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Chemical composition of stars in Ruprecht 106

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Abstract. High resolution spectra of 9 stars belonging to the globular cluster Rup 106 have been used to determine their chemical composition. The results reveal that Ruprecht 106 exhibits abundance anomalies when compared to galactic globular cluster of similar metallicity. The chemical composition of these stars is similar to what is found in Dwarf spheroidal galaxies favoring the hypothesis that Rup 106 has not been formed in our Galaxy.

Key words. Stars: abundances – Stars: atmospheres – Stars: Population II – Galaxy: abundances – (Galaxy:) globular clusters

1. Introduction

Ruprecht 106 is a globular cluster located at about 20 kpc from the Sun and about 5 kpc above the Galactic disk. Its Galactic coordinates place it along the great circle in the sky that contains the Magellanic Stream, which could suggest a tidal capture from the Magellanic Clouds (Lin & Richer 1992, and references therein).

It appeared to be the first discovered young metal-poor globular cluster in our Galaxy (Buonanno et al. 1990, 1993) .

The first spectroscopic studies of Ruprecht 106 were done by Da Costa et al. (1992) and François et al. (1997) using low to medium resolution spectroscopy and gave [Fe/H] values in the range –1.76 to –1.60, in fair agreement with the Buonanno et al. (1990, 1993) estimates ([Fe/H] = -1.90 ± 0.20). Kaluzny et al. (1995) produced a CMD for Rup 106 which is in agreement with that of Buonanno et al. (1990) but is more consistent with a metallicity of [Fe/H] ≥ -1.60 dex. The only determination of the metallicity based on high resolution stellar spectra has been done by Brown et al. (1996, 1997).

2. Observations and data reduction

These observerations have been carried out at the ESO Paranal Observatory, using the UVES high-resolution échelle spectrograph (Dekker et al. 2000) available on the Kueyen telescope (VLT-UT2). We successfully observed 9 stars in the globular cluster Ruprecht 106 using the star identification and the (V, B–V) photometry from Table 2 in the paper of Buonanno et al. (1990). For each of our targets, we took several individual exposures ranging from 35 min to 1 h 10 min, depending on the target's brightness (typically 1–2 exposures for the brightest targets and 4 exposures for the faintest ones).

In our observations with UVES, we used the dichroic beamsplitter DICHR#1 with crossdispersers CD#2 and CD#3 centered respectively at 390.0 and 580.0 nm, which resulted in a spectral coverage of ∼330.0–

450.0 nm for the blue spectra and ∼480.0–680.0 nm for the red ones. The slit width was set to 1.0″ for both arms, yielding a spectral resolution of $R \equiv \lambda/\Delta\lambda \gtrsim 40\,000$ at the central wavelengths. The slit lengths were standard for our chosen setup (8.0″ in the blue arm and 12.0″ in the red arm) so that an optimal sky substraction could be achieved. We used the standard 225 kHz readout mode with a 1×1 binning and low gain.

The individual spectra were reduced using the standard UVES ESO CPL pipeline. Individual spectra of the same star were then co-added and normalized. The final products reach signal-to-noise values that spread from ∼20 per pixel in the blue spectra to ∼80 per pixel in the red spectra. Typical S/N values are shown in Table 1, as well as radial velocities measurements. The latter were determined by cross-correlating detected Fe I absorption lines with our theoretical line list, and are given with the barycentric correction for direct comparison with the reference value of -44 km s^{-1} from the *Catalogue of Milky Way Globular Cluster Parameters* published by Harris (1996).

3. Abundance analysis

For our abundance analysis, we have used the OSMARCS model atmospheres.These models were originally developed by Gustafsson et al. (1975) and improved and updated over the years e.g. by Plez et al. (1992) or Edvardsson et al. (1993). The most recent improvements and the grid used in these codes have been described in Gustafsson et al. (2003). The solar abundances are from Grevesse & Sauval (2000).

3.1. Temperature and gravity

First guesses of the effective temperature were determined from photometric data available in the litterature that we used as an input for the equations of Alonso et al. (1999) for the calibration of effective temperatures of giant stars.For each star, we used an initial triplet(Teff, logg, vt) and a model metallicity of $[\mathrm{Fe/H}]_{mod}$ = -1.45 dex.

Starting with these first guesses, we then used the classical method that consists in iteratively fixing the temperature by minimizing the slope of the [Fe I/H] abundance ratio as a function of the excitation potential χ_{ex}.

The surface gravity was initially guessed from the position of the stars in the CMD, and used as an input parameter for our computations. For a given $(T_{\mathrm{eff}})_i$, we forced the ionization equilibrium between neutral and single ionized lines of Fe I – Fe II and Ti I – Ti II. This was done by iteratively varying the $\log g$ and comparing the abundance ratios [Fe I/H] to [Fe II/H] and [Ti I/H] to [Ti II/H]. Like for Fe I, for the other species we kept only unblended lines with equivalent widths in the range 20 mÅ $\leq W_\lambda \leq$ 160 mÅ. The final gravity was chosen when an equilibrium was found for both Fe and Ti at the same time.

3.2. Abundances

Line detection and equivalent widths measurements were done with `Fitline`, a semi-automatic code developped by P. François and based on the genetic algorithms of Charbonneau (1995). `Fitline` performs spectrum normalization, line and blends detection, radial velocity measurements, and Gaussian fits of the detected lines.

Chemical abundances of single lines were computed using these equivalent widths and the model atmospheres described earlier in this paper and an up-to-date version of the `ABOND` code by Spite (1967).

