yielded very little bone but many more implements than the loam.

The bone, which has proved difficult to handle because of its great fragility, is at present being identified, and will later be carefully examined for any evidence of human influence on it. One hopeful sign is an antler which seems to have been worked into a point, probably for use as a tool. Working on the assumption that he has found a refuse pit, Waechter enlisted a local band of small boys to emulate their Palaeolithic forebears and see how far they could effortlessly throw objects with the dimensions of his finds. Having concluded that about thirty yards was probably the limit for easy throwing of refuse to the dump, he said, he has marked with a twig the place where he thinks the Swanscombe camp site is to be found. Another two or three seasons should show whether he is right.

PULSARS

# Crab Pulsar and its Planet

from our Cosmology Correspondent

WITH the growing evidence that the entire source of energy for the Crab Nebula lies in the rotating neutron star believed to be associated with the pulsar NP 0532, several attempts have been made to determine the mechanism linking the two physically separated parts of this system, namely the small central star and the large expanding shell of luminous matter. These have been hampered by incomplete understanding of the processes producing supernovae and neutron stars, but A. Cavaliere and F. Pacini have now been able to describe in reasonably accurate terms the evolution of a supernova remnant which does contain a central rotating dense star. The star is taken to be coupled to the remnant largely through the electromagnetic forces involved, because gravitational radiation and mass loss subsequent to the original explosion seem likely to produce only small effects. Cavaliere and Pacini find (*Astrophys. J. Lett.*, **159**, 21; 1970) that the rate of decrease in luminosity of a remnant at any time is closely linked to the observable properties of the central neutron star, and that these parameters when measured for NP 0532 are in good agreement with the theory. The only other known supernova remnant with a radio emission which decreases measurably is Cas A, for which the model predicts an associated pulsar with period $\lesssim 0{\cdot}7$ s. Unfortunately, it seems unlikely that pulsed radiation from this source will be detected if the most widely favoured models for pulsars are at all correct, for the radiation would be highly directional and unlikely to be orientated towards the Earth.

The recent observations of NP 0532 indicating a quasi-sinusoidal variation in period suggestive of the perturbations due to a planet (D. W. Richards *et al.*, *IAU Circ. No. 2178*) and a sudden variation tentatively explained in terms of a "starquake" (D. W. Richards *et al.*, *IAU Circ. No. 2181*) can now both be explained in terms of disturbances due to a planetary companion. If a pulsar is created abruptly in a sudden explosion involving mass loss, then any associated planet initially in a circular orbit will be forced into an eccentric orbit with eccentricity $e = f(1-f)$, where $f$ is the ejected mass fraction (F. C. Michel, *Astrophys. J. Lett.*, **159**, 25; 1970). As Michel points out, an initially eccentric orbit could thus be changed to a roughly circular orbit, and although this is unlikely it seems the only way to account for the form of the sinusoidal variation in period of NP 0532, assuming that this is indeed caused by a planet.

The more likely case of a roughly circular orbit being changed to one of extreme eccentricity could well result in sudden changes in the pulsar's period as a result of close approaches to the parent body, as seen in both NP 0532 and PSR 0833. The rather short interval between the discovery of these pulsars and their observed sudden changes in period suggests that they each have a companion orbiting roughly once a year, clearly a very reasonable orbital period for planets. Such effects will be repeated regularly so there is a ready test of Michel's model, and if these variations do recur as predicted they should provide a useful tool for determining detailed structure of these pulsars.

SPECTROSCOPY

# Broadening of Lines

from a Correspondent

A BRANCH of atomic physics that is advancing rapidly in response to the demands of astronomy and plasma physics is the study of the broadening of spectral lines in gases and plasmas. This was the subject of a meeting held by the Institute of Physics and the Physical Society at Imperial College, London, on February 6, 1970.

Dr H. G. Kuhn (University of Oxford) summarized the two extreme case approximations for line broadening that dominated the theory until recently and are still very useful. These are quasi-static or statistical broadening (valid in the outer wings of a line) in which the motions of the perturbing atoms or ions are neglected, and impact broadening (applicable nearer to the line centre) in which superposition of phase shifts of the emitted radiation due to isolated encounters leads to a Lorentz profile accompanied by a small shift. Kuhn said that some lack of cohesion between theorists and experimenters, due to difficulties encountered by both, is now being overcome and understanding of interatomic forces is increasing.

Professor W. R. Hindmarsh (University of Newcastle upon Tyne) described recent studies with neutral perturbers. The classical Lindholm treatment, assuming pure van der Waals attraction, predicts incorrect line shifts, but agreement is much better when the repulsive interaction at small interatomic distances is included. Dr H. van Regemorter (Observatoire de Meudon) showed that repulsive forces probably account for the bulk of the line width as well. A further effect of complications in the interatomic potential curve is the appearance of satellites on either side of the unperturbed line, some striking examples of which were shown by Dr R. Granier (CNRS, Bellevue, Paris). When broadening is due to identical—as opposed to foreign—atoms, a stronger (dipole) interaction occurs. Dr D. N. Stacey (University of Oxford) showed that the theory of this resonance broadening effect is successful except at very low pressures where natural damping may invalidate the impact approximation. Dr C. Baron (Rank Precision Industries, Leeds) described experiments on pressure broadening of Zeeman components in a magnetic field.

The theory of broadening by charged perturbers has been greatly improved recently by the work of Baranger, Griem and others, but some problems remain.