COMPTEL DETECTION OF THE VARIABLE RADIO SOURCE GT 0236+610

R. van Dijk[1], H. Bloemen, W. Hermsen
SRON-Leiden, P.O. Box 9504, NL-2300 RA Leiden, The Netherlands

W. Collmar, R. Diehl, G.G. Lichti, V. Schönfelder, H. Steinle, A. Strong
Max-Planck Institute für Extraterrestrische Physik, P.O. Box 1603, 85740 Garching, F.R.G.

K. Bennett, R. Much
Astrophysics Division, ESTEC, NL-2200 AG Noordwijk, The Netherlands

M. McConnell, A. Connors
Space Science Center, Univ. of New Hampshire, Durham NH 03824, U.S.A.

ABSTRACT

The highly variable and non-thermal radio source GT 0236+610 exhibits outbursts with a period of 26.496 days, modulated by a four-year period. Recent EGRET observations confirmed that this source is the counterpart of the COS-B source 2CG 135+01.

COMPTEL observed this source during three observations in Phase I. We report here on the detections in each of the observations, the time-averaged spectrum, and address the question of time variability with respect to the radio phase.

INTRODUCTION

The γ-ray source 2CG 135+01 was one of the unidentified strong sources in the COS-B catalogue (Hermsen et al. 1977; Swanenburg et al. 1981). Soon after the discovery, two possible counterparts were proposed. One of these was the luminous low-redshift QSO 4U0241+61, for which the Uhuru and SAS 3 error boxes overlap the COS-B error box (Apparao et al. 1978). The other counterpart proposed was the highly variable, non-thermal radio source GT 0236+610 (Gregory & Taylor 1978). Recent observations of 2CG 135+01 with EGRET, have improved its location error box, and exclude the QSO from being the counterpart (von Montigny et al. 1993).

GT 0236+610, coincident with the B0 Ve star LSI+61°303, was shown to exhibit non-thermal radio outbursts with a period of 26.496 days (Taylor & Gregory 1982). These outbursts are characterised by a short (~few days) risetime, followed by a somewhat slower decline. During the onset of the outbursts, the spectral index α ($S_\nu \propto \nu^\alpha$) decreases with increasing radio flux, and reaches a minimum at maximum radio flux (Taylor & Gregory 1984). The radio outbursts are modulated with a four-year period (Gregory et al. 1989). The 26.496 day period has also been detected in the optical (Mendelson & Mazeh 1989), but not in the IR (D'Amico et al. 1987), UV (Howarth 1983), or X-rays (Bignami et al. 1981).

The current theoretical picture of 2CG 135+01/GT 0236+610/LSI+61°303 is that of a binary system consisting of a B0 Ve star and a compact object, with a 26.496 day orbital period. Spectroscopic observations indicate that, for an inclination $i = 70° - 80°$ and a 5 $M_\odot$ − 10 $M_\odot$ star, the mass of the compact object is in the range 1.1 $M_\odot$ − 1.5 $M_\odot$.

[1]Also Astronomical Institute, University of Amsterdam, Kruislaan 403, NL-1098 SJ Amsterdam, The Netherlands

Based on this, Maraschi & Treves (1981) proposed the so called *young pulsar* model. In this model, it is assumed that the compact object is a young pulsar (age $10^4 - 10^5$ yr), with a strong relativistic wind. The γ-ray emission is thought to originate in the shock front between the pulsar wind and the stellar wind, through inverse-Compton scattering of the primary's optical photons off the relativistic electrons. These electrons also produce the (periodic) radio emission through synchrotron radiation. Because the orbit is eccentric, the magnetic field at the shock is higher during periastron passage, such that the resulting larger accelerations of the electrons lead to the observed periodicity. Another model, the *supercritical accretion* model, was proposed by Taylor & Gregory (1982; 1984). In this model, the outbursts are caused by luminosity-driven shocks as a result of supercritical accretion. The required large $\dot{M}$ for this process is likely caused by Roche-lobe overflow of the primary.

