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METAL-POOR GLOBULAR CLUSTERS OF THE GALACTIC BULGE

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RESUMEN

Estamos realizando estudios sobre los cúmulos globulares pobres en metales en el bulbo galáctico. Estos objetos parecen ser muy viejos y podrían ser vestigios de los primeros objetos en la Galaxia. Presentamos observaciones de alta resolución realizadas con VLT-UVES, VLT-FLAMES y Gemini-PHOENIX, y un estudio de los patrones de abundancia de estos cúmulos globulares.

ABSTRACT

We are carrying studies on the metal-poor globular clusters of the Galactic bulge. These objects appear to be very old, and might be relics of the first objects in the Galaxy. High resolution observations carried out with VLT-UVES, VLT-FLAMES and Gemini-PHOENIX are presented, and the abundance pattern of these globulars is studied.

Key Words: Galaxy: bulge — globular clusters — stars: abundances

1. GENERAL

Among the 17 globular clusters located within 5° and 4 kpc of the Galactic center, five of them are moderately metal-poor ([Fe/H]≈ −1.0) together with a Blue Horizontal Branch (BHB).

The five clusters are: NGC 6558 (Rich et al. 1998; Barbuy et al. 2007); HP 1 (Ortolani et al. 1997; Barbuy et al. 2006); Al 3 recently discovered by Ortolani et al. (2006); NGC 6522 (Barbuy et al. 1994; Terndrup et al. 1998; Shara et al. 1998); the 5th of such clusters is NGC 6540 (Bica et al. 1994), of more difficult study due to a strong differential reddening.

Their characteristics of having a BHB combined to a moderate metallicity around [Fe/H]≈ −1.0, indicate that they should be very old (Lee et al. 1994). As a matter of fact, NGC 6522 is confirmed to be among the oldest globulars, as can be seen, e.g., in Meissner & Weiss (2006). The latter authors find an age in the range 13.9 to 16.1 Gyr if isochrones by Salaris & Weiss (2002) are used, and 12.2 to 15.4 Gyr is the BASTI isochrones by Pietrinferni et al. (2004) are adopted.

Therefore such clusters might be representative of the oldest stellar population in the Galaxy.

In order to derive abundance patterns of these clusters, we carried out detailed spectroscopic analyses of individual stars of HP 1, NGC 6558 and NGC 6522, as reported below.

2. OBSERVATIONS

The following observing programs were dedicated to the study of these clusters: (a) in 2000/2001 we have obtained VLT-UVES spectra (R=60,000) of two V≈17 stars of HP 1; (b) VLT-FLAMES spectra (R=22,000) were obtained for 5 stars of NGC 6558, and 8 stars of NGC 6522, within the program to observe 1000 bulge stars, as described by Zoccali et al. (2006); (c) PHOENIX@Gemini-South was used to obtained infrared high resolution spectra (R=50,000) of 5 stars in HP 1 and 5 stars in NGC 6558.

3. RESULTS

Abundances of α-elements O, Mg, Ca, Ti produced in SNII give clues on formation scenarios of globular clusters in bulges.

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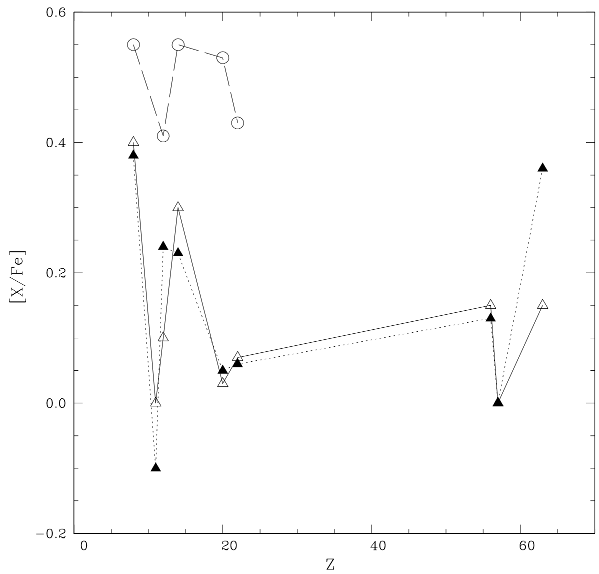

Fig. 1. Abundance pattern of HP 1 (open triangles), NGC 6558 (filled triangles) compared with the more metal-poor bulge globular Terzan 4 (open circles).

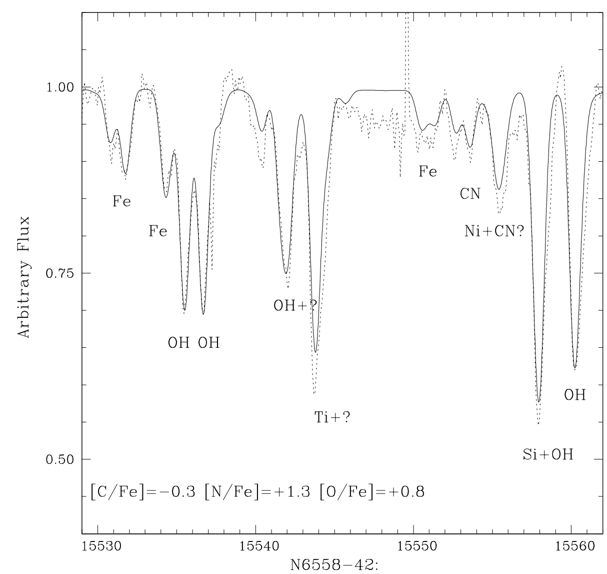

Fig. 2. Gemini-Phoenix spectrum of NGC 6558:F42 with synthetic spectrum overplotted.

The analyses of HP 1 and NGC 6558 presented in Barbuy et al. (2006, 2007) have shown that the abundance pattern of these elements is different from classical results for more metal-poor clusters such as Terzan 4, analyzed by Origlia & Rich (2004), as well as halo stars. This is illustrated in Figure 1, where it is clear that the α-enhancements of our two clusters are not as pronounced as in more metal-poor stars.

From our observing program (c), a preliminary calculation shows on the other hand, a high oxygen, and a very high nitrogen abundance for one star in NGC 6558, as shown in Figure 2. The infrared calculations have been done in the literature in two ways: by adopting the Einstein coefficients directly, or by assuming that the electronic, vibrational and rotational components are separable. A more careful investigation on the differences between such calculations is needed before a final conclusion can be made about abundances. We also point out differences in Calcium abundances between the optical and infrared. Such studies are under way in our group.

4. DISCUSSION

Colour-magnitude diagrams of moderately metal-poor globular clusters, combined to a blue HB indicate that these clusters are probably very old. Therefore they could be the most ancient relics in the Galaxy. A study of their abundance pattern can give clues on the earliest generation of stars, and the early formation of globular clusters. A possible formation scenario could be early star-forming sub-systems that formed the galactic nucleus, through both dissipational and dissipationless mergers, as predicted in ΛCMD high resolution simulations (e.g. Diemand et al. 2005; Moore et al. 2006).

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