THE GRO - COMPTEL MISSION :

INSTRUMENT DESCRIPTION AND SCIENTIFIC OBJECTIVES

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ABSTRACT

The imaging Compton telescope COMPTEL is one of the four instruments onboard NASA's Gamma Ray Observatory GRO which is to be launched in April 1991 by the Space Shuttle Atlantis. COMPTEL will explore the 1 to 30 MeV energy range with an angular resolution of a few degrees within a large field-of-view of about 1 steradian. Its medium energy resolution (8.8 % FWHM at 1.27 MeV) in addition makes it to a powerful gamma-ray line spectrometer. Within a 2-weeks observation period COMPTEL will be able to detect sources which are about 20-times weaker than the Crab. With these properties COMPTEL is well suited to perform the first complete sky survey at MeV-energies. Targets of special interest are galactic gamma ray sources (like radio pulsars, X-ray binaries, the Galactic Center, the unidentified COS-B sources, supernova remnants and molecular clouds), external galaxies (especially the nuclei of active galaxies), gamma-ray line sources (e.g. the distribution of the 1.8 MeV line emissivity throughout the Galaxy), the diffuse gamma-ray emission from interstellar space, the cosmic gamma-ray background, cosmic gamma-ray bursts, and gamma-ray and neutron emission during solar flares.

INTRODUCTION

COMPTEL covers an energy range (1 to 30 MeV) which was once classified "the impossible range" in astronomy. In spite of tremendous difficulties in exploring this range, quite some progress has been achieved during the last few years. The few existing results have already demonstrated that the scientific return of MeV-gamma ray astronomy is very high.

The imaging Compton telescope COMPTEL was proposed to NASA in 1978 in response to the Announcement of Opportunity for instruments onboard the Gamma-Ray Observatory GRO by an international collaboration consisting of the Max-Planck-Institut für extraterrestrische Physik in Garching, FRG, the Laboratory for Space Research in Leiden, The Netherlands, the University of New Hampshire in Durham, USA, and the Space Science Department of ESA in Noordwijk, The Netherlands. In 1981 - at the end of a three years lasting definition phase - COMPTEL was selected by NASA as one of the four GRO instruments. The other instruments on the Observatory are BATSE (Burst and Transient Source Experiment), OSSE (Oriented Scintillation Spectrometer Experiment), and EGRET (Energetic Gamma-Ray Experiment Telescope).

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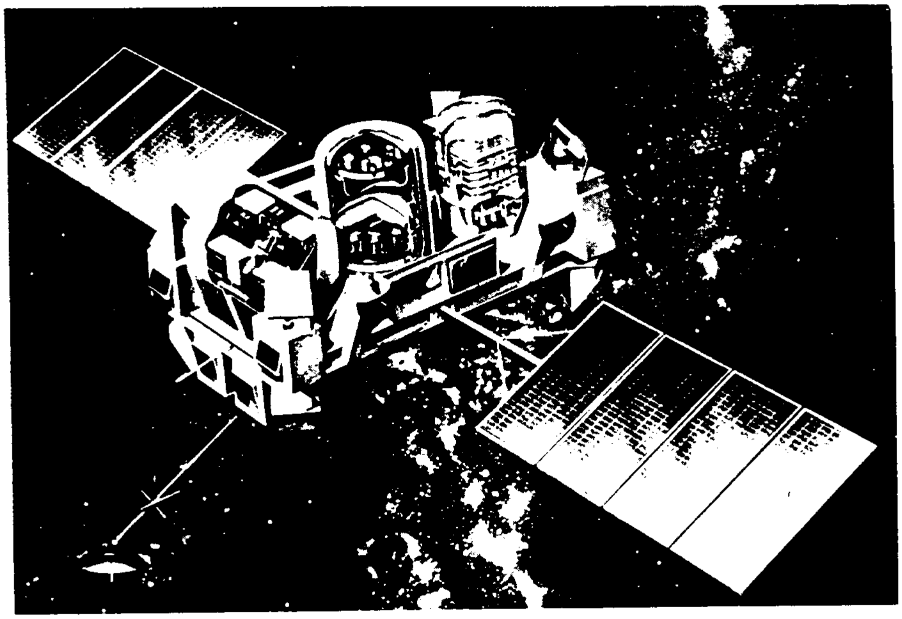


Fig. 1. Schematic View of GRO. OSSE is on the left, EGRET on the right side, COMPTEL is in the middle. BATSE consists of 8 detectors, two at each corner of the observatory.

A schematic View of the Gamma-Ray Observatory is shown in Figure 1. COMPTEL occupies the middle position of the spacecraft, EGRET is to the right, OSSE to the left. BATSE actually consists of 8 single detectors, two at each corner of the platform.

GRO will be a free flying satellite which is to be launched by the Shuttle Atlantis according to the present NASA schedule in April 1991. GRO is three-axis stabilized. The pointing accuracy is ± 0.5 degree, however, the pointing direction will be known at any time to an accuracy of 2 arc minutes. Absolute time will be accurate to 0.1 msec. GRO will have a circular orbit of 450 km and 28.5 degree inclination. This orbit guarantees a mission life time of at least 2 years and at the same time provides a low background environment. On the other side, about 50 % of the observation time will be lost due to occultation of the fields-of-view of the instruments by the Earth. The nominal observation time of GRO will be 2 weeks per viewing direction. During the first 15 months of the mission a complete sky survey will be made. During later phases of the mission detailed observations of selected objects are foreseen.

INSTRUMENT DESCRIPTION OF COMPTEL

COMPTEL has been otimized to perform the first very sensitive survey of continuum and line emission in the 1 to 30 MeV range. For this purpose it combines a wide field-of-view with imaging properties within that field. The high sensitivity is achieved by minimizing its response to undesired background events /1/.

