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First results from COMPTEL measurement of the ^{26}Al 1.8 MeV gamma-ray line from the galactic center region

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Abstract. — The COMPTEL instrument on GRO is designed to image celestial gamma radiation in the ~0.7-30 MeV region of nuclear lines. Within a large field of view of ~1 sr its angular resolution of ~1°enables mapping of extended emission and location of (strong) point sources to an accuracy of better than 0.5°. The Galactic center region was observed by COMPTEL for a 2 week period in July 1991. Here we report the detection of the line at 1.8 MeV attributed to ^{26}Al, addressing in particular the extent of the emission and the 1.8 MeV line flux.

Key words: gamma rays — gamma-ray lines — nucleosynthesis — novae — supernovae — Wolf-Rayet stars.

1. Introduction.

The 1.8 MeV gamma-ray line originating from the decay of radioactive ^{26}Al(decay lifetime 1 million years) has been predicted by Ramaty and Lingenfelter already in 1977, and was detected for the first time with the HEAO-C instrument (Mahoney *et al.*, 1984). Many other measurements were taken since then, and the existence of the line is solidly established since 1985 with the SMM measurement at a significance above 10σ. The line width was determined from Ge detector measurements to be not (or very little) broadened (Mahoney *et al.*, 1984; Teegarden *et al.*, 1990), indicating that the ^{26}Aldecay takes place in the interstellar medium. The formation of ^{26}Altakes place in nucleosynthesis sites such as novae, supernovae, or in the interior of massive stars (ref. Clayton, Woosley 1986, Prantzos 1990). As the Galactic distribution of these potential ^{26}Alsources is known to some extent from optical measurements, imaging of the 1.8 MeV emission in the Galaxy is believed to provide information on the nature of the source. Attempts to image the line emission have been reported by different groups: von Ballmoos, Diehl, Schönfelder, 1987 (MPE's imaging Compton telescope), Purcell *et al.*, 1990 (SMM analysis exploiting earth occultation), Teegarden *et al.*, 1991 (GRIS coded mask imaging telescope). Limitations in sky exposure or instrumental capabilities have prevented a conclusive result sofar, although extended source models appear somewhat more likely. The Compton Gamma-Ray Observatory had been successfully launched in April 1991, and the COMPTEL imaging telescope has adequate sensitivity (Schönfelder *et al.*, 1991) to provide new insight into the origin of ^{26}Al.

2. Data analysis.

The Galactic Center region was observed during the GRO sky survey in observations 5 (2 week pointing in July 1991 at l=0°/b=-4°), observations 7.5 and 13.0 (both 1 week pointings in August/November 1991 at 25°/-13°), and observation 16 (2 week pointing December 1991 at 18°/-9°). This paper concentrates on observation 5 analysis, using background data from other observations (1,4,10,11).

With an instrumental energy resolution of 8.5% ($FWHM$) at 1.8 MeV and a high photopeak fraction at MeV energies, the 1.809 MeV ^{26}Algamma- ray line is expected to be identified already in non-deconvolved data from the COMPTEL scintillation detectors. Known

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instrumental background lines exist e.g. at 1.46 and 2.2 MeV. The background for the Galactic center region measurements is determined from other observations at high Galactic latitudes. The dominant features of the instrumental background are similar for all observations, so that an average of these high-latitude observations provides a good first-order background model. Full imaging of the 1.8 MeV line requires more detailed background modelling including spatial signatures of the instrumental background, which is in progress; this paper is restricted to coarse imaging.

In summary the analysis steps are as follows:

- determination of measured energy spectra as described above. Averaged high-latitude energy spectra provide the background model; normalization to the Galactic Center region spectrum in different ways determines the uncertainty on the residual continuum flux underlying the 1.8 MeV line.
- first checks on presence of the 1.8 MeV line and its statistical significance
- coarse imaging analysis selecting events from constrained regions of the sky: events with scatter direction and scatter angle compatible with a selected region in the sky are accepted only, which results in an effective field of view of $\sim 12°(FWHM)$ for a nominal 3°acceptance radius of measured events. This is possible at energies $\lesssim$ 5 MeV because most of the photons are detected via a Compton scatter interaction in the upper COMPTEL detector plane, followed by total absorption in the lower COMPTEL detector plane (for details of the instrument, see Schönfelder *et al.*, 1984).
- qualitative testing of specific models by convolving the expected intensity distribution with the instrument response, and applying the same event selection as above to perform a coarse imaging.
- quantitative testing of specific source hypotheses, using the maximum likelihood method in the imaging dataspace of COMPTEL, exploiting the full response details of the instrument.

