

KINEMATICS OF STELLAR MULTIPLE POPULATIONS IN GLOBULAR CLUSTERS WITH GAIA

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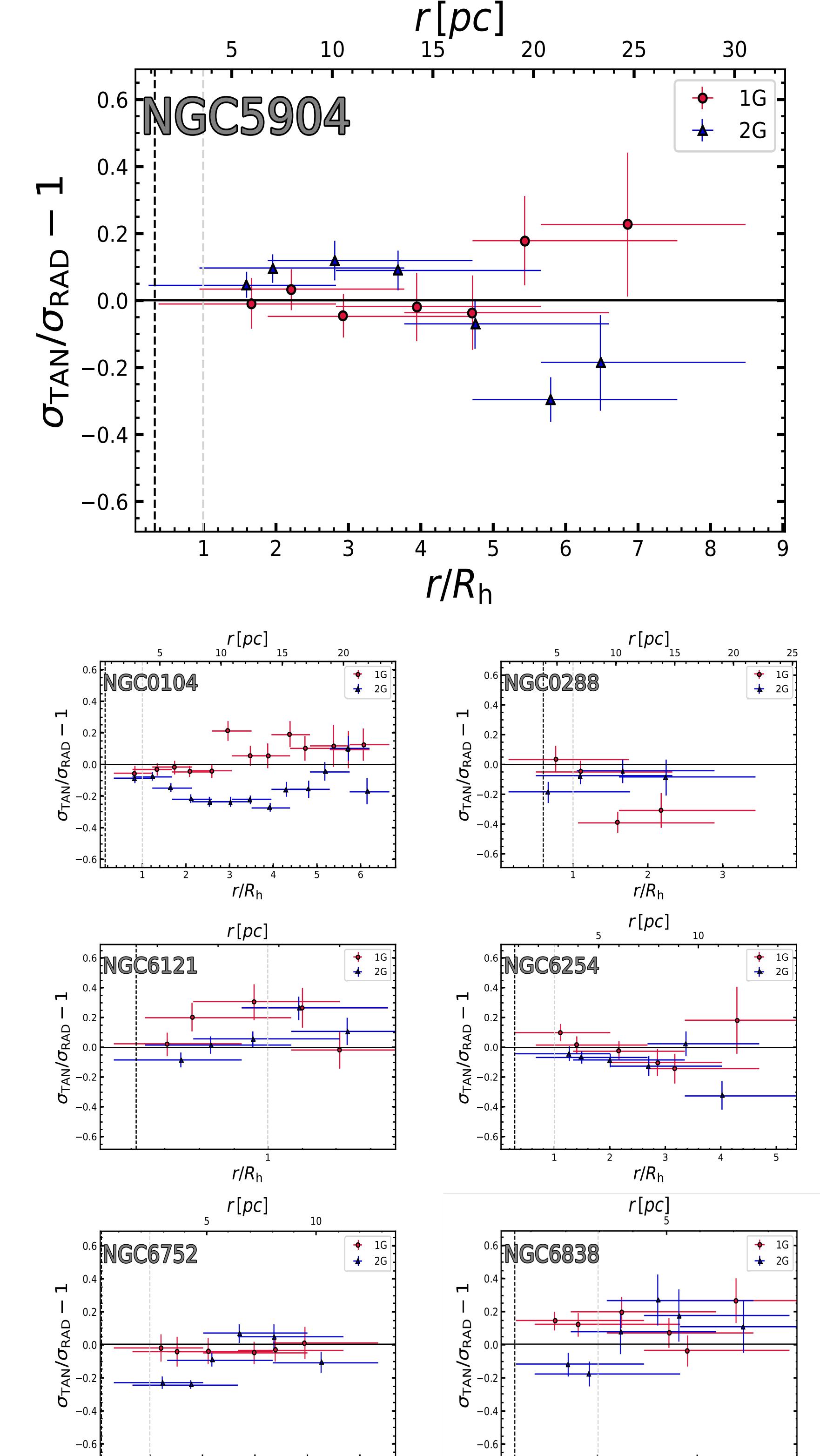
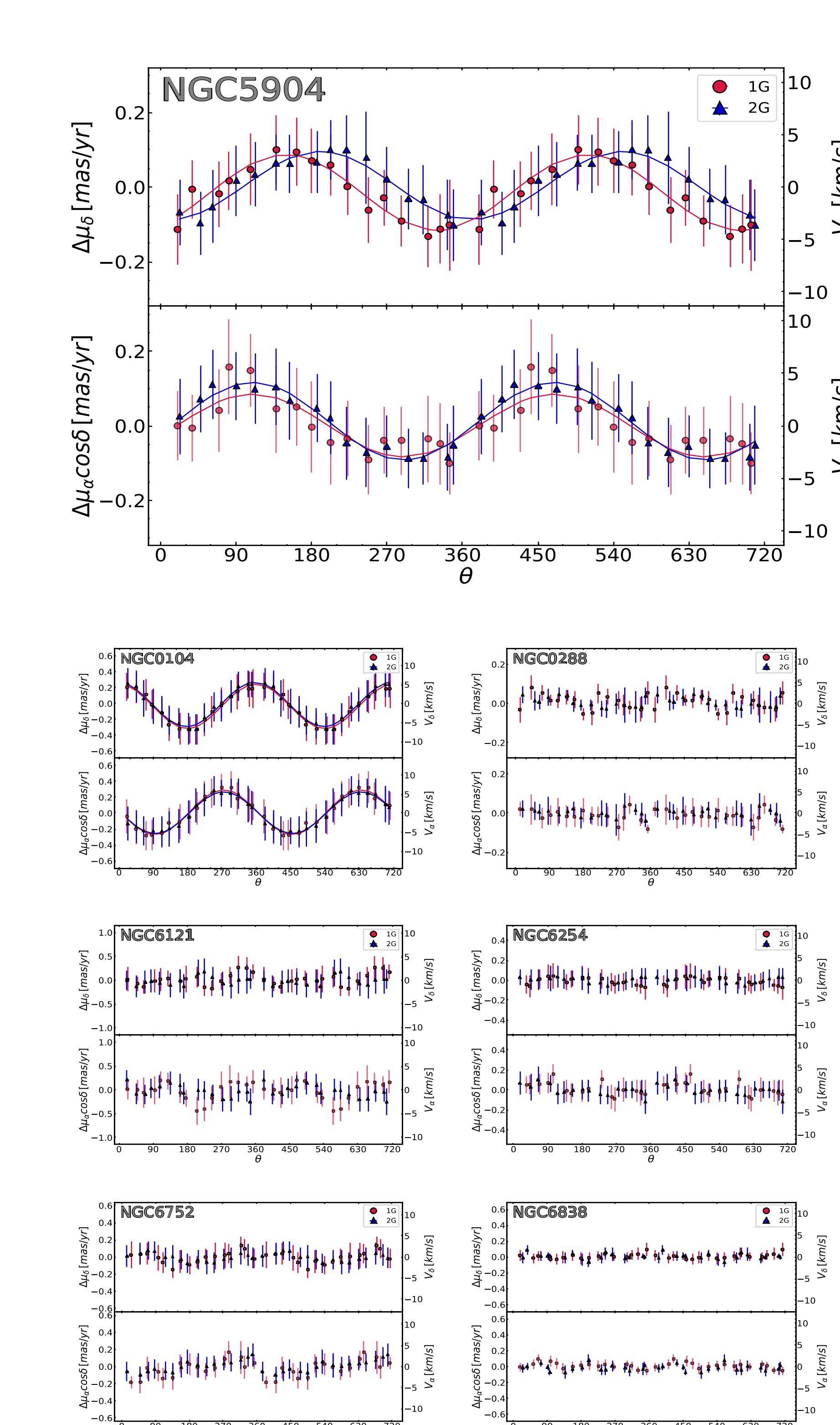
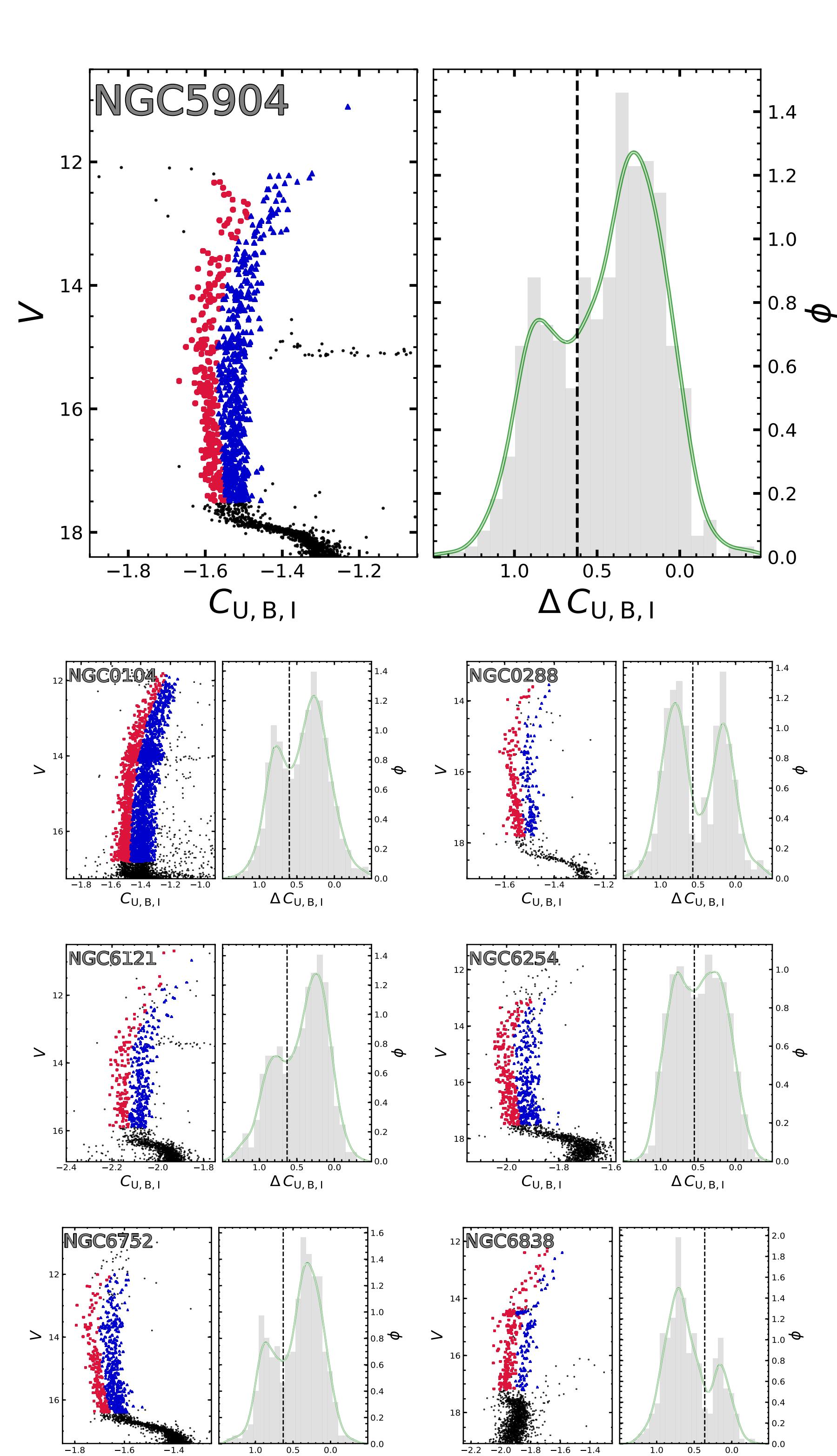
The internal dynamics of multiple stellar populations in Globular Clusters (GCs) provide unique constraints on the physical processes responsible for their formation. Specifically, the present-day kinematics of cluster stars, such as rotation and velocity dispersion, seem to be related to the initial configuration of the system. In a recent work (Milone et al. (2018)), we analyzed for the first time the kinematics of the different stellar populations in NGC 0104 (47 Tucanae) over a large field of view, exploiting the Gaia Data Release 2 proper motions combined with multi-band ground-based photometry. In this paper, we extend this analysis to six GCs, namely NGC 0288, NGC 5904 (M 5), NGC 6121 (M 4), NGC 6752 and NGC 6838 (M 71) and further explore NGC 0104.

