FEATURE IN THE CRAB PULSAR GAMMA-RAY SPECTRUM

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ABSTRACT

During the third flight of the FIGARO II experiment on July 9th 1990 the Crab pulsar PSR0531+21 has been kept in the axis of the telescope during 7.5 hours.
On line analysis showed the pulsar light curve with only 5 minutes of data acquisition time.
The complete analysis of the observation will probably help to search for gamma ray line in the pulsed part of the spectrum.
Particulary a line around 450 Kev has been previously detected by some experiments but at low statistical level and attributed ambiguously to the Nebula.

INTRODUCTION

The FIGARO II (French-Italian GAmma Ray Observatory) experiment is a large area, actively shielded, non collimatd detector for photons in the energy range 0.150-6 Mev, to be operated at high altitude by means of stratospheric balloons. It is especially designed to observe cosmic sources with a well established time signature as for instance pulsars.

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In this contribution we present preliminary results of a 7.25 hours observation of the Crab pulsar performed on July 9th 1990 in the course of the third flight of the experiment between Sicily and Spain. In particular we present the detection of an emission feature in the spectrum of the second peak in the pulse profile.

EXPERIMENT AND OBSERVATIONAL PARAMETERS

The experiment is described extensively elsewhere (Ref.1). It consists of an actively shielded, large area (3600 cm2), set of 9 NaI crystals 5 cm thick. The angular aperture is large (77 degrees FWHM). The emphasis is placed on the timing accuracy wich is better than 10 microseconds. The detector can be oriented in the direction of the observed source by means of a two-axis pointing system.
Each detected gamma ray is analysed in energy in 256 channels. The energy word is transmitted to the ground receiving station where the time is marked with an atomic clock with 10 microseconds accuracy. The absolute accuracy, in UT scale, is better than 50 microseconds. In parallel, the arrival time of the event is marked with an onboard quartz clock with 100 microseconds accuracy and is registered on board with the energy information on a magnetic tape recorder. For the third flight we reduced the energy range to .150-4.2 Mev. During the Crab observation the residual atmospheric column changed very little between 4.35 and 4.50 gr/cm2.

DATA ANALYSIS

The phase histogram of the Crab pulsar for the whole energy range is presented in figure 1. It was obtained by means of the folding technique: The arrival times of the accepted photons were converted to the solar system barycenter using the JPL DE200 ephemeris. The ephemeris of the pulsar itself at the observation date have been derived from a nearly contemporaneous radio measurement (1990 July 15) (Ref.2)

The pulse shape is typical of this energy range (Ref.3) the second peak (p2) is higher than the first one (p1) and separated by 0.40 unit of phase. The zero phase is the same given by radio astronomers. For the phase resolved spectroscopy study we have divided the period in several intervals corresponding to the various features: 0.95-0.05 for p1, 0.05-0.27 for the interpulse region, 0.27-0.47 for p2 and 0.47-0.77 for the off-pulse interval.

RESULTS AND DISCUSSION

In order to confirm a marginal detection obtained during the 1986 flight (Ref.3), we have looked for spectral features in the second pulse. For this purpose we have substracted the spectrum of the events corresponding to the off-pulse component from the spectrum with phase between 0.27 and 0.47, normalizing each spectrum to the corresponding phase interval lenght. The result is shown in figure 2. We observe a feature centered at about 0.450 Mev, consistent with the 1986 observation both in position and intensity.

A systematic effect is ruled out by performing the same analysis on different parts of the light curve having similar spectral indexes: nothing was found in the spectra of the first pulse and the interpulse. The width of the observed feature is 45+/-10 kev comparable with the instrumental resolution within the limited statisics. The excess observed in 3 channels around 450 Kev above an power law fit to the continuum is larger than 3 sigmas (1.8 sigma for the 1986 observation, which was only 2.5 hours long), and implies a flux of $(1.6+/-0.5)10^{-4}$ photons/cm2sec.

We stress that our result was made possible only due to the unprecedented sensitivity of FIGARO and that previous observations of lines have provided positive results (Ref.4,5,6) around 400 Kev for Crab Nebula but not for the pulsar alone. Conversely if, at the time of our observation, the pulsed spectrum contained a line as intense as those detected previously at lower energies, it should appear in the data at an unquestionable level of significance.

An appealing explanation of the detected feature is a redshifted electron-positron annihilation line: it would then be the first direct evidence for positrons in the vicinity of a pulsar, as predicted by the acceleration models of the "gap" type (Ref.7). With this interpretation, the redshift would be 12%, which implies $M_o/r_6 = 0.77$, where M_o is the pulsar mass in units of one solar mass and r_6 is the distance of the annihilation region in units of 10^{+6} cm. A narrow line and a steady position derive from a scenario where the annihilation occur at the pulsar surface, in which case the measured redshift has important applications for the neutron star structure.

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