OBSERVATIONS OF LOCAL INTERSTELLAR Mg I and Mg II

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ABSTRACT

We have combined *Copernicus* and *IUE* observations of 5 stars within 50 pc of the Sun to study the ionization of magnesium in the local interstellar medium (LISM). The high resolution *Copernicus* spectrometer was used to detect interstellar Mg I 2852 in the spectra of α Gru, α Eri, and α Lyr, while placing upper limits on Mg I in the spectra of α CMa and α PsA. Observations of Mg II 2795, 2802 for these stars were also obtained with *IUE* and *Copernicus*. The column densities of Mg I and Mg II are used to place constraints on the temperature of the LISM.

INTRODUCTION

Recent studies of the LISM indicate that the Sun is embedded in a cloud with a hydrogen density of $n_H \sim 0.1 - 0.15$ cm^{-3} (McClintock et al.,1978; Cash, Bowyer, and Lampton 1979; Frisch 1981; Bruhweiler and Kondo 1982a,b; and Bruhweiler 1982). Bruhweiler and Kondo (1982a) have also presented some evidence that the Sun is near the edge of this local cloud.

In the McKee and Ostriker (1977) model of the ISM, small clouds of dimension 2-3 pc are distributed in a hot ($10^5 - 10^6$K) coronal gas. The edges of the clouds are partially ionized by evaporation and the diffuse UV and X-ray background and are predicted to have temperatures of $\sim$ 8000K and densities of $\sim$ 0.25 cm^{-3}. In this warm, partially ionized gas, detectable amounts of Mg I should be present due to dielectronic recombination, which is the principal means of recombination at temperatures of $\sim 10^4$K (York and Kinahan 1979). Consequently, studies of the Mg II/Mg I ionization balance in the LISM can be used to place constraints on the physical properties of this local cloud.

DATA

In Table 1, we present the equivalent widths of interstellar Mg I 2852 and Mg II 2795, 2802 in the spectra of α CMa (A1V, d=2.67 pc), α Gru (B5V, d=19.6 pc), α Eri (B5IV, d=40 pc), α Lyr (A0V, d=8.12 pc), and α PsA (A3V, d=6.94 pc). The corresponding column densities for the two ions are also listed. All the Mg I data was obtained with the *Copernicus* spectrometer. The Mg II data presented here was obtained by both the *IUE* and *Copernicus*.

The *Copernicus* near-UV photomultiplier tubes were subject to large particle backgrounds. In obtaining the Mg I data used here, special background measurements (off-source) were taken and were used in reducing the data. The *Copernicus* data for the Mg II lines in

https://doi.org/10.1017/S0252921100097980 Published online by Cambridge University Press

Table 1 were obtained by Kondo et al. (1978), except for the α Eri data. The special techniques used to reduce the *IUE* data will be presented elsewhere along with figures displaying the spectra.

DISCUSSION

The Mg II lines in the spectra of α CMa are fairly weak, and the Mg I line was not detected. Based on the geometry of the local cloud (Bruhweiler and Kondo 1982a), the line of sight to α CMa is away from the cloud core. This could possibly explain the low column densities in this direction. The Mg I 2852 line was also not detected in the direction of α PsA (to be discussed further below).

Assuming that the LISM is in ionization equilibrium, we have

$$\frac{\mathrm{N(Mg\,II)}}{\mathrm{N(Mg\,I)}} = \frac{\Gamma}{n_e \alpha_t(T)} ,$$

where $\alpha_t(T)$ is the total recombination rate (radiative plus dielectronic) and Γ is the photoionization rate for Mg I. The total recombination rate is a fairly strong function of temperature, thereby making it possible to define the temperature of the absorbing gas if values of N(Mg II)/N(Mg I), Γ and n_e are known. The value of the recombination rate used here was obtained from Shull and Van Steenberg (1982).

Based on the data for the 3 stars in Table 1 for which a Mg I line was detected, we adopt N(Mg II)/N(Mg I)=500 for the LISM. The photoionization rate is a function of the local interstellar radiation field. Models for the radiation field have been calculated based on observations made with OAO (Witt and Johnson, 1973) and TD-1 (Gondhalekar, Phillips and Wilson (GPW), 1980). The radiation field in the wavelength region 1000-2000A calculated by Witt and Johnson (1973) was much larger than previous calulations (Habing 1968) and is larger than the more recent calculations of GPW. Using the radiation field from Witt and Johnson, we find $\Gamma = 7.9\times10^{-11}$ s^{-1} in agreement with the value calculated by de Boer, Koppenaal, and Pottasch (1973). Using the radiation field calculated by GPW, however, gives $\Gamma = 3.8 \times 10^{-11}$ s^{-1}, about a factor of two smaller.

Weller and Meier (1981) have recently calculated the density and ionization level of H and He in the LISM, based on EUV observations of backscattered He I 584 in the solar neighborhood combined with similar observations of H I Lyα. These authors find $0.06 \le n_e \le 0.09$ cm^{-3} and $n_e/n(HI) = 1.5$. This value of $n_H = 0.1 - 0.15$ cm^{-3} is in good agreement with other determinations of the density of the LISM (McClintock et al. 1978; Frisch 1981; Oegerle et al. 1982; and Bruhweiler and Kondo 1982a,b). The range in possible values of n_e and Γ, therefore, results in a range of possible values for the temperature of the LISM. Consequently, we find $7500 \le T \le 10,000$K. The ratio N(Mg II)/N(Mg I) increases rapidly with decreasing temperature below 7500K, making it extremely difficult to detect Mg I lines formed in a cool gas with low column density. The non-detection of Mg I in the spectrum of α PsA, when combined with the limits on the density of the ISM in this line-of-sight (Bruhweiler and Kondo (1982b), indicates temperatures below 7500K in this direction.

The temperature of the LISM derived here overlaps the lower end of the temperature range found by Weller and Meier (1981) for the very local ISM (9000-15000K). It is also in good agreement with the temperature of 8000K predicted for the warm, ionized material (WIM) in the cloudlet model of McKee and Ostriker (1977). More detailed results of this work will appear elsehere.

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TABLE 1. Mg 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	≤ 1.5	3.3×10^{12}	$\leq 1.1 \times 10^{10}$
α Gru	162 ± 3 (3)	147 ± 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 (3)	-	-	-
	120 ± 22	100 ± 31	22	8.1×10^{13}	1.9×10^{11}
α PsA	183 (4)	162,157 (4)	-	-	-
	133:	127:	≤ 2.5	4.0×10^{13}	$\leq 1.8 \times 10^{10}$

Notes: For each star (except α CMa) there are two rows of data. The top row contains measurements from the *IUE* spectra, while the lower row is from *Copernicus*. The number in parenthesis for the *IUE* data is the number of spectra that were combined to get the result. The α CMa data is from *Copernicus*. The photospheric and interstellar features are probably not resolved in the spectra of α Lyr, which has vsini=17 km s^{-1}.

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