Tidal Tails in the Globular Cluster Segue I

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Segue 1

The discovery of Segue I is described in Belokurov et al. (2007). It is located at right ascension 152° declination 16° 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 2001,2003). The globular cluster is unusually faint for its size ($M_V \approx 3$). Segue I 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 I is marked in red, and we see that it follows the trend closely. We believe that Segue I 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 I by searching for structures connected to Segue I in a 10° by 10° square centered on the cluster. To this end we use data from the Sloan Digital Sky Survey (SDSS) Data Release 6.

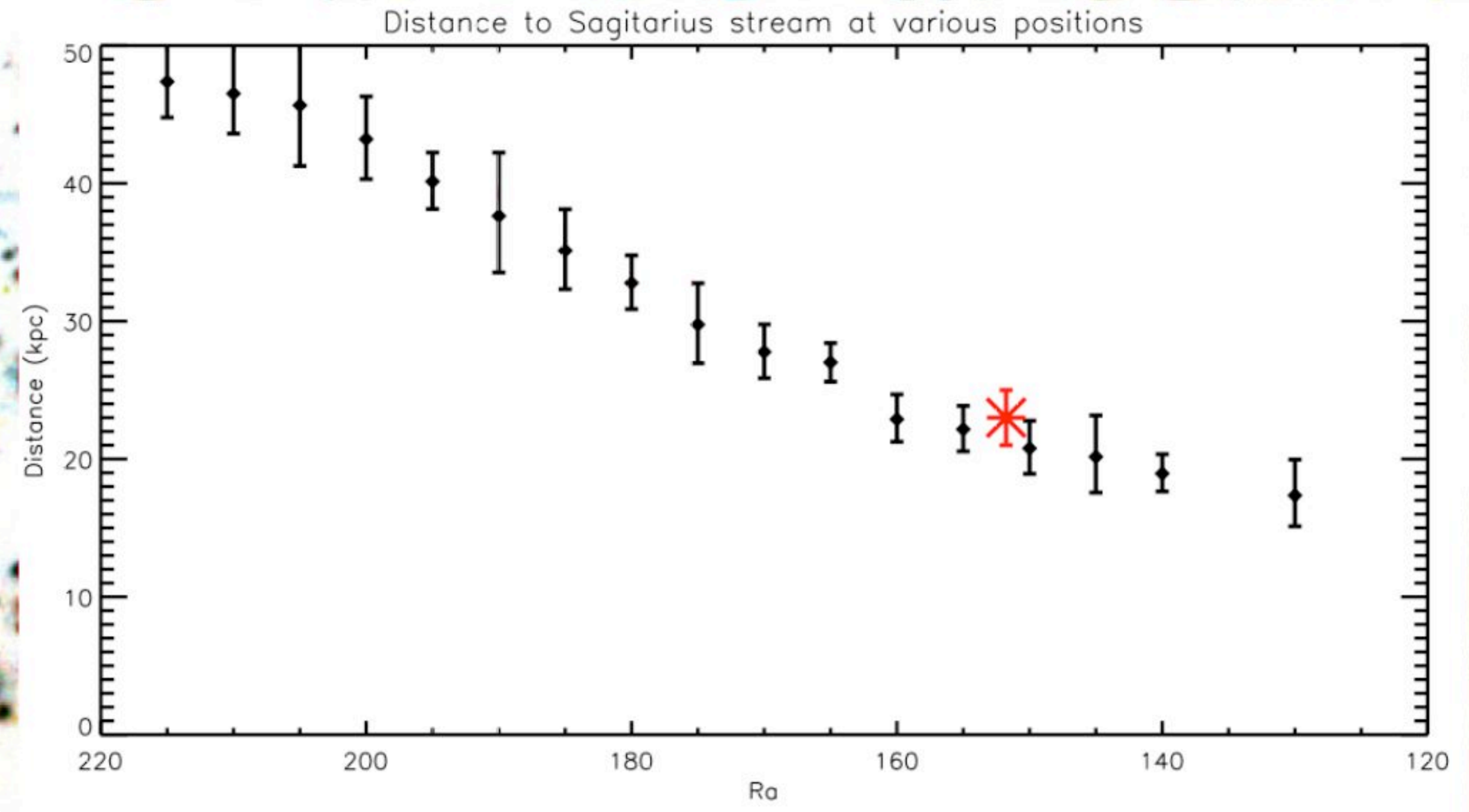

Figure 1: Distances to Sagittarius tidal debris at different locations measured by Belokurov et al. (2006). Segue I is marked by the red star.It fits well into the distribution suggesting that it was once part of Sagittarius.

