a blurring in the cores of the Balmer lines. It seems that the observed lines are sufficiently sharp that even a conservative upper limit on the field strengths at the surface of these stars requires a reduction of Preston's figure by a factor of two, the lowest field found by Angel and Landstreet being $\sim 3 \times 10^4$ gauss for the star 40 Eri B. These figures are definitely not in agreement with the suggestion that flux is conserved during the evolution of a star from the main sequence to the white dwarf state, and there is correspondingly little reason to believe that flux will be conserved when neutron stars are formed.

QUASARS

Beyond the Lyman Limit

from our Observatories Correspondent

A FEW weeks ago the quasi-stellar radio source 4C 05·34 was reported to have the largest redshift yet observed, $z = 2{\cdot}877$ (R. Lynds and D. Wills, *Nature*, **226**, 532; 1970). Ultimately this object may lead to new insights into cosmology and the question of the origin of the quasars. But more immediately, 4C 05·34 is important because for the first time observations can be made of a quasar shortward of the confluence of the Lyman series of hydrogen. The Lyman limit has a rest wavelength of 912 Å and therefore occurs at a wavelength of 3536 Å in the Earth's frame. This is comfortably longward of the ozone absorption which limits terrestrial observations to wavelengths longer than about 3100 Å. J. B. Oke of the Hale Observatories has reported recently (*Astrophys. J. Lett.*, **161**, L17; 1970) the first photoelectric measurements of the behaviour of the continuous spectrum of 4C 05·34, made with a 20 channel photometer attached to the 200-inch telescope at Palomar. Oke's observations show that shortward of the Lyman limit the intensity of the quasar emission is lower by a factor of 2 than immediately above. This result is expected because the opacity of neutral hydrogen to photoionization undergoes a discontinuity at the Lyman limit. Photons with wavelengths less than 912 Å can ionize hydrogen directly from the ground state; photons of slightly longer wavelength can only ionize those hydrogen atoms which have their electron in one of the excited states.

Oke's measurement has two important implications. First, it shows that the emitting gas in this quasar is optically thin in the Lyman continuum. Moreover, there cannot be much neutral hydrogen around the largely ionized emitting region—otherwise no radiation shortward of 912 Å would be able to escape from the object. If an object is optically thick in the Lyman continuum it can easily be shown that one Lyman α photon is produced for every Lyman continuum photon absorbed. This fact enabled Oke to check his conclusion that not all the Lyman continuum photons are being absorbed within the quasar. Above the Lyman limit, most quasars have a roughly power law dependence of the continuum intensity on frequency. Oke used this to estimate the expected number of continuum photons with wavelengths less than 912 Å. He found that it was a factor of 3·4 greater than the observed number of photons radiated per second in the Lyman α emission line, thus checking his conclusion.

The fact that radiation does get out of 4C 05·34 beyond the Lyman limit increases the mystery of why quasars with even higher redshifts have not been found. Quasars are easily identified optically because they are much bluer than most stars. It was suggested some years ago that quasars with a redshift larger than $z \simeq 3$ would appear red if they were optically thick in the Lyman continuum. Oke's observation removes this possibility, although it does perhaps suggest that high redshift quasi-stellar objects would be less blue than those of low redshift.

SEISMOLOGY

Earthquakes and Temperature

from our Geomagnetism Correspondent

CALIFORNIAN earthquakes share a curious property—they are all shallow, with foci limited to depths of 10 to 20 km. But why should this be so ? It is unlikely that movement along a fault as long as the San Andreas is limited to these depths, especially as plate tectonic theory predicts the existence of plates much thicker than 20 km. The only other possibility seems to be that, although fault movement takes place at all depths, for some reason the motion below about 20 km is earthquake free. In that case, what is the basic difference between the sliding above and below the 20 km point ?

The results of laboratory experiments suggest to Brace and Byerlee (*Science*, **168**, 1573; 1970) that the answer is simply temperature—above a certain temperature, stick-slip earthquake-producing motion gives way to stable sliding earthquake-free movement. The trouble with laboratory experiments, of course, is that it is impossible to simulate natural conditions accurately; but Brace and Byerlee's work strongly supports their hypothesis. They have simply studied frictional sliding in granite and gabbro containing natural fractures and artificial sawcuts, in various conditions of temperature and pressure. Actually, "simply" is hardly the right word, for although it is rather easy to visualize an experiment like this in general terms, the practical problems are almost intractable. Brace and Byerlee have done for the first time something which has taxed the ingenuity of scientists for many years.

It emerged that frictional sliding is markedly dependent on temperature. At pressures from 1 to 5 kbar, stick-slip gave way to stable sliding as temperature was increased from 200° C to 500° C. So far, this is simply an experimental fact with no known physical explanation. But its possible application to California, where the temperature at a depth of 15 km is estimated to be 300° C to 500° C, is clear. In fact, the agreement is almost too good to be true, because in a real fault conditions will be modified by debris on the sliding surface and water in the rocks. Furthermore, the strain rates used in the laboratory (10^{-4} to 10^{-6} s^{-1}) were probably higher than those occurring in the field.

If Brace and Byerlee are correct about the temperature effect, what other consequences might follow ? For one thing, it turns out that the temperature boundary between stable and unstable sliding in the laboratory is close to the geothermal gradient in the field. This could mean that the lower limit of earthquakes might be irregular with depth, and that local cold spots along the San Andreas fault, which are known to exist, might be regions of higher than average seismic activity. A correlation of this type is, in principle, testable, though it has not been tested yet.