Globular clusters with multiple stellar populations. Where they came from.

by Sharina M.E. (SAO RAS) and Shimansky V.V. (Kazan Federal University) (Russia)

Resume. *We found a group of old Galactic globular clusters (GCs) with very similar medium-resolution spectra: NGC6254, NGC7089, NGC5286, NGC6752 and NGC1904. Long-slit spectra of the studied GCs (14 in total) were taken from the library of Schiavon et al (2005) and obtained with the CARELEC spectrograph of the 1.93-m telescope in the Haute Provence Observatory. We analyzed the spectra using our method of population synthesis using stellar atmospheres models (Sharina et al. 2013, 2014; Khamidullina et al. 2014). Our method allows to derive age, [Fe/H], helium content (Y) and abundances of ~8-10 chemical elements using medium-resolution integrated-light spectra of globular clusters . A mean metallicity of the group is [Fe/H]=-1.6 dex. All five GCs are at the brightest end of Galactic GC luminosity function. They have extended blue horizontal branches and similar half-light radii Rh=2.7±0.2. Their absolute magnitudes in the V-band are in the range: from -7.7 (NGC6752) to -9.0 (NGC7089). Multiple stellar population were discovered in NGC5286 (Marino et al., 2015),NGC7089 (Young et al., 2014), NGC6752 (Dotter et al., 2015) . We study whether they may be associated with Galactic satellites and streams.*

Massive Galactic GCs with extended horizontal branches (EHBs) and multiple stellar populations show spatial distribution, kinematic and structural properties distinct to that of other Galactic GCs (Lee et al. 2007). They might be formed in old Galactic building blocks and accreted during assembling process of the halo. Galactic GCs are divided in two groups - 1) old objects with almost the same age and no age-metallicity relation (AMR) and 2) younger clusters following the AMR of the Sgr dSph (Marin-Franch et al., 2009, M-F09). Five selected GCs with similar spectra have metallicity z = 0.0004, helium content Y = 0.30 and log(Age) = 10.10, according to our analysis. Chemical composition of the GCs is very similar according to our analysis and high-resolution spectroscopic studies (see **Table 1**). All these GCs were classified as old halo objects by M-F09. At the same time, they correspond well the age-metallicity relation of the Sgr dSph and CMa dwarf galaxies (Forbes & Bridges, 2010).

Table 1. Elemental abundances in dex from literature high-resolution spectroscopic studies of red giant stars in five Galactic GCs and the result of our medium-resolution analysis (last row).

