Tidal Tails in the Globular Cluster Segue I

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Segue 1

The discovery of Segue 1 is described in Belokurov et al. (2007). It is located at right ascension 152° 00' 25" at a heliocentric distance of 23 ± 2 kpc. With a half-light radius of approximately 30 pc it is amongst the largest Milky Way globular clusters such as Pal 5 (Odenkirchen 2001). The globular cluster is unusually small for its mass (M ~ 3). Segue 1 is superimposed on the Sagittarius stream which is approximately 20 kpc away at the relevant location. Figure 1 shows the distances to Sagittarius tidal debris at various positions. Segue 1 is marked in red, and we see that it follows the trend closely. We believe that Segue 1 might have been part of the Sagittarius dwarf galaxy and has been tidally disrupted by the Milky Way after being stripped from Sagittarius. In this work we follow up the previous analysis of Segue 1 by searching for structures connected to Segue 1 in a 0.5° by 1° square centered on the cluster. To this end we use data from the Sloan Digital Sky Survey (SDSS) Data Release 5.

SDSS Photometry

We select stars in a 10° by 10° box centered on Segue 1 and use the SDSS Sloan photometry flags and a magnitude cut (m2 < 22.5) to remove stars in the halo. In addition we correct for extinction using the maps of Schlafly, Finkbeiner, and Davis. Figure 2a shows the spatial density of all stars selected divided within 75% by 75 pixels smoothed with a gaussian kernel (FWHM: 1.5 pixels). Figure 1 is too faint to be clearly visible in this plot. Figure 2b shows a density plot of stars that have removed from the sample using our magnitude cut. Structural features due to problems in data reduction are clearly visible and correspond to the SDSS scan patterns on the sky. Using the cleaned sample we develop a understanding of the background of field stars. Figure 2c shows our estimate of the background star density with extinction contours overplotted. We arrive at the background estimate by first replacing the Segue 1 overdensity within 1° with a representative patch of background stars at 14°-dez-19°. By a similar cleaning method we remove the Leo I dwarf galaxy (m < 152° 2° dez-12.5°), the other obvious overdensity in the field. We then compare the field density and smooth the resulting distribution with a gaussian kernel (FWHM: 5 pixels) and box cut smoothing over 35 pixels.

Mapping Out Candidate Stars

In order to find evidence of tidal debris around Segue 1 we employ a set of color-magnitude criteria which allow us to distinguish cluster stars from the background. We determine the color-magnitude distribution of Segue 1 by considering all stars that lie within a 0.12° aperture around the cluster center. Similarly we determine the field star color-magnitude distribution by considering stars outside of an aperture of 0.12°. In order to determine whether a star is part of Segue 1 we take the ratio of the two distributions, draw a box around the relevant region of the Hertzsprung-Russell diagram and query the ratio within the box. We then select a weight for each star depending on its location in color-magnitude space. The weights represent the likelihood that a star is a member of Segue 1. Following the optional filter technique described in Odenkirchen et al. (2003) we determine the cluster star density which is shown in Figure 4.

Tidal Tails?

Figure 3 above shows the tidal density distribution determined. We find a significant number of candidate stars in the vicinity of Segue 1. Part of the structure extends from south to north. In addition we find a slightly lower significance overdensity that extends along the direction of the Sagittarius stream. In order to support that the features are associated with Segue 1 we look at Hertzsprung-Russell diagrams and luminosity functions of the tidal debris. We observe that the tidal stars start atnging distribution is similar to that of Segue 1 and find that the luminosity functions of the debris and cluster are similar. Using the previously determined mass and size of the cluster we are able to locate it on the cluster survival diagrams (Cuesta/Odenkirchen 1997) and find that the cluster had formed with its given size and mass it should have already been destroyed. We need to better investigate whether or not the observed tidal structures are possible given the cluster's orbital and if the idea that it is previously existed in the Sagittarius dwarf will influence the tidal disruption.

CFHT Follow Up

Using available CFHT data we are able to get a view of a smaller but deeper field containing Segue 1. The field is not sufficient to resolve the tidal debris identified in the SDSS, however, we are able to analyze the density profile of the cluster in more detail (Figure 5). We fit a Plummer law to the profile and find that the cluster deviates from the line suggesting that it is indeed being disrupted. The chi-squared of the fit is 15.9.

References


Figure 1: Distances to Sagittarius tidal debris at various control measured by Belokurov et al. (2006). Segue 1 is marked by the red star, as well as the distribution suggesting that was once part of Sagittarius.

Figure 2a: Distribution of all stars in one field of view cleaned using the SDSS photometry flags and a magnitude cut (m2 < 22.5) to remove stars in the halo. In addition we correct for extinction using the maps of Schlafly, Finkbeiner, and Davis. Figure 2a shows the spatial density of all stars selected divided within 75% by 75 pixels smoothed with a gaussian kernel (FWHM: 1.5 pixels). Figure 1 is too faint to be clearly visible in this plot. Figure 2b shows a density plot of stars that have removed from the sample using our magnitude cut. Structural features due to problems in data reduction are clearly visible and correspond to the SDSS scan patterns on the sky. Using the cleaned sample we develop a understanding of the background of field stars. Figure 2c shows our estimate of the background star density with extinction contours overplotted. We arrive at the background estimate by first replacing the Segue 1 overdensity within 1° with a representative patch of background stars at 14°-dez-19°. By a similar cleaning method we remove the Leo I dwarf galaxy (m < 152° 2° dez-12.5°), the other obvious overdensity in the field. We then compare the field density and smooth the resulting distribution with a gaussian kernel (FWHM: 5 pixels) and box cut smoothing over 35 pixels.

Figure 3: Distribution of star count as they appear as they are in the background of the image which are associated with the tidal debris. The colors show the 15.2 - 1.25 stars levels above average and correspond to the colors used in the density contours of Figure 4.

Figure 4: Positions-space density produced using the optimal filter technique (Odenkirchen 2003). The circles correspond to the signal levels described in Figure 3. Segue 1 is clearly visible as well as an arcuate of stars in its vicinity, possibly tidal tails. A significant excess runs from north to south and there is also a distribution of excess stars following the direction of the Sagittarius stream.

Figure 5: Star count is effectively zero around 1° centered on Segue 1. The crow shows a Plummer law fit to the data. The cluster deviates from the profile suggesting that it is tidally disrupted.