COMPTEL consists of two detector arrays, an upper one of low Z material, (liquid scintillator NE 213A), and a lower one of high Z material (NaI (Tl) scintillator). In the upper detector (D1) an infalling gamma ray is first Compton scattered and then the scattered gamma ray makes a second interaction in the lower detector (D2). The sequence is confirmed by a time-of-flight measurement. The locations and energy losses of both interactions are measured. For completely absorbed events the arrival direction of the gamma ray is known to lie on the cone mantle of half opening angle φ around the direction of the scattered γ-ray (see Fig. 2), where

$$\cos \bar{\varphi} = 1 - \frac{m_0 c^2}{E_2} + \frac{m_0 c^2}{E_1 + E_2} \tag{1}$$

$$E_\gamma = E_1 + E_2 \tag{2}$$

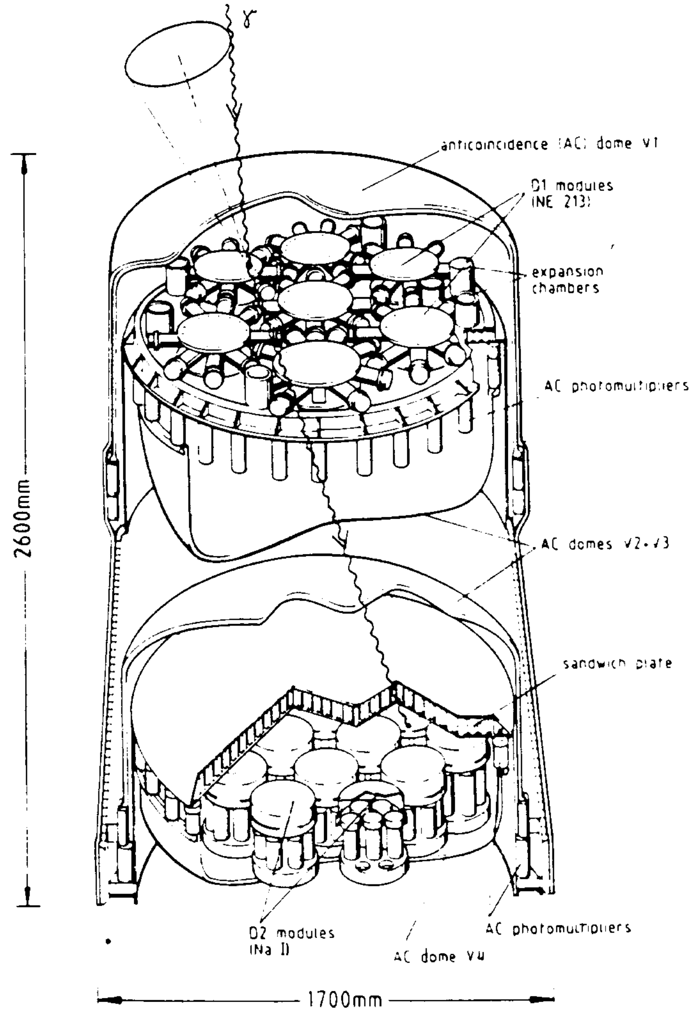


Fig. 2. Schematic View of COMPTEL

A celestial source therefore can be located from the cones of different source gamma rays. Incompletely absorbed events produce cones which do not contain the source position. The angular resolution of the telescope depends on the accuracy to which $\bar{\varphi}$ and the direction of the scattered gamma ray are determined. In some ways COMPTEL is similar to an optical camera: the first detector, which can be compared with the camera's lens, directs the light into the second detector, comparable to the film, in which the scattered photon is absorbed. Although the photons are not focussed as in case of the optical camera, COMPTEL is able of reconstructing sky images over a wide field-of-view with a resolution of a few degrees.

A schematic drawing of the telescope is shown in Figure 2. The two detectors are separated by a distance of 1.5 m. Each detector is entirely surrounded by a thin anticoincidence shield of plastic scintillator which rejects charged particles. Off to the sides between both detectors are two small plastic scintillation detectors containing weak Co^{60} sources; these are used as gamma-ray calibration sources.

The Upper Detector (D1) consists of 7 cylindrical modules of liquid scintillator NE 213. Each module is approximately 28 cm in diameter and 8.5 cm thick and viewed by 8 photomultiplier tubes. The total area of the upper detector is 4310 cm^2. The Lower Detector (D2) consists of 14 cylindrical NaI (Tl) blocks of 7.5 cm thickness and 28 cm diameter, which are mounted on a baseplate with a diameter of 1.50 m. Each NaI-block is seen from below by seven 7.5 cm photomultipliers. The total geometrical area of the lower detector is 8620 cm^2. Each anticoincidence shield consists of two 1.5 cm thick domes of plastic scintillator Ne 110. A dome is viewed by 24 photomultipliers. Each calibration source consists of a cylindrical piece of Co^{60}-doped plastic scintillator of 3 mm thickness and 1.2 cm diameter which is viewed by two 1.9 cm photomultipliers. Except for the front-end electronics of the photomultipliers, all main electronics are mounted on a platform outside the detector assembly.

A gamma ray is electronically identified by a delayed coincidence between the upper and the lower detector, combined with the absence of a veto signal from all charged particle shields and from the calibration detectors. The quantities measured for each event are as follows:

1. the energy of the Compton electron in the upper detector ($E_1 > 50$ keV);
2. the location of the interaction in the upper detector;
3. the pulse shape of the scintillation pulse in the upper detector;
4. the energy loss E_2 in the lower detector ($E_2 > 500$ keV);
5. the location of the interaction in the lower detector;
6. the time-of-flight of the scattered gamma ray from the upper to the lower detector;
7. the absolute time of the event.

The locations of the interactions are derived from the relative pulse heights of all phtomultipliers viewing one detector module. The pulse shape measurements and the time-of-flight measurements are performed in order to reject background events. A gamma-ray event is initially selected onboard according to coarse criteria established on the pulse heights of signals from D1 and D2, time-of-flight, the absence of a veto signal from all anticoincidence domes, and provided no preceding interaction has deposited a large amount of energy in the triggered cell (overloads). If the initial event selection logic is satisfied, a series of actions are initiated:

1. pulse height analysis of the 15 photomultiplier tubes of the identified modules of D1 and D2, plus the sum of the eight D1 and seven D2 PMT's;

2. time-to-digital conversion of the time-of-flight and pulse-shape discriminator circuit outputs;

3. the triggering of the digital electronics, which time-tags the event.