3. Results.

Measured energy spectra from different regions of the sky are shown in Figures 1 and 2. Figure 1 displays spectra from observations excluding the Galactic plane. The expected features at 1.46 and 2.2 MeV from known instrumental lines are clearly visible (^{40}K radioactivity originating in the structure of the EGRET instrument, and neutron capture in the COMPTEL upper detectors, respectively). In the regime around 1.8 MeV no line feature is seen. When the Galactic disc is included in the field of view (Fig. 2), these raw spectra do show a hint for a feature around 1.8 MeV. Figure 3 shows the measured background-subtracted energy spectrum for observation

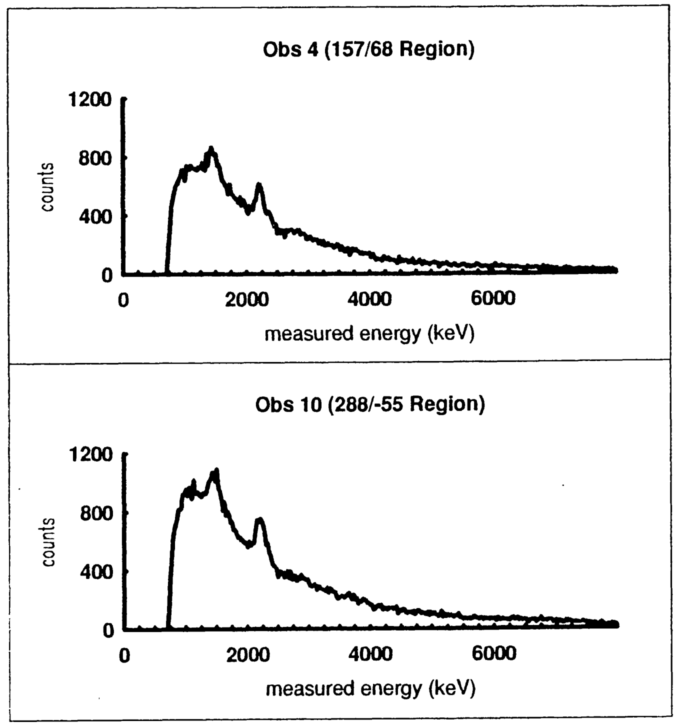

FIGURE 1. Energy spectra from COMPTEL observations of sky regions excluding the Galactic plane. A narrow field of view of $\sim 12°$pointed at the indicated coordinates was selected.

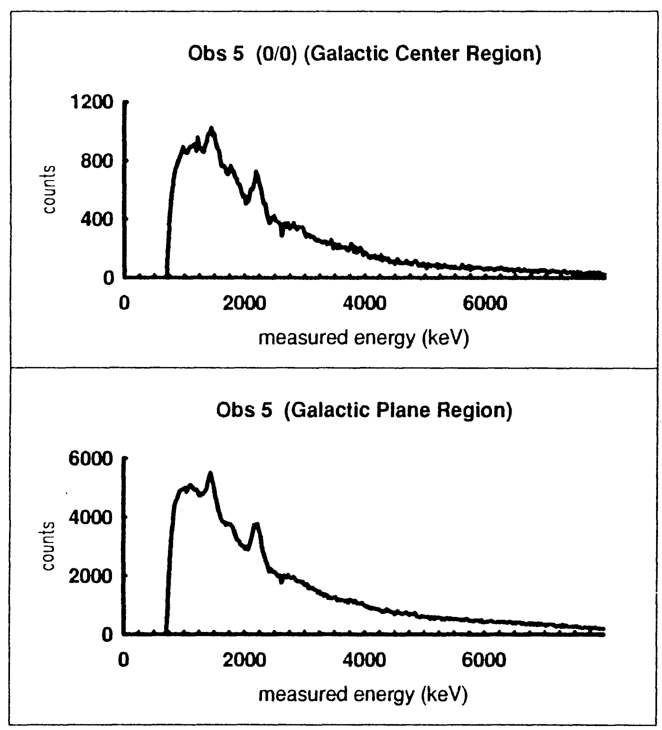

FIGURE 2. Measured energy spectra from the Galactic center region, selecting a narrow 3°region at 0°/0°, and a wide region including the Galactic plane (±30°, ±5°), respectively.