Among the analyzed clusters only NGC 0104 and NGC 5904 show significant rotation in the plane of the sky. By separating our sample in 1G and 2G stars we find that overall these two populations exhibit a similar rotation pattern in NGC 0104. However, some hints of different rotations between 1G and 2G stars are observed in the external regions of this cluster.

Interestingly, 1G and 2G stars in NGC 5904 exhibit different rotation curves, with distinct phases. The radial components of the motion of 1G and 2G stars show different radial trends, in contrast with what is observed in most of the other clusters. There is no evidence for rotation among the selected 1G and 2G stars of the remaining clusters. The analysis of the velocity-dispersion profiles of multiple populations confirms that 2G stars of NGC 0104 show stronger anisotropy than the 1G.



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MULTIPLE POPULATIONS

In order to study the kinematics of multiple stellar populations over a large field of view, we started a project based on Gaia Data Release 2 accurate proper motions and multi-band wide-field ground-based UBVI photometry. We exploit the pseudo color $C_{U,B,I} = (U - B) - (B - I)$, which provides an efficient tool to identify stellar populations with different light-element abundance along the RGB and will be used in the following to identify 1G and 2G stars.

We determined cluster memberships of each star exploiting Gaia DR2 accurate proper motions, parallaxes and astrometric quality parameter, and we corrected our photometry for differential reddening. As shown in the panels on the right, in every clusters RGB stars define two distinct sequences, namely a first generation (1G, in red circles) and a second generation (2G, in blue triangles).

INTERNAL ROTATION

For each cluster, we studied the internal rotation of 1G and 2G stars on the plane of the sky by means of Gaia DR2 proper motions. The Figure above show the median motion for different angular regions for each cluster. NGC 0104 and NGC 5904 are the only two clusters with clear evidence of rotation among 1G and 2G stars, showing a well-defined sinusoidal pattern. The two populations of NGC5904 exhibit different rotations. The phase difference between the rotation curves of 1G and 2G stars is significant at 3 level. On the contrary, NGC 0104 is consistent with the two populations having the same rotation. However, some hints of different rotations between 1G and 2G stars are observed in the external regions of this cluster.

→ **NGC 5904**
different rotation

→ **NGC 0104**
same rotation



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→ **NGC 0104**
same rotation

ANISOTROPY PROFILE

To study the internal motion of stars as a function of the radial distance from the cluster center we divided the cluster field into different circular annuli and, for each bin we computed the median radial (μ_{RAD}) and tangential (μ_{TAN}) components of proper motions for 1G and 2G stars. We then derived the velocity dispersion profiles, σ_{RAD} , σ_{TAN} . Finally, for each cluster, we computed the quantity $\sigma_{TAN}/\sigma_{RAD} - 1$, shown in the above Figure, indicative of the degree of anisotropy of the internal motion. Besides NGC 0104, also NGC 6752 and NGC 6838 show hints of a more radially anisotropic 2G within 1-2 R_h from the cluster center. On the other hand, for NGC 6121 a more tangential anisotropic 1G within $1R_h$ is suggested. The remaining clusters are consistent with the presence of isotropic stellar systems.

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