THE [O/Fe] RATIO IN HALO, DISK AND BULGE STARS

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1. Introduction

The oxygen-to-iron ratio in the different stellar populations is a tracer of the chemical enrichment by supernovae of types II and I: SNII/SNI along the Galaxy lifetime, given that the bulk of oxygen is produced and ejected by massive stars ($M > 10$ $M_\odot$), whereas the bulk of iron is produced by SNI of intermediate masses. Otherwise, the O overabundances are generally accompanied by α-elements (^{24}Mg, ^{28}Si, ^{40}Ca, ^{48}Ti) overabundances (Wheeler et al, 1989).

The classical scenario of the time lag between the enrichment by massive stars, which can be considered to start immediately after the formation of the first stars, and that by the intermediate mass type I SNae, which starts to occur at about 10^8 years later, leads to the following characteristics for the different stellar populations: (a) [O/Fe] > 0 in the old stars; (b) [O/Fe] grows to the solar value from the old disk to the young stars.

2. Observational evidences

Only a few oxygen lines are available in stellar spectra, as reported by Lambert (1978). The OI triplets at λ 615.6, .7, .8 nm, λ 777.1, .4, .5 nm, λ 844.57, .64, .67 nm, λ 926.0, .2, .5 nm are commonly used to derive the oxygen abundances in dwarf stars, whereas the forbidden [OI] λ 557.7 nm, λ 630.03 nm and λ 636.38 nm are used in giants. The use of different lines to derive O abundances in giants and dwarfs, is due to the fact that the forbidden lines disappear in dwarfs, and more so in hotter ones, whereas the OI triplets disappear in giants.

2.1 Halo

Oxygen overabundances in the halo, first obtained by Conti et al. (1967), were confirmed by all subsequent work: Lambert et al. (1974), Sneden et al. (1979, SLW79), Clegg et al. (1981), Leep & Wallerstein (1981), Barbuy (1983), Luck & Bond (1985), Gratton & Ortolani (1986, GO86), Barbuy (1988, B88), Barbuy & Erdelyi-Mendes (1989, BE89), Abia & Rebolo (1989, AR89), Gratton (1990, G90), Sneden et al. (1990, SKP90), Spiesman & Wallerstein (1991, SW91), Bessell et al. (1991, BSR91), besides the preliminary work by Edvardsson et al. (1991), Tomkin et al. (1991, TLLS91), Spite & Spite (1991).

Disagreements occur however regarding the [O/Fe] absolute value in the halo.

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A particularly striking discrepancy is seen between data by GO86, B88, SKP90, SW91, who used the [OI] lines in giants, and those by AR89 who used OI lines in dwarfs - see Figure 1. Two main evidences, shown in fig. 1, are to be pointed out: (1^o) a disagreement between data by AR89 and results also derived using the OI triplet lines in dwarfs by SLW79, G90 and TLLS91; (2^o) the results by G90 and SW91 based on [OI] lines in dwarfs, and those by BSR91 using OH bands in dwarfs, where $[O/Fe] \approx +0.4$ and $+0.5$ respectively, eliminate the suggestion by AR89 of a conversion of a large fraction of O into N, occurring from the dwarf to the red giant stage. This possibility is largely unlikely, in any case, since overabundances of N in halo giants are only moderate (Kraft et al., 1982).

These evidences leave only two possibilities:

The OI 777 nm triplet give systematically higher oxygen abundances than the other lines: this possibility has been quantified by Kiselman (1991), through non-LTE calculations of the OI triplet for a grid of stellar parameters. The results (his fig. 3) is not able to reconcile results from the permitted oxygen lines with those from the forbidden lines. Kiselman (1991) does not succeed to reproduce even the solar lines adequately, and therefore recommends not to use such lines.

(2) Stellar parameters used are not appropriate, and the agreement of oxygen abundances derived from the forbidden and permitted lines is sensitive to the stellar parameters. One example of the influence of stellar parameters is illustrated by the case of the halo star HD 19445: adopting stellar parameters by Spite & Spite (1978, SS78) and by AR89, (θ_{eff}, log g, [M/H]) = (0.87, 4.0, -1.9) and (0.86, 4.5, -2.3), respectively, the result is that in order to bring the synthetic oxygen line computed with parameters by AR89 to the intensity of that for the SS78 parameters, an O overabundance of $[O/Fe] = +0.55$ is necessary.

Halo field versus globular clusters stars: The oxygen abundances in the halo field stars using the [OI] line result is an approximately constant value, cf. B88. In globular clusters giants, however, a variation seems to be present (Pilachowski et al., 1983; Brown et al., 1990). This may be a very important information regarding a possible self-enrichment of globular clusters, but further studies are still necessary for such inferences.

