</tr>
<tr>
<td>apocenter (kpc)</td>
<td>56-58</td>
<td>59</td>
<td>56-59</td>
</tr>
</tbody>
</table>

Comparison of this best fit model with the data leads to the suggestion that the M giant data is mainly traced by debris released during the last two pericentric passages of the model dwarf and possibly by debris released three passages ago. This corresponds to M giants becoming unbound over the last 1.5 - 2.5 Gyr. This model also shows that oblate and spherical halo potentials fail to fit the leading velocity trend, while the prolate model succeeds and provides a convincing fit
to the apparent trend of M giant distances. The model is not always consistent with earlier published carbon data. However, it is possible that carbon data trace debris older than the $\sim 2.5$ Gyr old M giants. The model is nicely consistent with K-giants representing debris stripped three pericentric passages ago from Sgr. The best fit model for oblate and spherical potentials predicts that the sun is located in the middle of a stream of debris from Sgr. Models orbiting in a prolate potential do not predict this. The presence of Sgr debris in the solar neighborhood could be a useful tool for determining the Galactic potential.

Main findings

The main results of this paper is the insight that some evolution of the orbit of Sgr may have occurred over the past few gigayears. A single orbit in the explored static potentials cannot fit the data. The presence of Sgr debris in the solar neighborhood could help to determine the potential of our galaxy. Next to this insight the mass and velocity of Sgr in each potential type is constrained to smaller ranges. These constraints can be used for higher order models of Sgr.