1.0 INTRODUCTION

Since the launch of the Compton Gamma-Ray Observatory (CGRO) in 1991, transient phenomena have been observed across the entire CGRO energy regime. It is now quite clear that the high energy universe is a very dynamic one, with variability at all observable time scales. Most notable among these transients are the γ–ray bursts. Although most of the GRB data has come from BATSE, significant contrbutions have also been made by OSSE, COMPTEL and EGRET. Transient sources with longer time scales have also been observed. Most notable among these are the so-called X-ray transients, which can vary by orders of magnitude on time scales of a few days (Tanaka and Shibazaki 1996). Hour-long transients have also been observed on occasion (e.g., Jacobson et al. 1978). One such particularly intriguing observation was that of a strong MeV flare from GRO J1655-40, which lasted no more than one hour (Boggs et al. 1996). Several blazar-type AGN have also been observed to vary on time scales of a few days. Data from both BATSE and EGRET have clearly demonstrated considerable variability at their respective energies. *Here, we wish to concentrate on studies of variability in the intermediate range of energies observed by COMPTEL (0.75-30 MeV)*. To date, there have been only limited efforts to perform an independent search for transient phenomena in the COMPTEL database (van Dijk 1997a; 1997b). Observations of transient phenomena have generally relied on detection by other instruments (notably BATSE and EGRET). *We propose to carry out independent searches of the COMPTEL database for heretofore undetected transient events on various time scales ranging from < 1 second to ~few days.* This search will include transients previously undetected by other CGRO instruments. *We also propose to establish a real-time detection system for MeV γ–ray bursts using the COMPTEL ground station at UNH* which would provide rapid dissemination of information regarding any transient via the internet. Such a detection system may well be sensitive to a class of events not detectable by BATSE (Piran and Narayan 1996).

2.0 MeV GAMMA-RAY BURSTS

A long-standing goal in γ–ray burst research has been to classify events based on observable parameters in hopes that this will provide clues to the nature of the phenomena. A recent classification has been suggested based on BATSE spectral measurements that shows two general types of bursts: those lacking fluence above 300 keV and those with significant high-energy fluence throughout their duration (Pendleton et al. 1996 and references therein). The two classes are further distinguished in that the soft-spectrum events have lower intensity, on average, and follow an intensity distribution consistent with homogeneity. While this does not necessarily mean that soft and hard events come from different source populations, it does suggest different γ–ray emission properties. A potential weakness of this spectral classification is that the BATSE bursts are selected based on emission detected primarily below ~500 keV. BATSE is insensitive to bursts that have peak power (E_{peak}) at MeV energies. An independent sample of high-energy selected events is thus crucial for a meaningful investigation of the hard-spectrum class of bursts. It has even been suggested that an entire class of undetected GRBs may exist that have peak-power at energies above 1 MeV (Piran & Narayan, 1996). If "MeV bursts" do exist, they would cause a drastic re-interpretation of the distribution of E_{peak} – the most obvious measureble feature of burst spectra (Mallozzi et al. 1995). We propose an independent search for γ–ray bursts using the COMPTEL telescope-mode data. COMPTEL has the superior high-energy sensitivity and large field-of-view needed to fully investigate the distribution of MeV γ–ray bursts and their relation to events observed by BATSE.

COMPTEL regularly observes γ–ray bursts. However, the search for bursts in COMPTEL data has previously been based *only* on coincidences with known BATSE detections. An *independent* search for γ–ray bursts in the COMPTEL data has never been performed. In four years of observations, COMPTEL detected 29 of the 302 BATSE bursts that occured in the telescope FoV (Kippen et al. 1997). There are two reasons why we can expect to detect more events in an independent search of the data:

Insensitivity to short events. The 29 COMPTEL bursts reported by Kippen et al. (1997) were selected with an imaging-based detection threshold. This imaging analysis is only sensitive when enough telescope events are detected from a burst such that the signature of a point-source can be identified. The photon-limited detection sensitivity of COMPTEL burst imaging analysis results in a severe bias against the detection of short duration bursts. Short bursts frequently do not result in enough events for meaningful imaging, even though the number of events IS statistically significant compared to the low COMPTEL background rate (~3 events per second). We thus expect to detect several short bursts in the proposed independent search of the data. The excellent time resolution of time-tagged COMPTEL telescope event data (125 μsec accuracy) will allow us to investigate extremely short

duration bursts, where only a few telescope events are required for a statistically significant detection. The BATSE finding that short-duration bursts tend to have harder spectra (Kouveliotou et al. 1996) gives us additional confidence that many short bursts will be detected in the search of COMPTEL data.

