# Impact of the accretion of Sagittarius dwarf on the distribution of Milky Way's globular clusters

Arakelyan N.R., Pilipenko S.V., Sharina M.E.

Astro Space Center, P.N. Lebedev Physical Institute

Moscow Institute of Physics and Technology

Some globular clusters (GCs) were not born in the Milky Way, they got there because of partial destruction of the satellite galaxies which pass through our Galaxy. So it was interesting to find the GCs that belong to the tidal streams and understand how much the GCs belonging to tidal streams affect the distribution of GCs in our Galaxy. This paper discusses the tidal stream of Sagittarius, for which there is a large amount of data.

## The method of determining the GCs belonging to the tidal stream of Sagittarius

We take from literature data for GCs, observed and model stars belongign to the tidal stream. We determine median of distances for each star in the arms (Trailing arm and Leading arm) of tidal stream to the nearest six stars. After that we take Gcs that are closer then this median from one of the stars in the stream. Next we remove Gcs that are close to the center of the Galaxy. Those GCs that satisfy this selection criterion are added to the list of GCs belonging to the tidal stream of Sagittarius. This method applies to both: 1) obsreved stars; 2) all particles from the LM10 model. As a result, we get 2 lists (22 GCs for real data and 8 GCs for model). Then we note that 7 of 8 GCs for the model coincide with GCs from real data. As a result, we can be concluded that the 7 GCs that are present in 2 lists at the same time can be considered as clusters belonging to the stream of Sagittarius. But we will consider all 8 GCs obtained from the model as clusters belonging to the stream, since the NGC 6715 is located directly next to Sgr dSph. The remaining 15 clusters can be attributed to the list of candidates.

List of GCs belonging to the tidal stream of Sagittarius: NGC 6715, Terzan 8, Arp 2, NGC 7492, Whiting 1, Pal 5, NGC 5024, NGC 4147.

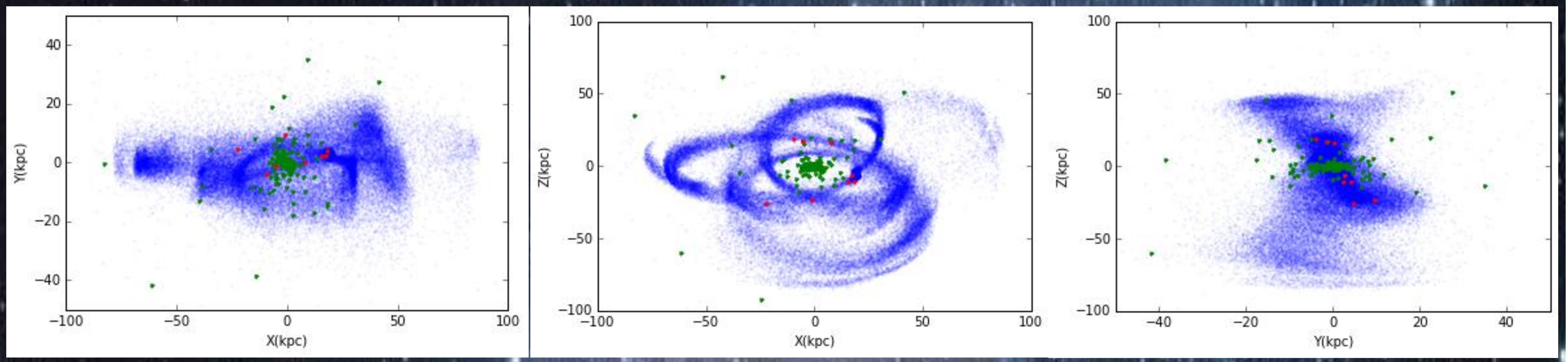



Figure 1. Distribution of the model (blue dots) of the tidal stream of Sagittarius. XYZ – Cartesian coordinates relative to the centre of the Galaxy. In the top row, the red dots show 8 GCs belonging to the stream and the green dots show the remaining 149 GCs of our Galaxy.