SDSS Photometry

We select stars in a 10° by 10° box centered on Segue I and use the SDSS clean photometry flags and a magnitude cut (r<22.5) to remove data reduction artifacts from the field. In addition we correct for extinction using the maps of Schlegel, Finkbeiner, and Davis. Figure 2a shows the spatial density of all stars selected dividing the area in 75 by 75 pixels smoothed with a gaussian kernel FWHM=1.5 pixels. Segue I is too faint to be clearly visible in this plot. Figure 2b shows a density plot of stars that we have removed from the sample using our magnitude cut. Structural artifacts 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 an understanding of the background of field stars. Figure 2c shows our estimate of the background field star density with extinction contours overplotted. We arrive at the background estimate by first replacing the Segue I over density within 1° with a representative patch of background taken at ra=149°,dec=19°. By a similar cloning method we remove the Leo I dwarf galaxy (ra= 152.2°, dec=12.5°), the other obvious overdensity in the field. We then compute the field density and smooth the resulting distribution with a gaussian kernel FWHM=5 pixels and a box-car smoothing over 35 pixels.

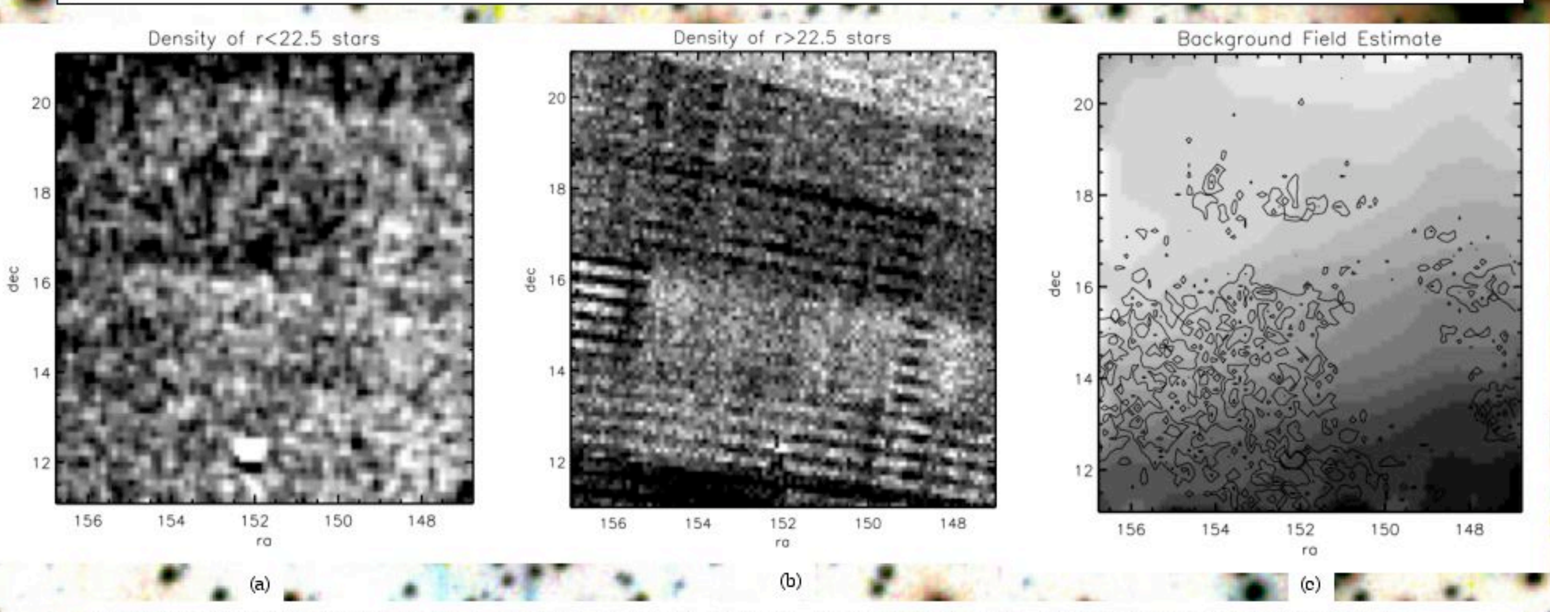

Figure 2: (a) Distribution of all stars in our field of view cleaned using the SDSS photometry flags and a magnitude cut r<22.5. (b) Stars removed using the magnitude cut, showing SDSS stripe patterns. (c) Background estimate with overplotted extinction contours

Mapping Out Candidate Stars

In order to find evidence of tidal debris around Segue I 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 I 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 0.4°. In order to determine whether a staris part of Segue I we take the ratio of the two distributions, draw a mask about the relevant region of the Hess diagram and using the ratio within the mask we attach a weight to each star depending on its location in color-magnitude space. The weights represent the likelihood that a star is a member of Segue I. Following the optimal filter technique described in Odenkirchen et al. (2003) we determine the cluster star density which is shown in Figure 4.

