NEWS AND VIEWS

Earthquakes and the Chandler Wobble

THE matter of a neutron star can theoretically be a solid, or a solid mantle enclosing a liquid core, and thus somewhat similar to the Earth. This highly theoretical solid necessarily invokes the attention of highly theoretical solid state physicists and so it comes about that a new variety of scientist pays attention to some old problems about rotating elastic bodies, earlier considered in relation to the Earth. Furthermore, if the neutron star is analogous in structure to the Earth, it may exhibit phenomena analogous to earthquakes, a possible interpretation of sudden changes in the frequency of pulsars. Hence these scientists also approach these problems with seismicity in mind. Now, Pines and Shaham return from consideration of neutron stars to take a new look at these matters in relation to the Earth itself (see page 77 of this issue of *Nature* and *Nature Physical Science*, **243**, 122 ; 1973).

Pines and Shaham in their analysis define tensors, having the form of moment of inertia tensors, which represent (as far as quadrupolar terms) the departure from spherical symmetry in the Earth's moment(s) of inertia $\delta\mathbf{I}$, its configuration $\delta\mathbf{I}_c$, its distribution of density $\delta\mathbf{I}_1$, and (this being where the novelty of their treatment enters) that part of the Earth's asphericity which is sustained by shear stresses in the solid, defined as $\delta\mathbf{I}_c-\delta\mathbf{I}_0$. They find it possible to estimate all of these from the available observational data. Their analysis leads to the conclusion that the Earth holds an elastic energy store of about 10^{25} J, mostly due to insufficient oblateness for elastic equilibrium but to some extent (10%) due to a non-optimal direction of the pole of flattening. This "angular" part of the elastic energy is much larger than has appeared in any previous estimates, which has important consequences for the effect of superposed tidal stresses.

Pines and Shaham adopt the very acceptable hypothesis that earthquakes occur to reduce the elastically stored energy in the Earth, and plausibly assume non-linear mechanical properties such that an earthquake will be triggered when the elastic energy exceeds a sufficient magnitude for a sufficient time—so that longer period variations in elastic energy are emphasized by comparison with the larger variations of short period, such as diurnal tides. One such variation with a period of 6 or 7 yr arises from interference between the annual term and the Chandler wobble period in the polar tides.

Euler, in 1765, calculated that the Earth should have a free nutation period of 10 months. Observations failed to reveal such a motion, but in 1891 S. C. Chandler, a merchant of Cambridge, Massachusetts, analysed discrepancies in determinations of latitude and discovered a small wobble of the Earth with a period of 14 months and an amplitude of polar displacement of about 6 m ; then in 1892 Lord Kelvin was able to tell the British Association that Euler's calculation had been wrongly made for a rigid Earth, and Newcomb had been able to show that elastic yield in the Earth would account for the lengthening of period.

The persisting problem has been to discover what source of energy maintains the Chandler wobble, which should be damped out by tidal friction. Earthquakes have been suggested as a driving source, but are inadequate to account for the observed amplitude of wobble if they occur randomly in time. Pines and Shaham's theory, however, suggests preferential triggering of earthquakes at intervals of 6 or 7 yr, in a consistent phase relationship to the Chandler wobble that is right for the maintenance rather than the suppression of the wobble. Whitten, in 1970, examining the variations in annual seismic energy release from 1900 onwards, found evidence of a 7 yr periodicity and suggested a connexion between this periodicity and polar motion. Earthquakes occurring with correct preferential phasal relationship to the Chandler wobble as predicted by Pines and Shaham's theory can keep it going.

To attach importance to this theory, one is not obliged to accept the authors' "scenario" according to which the present 10^{25} J of elastically stored energy is the residue of a much larger quantity created in an "elastic energy epoch" some 10^8 or 10^9 yr ago. The seismic energy release rate of 10^{18} J yr^{-1} is much exceeded by the heat flow from the Earth, 50 mW m^{-2} making 6×10^{20} J yr^{-1}, and it is no less compatible with their theory that the unshapeliness of the Earth, and its consequent elastic energy store, is continuously maintained by thermally induced transport of matter associated with this heat flow. F. C. F.

Jupiter's Magnetosphere

WITH two spacecraft on their way to Jupiter, considerable theoretical effort is being made to predict details of the planet's environment. In December of this year when Pioneer 10 reaches its point of closest approach, 2.86 R_J (Jupiter radii), many of these predictions can be tested.

One aspect of Jupiter's environment which has received particular attention is its magnetosphere and the associated trapped radiation belts. Recently, Mead of NASA Goddard Space Flight Center and Hess of the Environmental Research Laboratories, Boulder, Colorado, have shown that Jupiter's satellites may appreciably modify the particle fluxes trapped in the Jovian radiation belts (*J. geophys. Res.*, **78**, 2793 ; 1973). Five (Amalthea, Io, Europa, Ganymede, Callisto) of Jupiter's twelve satellites lie entirely within the magnetosphere.

The fact that Jupiter has a magnetosphere was deduced from the study of radio emissions from the planet. The 10.4 cm radiation was first discovered by Sloanaker (*Astr. J.*, **64**, 346 ; 1959) and later shown not to come from the surface of the planet but to have a brightness distribution which peaks in the equatorial plane at an altitude of 0.9 R_J. The radiation also has a strong linearly polarized component which suggests that it is synchrotron radiation from high energy electrons trapped in a magnetic field. Decametric radio bursts are also observed from Jupiter with frequencies ranging from 38 MHz down to the lowest frequency which can penetrate the Earth's ionosphere. On the assumption that this radiation is at the electron gyrofrequency close to the planet one can conclude that the surface magnetic field