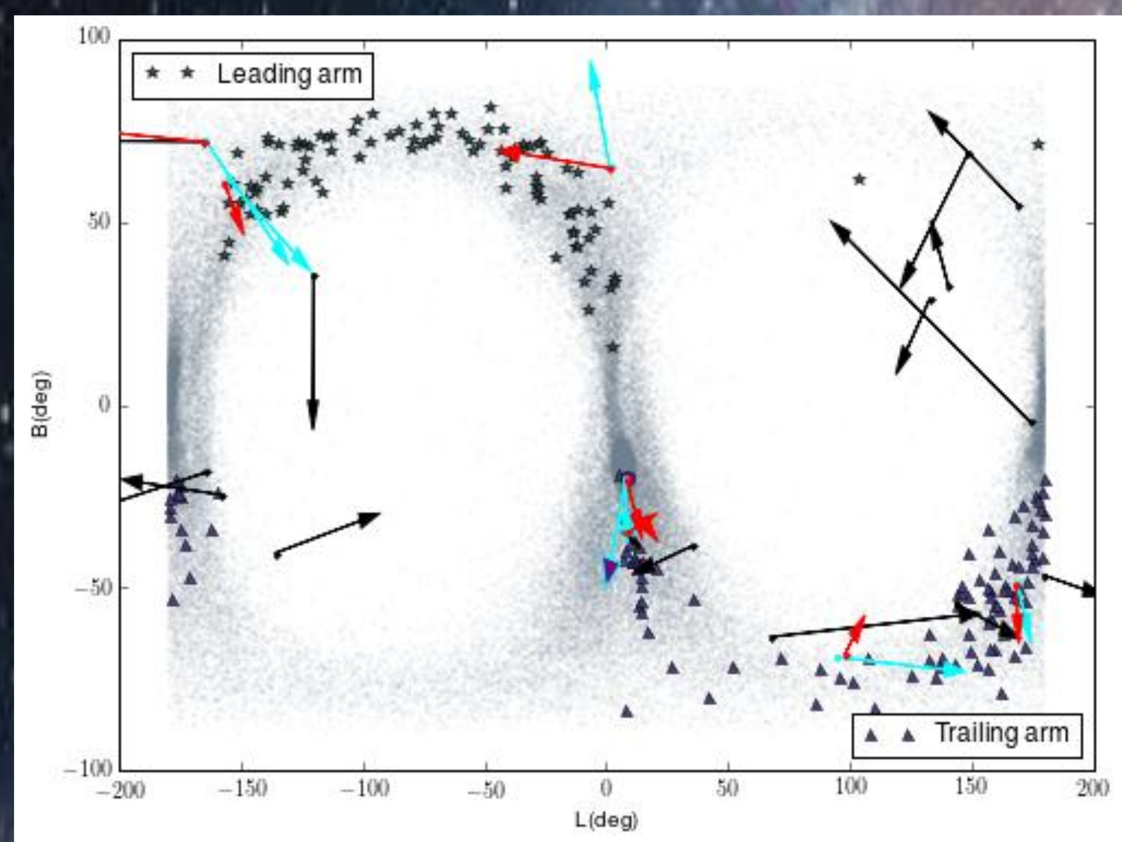



Figure 3. Map of the sky in Galatic coordinates. Gray dots represent the Sagittarius tidal stream model (LM10). Star marks show stars in the Leading arm and triangles show stars in the Trailing arm (real data). Red and black arrows show proper motions for 8 GCs belonging to the stream and for 15 candidates respectively. The cyan arrow is the average proper motion of the 6 nearest neighbors of the stars in the stream and cyan arrow with a purple tip is proper motion of Sgr dSph.

