AN X-RAY PULSAR IN THE CRAB NEBULA

BRUNO ROSSI

Massachusetts Institute of Technology, Cambridge, Mass., U.S.A.

I wish to report the preliminary results obtained by Hale Bradt, William Mayer and Saul Rappaport of MIT in a recent rocket flight devoted entirely to the observation of the X-ray emission from the Crab Nebula. The flight had been planned originally for April 3. Because of administrative difficulties, it was delayed until April 26.

The launching took place from the White Sands Missile Range. The instrumentation included a bank of proportional counters with 2 mil Be windows about 800 cm^2 in area, and a second bank of counters, with windows of $\frac{1}{3}$ mil Al, ~ 90 cm^2 in area. The results reported here are based on the data provided by the Be window counters, whose spectral sensitivity extended from about 1.5 to about 10 keV.

The rocket was provided with an aspect control system, which kept the Crab Nebula within the field of view of the counters ($11° \times 11°$) during most of the useful flight time (about 190 sec). In this time, about 300000 X-ray pulses were recorded, with a timing accuracy of about 1 ms. Simultaneously, the WWV time standard was also recorded. This made it possible to correlate the X-ray data with optical observations of the pulsar in the Crab that were carried out within one-half hour of the flight by R. Edward Nather, Brian Warner, and Malcolm MacFarlane at the

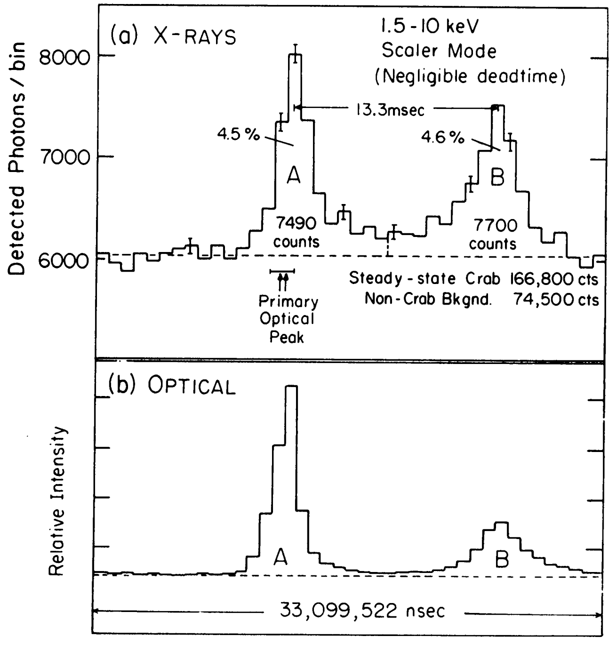

Fig. 1. X-ray and optical data from the MIT and McDonald groups respectively.

L. Gratton (ed.), Non-Solar X- and Gamma-Ray Astronomy, 183–184. *All Rights Reserved*

https://doi.org/10.1017/S0074180900004253 Published online by Cambridge University Press

McDonald Observatory, and by Jerome Kristian at the Mt. Palomar Observatory.

The occurrence times of the X-ray pulses were reduced to the module of the precise apparent period of the optical pulsar (33.0995 ms). This interval was then divided into 40 equal time 'bins' of about 0.83 ms each, and the pulses were distributed among these bins. The resulting distribution is shown by Figure 1a. For comparison, Figure 1b (adapted from a paper by Warner *et al.*, 1969) shows light curves of the optical pulsar, as obtained at the McDonald Observatory.

One sees that the X-ray emission undergoes strong periodic variations whose essential features match those of the optical emission. Within each period, the X-ray curve, like the optical, exhibits two peaks of different widths. The narrow X-ray peak is simultaneous with the principal narrow optical peak, within the 1 ms uncertainty of the correlation. The separation of the two peaks is about 13.5 ms both in the X-ray and in the optical range of the spectrum. The X-ray intensity between the two peaks remains appreciably above background, as does the optical intensity.

On the other hand, the strength of the pulsating component, relative to the background, is much greater for the X-ray than for the visible radiation. In the X-ray range, the total pulsating power amounts to about 9% of the background due to the continuous emission of the nebulosity, whereas in the optical range the pulsating power amounts to about 0.1% of the background. Moreover, the two X-ray peaks have about the same area, whereas the principal narrow optical peak has a considerably larger area than the secondary wide peak. Note that, in the pulsed mode, the total X-ray power is about 100 times the total optical power and about 10^5 times the radio power; thus the pulsar in the Crab emits by far the largest amount of its radiating energy in the form of X-rays.

The figures quoted above are still preliminary. However, it should be pointed out that the X-ray data on which Figure 1 is based were taken from a channel for which the dead-time corrections should be negligible.

The spectral data on the pulsating X-ray emission are still meager. At the present state of the analysis, there is no clear evidence for a difference in the spectra of the pulsating and of the continuous components in the X-ray region.

Reference

Warner, B., Nather, R. E., and MacFarlane, M.: 1969, *Nature* **222**, 233.