The Sagittarius Dwarf Galaxy Tidal Debris in the South Galactic Cap

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Abstract:

We characterize the spatial properties of the Sagittarius dwarf galaxy tidal debris, both primary and secondary (bifurcated) tidal tails, in the south Galactic cap. The Sagittarius dwarf galaxy is currently being ripped apart by tidal forces from the Milky Way galaxy. The spatial density of turnoff stars from the Sloan Digital Sky Survey Data Release 8 are fit using statistical photometric parallax with half a petaFLOPS of computing power from the MilkWay@home volunteer computing platform. The secondary tail appears to be significantly wider than the originally detected primary tail. These results are compared with the leading tidal tail stream density measured in the north Galactic cap. This research was funded by NSF grant AST 10-09670.

SDSS DR 8 MSTO Stars in the south Galactic Cap

The technique of Statistical Photometric Parallax (Newberg 2013) was developed to use the large data sets available from the Sloan Digital Sky Survey. In Newby et al 2013, the spatial density of Main Sequence Turn Off (MSTO) stars in the Sagittarius dwarf tidal stream was measured from the Sloan Digital Sky Survey Data Release 7 (SDSS DR7), using statistical photometric parallax. The publication of the SDSS Data Release 8 (SDSS DR8), extended the the coverage of the survey by 3000 square degrees, particularly in the south Galactic Cap (Aihara et al. 2011).

To map the spatial density of halo stars in the south, we chose stars from the SDSS DR 8 with the selection criteria described in Cole 2008 and summarized in Newby et al 2013 as; galactic latitude $b < -20°$, magnitude $16.0 < g_0 < 22.5$, color $0.1 < (g - r)_0 < 0.3$ and color $(u - g)_0 > 0.4$. These criteria select stars low enough in latitude to be out of the galactic plane, This data set contained 1,690,858 MSTO stars, which were separated into files corresponding to the SDSS stripes. The stripes 79 through 86 were selected for analysis containing approximately 500,00 MSTO stars.

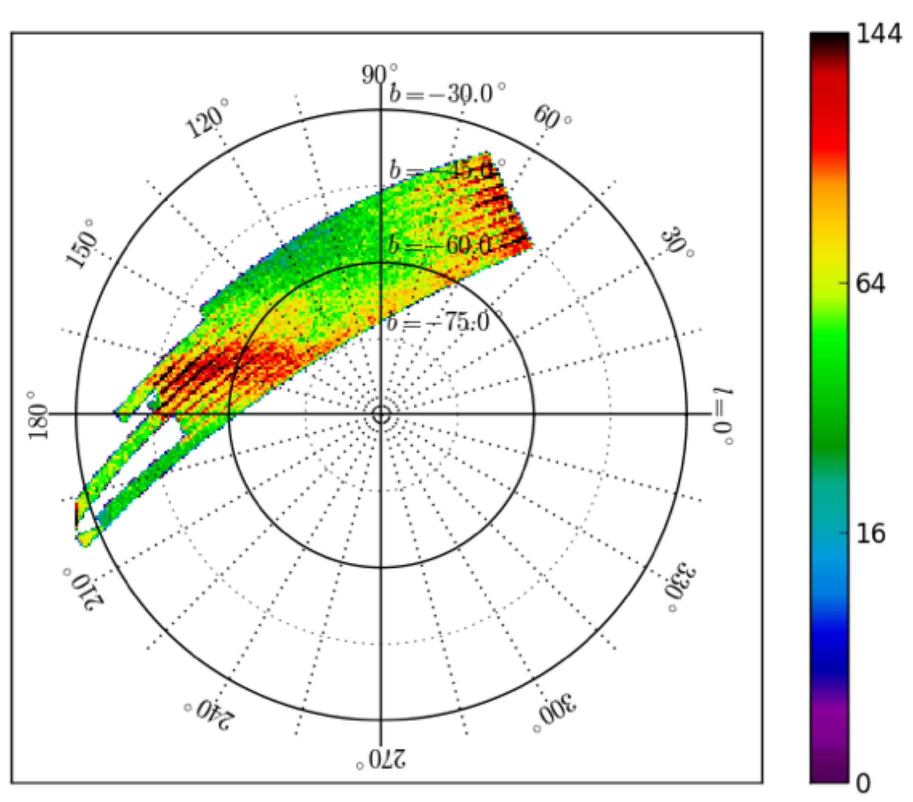


Figure 1 - A density plot of SDSS DR 8 MSTO stars in the south Galactic Cap plotted in Galactic *l b* coordinates. The Sagittarius Tidal debris can be seen in orange and red between *l* of 120° and 180°.

