This high degree of correlation is unexpected for the following reasons:

1. The temperature regimes, in which the soft X-ray and Balmer emission arise, are widely different; the former at $10^6$ - $10^7\,K$ and the latter at $10^4\,K$.

2. The time-profiles (light curves) of some flares show an appreciable impulsive component in the Balmer flux, (see Houdébine et al. 1990), whereas the soft X-ray flux is commonly supposed to arise from the thermal or gradual phase of a flare.

3. The lower Balmer lines H$\alpha$, H$\beta$ and H$\gamma$ are expected to be optically thick and therefore their integrated flux should depend on the shape of the plasma.

The relationship between Balmer and soft X-ray emission should be taken into consideration in forming models of flares. A model that might at first sight be suitable would be one in which the Balmer emission originates from hydrogen atoms excited directly by the backwards-directed soft X-rays. However, for this to be the case, the total energy in the soft X-rays must exceed twice the energy of the total hydrogen emission and, as discussed in Paper I, this does not seem to be the case. However, if one also includes the EUV flux, which is capable of exciting the hydrogen atoms, it is possible that the combined EUV and soft X-ray flux would be sufficient to explain the correlation. Simultaneous ROSAT and Balmer observations may enable us to confirm whether or not this explanation is valid.

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**References**


**Determination of Cosmic Abundances**

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This paper discusses how accurate cosmic abundances may be derived using weak stellar absorption lines in the spectra of main sequence early-type stars. Such stellar atmospheres should be uncontaminated by the products of interior nuclear reactions. As the stars will also have short lifetimes, the stellar abundances should reflect the current chemical composition of the solar neighbourhood.

1. Introduction

Recent studies of gas phase abundances in the interstellar medium have benefitted from the availability of high resolution, low noise observations of weak interstellar absorption lines (Bohlin et al 1983) together with accurate values for the corresponding radiative rates (Murray et al 1984, Hibbert et al 1985, Dufton et al 1986). This combination leads to far more reliable gas phase element abundances (principally because the analysis is independent of assumptions about the intervening interstellar material), and has allowed results accurate to ±0.1 dex to be deduced for several elements, for example magnesium (Murray et al 1984), nitrogen (Hibbert et al 1985), oxygen (Keenan et al 1985) and phosphorous (Dufton et al 1986). One major aim of such studies is to derive element depletions, and hence the chemical composition of dust grains (York et al 1983).

The cosmic abundance values employed in this work are usually determined from the sun and meteorites, and are often uncertain (Grevesse 1984, Meyer 1985a,b), thereby vitiating the accuracy of the interstellar depletions. Furthermore, cosmic abundances determined in this way apply to the interstellar medium as it was in the solar neighbourhood some 5 $10^9$ yrs ago, and hence are not necessarily appropriate to studies of current depletions.

At Queen’s we have therefore recently undertaken a programme to derive accurate contemporary cosmic abundances using a similar approach to that employed in our interstellar work described above. Weak stellar absorption lines (with typical equivalent widths $W_\lambda \approx 5$ mA) are observed in the spectra of main sequence early-type stars. Due to their weakness, these lines have equivalent widths which
are very sensitive to the element abundance, but not to the assumptions made in the model atmosphere analysis.

We have initially observed weak lines of argon as the cosmic abundance of this element is particularly uncertain (Grevesse 1984, Meyer 1985a,b), and it has been extensively detected in the interstellar medium through absorption lines of Ar I at 1066.7 and 1048.2 Å (see Duley 1985 and references therein).

2. Observations and method of analysis

Observational data were obtained using the coude spectrograph with a CCD detector on the Coude Feed Telescope at the Kitt Peak National Observatory in December 1988 (see Keenan et al 1990 for more details). For γ Peg, δ Cet and HR 1765 the 4587–4611 Å wavelength region was observed, which includes the Ar II line at 4589.98 Å. In addition, spectra covering the wavelength interval 4647–4672 Å (which contains the Ar II line at 4657.94 Å) were obtained for γ Peg. Equivalent widths for the Ar II 4590 and 4658 Å lines were in the range \( W_\lambda = 5–7 \) mÅ, with errors of typically ±0.5 mÅ (Keenan et al 1990).

The observational data were analysed by comparing measured stellar Strömgren colours (effective temperature indicators), \( \beta \) indices (surface gravity indicators) and Ar II equivalent widths with those predicted by local thermodynamic equilibrium (LTE) model atmosphere codes. All theoretical results were deduced using the line blanketed grid of models of Kurucz (1979), or new models calculated with Kurucz’s program. The derivation of effective temperatures and surface gravities have been discussed in detail by Keenan et al (1990).

