BEAM-RETURN CURRENT SYSTEMS IN SOLAR FLARES

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The importance of electron beams in solar flare dynamics is well known. In order to understand the dynamics produced by beams it is essential to have a clear understanding of the role beam driven return currents play and whether electrostatic or inductive electric fields maintain the return current. We show that inductive electric fields are responsible for driving return currents under solar conditions. The significant conclusions that follow from this result, as applicable to solar flares, are the following:

(a) If there is no source of anomalous resistivity, either due to a beam driven two stream instability or due to the return current becoming electrostatically unstable, our results will not alter previous results;

(b) however, if there is a source of anomalous resistivity, either due to a beam driven two stream instability or due to the return current becoming electrostatically unstable, our results modify significantly previous results;

(c) if (b) is true, we find

(1) a beam under solar conditions cannot exist for times greater than

$$\Delta t_{max} \lesssim t_D \ln\left[\frac{1}{1 - \frac{acB_z}{2I_B(0)}}\right] ,$$

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where t_D is the resistive diffusion time, as determined by the level of resistivity and the beam radius a, B_z the axial guide field along which the beam propagates, and $I_B(0)$ is the beam current in statamps at t=0;

(2) if the beam radius is determined by the spatial scale of the acceleration region and the resistivity is anomalous we find $\Delta t_{max} \lesssim 0.5$ secs is a typical maximum beam pulse time;

(3) the plasma temperature that results from the return current being unstable is ~ 15 kev;

(4) a typical flare x-ray burst of ~ 10 secs at 15 kev must be made up of many beam pulses of ~ 0.5 secs.

(5) beam energy losses due to the larger induction electric field resulting from anomalous resistivity will exceed direct classical collisional beam energy losses; and

(6) anomalous return current Joule heating will be the dominant heating mechanism of the beam and a quasi-thermal x-ray source will result.

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