

SOLAR ABUNDANCES OF C, N, AND O

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Abstract. We briefly review the many indicators, atoms as well as molecules, of the photospheric abundances of C, N and O and present preliminary updated values of these abundances.

Key words: C, N, O – infrared: stars – stars: abundances – Sun: abundances

1. Introduction

We briefly recall the main reasons why accurate values of the solar abundances of C, N and O are so important.

They contribute about 70 % to the metallicity Z ; their detailed contribution to this metallicity is of crucial importance, as has been shown by the new opacity calculations for stellar interiors like OPAL (Iglesias and Rogers, 1991) and the OPACITY PROJECT (Seaton *et al.*, 1992) and for stellar envelopes (Kurucz, 1991).

The solar photosphere is the only reliable source for the abundances of these elements. It is well known that they have partially escaped from meteorites. Furthermore, although their abundances can be derived from the coronal spectrum and from solar wind and solar energetic particles data, the fractionation process between the outer solar layers and the photosphere makes accurate comparisons difficult (see e.g. Anders and Grevesse, 1989).

It is also well known that the C/O ratio is a crucial parameter for the physico-chemistry during the early phases of the evolution of the solar system.

2. Indicators of the Solar C, N and O Abundances

With the availability of the *ATMOS* infrared solar spectra obtained from space (Farmer and Norton, 1989) and covering the region from 2 to 16 μm , we have been able to use all the best indicators of the abundances of these elements, *i.e.*, atomic as well as molecular lines. The best indicators should have reliable atomic data (*gf*-values) and/or molecular data (transition probabilities, dissociation energies) as well as solar data (equivalent widths). We therefore disregarded some transitions in the visible spectrum which are too difficult to measure with accuracy in the solar spectrum because of the increasing blending problem as one goes to shorter wavelengths. The indicators we retained are the following: C I and [C I], N I, O I and [O I], CH (A-X), CH vibration-rotation, C₂ (Swan, Phillips and Ballik-Ramsay), NH vibration-rotation and pure rotation, OH vibration-rotation and pure rotation, CN red system, CO vibration-rotation ($\Delta v = 1$ and 2). Most of these indicators are in the infrared.

3. This Work

In several recent papers (Sauval *et al.*, 1984; Grevesse *et al.*, 1984; Grevesse *et al.*, 1990, 1991; Geller *et al.*, 1991; Grevesse and Sauval, 1991) we have analyzed these indicators and have shown how remarkably well they lead to the same results. It also became clear from these, and previous studies whose references are given in these papers, that permitted atomic lines are not the best indicators because of problems with the transition probabilities (although much progress has recently been made; see Biémont *et al.*, 1991a; Hibbert *et al.*, 1991) and of possible non-LTE effects. The best indicators are without any doubt the numerous molecular lines and particularly, the infrared lines.

We also showed (Grevesse and Sauval, 1991) how the numerous CO lines ($\Delta v = 1$ and 2), which can now be measured with high accuracy on the *ATMOS* infrared solar spectra, can be used to refine the solar photospheric model of Holweger and Müller (1974) that we have used throughout these analyses.

Very recently the solar photospheric abundance of iron – which was found to be higher ($A_{Fe} = 7.67$ (in the usual scale where $\log N_H = 12.00$; Blackwell *et al.*, 1984) than the meteoritic value (7.51; Anders and Grevesse, 1989) – was decreased down to the meteoritic value thanks to the use of higher excitation lines of Fe I, and to lines of Fe II for which accurate *gf*-values have recently been obtained (Holweger *et al.*, 1990; Holweger *et al.*, 1991; Biémont *et al.*, 1991b; Hannaford *et al.*, 1992; Johansson *et al.*, 1993).

As Fe is a substantial electron donor, this decreased abundance has led to modifications in the electron and gas pressures. These modifications have non-negligible effects on the temperature structure as derived from the CO infrared lines, and therefore on the abundances derived from the many different atomic and molecular indicators of the C, N and O abundances described in Section 2.

Work is in progress to reanalyze all these effects in detail. Preliminary results indicate that our previous results should be decreased by about 0.05 dex. Thus, the preliminary recommended values of the solar abundances of C, N and O are:

$$A_C = 8.55$$

$$A_N = 7.99$$

$$A_O = 8.87.$$

The infrared CO vibration-rotation bands show numerous lines due to $^{13}\text{C}^{16}\text{O}$, $^{12}\text{C}^{18}\text{O}$, and even $^{12}\text{C}^{17}\text{O}$ which was identified for the first time in the solar photospheric spectrum. Isotopic ratios derived from these lines agree with the terrestrial ratios but, new more accurate, transition probabilities are urgently needed for these isotopic species.

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