In addition to this normal double scattering measuring mode, two of the NaI-crystals of the telescope will be used to measure the energy spectra of cosmic gamma-ray bursts and solar flares. In case of a solar flare, COMPTEL receives a solar flare trigger indirectly from BATSE. COMPTEL then goes into an alternate event selection mode, which also allows to measure solar neutrons in addition to gamma rays.

The digital outputs of the pulse height analysis and the time-of-flight conversions are further checked against upper and lower limits, loaded via serial telecommands. The data are stored in the event buffer, with those events satisfying the final selection criteria having first priority and those failing one or more criteria having second priority for transmission through the telemetry. Calibration data are transmitted regularly either as events or as spectra. Estimates of the orbital trigger rate and the need to transmit an adequate sample of calibration events are consistent with an event message rate of 48 events per 2.048 seconds. For one event 16 x 16 bit words are required.

TELESCOPE PERFORMANCE

The calibration of the fully integrated instrument with radioactive sources and γ-rays produced by nuclear interactions at a van de Graaf-accelerator was performed in 1987 at the Gesellschaft für Strahlenforschung at Neuherberg, near Munich. The radioactive sources/beam targets were placed at distances of 8.0 to 8.5 m from the COMPTEL D1-detector. After each source run a background run was performed in which the radioactive source was blocked by a thick lead shield. The analysis of the calibration data is now near its completion. Here the preliminary results from a few source runs are presented /2/.

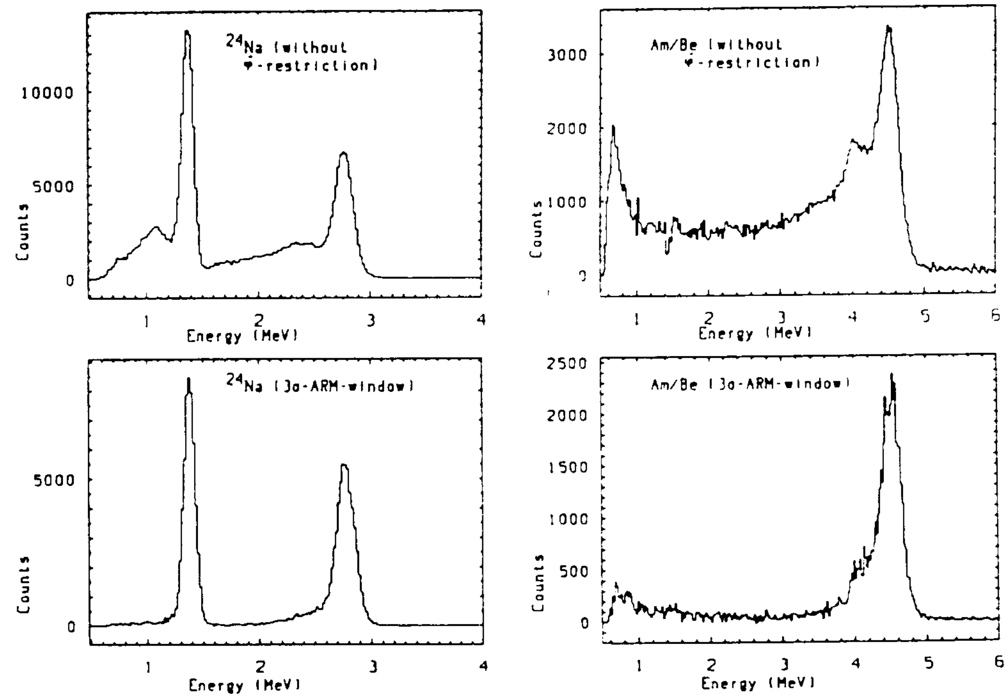
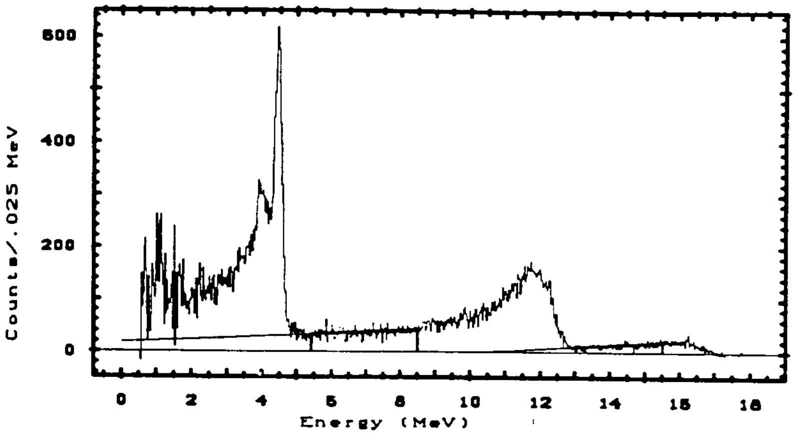


Fig. 3a. Energy spectra measured with COMPTEL at 2.75 MeV (Na^{24}) and 4.43 MeV (Am/Be). The term ARM-window is defined in the text.

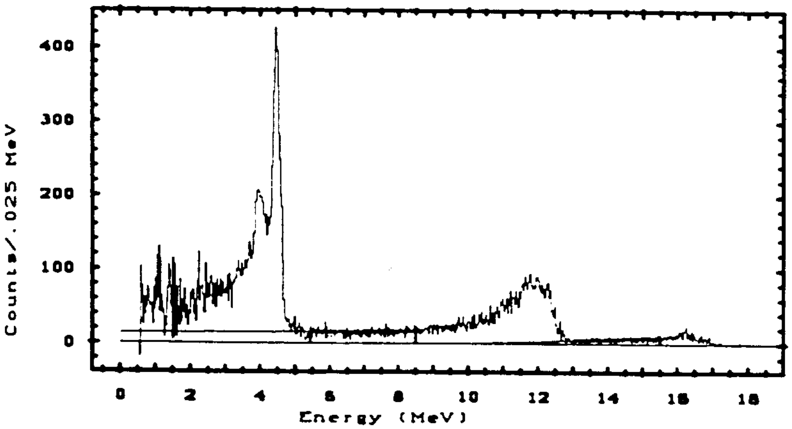
Energy Resolution.

