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SUPPLEMENTS

# *BeppoSAX* observation of the transient X-ray pulsar GS 1843−009

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The transient X-ray pulsar GS 1843+009 was observed by *BeppoSAX* satellite on 1997 April 4, while it was at flux level of 50 mCrab in the 20-200 keV energy band. Using the MECS and LECS concentrators, the source position was measured with unprecedented accuracy of 30"
In this poster we present results on both spectral and temporal analysis.

## 1. INTRODUCTION

GS 1843+009 is a transient X-ray pulsar. It was discovered[1] near the Scutum region on 1988 April 3 by the GINGA satellite. During a galactic plane scan observation, the Large Area Counter on board GINGA detected a coherent pulsation having period of 29.5 sec and X-ray intensity a 50 mCrab level. On 1988 April 19-20 Ginga carried out a pointed observation, measuring an X-ray flux highy variable on wide range of time scales, ranging from 30 to 60 mCrab[1]. In addition to coherent oscillation an energy-dependent aperiodic variation was found.
At beginning of 1997 a new outburst of GS 1843+009 has been observed by CGRO[3], RXTE[4,5], ROSAT[6] and *BeppoSAX* [7] satellites. In Table-1 we summarize the observations. Aim of this paper is to report some results from both the timing and spectroscopic analyses of the *BeppoSAX* Narrow Field Instruments observation.

## 2. OBSERVATION

The satellite for X-Ray Astronomy *BeppoSAX* [9] is a major program of the Italian Space Agency (ASI) with participation of the Netherlands Agency for Aerospace Programs (NIVR). *BeppoSAX* covers a very wide energy range, from 0.1 to 300 *keV*, carring four co-aligned Narrow Field Instruments: the Low Energy Concentrator Spectrometer (LECS)[11], the three Medium Energy Concentrator Spectrometers (MECS)[10], the High Pressure Gas Scintillation Proportional Counter (HPGSPC)[12] and the Phoswich Detector System (PDS)[13]. The LECS and MECS instruments have imaging capability at 1' level in the 0.1-10 *keV* energy band. The HPGSPC and PDS are collimated instruments and operate respectly in the 4-120 *keV* and 15-300 *keV* nominal energy band.
On April 4, following a Core Program Target of Opportunity Observation (TOO) program, GS 1843+009 was pointed by the *BeppoSAX* Narrow Field Instruments.
The total exposure time was about 9 *ks* for the LECS, 22 *ks* for the MECS, 10 *ks* for HPGSPC and PDS.
Background subtraction was performed on spectra from all the instruments. Blank sky spectra, extracted from the same region of the detector field of view, have been used for the imaging instruments background subtraction. While, spectra obtained with the collimators in the off-axis position, have been used for the HPGSPC and PDS background subtraction. Spectra from all instruments have been rebinned to achieve at least 20 counts per bin, in order to ensure the applicability of $\chi^2$ test in the spectral fits.
Publicly available matrices have been used to fit the data.


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Table 1
Observations of the Mars-April 1997 OUTBURST of GS 1843+009

| OBSERVATION | RANGE keV | PULSE PERIOD s | FLUX mCrab | POSITION equinox 2000 |
|---|---|---|---|---|
| CGRO BATSE (Mar,3) | 20-50 | 29.5631 ± 0.0003 | 20 | |
| RXTE PCA (Mar,5) | 2-60 | 29.565 ±0.002 | 52 | |
| RXTE PCA (Mar,16) | 2-60 | | | $\alpha = 18^h45^m.6$, $\delta = 0°50' \pm 2'$ |
| RXTE ASM (Mar,6-23) | 2-10 | | 25 | |
| BSAX WFCs (Mar,11-12) | 2-28 | | | |
| ROSAT HRI (Apr,4) | 0.1-2.4 | | | $\alpha = 18^h45^m36^s.9$, $\delta = 0°51'45''$ |
| BSAX NFIs (Apr,4) | 0.1-200 | 29.4764±0.0008 | $13_{(2.0-10keV)}$<br>$55_{(20-200keV)}$ | $\alpha = 18^h45^m34^s$, $\delta = 0°52'.5$ |

## 3. RESULTS

Using the imaging capability of LECS and MECS, the position of GS 1843+009 has been constrained in a 30" circular error box centered at $\alpha(2000) = 18^h45^m34^s$, $\delta(2000) = 0°52'.5$ [7].
To search for the, still unidentified, optical counterpart, optical observation were carried in this region. Analysis of data is still in progress.

### 3.1. Temporal Analysis

In Fig. 1 we show the background subtracted X-ray light curves obtained in three energy ranges with 300 *s* time bin size. The Maximum variation is, about 30% in the 1.6-10 *keV* and 20-60 *keV* ranges, and 60% in the 10-20 *keV* range. On lower timescales the flux shows random fluctuations up to 50 %.
By folding the data the period was determined to be 29.4764±0.0008[8].
The pulse profile in five energy bands is shown in Fig. 2. The pulse profile evolves with energy from a double-peak shape to single-peak shape.

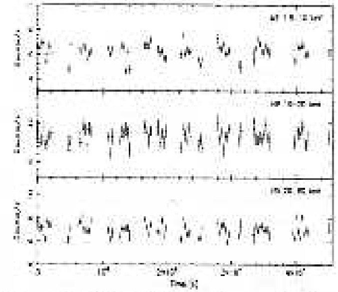

Figure 1. GS 1843+009 background subtracted light curves in three different energy ranges.

