POSSIBLE DETECTION OF THE GEMINGA PULSAR IN THE ENERGY RANGE (0.15-0.48) MeV WITH THE FIGARO II EXPERIMENT

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ABSTRACT

The gamma-ray source Geminga (2CG195+04) has been observed in the energy range (0.15-4) MeV with the FIGARO II experiment on July 9th, 1990, during a transmediterranean balloon flight. The data were folded at the period value derived from the recent EGRET ephemeris. The resulting light curve shows a broad peak (phase width ~ 0.3) in the energy range (0.15-0.48) MeV. The chance occurrence probability turns out to be about 2.8 gaussian standard deviations.

INTRODUCTION

The FIGARO II (French Italian GAmma Ray Observatory) is a balloon borne experiment specifically designed to study sources with a well established time signature in the low energy γ rays. The main characteristics of the detector are the large area (3600 cm^2) and the wide field of view (about 77°); a more detailed description is given in Agnetta *et al.*[1].

In the course of the last transmediterranean balloon flight on July 9, 1990 the instrument was pointed at the direction of the Crab for more than seven hours. Because of the large field of view the γ-ray source Geminga, at an angular distance from Crab of about fifteen degrees, was also observed with only a small reduction of the exposed area. After the discovery that the X and γ-ray emission of Geminga is periodic at 237 ms [2,3], we searched the FIGARO data for a pulsed signal at the expected period for the epoch of our observation. In this contribution we report preliminary results of this analysis indicating the occurrence of a weak signal in the energy band 0.145-0.480 MeV.

DATA ANALYSIS AND RESULTS

The pulsed light curve of Geminga was obtained by folding the arrival time (converted to the solar system barycenter by means of the JPL Ephemeris DE200) of each accepted event with the instantaneous period. The pulsar parameters for the observation epoch (J.D.=2448081.5) were derived from the frequency and its first and second derivatives as given by Mattox *et al.*[4], which are expected to provide the phase of the pulsed signal with an uncertainty not larger than 0.1 in the time interval 1990.5-1992.9 (Mattox, private communication).

Two resulting phase histograms in five and fifteen bins are shown in Fig. 1a and 1b, respectively: a broad peak with a duty cycle of about 0.3 and roughly centred at phase 0.6 is apparent. The statistical significance of this feature is not high: a simple χ^2 test gives for the curve of Fig. 1a a significance of 2.6 gaussian standard deviations. Because of the broad structure of the signal, the χ^2 test is not the most efficient method to estimate the probability. We applied therefore to the light curve of Fig 1b the non-parametric "run" test: considering that the excess of the counting rate is concentrated in only six consequent bins over fifteen, the probability to have a chance effect is $4.9\ 10^{-3}$ We computed also the Fourier power associated with the fundamental frequency and obtained a value whose chance occurence probability is $4.6\ 10^{-3}$. In conclusion, we have evidence for the detection of a pulsed signal at a level of about 2.8 gaussian standard deviations.

To evaluate the pulsed flux of the source we considered the source signal within the phase interval (0.4-0.7) and subtracted from it the mean value of the counts from the other bins, corresponding to the off-pulse region.

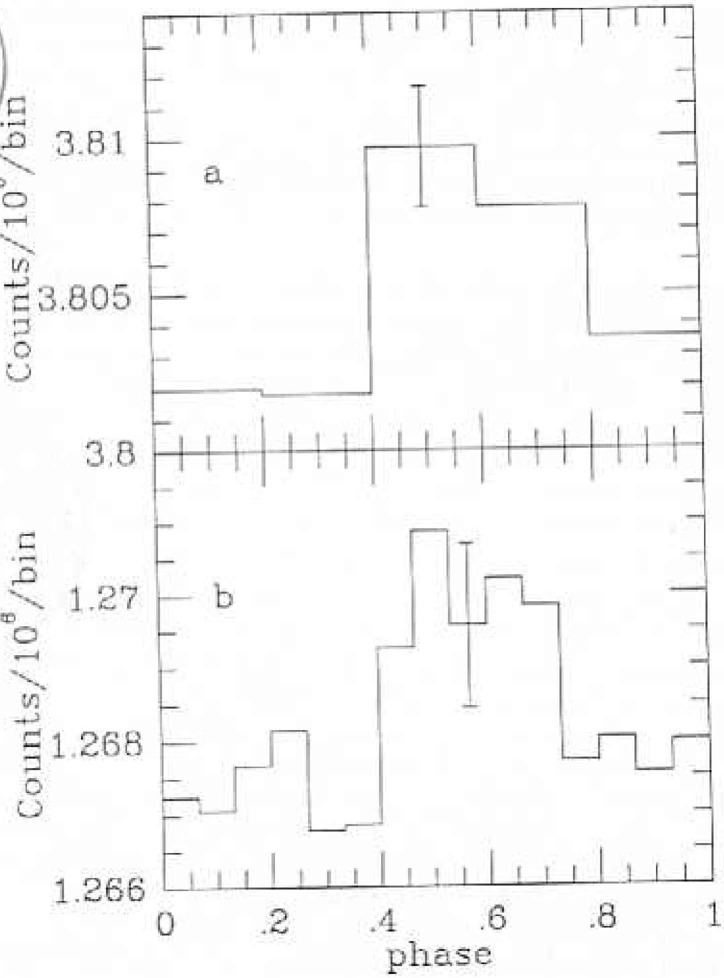

Fig. 1a,b - Phase histograms of Geminga in the energy band 0.145-0.480 MeV in five (panel a) and fifteen (panel b) bins.

