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Research Note

Super metal-rich clusters G 158 and G 177 in M 31: clues on the inner bulge/disc transition*

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Abstract. The star clusters G 158 and G 177, located at projected distances smaller than 1.5 kpc from the semi-stellar nucleus of M 31, show spectra extreme in absorption-line strengths, comparable to those from the nuclei of giant ellipticals or from the M 31 nucleus itself. A synthesis has been performed of the integrated spectrum of the Galactic globular cluster 47 Tucanae ([Fe/H] = −0.7) with a solar neighbourhood stellar library: as expected, lines of elements like Mg and Fe are stronger in the solar metallicity model. In turn, 47 Tuc presents a blue-violet blanketing excess which, from a detailed study of the spectral residuals (47 Tuc-model) using laboratory molecular patterns, was found to arise from molecules containing C, N and O. In this Research Note we discuss, at a much higher metallicity level, a very similar blanketing excess observed in G 177 with respect to G 158. We suggest that G 177 is an inner bulge cluster, whereas G 158 is an inner disc one, in analogy with the difference found between the halo cluster 47 Tuc and the model which simulates an old cluster with disc stars. In this scenario the [O/Fe] overabundance, known to exist in metal poor Galactic halo stars as compared to the disc, would persist through the bulge and inner bulge. The inner disc stars might have in common with solar neighbourhood ones the solar CNO/Fe ratio.

Key words: galaxies: individual M 31 – clusters: globular – galaxy: bulge – galaxy: disc – galaxies: stellar content of – spectroscopy – stars: abundances

1. Introduction

The inner parts of our Galaxy are difficult to study in the optical, owing to heavy dust absorption, further complicated by differential reddening and depth effects. From this point of view, the M 31 bulge is a more favourable target. In the Galaxy, only a few relatively transparent regions like the Baade window together with some absorbed star clusters allow one to probe the metal-rich bulge population (Frogel 1990; Ortolani et al. 1990). In the Andromeda galaxy many star clusters are seen projected close to the very nucleus (Battistini et al. 1980) and some of them might be associated with the stellar population in the inner bulge or perhaps even with the inner disc. It is obvious that a detailed spectroscopic study of these clusters is very important and might provide new clues to the understanding of the bulge/disc transition, a difficult task in our own Galaxy.

Recently Jablonka et al. (1991; hereafter JAB91) have undertaken such a study, observing G 158 and G 177 and other M 31 bulge clusters, as well as more distant disc and halo clusters in that galaxy. The CCD spectral observations were carried out with the CFHT 3.6 m telescope and are discussed in detail in that paper. A characteristic of this new data set is its broad wavelength range (3500–10 000 Å). Accordingly, the increased number of observational constraints, spectral equivalent widths and continuous energy distribution, allows one to infer the cluster age, metallicity and reddening with more confidence (JAB91), as compared to previous spectroscopic studies of M 31 clusters, which were restricted to the visible range, mostly in the blue (Burstein et al. 1984; Tripicco 1989). As discussed in JAB91, G 158 and G 177 exhibit very strong-lined spectra, comparable to that from the M 31 nucleus or those from giant elliptical galaxies. Consequently, if super metal-rich star clusters do exist, they are to be identified with G 158 and G 177, although the absolute value of their metal content is still under discussion. They are more strong-lined than NGC 6553 or NGC 6528 in the Galaxy which, as pointed out by Bica & Alloin (1986) are already more metallic than globular clusters usually called metal-rich like 47 Tuc and NGC 6356.

In detail, however, the G 158 and G 177 spectra differ from each other in the sense that G 158 is somewhat bluer and that some spectral lines and molecular bands are noticeably different. The purpose of this letter is to clarify the nature of this spectral difference at such an extremely high global metal content.

In Sect. 2 we analyse this result in comparison to a similar difference found by santos Jr. et al. (1991; hereafter SBD91) in a population synthesis of 47 Tuc using a library of solar metallicity stars. In Sect. 3 we discuss the implications of the results on the possibility of a CNO overabundance with respect to Fe, in the bulges of M 31 and of the Galaxy, as it is the case for [O/Fe] in the Galactic halo (Barbuy 1988 and references therein). Inferences are made on the inner bulge/disc transition. The conclusions are summarized in Sect. 4.

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* Based upon data collected at the CFHT (Hawaii) partly supported by CNRS and upon data collected at the ESO telescopes (La Silla)

2. Spectral differences between G 158 and G 177

We have displayed in Fig. 1 the spectra of G 177, G 158, 47 Tuc and a globular cluster model built with solar metallicity stars. The observed spectra were smoothed to match the resolution (20 Å) of the stellar library, which was used in the model (Gunn & Striker 1983). The spectrum of 47 Tuc was obtained with CCD detectors at ESO (La Silla) at the 1.52 m and the 2.2 m telescopes, respectively, for the visible/near-infrared and blue-violet regions which were connected by means of the IDS spectrum in Bica & Alloin (1986). It is clear that metallic features are much stronger in G 177 and G 158 than in 47 Tuc and its model. The model cluster has heavy element lines such as Mg I and Fe I stronger than those observed in 47 Tuc, as expected from the iron deficiency of the latter. An extensive discussion on the reliability of the model cluster is provided in SBD91.

