# *ABUNDANCE ANALYSIS OF ALPHA URSAE MINORIS*

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*Abstract. We have derived atmospheric abundances of the bright Cepheid α UMi in order to study the abundance anomalies in different elements. The atmospheric abundance of C, O, Fe-peak elements Ca, Sc, Ti, Cr, Fe and heavier s-process elements Y, Ba, Ce and Sm have been derived using the method of spectrum synthesis. The abundance of carbon is derived using the C I lines in 4700A region, whereas for oxygen, the forbidden line at 6300.311A is employed. Abundances of the Fe-peak elements and s-process elements are obtained by synthesizing selected portions in the wavelength range 4330A - 4650A. The estimates of C/O derived from the present investigation are compared with other Cepheids of similar period. The evolutionary status of α UMi is discussed in the light of these derived abundances.*

## *INTRODUCTION*

*The atmospheric abundances of various elements and abundance ratios like C/O, $^{12}C/^{13}C$, s/Fe etc. lead us towards a better understanding of the evolutionary processes that take place in stellar interiors. The effect of various processes like mixing between the interior and the atmosphere of a star, mass loss, and enrichment of interstellar medium in different elements caused by massive and intermediate mass stars, could be studied in detail when good estimates of light as well as heavy elements are available.*

*Atmospheric abundances of Fe-peak elements have been derived for a number of bright Cepheids by many investigators. For the Cepheids belonging to the solar neighbourhood these abundances do not differ considerably from the solar value. The abundances of C, N and O for a sample of 14 Cepheids have been derived by Luck & Lambert (1981; hereafter LL) who reported considerable deficiency of carbon and oxygen accompanied by an enhancement in nitrogen. Though the direction of changes in the abundances reported by LL are in accord with the predictions of evolutionary calculations, the magnitude of the changes is larger than the predictions. LL have suggested the extensive mixing into hydrogen-burning region and ON-processing region caused by more convection or meridianal circulation current as possible mechanisms to explain the observed abundance anomalies.*

*Here we report the derived atmospheric abundances of C, O and Fe-peak elements Ca, Sc, Ti, Cr & Fe and heavier s-process elements Y, Ba, Ce* and Sm for the bright Cepheid α UMi.

## OBSERVATIONS AND ABUNDANCE ANALYSIS

High-resolution spectra of α UMi were obtained with the 102-cm reflector of Kavalur Observatory. The details of observations are given in Table 1. We have used the forbidden line of O I at 6300.311A to derive the oxygen abundance. We have used a spectrogram with a dispersion of 4.2 A mm$^{-1}$ to measure this weak line of oxygen. At this dispersion one could resolve the O I line and also the Sc II line at 6300.678A into two components. We used C I 4769.997A and 4775.877A to derive the carbon abundances. The gf values for the O I line and C I 4775.87A are taken from Lambert (1978). The gf value of C I 4769.997A is taken from Kurucz & Peytremann (1975). The other line of C I arising from the same multiplet (6) at 4771.72A is very badly blended with Fe I 4771.712A and therefore could not be used. The abundances of Fe-peak elements are derived using several lines in the 4350A-4700A spectral region. The solar gf values derived from inverted solar analysis were used for these metalic lines. Selected portions of the stellar spectrum were synthesized using the model atmospheres selected from the grid of model atmospheres by Kurucz (1979), employing the spectrum synthesis code of Sneden (1974). The atmospheric parameters derived by Parsons (1970) by matching the computed and observed UVBGRI colours were used as first guess to the atmospheric parameter.

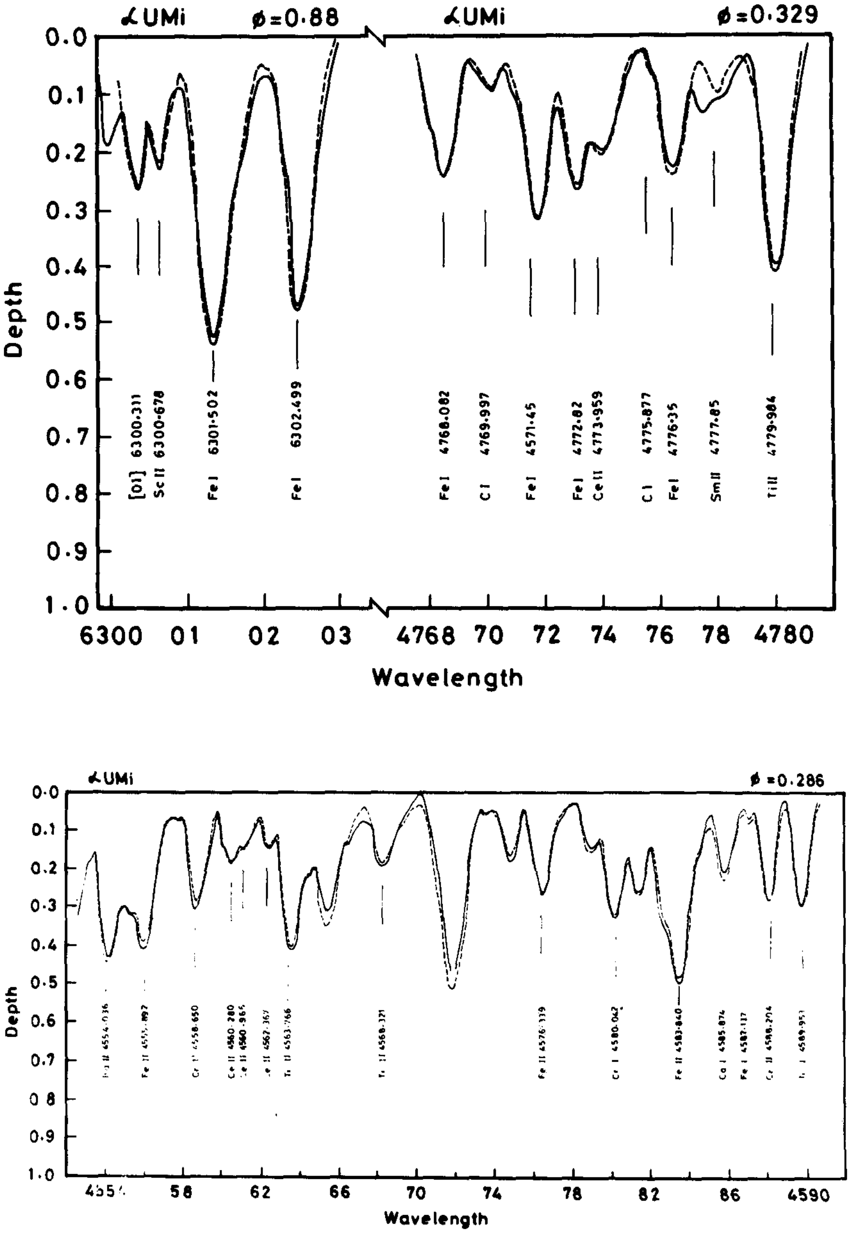
Table 1. Journal of Observations, and derived Atmospheric Parameters