The pulse amplitude is small and the fractional period variation, pulse amplitude (peak-to-peak) divided by an average intensity, decreases up to 10 *keV* (Fig. 3). By BATSE, XTE and BeppoSAX data an evident spin-up trend is detected (Fig. 4). The mean pulse period variation, $\dot{P}/P$, was found to be $-3.8\times10^{-3}$ $s\ yr^{-1}$.

### 3.2. Spectral Analysis

Exploiting the *BeppoSAX* spectral capability we have been able to obtain the simultaneous wide band (0.1–200 keV) spectrum of GS 1843+009 . The source shows a very strong ab-

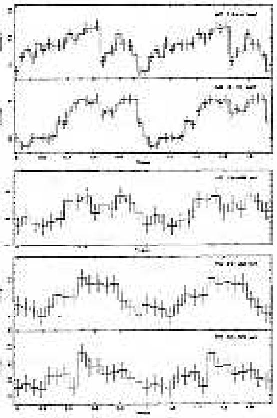

Figure 2. GS 1843+009 pulse profiles in five energy ranges.

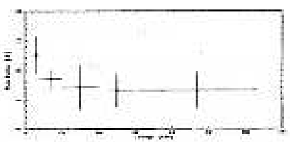

Figure 3. Pulsed fraction vs energy.

Figure 4. Frequency history of GS 1843+009 outburst, from early March to early April 97. The Batse and XTE data are provided respectively by the BATSE pulsar team and ASM/RXTE team.

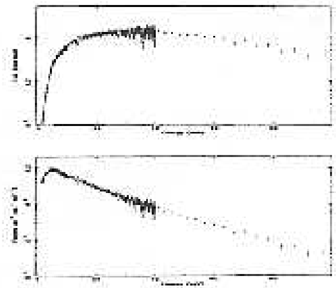

Figure 5. Upper panel: ratio between the GS 1843+009 and Crab spectra. Lower panel: Crab ratio times the functional form of the Crab spectrum, $E^{-2.08}$.

sorption at low energy and a very hard spectrum. This can be seen from Fig. 5 in which the ratio between spectra of the source and Crab is reported. The ratio monotonically increases up to 40 keV(upper panel). In the lower panel of the same figure, following the technique described in [14–16], the Crab ratio times the functional form of the Crab spectrum is shown. No deviation from continuum is observed.

Data were also fitted with the conventional law used to describe the spectrum of X-ray pulsar[17, 18]: a power law with exponential cutoff at higher energies, i.e. a photon spectrum of the form

$$f(E) = AE^{-\alpha}\exp\{-N_H\sigma(E) - H(E)\} \qquad (1)$$

where E is the photon energy, $\alpha$ is power law photon index, $N_H$ is the absorption column and $\sigma(E)$ is the Wisconsin cross section of photoelectric absorption due to cold matter[19]. The high-energy cutoff is simulated by the function

$$H(E) = \begin{cases} 0 & E < E_c \\ \frac{E-E_c}{E_f} & E > E_c \end{cases} \qquad (2)$$

where $E_c$ is the cutoff energy and $E_f$ is the e-folding energy.



Table 2
Spectral Parameters for the broad band fit of GS 1843+009

| | | |
|---|---|---|
| $N_H$ | 2.30± 0.13 | $10^{22}$ $cm^{-2}$ |
| $\alpha$ | 0.34± 0.04 | |
| $E_c$ | 5.95± 0.45 | $(keV)$ |
| $E_f$ | 18.4± 0.6 | $(keV)$ |
| $\chi^2_\nu$ (dof) | 1.091 (477) | |

NOTE — All quoted errors represent 90% confidence level for a single parameter.

Using this model, we fitted simultaneously the pulse-averaged spectra of the four detectors, obtaining a $\chi^2_\nu$of 1.091 ( 477 dof). Fit parameters are summarized in Tab. 2.
Data and model are shown in upper panel of Fig. 6. Still there is no evidence of any absorbtion feature in the residuals reported in lower panel of figure.

## 4. CONCLUSION

On April 4, GS 1843−009 was already in the fading phase of outburst.
The large value of mean pulse period variation $\dot{P}/P$ suggests the existence of an orbital Doppler motion. This might indicate that the source is a member of a X-ray binary system.
GS 1843−009 has been classified by Mihara[20] as a cyclotron source. Indeed, fitting the phase resolved spectra of Ginga observation, Mihara found a feature at about 20 keV that was not clearly visible in the average spectrum.
From this *BeppoSAX* observation we conclude that no feature is present in the wide band phase average spectrum. Nevertheless, search for cyclotron signature in the *BeppoSAX* phase resolved spectra is currently ongoing.

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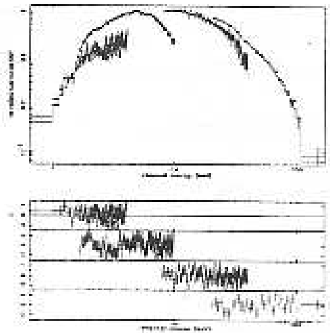

Figure 6. Broad band X-ray spectrum of GS 1843+009 outburst fitted with model (1). In the lower panel residuals are shown in terms of sigmas with error bars of size one.

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