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# DETECTION OF THE COS-B/EGRET SOURCE GRO J2227+61

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## ABSTRACT

While studying Cas A a strong continuum source at galactic coordinates l$\simeq$ 106.0$^o$ and b$\simeq$ 2.0$^o$ (e.g., $\sim$ 7$^o$ off Cas A) has been seen by COMPTEL. At a statistically consistent position a source was seen by EGRET in the Phase 1 and in the Phase 2 of the CGRO mission. The position of the gamma-ray source designated GRO J2227+61 has galactic coordinates l=106.6$^o$ and b=3.1$^o$, e.g., position consistent also with the COS-B source at l$\simeq$ 106.0$^o$ and b$\simeq$ 1.5$^o$.
The source gamma-ray spectrum fitted over the COMPTEL and EGRET energy domains, could be described by the power law with a photon index of -2.20$\pm$0.14. The source most probably has a galactic origin because of its low galactic latitude and may be positionally associated with the Cep OB2. Possible detections of the GRO J2227+61 by X-ray instruments in the past are also discussed.

## INSTRUMENT AND ANALYSIS TECHNIQUE

COMPTEL aboard the Compton Gamma-Ray Observatory (CGRO) is the first $\gamma$-ray imaging telescope capable to perform an all sky survey in MeV energies. In the $\gamma$-ray sky different types of objects were already detected by COMPTEL. Among them are active galactic nuclei (AGN), pulsars, X-ray binaries and SNRs (Schönfelder et al. 1996), but a new class of $\gamma$-ray emitting objects might be expected as well in the relatively new field of a MeV $\gamma$-ray astronomy.
COMPTEL operates in the 0.75 to 30.0 MeV energy range with a field-of-view of about 1 steradian, a position location accuracy of $\sim$ 1$^o$, and an energy resolution of 5-10% FWHM. Sources separated by more than 3$^o$-5$^o$ can be resolved by COMPTEL. A detailed description of the instrument, its calibration and COMPTEL data analysis in the 3-dimensional dataspace is given by Schönfelder et al. (1993).
The standard energy intervals of COMPTEL were analysed and maps were generated by applying the maximum-likelihood method (de Boer et al. 1992; Bloemen et al. 1994). This method tests for the presence of 3-D source signatures in the COMPTEL data space, superimposed on a background model derived by applying a filter technique to the 3-D dataspace (Bloemen et al. 1994). The display of the maximum-likelihood ratios over the field of view is usually refered to as the maximum-likelihood map. This map allows determination of the source significance, flux, error region, etc. Usually, for the preliminary source parameters evaluation an E$^{-2}$ input spectrum is assumed in calculating the instrument response: uncertainty in the flux measurements due to this assumption is $\leq$ 5%. In this paper the final source parameters were derived with the use of an E$^{-2.2}$ input spectrum in the COMPTEL energy range.

## RESULTS

The source at l $\sim$ 106$^o$ was first time seen by COMPTEL (Iyudin et al. 1994) in viewing period 34 of the CGRO Phase 1, at about 4.4 $\sigma$ for 1 d.o.f.. The source 2EG J2227+6122 was seen independently by EGRET at the position l=106.6$^o$, b=3.1$^o$ in the viewing periods (VPs) of Phase 1 (Fichtel et al. 1994) and Phase 2 (Thompson et al. 1995) of CGRO mission plan, which is consistent with the best position derived by COMPTEL for the combination of the Phase 1 VPs (Iyudin et al. 1997). We reanalysed the EGRET data for the best source position once again, taking all available VPs in consideration.

Because of the narrower field of view of EGRET only 7 VPs, out of 17 VPs in total where a source was in FoV of COMPTEL, were used for EGRET analysis. All 7 viewing periods have a significant signal from the GRO J2227+61 in the EGRET energy domain. Taking significances of the source detection in COMPTEL energy domain from the combination of VPs where it was seen above 2 $\sigma$, we could derive the probability of GRO J2227+61 spurious detection by COMPTEL as $2.0 \times 10^{-11}$ after taking into account the total number of trials in all phases of CGRO and all combinations of viewing periods (Iyudin et al. 1997). This value corresponds to more than a 6 $\sigma$ significance for the source detection by COMPTEL. Overall significance of the GRO J2227+61 detection by EGRET in Phases 1 and 2 of CGRO was $\geq 7\ \sigma$ (Thompson et al. 1995) and is $\geq 8\ \sigma$ for all EGRET data available for this source. Figure 1 presents a map of the source region in the COMPTEL and EGRET energy domain. In order to get the best estimate of the new source position, data from the viewing periods for which the source was detected with significance above 2 $\sigma$ were combined and treated with the maximum-likelihood method as described above. The most probable position of the new source derived from COMPTEL data is $l=106.6^o$ and $b=3.1^o$, with a 95 % error region of about $1.5^o$ radius.