Disabled BATSE trigger**.** Following all BATSE triggers, data are accumulated for a period of 4–8 minutes and read-out during the following 90 minutes. The BATSE triggering system is completely disabled during the accumulation periods and insensitive to new, weaker events during the readout intervals (Meegan et al. 1996). The BATSE trigger is also disabled during parts of the spacecraft orbit (not including SAA). There is thus a significant amout of dead-time during which bursts could occur that would not be detected by BATSE or by COMPTEL (since COMPTEL searches have so far been based on BATSE triggers). In the four-year COMPTEL burst catalog interval, we estimate that the BATSE trigger was disabled for ~15 days during data accumulation, ~50 days for orbital exclusion and partially disabled for ~225 days during data read-out. Assuming that 50% of the readout deadtime could have resulted in bursts bright enough to be detected by COMPTEL, we expect to find AT LEAST three additional bursts in this interval in the independent COMPTEL search. In the two years following the COMPTEL catalog interval, the BATSE trigger was disabled even more often due to recurrent outbursts from the bursting pulsar (GRO J1744-28).

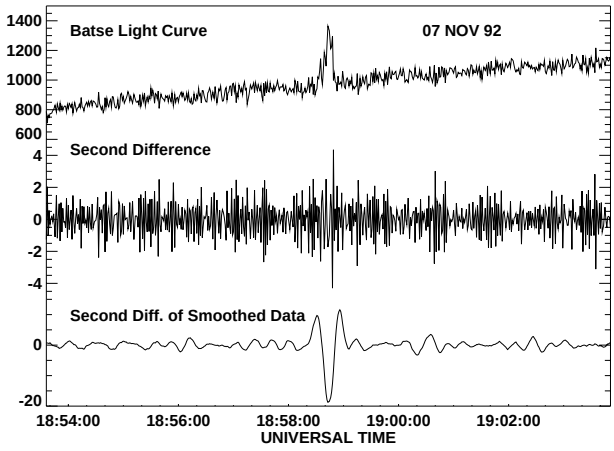

Figure 1: An example of the second difference search method applied to BATSE data (Biesecker 1994).

The algorithm that we would employ for the search is one that has been successfully employed at UNH in studies of solar microflares with BATSE (e.g., Biesecker 1994; Arndt et al., 1997). This algorithm is based on the second time derivative of the measured count rate (Mariscotti, 1967). This method is employed because it is relatively insensitive to slowly varying background. The sensitivity of the search method can be improved by the application of smoothing techniques. Figure 1 shows an example of this algorithm as applied to BATSE data. The up-down nature of the signal in the second difference of the smoothed data represents a typical burst signature. The proposed search would be performed on sub-second time-scales in each of the standard COMPTEL energy bands (0.75–1.0, 1.0–3.0, 3.0–10.0, and 10.0–30.0 MeV), as well as the full COMPTEL energy range (0.75– 30.0 MeV). Event selections would be used to limit the FoV over which the search would be sensitive, thus providing some nominal level of source location information (±30°). For sufficiently intense events, COMPTEL images would also be generated to more precisely define the location.

As part of our study of MeV γ-ray bursts, we propose to implement a real-time search using COMPTEL data as it is received at the UNH ground station. A major upgrade of the present ground station is expected to be completed by October of 1997. Once this upgrade is completed, all COMPTEL data will be transmitted to UNH in real-time. Our search would tap into this data stream and, using the algorithm defined for the archival search, recognize transient events within seconds. The trigger data would be distributed to the community via the BACODINE system. In addition, the data would be directed to the COMPTEL rapid response software for immediate processing and image analysis. The results from the COMPTEL image processing would then also be distributed via BACODINE.

3.0 SEARCHES ON LONGER TIME SCALES

3.1 Options for Transient Searches with COMPTEL

The γ–ray burst search discussed above is meant to look for events on time scales from under 1 second to several 10's of seconds (perhaps up to a few minutes) using COMPTEL telescope mode data (0.75–30.0 MeV). Generally speaking, transient searches with COMPTEL telescope mode data can be performed in one of two ways. One way is to make use of the unique imaging capabilities of COMPTEL to generate images on various time scales and then to search each image for evidence of transient emission. We will refer to this aproach as being *image-based*. The limitation of an image-based transient search is that the generation of a single image using standard COMPTEL tools and covering the entire COMPTEL FoV can take up to two hours of processing time. An alternative approach is to generate a time history of telescope event rates (with some specified time resolution) that can then be searched

for transient events. (This is precisely the approach to be taken with the burst search described above.) We will refer to this aproach as being *rate-based*.

