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# Spectroscopic studies of selected F-G supergiants[1]

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## 1. Summary

Yellow supergiants are very important objects to study. With their large luminosity and small age, they are very useful in the study of galactic structure. An empirical relation has been developed between their absolute magnitudes and the strengths of OI triplet in 7774Å region (Osmer 1972, Arellano Ferro, et al. 1991), that helps in determining their distances. Secondly, the temperature range of the stars is such that lines of many important elements are present but the spectrum is not excessively crowded and hence the line strengths can be measured accurately. Further, the temperatures are not so high that non-LTE calculations become mandatory. Chemical analysis of reasonable accuracy can be done even with the assumption of LTE. These objects have therefore been used in the study of the chemical evolution of the Galaxy as well as tracers of spiral arms in the Galaxy. The metallicity derived for them is also used for calibrating the photometric metallicity indices.

In the past few years, another important feature has emerged from the study of high galactic latitude F-G supergiants. It is found that many of them are not massive supergiants but are in reality highly evolved low-mass stars though their spectra resemble those of yellow supergiants. Many of them are surrounded by circumstellar material and hence show large infrared fluxes. For a few of them, envelope remnants are detected via the observations of molecular lines and submillimeter continuum.

A high galactic latitude may not always imply a large distance above the galactic plane and the actual distance is hard to determine for field objects. Detection of infrared excess to ascertain if the star is an evolved object has been a very important but not a final clue towards their evolutionary status. One may recall that the well-known post-AGB star BD +39° 4926 studied by Kodaira, et al. (1970) does not have infrared excess.

[1]Based on observations obtained at the European Southern Observatory, La Silla; VBO, Kavalur and McDonald Observatory

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Then it would appear that the most reliable way of ascertaining the evolutionary status was by determining accurate abundances. These abundance determinations not only help in ascertaining the evolutionary status of these objects, but can also be used for calibrating photometric metallicity indices in various photometric systems.

The detailed spectroscopic studies of these objects have yet another important aspect. In addition to metallicity, accurate temperatures and gravities are also derived. A good fraction of F-G stars of high galactic latitude are in reality subgiants or dwarf stars (misclassified as supergiants in the Bright Star Catalogue) as reported by Mendoza and Arellano Ferro (1993). That makes the detailed spectroscopic study of field F-G supergiants (high galactic latitude or not) a very important task. The spectroscopically derived gravities can serve in identifying the different luminosity classes.

We, therefore, decided to investigate a large sample of F-G star and at first stage, have completed the analysis for seven supergiants. They are HR 3229 (HD 68752, G5Ib/II), HR 4114 (HD 90853, F2II), HR 4912 (HD 112374, F3Ia), HR 5165 (HD 119605, G0Ib-IIa), HR 7671(HD 190390, F1III), HR 8470 (HD 210848, F7II) and HD 114520 (F2II).

We used high dispersion spectra of these objects and the model atmospheres technique to derive the atmospheric parameters and chemical compositions of these stars. Those details are given in a more comprehensive paper that would shortly appear in PASP (Giridhar et al. 1997). This paper also describes the use of spectroscopically derived metallicity in calibrating the photometric metallicity index.

Our spectroscopically derived gravities show that two of the stars studied in this paper, HR 5165 and HD 114520, are not supergiants as classified in the Bright Star Catalogue but are subgiants belonging to the solar neighbourhood. In our sample, HR 3229 and HR 8470 display solar abundances and the derived gravities support the bright giant luminosity class ascribed to them. HR 4114, HR 4912 and HR 7671 have abundances significantly different from those of young supergiants of galactic disk.

