The Binary Pulsar PSR 1913+16

J. H. Taylor and R. A. Hulse of the University of Massachusetts have detected a new rdaio pulsar which is a member of a binary system (*IAU Circular* 2704). The position coordinates of the pulsar are: $\alpha(1950.0)=19^h13^m13^s \pm 24^s$; δ (1950.0) = + 16°00′ ± 24″. The dispersion measure and the average flux have been estimated to be 167 ± 5 pc cm^{-3} and 5×10^{-29} wm^{-2}Hz^{-1} respectively. The apparent period of the pulsar varies between 58.967ms and 59.045ms depending on the component of velocity of the pulsar along the line of sight of the observer. Taylor and Hulse have used their measurements of the variation of the apparent period of the pulsar with time to compute the following parameters of the binary system; period of the orbit, 27907 ± 30^s (0.3230 day); radial velocity semi-amplitude, 198 km sec^{-1}; eccentricity of the orbit, 0.61; projected semi-major axis, 690,000 km and mass function, 0.13 $M_\odot$.

For the above object, P. Margon, A. Davidson, K. Mason and P. Sanford have put an upper limit of 10^{-10} ergs sec^{-1} on the pulsating X-ray flux between 1 Å—3 Å (*IAU Circular* 2712). W. Liller (*IAU Circular* 2714) has examined the plates of the region taken between 1891 and 1963 and does not find evidence of any kind of variable object brighter than 11th magnitude.

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The Binary Pulsar PSR 1913+16

Seven years have elapsed since the discovery of the first pulsar. More than 150 pulsars have been discovered during that period. However, it is a curious fact that none of the pulsars is a member of a binary system. Several theories have been proposed to explain this fact. One of these is that, if the progenitor of a pulsar is originally a member of a binary system, the explosion will always disrupt the system. However, this does not seem to be the commonest case since the exploding star in a close binary system is usually the less massive component, as a consequence of the mass transfer preceding the explosion; in this case, the explosion is generally incapable of disrupting the system. Shvartsman (*Sov. Astr.*, **15**, 342, 1971) suggested that a neutron star in a binary system can appear as a pulsar only for a comparatively short time. Stellar wind from the companion will suppress the ejection of material from the neutron star so that the neutron star will cease to be a pulsar and become an X-ray source. Another theory has recently been proposed by Bisnovatyi-Kogan and Komberg (*Sov. Astr.*, **18**, 217, 1974). They suggest that the magnetic field of a neutron star in a binary system will decay due to the mass transfer from the primary. They give evidence that the magnetic field of the neutron stars in the X-ray binaries is at most two order of magnitude less than in pulsars.

It is indeed very interesting that at the very moment when a lot of attention is being given to X-ray binaries, i.e., binaries with compact component, the first binary pulsar (PSR 1913+163) is discovered.

Flannery and van den Heuvel (preprint) have proposed two evolutionary scenarios for this system. In the first scenario, it is suggested that the exploded star is a white dwarf which is a member of a cataclysmic variable type binary with mass very near to the Chandrasekhar limit. As is well known, the period of such binary systems is usually only of the order of a few hours. Mass transfer from the companion will push the white dwarf above the Chandrasekhar limit and thus an explosion is expected. This is the mechanism suggested by Whelan and Iben (*Ap. J.*, **186**, 1007, 1973) for Type I supernova. The explosion should be asymmetric in order to explain the very short binary period of the resulting binary pulsar. In this scenario, the companion of the pulsar is thus expected to be a low mass main-sequence star ($\gtrsim 1\ M_\odot$). The apsidal motion of the system is predicted to have a period of a few months. In the second scenario, the authors point out that, as suggested by van den Heuvel and De Loore (*Astr.* & *Ap.*, **25**, 387, 1973), massive X-ray binaries like Cen X-3 and Cyg X-1 may evolve into very short period binary systems as a consequence of the mass transfer from the primary. At the end of the mass transfer, the system consists of a helium star (originally the helium core of the primary) and a compact object. Systems like Cyg X-3 (X-ray binary with period of a few hours) might be a result of such an evolution. The helium star will eventually explode as a Type II supernova and leave behind a neutron star as a remnant. PSR 1913+16 is proposed to be a result of such an evolution. The system will then consist of a young neutron star (the pulsar) and an old compact object (either a black hole or a neutron star). Since in this case the amount of mass ejected by the explosion is most likely larger than one half of the total mass, it is required that the explosion should be highly asymmetric, i.e. the exploded star acquires a kick velocity in a favourable direction due to some internal forces, in order to maintain the system in a close orbit. The fact that binary pulsar is very rare implies that the kick velocity is in general large to maintain the system remaining bound.

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Is the Gravitational Constant, G, Changing with Time?