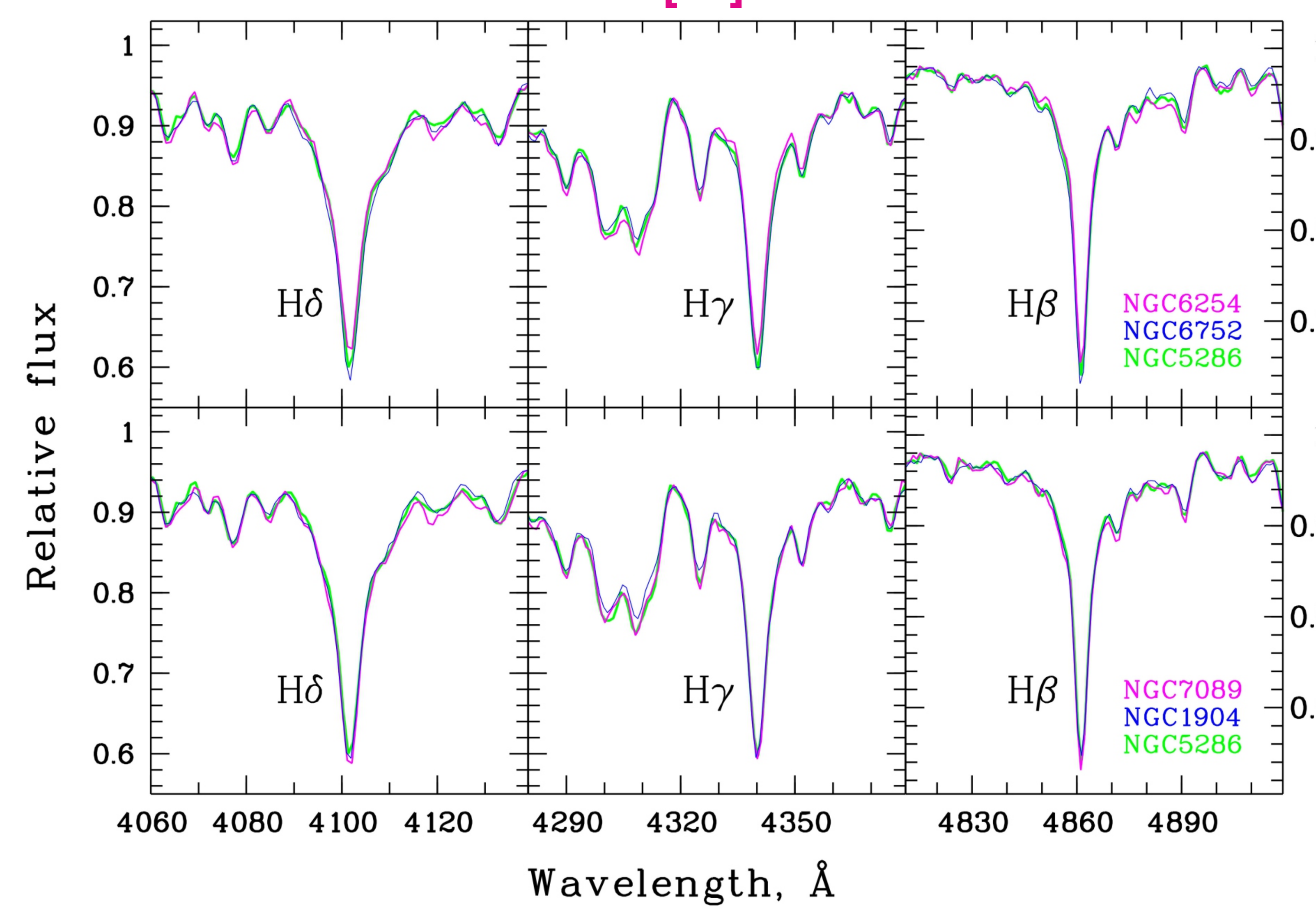
GC ID	[C/Fe]	[N/Fe]	[O/Fe]	[Na/Fe]	[Mg/Fe]	[Si/Fe]	[Ca/Fe]	[Ti/Fe]	[Cr/Fe]	[Mn/Fe]
NGC5286 (Mar15)	–	–	0.44±0.22	0.34±0.22	0.55±0.22	0.40±0.22	0.31±0.22	0.33 ±0.22	-0.05 ±0.22	-0.44±0.22
NGC1904 (R14)	–	–	0.10±0.19	0.32±0.25	0.26±0.07	0.28±0.03	0.22±0.04	0.22±0.10	-0.28±0.14	–
NGC6752 (R14)	-0.45±0.37	0.93±0.63	0.26±0.25	0.32±0.26	0.38±0.15	0.47±0.19	0.31±0.09	0.20±0.11	-0.13±0.12	–
NGC7089 (R14-C, Y14 (r-only))	-0.62±0.14	–	0.42±0.16	0.06±0.23	0.38±0.08	0.40±0.01	0.28±0.02	0.17±0.02	-0.06±0.03	-0.41±0.05
NGC6254 (R14)	-0.77±0.37	1.01±0.45	0.23±0.24	0.17±0.27	0.44±0.13	0.28±0.07	0.33±0.11	0.26±0.12	0.01 ±0.15	–
NGC5286 (our)	**0,02±0.15**	**0.35±0.20**	**0.50±0.30**	**0.20±0.20**	**0.38±0.10**	**--**	**0.25±0.10**	**–**	**0.25±0.20**	**0.40±0.20**

Three of the five GCs were accociated with the Sgr and Monoceros stream in the literature (Bellazzini et al. 2003, Penarrubia et al. (2005): NGC1904 (MS), NGC5286 (MS),NGC7089 (Sgr. Str.). Table 2 shows the comparison of the properties of these GCs with the corresponding parameters for the the prograde motion model (pro1) of the Monoceros stream (MS) by Penarrubia et al. (2005, their Figures 8 and 11). It is seen that all the properties of NGC6254, NGC6752 and NGC7089, except for a few, are consistent with that of the MS. The galactocentric distances of NGC6254 and NGC6752 look too small. The proper motions of NGC6254 and NGC7089 are large. Note, however, that NGC6254 and NGC6752 are fainter then the other objects and locate closer to the Galactic plane. If the objects experienced interaction with the Galactic disk , their orbits might have been changed.