The energy resolution of COMPTEL is determined by the energy resolution of both detector assemblies. Figure 3a displays the energy spectra mesured with COMPTEL for γ-rays at 2.75 MeV (Na^{24}) and 4.43 MeV (Am ^{241}/Be^{9}) after background subtraction. The top spectra contains all events above the energy thresholds (50 keV in D1, and 500 keV in D2). The Compton tails in the energy spectra (resulting from incompletely absorbed events in D2) can be suppressed by applying event selection criteria, e.g. by limiting the Compton scatter angle φ to values smaller than 30°, or by accepting only events whose event circles pass (within $\pm$ 1.5 σ) through the position of the radioactive source. By this latter event selection a nearly complete suppresion of the Compton tail can be achieved as illustrated in the bottom spectra of Figure 3a. This technique can be applied, if the position of a celestial gamma-ray source is known. The photo-peak energy resolutions of COMPTEL are summarized in Table 1.

At photon energies above about 10 MeV , the photopeak fraction becomes two small to make the photopeak visible. But still, multiple Compton collision cause a peak near the photopeak energy, and the width of this peak is about 10 % FWHM between 10 and 20 MeV (see Fig. 3b).



Boron no standard $\bar{\varphi}$-restriction

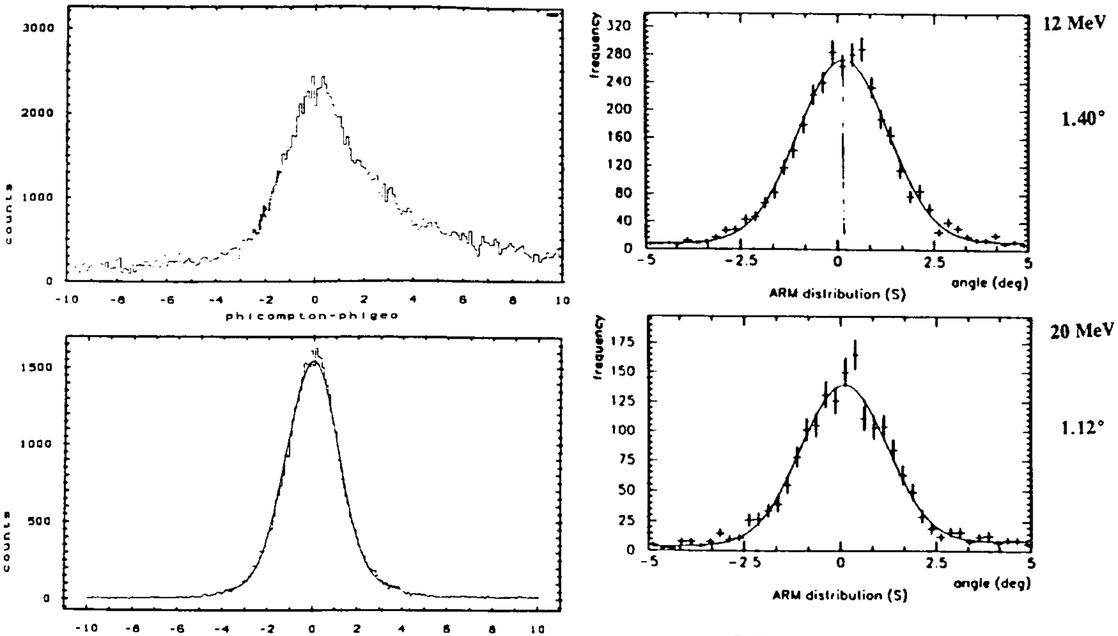


Boron with standard $\bar{\varphi}$-restriction

Fig. 3b. Measured energy spectrum from Boron target (12.14 Mev and 4.43 MeV), Background is subtracted. The peak resolution at 11.5 MeV is 9 % FWHM.

TABLE 1. Energy and Angular Resolution of COMPTEL

Energy [MeV]	photopeak-energy resolution [FWHM]	ARM-width [FWHM]
1.27	8.8 %	4.74°
2.75	6.5 %	3.10°
4.43	6.3 %	2.71°



Only photo peaks accepted.

Fig. 4. Left side: ARM-distribution of 4.43 MeV gamma rays. Top: all events above threshold accepted. Bottom: only photopeak events (FWHM) accepted. Right side: ARM distributions at 12.14 MeV and 20.52 MeV. Only events within 3 σ energy peaks are accepted.

Angular Resolution

An appropriate measure of the angular resolution of COMPTEL is provided by the ARM-distribution (Angular Resolution Measure), which is displayed in Figure 4 for 4.43 MeV, 12.14 MeV, and 20.52 MeV gamma rays. Here on the abszissa the difference $\bar{\varphi}$ - φ_{geo} is plotted, where $\bar{\varphi}$ is derived from the measured energy losses via equation (1), and where φ_{geo} is the geometric scatter angle, which is derived from the knowledge of the gamma-ray source position and from the location of the interactions in D1 and D2.

If all events above threshold are accepted, then the incompletely absorbed events in D2 cause an asymmetric distribution with an excess at positive $\bar{\varphi}$ - φ_{geo} - values (see top of 4.43 MeV distribution). If, instead, only photopeak events are accepted, then incompletely absorbed events are rejected and the resulting ARM distribution is symmetric (bottom of 4.43 MeV distribution). Table 1 lists the widths of the ARM distributions of photopeak events for three gamma-ray energies. Figure 5 illustrates how much the spatial and the energy uncertainty contribute to the total angular resolution.

Absolute Detection Area

The absolute effective detection area for vertical incidence is shown in Figure 6a for various event selections, for the top curve no $\bar{\varphi}$-restriction was applied to the data, in the bottom curve only events within the 3 σ ARM window around the source position are accepted. The two curves in between were derived for a special $\bar{\varphi}$-restriction: $\varphi < 30°$ below E1 + E2 = 2.6 MeV, $\bar{\varphi} < 15°$ above E1 + E2 = 10 MeV, and E1 < 0.4 (E1 + E2) in between. The dashed curve was predicted in 1982, the solid curve represents the calibration results.

