0.04. This ratio exceeds, but does not disagree with, the results obtained by Fishman *et al.*³ and Floyd *et al.*⁴ for a similar energy range. The comparison is shown in Fig. 3, which also presents observations at lower X-ray energies⁵⁻⁷.

The chief outcome of this experiment is that a further increase of the pulsation ratio above 20 keV cannot be ruled out. This favours a model of Slysh⁸, in which the total X-ray output of the Crab Nebula is pulsed at the source.

A. J. M. DEERENBERG
J. A. M. BLEEKER

*Cosmic Ray Working Group,
The Royal Dutch Academy of Sciences,
Kamerlingh Onnes Laboratorium,
Leiden*

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Upper Limit on Radio Flux from the X-ray Source Sco X-1 at 327 MHz

THE X-ray source Sco X-1 has been observed by radio telescopes at frequencies of 6.5 GHz by Andrew and Purton¹ and 5 GHz by Ables². Ables² found the source highly variable. These two determinations, however, do not yield a spectrum in the radio range. I have tried to observe the source with a cylindrical radio telescope (located at Ootacamund, India) at a frequency of 327 MHz with a band width of 4 MHz. The telescope covers an area of the sky of 2° in right ascension and 3' in declination. The radio telescope has an effective collecting area of about 9,000 m² and is steerable for 9½ h per day. We used the coordinates of the optical object corresponding to Sco X-1 (ref. 3). A signal of about 1 flux unit (10⁻²⁶ W m⁻² s⁻¹ Hz⁻¹) was observed when the telescope was centred on Sco X-1. This, however, is less than the expected confusion limit of about 1.5 flux unit for the radio telescope on the basis of 5 times the r.m.s. fluctuations caused by background radio sources lying within the beam of the radio telescope. Therefore the measured value should be the upper limit on the radio flux from Sco X-1 at 327 MHz. This upper limit together with the flux of Andrew and Purton and Ables gives an index $\alpha \lesssim 1.2$, if the radio spectrum is expressed in a form $J(\nu) = K\nu^{-\alpha}$, where ν is the frequency and K and α are constants.

I have observed the source on five days for a total of ten hours and found no change in the flux.

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KRISHNA M. V. APPARAO

*Tata Institute of Fundamental Research,
Bombay-5*

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Magnetohydrodynamic Oscillations of Neutron Stars

FLUID motions in neutron stars have been investigated theoretically several times¹⁻³, but the problem of free magnetohydrodynamic oscillations has evidently not been considered previously, notwithstanding its possible importance in connexion with the interpretation of pulsar observations⁴⁻⁷, especially the modulation of pulse rates^{8,9}. The arguments put forward in the letter indicate that the spectrum of these oscillations would typically range in period from 0.5 to several powers of ten times the rotation period of the star.

If $2\pi/k$ is a characteristic length scale and $\omega/2\pi$ the corresponding eigenfrequency of an eigenmode of a highly conducting³ fluid sphere or spherical shell of outer radius a , and C is the speed of propagation of elementary waves within the fluid, then

$$\omega \simeq Ck \quad (1)$$

Recent theoretical work on the liquid core of the Earth (ref. 10 and references contained therein) has shown that in the case of an incompressible fluid of uniform density ρ , the extent to which these elementary waves are affected by Coriolis forces due to the rotation of the sphere with angular velocity Ω relative to an inertial frame is determined by the value of the dimensionless parameter

$$\mathcal{R} \equiv V/2\Omega a \quad (2)$$

Here

$$V \equiv B/(4\pi\mu\rho)^{1/2} \quad (3)$$

where B is the magnetic field strength and μ is the magnetic permeability.

When Ω is so small that $\mathcal{R} \gg 1$, the elementary waves are transverse, plane polarized and nondispersive and they propagate at the Alfvén speed V (that is, $C = V$) along the magnetic lines of force; the corresponding range of ω is given by

$$\omega \gtrsim V/a \quad (4)$$

$\mathcal{R} k \geq a^{-1}$. On the other hand, when (as in the case of the Earth's liquid core and the Sun), Ω is so large that

$$\mathcal{R} \ll 1 \quad (5)$$

the properties of all but the very shortest waves, notably those for which $k \ll (Va/\Omega)^{-1/2}$, are strongly affected by Coriolis forces. These forces render the waves highly dispersive and, depending on the details of their complicated two or three-dimensional particle orbits, they propagate at speeds C that are either very much greater than or very much less than V , notably

$$C \simeq 2\Omega/k^2 a = V/k^2 a^2 \mathcal{R} \quad (6)$$

for the fast waves, and

$$C \simeq V^2 a k^2 / 2\Omega = V k^2 a^2 \mathcal{R} \quad (7)$$

for the slow waves. The corresponding approximate range of ω is given by

$$2\Omega \geq \omega \geq V^2 / 2\Omega a^2 \quad (8a)$$

or

$$1 \geq \omega / 2\Omega \geq \mathcal{R}^2 \quad (8b)$$

Additional complications must arise when effects due to density inhomogeneities^{11,12}, compressibility, superfluidity^{1,2} and various types of friction including ohmic effects^{10,3} are taken into account, but they should not invalidate equation (5) as a criterion for the occurrence of important rotational effects.

The electrically conducting component of a typical neutron star consists of protons and electrons and probably makes up a few per cent of the total mass, the remainder being neutrons⁶. If we take $B \sim 10^{13}$ G (ref. 13), $\rho \sim 10^{15}$ g cm⁻³ (ref. 6) and $\mu \sim 1$, then $V \sim 10^5$ cm s⁻¹. As the solid crust is presumably very thin compared with the radius of the star^{14,6}, most of the star will be fluid and electrically conducting, and so we can