OBSERVATIONS OF MG I AND MG II IN THE LOCAL ISM

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ABSTRACT

We have used high quality IUE data combined with that acquired by Copernicus to study the Mg II/Mg I ionization balance in the local interstellar medium within 50 pc of the Sun. The high resolution, high signal-to-noise Copernicus data reveal, in three stars, weak interstellar Mg I features at 2852 A. High quality IUE data for interstellar Mg II near 2800 A were acquired by coadding high dispersion images and incorporating an observing technique that minimized the effects of camera fixed-pattern noise. The results are in agreement with the local cloud model as presented previously by Bruhweiler. The Mg I and Mg II column densities are used to place constraints on the physical conditions of the interstellar gas near the Sun.

INTRODUCTION

Recent studies of the local interstellar medium (LISM) (Bruhweiler and Kondo 1981, 1982a, 1982b; Bruhweiler 1982) based primarily on IUE data show the Sun is embedded in and near the edge of a rather diffuse cloud with a total column density of $(1\text{-}2)\times10^{19}\,\mathrm{cm}^{-2}$. However, in directions away from the cloud core lies the pervasive, extremely low density ($n\sim10^{-2.5}\,\mathrm{cm}^{-3}$), high temperature ($T\sim10^{5.5}\,\mathrm{K}$) gas with no evidence of additional clouds within at least 50 pc for the lines of sight studied.

If the Sun is indeed embedded in and near the edge of the local cloud, then the gas in the immediate vicinity should be quite warm ($T\sim8{,}000$°K; McKee and Ostriker 1977).

Since neutral magnesium originates primarily in the interstellar medium through dielectronic recombinations near $10^{4}\,\mathrm{K}$, significant amounts of Mg I would be present in any warm gas near the Sun. Thus, Mg I might be useful as a tracer for the warm neutral and ionized gas components (WNM and WIM) discussed by McKee and Ostriker (also see York 1983).

OBSERVATIONAL DATA

We present IUE and Copernicus data corresponding to the interstellar lines of Mg I and Mg II (Mg I 2852; Mg II 2795, 2802 A) for five B and A stars within 40 pc of the Sun. All the Mg I data presented were acquired using the spectrometer aboard Copernicus. The Mg II data presented were obtained by both the IUE and Copernicus.

Although the Copernicus data is of high resolution, and in most cases higher signal-to-noise than that obtained with the IUE, Copernicus data obtained with the near-UV detectors have large charged particle backgrounds.

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This background can in some cases far exceed the stellar signal. Techniques, developed to correct for this background (Weiler 1978), have proven quite successful when the background levels are comparable or less than the stellar signal. This is a negligible problem in the case of Mg I, where the expected and observed features are weak and on the linear portion of the curves-of-growth. However, the Mg II features can be quite strong and approaching saturation. Since each member of the Mg II doublet is scanned seperately and have seperate background corrections applied, any errors in the background subtraction might be magnified in deriving the Mg II column densities.

The *IUE* data is of lower resolution than *Copernicus* data and of limited signal-to-noise. However, background subtraction is no problem near 2800 A where the echelle orders are widely spaced and the interorder signal can be reliably measured. To achieve good signal-to-noise in *IUE* data, one must choose exposure times which maximize the signal-to-noise for specific features. When interstellar lines are in troughs of photospheric features, one must overexpose the stellar continuum. Also, the signal-to-noise can be improved by coadding data from multiple *IUE* images (Bruhweiler and Kondo 1982b). Yet, the detector fixed-pattern noise limits the increase in signal-to-noise, when *IUE* images acquired during a single observing session are coadded. For images significantly seperated in time, the thermal behavior of the *IUE* camera (Thompson, Bohlin, and Turnrose 1982) effectively uncorrelates the fixed-pattern noise and does not seriously limit the improvement in signal-to-noise when images are coadded. One can artificially uncorrelate the fixed-pattern noise by taking repeated images in a short time period with the target positioned at different locations in the 10"x22" aperture. During the data reduction process, the spectral data can be aligned and coadded with the desired results. This technique was applied in acquiring the *IUE* spectral images for α Gru. (See Figures 1 and 2.)