Spectral synthesis of neutron-capture elements or very strong lines with possible saturation (e.g. Mg I) was performed using the latest version of the `FANTOM` synthetic spectrum code also originally described in the paper of Spite (1967).

4. Results and conclusion

The detailed abundance ratios found for each star will be published in a forthcoming paper. In this poster, we focus on the mean abundance of the globular cluster computed as the mean value of the abundance found for our sample of 8 stars. In Fig 1 the mean [α/Fe] found

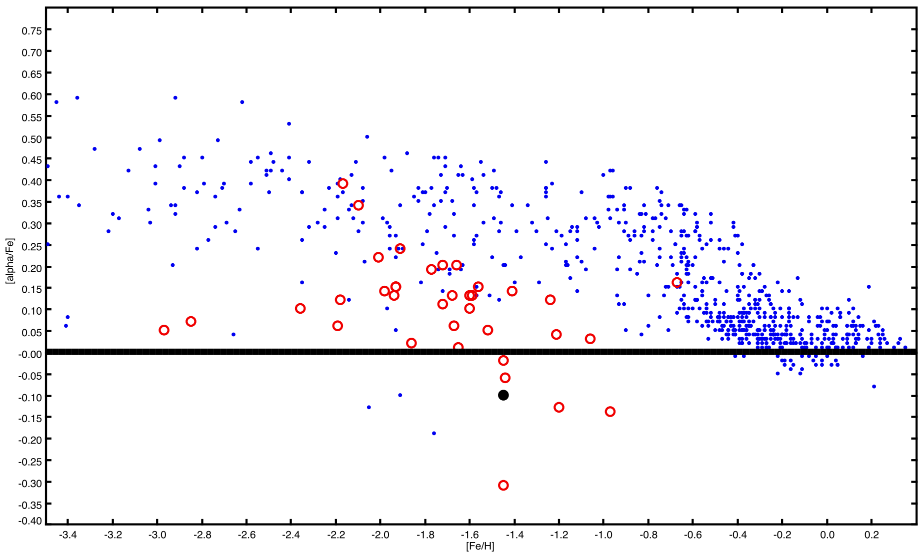

Fig. 1. [α/Fe] ratio as a function of [Fe/H] . The black dot represents the result found for Ruprecht106 in this study. Small blue dots are data for field and globular cluster stars. Large red open circles are results for stars in Dwarf Spheroidal galaxies.

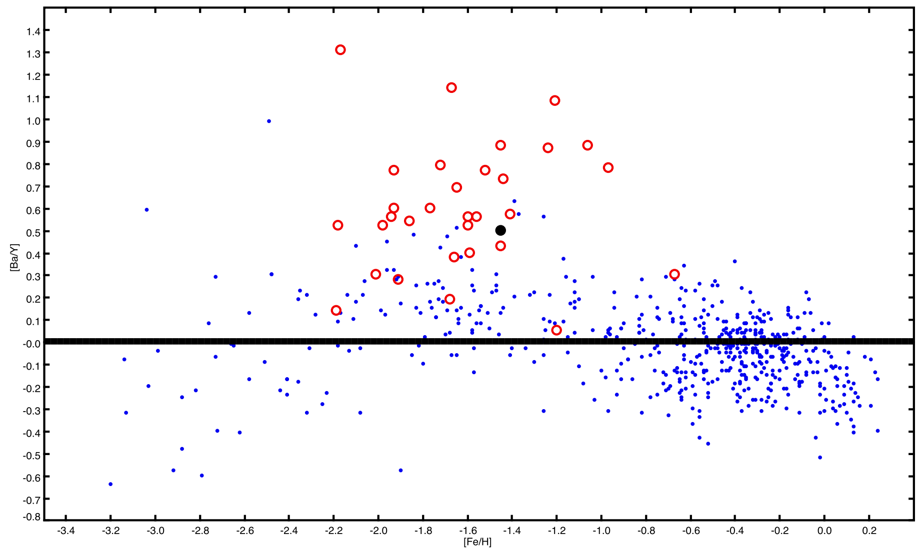

Fig. 2. [Ba/Y] ratio as a function of [Fe/H] . Symbols are the same as in Fig. 1.

Table 1. Typical measured signal-to-noise ratios and estimated barycentric radial velocities.

Star #	S/N @ 420 nm	@ 550 nm	@ 620 nm	$v_{\rm rad}$ (km s^{-1})
1614	20	62	80	–39.6
2004	19	65	88	–43.2
1951	23	71	82	–40.2
970	21	69	77	–43.0
676	22	66	81	–42.8
1863	27	61	78	–42.2
2032	24	65	74	–42.7
1445	23	60	70	–44.8
801	19	45	59	–44.3

for Ruprecht 106 is represented as a black circle. The blue dots represent field and globular cluster stars. The large red open circles are the values obtained for a sample of dSph galaxies. The data sample has been taken in the article of Venn et al. (2004). Our analysis confirms a low [α/Fe] ratio, as found by Brown et al. (1996, 1997) on a smaller sample of stars. Fig 2 gathers the mean [Ba/Y] value for Ruprecht 106 together with literature data for field stars, globular cluster stars and dSph stars. These two figures clearly show that the chemical composition of Ruprecht 106 is similar to what is found in Dwarf spheroidal galaxies. Ruprecht 106 has very probably an extragalactic origin and may have been caught by the Milky Way during a past encounter with a dSph galaxy where the globular cluster has been formed. Detailed kinematical and dynamical studies would be necessary to confirm this hypothesis.

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