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ELECTRON IMPACT POLARIZATION OF RESONANCE LINES FROM Li LIKE IONS

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One of the basic problems yet unsettled regarding the physics of solar flares is whether X ray bursts are produced by thermal electrons or by non thermal electrons Fo non thermal interpretation the distribution of energetic electrons is anisotropic and hence, the X radiations produced by energetic electrons colliding with atoms (ions) should show polarization properties Polarization of X ray continuum has been theoretically investigated in detail by a number of authors, however, a very little work has been devoted to line polarization Percival and Seaton (1958) developed a quantum mechanical theory for line polarization and the angular distribution of Stokes parameters I and Q is given by

$$I(\theta) = \frac{3}{4\pi(3 \quad P_0)} (1 \quad P_0 \cos^2\theta) I_0 \tag{1}$$

$$Q(\theta) = \frac{3}{4\pi(3 \quad P_0)} P_0 I_0 \sin^2\theta \tag{2}$$

where θ is the angle between the directions of the exciting electron and the emitted photon, I_0 the total intensity integrated over all directions, and P_0 is the maximum polarization at $\theta = \pi/2$ Now,

$$\cos\theta = \cos\alpha \cos\nu + \sin\alpha \sin\nu \cos\psi \tag{3}$$

where ν is the angle between the line of sight and solar magnetic field α is the pitch angle of recoiling electron and ψ is the azimuthal angle of electron about the magnetic field

Averaging over the azimuthal angle ψ and the pitch angle distribution $f(\alpha)$, the Stokes parameters are given by

$$I(\nu) = \int_{\psi=0}^{2\pi} \int_{\alpha=0}^{\pi} I(\theta)\, f(\alpha) \sin\alpha \, d\psi \, d\alpha \tag{4}$$

$$Q(\nu) = \int_{\psi=0}^{2\pi} \int_{\alpha=0}^{\pi} Q(\theta) \cos 2\psi \, f(\alpha) \sin\alpha \, d\psi \, d\alpha \tag{5}$$

where an analytical expression for the normalized pitch angle distribution $f(\alpha)$ is given by

$$f(\alpha) = \frac{n+1}{4\pi} \cos^n\alpha \qquad 0 \leq \alpha \leq \pi, \text{ n is an even integer} \tag{6}$$

However, a forward cone distribution

$$f(\alpha) - \begin{cases} \frac{n+1}{2\pi} \cos^n\alpha & 0 \leq \alpha \leq \frac{\pi}{2}, \quad n \text{ is a real number} \\ 0 & \frac{\pi}{2} \leq \alpha < \pi \end{cases} \tag{7}$$

has been used by Haug (1981)

We have yet assumed monoenergetic electrons The parameter I_0 and P_0 depend on the energy of incident electrons

$$I_0(E) \sim E^{\frac{1}{2}} \sigma(E) \tag{8}$$

where σ(E) are the excitation cross sections which for the transition 2s → 2p in Li like ions have been fitted by Sampson and Parks (1974)

$$P_0(E) = \frac{3(R\ \ 1)}{5R+7} \quad \text{for } 2^2P^0_{\frac{3}{2}} \rightarrow 2^2S \text{ line}$$

$$P_0(E) = \frac{3(R\ \ 1)}{7R+11} \quad \text{for } 2P \rightarrow 2s \text{ multiplet} \tag{9}$$

where $R = \sigma_0/\sigma_1$, σ_0 and σ_1 are the component of the excitation cross section, such that

(i) $\sigma - \sigma_0 + 2\sigma_1$

(ii) $\sigma_0/\sigma = 1$ and σ_1/σ 0 (at excitation threshold)

The cross sections for the line $2^2S \rightarrow 2^2P^0_{\frac{3}{2}}$ may be approximated by

$$\sigma(2^2S \rightarrow 2^2P^0_{\frac{3}{2}} = \frac{4}{6}\sigma(2s \rightarrow 2P) \tag{10}$$

but the expression for the ratio R remains unaltered For non thermal electrons the energy distribution F(E) of electrons can be expressed by power law (Bai and Ramaty, 1978)

$$F(E) \sim E^{3\ 5} \tag{11}$$

After averaging the Stokes parameters over the energy of incident non thermal electrons, the degrees of polarization may be expressed as

$$p(\nu) = \frac{Q(\nu)}{I(\nu)} \quad \frac{n \sin^2\nu}{A + nB + n \sin^2\nu} \tag{12}$$

The calculated values of the parameters A and B for the line $2^2P^0_{3/2} \rightarrow 2^2S$ and the multiplet 2p → 2s emitted from Fe XXIV, Ca XVIII, S XIV and Si XII are given in Table I

Table I

Values of the Parameters A and B

Atomic number Z	Specie	$2^2P^0_{3/2} \rightarrow 2^2S$ line		2p → 2s multiplet	
		A	B	A	B
26	Fe XXIV	4 0111	0 6704	6 0153	1 3384
20	Ca XVIII	4 0139	0 6713	6 0200	1 3400
16	S XIV	4 0186	0 6729	6 0274	1 342[illegible]
14	Si XII	4 0231	0 6744	6 0342	1 3447

Obviously for isotropic distribution of electrons n = 0 the degrees of polarization being zero Table I show that the degrees of polarization depend on the atomic number of the ion weakly

If we adopt the forward cone distribution (7) with $n = F/E_0$, E_0 being a free parameter the degree of polarization can be expressed by

$$P(\nu) = \frac{Q(\nu)}{I(\nu)} = \frac{\sin^2\nu}{C + \sin^2\nu} \tag{13}$$

The value of the parameter C for three values of free parameter E_0 are given in Table II

Table II

Values of the Parameter C

Atomic number Z	Specie	$2^2P^0_{3/2} \rightarrow 2^2S$ line			2p → 2s multiplet		
		$E_0 = E_{th}/4$	60 eV	15 eV	$E_{th}/4$	60 eV	15 eV
26	Fe XXIV	1 3996	3 2902	1 3481	2 4324	5 6118	2 4446
20	Ca XVIII	1 4003	4 7414	1 7272	2 4336	7 7008	2 9903
16	XIV	1 4015	6 2441	2 1195	2 4355	9 8744	3 5577
14	Si XII	1 4027	7 2993	2 3948	2 4373	11 4166	3 9601

An interesting feature to be noted from Table II is that if E_0 depends on the specie e g $E_0 = E_{th}/4$ E_{th} is the excitation threshold energy, the degrees of polarization are nearly independent of the atomic number Z This behaviour is same as obtained for pitch angle distribution (6) But when E is constant, irrespective of the specie, the degrees of polarization vary with the atomic number of the ion When $E_0 \rightarrow \infty$, $n \rightarrow 0$ and $C \rightarrow \infty$ and hence $p(\nu) \rightarrow 0$ a case of isotropic distribution of electrons

So far no observational data for line polarization are available to our knowledge In the lack of observational evidence, no conclusion about the distribution of electrons can be drawn

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