RESULTS

A comparison of the *IUE* and *Copernicus* results for Mg II in Table 1 shows excellent agreement. Although the comparisons are limited, the agreement, especially for α Gru, implies that the background corrections for the Copernicus data are quite good. The nine individual measurements of the Mg II interstellar lines in the three *IUE* images (Mg II 2802 is in echelle orders 82 and 83) yielded a maximum deviation of 8 mA. This suggests that the co-added equivalent widths for α Gru have an accuracy on the order of 3 mA. The *IUE* results suggest that for a b-value on the order of 4.5 km s^{-1} (typical of those found here), reliable column densities can be obtained for interstellar features with equivalent widths $\lesssim$ 170 mA. For larger b-values and more observations, this limit might be pushed to larger equivalent widths. These results show that useful interstellar data can be obtained with the *IUE*, providing care is taken in collecting, reducing, and analyzing the data. The apparent disagreement in the case of α PsA is most likely due to the very high background level in the *Copernicus* data. Kondo et al. (1978) cautioned that their *Copernicus* results on α PsA were highly uncertain due to the high background level for that star. In contrast, the background level for the other *Copernicus* observations were equal to or less than the local continua for the Mg I and Mg II interstellar features. (See accompanying Figures and

Table 1.)

Backscattering results for H I Lymanα and He I 584 A imply a neutral hydrogen number density near the Sun of n(H I)=0.04-0.06 and that (N(H II)/N(H I)) $\approx$ 1.5 (Weller and Meier 1981). From Table 1, we adopt (N(Mg II)/N(Mg I))=500. By substituting $\Gamma = 8\times10^{-11}\ s^{-1}$ (de Boer et al. 1973) and the total recombination rate of $\alpha_T(T)$ (Shull and Van Steenburg 1982) into the ionization equation, N(Mg II)/N(Mg I)=$\Gamma/n_e\alpha_T(T)$, we find that T = 7,500 - 10,000 K, in the local solar vicinity. This result compares favorably with the 9,000 - 15,000 K deduced by Weller and Meier. The absence of Mg I toward α PsA, when combined with limits on n (Bruhweiler and Kondo 1982b) indicates much lower temperatures. More detailed results of this work will appear elsewhere.

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TABLES AND FIGURES

TABLE 1

SUMMARY OF MAGNESIUM DATA*

Star	Equivalent Width(mA)					Column Density(cm^{-2})	
	Mg II 2795		Mg II 2802		Mg I 2852	N(Mg II)	N(Mg I)
α CMa							
	71		47		$\leq$1.5	3.3×10^{12}	$\leq1.1\times10^{10}$
α Gru	161.7±3	(3)	146.7±3	(3)		6.1×10^{13}	
	170+14		153+11		12.5	5.4×10^{13}	9.8×10^{10}
α Eri	312	(1)	297	(1)			
	292		266		29.5	1.35×10^{14}	2.4×10^{11}
α Lyr	105	(2)	102	(2)			
	120±22		100±31		22	8.1×10^{13}	1.9×10^{11}
α PsA	183	(4)	162,157	(4)		4.0×10^{13}	
	133:		127:		$\leq$2.5		$\leq1.8\times10^{10}$

*The ratios given in each row are the IUE value over the Copernicus value. Numbers in parentheses are the number of IUE images used to get the result. Notes for individual objects are given below:

α CMa= This direction is away from cloud core, hence the low Mg I and Mg II column densities.

α Lyr=IUE data have very low exposure levels for local continuum for IS lines. Photospheric features are quite sharp(v sin i =17 km/s). Interstellar and photospheric features likely not completely resolved.

α PsA= Very high Copernicus background level,(background/local continuum)=15. IUE data from Bruhweiler and Kondo 1982b.