Field-of-View

The field-of-view of COMPTEL around its axis can be influenced by introducing restrictions on

Angular Resolution for Photopeak Selected Data:

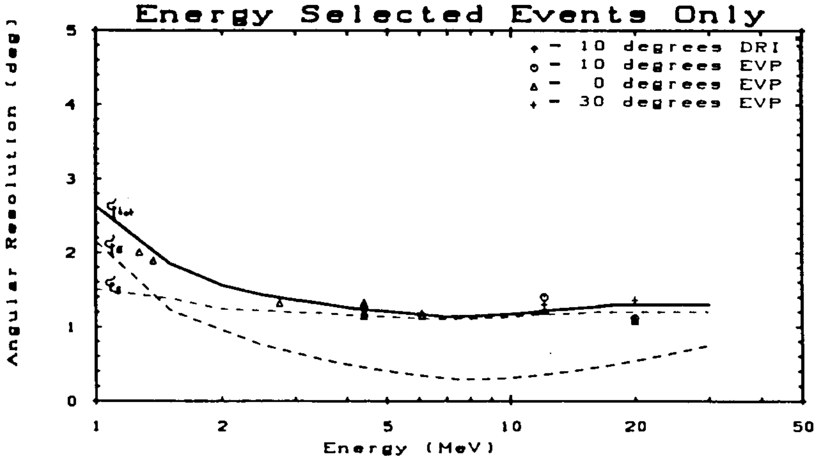
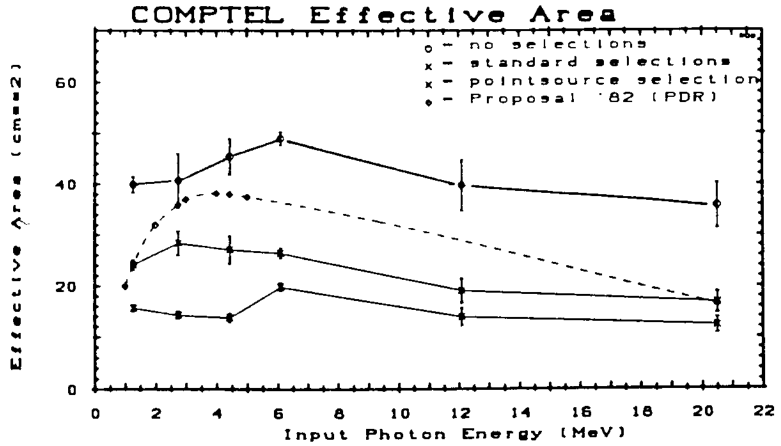


Fig. 5. 1 σ - angular resolution of COMPTEL (ARM - width divided by 2.36) as a function of gamma-ray energy. The contributions to the total resolution from the spatial and energy uncertainty are shown separately.

COMPTEL EFFECTIVE DETECTION AREA FOR VERTICAL INCIDENCE, FOR VARIOUS EVENT SELCTIONS (Veto subsystem in operation)



Notice: The "proposal"-curve was for "standard selections". The values shown at 20 MeV are from Monte Carlo simulation. The effective area at 20 MeV from the COMPTEL calibration is consistent with these values considering the large uncertainties of the actual beam strength.

Fig. 6a. COMPTEL effective area for vertical incidence.

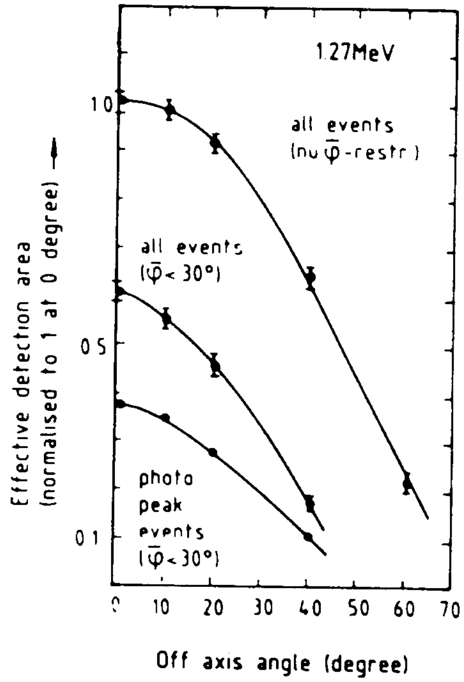


Fig. 6b. Relative dependence of effective detection area as a function of off-axis angle at 1.27 MeV (Na^{22}). The lines are for eye guidance, only.

$\bar{\varphi}$; also the energy thresholds in D1 and D2 affect the field-of-view. Figure 6b displays the dependence of the relative effective detection area of COMPTEL with off-axis angle at 1.27 MeV (Na^{22}). The widest field-of-view is obtained, if no $\bar{\varphi}$-restriction is applied to the data. A narrower field-of-view can be achieved by applying event selection criteria (e.g. $\bar{\varphi} < 30°$) at the cost of a lower detection area for vertical incidence. A limitation of the field-of-view is necessary in order to reduce the contribution of atmospheric gamma rays from the Earth horizon.

COMPTEL Sensitivity

With the values of Figure 6a of the absolute detection area (reduced by the appropriate event selection factors) and the background rates measured with the MPI balloon borne Compton-telescope (scaled to the COMPTEL size and the GRO orbit) the COMPTEL sensitivities shown in the later Figures 9, 10, and 11 were derived.

Image Deconvolution

In Compton telescopes no one-to-one relation exists between individual sky and data bins. This is due to the fact that for a gamma ray of fixed energy and angle of incidence a wide range of Compton scattering angles in D1 is possible. In such a situation the maximum entropy method is a powerful choice for imaging. This method requires the knowledge of the telescope response to any given sky image.

The telescope response can be described in the simplest way in a three-dimensional data space defined by the scatter direction (χ, ψ) and the Compton scatter angle $\bar{\varphi}$. In the idealized case, in which the scattered gamma ray is totally absorbed in the lower detector, the pattern of all data points originating from a gamma ray source with the coordinates (χ_0, ψ_0) lies on a cone in (χ, ψ, $\bar{\varphi}$) - space, where the cone apex is at (χ_0, ψ_0) and the cone semi-angle is 45° (see Fig. 7).

The response density along the cone is given by the variation of the Klein-Nishina cross-section for Compton scattering. This idealized "cone mantle" response is blurred by measurement inadequacies in the scintillation detectors, especially by incomplete absorption in D2.