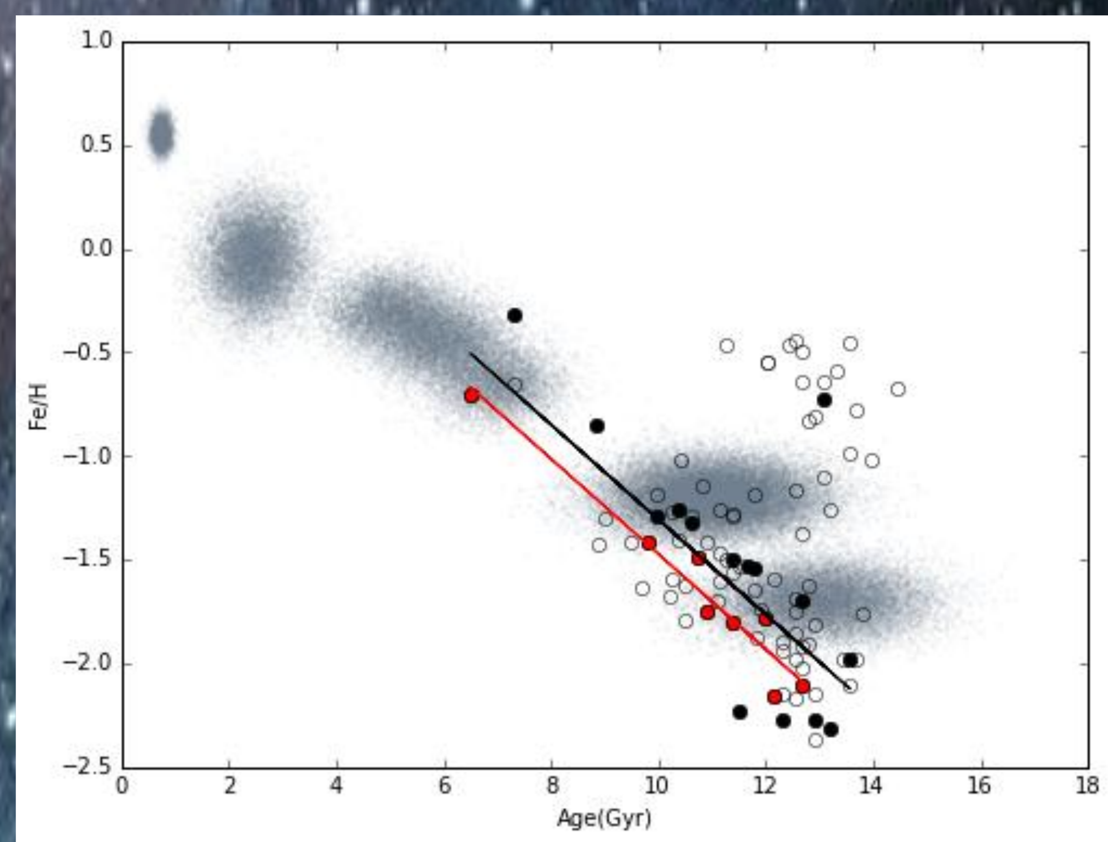
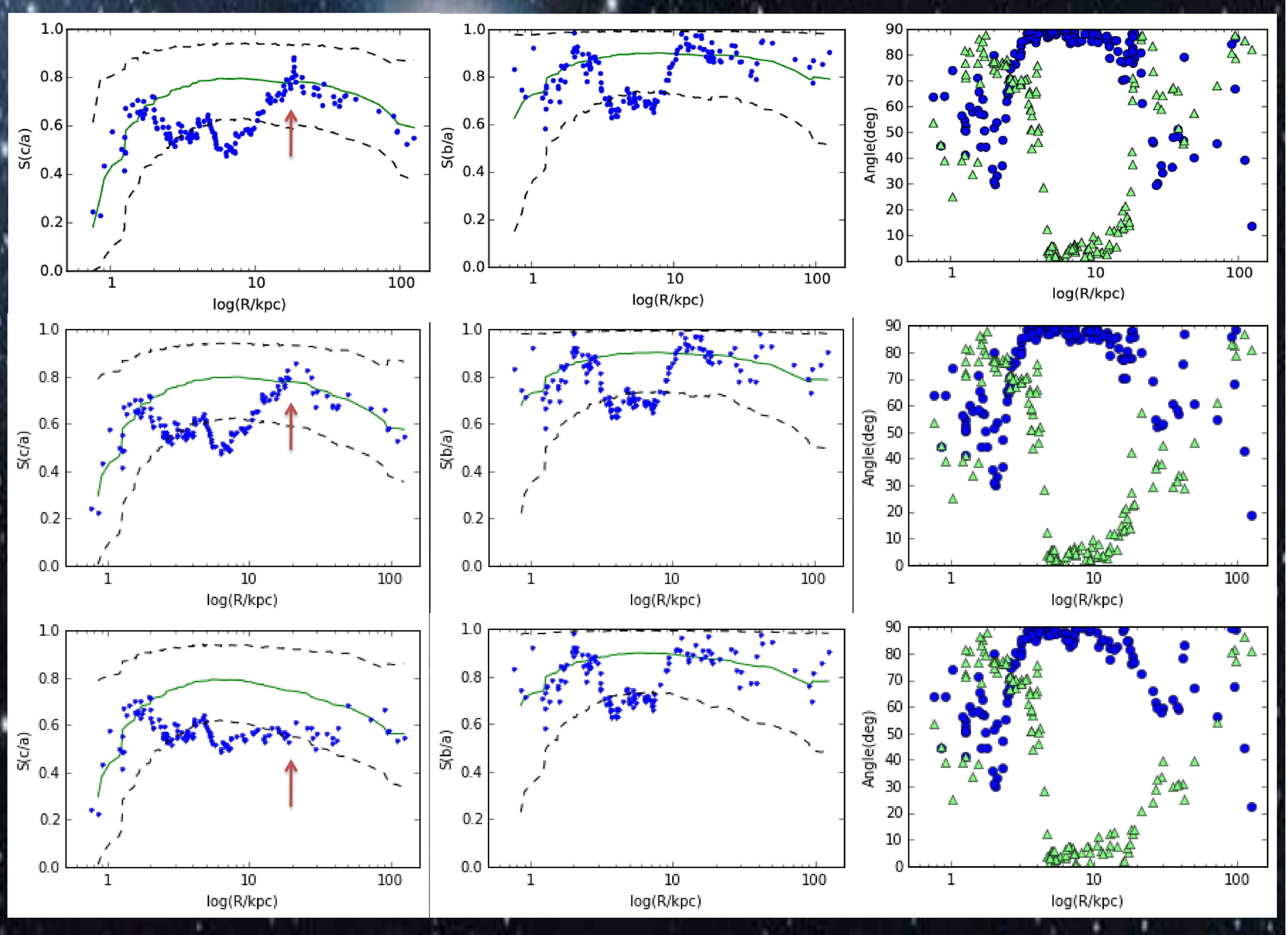