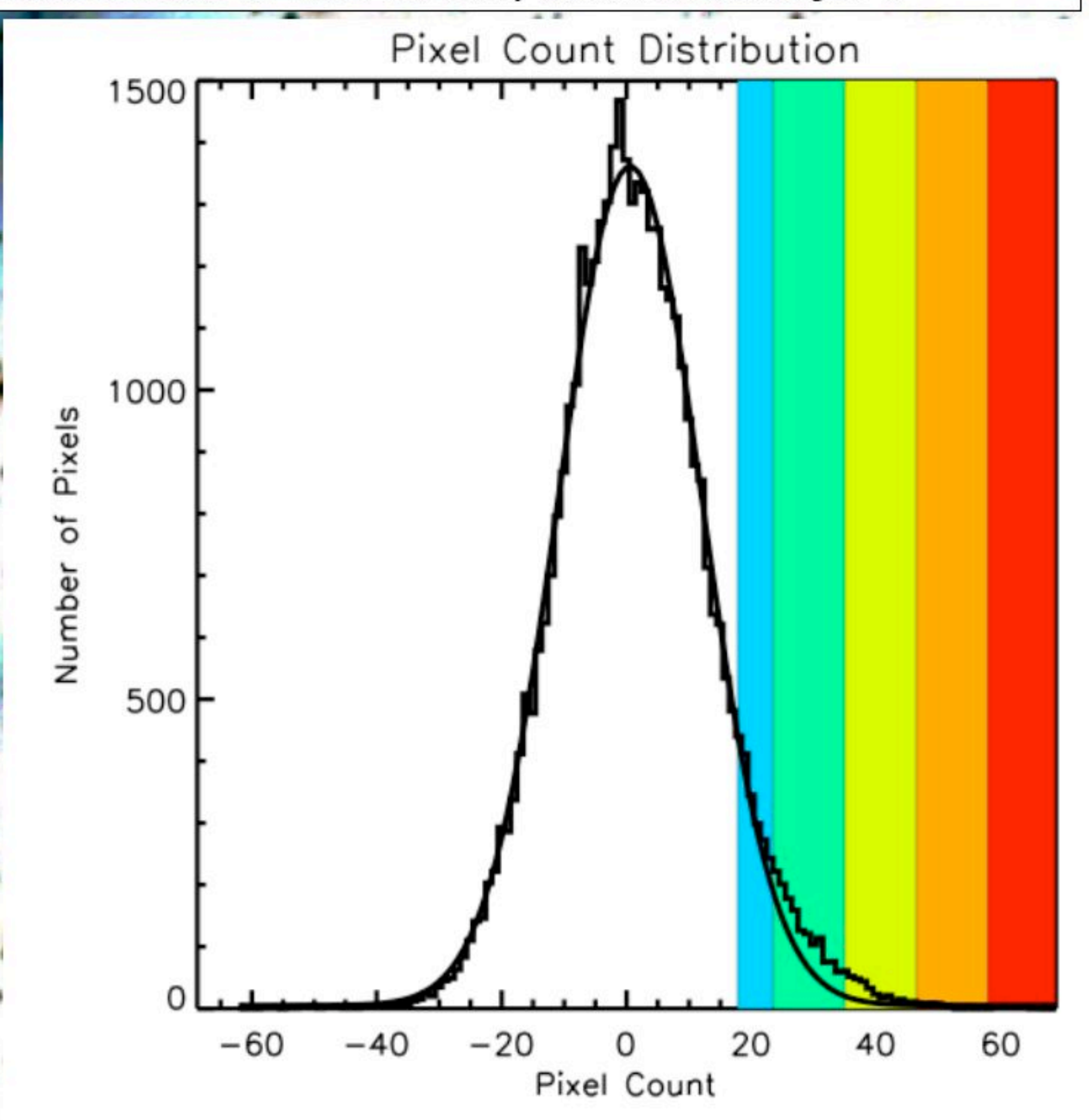

Figure 3: Distribution of star counts in density pixels after background subtraction (Figure 4). A gaussian fits the distribution well but there is an excess at the positive end which we associate with the tidal debris. The colors show 1.5,2,3,4,5 sigma levels above average and correspond to the colors used in the density contours of Figure 4.