5. The field of view was defined by event selections in

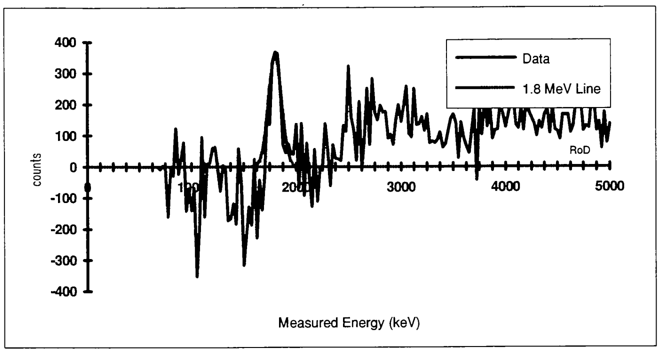

FIGURE 3. Background-subtracted energy spectrum from the Galactic Center region.

the Galactic longitude range -30°≤ l ≤30° and Galactic latitude range -5°≤ b ≤5°. Background was defined by high latitude observations 4 and 10 at latitudes of 68°and -55°, respectively. The line profile at 1.8 MeV is consistent with the instrumental response from prelaunch calibration, as demonstrated by the indicated Gaussian profile. In the measured energy range 1.7-1.9 MeV, 1706 events are obtained from this analysis, equivalent to a photon flux of ~4 × 10^{-4} photons cm^{-2} s^{-1} from the selected region. The statistical significance of the line depends on the statistical accuracy of the background modelling; for the ~26000 events (1.7-1.9 MeV) used in this analysis the significance is 5.5σ.

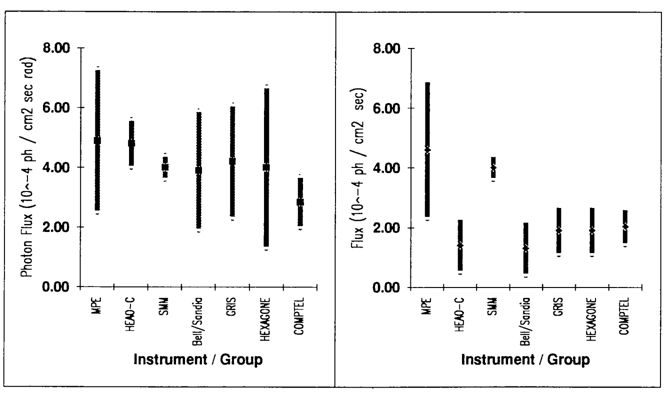

FIGURE 4. Comparison of 1.8 MeV photon fluxes derived from different instruments.

Flux values for the 1.8 MeV line are determined from different instruments with different field-of-view sizes (Varendorff and Schönfelder, 1992 (MPE balloon borne Compton telescope), Mahoney *et al.*, 1984 (HEAO-C), Share *et al.*, 1985 (SMM), MacCallum *et al.*, 1987 (Bell/Sandia), Teegarden *et al.*, 1990 (GRIS), Malet *et al.*, 1990 (HEXAGONE)). For comparison and due to the lack of source imaging, the values are usually derived under the assumption of either a point source at the Galactic center, or a diffuse, extended source similar to the distribution of the high-energy gamma rays as measured by COS-B, and determining the flux for the central radian of the Galaxy. Figure 4 compares the flux values derived from different instruments and COMPTEL under these two assumptions.

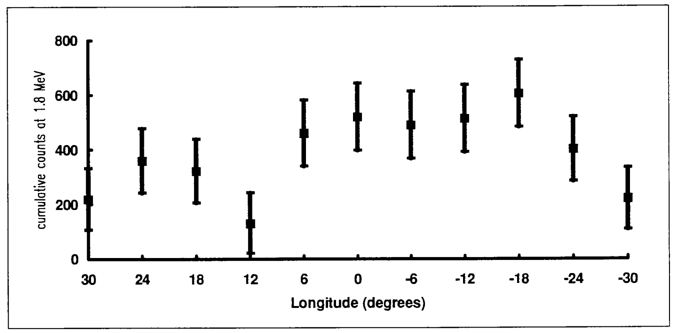

FIGURE 5. Observed Galactic longitude scan of 1.8 MeV emission (convolved with the COMPTEL response).

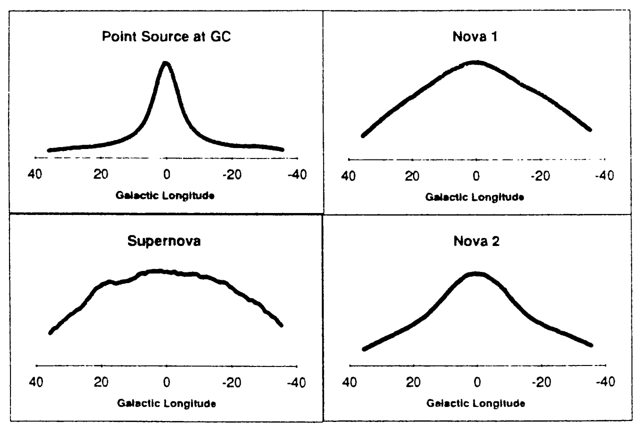

FIGURE 6. Galactic longitude scans for source models convolved with the COMPTEL response from Observation 5, and folded through the same analysis as the measured data (compare with Fig. 5).