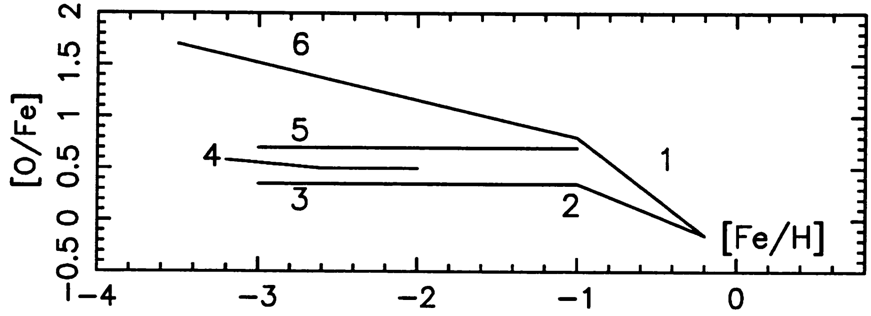

Figure 1 - Schematic behaviour of [O/Fe] vs. [Fe/H] by 1 Clegg et al, Edvardsson et al; 2 GO86,BE89; 3 GO86, B88, SKP90, SW91; 4 BSR91; 5 SLW79,G90,TLLS91; 6 AR89

2.2 Disk

The [O/Fe] data for the disk also show a disagreement between results from the forbidden and permitted lines, as can be seen in Fig. 1. It is clear that during the disk evolution the [O/Fe] drops from the halo value, gradually reaching the solar value at the solar metallicity. Interesting questions to ask are: (i) which is the metallicity corresponding to the transition halo-disk ? An interesting plot using [Ca/Fe] was presented by Nissen (1990), where a drop is seen at [Fe/H] $\approx$ -0.9, however the transition might occur at metallicities as low as [Fe/H] $\approx$ -1.6. (ii) Is there a spread of CNO/Fe abundances at this metallicity transition ? A mixture of populations (halo, thick disk, thin disk) might give this effect. No strong spread is seen, although some spread is detected at metallicities typical of the thick disk ([Fe/H] $\approx$ -0.9 to -0.6).

2.3 Bulge

The interest in the study of bulge stars resides, not only in the understanding of the chemical enrichment steps of our own Galaxy, but also in their probable similarity to the old galaxy populations of ellipticals and bulges of spirals.

The stellar content can be investigated in much greater detail than is possible by methods that seek to match the spectrum of the integrated light of unresolved systems. A star-by-star determination of their properties could yield information on the evolutionary history of such systems.

A major problem in the abundance determination of the bulge metal-rich stars is the uncertainty in their temperature. Besides the fact that relations temperature vs. colours for metal-rich giants are not precise, there is a strong reddening. It is therefore preferable to study the bulge clusters, given that the reddening can be roughly derived by comparing their colour-magnitude diagrams to that of 47 Tuc for example.

2.3.1 Individual stars in NGC 6553: NGC 6553 is the closest bulge cluster at a distance d $\approx$ 4.1 kpc, its brightest stars, of V $\approx$ 15, being observable at the 3.6m telescope using the Caspec spectrograph, at ESO.

Barbuy et al. (1991) have studied the star III-17, for which a metallicity of [M/H] $\approx$ -0.2 was found. Preliminary CNO abundances found are [C/Fe] = +0.1, [N/Fe] = +0.4, [O/Fe] = 0.0; the O abundance derived from the [OI]λ557.7 nm line, is imprecise, due to a defect in the spectrum in that region.

2.3.2 Bulge-like nearby metal-rich stars: A sample of nearby metal-rich stars was selected from the proper motion NLTT catalogue, combined with a study of their photometric metallicities and space velocities. The selected stars are candidates to be the local component of the bulge population, since about 4% of nearby stars correspond to an old disk population characterized by eccentricities $e < 0.5$, pericentric distances $R_p \approx 3.5$, apocentric distances $R_a < 11$ kpc, and high metallicities.

The CNO results for a dozen of these stars (Barbuy & Grenon, 1991) give: [C/Fe] $\approx$ 0.0, [N/Fe] $\approx$ 0.0 and [O/Fe] $\approx$ 0.0 to 0.2. The O abundance was derived for the forbidden plus permitted lines, and there was agreement.

As conclusion, these first [O/Fe] $\approx$ 0.0 for bulge stars lead to idea that the bulge seems to be somewhat different from the halo.

3. The "cosmic" oxygen abundance

O emission lines in nearby HII regions - such as the Orion nebula, are well-known to provide a O abundance lower than that of the Sun by about a factor 2. Luck &

Lambert (1985, LL85) also obtained an oxygen deficiency of 0.2 to 0.3 dex for intermediate mass supergiants, having evolved from main-sequence B stars, therefore in agreement with the HII regions value.

These deficiencies, together with the evidences for a He, C, N and O depletion in the solar wind, might indicate, as proposed by LL85, that the solar photospheric CNO abundances are enriched relative to the original solar nebula.

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B. Pagel: In my talk I suggested [O/Fe] starts to go down as [Fe/H] increases through -2; Serrano privately persuaded me that it should be -1.6. You say -1 to -0.9. It is important from the modelling point of view to fix this point if we can.

B. Barbuy: I have only shown the data on [Ca/Fe] by Nissen (1990) where a clear drop is seen at [Fe/H] $\approx$ -0.9.

J. Laird: I want to emphasize the possible danger of using only metallicity to separate stars. We may be, as Dr. Pagel said yesterday, mixing cats and dogs, that is, mixing stars of different populations. There may not exist a single unique relationship between [O/Fe] and [Fe/H]. It is important to consider the velocities of the stars being studied.