BEPPO-SAX OBSERVATION OF THE CRAB PULSAR

A. SEGRETO[1], G. CUSUMANO[1], D. DAL FIUME[2], S. GIARRUSSO[1], E. MASSARO[3], T. MINEO[1], L. NICASTRO[2] and A.N. PARMAR[4]

1. Istituto di Fisica Cosmica e Appl. Informatica, CNR, Palermo
2. Istituto TeSRE, CNR, Bologna
3. Ist. Astr., Unità GIFCO Roma 1, Univ. "La Sapienza", Roma
4. Astrophysics Division, SSD-ESA, ESTEC, Noordwijk

Abstract

The Crab Pulsar (PSR 0531+21) was observed by the four Narrow Field Instruments on board the Italian-Dutch satellite Beppo-SAX in August and September 1996, during the Science Verification Phase. The fine time resolution and the high statistics provided phase histograms well suited for the study of the pulse shape and phase resolved spectroscopy. Preliminary results are presented.

1 Introduction

The Crab pulsar (PSR 0535+21) is the most observed rotation powered pulsar since about thirty years from radio to γ rays. Many problems, however, concerning the physics and the geometry of the emission are still unresolved. The broad energy band and the high throughput of the Beppo-SAX instruments allow a detailed study of the pulse profile and an accurate spectral analysis, useful to understand the physical processes occurring in the neutron star magnetosphere. The fine time resolution and the high statistics provided phase histograms of very good quality, well suited for phase resolved spectroscopy and pulse shape analysis. In this contribution we present some preliminary results of the Beppo-SAX observation of this source carried out during the Science Verification Phase.

2 Instruments and Observations

The Crab was observed from 31th August to 1st of September and from 6th to 7th of September 1996 with the Narrow Field Instruments (NFI) on board Beppo-SAX.

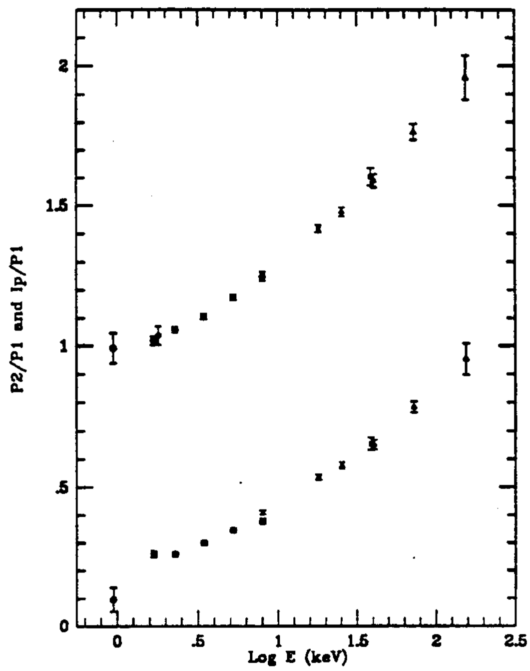

Figure 2: The P2/P1 (upper data) and Ip/P1 (lower data) ratios *vs* Log E (keV) measured by all Beppo-SAX NFI: LECS (filled circles), MECS (open circles), HPGSPC (crosses) and PDS (triangles).

December were used.

3 X-ray pulse profiles and spectra

The pulse profiles of PSR 0531+21 in six energy bands from 0.1-150 keV with a phase resolution from 300 (0.11 ms) to 100 bins (0.33 ms) are shown in Fig. 1. These histograms were obtained with the usual folding technique of the photon arrival times, after conversion to the Solar System Barycenter, using the radio ephemeris derived from A.G. Lyne and R.S.Pritchard (Jodrell Bank Crab Pulsar Timing Results). We took the zero phase at the centre of the main peak (P1).

The energy dependence of the well known double peaked structure is very clearly evident in this profile series with a very high statistical significance. The increase of the second peak (P2) intensity with respect to that of P1 is a well known phenomenon, but we stress that it is the first time that it can be studied over an energy interval more than two orders of magnitude wide with simultaneous observations (see Massaro, Feroci and Matt 1997 for a compilation of all published X- and γ-ray pulse profiles). Notice also as the same trend is also well apparent in the interpeak (Ip) region. These behaviours are usually quantified by means of the ratios between the intensities of the two main peaks P2/P1 and of the Interpeak to P1 Ip/P1. We evaluated these quantities for several profiles in different energy ranges after the subtraction of the off-pulse level, defined as the mean value in the phase interval (0.47,0.77); the phase boundaries of P1 and P2 and Ip were (-0.05,0.05), (0.27,0.47), (0.05–0.27), respectively. The resulting values of P2/P1 and Ip/P1 are plotted in Fig. 2: the energy of each point corresponds to that of