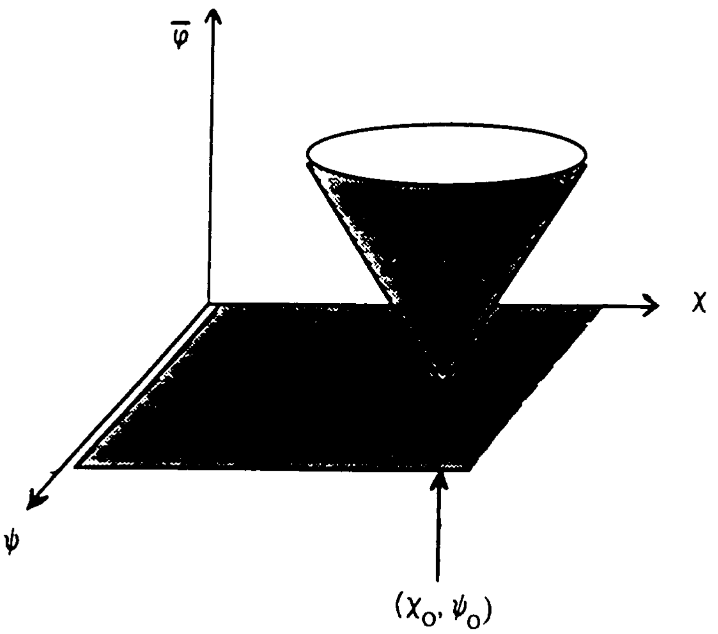


Fig. 7. Illustration of the COMPTEL response of a celestial point source in the 3-dimensional data space (χ, ψ, $\bar{\varphi}$). The data lie on a cone, the apex of which is at the position of the celestial source (χ_0, ψ_0). The cone semi-angle is 45°. Actually, the cone mantle is blurred due to measurement inaccuracies.

Therefore, the event density in data space can be represented by (see /3/):

$$n(\chi, \psi, \varphi) = g(\chi, \psi) \cdot \int\int I(\chi_0, \psi_0)\, A(\chi_0, \psi_0)\, f(\chi - \chi_0, \psi - \psi_0, \bar{\varphi})\, d\chi_0\, d\psi_0 \qquad (3)$$

where I (χ_0, ψ_0) is the infalling sky intensity distribution, A (χ_0, ψ_0) is the exposure factor (product of effective detection area times observation time), f $(\chi - \chi_0, \psi - \psi_0, \bar{\varphi})$ is the "cone" - function and g (χ, ψ) is a geometrical function accounting for the incomplete coverage of the upper and lower planes by the detectors.

The maximum entropy image approach is to convolve a (2-dimensional) sky image with the full response of the telescope in the 3-dimensional dataspace $(\chi, \psi, \bar{\varphi})$ and to try to match the "mock data" from the trial image to the measured data in the 3-dimensional dataspace. The trial image yielding a statistically acceptable match to the measured data, and at the same time fulfilling the entropy criterion, is defined to be the maximum entropy image.

An exloratory application to this method has been made to the COMPTEL calibration data. Two calibration runs with 6.1 MeV gamma-ray beams, separated by 10°, were superimposed to simulate a dataset of two sources in the field. The maximum entropy method was then applied. Figure 8 shows the resulting map. The thwo sources are successfully resolved.

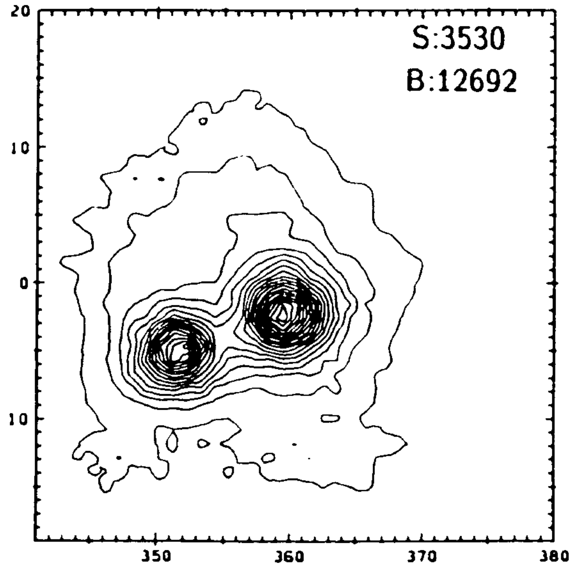


Fig. 8. Image from COMPTEL calibration data at 6.1 MeV from 2 sources, separated by 10°.

ASTROPHYSICS WITH COMPTEL

Due to the more than 10-times higher sensitivity of COMPTEL in comparison to previously flown instruments, a significant progress in the exploration and understanding of the MeV gamma-ray sky can be expected.

The main targets of interest are listed below. These are:

- discrete objects in the Galaxy that show steady gamma-ray emission;
- the diffuse gamma-ray continuum emission from interstellar space;
- gamma-ray line emission from discrete or extended sources;

- external galaxies, especially Seyferts and Quasars;
- the diffuse cosmic gamma-ray background;
- cosmic gamma-ray bursts (their localization and the study of their energy spectra and time histories);
- the Sun (solar flare gamma-ray and neutron emission).

Each of these topics is briefly addressed below:

Galactic Gamma-Ray Sources

The key question in this field is: "What kind of objects do we see as gamma-ray sources in the Milky Way?"

At present radio pulsars and X-ray binaries are the most promising candidates. Both kinds of objects contain stars in the end stage of their evolution (neutron stars, and in case of binaries perhaps black holes). We know that the Crab and Vela pulsars, both, radiate 5 orders of mangitude more power at gamma-ray energies than in the radioband. If this is true in general for pulsars, then the key for an understanding of the pulsar radiation mechanism may be found at gamma-ray energies. COMPTEL should be able to see more than these two pulsars at gamma-ray energies. The estimates range from a few to about a dozen depending on the pulsar model, which one uses.

X-ray binaries are known to be very common X-ray sources which are powered by accretion. A few of them have also been observed at very hard X-ray energies around 100 keV. Among these are Cyg X-1 - the best black hole candidate, Cyg X-3 - the source which has attracted so much attention by its possible TeV and PeV gamma-ray emission, and other sources like GX 5-1, GX 1+4, GX 339+4. Except for Cyg X-1 and possibly Cyg X-3 none of these sources so far could be detected at gamma-ray energies. From COMPTEL we shall learn how far the emission of these sources extends into the MeV-range, and whether there is a non-thermal component in addition to the thermal one.