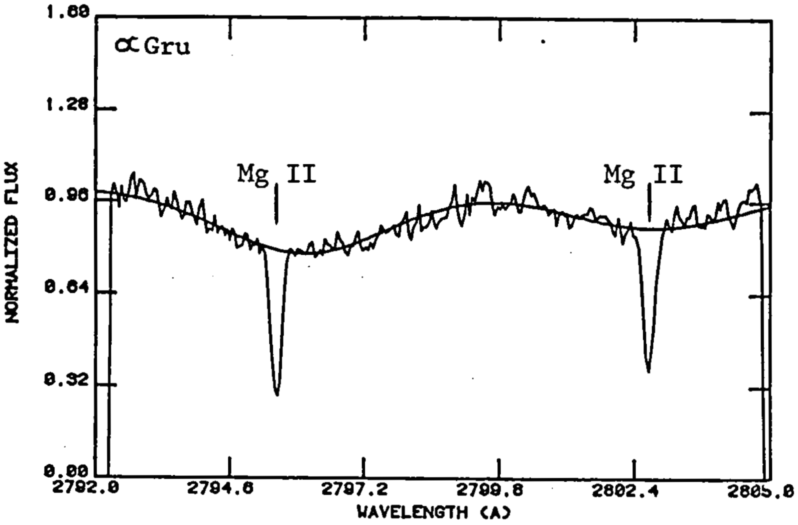

Figure 1. Coadd Mg II data for three IUE images of αGru. Corrections for echelle ripple have been applied. Data were normalized after coadding images. The smooth curve is a Gaussian fit to the broad spectral features of αGru.

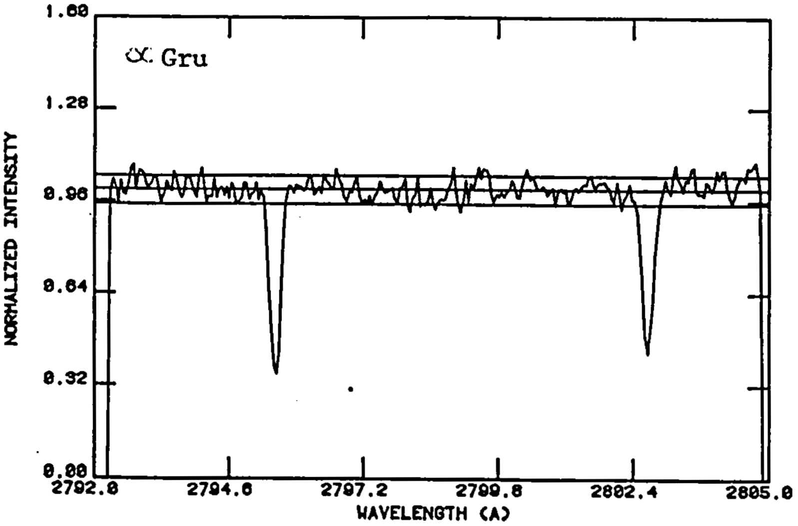

Figure 2. Rectified Continuum for Mg II Interstellar Lines. The IUE data in Fig. 1 are divided by the Gaussian fit. Deviations of ±5% from unity are noted, which correspond closely to ±2 σ deviations over most of the displayed data.

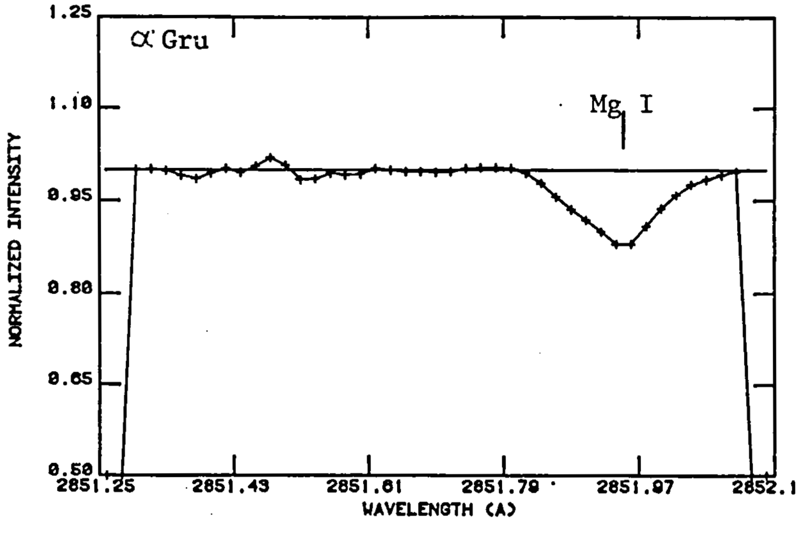

Figure 3. Interstellar Mg I in Copernicus Data showing Interstellar Mg I in αGru.