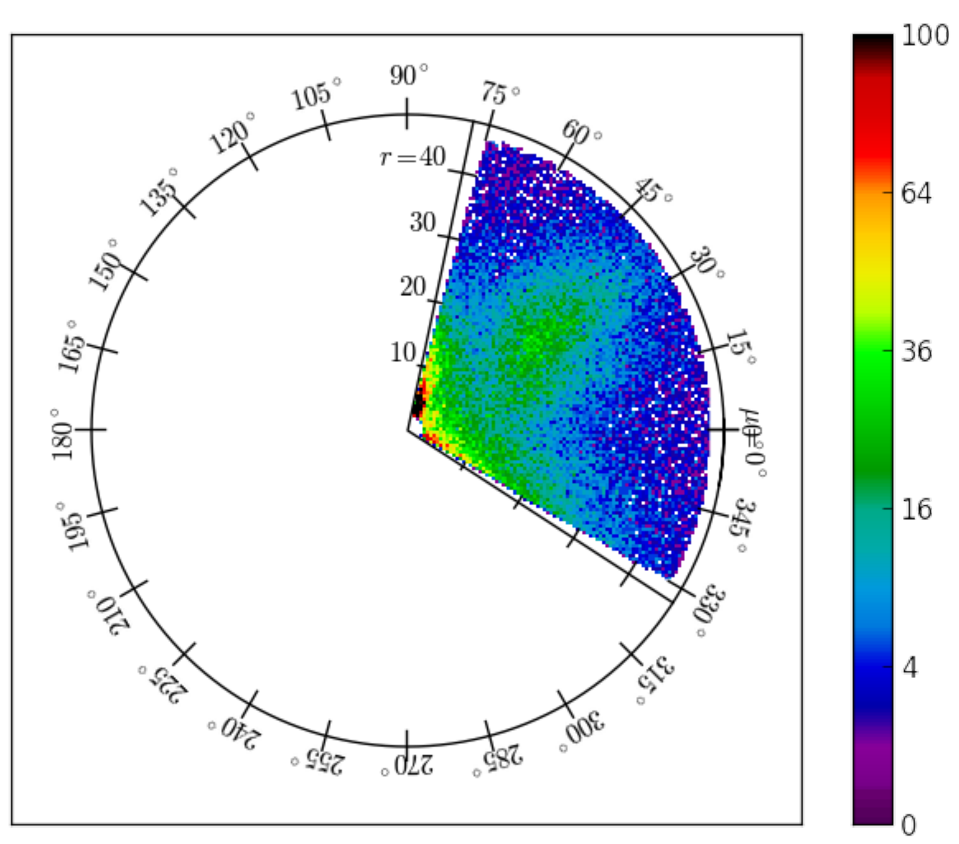
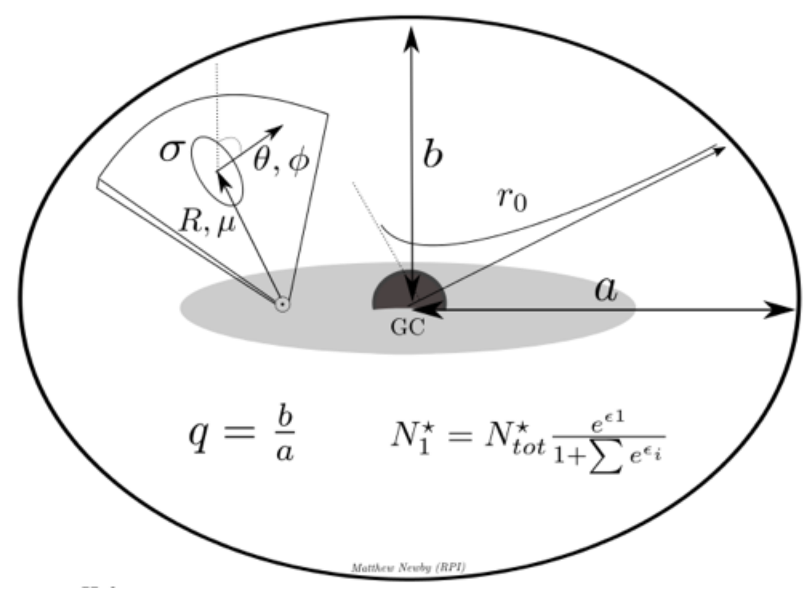


Figure 2 - A density plot of SDSS DR8 MSTO stars in stripe 82 with distance from the Sun in kpc plotted on the radial axis and SDSS Great Circle coordinate μ plotted as the polar angle. The SDDS coordinate ν which represents the 2.5° scanning width of the survey is flattened in this graph.