Recent analysis of astronomical data by P. M. Muller (from Jet Propulsion Laboratory, Pasadena California and School of Physics, The University, Newcastle upon Tyne, U.K.) answers the above question in the affirmative. Muller obtains the following value for $\mathring{G}/G$:

$$\mathring{G}/G = -4.5 \pm 2\times10^{-11}\ \text{year}^{-1}.$$

Thus G is very slowly decreasing with time.

Muller has obtained this value by a careful analysis of the earth-moon system and the motion of other planets. If G were decreasing, the moon's mean angular velocity should decrease. However, the old recorded data makes use of the astronomical time rather than the more reliable atomic time. Also, tidal effects contribute towards the change of moon's mean motion. These and other smaller corrections must be properly taken into account before deciding whether moon's mean motion is indeed affected by a decreasing G. Muller claims to have taken these corrections into account in arriving at the above value.

Although a changing G will prove embarrassing to the gravitation theories of Newton and Einstein, some other theorists may feel happier. Brans and Dicke predict a decreasing G, and for a certain range of a parameter in their theory, the rate of decrease could lie in the error bars of Muller. The Hoyle-Narlikar theory is independent of any parameter and predicts a value $\overset{\circ}{G}/G = -H$, where H is Hubble's constant. For Sandage's recent determination of $H = -(5.6 \pm 0.7) \times 10^{-11}$ year^{-1} there is a good agreement between Muller's result and the Hoyle-Narlikar theory. Dirac's cosmology appears to predict a faster rate of decrease than that observed but Muller is uncertain about the interpretation of Dirac's theory.

Muller suggests new approaches, like the lunar laser ranging experiment (LURE), to narrow down the error bars on $\overset{\circ}{G}/G$.

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Diffuse Interstellar Clouds

Apart from the observed dense molecular clouds, the interstellar medium is generally assumed (G. B. Field, D. W. Goldsmith and H. J. Habing, *Ap. J.* **155,** L149, 1969) to exist in two phases in pressure equilibrium with each other, the phases being (i) diffuse clouds with typical density $n \sim 10$ cm^{-3} and temperature $T \sim 100$°K and (ii) an intercloud medium with $n \sim 0.1$ cm^{-3} and $T \sim 10^4$ °K. A calculation of molecular hydrogen concentration in the diffuse clouds assuming uniform n and T (D. J. Hollenbach, M. W. Werner and E. E. Salpeter, *Ap. J.*, **163,** 165, 1971) shows that H_2 is mostly contained in the interior of these clouds as a result of the selfshielding of the dissociating ultraviolet radiation. This will then cause inhomogeneities in the structure of the cloud, which will in turn affect the H_2 concentration. It is therefore necessary in order to obtain information regarding the existing physical conditions in the clouds from the observations, to have a detailed theoretical model which will account simultaneously for the pressure thermal, electrical and chemical equilibrium of the cloud. One such calculation for an isobaric cloud has been recently reported by Glassgold and Langer (*Ap. J.*, **139,** 73, 1974). The isobaric assumption may be valid as the typical sound crossing time for the clouds observed by OAO—III seems to be less than the average life time of a cloud. Only H, H_2, C I, C II, electrons and grains have been considered, as other components probably do not affect the thermal properties of the clouds significantly. Inhomogeneous density and temperature distributions have been obtained for given values of pressure, cosmic ray ionization rate and interstellar ultraviolet radiation field. The effect of varying the various parameters involved has been studied. The observed C I column densities can be explained by this model with cosmic ray ionization rate smaller than 10^{-16} S^{-1}. This seems to be consistent with the results of Jura (*Ap. J.*, **191,** 375, 1974) and O'Dennell and Watson (*Ap., J.* **191,** 89, 1974). Grain photoelectron heating has been found to be very important to achieve the observed cloud temperatures of 80 °K. Though a qualitative agreement with the OAO—III observations of fractional H_2 abundance has been obtained, it is not possible to determine the values of various parameters uniquely. Detailed analysis of individual clouds are necessary for more quantitative results.

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The gravitational N-body problem was discussed by R. K. Varma while the gravitational interactions between galaxies were highlighted by S. M. Alladin.

Theoretical bases for ion-atom and electron-atom collisions were discussed by N. C. Sil and A. S. Ghosh. The talk by S. M. R. Ansari summarized the atomic collision processes of interest to astrophysicists.

The importance of the properties of 'ambiplasma' for astrophysics, especially for the formation of galaxies, was discussed by P. K. Kaw. Yash Pal gave a popular talk on the 'Ancient Universe', emphasizing the importance of the recent measurements of deuterium in interstellar space.

An important feature of the symposium was the panel discussion on the 'Astrophysics in the 1970s' which brought forth the most fruitful areas of interest in Astrophysics.

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