who had timing data for this period were not prepared to admit the presence of a jump of similar magnitude, and were inclined to seek an explanation in the processes occurring nearer the surface of the neutron star.

Dr L. Woltjer (Columbia) noted the well established fact that the energy released from the continuing slowdown of the pulsar is comparable with the energy radiated from the nebula, and he emphasized the high efficiency (20–100 per cent) of accelerating electrons and protons to relativistic energies. Although the precise mechanism is not agreed, pulsars can efficiently provide sources of highly relativistic particles in the Galaxy.

Are the Crab Nebula and its associated pulsar unique? Dr D. K. Milne (Radiophysics Division, CSIRO, Sydney) concluded from an extensive survey of about 100 radio supernova remnants that there may be several with the same centrally filled structure as the Crab. These are, however, more evolved, and clearly there is no other source of the same age as the Crab Nebula in the Galaxy. A similar conclusion was reached for the Crab pulsar—none of the same age have been detected, but several have similar pulse shape and polarization characteristics.

Many problems remain. What, for example, is the role of general relativity in the high densities of neutron stars? Why do all the 55 pulsars known have a pulse width close to 3 per cent of their period? Professor F. G. Smith (Jodrell Bank) reminded delegates that although many pulse characteristics could be conveniently explained in terms of the generally accepted oblique rotating magnetic field model, there were difficulties in explaining the high degree of circular polarization at the edge of the pulses. He suggested that this is some maser amplification process operative at radio wavelengths.

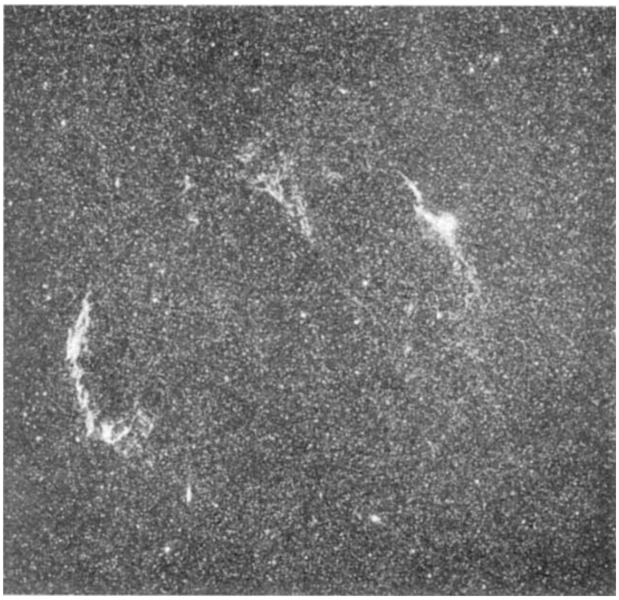
SUPERNOVAE

X-rays from Cygnus Loop

from our Observatories Correspondent

THE detection of soft X-rays from a source (Cygnus X-5) which is thought to be the Cygnus Loop has been reported recently in *Astrophysical Journal Letters* (**161**, L45; 1970). The discovery was made by a team from the Lawrence Radiation Laboratory of the University of California, R. Grader, R. Hill, and J. Stoering, who used rocket-borne equipment.

The Cygnus Loop is the classical example of an old supernova remnant. It is composed of very fine filaments of emitting nebulosity which comprise two large diametrically opposed segments of a circle, about a degree across in the sky. (Portions of these filamentary structures, which by and large are tangential to the circle, are frequently used as illustrations in popular books on astronomy under such beguiling names as the "veil nebula" or the "network nebula".) In 1946 J. H. Oort suggested that the filaments form an expanding shell which resulted from the explosion of a supernova some 50,000 years ago and that the emitting gas is excited by collision with the ambient interstellar medium. E. Hubble had earlier shown that the fine filaments are indeed moving outwards at a measurable rate, about 3 seconds of arc per century. In 1958 R. Minkowski showed from spectroscopic measurements that the radial expansion velocity of the shell is about 100 km s^{-1}. The luminous filaments seem to be shock fronts moving at about this speed into the



Cygnus Loop

undisturbed interstellar gas. The gas immediately behind a shock front moving at 100 km s^{-1} would be ionized and heated to a temperature of a few hundred thousand degrees. Minkowski's use of both the radial and transverse components of the motion enabled him to estimate that the shell is at a distance of about 770 parsecs and that its diameter is about 40 parsecs. A sphere of this diameter in the galactic disk would be expected to contain about 2,000 solar masses of interstellar neutral hydrogen which in this case has been swept up by the shock front created in the initial supernova explosion.

The LRL group detected X-rays from the Cygnus Loop in the energy range 0·1 to 2 keV with a peak at 0·2 keV. This fall in emission below 0·2 keV can plausibly be attributed to absorption by interstellar gas. The experimenters are not certain of the origin of the emission. The observed X-ray spectrum above 0·2 keV can be fitted either by a power law of the kind produced by synchrotron radiation or by an exponential which would be produced by thermal bremsstrahlung from a hot gas at about 4 million K. A thermal origin seems to be the more likely hypothesis, although the required temperature seems a little high in view of the known expansion velocity of the shell. Nonthermal radio emission is observed from the Cygnus Loop. According to H. van der Laan it is synchrotron radiation produced by galactic cosmic ray electrons as they traverse the compressed interstellar magnetic field behind the shock front.

Whichever theory turns out to be right, it seems that X-ray observations will give important data on the evolution of supernova remnants from relatively young objects such as the Crab Nebula to objects as old as the Cygnus Loop.

ATOMIC PHYSICS

More Uses for Lasers

from a Correspondent

ADVANCES in experimental techniques reported at the international conference on atomic physics, held in