Milkyway@Home Separation:

MSTO stars were chosen to map the spatial structures of the halo, as they have an average absolute magnitude of *4.20* (Newberg and Yanny 2006). The data set for each stripe form a wedge (*r*, μ, ν). The smooth component of the halo is modeled using the Hernquist density profile with a flattening parameter *q* and scale length r_0. The tidal streams are modeled as cylinders with a Gaussian density about the center.

Each cylinder is fit to 6 parameters:the distance to the cylinder center from the Sun *R*, the position of the cylinder center in SDSS Great Circle coordinate μ, the width of the stream σ, the orientation of the cylinder relative to the galactic x and z coordinates (ϕ, θ) and the weight ε that determines the number of stars. This is illustrated in the figure above from Newby 2013.

Cole et al. in 2008 developed a maximum likelihood algorithm to determine the best fit parameters for each SDSS stripe. Each stripe needs to be fit to 8 to 20 parameters depending on the number of streams that are being fit, typically 1 to 3 streams. The large parameter space and the large number of stars require massive computing resources. MilkyWay@home uses the Berkeley Open Infrastructure for Network Computing (BOINC) to distribute the work amongst volunteers across the globe. This volunteer network is currently running at ~0.5 PetaFLOPS.

We used MilkyWay@home to characterize the spatial properties for three streams across the dataset. Two streams were used for the primary and secondary tidal tails, while the third stream was used for "garbage collection."

Current Results

Parameters for the Sagittarius Tidal Debris

The Primary Tidal Tail

Stripe Number	μ (°)	r_0 (kpc)	X (kpc)	Y (kpc)	Z (kpc)	σ (kpc)
79*	45.09	28.88	-28.86	3.05	-20.26	5.34
80*	44.00	33.02	-30.91	3.16	-24.05	1.78
82*	33.01	28.15	-23.19	4.84	-23.52	4.65
83	29.02	27.21	-20.81	5.06	-23.73	3.53
84	26.81	26.56	-19.21	4.74	-23.84	4.41
85	25.79	27.45	-18.64	4.30	-25.14	1.42
86	21.17	26.38	-15.99	4.46	-24.90	2.50

*Initial computation is done across the parameter space. The detection of substructure in the initial runs is used to constrain the range of parameters on subsequence runs , stripes 79-82 have not been constrained. Stripe 81 has not completed initial runs. Stripes 83-86 have been processed twice

The Secondary Tidal Tail

Stripe Number	μ (°)	r_0 (kpc)	X (kpc)	Y (kpc)	Z (kpc)	σ (kpc)
83	-26.02	12.35	-4.15	7.54	-8.76	6.07
84	-41.95	16.95	1.1962	10.49	-9.11	8.59
85	-12.98	19.97	-4.43	9.69	-16.99	5.19
86	-17.72	15.92	-3.84	7.64	-13.16	7.19

The detection of the secondary tail in the stripes 83-86 consistently show a stream width considerably larger than the primary stream.