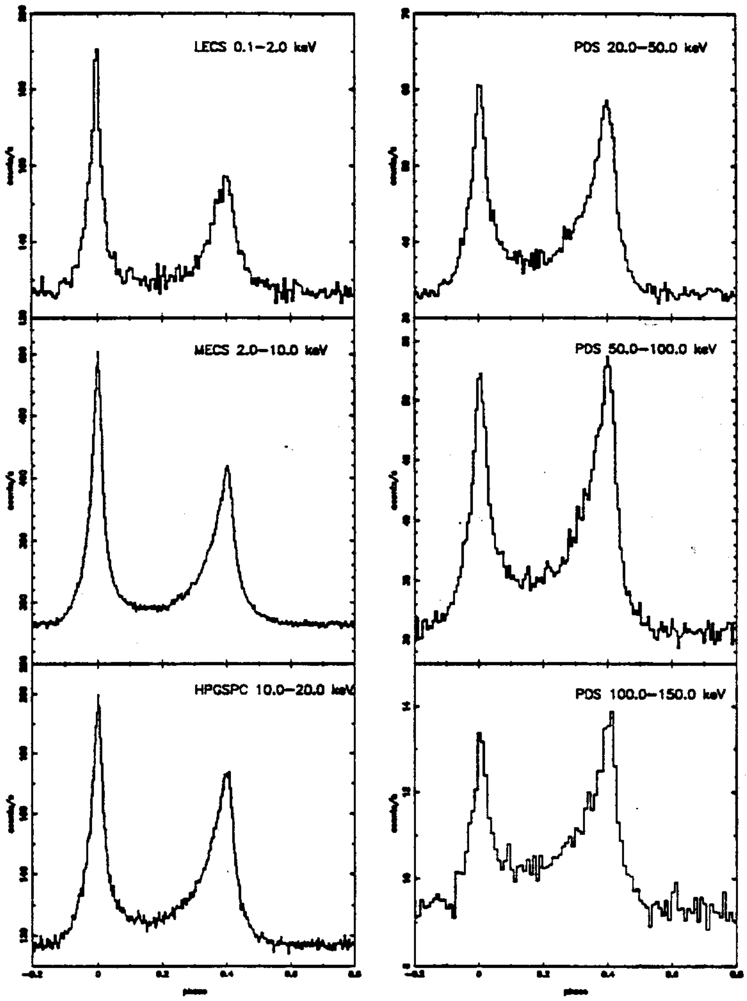

Figure 1: Phase histograms of PSR 0531+21 (Crab) observed with the NFI of Beppo-SAX in six energy ranges from 0.1 to 150 keV.

The NFI consist of four systems of coaligned detectors: the Low Energy Concentrator Spectrometer (LECS) operating in 0.1-10 keV range (Parmar et al. 1997), the Medium Energy Concentrator Spectrometer (MECS) which consists of three units operating in the 1-10 keV range (Boella et al. 1997), the High Pressure Gas Scintillation Proportional Counter (HPGSPC) operating between 4 and 120 keV (Manzo et al. 1997) and the Phoswich Detector System (PDS), with four detection units, operating in the 15-300 keV energy band (Frontera et al. 1997). A more complete description of the mission and the payload can be found in Scarsi et al. (1993). The events were acquired in the direct telemetry mode, necessary to reach the finest time resolution (15 μs); the total exposure times were ~7000 s for the LECS, ~33000 s for the MECS and ~21000 s for both HPGSPC and PDS.

We computed the spectra of the LECS and MECS data considering only spatially selected events within circular regions with diameters of 16 and 10 arcmin, respectively; the PDS and HPGSPC net signals were obtained by subtracting the on-off collimator position count rates. Response matrices available to all observers after the 31th of the channel mean value, weighted with the total count rate in the selected range, and therefore both the energy dependence of the effective area and the pulsar spectrum were taken into account. The increasing trends of the two ratios are very well defined are very similar each other, suggesting that the growth of P2 and Ip can be due to a unique phase extended component whose spectrum is peaked in the the low energy γ-rays.

Spectral analysis is still very preliminary because the intercalibration of the NFI must be completed. Separate power law fits of the total pulsed flux for each instrument give different spectral indices: -1.63 (LECS), -1.70 (MECS), -1.78 (HPGSPC) and -1.87 (PDS). Notice the regular change with the increase of the energy instrumental ranges which could indicate a softening of the spectral distribution. Similar trends are also apparent in the spectra of P1, whose spectral index varies from -1.81 to -2.00, in P2 (from -1.61 to -1.84) and Ip (from -1.61 to -1.75). We can see also that the P1 spectrum is steeper than the other two.

4 References

Boella,G. et al., 1997, AA 320, in the press
Frontera,F. et al., 1997, AA 320, in the press
Manzo,G. et al., 1997, AA 320, in the press
Massaro,E., Feroci,M., Matt.,G., 1997, AAS in the press
Parmar,A.N. et al., 1997, AA 320, in the press
Scarsi,L. et al., 1993, AAS 97, 321