The spectra of G 158 and G 177 have been corrected for a foreground reddening $E(B-V)=0.04$, and G 158 was corrected in addition for the M 31 internal reddening $E(B-V)_i=0.23$ (JAB91). Towards M 31, we use a low Galactic foreground reddening, $E(B-V)=0.04$, which has been derived from three galaxies in the field off the H I disc of M 31 itself (JAB91). Would this value be raised to that adopted in previous studies, $E(B-V)=0.10$, it would not affect much our conclusions, which rely upon the difference spectrum (G 177 − G 158). The cluster 47 Tuc has been corrected for $E(B-V)=0.04$ (SBD91 and references therein).

The M 31 cluster G 158 shows a flux excess in the blue relative to G 177, as does also the model with respect to 47 Tuc. Some spectral-feature differences can be noticed also between G 158 and G 177, in particular the weaker TiO bands in the former.

The difference spectra (G 177 − G 158) and (47 Tuc-model) are shown in Fig. 2. Similar patterns are observed, although we are dealing with supermetallic clusters in the first case and subsolar (47 Tuc) or solar (model) ones in the second case. The (47 Tuc-model) residual spectrum was synthesized by SBD91 with a base of absorption patterns from 28 molecules in the blue–violet region built from Pearse & Gaydon's catalogue (1965). The molecules CO and SiN appear to be the major absorbers causing the residuals, followed by other molecules also involving CNO elements. Figure 2 suggests that the same absorbers could be responsible for the blanketing excess of G 177 relative to G 158.

3. CNO overabundance in G 177 relative to G 158?

The possible CNO blanketing excess in the blue–violet region of G 177 with respect to G 158 is corroborated by the weaker TiO bands in the red and near-infrared ranges in the latter (Fig. 1). A possible interpretation of these results is that G 177 behaves like Galactic halo giants, which are known to have an oxygen to iron ratio higher than the solar one (Barbuy 1988). This appears to be the case also for the halo/bulge transition cluster 47 Tuc relative to the model with disc stars (SBD91). A natural extrapolation of this trend would be that bulge/inner bulge stars and star clusters behave in the same way.

The unusual spectrum of G 158, which has a continuum distribution resemblance (at a higher metallicity) with the solar metallicity model, suggests that the CNO/Fe ratio is comparable to that of the Sun.

The scenario described above would indicate that G 177 is a genuine inner bulge cluster while G 158 belongs to an inner disc

