STOKES PARAMETERS FOR THOMSON SCATTERING IN MAGNETIZED PLASMA

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The effect of a superstrong magnetic field on neutron stars or white dwarfs is studied for Thomson scattering in a fully ionized collisionless plasma. The equation of motion for an electron in the presence of both the induced electric field of the plasma and a static uniform external magnetic field is used to determine the acceleration of the electron. The collective plasma effects due to the field and density fluctuations are investigated by using the test-particle picture. The scattering of a photon by a plasma is a function of the acceleration of particles by the electric field of the incident wave and the static external magnetic field $\vec{B}_0$. Assuming that the electrons are distributed with density $n_e(\vec{r}',t')$, the radiation field far from the scattering center is

$$\vec{E}_{sc.} = \frac{r_0}{R(1-u)} \int n_e(\vec{r}',t')\, \hat{k}' \times \hat{k}' \times \begin{pmatrix} E_x + i\sqrt{u}\, E_y \\ E_y - i\sqrt{u}\, E_x \\ (1-u)\, E_z \end{pmatrix} e^{-i\vec{k}'\cdot\vec{r}'}\, \delta(t'-t+\frac{R}{c}) \cos\delta_\lambda \, d\vec{r}' ,$$

$$\hat{k}' = \vec{k}'/k', \quad R = |\vec{r}-\vec{r}'|, \quad u = \omega_c^2/\omega^2, \quad v = \omega_p^2/\omega^2, \quad r_0 = e^2/m c^2.$$

where the delta function indicates that all quantities are to be evaluated at the retarded time $t' = t - |\vec{r} - \vec{r}'|/c$, and δ_λ is the angle between the wave vector $\vec{k}$ and the Poynting vector, which is given by

$$\tan\delta_\lambda = \frac{-1}{2\, n_\lambda^2(\alpha)} \left(\frac{\partial\, n_\lambda^2(\alpha)}{\partial\, \alpha} \right) .$$

The two indices of refraction, $n_\lambda(\alpha)$ are defined by

$$n_\lambda^2 = 1 - \frac{2\, v \cdot (1-v)}{2\,(1-v) - u \sin^2\alpha + (-1)^\lambda \sqrt{u^2 \sin^4\alpha + 4\, u\, (1-v)^2 \cos^2\alpha}}$$

where α is the angle between the wave vector and the static magnetic $B_0\, \hat{z}$.

E. R. Priest and V. Krishan (eds.), Basic Plasma Processes on the Sun, 93–94.

The Stokes parameters for the scattered radiation are computed explicitly in terms of the state of polarization of the incident wave, the electron-cyclotron frequency, the plasma frequency, the angle of incidence, and the angle of scattering. The effect of the magnetoactive plasma on the polarization parameters of the scattered radiation is considered in detail for incoming radiation propagating along or across the static magnetic field.

For a cold plasma with uniform particle density, the scattered field is reduced essentially to the vacuum radiation expression (in the single-particle limit). The collective effects of the magnetoactive plasma on the scattered radiation is then determined entirely by the acceleration of the particles in the plasma. For a hot inhomogeneous plasma with a strong static magnetic field, thermal effects must be included, and it is expected that magnetic Thomson scattering on thermal electrons is partially or completely cancelled by nonlinear scattering on the polarization clouds of the electrons. Such joint thermal and nonlinear effects on Thomson scattering will be considered in future publications.

The most distinguishing feature is the fact that the superstrong magnetic field ($B \approx 10^{12}$ G) greatly affects the Thomson scattering process, resulting in resonances in the scattering cross section. The important consequences of these cyclotron resonances are the increase in the photon mean free path in the scattering regions, strongly affecting the angular distribution and polarization properties of the scattered photons.

The effects of the plasma are very insenitive to the specific values of v ($v = \omega_p^2 / \omega^2$, ω_p denotes the electron plasma frequency) so long as $v \ll 1$, whereas the criterion for the magnetic field to substantially affect the Stokes parameters is that the photon frequency be less than the electron-cyclotron frequency. The effects of classical radiation damping (and natural line broadening) are briefly discussed. The corresponding quantum mechanical treatment for Compton scattering in a relativistic plasma is now under investigation.

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