Another object of high interest is the Galactic Center - one of the other most prominent black hole candidates. First positive gamma-ray observations from the galactic center have already been made during the last two decades. Further observations will be needed to derive firm conclusions about the nature and the physical processes of this source..

Then, of course, the puzzle of the unidentified COS-B sources has to be solved. Though about half of the originally 22 objects contained in the COS-B source catalogue are now known to be simply regions of enhanced interstellar matter, about half a dozen of these sources remain unidentified till now. Nobody at present knows the nature of these sources! Do they represent a new class of celestial objects which mainly radiate at gamma-ray energies? We expect that GRO will be able to answer this question.

Finally, also extended objects, like Supernova remnants and molecular clouds will be studied by COMPTEL. From previous COS-B gamma-ray observations we know already that both these objects are very promising targets.

The prospects of COMPTEL for studying galactic gamma-ray sources can be judged from the sensitivity diagram in Figure 9. Here the 3σ sensitivities of the 3 instruments OSSE, COMPTEL, and EGRET over their energy ranges are compared with the fluxes of known gamma-ray sources, e.g. the Crab, Cyg X-1 in its low and high intensity state, and the COS-B source Geminga. Between 1 and 30 MeV COMPTEL will be able to detect sources that are roughly 20-times weaker than the Crab. Intensity variations of the high intensity state of the Galactic Center and Cyg X-1 can be recorded with high precision on a very short time scale.

Diffuse Galactic Gamma-Ray Emission

The diffuse galactic gamma-ray emission so far has been studied at high gamma-ray energies (around 100 MeV), only. From the interpretation of the SAS-2 and COS-B sky maps we know that the cosmic ray density is not constant throughout the Galaxy, but higher in the inner part and lower in the outer parts. COMPTEL will extend the survey to lower energies down to 1 MeV and therefore allow to study the electron-induced gamma-ray component. The high sensitivity of COMPTEL combined with the good angular resolution will (hopefully) allow to separate the so far unresolved source component from the really diffuse interstellar component. Measurements at different galactic latitudes will help to separate the two electron-induced components: the bremsstrahlung and the inverse Compton component. We can expect that the COMPTEL measurements will lead to a better understanding of the distribution of low energy cosmic ray electrons throughout interstellar space.

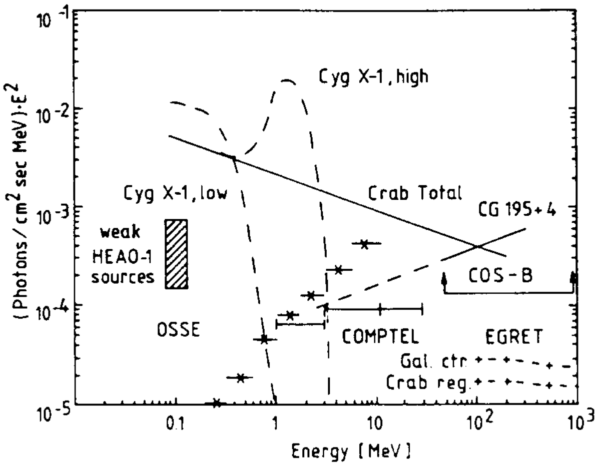


Fig. 9. 3 σ - sensitivity of COMPTEL for the detection of galactic gamma-ray point sources within a 2-weeks observation period.

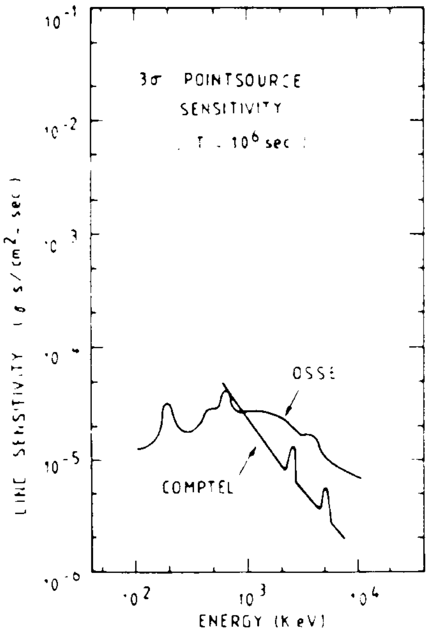


Fig. 10. 3 σ point source sensitivity of COMPTEL to gamma-ray lines.

Gamma-Ray Line Spectroscopy

The field of gamma-ray line spectroscopy is closely related to the question: "How were the chemical elements in the Universe synthesized?"

Gamma-ray astronomy provides a powerful tool to answer this question. During the formation of chemical elements not only stable but also radioactive ones were produced. Some of them are gamma-ray emitters and these can be detected by means of gamma-ray telescopes. The first two cosmic gamma-ray lines that were detected are the 511 keV annihilation line and the 1.8 MeV line from radioactive ^{26}Al. The origin of both these lines is not yet really understood. Whereas the ^{26}Al was probably synthesized in galactic objects that are concentrated close to the Galactic Center (like novae or special massive stars), the 511 keV line seems to consist of two components - one which is more widely spread (probably produced in supernovae), and another one which seems to come from a point source near the Galactic Center.

COMPTEL will be able to map the entire galactic plane in the light of the 1.8 MeV gamma-ray line. These measurements can then be used as tracers of those objects in the Galaxy which produced these lines - very much like the 21 cm line at radio-wave lengths is used as a tracer of interstellar neutral hydrogen. Probably other gamma-ray lines from nucleosynthesis processes will be observed by COMPTEL in addition, e.g. from the Ti^{44}-decay or from nucleosynthesis products in supernovae in the Virgo cluster. Unfortunately, the Co^{56}-lines from the SN 1987a in LMC will be too weak at the time of the GRO launch to be still seen by COMPTEL. The COMPTEL point source sensitivity for gamma-ray lines is shown in Figure 10.

External Galaxies

In the extragalactic sky there is a certain chance that continuum emission from LMC will be seen by COMPTEL in a deep exposure.