Using the stellar atmospheric parameters, argon abundances were deduced by comparing the observed Ar II line strengths with those predicted from LTE model atmosphere calculations (see Brown et al 1986 for more details). A microturbulent velocity \( V_t = 5±5 \) km s\(^{-1}\) was adopted for all the stars, as this value has been found to be appropriate for LTE analyses of near main sequence early-type stars (see, for example, Hardorp and Scholz 1970, Kodaira and Scholz 1970); however for the programme stars the derived Ar II abundances are effectively independent of the choice of \( V_t \). Oscillator strengths for the Ar II 4590 and 4658 Å transitions were taken from Garcia and Campos (1985), who measured Ar II lifetimes (and hence \( f \)-values) to an accuracy of better than 10% using the delayed-coincidence method.

3. Results and discussion

For the three stars a mean abundance of \( \log [A] = 6.49±0.04 \) was obtained, where the error bar refers to the sample standard deviation (see Keenan et al 1990). There is also an uncertainty in \( \log [A] \) which arises from possible non-LTE effects. However very recent non-LTE calculations for Ar II performed by us (Holmgren et al 1990) indicate that these effects should be small (\( \leq 0.02 \) dex) for the transitions under consideration. In view of this, and the fact that there is a possible 10% uncertainty in the adopted Ar II \( f \)-values (Garcia and Campos 1985), we therefore conclude that our mean argon abundance should be accurate to ±0.05 dex.

As the stars under consideration are on or near the main sequence, their atmospheres should be uncontaminated by the products of interior nuclear reactions (Brown et al 1986), and hence any derived abundances should reflect those of the interstellar.

During these short lifetimes it is unlikely that the stars have moved significantly from their places of origin, and as they lie within typically 500 pc of the sun (Savage et al 1985), our result of \( \log [A] = 6.49±0.05 \) therefore represents an accurate evaluation of the current cosmic abundance value of argon in the solar neighbourhood.

As argon is not present in the solar photospheric spectrum (see, for example, Grevesse 1984), previous estimates of the cosmic abundance value have been determined from emission lines formed in the solar corona, which are detected in the X-ray region of the spectrum. In these analyses most authors have calculated argon abundance ratios (for example Ar/Fe, Dorschek et al 1985), and used the solar abundance of the denominator to infer that for argon. Using this method, Withbroe (1971), Walker et al (1974) and Dorschek et al have determined values for \( \log [A] \) of 6.65, 6.78 and 6.44, respectively, with error estimates of approximately ±0.2–0.3 dex. According to Meyer (1985b), the only absolute argon abundance determination is that of Veck and Parkinson (1981), who found \( \log [A] = 6.38±0.18 \) from an analysis of solar flare data from the OSO-8 satellite. These authors were able to measure the absolute abundance as they analysed not only the Ar XVII emission line at \( \lambda \)Å, but also the continuum emission, which is dominated by free-free and free-bound processes in hydrogen. We note that our result is in good agreement with that of Veck and Parkinson, and also with the recent measurement by Dorschek et al. However the error estimate in our argon abundance is 12% or less, as opposed to the \( \approx 75% \) uncertainty in those of Veck and Parkin-
son and Doschek et al.

It is interesting to note that although up to now the most reliable cosmic argon abundance estimate is the log [A] = 6.38 of Veck and Parkinson (1981), many workers have adopted the Withbroe (1971) value of log[A] = 6.65 in interstellar depletion studies of argon (see, for example, York 1983, Duley 1985). For the lines of sight to λ Sco and α Vir, York (1983) and York and Kinahan (1979) found argon depletions of ~0.20 and ~0.15 dex, respectively, using the Withbroe cosmic abundance value. However adoption of the present result implies that argon is effectively undepleted in these lines of sight, which is to be expected as they are unreddened and hence contain few interstellar grains (see Keenan et al 1986).

In the future we plan to extend our work by observing weak absorption lines of P II in early-type stellar spectra, as this species is extensively observed in the interstellar medium (Dufton et al 1986), and accurate oscillator strength calculations performed at QUB are available (Hibbert 1988).

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References


The Second Order Fermi Acceleration of Pick-up Ions

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Abstract

A theoretical model for the second order Fermi acceleration of photo-ionised, pick-up ions is presented. This acceleration is caused by the scattering off magnetic turbulence in the solar wind upstream of the comet's bow shock. Exact solutions for the energetic particle spectrum are found and compared with measurements made near comet Halley. (Paper submitted to the proceedings of the Chapman Conference on Cometary Plasma Processes, University of Surrey, 1989)