The photon flux in the band (0.15-0.48) MeV, taking into account the average atmospheric thickness and the dead time corrections, and assuming an E^{-2} spectrum, is 2.7 ($\pm$0.9) 10^{-4} photons cm^{-2} s^{-1}. In Fig. 2 we have plotted the corresponding flux density, multiplied by E^2, in comparison with the integrated flux of ROSAT[2], the COS B data[6] and the upper limits of SIGMA[7] and COMPTEL[8].

DISCUSSION

The recent discovery that the puzzling Geminga is a γ-ray pulsar[2,3] and that its emission above 50 MeV shows a phase pattern quite similar to those of Crab and Vela is a major step towards explaining the nature of the galactic γ-ray sources. The physical mechanisms responsible for the pulsar emission in the various bands of the electromagnetic spectrum, however, are still poorly understood, particularly in the low energy γ rays where the instrumental limits are more severe.

The FIGARO data provide a first indication of a pulsed low energy γ-ray emission from Geminga; the statistical significance of this result is not compelling and a confirmation from future measurements is necessary. Preliminary results of the BATSE and OSSE experiments (Wilson et al., Ulmer et al., this symposium) give upper limits below the present estimate of the possible flux. An explanation of this disagreement could be that the effect is limited within a rather narrow energy band. A few comments are nonetheless in order.

As a first remark we see that the light curve of Fig. 1 does not show the double peak pattern as in the EGRET data[3], while it seems ideed more similar to the low energy X-ray curve of the ROSAT measurement[2]. These data are explained as thermal emission from a hot region of the neutron star surface: the spectral shape, in fact, can be fitted with a black body law with the exception of a tail in the high energy part of the band. One could try to explain the FIGARO data as an extension of the hard tail; the extension would have a very flat slope in order to pass through the FIGARO point, and would violate the COMPTEL upper limits unless a very sharp cutoff were invoked. Alternatively, and perhaps more likely, one could relate the light curve of Fig. 1 with those observed at higher energies, provided that in the FIGARO passband the ratio of the two peaks is very unbalanced. Such an unbalance is indeed seen in the Crab pulsar at energies around 1 MeV [5]; if the analogy is correct, more sensitive observations in the low energy γ rays should detect another peak at phase 0.1.

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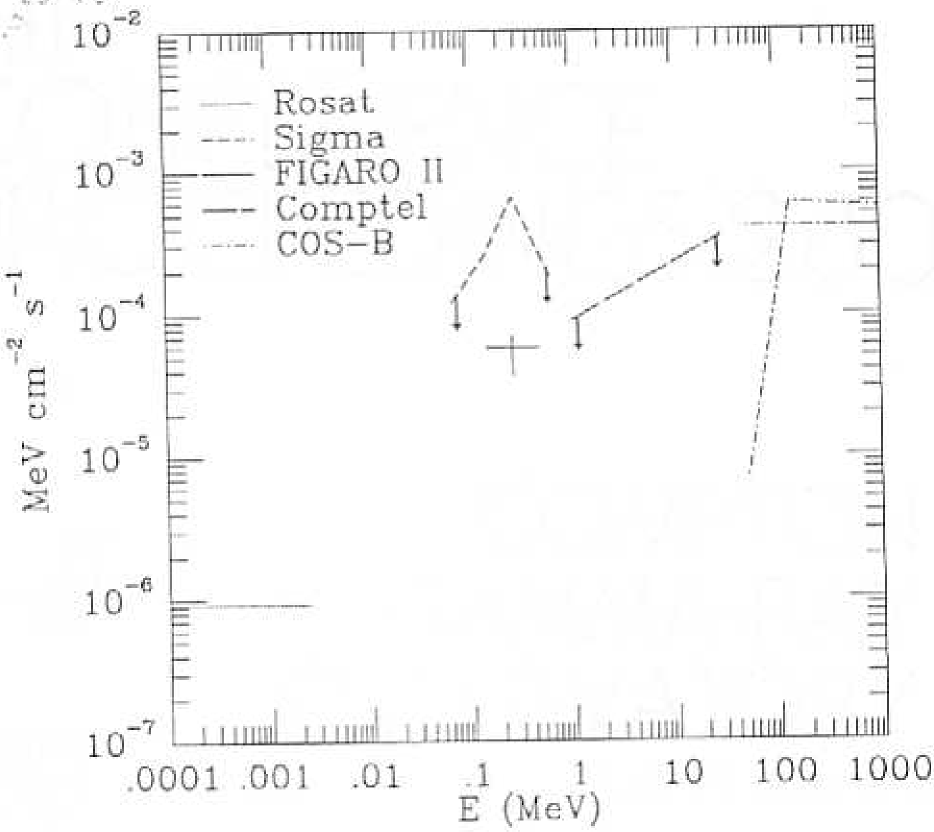

Fig. 2 - The energy spectrum of GEMINGA from X to γ rays

REFERENCES

1. Agnetta, G., *et al.*, Nucl. Instr. Methods A 281, 197 (1989).
2. Halpern, J.P. and Holt, S.S., Nature 357, 222 (1992).
3. Bertsh, D.L., *et al.*, Nature 357, 306 (1992).
4. Mattox, J.R., *et al.*, I.A.U. Circ. 5583 (1992) .
5. Agrinier, B. *et al.*, Ap.J. 355, 645 (1990).
6. Grenier, I.A., Hermsen, W. and Hote, C., Adv. Space Res. 11, 107 (1991).
7. Lebrun, F. *et al.*, Proc. 22nd ICRC, vol. 1, p. 165 (1991) .
8. Strong, A.W. *et al.*, COSPAR Symp. Proc. in press (1992) .