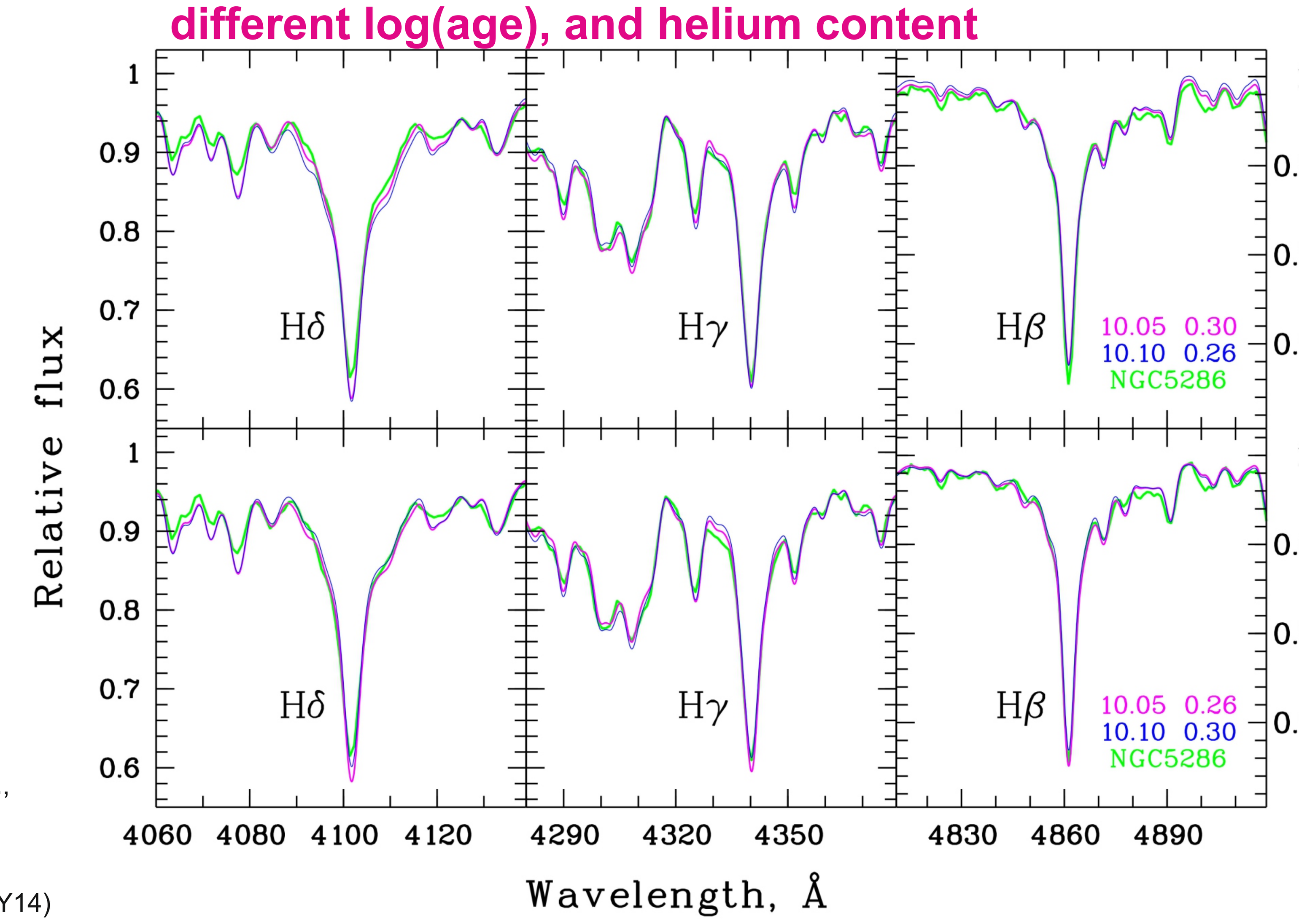
Table 2. Properties of the selected Galactic GCs. The data were taken from the catalogues by Kharchenko et al. (2013, K13) and Harris (2010, H10). We estimated approximately the ranges of b, D_{GC}, V_r, μ_l, μ_b, X,Y, for the Monoceros stream (MS) debris using the prograde motion model (pro1) by Penarrubia et al. (2005, P05) (Figures 8 and 11 in P05). The colums contain the following data: (2) Galactic longitude and latitude (l,b) from H10, (3) the range of b at a given l of each GC approximated using the MS model, (4) distance from the Sun (H10), (5) the range of distances from the Sun for the MS debris at a given l of each GC, (6) heliocentric radial velocity from H10, (7) the range of heliocentric radial velocities for the model MS at a given l of each GC, (8) proper motions in l and b from K13 for the GCs, (9) the range of l and b at a given l of each GC for the model of MS, (10) Galactic distance components X, Y and Z in the Galactocentric coordinate system from H10, (11) the range of Y at a given X of each GC for the model of MS (2ve consider the nearest part of the stream (Fig.11, top panel in P05)), (12) Horizontal-branch ratio $(HBR = (B-R)/(B+V+R))$ from H10, (13) metallicity from H10, (14) King-model central concentration from H10, $c = log(r_t/r_c)$.