For telescope-mode data, event selections can be chosen to aid in optimizing the search. One possible approach might be to select events obtained only when the COMPTEL pointing direction is near the local zenith. This would not only reduce the atmospheric background, but it would also provide some effective level of collimation. Further restrictions could be imposed based on the individual event parameters. In particular, selections on the event scatter angle and the angular distance of the scattered photon direction from the Earth's horizon, could be used to further insure that the so-called "event circle" is well removed from the Earth's horizon. Such selection criteria are similar to those used in COMPTEL studies of the cosmic diffuse γ-radiation (Kappadath et al. 1996). This type of selection process could be designed to provide sensitivity to transient events over a relatively large FoV. If a particular source is being studied, one may further select events based on the so-called ARM parameter (Schönfelder et al. 1994) to pick out events which are consistent with an origin in the direction of the source of interest. The time-tagged nature of the telescope mode data also permits further optimizations based on the time scale of the search.

In addition to the telescope mode data, COMPTEL also collects data at energies above 300 keV in a parallel burst mode (Schönfelder et al. 1994). These data are collected as integrated count spectra using two of the large D2 NaI detectors on COMPTEL. These two detectors operate in the energy ranges of 0.3–1.3 MeV and 0.6–10.0 MeV. In normal background mode, these spectra are accumulated in 100 second intervals. Upon the receipt of a BATSE trigger signal, the burst detectors cycle through a sequence of integration times ranging from 0.5–6 seconds. These data, integrated over energy, are well-suited to a rate-based search for transients (Figure 2).

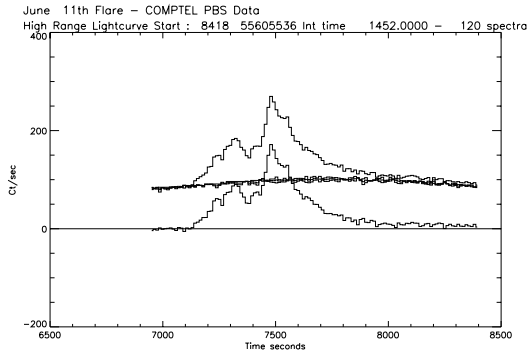

Figure 2: An example of ±15 orbit background subtraction using COMPTEL burst mode data for the solar flare of 11-June-1991. The upper traces show both the flare data and two sets of data taken ±15 orbits later. Once the average background is subtracted, the lower curve is obtained, showing evidence for significant post-impulsive flare emission.

3.2 Searches on Timescales Less than One Day

For searches on time scales up to ~1 day, a rate-based search for transient events is more practical. On these timescales, the search could be carried out using the second difference algorithm discussed in §2. For more slowly varying transients, however, a search method involving a background subtraction process should be considered. In this case, great care must be taken to perform a proper background subtraction. One effective scheme is based on experience with both SMM and COMPTEL analysis of solar flares. It is found that the background environment roughly repeats itself every 15-16 orbits as a result of the spacecraft passing through similar geomagnetic conditions. Very good background estimates for solar flares (transients lasting up to 10's of minutes) can be obtained by averaging the background collected ±15 orbits (~22.5 hours) from the time of interest. COMPTEL analysis of solar flares is routinely performed using just such an approach (Figure 2). Extending this to a systematic search through a set of data would be a straightforward process. Note that this empirical background subtraction works well only during times when COMPTEL is in a stable operating mode and in a fixed aspect. This implies that the background subtraction must be performed using data contained in the same viewing period. The process may also be compromised by data gaps due to limited telemetry coverage. These are issues which would have to considered in the development of an automated search algorithm. It is also worth noting in this context that there has been an effort within the COMPTEL team (Varendorff et al. 1996) to develop a means of estimating the scalar background of COMPTEL using a neural net analysis trained on various orbital parameters. This approach to background estimation has been moderately successful so far and may prove useful in rate-based search schemes. Image-based searches on these time scales have been carried out in limited situations. Prompted by an observation of a ~1 hour transient event observed from GRO J1655-40 (Boggs et al. 1996), Van Dijk et al. (1997a, 1997b) reported on efforts to search for gamma-ray flares from a selected set of black hole candidates on time scales down to ~1.5 hours (1 orbit). The sensitivity of this approach was a few times the Crab flux. For a more complete search of the COMPTEL database on the these time scales, such an approach may become prohibitively time-consuming.

