LETTERS TO THE EDITOR

PHYSICAL SCIENCES

Pulsar Periods and Rapid Changes in the Terrestrial Rotation Rate

We wish to point out that the random fluctuations in the rotation rate of the Earth[1-4] are occasionally large enough significantly to affect the measured values of $\Delta P/P$ for pulsars. Recent measurements of $\Delta P/P$ (P is the pulse repetition period) reported by P. E. Reichley, G. S. Downs and G. A. Morris to a meeting of the US National Committee for URSI (Washington, April 22, 1969) have attained a precision of 1 part in 10^{16} or better. Such observations are usually corrected for effects due to the annual and diurnal motions of the Earth, the long term variation in the relationship between Universal Time and Atomic Time, and so on, in order to reduce them to the heliocentric frame or even that of the solar system barycentre. One then examines the reduced data for possible second-order terms in the pulsar slow-down process, such as the 1 per cent increase in $\Delta P/P$ that occurred after an abrupt change in the period of *PSR* 0833–45 (ref. 5). As we will show, however, it is necessary to analyse the data carefully in order to exclude effects due to the random variations in the length of the day (l.o.d.).

The mean equatorial rotational velocity of the Earth is $0{\cdot}4651\ \text{km s}^{-1}$ (ref. 6). The doppler effect on the apparent period of a pulsar, due to this velocity, is then approximately

$$\left(\frac{\Delta P}{P}\right)_{\text{rot}} = (1{\cdot}55\times10^{-6})\cos\lambda\sin H\cos\delta$$

for an observer located at latitude λ. The quantities H and δ are the hour angle and declination of the pulsar, respectively. Inspection of the data presented in the literature[1-4] shows that random fluctuations as large as 0·5 ms in the l.o.d. occur with time scales of the order of a month. The corresponding term in the apparent period change of a pulsar is then

$$\left(\frac{\Delta P}{P}\right)_{\text{random}} \approx (8\times10^{-15})\cos\lambda\sin H\cos\delta$$

The question thus becomes, can such an effect be detected in pulsar observations over time scales of the order of a month? Let us for simplicity assume a pulsar with period $P = 0{\cdot}1$ s and daily observation period (selected to coincide with a time of substantial contribution of the Earth's rotation to the apparent pulsar period, that is, to a time when the pulsar is at a rather large zenith angle) of order 10^4 s (slightly less than 2·8 h). Let us also assume, as stated, that the arrival time of a pulse is measured to an accuracy of 0·1 ms (10^{-4} s). The measured period and instrumental error at the end of one observing period are then approximately

$$P = \frac{10^4 \pm 2\times10^{-4}}{10^5} = (0{\cdot}1 \pm 2\times10^{-9})\ \text{s}$$

where 10^5 is the number of pulses that occur during the observing period.

Then the fractional error due to the limitation that a pulse can be measured with an accuracy of only 0·1 ms is (for the stated observing period)

$$\left(\frac{\Delta P}{P}\right)_{\text{instrumental}} \approx \frac{2\times10^{-9}}{0{\cdot}1} = 2\times10^{-8}$$

Then, in one month of observation, the fractional period change can be measured to an accuracy

$$\left(\frac{\Delta P}{P}\right)_{\substack{\text{instrumental}\\ \text{month}}} \approx \frac{1}{n}\left(\frac{P_2-P_1}{P}\right) \approx \frac{4\times10^{-8}}{2{\cdot}5\times10^7} = 1{\cdot}6\times10^{-15}$$

where n is the number of pulse periods in a month and P_1, P_2 are the measured periods on the first and last days of the month.

This error is small enough to permit the detection of the terrestrial effect and indeed can be regarded as a realistic estimate: Reichley, Downs and Morris have attained a precision of 1×10^{16} in pulsar timings over several months.

It is seen that the random variations in the l.o.d. can affect pulsar observations. The effect can be minimized by taking the measurements at small hour angles, or symmetrically about the meridian. Conversely, closely spaced observations of several pulsars can be used to study the random variations of the terrestrial rotation rate, for which a definitive explanation is not yet available. In fact, the pulsar observations could be used to check the possibility that the random variations in the l.o.d. are simply an artefact of the stellar measurements used to determine the l.o.d. The high precision obtainable in pulsar timings also requires that careful attention be paid to the exact position of the telescope with respect to the terrestrial axis of rotation; an uncertainty of one metre in the altitude could lead to systematic errors in excess of 1 part in 10^{14}.

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[1] Markowitz, W., in *The Earth-Moon System* (edit. by Marsden, B. G., and Cameron, A. G. W.), 9 (Plenum Press, New York, 1966).
[2] Schatzman, E., in *The Earth-Moon System* (edit. by Marsden, B. G., and Cameron, A. G. W.), 12 (Plenum Press, New York, 1966).
[3] Yeh, S. H., and Shaw, B. T., *Acta Astron. Sinica*, **8**, 68 (1960).
[4] Ijima, S., and Okazaki, S., *Publ. Astron. Soc. Japan*, **13**, 125 (1961).
[5] Reichley, P. E., and Downs, G. S., *Nature*, **222**, 229 (1969).
[6] Allen, C. W., *Astrophysical Quantities* (Univ. London, Athlone Press, 1963).

Observations of the Crab Pulsar during an Occultation by the Solar Corona

We have measured the difference in time of arrival between individual pulses from *NP* 0532 (refs. 1 and 2) in frequency bands at 112, 142 and 170 MHz with the 300 foot telescope of the National Radio Astronomy Observatory. Observations were made between June 12 and June 23, 1969, when the pulsar had heliocentric angular distances in the range 1·5 to 8·7 degrees.

The low frequency band contained four adjacent 30 kHz channels, and the middle and high frequency bands each contained three adjacent 100 kHz channels. Each of the ten channels was separately detected and a.c. coupled to a light-beam oscillograph. The oscillograph, supplied