In order to construct a longitude profile of measured 1.8 MeV events, the analysis method described above was applied to small regions along the Galactic equator. The result is shown in Figure 5. Note that this longitudinal profile is convolved with the instrument response. Various expected distributions are shown in Figure 6 (point source at the Galactic Center, nova model derived from optical measurements of our Galaxy (N1, Mahoney *et al.*, 1984), nova model based on M31 optical observations (N2, Leising and Clayton, 1985), supernova model based on Galactic gas distribution (Leising and Clayton, 1985). These distributions were obtained via the same analysis technique

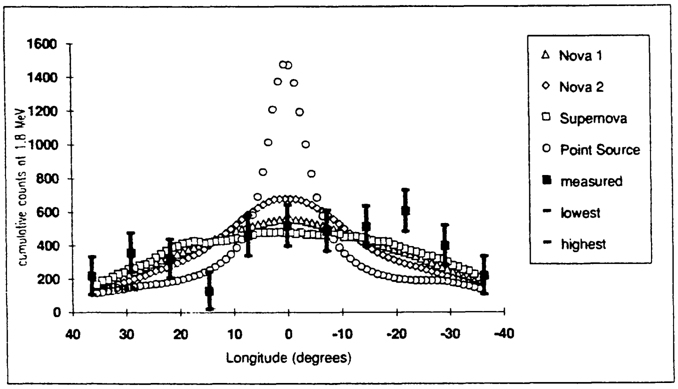

FIGURE 7. Comparison of measured and modelled Galactic longitude profiles. The profiles are normalized to the integrated number of counts.

as described above, after the model intensities had been convolved with the instrument response. All these model profiles differ somewhat from our measurement (Fig. 7), but neither of the 'extended' models can be excluded at this stage. However, the 'single point source at the Galactic center' model obviously differs significantly from our measurement and can be excluded. This was confirmed by a maximum likelihood test in a more detailed imaging analysis, which yields a highly significant rejection for this model. From Figure 7 it appears that fairly extended emission models are required. Further analysis exploiting the imaging capabilities of COMPTEL is required to set stringent constraints on source models. Combinations of adjacent observations of the Galactic plane, supplemented by deeper analysis of the global background signatures in COMPTEL data, will enhance the signal-to-background ratio and yield more detailed imaging results of the Galaxy in the 1.8 MeV line.

4. Conclusions.

The 1.8 MeV gamma ray line from radioactive ^{26}Alis clearly observed by the COMPTEL instrument aboard the Compton Gamma-Ray Observatory. A first imaging analysis rules out a single pointsource at the Galactic center as origin of the 1.8 MeV emission, the emission region appears to be extended. COMPTEL data obtained during the GRO sky survey period will enable a more detailed study of the distribution of the Galactic 1.8 MeV emissivity, thus setting more stringent constraints on the different source models for ^{26}Al.

References

Clayton D.D., 1984, ApJ 280, 144
MacCallum C.J. *et al.*, 1987, ApJ 317, 877
Mahoney W.A. *et al.*, 1984, ApJ 286, 578
Malet I. *et al.*, 1990, in: AIP Conf. Proceedings 232, Eds. P. Durouchoux and N. Prantzos, 123
Prantzos N., 1991, in: AIP Conf. Proceedings 232, Eds. P. Durouchoux and N. Prantzos, 129
Purcell W.R. *et al.*, 1989, in: AIP Conference Proceedings 170, Eds. N. Gehrels and G. Share, 181
Ramaty R. and Lingenfelter R.E., 1979, Nat 278, 127
Share G. *et al.*, 1985, ApJ 292, L61
Schönfelder V. *et al.*, 1991, in: 2^{nd} GRO Science Workshop, NASA Rep. No. CP-3137
Schönfelder V. *et al.*, 1984, Nucl.Instr.& Meth., NS-31, 1, 766
Teegarden B.J. *et al.*, 1991, in: AIP Conf. Proceedings 232, Eds. P. Durouchoux and N. Prantzos, 116
Varendorff M. and Schönfelder V., 1992, ApJ 395, 158
von Ballmoos P., Diehl R., Schönfelder V., 1987, ApJ 312, 657
Woosley S.E., 1986, in: 'Nucleosynthesis and Chemical Evolution', Eds B. Hauck, A. Maeder, and G. Meynet, 78