INSTRUMENT AND OBSERVATIONS

The COMPTEL instrument aboard CGRO, is sensitive to γ-rays between 0.75 MeV and 30 MeV, and has a field of view of $\sim$ 1 steradian. The energy resolution is 5 – 10%, and the positional accuracy is typically 1°. The detection mechanism is based on Compton scattering, the dominant process in this energy range. Incoming photons are ideally first Compton scattered in the upper detector, and subsequently totally absorbed in the lower detector. In practice, however, the absorption in the lower detector is not always complete. This, and other effects, complicate the response function. For a complete description of COMPTEL, and its characteristics, the reader is referred to Schönfelder et al. (1993).

Table I. List of COMPTEL observations during 1991 – 1992 of GT 0236+610 (in CGRO notation). The columns list: 1) the start time, 2) the end time, 3) the corresponding radio-phase intervals (see Gregory et al. 1989) and 4) the angular distance ζ to the pointing direction.

Obs.	Start *UT*	End *UT*	Radio Phase	ζ [°]
15.0	Nov. 28, 12:41	Dec. 12, 16:42	[0.096 – 0.631]	22.7
31.0	Jun. 11, 16:11	Jun. 25, 13:17	[0.499 – 0.023]	29.9
34.0	Jul. 16, 16:40	Aug. 06, 14:38	[0.820 – 0.610]	26.5

COMPTEL completed a sky survey during the observations of Phase I (May 1991 - November 1992). GT 0236+610 was within 30° of the pointing in three Phase I observations: Obs. 15.0, 31.0 and 34.0. Table 1 lists the observation periods, the corresponding radio phases and the angular distance ζ to the pointing direction. During Obs. 31.0 and 34.0 only real-time telemetry existed. Due to incomplete telemetry coverage, the effective exposures are less than expected based on the durations of these observations.

According to Taylor et al. (1992), the radio-outburst patterns differ drastically between cycles. On the average, however, the peak flux occurs at phase 0.6 ± 0.1. Obs. 31.0 therefore has the best coverage of the radio-outburst phase interval (see also Fig. 3).

ANALYSIS

Each of the three observations was analysed in four energy ranges: 0.75-1 MeV, 1-3 MeV, 3-10 MeV and 10-30 MeV. In addition, the data of the different observations were added and analysed together. Location maps were produced using a maximum-likelihood method, which is also used to determine the fluxes. A full description of this method can be found elsewhere (de Boer et al. 1992; Bloemen et al. 1993). Note that the point-spread function of the COMPTEL instrument is energy dependent. Assuming a certain spectrum (e.g. power law, Wien), the exact spectral shape (e.g. spectral index, temperature) must be found iteratively by varying the relevant parameters. Convergence is reached when the ratio of the fluxes in different energy ranges is consistent with the assumed spectral shape.

RESULTS

We have detected GT 0236+610 in all three observations. The detection significance in the sum of the three observations in Table 1 is $\sim 5.5\sigma$ ($1-30$ MeV). In the single observations, GT 0236+610 is detected only below 3 MeV with significances $\sim 3.0\sigma$, $\sim 3.5\sigma$ and $\sim 2\sigma$ respectively. Fig. 1 shows the 95% and 99% error location contours for the sum of the three observations of Table 1 (1-30 MeV). The position of GT 0236+610 is denoted by the asterisk. Note that, although the error box of COMPTEL is relatively large, the EGRET observations exclude the QSO 4U0241+61 from being the counterpart (von Montigny et al. 1993).

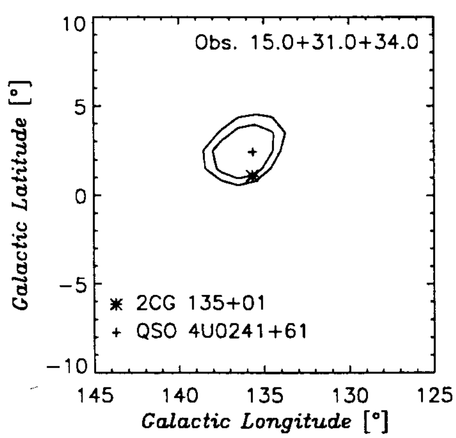

Fig 1. Location map for the sum of the observations 15.0, 31.0 and 34.0 ($1-30$ MeV). The contour levels are the 95% and 99% error location contours. The position of GT 0236+610 is denoted by the asterisk. For completeness, the position of the QSO 4U0241+61 is also indicated.

