were once part of a single body which orbited the Sun at this radius. The other example is the system Neptune–Pluto, in which the orbit of Pluto overlaps that of Neptune, but in a resonance which prevents close interaction. Although the significance of this is not yet completely understood, this overlap has been interpreted to mean that Pluto may be a former satellite of Neptune[7].

The main conclusion is that in the absence of any plausible means for subsequent circularization of the orbits it is highly unlikely that fission of primary planetary bodies could have given rise to the planetary configurations observed today.

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Planetary Fission Events—Reply to J. M. Bailey

WERE it suggested that planetary fission might occur in the solar system in its present state, then Dr Bailey's conclusions would evidently be applicable. But if we ascribe the smallness of the eccentricities of the planetary orbits to the effect of a resisting medium that was present in the early stages of the system, Bailey's criticism would not apply to fission occurring during those stages.

In the recent reports[1] to which Bailey refers, the cases of fission I discuss are envisaged as taking place at, in fact, an early stage in the evolution of the solar system when there would necessarily be debris present to supply the resisting medium. Such fission results from rotational instability, and this implies the speeding-up of the rotation of whatever part of the proto-planet concerned it is that undergoes fission. The speeding-up is achieved by condensation in a more slowly rotating body. In the case of a planetary body the only way to get considerable condensation is for heavy material to settle towards the centre of a body consisting originally of a mixture of the heavy material with light gases. In the case of a terrestrial planet the light gases would be lost in the course of the subsequent development, the necessary escape energy being mainly the gravitational energy released by the condensation of the heavy material. It is seen that all this does belong to the very early history of such bodies.

Bailey states, on the other hand, "It is generally considered that planetary accumulation was essentially complete and the interplanetary medium depleted before differentiation of the core and mantle of the Earth took place". The reason for mentioning this differentiation in the context is, presumably, that this would evidently precede any fission that could have produced Mars. The general view is, no doubt, that stated by Bailey, but the ideas I presented are part of a different view of the formation and evolution of the solar system. In particular, I suggested a new process of differentiation that would have the merit, from the standpoint of the present discussion, of taking place very early in the formation of the proto-Earth, being indeed a feature of the process that could have led to rotational instability and fission. The picture seems to be self-consistent throughout. Because any fission that took place must have occurred at a very early stage, "the circularization of the orbits" of the fission products and of the other planets would all have proceeded at the same time. Thus the "circularization" of the orbit of Mars, even if Mars originated by fission from the Earth, would be produced in the same way as that of the orbit of, say, Jupiter or of the Earth itself.

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VLF Wave Generation by the Čerenkov Process in the Inner Magnetosphere

ELECTROMAGNETIC waves of very low frequencies (VLF) are generated by a variety of natural processes. This letter is to offer support for the Cerenkov process, in which radiation is produced by the interaction of moving electrons with the ambient plasma.

VLF observations at high latitudes are correlated with the influx of electrons[1,2]. VLF outbursts are also observed at low latitude stations[3], and in trying to explain the origin of these VLF waves, Gurnett[3] discarded the Čerenkov process because he was not able to find any correlation with the simultaneous intense electron influx. The recent measurements of low energy (10 eV) electron influx reported by Knudsen[4] and its correlation with VLF hiss at low latitudes ($L = 1{\cdot}1$) once again raises support for the Čerenkov process. Knudsen showed that the intense electron influx of energy 10 eV and the VLF hiss observed between 240 km and 320 km in the non-equatorial zone and up to a height of 2,785 km in the equatorial zone have similar spatial distributions.

We calculate the VLF power radiated by an influx of 10 eV electrons and show that the measured VLF power could be explained easily by the Čerenkov process. We have used McKenzie's[5] formulation which is valid for low frequency electromagnetic radiation from low energy electrons for a detailed study of electromagnetic radiation from the magnetosphere[6]. The expression for radiated power under the condition $(cf_h/vf_p)^2 \gg 1$ and for frequencies $0 < f < f_2$ is

$$\frac{dW}{df} = \frac{e^2\pi cf}{\varepsilon_0 v^2 f_p^2}(f_2^2 - f^2) \text{ W Hz}^{-1} \qquad (1)$$

where e and v are the electronic charge and velocity, c is the velocity of light, ε_0 the permittivity of free space; f, f_p and f_h the emitted, plasma, and gyro frequencies, and $f_2 = f_h(1 - v^2 f_p^2/(c^2 f_h^2))$.

The electron density distribution for low latitude ($L = 1{\cdot}1$) has been reported by many workers[7–9]. Using the measurements of Knudsen[7] we have calculated the plasma frequency which is assumed to be constant for a major part of geomagnetic lines of force corresponding to $L = 1{\cdot}1$. The variation of gyrofrequency along field lines is calculated assuming a dipole field for which

$$B = B_0(R_0/R)^3(1 + 3\sin^2\varphi)^{1/2} \qquad (2)$$

where B_0 is the magnetic field at the equator on the Earth's surface and R_0 is radius of the Earth. R and φ are the geocentric distance and latitude angle of points along a field line. The Čerenkov power radiated by an electron of 10 eV is found to be $2{\cdot}6 \times 10^{-28}$ W Hz^{-1}. The influx of 10 eV electrons is 2×10^7 m^{-3}, and therefore the total power density of the Čerenkov radiation is $5{\cdot}2 \times 10^{-21}$ W Hz^{-1} m^{-3}. The radiated power is found to increase with increasing radiation frequency, which is consistent with the experimental prediction of Bell[10] and our recent calculations[6].

It is well known that VLF waves propagate along field lines and are received on the ground. We therefore need to evaluate the integrated VLF power at certain