| Date of observation | Phase | Spectral region | Dispersion A mm$^{-1}$ | $T_{eff}$ | Log g | $V_t$ |
|---|---|---|---|---|---|---|
| 12-10-1979 | 0.880 | 6300 | 4.2 | 6300 | 2.0 | 5.3 |
| 27-09-1980 | 0.286 | 4550 | 11.3 | 6000 | 2.0 | 5.0 |
| 02-11-1980 | 0.329 | 4700 | 11.3 | 5800 | 1.8 | 4.8 |

Table 2. Elemental abundances in α UMi with respect to the solar value

| Element | Z | Lines | | $\phi=0.286$ | $\phi=0.329$ | $\phi=0.880$ |
|---|---|---|---|---|---|---|
| | | Max | Min | | | |
| C | 6 | 2 | 2 | | -0.30 | |
| O | 8 | 1 | 1 | | | -0.05 |
| Ca | 20 | 4 | 2 | -0.25 | -0.20 | |
| SC | 21 | 2 | 2 | | -0.10 | |
| Ti | 22 | 10 | 6 | +0.05 | +0.10 | |
| Cr | 24 | 12 | 8 | +0.15 | +0.17 | |
| Fe | 26 | 25 | 20 | -0.05 | -0.10 | -0.05 |
| Y | 39 | 2 | 2 | | -0.10 | |
| Ba | 56 | 1 | 1 | -0.20 | | |
| Ce | 58 | 4 | 2 | -0.10 | -0.15 | |
| Sm | 62 | 2 | 2 | -0.15 | -0.10 | |

Figure 1. Observed (continuous line) and computed (broken line) spectra of α UMi in different spectral regions: (a) the spectral region containing important lines of BaII and CeII; (b) the spectral region containing the forbidden line of OI and (c) the spectral region containing the lines of CI.



Our method of deriving the final atmospheric parameters and abundances, and justification of assumptions employed in synthesis calculation is given by Giridhar (1983). Spectroscopic gravities derived by requiring neutral and ionised species of the same element leading to the same value of abundances are in good agreement with the gravities calculated using the evolutionary models of Becker et al. (1977). Assuming the second crossing of pulsation strip for α UMi we estimate a mass of 5.91 $M_\odot$. Using the period-luminosity relation of van den Bergh (1977) we derived the luminosity, and using the mass derived above we deduced the surface gravity of the star. The value of log g=2.06 derived from evolutionary consideration is in good agreement with the spectroscopic estimate given in Table 1.

## RESULTS

The estimates of the abundances of different elements are listed in Table 2. Calcium appears to be underabundant and chromium shows slight enhancement with respect to the solar value. The abundances of Sc, Ti and Fe do not differ significally from the solar value. The s-process elements Y, Ba, Ce and Sm are marginally underabundant and there is no indication of s-process anomalies with respect to iron abundance. Carbon is underabundant by 0.3 dex whereas the abundance of oxygen is not significantly different from the solar value. Figure 1 shows the agreement between the computed and observed spectra.

## DISCUSSION

For the stars of intermediate mass passing through the red giant phase, the evolutionary calculations predict the carbon in the stellar atmosphere to be reduced, nitrogen enhanced, while oxygen remains almost unaffected. The magnitude of the changes becomes higher with increasing mass. However, for the sample of LL, the abundances did not show any dependence on period and hence on the mass, and also the observed differences much higher than the predicted ones. Various mechanisms, like extensive mixing of ON-processed material induced by meridianal circulation currents, have been suggested to explain this anomaly. However, it appears that each Cepheid has its own peculiar evolution; i.e, the efficiency of mechanism suggested by LL seems to differ from star to star independent of its period. Nearly solar value of oxygen abundance, with underabundant carbon observed for α UMi could imply an evolution entirely different from the stars from the sample of LL. A study of $^{12}C/^{13}C$ ratio which is a sensitive monitor of CN-processing for a large sample of stars could be a useful step towards understanding the evolutionary differences between individual Cepheids.

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