The most interesting objects in the extragalactic gamma-ray sky are, however, the nuclei of active galaxies. At least some of the known active galaxies and quasars do have their maxima of luminosity at gamma-ray energies. The situation is illustrated in Figure 11, where the sensitivities of OSSE, COMPTEL, and EGRET for detecting AGN's are compared with the observed spectra of the radio galaxy Cen A, the quasar 3C273 - which both peak at gamma-ray energies - and the X-ray spectra of 12 AGN's - mostly Seyferts - that were observed by HEAO-A1. From the diagram we can estimate that COMPTEL will be able to study - say a dozen or even more AGN's - if all AGN's have spectra similar to Cen A and 3C273. We may get the first measurement of the luminosity function of AGN's at gamma-ray energies. This function - together with the measured properties of individual galaxies - may lead to a better understanding of the engine that powers the objects. The question of the nature of the central source in AGN's is one of the most fascinating one in modern astronomy. Many theoreticians believe that the energy source is a mass accreting black hole. The COMPTEL observations may be crucial for an understanding of the central source.

The Diffuse Cosmic Gamma-Ray Background

A cosmic background radiation exists at practically all wavelengths. Best studied is the microwave background at 2.7 K. The origin of the cosmic ray background is not yet really understood.

COMPTEL will not only provide an accurate measurement of the background spectrum at MeV-energies, it will also search for angular fluctuations of the intensity. The COMPTEL data should allow to address the question of the origin of the cosmic gamma-ray background and to decide between the two classes of models which presently are under discussion: an unresolved source origin (e.g. from unresolved AGN's) or a really diffuse origin (e.g. from matter-antimatter annihilation in a baryon symmetric universe).

Gamma-Ray Bursts

Though the gamma-ray bursters are the strongest gamma-ray sources in the sky during their short outburst, their nature is not yet known. Most people believe that - at least for a large number of bursts - a neutron star is somehow involved. This thinking is mainly based on lines found in some of the burst spectra - though the physical trigger for the outburst is not yet known. Under discussion are at present starquakes, the impact of an asteroid or comet onto the neutron star, magnetic instabilities or accretion of matter onto the neutron star. COMPTEL can locate bursts that happen to be within the COMPTEL field-of-view ($\approx$ 1 ster) with an accuracy which is better than 1°. We expect to see about 1 burst per

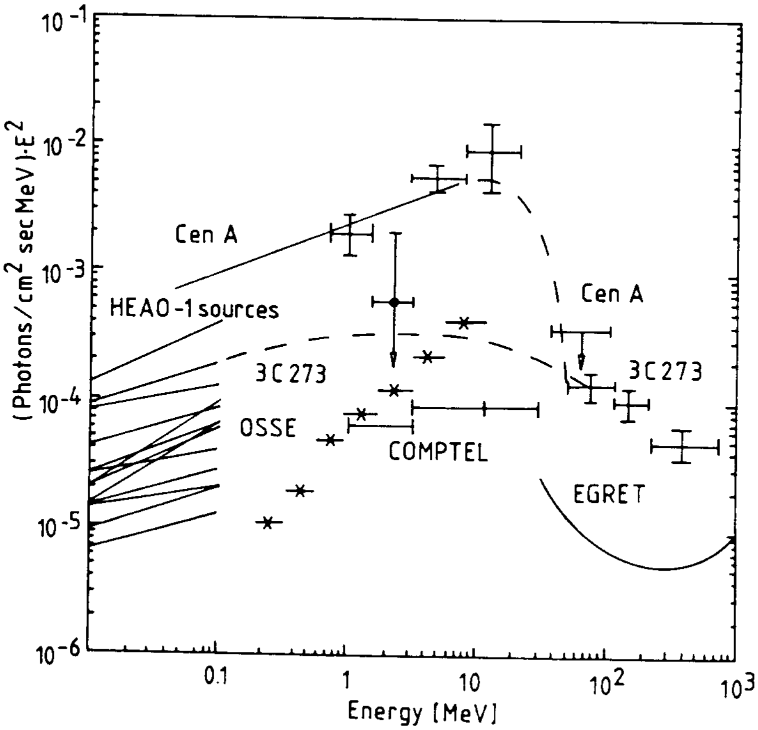


Fig. 11. 3 σ - sensitivity of COMPTEL to detect active galactic nuclei within a 2-weeks observation time.

month within the field-of-view with a fluence S (E > 1 MeV) ≥ 2 · 10^{-6} erg/cm^2. In addition, the single detector mode of COMPTEL with its 2.5 ster unobstructed field-of-view allows to measure the energy spectra and time histograms of bursts seen by BATSE in the energy range 0.1 to 12 MeV. This mode is especially important for the search for gamma-ray lines in burst spectra /4/.

The Sun

The Sun is not a prime target of GRO. COMPTEL - like the other 3 GRO instruments does have, however, certain capabilities to measure gamma rays and also neutrons from the Sun /5/. First, COMPTEL can study solar flare gamma-ray emission in the telescope mode, if the Sun happens to be within 30° off-axis. Second, in case of a solar event COMPTEL obtains a solar burst indication trigger from BATSE. As a consequence COMPTEL switches into a solar-neutron mode, which allows measurements of solar neutrons in addition to gamma rays. Third, the single detector mode of COMPTEL allows to measure energy spectra and time histories of solar flare gamma-ray emission. This mode again is especially important for the search of gamma-ray lines in solar flare spectra.

The sensitivities of COMPTEL for observing gamma-ray emission from solar flares are comparable to the sensitivity of the SMM-spectrometer. During the GRO mission we therefore can expect to study a large number of additional flares. The gamma-ray and neutron measurements in conjunction with those of other instruments (interplanetary particle detectors, ground based neutron monitors) provide the best possible observation of production, acceleration, and propagation aspects during solar flares.

CONCLUSION

Significant progress in the exploration and understanding of the MeV gamma-ray sky is to be expected from COMPTEL. The results of COMPTEL and the other GRO instruments, especially if combined with observations in other spectral ranges from both space and ground based observatories, will certainly make the field of gamma-ray astronomy attractive to the whole community of Astronomers and Astrophysicists as can already now been judged from the wide response to the NASA Research Announcement for the GRO Guest Investigator Program.

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