GC ID	l, b [degr.] (2)	b^{MS} [degr.] (3)	$D_{\odot}$ [kpc] (4)	$D_{\odot}^{MS}$ [kpc] (5)	V_r [km/s] (6)	V_r^{MS} [km/s] (7)	$\mu_l*, \mu_b(\mu^{err})$ [mas/yr] (8)	μ_l*, μ_b^{MS} [mas/yr] (9)	X, **Y**, Z [kpc] (10)	$\mathbf{Y}^{MS}$ [kpc] (11)	HBR (12)	[Fe/H] [dex] (13)	c (14)
NGC1904	227.23,-29.35	-40÷45	12.9	5÷40	205.8	0÷200	-1.01, 0.30(0.43)	-7÷-1, -3÷7	-15.6,**-8.3**,-6.3	**-15÷23**	0.89	-1.60	1.70
NGC5286	311.61, 10.57	-25÷20	11.7	11÷40	57.4	-50÷140	-4.60, 0.21(0.83)	-7÷1, -2÷3	-0.4,**-8.6**,2.1	**-26÷10**	0.80	-1.69	1.41
NGC6254	15.14, 23.08	-27÷20	4.4	15÷50	75.2	-120÷90	-10.65,-0.75(0.36)	-6÷1, -2÷2	-4.1,**1.1**,1.7	**-26÷10**	0.98	-1.56	1.38
NGC6752	336.49,-25.63	-25÷25	4.0	15÷50	-26.7	-80÷150	-5.19,-0.44(0.62)	-6÷1, -2÷2	4.7,**-1.4**,-1.7	**-26÷10**	1.00	-1.54	2.50
NGC7089	53.37,-35.77	-30÷25	11.5	12÷40	-5.3	-200÷70	-0.05,-6.24(0.42)	-6÷1, -2÷2	-2.4,**7.5**,-6.7	**10÷30**	0.96	-1.65	1.59

Comparison of the hydrogen lines in the spectra of 5 Galactic GCs from [16]



Comparison of the spectrum of NGC5286 [16] with the model spectra of [Fe/H]=-1.85 and different log(age), and helium content



References

1 Bellazzini M. and Ferraro F., 2003, AJ, 125, 188
2 Bertelli, G.; Nasi, E.; Girardi, L.; Marigo, P., 2009, A&A, 508, 355
3 Castelli F., Kurucz R. L., 2003, Proceedings of IAU Symp.210: Modeling of Stellar Atmospheres, Eds. N. Piskunov et al., Poster A20
4 Chabrier G., 2005, The initial mass function 50 years later Astrophysics and Space Science Library, 327, 41
5 Forbes D.A., Bridges T., 2010, MNRAS, 404, 1203
6 Khamidullina, D. A.; Sharina, M. E.; Shimansky, V. V.; Davoust, E., 2014, Astrophysical Bulletin, 69, 409
7 Khamidullina D. A., Sharina M. E., Shimansky V. V., Davoust E., 2014, Baltic Astronomy 23, 260
8 Milone A.P. et al.,2013, ApJ 767, 120
9 Lee Y.-W. et al., 2007, ApJ 661, L49
10 Mackey A.D. & van den Bergh S., 2005, MNRAS, 360, 631
11 Marin-Franch A. et al.,2009, ApJ, 694, 1498
12 Marino A.F. et al., 2015, MNRAS, 450, 815 (Mar15)
13 Penarrubia et al., 2005, ApJ, 626, 128 (P05)
14 Roediger J.C., Courteau S., Graves G. and Schiavon R.P, 2014, ApJS, 210, 10 (R14)
15 Sharina M. E., Donzelli C. J., Davoust E., Shimansky V.V., Charbonnel C., 2014, A&A, 570, 48
15 Sharina M.E., Shimansky V. V., Davoust E., 2013, Astronomy Reports, 57, 410
16 Shiavon R.P., Rose J.A., Courteau S., MacArthur L.A., 2005, ApJS, 160, 163
17 Yong D. et al., 2014, MNRAS, 441, 3396 (Y14)