LETTERS TO THE EDITOR

PHYSICAL SCIENCES

Possible Pulsed Gamma Ray Emission from the Crab Nebula Pulsar

VASSEUR *et al.*[1] have recently presented results which, they suggest, appear to show that the Crab pulsar NP 0531+21 emits a flux of $\sim 10^{-5}$ photons cm^{-2} s^{-1} at a photon energy >50 MeV. Their results, based on balloon-borne spark chamber observations, would, if confirmed, be of great significance not only for the Crab pulsar but also for the field of gamma ray astronomy as a whole, where the evidence for point sources of gamma rays remains marginal[2]. We feel, however, that the statistical weight of the data in the report is much weaker than the authors suggest.

The two histograms presented in their paper (Fig. 1, ref. 1) show peaks sufficiently high that the probability of their occurring from random fluctuations is apparently less than 2 per cent. In evaluating this probability, however, no account has been taken of the fact that the data presented have already been selected by treating the following as variables: (1) the pulsar position, (2) the angular resolution of the equipment, and (3) the pulsar period. The precise effect of this selection process depends on the order in which the various steps of optimization were carried out and on the allowed ranges within which the variables were chosen. The original paper does not give sufficiently detailed information on these points and therefore we can only make rather approximate estimates of the influence of (1), (2) and (3) on the significance of the peaks in the final histograms.

In evaluating (1) we recall that four adjacent exploration cones of 4·5° semi-angle of the twenty-five used showed evidence of pulsation. Depending on the precise geometry of lattice used, there are twelve or sixteen ways of choosing four adjacent cones; these do not all contain entirely independent data. Effect (2) must be included as a variable because the final cone half-angle (5·5°) used in presenting the data was based on the number of adjacent exploration cones showing possible pulsation rather than on the independently assessed angular resolution of the equipment (4·5°). We estimate roughly that, in combination, effects (1) and (2) are equivalent to at least ten independent analyses of the data. Considering now (3), in order to optimize the phase peaks the original authors tried forty-one different periods in the interval $T-100$ ns to $T+100$ ns where T was the nominal pulsar period based on observations at lower photon energies with appropriate Doppler corrections. The increment of period used, 5 ns, produces a shift of one complete time channel over the flight length of three hours, so that the forty-one periods may be regarded as yielding independent analyses. In fact, if reference time signals from MSF Rugby were frequently recorded, they provide constraints on any possible systematic drifts in the recording system.

Thus for events contained within a cone of 5·5° half-angle during the first flight the evaluation of the probability that the observed effect is due to chance is roughly as follows. The probability of getting a peak of seven events or more when the expected number equals 1·45 is $\sim 9\times10^{-4}$. There are twenty independent time channels, at least four independent angular cones and forty-one independent periods. Thus the expected number of such peaks is about

$$9\times10^{-4} \times 20 \times 4 \times 41 \simeq 3{\cdot}0$$

On this basis then, it is not surprising that such a peak was observed. Although they do not specifically say so, the original authors were not, presumably, prepared to accept too large a difference between the optimum and expected period, or in the estimated pulsar position. But it would appear entirely compatible with chance that the observed peak should occur when the period difference and angular error were allowed to be ~ 20 ns and 2° respectively.

If we then say that the optimum direction and acceptance cone for the first flight defined that used in analysing the results for the second flight (the authors state that they were "about the same") and also that the difference between the optimum and expected periods should be about the same on the two flights, with perhaps only ten different periods used, we find that the expected number of peaks as high as or higher than that observed in Fig. 1*b* of ref. 1 is $\sim 0{\cdot}15$.

We feel, then, that the case for the emission of pulsed gamma rays by the Crab pulsar remains unproven so far, and trust that further analysis of the complete range of balloon observations will provide a firmer basis for such a claim. It should be noted that crude extrapolation of the X-ray data for this pulsar[3] to energies ~ 50 MeV yields a flux $\sim 3\times10^{-6}$ photons cm^{-2} s^{-1} which might be detectable in long balloon flights.

W. N. CHARMAN

Nuclear Physics Division,
AERE Harwell,
Berkshire.

G. M. WHITE

University College,
Dublin.

Received June 1, 1970.

[1] Vasseur, J., Paul, J., Parlier, B., Leray, J. P., Forichon, M., Agrinier, B., Boella, G., Maraschi, L., Treves, A., Buccheri, R., and Scarsi, L., *Nature*, **226**, 534 (1970).

[2] Fazio, G. G., *Nature*, **225**, 905 (1970).

[3] Fishman, G. J., Harnden, F. R., Johnson, W. N., and Haymes, R. C., *Astrophys. J. Lett.*, **158**, L61 (1969).

Pulsed Gamma Rays from the Crab Nebula?

RECENTLY Vasseur *et al.*[1] reported the possible detection of pulsed gamma emission above 50 MeV from the Crab Nebula. They analysed their data from two balloon flights and stated that the probability of the observed pulsed effects on each flight had a 2 per cent chance of resulting from random fluctuations as they did not know in which of the twenty time channels to expect the pulsation. The overall chance probability for both flights is 0·04 per cent. The purpose of this letter is to point out that their method of analysis leads to a much higher probability for these effects to arise from random fluctuations.

In carrying out the analysis they used the corrected calculated period, T, for the pulsar NP 0532. They then varied the period from $T-100$ ns to $T+100$ ns in 5 ns intervals, a total of 41 changes for each flight to obtain maximum effects at $T-20$ ns and $T-15$ ns for both flights, but did not allow for this in calculating the statistical significance of the observed effects. A time change in arrival of the pulsed radiation of 1·6 ms over the duration of a three hour flight results from a change in period of 5 ns and hence the variation of the period can be considered to be essentially 41 independent observations and must be weighted accordingly. They also state that the time of each event was recorded to better than ± 1 ms and yet the period that optimizes the effect differs from T by