For the analysis presented here, a power law was assumed as input spectrum. From the flux values derived for power laws with different spectral indices, we find that the COMPTEL flux points are consistent with a power-law spectrum with spectral index ~ 1.7. This spectrum is thus softer than the spectrum measured at energies < 1 MeV ($\alpha \approx 1.0$, Perotti et al. 1980), but not as soft as the spectrum measured at higher energies ($\alpha = 2.0^{+0.40}_{-0.25}$, Swanenburg et al. 1981). Fig. 2 shows the COMPTEL spectral points, together with the results from the MISO and COS-B instruments.

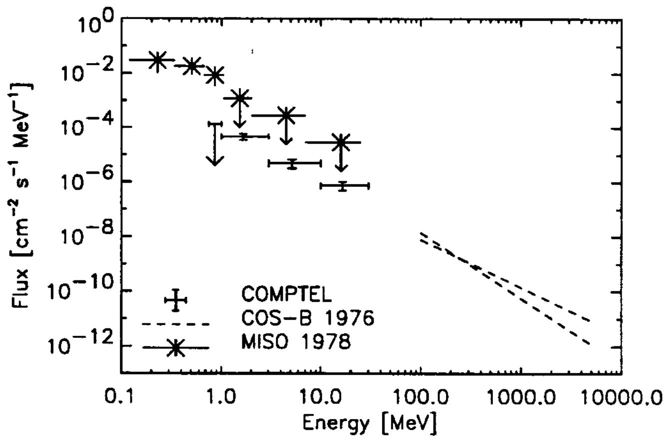

Fig 2. The COMPTEL data points and 2σ upper limit for the time-averaged spectrum of observations 15.0, 31.0 and 34.0. Also plotted are the MISO flux points (Perotti et al. 1980) and the COS-B > 100 MeV flux represented by two power laws with spectral indices 1.75 and 2.4 (Swanenburg et al. 1981).

TIME VARIABILITY?

Since a 26.496 day periodicity has been detected at optical and radio wavelengths, it is interesting to see whether the three COMPTEL observations show any hint for time variations. Because each observation has a different coverage of the radio outburst phase interval, time variations might be visible if the flux variation with phase is strong enough.

A simple comparison of the fluxes in the 1-3 MeV energy range (for which the most significant results were obtained in each of the three observations), does not reveal significant deviations from a constant flux. This is shown in Fig. 3, where the 1-3 MeV fluxes for the complete observations have been plotted against the coverage of the radio outbursts phase interval. This implies that any time variations present in the MeV emission must be small. In order to place more stringent limits, the observations will be binned according to phase, and each phase interval will be analysed separately (van Dijk et al. 1994).

SUMMARY

COMPTEL observed the binary GT 0236+610 three times in Phase I. In two observations a $\sim 3.5\sigma$ detection is obtained. The detection significance for the sum of the observations is $\sim 5.5\sigma$ (1 − 30 MeV). The spectral points measured by COMPTEL are consistent with a power law of spectral index $\sim$ 1.7. Between the three observations, no significant time variability is detected.

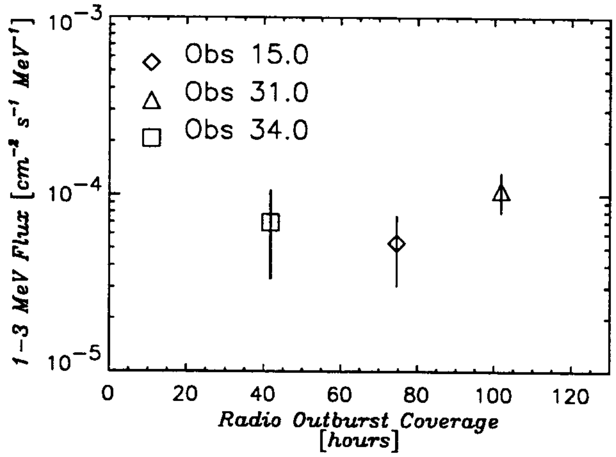

Fig 3. The COMPTEL 1-3 MeV flux points plotted against the coverage of the radio-outburst phase interval 0.5-0.7.

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