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RUTHERFORD APPLETON LABORATORY

SCIENCE AND ENGINEERING RESEARCH COUNCIL

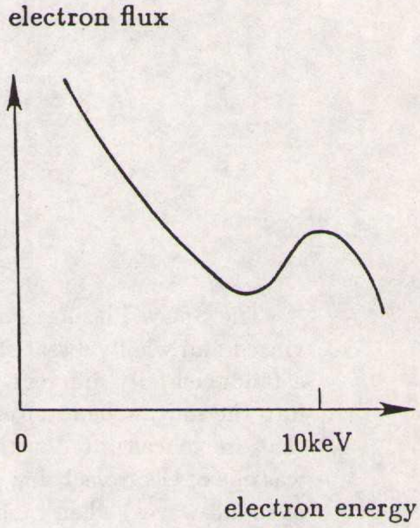
How are the Northern Lights powered?

The Northern Lights remain one of the unsolved puzzles of the Earth's upper atmosphere — a mystery extending to the planets Jupiter, Saturn and Neptune also. The glow that is always present at altitudes of 100-200km over the northern and southern auroral zones (centred on latitudes of 70deg) is well understood to be the flourescence of atmospheric oxygen and nitrogen under constant bombardment from electrons scattered from the radiation zones that surround the Earth.

The puzzle is that the electrons that produce the spectacular auroral curtains have been found, from numerous rocket and satellite missions to be concentrated in a narrow range of energies, with a maximum usually near 10keV. It is not that such particles are hard to produce — after all, the ones that cause our television screens to glow, in close analogy to the phenomenon of the aurora, have more than double this energy. Television sets, though, are highly contrived devices that use the power of the electrical supply to force electrons to the high (25,000V) electrical potential from which they are released at high speed, just like a skier whose impressive speed downhill derives from the fuel that drives the ski lift uphill.

For more than 30 years now it has been widely accepted (nb not a guarantee of validity) that the narrow band of energies must have been caused by the electrons descending from a potential hill, though no explanation has ever been offered for how the potential energy was acquired, or what agency provided it!

Is the electron accelerator...



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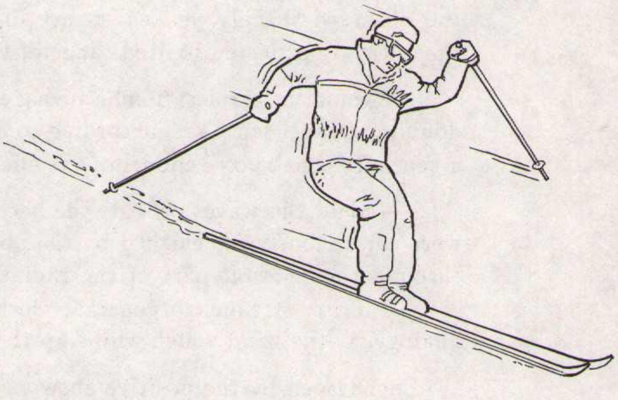
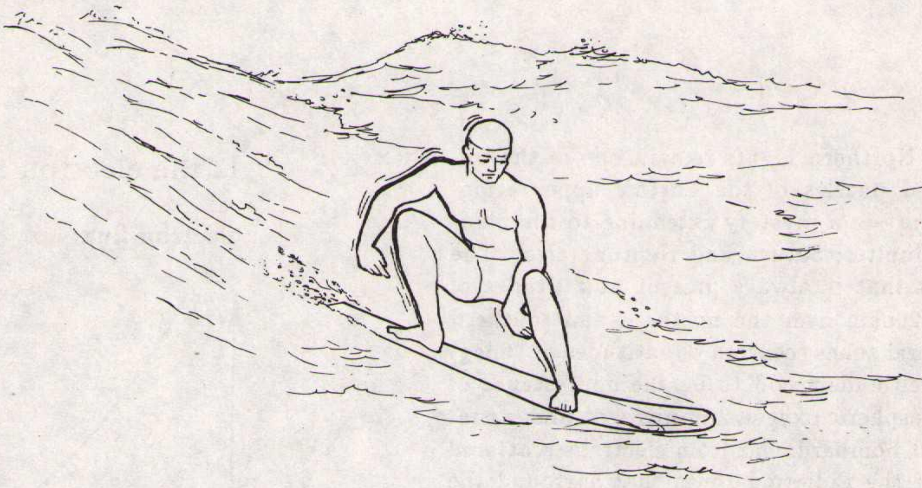


OR...

THIS...?



The Space Plasmas Group at the Rutherford Appleton Laboratory, decidedly unconvinced and wholly dissatisfied by this state of affairs, has, over a number of years developed a fundamentally different theory. The question they posed was —-could the acceleration into the narrow band of energies be the result of buffeting by the turbulent electric fields that are concentrated in the auroral regions of the radiation zones? The process envisaged was one of electrons being propelled forward by electrostatic waves (the electrical equivalent of sound waves) when caught up by a faster-moving wave —- just as a surfer is accelerated by an ocean wave. In both cases the speeds of the electron/surfer and electrostatic/ocean wave need to be closely matched, or the wave will just slip past. The crucial questions that had to be answered were

—- could the random jostling of electrons, with both gains and losses of energy, create the observed sharply peaked energy distribution? [Yes, it could if the waves have the theoretically expected limited range of velocities.]

—- would the acceleration be strong enough and rapid enough to account for the observed doubling of speeds? [Yes, according to assessments based on standard diffusion theory and a specially constructed model of the effects of random gains and losses.]

—- could the waves provide the necessary power of 10,000 MW? [Yes, as long as they were continuously replenished by the positive ions (mainly protons) found to be streaming through the relevant part of the radiation zones. Instabilities, not yet fully understood, cause the ion streams to generate electrostatic waves ,and thus serve, to use our earlier analogy, as the wind which whips up the waves on which the surfer rides.]

Encouraged by the positive answers to these and other vital questions, the new theory of wave acceleration is advancing steadily, and slowly beginning to gain ground from the established potential-difference theory.