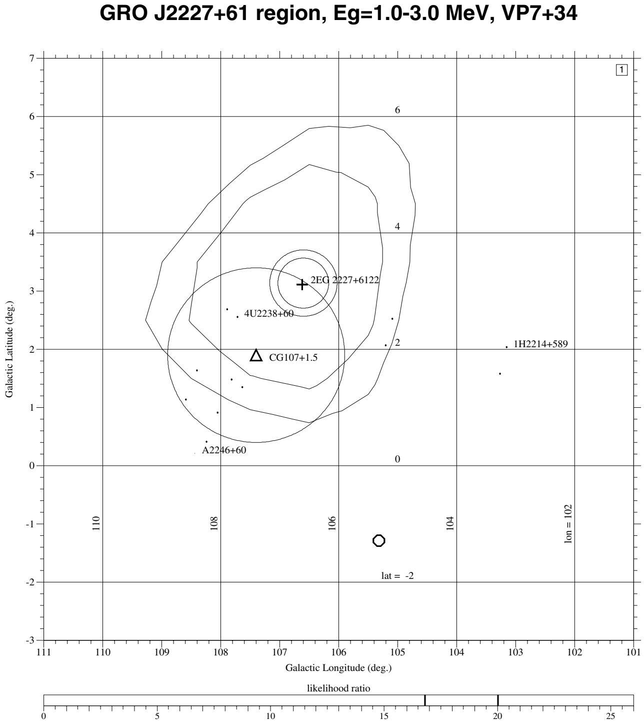


*Fig. 1: Maximum-likelihood map of the GRO J2227+61 region for the combination of VP 7and 34. The cross marks position of GRO J2227+61 (2EG 2227+6122). The triangle shows position of CG107+1.5. Contour lines are drawn at the 95 and 99% confidence level of the source position for COMPTEL and EGRET (stylized as a circle for EGRET). For the position of CG107+1.5 is given 90% confidence contour (Wills et al. 1979). The error boxes of the nearest X-ray sources are shown. Galactic coordinate grid is overlayed.*

Time averaged spectrum

The analysis of the GRO J2227+61 is complicated by the presence of another source at $l\sim 105^o$, $b\sim -1.5^o$. This source, whose position is consistent with the known binary CQ Cep, has shown a flux comparable to the GRO J2227+61 flux in the 1-3 MeV energy band during Phase 1 and Cycle 5 of the CGRO mission. For the determination of the GRO J2227+61 spectrum we have generated response models for the diffuse emission, for the assumed CQ Cep and GRO J2227+61 itself and included them in the likelihood fitting process, where their flux values were free parameters. The resulting time averaged source spectrum produced for the combination of the seven VPs of EGRET and 3 VPs of Phase 1 for COMPTEL is presented in Figure 2. The best fit power-law spectrum to the points of EGRET has a photon spectral index of ($-2.2\pm 0.14$). The two points of COMPTEL for 0.75-1.0 and 1-3 MeV and upper limits for 3-10 and 10-30 MeV energy bands are consistent with the extrapolation of the spectrum derived by EGRET. We analysed also EGRET spectra for individual VPs and found that no spectra derived for individual VPs contradict time averaged spectrum.

Flux variability

A quantitative analysis of the source flux in different viewing periods was performed for EGRET and COMPTEL data. The conclusion drawn is that 7 EGRET measurements are consistent with the source being constant in flux above 100 MeV at the $(4.26\pm 0.51)\times 10^{-7}$ $cm^{-2}s^{-1}MeV^{-1}$ value. The sample of flux values in the EGRET energy domain has reduced $\chi^2$=1.09 for N-1=6, under the assumption being derived from a distribution with the same mean flux value (confidence level $\geq$35%). This conclusion is supported by the fact that COS-B measurements (Mayer-Hasselwander and Sympson (1990)), separated in time from those of EGRET by $\sim$ 15 years, are only slightly above the EGRET power-law spectrum at the 70-150 MeV and 150-300 MeV energy intervals (see Figure 2). A similar statement could be made for the fluxes measured in 1-3 MeV energy domain of COMPTEL, but with confidence of only $\geq$9%. The flux values of the GRO J2227+61 were measured by COMPTEL in 17 VPs, between June 8, 1991 and October 3, 1996. The COMPTEL points do not constrain much against the assumption of constant flux and allow for possible source variability on the time scale of 2-3 years.