**Table 1.** Important [X/Fe] for HR 4114 and other high galactic latitude objects of similar metallicity.

| Star | [Fe/H] | [C/Fe] | [Mg/Fe] | [Ca/Fe] | [S/Fe] | [Y/Fe] | Ref. |
|---|---|---|---|---|---|---|---|
| HR 4114 | -0.31 | +0.10 | -0.02 | +0.12 | +0.27 | +0.02 | 1 |
| 89 Her | -0.41 | +0.15 | +0.39 | -0.03 | +0.15 | +0.01 | 2 |
| HD 161796 | -0.31 | +0.20 | +0.71 | -0.05 | +0.72 | -0.23 | 2 |
| HD 70379 | -0.31 | +0.42 | +0.01 | -0.17 | +0.34 | +0.40 | 3 |

References:

1. Present work 2. Luck et al. (1990) 3. Reddy (1996)

HR 4114 shows a moderate metal deficiency by a factor of 2 or so. The Fe-peak elements Sc, Ti and Cr show deficiency of similar magnitude. The light elements C and Mg also show deficiency of similar magnitude. Sulphur is less deficient, almost solar. Significantly, this star has the largest infrared flux in our sample. As one can see in Table 1, the relative abundances of C, α elements Mg, S and Ca and those of heavy s-process elements like Y relative to Fe found for HR 4114 bear good resemblance to those found in 89 Her, HD 161796 and HD 70379. The [Fe/H] for these objects is in -0.3 to -0.4 range. All the three objects mentioned above have significant infrared fluxes and their [C/Fe], [N/Fe], [O/Fe] (the last two ratios are not given in Table 1) cannot be accounted by CN processing that occur at RGB evolution and indicate a more advanced evolutionary stage, most likely post AGB state. However, 89 Her and HD 161796 do not show s-process enrichment that should follow third dredge-up but HD 70379 shows mild s-process enrichment.

We have presented in Table 2, the [X/Fe] for several elements for HR 4912 and a few post-AGB stars. HD 44179 is a very metal-poor post-AGB star.

**Table 2.** Important [X/Fe] for HR 4912 and a few well-known post-AGB stars and halo giants.

| Star | [Fe/H] | [C/Fe] | [N/Fe] | [O/Fe] | [S/Fe] | [Ca/Fe] | [Zn/Fe] | [s/Fe] | Ref. |
|---|---|---|---|---|---|---|---|---|---|
| HR 4912 | -1.10 | -0.17 | +0.50 | +0.84 | +0.30 | +0.02 | +0.24 | -0.30 | 1,2 |
| SAO 239853 | -0.90 | +0.49 | +0.60 | +0.72 | +0.49 | +0.40 | +0.20 | -0.20 | 3 |
| IRAS 180955+2704 | -0.82 | +0.32 | +0.76 | +0.59 | +0.50 | +0.08 | +0.07 | -0.60 | 4 |
| HD 47603 | -1.70 | +1.70 | 1.70 | +1.60 | +1.30 | +0.70 | +0.40 | -0.20 | 5,6 |
| HD 44179 | -3.30 | +3.30 | +3.30 | +2.90 | +1.70 | | | | 3 |

References:

1. Luck, Lambert and Bond (1983) 2. This work 3. Van Winckel (1995) 4. Reddy (1996) 5. Luck and Bond (1984) 6. Bond and Luck (1987)

It is obvious from Table 2 that the abundance pattern of HR 4912 is quite similar to those of oxygen-rich post AGB stars SAO 239853 and IRAS 180955 +2704. Much larger values of [S/Fe] and [Zn/Fe] are found in post-AGB stars with C/O >1. Some of this carbon-rich post-AGB stars show s-process enrichment.

HR 7671 is indeed a post-AGB star and is metal poor by a factor of 10 to 15. This deficiency is shared by all Fe-group elements Ca, Sc, Ti, Cr, Fe and Ni. This star is discussed in detail by Luck, Bond and Lambert (1990) who reported it to be slightly deficient in C and O, enhanced s-process elements and an unusually high Li abundance of log$\varepsilon$ (Li)=2.3. This star does not possess very large infrared flux.

We find that two stars of our sample HR 5165 and HD 114520 are not yellow supergiants of high galactic latitude as considered earlier, but are subluminous giants belonging to the galactic disk. HR 4114 has abundances similar to those of post-AGB stars 89 Her, HD 161796 and HD 70379. This star has the largest infrared flux in our sample although H$\alpha$ suggests only very mildly a shell structure. It is a potential post-AGB candidate, but a more detailed investigation is required to confirm it.

The abundance pattern of the semi-regular variable HR 4912 is very similar to that found in oxygen-rich post-AGB stars.

HR 3229 and HR 8470 are young bright giant members of the galactic disk.

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