scopes at Kitt Peak and Mount Wilson revealed magnitudes between 12 and 15.5. Pairs of observations on the same day and on successive days show that the variability can be as fast as a third of a magnitude per day. But in general the spacing of the measurements is too haphazard to pick up hints of periodicities, or to match the optical variability to the sparse radio measurements available for 1968.

Unfortunately no lines have been picked up in the optical spectrum of *BL Lac*, which DuPuy *et al.* see as particularly ominous for the quasar theory. Quasar emission lines are usually prominent when the background continuum is weak, but even when *BL Lac* is at its faintest no lines can be seen. With no lines to be red-shifted, there is no knowing whether or not it is extragalactic.

Earlier this year Visvanathan described the optical continuum in some detail, and contended that most of it is synchrotron radiation (*Astrophys. J. Lett.*, **155**, L133; 1969). The possibility that the continuum is thermal radiation from a cool dwarf star is rejected because of an excess of radiation in the blue and ultraviolet and because of nearly ten per cent linear polarization. So far, however, nobody has ventured to devise a model for the emission.

FERROELECTRICS

Tunnelling and Scattering

from our Solid State Physics Correspondent

THE spontaneous electric dipole moment which is the mark of a ferroelectric crystal endows a solid of this kind with a rich collection of properties. The mechanics of ferroelectric transitions and of the dielectric and particle scattering properties of ferroelectrics have been the focus of a great deal of research in the past ten years. In the process of trying to unify some of the knowledge gained, W. Cochran (*Advances in Physics*, **18**, 157; 1969) has demonstrated that the connexion between the frequency dependent susceptibility and the coherent neutron scattering cross-section has a special significance for ferroelectrics, being determined in each case by a ferroelectric mode of vibration.

Phonon modes of vibration are common to all ordered structures in which atoms vibrate about given sites in a lattice. Many ferroelectric crystals, however, of which KH_2PO_4 is an example, are also capable of a particular type of excitation known as a tunnelling mode. In KH_2PO_4 , there are two positions of minimum potential energy for each hydrogen atom, and if the states overlap and the protons interact, a new wave-vector and temperature dependent set of modes will exist in the solid. These are called tunnelling modes. This arrangement can be thought of as analogous to a system with spin $\frac{1}{2}$.

Making fairly straightforward assumptions, Professor Cochran has shown that the relations which link the dielectric susceptibility and the coherent neutron cross-section are essentially the same for tunnelling modes as for phonon modes. One difference, however, is that there are no multi-excitation contributions to the cross-section for tunnelling modes. To account for the properties of real ferroelectrics of the KH_2PO_4 type, and in particular for the angular relationship of the hydrogen bonds to the ferroelectric axis, it is necessary

to assume a coupling between phonon and tunnelling modes. Cochran shows that there are the same relationships of dielectric to scattering in this coupling model as in the purely tunnelling model.

The Ising model is known to give a fair description of the dynamics of a different type of ferroelectric— NaNO_2 . Cochran points out that the results from the Ising model can also be arrived at as limiting cases of the tunnelling model. It is interesting to note that the form of the scattering by tunnelling modes closely resembles that by spin waves in a magnetic material. One of the chief problems in obtaining neutron scattering data from KH_2PO_4 is that the hydrogen atoms scatter incoherently. If deuterium atoms are substituted for the hydrogen atoms, it has been suggested that scattering by the ferroelectric mode should be observable. This prophecy looks like being upheld, according to experimental evidence now in the pipeline.

PALAEOMAGNETISM

Dipole Hypothesis

from our Geomagnetism Correspondent

THERE seems little doubt that the principal aim of the early palaeomagnetists was to determine the nature and form of the geomagnetic field during the period covered by the rock record. The most obvious question was whether or not the Earth's field has always maintained its chiefly dipolar character. When it subsequently became clear that palaeomagnetic directions were consistent with the drifting of continents, the emphasis in palaeomagnetism changed towards the solution of geological problems which had no direct connexion with magnetic fields. The hypothesis that, when averaged over 100,000 years or so, the axis of the dipole field coincides with the axis of rotation then appeared as an assumption. As opponents of continental drift are fond of pointing out, the validity of the axial dipole assumption over geological time has never been confirmed satisfactorily.

The grouping of Holocene and Tertiary mean pole positions around the geographic pole seems to imply that the assumption is valid for these periods, although Doell and Cox's results from Hawaii (*J. Geophys. Res.*, **70**, 3377; 1965), which suggest a persistent 6° offset of the pole during the past million years, have cast some doubt on this. Further tests were clearly needed, and have now been provided by Opdyke and Henry (*Earth and Planet. Sci. Lett.*, **6**, 139; 1969), who have access to the large collection of ocean sediment cores being investigated at the Lamont-Doherty Geological Observatory. Fifty-two of these cores, from all the oceans of the world and from between latitudes 55°N and 62°S , were chosen for analysis. Selection was limited to cores which included the Brunhes-Matuyama polarity reversal and in which the standard deviation

Pole position		Description	Standard deviation
Lat. °N	Long. °E		
90	0	Geographic pole	3.4
89	211	Best fitting pole	3.1
79	290	Present magnetic pole	7.4
84	313	Hawaiian pole	5.5