GAMMA RAY FLASHES DUE TO PLASMA PROCESSES IN THE ATMOSPHERE: ROLE OF WHISTLER WAVES

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Whistler waves generated during a lightning play an important role in the generation of energetic electrons and their propagation to higher altitudes. The relativistic electrons produced by a cosmic ray shower during a thunderstorm can form the seed population that leads to a runaway discharge at an altitude of about 5 km. In such a discharge the energetic electrons ionize the neutral gas, thus producing thermal electrons which are accelerated to runaway energies by the thunderstorm electric field, and thus generating further ionization [1, 2]. Furthermore these relativistic electrons drive the whistler waves unstable and lead to the formation of ducts by the self-focusing as first suggested by Kaw et al.[3]. These ducts in turn facilitate the propagation of the energetic electrons to heights of about 30 km. At such altitudes the gamma rays produced by bremsstrahlung of the relativistic electrons can escape the atmosphere, and are well correlated with the gamma ray flashes detected by Compton Gamma Ray Observatory [4], and recently by the Reuven Ramaty High Energy Solar-Spectroscopic Imager (RHESSI) spacecraft. The focus of this paper is on the processes associated with the whistler waves excited by a beam of hot magnetized electrons in the atmosphere. We consider whistlers propagating in the two component plasma, which consists of a beam of relativistic runaway electrons and of cold electrons produced by the impact ionization of neutral gas (air). In this specific case the hot electron are magnetized, while the cold electrons are demagnetized due to electron-neutral collisions as it typical in the atmosphere from above 15 km and up to 70 km. The drift of the energetic electrons relative to the bulk electrons leads to a negative energy instability of the whistlers. The growth rate of the instability depends on the number density of the energetic electrons and their collision rate, and peaks at about 25 km. The runaway breakdown, which is essential for the whistler instability, develops under conditions similar to those leading to the generation of strong narrow bipolar radio pulses, which have been observed recently. The main conclusions are:

- An instability develops in the lower stratosphere when whistlers interact with plasma consisting of a beam of relativistic magnetized electrons and the bulk of unmagnetized electrons.
- The instability growth rate nonlinearly depends on the plasma density and altitude, and corresponds to the conditions of interest to runaway discharges.
- Preliminary results from a numerical simulation shows a sustained runaway discharge and indicate the formation of ducts and transport of hot electrons to the desired height of 30-35 km where the gamma rays due to bremsstrahlung escape into space.

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