Separation of the Sagittarius Tidal Streams

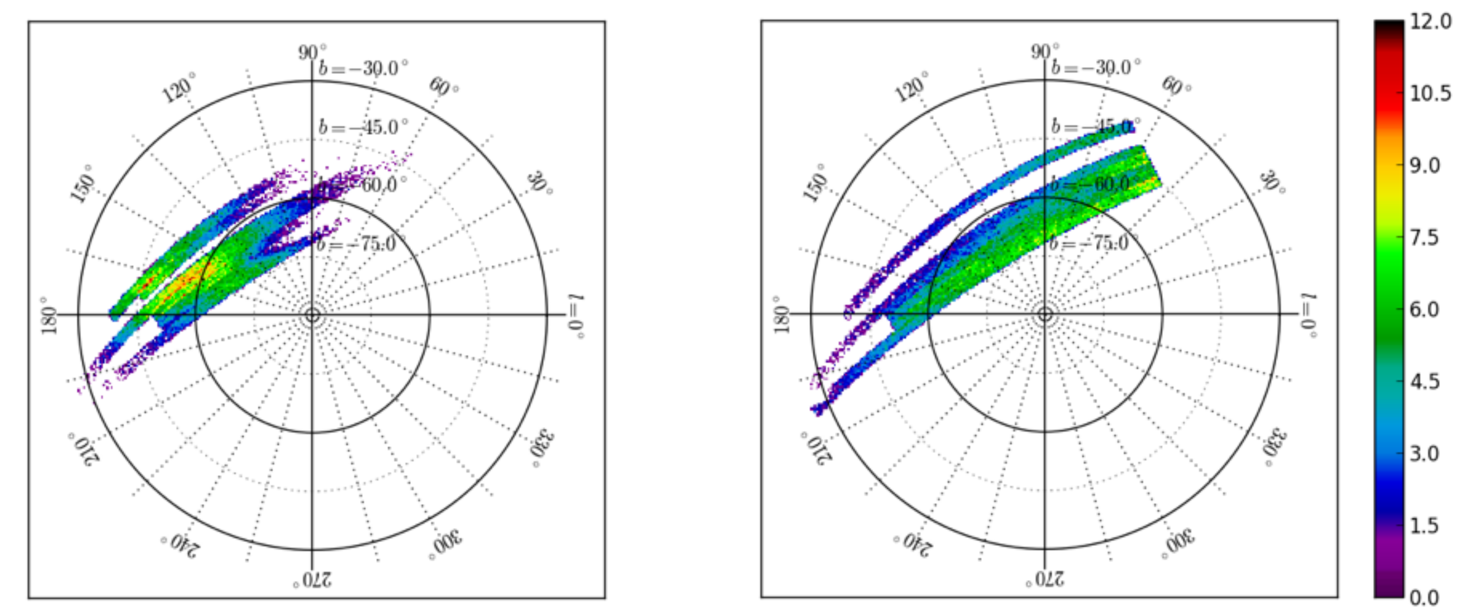


***Figure 4:* Left -** The density of MSTO stars for the Sagittarius primary tidal tail. This is data for stripes 79-86 excluding stripe 81 which is currently reprocessing. **Right -** The density of MSTO stars for the Sagittarius secondary tidal tail.

The Sagittarius Primary Tidal Tail:

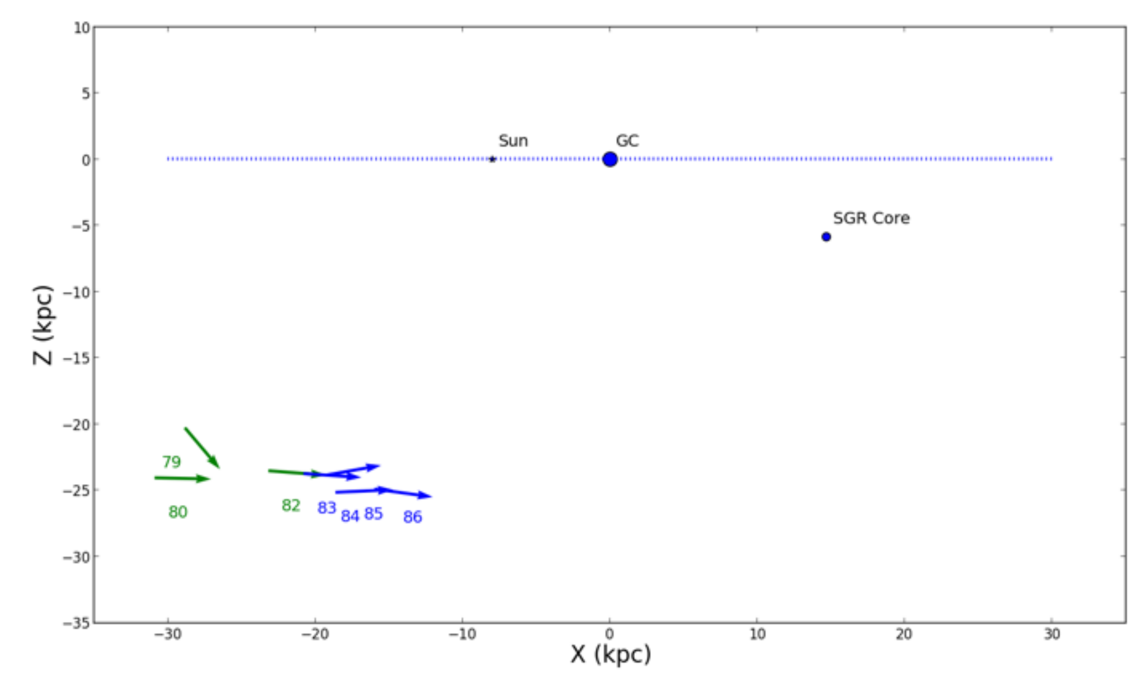


Figure 5 The Primary Tidal Tail in the south Galactic Cap. The vectors show stream orientation. The blue vectors have finished a second run with constraints. The green vectors have finished one run without constraints and are currently in processing with constraints.

Results and Future Work:

The initial processing of the data has detected both the primary and secondary streams of the Sagittarius Tidal Debris in the south Galactic Cap. Consistently the secondary stream is seen to be much wider than the primary stream. These initial detections need to be used to constrain new runs across the dataset. Continuity between SDSS stripes should be used to limit the range of parameters.

The secondary stream's center is being detected past the boundary of the data in stripes 79 – 82. The large width of the secondary stream requires future runs to allow the center parameter to search more space outside of the dataset.

References:

Aihara 2011
Newberg and Yanny 2006
Newby 2013
Cole 2008
Newberg 2013