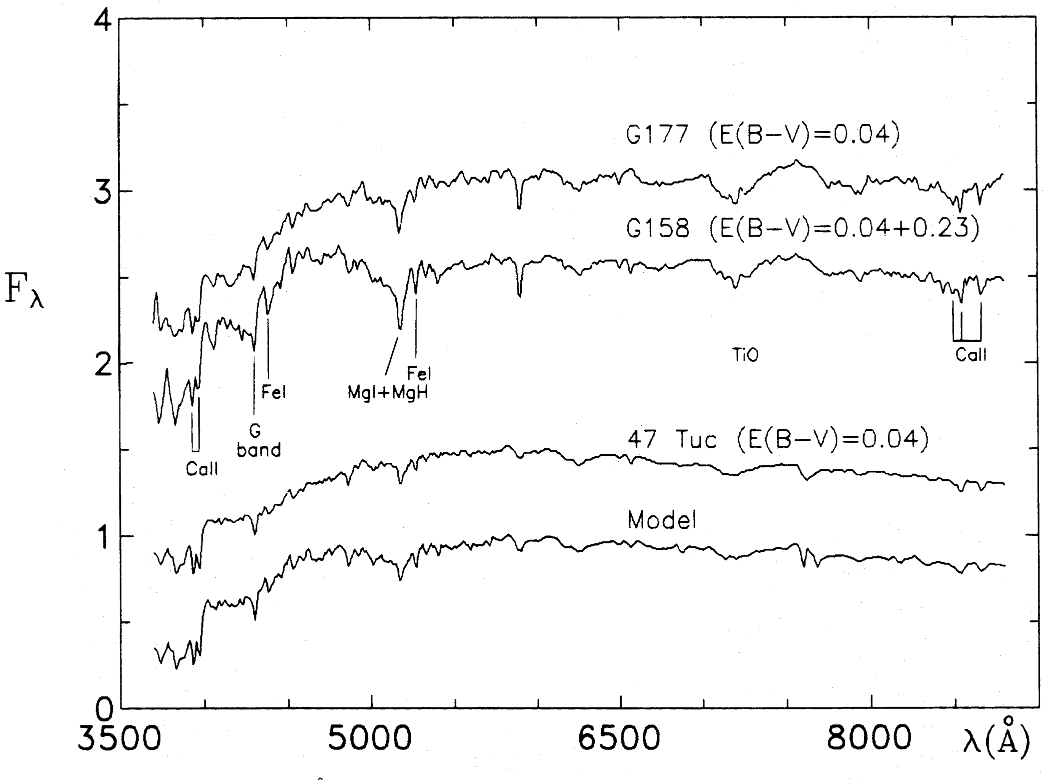

Fig. 1. Spectra, smoothed to a 20 Å resolution, of two high metallicity clusters in M 31: G 177 and G 158. For comparison, we show the spectrum of 47 Tuc and its synthetic model from a stellar library with solar abundance. The reddening correction applied to each object is indicated in terms of $E(B-V)$. The spectra are normalized to the continuum value $F(5870\,\text{Å})=1$ and, for visualisation purpose, have been shifted one from the other

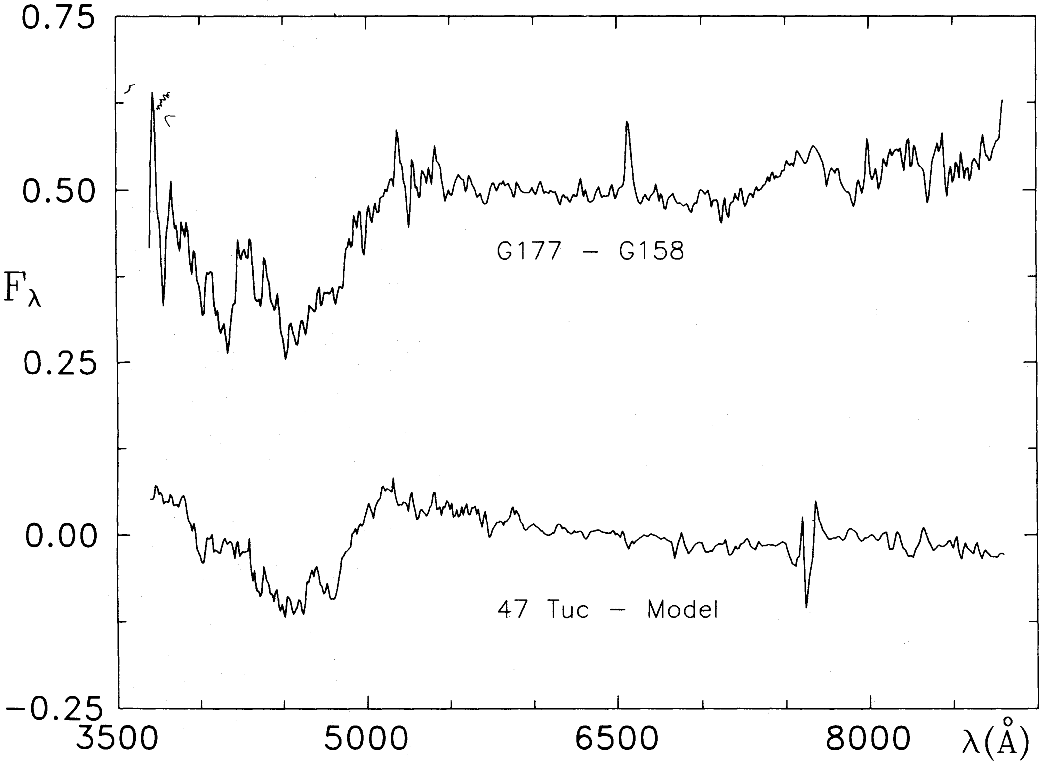

Fig. 2. The difference spectra (G 177–G 158) and (47 Tuc − model)

stellar population. It is not possible to measure an age difference between them from the star cluster base presently available as the age step of the base is large at old ages (Bica & Alloin 1986). Indeed, the age difference might be as large as several Gyr, before inducing the significant spectral changes which would lead us to conclude that G 158 is an intermediate age cluster. The fact that G 158 suffers a significant internal reddening in M 31, while G 177 does not, is compatible with the conclusion that the former might belong to the disc.

Further studies of star clusters in the M 31 central parts are needed to improve our understanding of the transition between the inner bulge and the disc components.

4. Conclusions

The central super metal-rich star clusters G 158 and G 177 in M 31 appear quite different from each other in a detailed spectroscopic analysis (JAB91). The stronger blue-violet blanketing of G 177, exacerbated in the difference spectrum (G 177 − G 158), is similar to that of 47 Tuc relative to its spectral model built from solar neighbourhood disc stars. The (47 Tuc-model) residuals have been well reproduced with absorption laboratory patterns of molecules containing CNO elements (SBD91), suggesting that the [O/Fe] anomaly of metal-poor halo giants persists in bulge objects. In this scenario G 177 would be an inner bulge star cluster and G 158 an inner disc one in M 31.

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