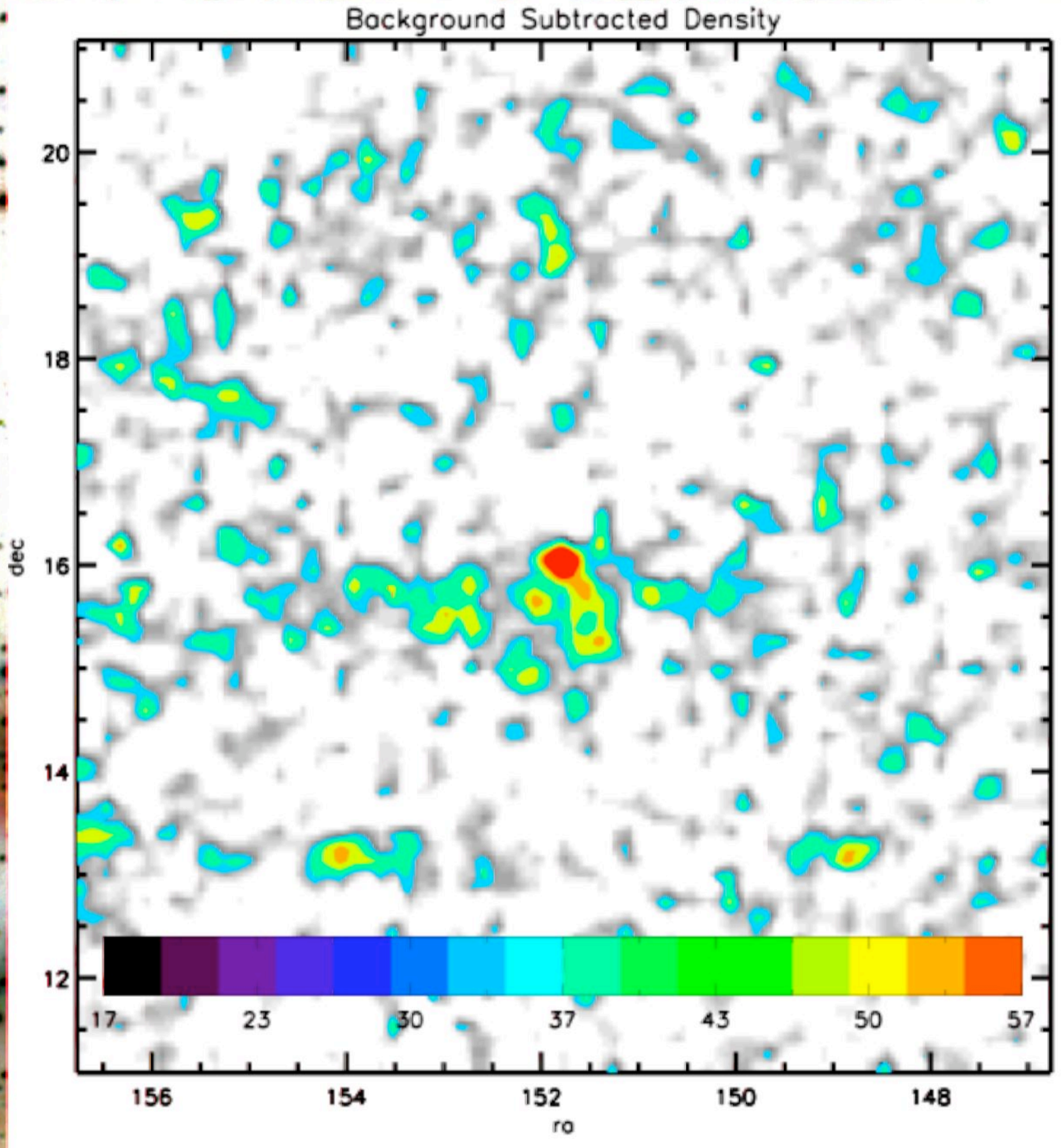

Figure 4: Position-space density produce using the optimal filter technique (Odenkirchen 2003). The colors correspond to the sigma levels described in Figure 3. Segue I is clearly visible as well as an excess of stars in its vicinity, possibly tidal tails. A significant excess runs from north to south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

Tidal Tails?

