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# SEARCH FOR NANOSECOND OPTICAL PULSES FROM CRAB PULSAR NP 0532

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In a recent IAU circular telegram, N. A. Porter, D. M. Jennings, and E. P. O'Mongain report observations at Malta on January 19, 1969 of three-nanosecond optical pulses coming from the vacinity of the Crab Nebula and having the periodicities of both NP 0532 and NP 0527.[1] The reported angular diameter of their field of view was 28'; the detection threshold intensity was 30 photons $m^{-2}$; the counting rate was not given.

If we multiply the detection threshold of Porter et al. by the 7 $m^2$ collecting area of the Lick Observatory 120-in. telescope and the 20% photomultiplier detection efficiency we get an expected 40 photoelectrons per 3-nanosecond (ns) pulse. Thus, with a resolution time greater than 3 ns we would see a pulse from the photomultiplier some 40 times larger than the normal single-photoelectron-generated pulse. A normal pulse-counting system, such as was used by earlier observers, is insensitive to pulse height. Such a system would record the postulated many-photoelectron event as an ordinary single photoelectron event.

Furthermore, most multiscalers that we know of have a pulse-pair resolution of 100 ns. If several photoelectrons were spread out over that long a time interval but separated by the photomultiplier resolution time, they still would be recorded as a single event. Therefore the phenomenon reported by Porter et al. would have been missed by multiscaler observers.

On March 13 and 22, 1969 we made a search for short optical pulses coming directly from the south preceding star of the Crab central double, using the 120-in. telescope of Lick Observatory. This star has already been identified as an optical pulsar having the 33-ms period of NP 0532.[2—5] We found no such pulses in several 5-min. observations each corresponding to some 9000 pulsar pulses. We obtain the following upper limit: We would have detected with certainty any pulse with as many as 5 photoelectrons produced in an interval of $10^{-8}$ s. In each major pulsar pulse we detected with a multiscaler about 50 photoelectrons in a time interval of 1.5 ms full width at half maximum. Therefore the amount of optical radiation from the south preceding star which is bunched into time intervals of $10^{-8}$ sec is less than 5 out of 50, or less than 10%.

Similar observations convince us that less than 10% of the pulsar light is bunched into intervals of duration $10^{-7}$, $10^{-6}$, $10^{-5}$, or $10^{-4}$ s.

The pulsar light was detected by a FW-130 photomultiplier at the prime focus of the 120-in. reflector with a 5.5 '' angular aperture. The photomultiplier output was divided and fed simultaneously to a time-analysis system, and to a pulse-height analysis system.

The time-analysis system consisted of a preamplifier, followed by a fast discriminator having a standard output. This output was fed to recording instruments and was also displayed in real time on a 1024-channel multiscaler having 50-μs channel widths, and triggered at the frequency of the pulsar.[6] During a typical run of 5 minutes, the average number of detected photoelectrons in the major pulsar peak was 50 photoelectrons per pulsar pulse, after subtracting the Crab Nebula background of about 170 photoelectrons spread uniformly over the 33-ms period. The photomultiplier was cooled with dry ice; dark current was negligible. The pulsar signal disappeared when the aperture was moved away from the south preceding star.

The pulse-height analysis system consisted of the photomultiplier with a 5-ns rise time and 30-ns full width at base, a fast linear amplifier with 2-ns rise time, and a fast oscilloscope with 5-ns $cm^{-1}$ sweep with the scope operating on internal trigger. The fast photomultiplier signal was also stretched and put into a pulse-height analyzer.

By looking at pulses from a small light leak, or night sky background, or Crab Nebula background, we ascertained the pulse-height distribution that results when a single photoelectron is released from the photocathode. The variations in pulse height are mainly due to the Poisson distribution of multiplication at the first dynode, with average multiplication about 4. Then with the aperture centered on the south preceding star, we inserted a linear 5-to-1 attenuator at the input to the linear amplifier. Pulses resulting from 5 photoelectrons released within the resolution time would then have the same average pulse height as for a single photoelectron with no attenuator. No pulses were seen corresponding to the release of 5 or more photoelectrons. In all of our observations the pulse-height distribution was consistent with the observed distribution for single photoelectrons.

During each of our negative observations with the pulse-height analysis system, simultaneous observations with the time-analysis system assured us that the pulsar was being detected. The pulse-height analysis system was checked by looking at single photoelectron pulses, and by means of a nanosecond pulser having a pulse shape approximating the photomultiplier pulse.

To look for pulse structure in longer time intervals, we inserted a passive RC integrating circuit into the photomultiplier output. This allowed us to look for large pulses coming in an interval of $10^{-7}$ s. For intervals of $10^{-6}$, $10^{-5}$, and $10^{-4}$ s we used a pulse stretcher as an integrator. When the time constant was increased to $10^{-3}$ s, the pulsar signal could be seen on individual oscilloscope sweeps.

We would have easily detected a short pulse as large as 5 photoelectrons if it came from the south preceding star, and if the counting rate were more than about one per minute. We conclude therefore that the nanosecond light pulses seen by Porter, Jenkins, and O'Mongain do not come all the way from the Crab pulsar in the form of optical photons.

However, Porter, et al. used an angular aperture of 28', about ten times the size of the Crab Nebula, whereas ours was 5.5'' during most of the observing. To search for large short pulses coming from a much larger angular region we opened our aperture to 2.4', or about half of the Crab diameter. Holding the declination constant we swept in right ascension across the Crab at 1 degree per hour. Thus each part of the central 2' of the Crab was visible in the aperture for about two minutes of time. No large pulses were seen. We then went to right ascension $5^h\ 20^m$, which was reported to have been the position of another peak in the counting rate. We swept through this location at the earths turning rate of 15 degrees per hour. A line source of constant right ascension would have been visible in our 2.4' aperture for about 7 or 8 seconds of time. Again, no large pulse was seen.

We are particularly grateful to J. S. Miller and E. J. Wampler for allowing us to operate our system with their photomultiplier output and for generous donations of their own observing time, which was provided by the Lick Observatory. The support and encouragement of Luis W. Alvarez is gratefully acknowledged. We thank Robert Tripp for help with the observations and for extensive discussions.

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