Figure 2. Age - metallicity distribution. Gray dots represent the Sagittarius tidal stream model (LM10). The red dots show 8 GCs belonging to the stream and the red line is the trend line for the 8 Gcs.. Black dots show candidates (15 GCs), respectively, the black line is the trend line for these points. Empty black circles are the remaining GCs of the Galaxy.

From the Fig. 3 and from the obtained data, we see that the proper motions of 4 clusters (NGC 7492, Pal 5, NGC 5024, NGC 4147) differ from the average proper motions of their closest neighbors of stars in the stream. This leads to the idea that out of 8 GCs, only 4 clusters (NGC 6715, Terzan 8, Arp 2, Whiting 1) belong to the tidal stream of Sagittarius, while the remaining 4 become candidates.

Figure 4. The anisotropy of GCs quantified by the inertia tensor: top row for 157 GCs; middle row without 8 GCs in the stream; bottom row without 23 GCs (8 clusters in the stream and 15 candidates). The left and middle columns show the distribution of c/a and b/a as a function of satellite Galactocentric distance, respectively. Each blue dot represents the cumulative eigenvalue ratio of these tensors computed for all galaxies interior to that position. The solid green line represents the median eigenvalue ratios for 10 000 random samples that maintain the same radial distribution as the data, but whose polar and azimuthal angle has been randomized. The dashed lines represent the ±3σ of such random distributions. The right-hand column shows the angle, measured in degrees, subtended between the Milky Way's Galactic pole and the major (blue dots) and the minor (green triangles) axis of the two inertia tensors. Green triangles close to 90◦ indicate a polar plane.




## Influence of the Sagittarius Tidal Stream

In order to check of the anisotropy of the distributions of GCs in the Galaxy quantitatively, the inertia tensor was used. The degree of the anisotropy is characterized by the ratios of the eigenvalues, c/a and b/a (a > b > c), both of which approach to 1 in case of isotropic distribution. We call the anisotropy statistically significant if the ratio of tensor eigenvalues for a real catalogues differs from the median of the random samples by more than 3σ. The anisotropy of the spatial distribution of GCs in the Galaxy is more thoroughly considered in the article MNRAS 481, 918–929 (2018). Anisotropy for all Gcs is shown in the top row of Fig. 4. There is a transition from a disc-like structure to a polar structure at 18 kpc (see red arrows). If we compare the middle and lower rows with the first row of Fig. 4, we note that the transition becomes more smooth when we remove Gcs belonging to the tidal stream and candidates.

**Conclusions:** As a result of this work, a list of clusters belonging to the Sagittarius tidal stream was obtained (8 Gcs. For 4 of 8 Gcs there is a discrepancy in the proper motions, because of this they can be considered as candidates), and a list of possible candidates (15 Gcs). The test of the spatial distribution of GCs showed that the presence of tidal stream affects the distribution of GCs and this effect is very pronounced at a distance from 15 kpc to 40 kpc.