Figure 4 above shows the final density distribution determined. We find a significant number of candidate stars in the vicinity of Segue I. Part of the structure extends from north to south. 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 we identify are associated with Segue I we look at Hess diagrams and luminosity functions of the tidal debris. We observe that the tail star color-magnitude distribution is near to that of Segue I 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 diagram (Gnedin&Ostriker 1997) and find that if the cluster had formed with its given size and mass it should have already been destroyed. We need to further investigate whether or not the observed tidal structures are possible given the cluster's orbit and if the idea that it previously resided 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 I. 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 law suggesting that it is indeed being disrupted. The chi-squared of the fit is 153.9.

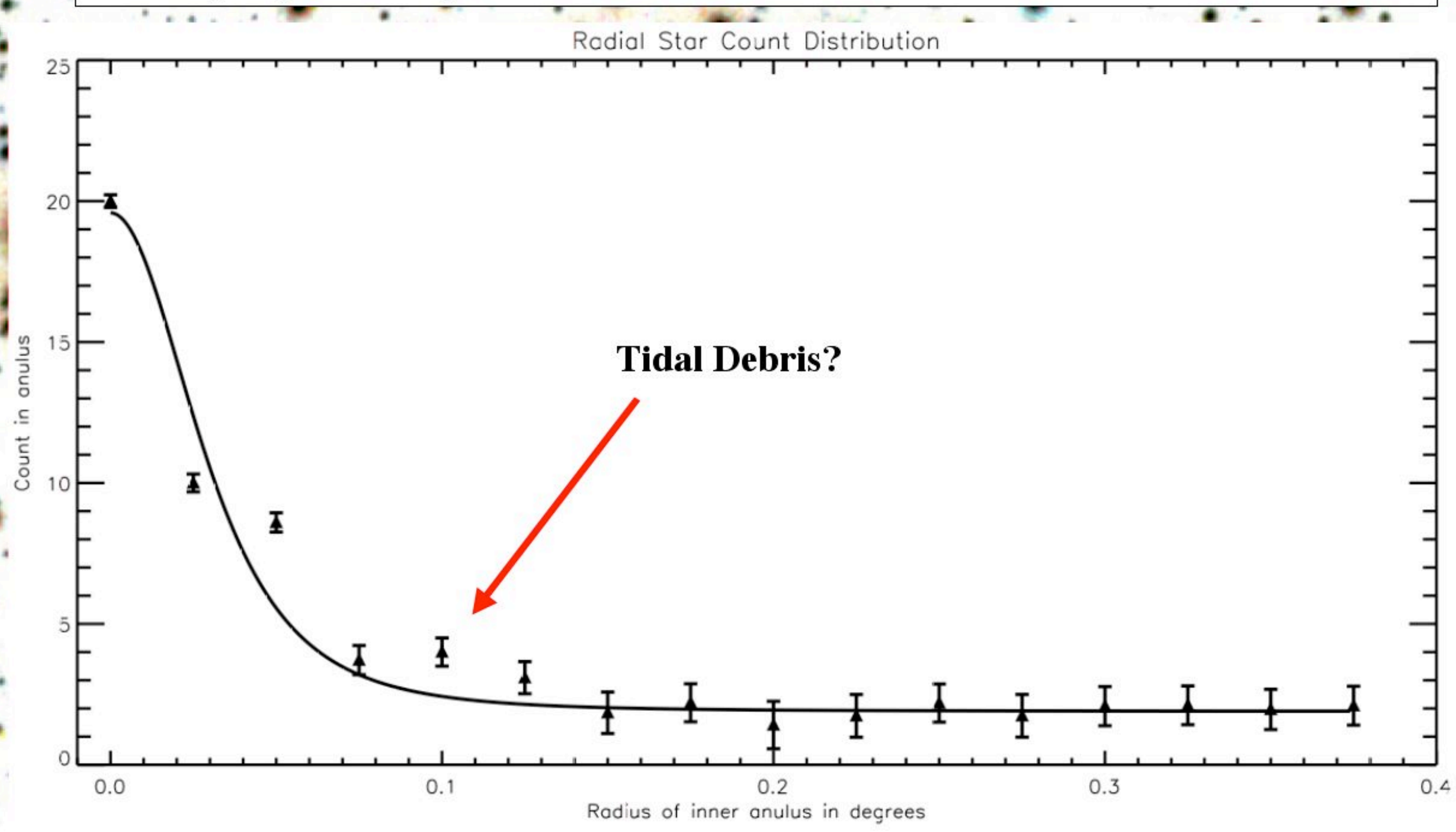

Figure 5: Star counts in successive annuli centered on Segue I. The curve shows a Plummer law fit to the data. The cluster deviates from the profile suggesting that it is tidally disrupted.

References

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Background Picture: Globular Cluster NGC290, European Space Agency & NASA, E. Olszewski (University of Arizona)