3.2 Searches on Timescales Greater than One Day

For time scales longer than ~1 day, an image-based search may be more attractive, since the number of required images is down by an order of magnitude over what would have been required for a 1.5-hour timescale search, for example. One day exposures can easily reach a sensitivity level of 1 Crab, so a sequence of images generated with a one or two-day cadence would easily be sensitive to any transient approaching a flux level equivalent to that of the Crab. Typically, a COMPTEL image requires ~2 hours of CPU time for processing, including the generation of the so-called DRI data which is used in the image reconstruction. If we were to generate a series of images in each of the four standard COMPTEL energy bands (0.75–1.0, 1.0-3.0, 3.0-10.0 and 10.0-30.0 MeV), a single 14-day observation would require ~5 days of processing. This approaches a level where a complete systematic image-based search of the data becomes practical. In the case where a transient is detected, a cross-check would be performed using a rate-based analysis.

4.0 PROPOSED ACTIVITIES FOR CYCLE 7

The primary effort we are proposing for cycle 7 is a search of the COMPTEL database for MeV γ–ray bursts, i.e., bursts for which BATSE has relatively poor triggering sensitivity. This search would be carried out on time scales ranging from under one second to ~1 minute. In addition to a search of the archived data, *we also propose establishing a real-time search for such events using the COMPTEL ground station at UNH*. A major upgrade of this system (from an HP 1000 to a Silicon Graphics workstation), scheduled to be established by October of 1997, will provide substantial improvements in the ground station capability. The BACODINE system would provide rapid dissemination of burst information derived from such a detection system.

Recognizing the possibility of detecting other classes of transient events at longer timescales, we propose to search the COMPTEL database for transient events on longer timescales (from hours to days). *We would search both the telescope mode event data anad the burst mode data from COMPTEL using rate-based search algorithms for transients with timescales of less than about one day.* Both a second-difference technique and a background subtraction technique (based on ±15 orbit background levels) would be used. The search would be carried out in several broad energy bands. *We would also search the COMPTEL database for transient events on a 2-day basis using an image-based search method.* An image-based search would necessarily be performed with telescope mode data (0.75–30.0 MeV).

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SUMMARY OF PREVIOUS CGRO WORK (M. McConnell)

The PI has been an active co-investigator on the CGRO-COMPTEL instrument team since 1987. He has participated in the pre-flight calibration activities, the analysis of the pre-flight calibration data, and the development of software (with the COMPTEL-COMPASS analysis system) for COMPTEL data analysis. His scientific activities with COMPTEL data have been focused largely on X-ray binary systems (especially Cygnus X-1) and solar studies. On-going CGRO-related activities in which he plays a significant role include:

- Continued analysis of Cyg X-1 data from COMPTEL and comparison with other CGRO instruments. The latest results were recently presented at the 4th Compton Symposium and are being prepared for publication in the conference proceedings. A journal publication regarding the full set of Cygnus data from phases 1-3 currently in preparation.

- Mapping of the full sky at 2.2 MeV using data from COMPTEL. This includes efforts to improve the modeling of the COMPTEL background. Evidence has recently emerged for a potential point source of emission at this energy. The latest results were recently presented at the 4th Compton Symposium and are being prepared for publication in the conference proceedings. A proceedings paper has also been submitted for the upcoming ICRC. A journal publication is currently in preparation.

- Analysis of COMPTEL solar data, integrating over all available observations to search for emission from the quiet-time sun. This work has established upper limits for several different energy bands, some of which place constraints on certain models for coronal heating. The latest results were presented at a recent meeting of the AGU and will also be presented at the upcoming meeting of the AAS Solar Physics Division. A proceedings paper has also been submitted for the upcoming ICRC. This work is related to a GI program proposed for Cycle 6.

- Analysis of COMPTEL data pertaining to X-ray transients. Quick-look analysis of COMPTEL ToO data is performed at UNH for any declared targets-of-opportunity. This represents part of a CGRO-wide effort related to past GI proposals (PI - R. Kroeger).

- A study involving an effort to search for evidence of polarization in solar flares and in gamma-ray bursts using data from BATSE. Simulations of the albedo flux from such events have been used to estimate the BATSE sensitivity to polarization. Two related proceedings papers (one for the High Energy Solar Workshop and one for the most recent Huntsville Gamma Ray Burst Workshop) have been published within the past year. This is related to GI programs funded in Phase 3 and Cycle 5.

Approved CGRO Guest Investigations (PI - M. McConnell)

Phase 3	"COMPTEL Observations of X-Ray Binaries"
Phase 3	"Investigation of BATSE Sensitivity to Polarized Radiation"
Cycle 4	"COMPTEL Observations of X-Ray Binaries"
Cycle 5	"COMPTEL Observations of Cygnus X-1"
Cycle 5	"Search for Nuclear Line Emission from Accreting Binaries"
Cycle 5	"BATSE Albedo Polarimetry of Gamma-Ray Bursts and Solar Flares"
Cycle 6	"Quiescent Solar Gamma-Ray and Neutron Emission"

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