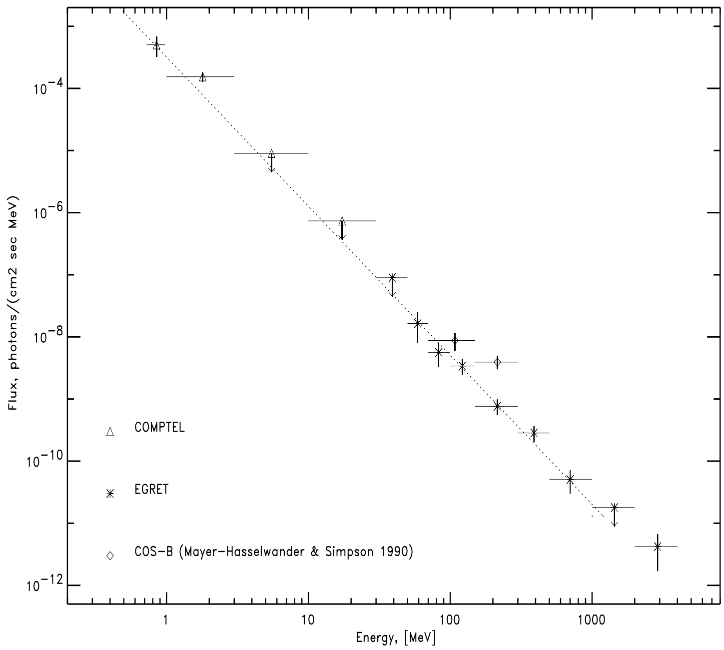


*Fig. 2: The GRO J2227+61 spectrum include quasicontemporaneous measurements by COMPTEL and EGRET, and non-contemporaneous COS-B measurement. The dotted line corresponds to the power law with a photon index of -2.20±0.14, as derived from the EGRET measurements.*

## DISCUSSION

GRO J2227+61 was detected by COS-B in 1979 (Wills et al. 1980). The source 2EG J2227+6122 was seen independently by EGRET at the position l=106.6$^o$, b=3.1$^o$ in the viewing periods of Phase 1 (Fichtel et al. 1994) and Phase 2 (Thompson et al. 1995) of CGRO mission plan, which is also consistent with the position of GRO J2227+61 (Iyudin et al. 1997). Therefore, we consider the source detected by the three different experiments as one source at the position of 2EG J2227+6122.

### Possible counterpart candidates

There is no evidence for the AGN presence in the error box of the GRO J2227+61 according to Hewitt & Burbidge (1987) and Veron-Cetty & Veron (1996) catalogs, although one could not rule out the possibility of the background AGN alignement with the GRO J2227+61, as there are optically thick dark clouds (Lynds 1962) in the foreground. The source most probably has a galactic origin because of its low galactic latitude and may be positionally associated with the Cep OB2 (Humphreys 1978). There are possible counterparts of the source in the radio [GB87] 2226+6122 (Becker et al. 1991; White & Becker 1992) and IR wavelenghts IRAS F22267+6124 and IRAS F22268+6122 (IRAS Catalogs and Analysis, 1988, NASA RP-1190) inside of the EGRET 3 $\sigma$ error box of $\sim$1$^o$, which are extended sources and could be considered for further exploration. It is quite possible that two IRAS sources appear as one gamma-ray source due to limited angular resolution of the gamma-ray experiments.
Potential galactic counterpart sources include SNRs, pulsars, binaries and OB associations. But there are no SNR at this position in the Green's catalogue (Green 1988), no new SNR candidate from the ROSAT survey (Aschenbach 1995), or X-ray pulsar in a catalogue of the known X-ray pulsars (Becker 1995). The source GRO J2227+61 is rather close ( $\sim$ 0.8$^o$) to the position of the radio pulsar PSR B2227+61 with 443 ms period, a distance of $\sim$ 5.5 kpc and $\dot{E}$=10$^{33.1}$ erg s$^{-1}$ (Taylor et al. 1993), which makes pulsar detection by CGRO unlikely. The nearest possible binary counterpart, X-ray binary 1H2214+589 is $\sim$ 3$^o$ from the position of GRO J2227+61 (van Paradijs 1995). Position of the GRO J2227+61 is consistent with the position of the dark nebulae L1195 and L1196 (Lynds 1962). A hypothesized accreting compact object inside nebulae could be a possible counterpart for the GRO

J2227+61. Alternatively, OB stars (see e.g., Neckel 1967; Humphreys 1978) with their strong stellar wind could be responsible for the local cosmic ray enhancement and for the subsequent γ-ray emission. It is not posible to pin counterpart source for the EGRET/COMPTEL position from the X-ray source catalogs (Amnuel et al. 1982; Wood et al. 1984; Gioia et al. 1990). The X-ray source 4U2238+60 is $\leq 1.5^o$ off, while 1H2214+589 and A 2246+60 are $\sim 3^o$ off the best gamma-position. Unfortunately no pointing observations by ROSAT were made for this region.

## CONCLUSION

The large γ-ray error box of the GRO J2227+61 precludes the use of the follow-up measurements in the optical, radio or IR wavelengths for the purpose of the source identification and analysis of the physical mechanisms of the γ-ray production. The X-ray imaging telescope, like a SAX's Wide Field Camera (WFC) with wide field of view and good positional resolution (5 arcminutes) (SAX Observers Handbook 1995), have to be used first for improving the positional accuracy of the GRO J2227+61 and to get information on the source X-ray spectrum and possible variability in the X-ray energy domain.


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