1. Introduction

One of the most exciting events in γ-ray astronomy during the past year was GRB 990123. One of the brightest events observed by BATSE since its launch in 1991 (Briggs et al. 1999), it was the first event in which coincident optical emission was clearly observed (Akerlof et al. 1999). The optical emission reached an astonishing 9th magnitude. A comparison of the high energy light curves with those obtained in the optical provides important constraints on models for the burst. The results from GRB 990123 were made possible by the GRB Coordinates Network (GCN), a network of observers whose common goal is to obtain multi-wavelength observations of γ-ray bursts as rapidly as possible after the onset of an event. An important component of the GCN is the COMPTEL Rapid Burst Response (RBR) system. The initial BACODINE results provide large error boxes with a total (statistical plus systematic) error of 10°-15° within 10 seconds of the burst trigger. The COMPTEL-RBR system, responding to > 1 MeV emissions, can provide substantially improved event locations (systematic errors of ~0.5° and average statistical errors of ~1.6°) within minutes of a GRB, allowing for more rapid response by small FoV instruments.

As numerous authors have pointed out (Kazanas, Titarchuk & Hua 1998; Katz, Piran & Sari 1998; Mészáros & Rees 1997; Pilla & Loeb, 1998; and references therein), observational constraints on the broad band GRB shape from IR to X-ray to γ-ray may help distinguish which physical mechanisms actually drive such strong bursts of γ-rays. Some observations show that both the X-ray and γ-ray flux detected during this time vary above simple power-law predictions (Connors & Hueter 1998; Piro et al. 1998; Share et al. 1999), making prompt high energy observations particularly interesting. The multi-wavelength analysis made possible by the exciting detection of optical emission coincident with the high energy emissions of GRB 990123 clearly showed multiple spectral components varying independently with differing time scales (Briggs et al. 1999). From the differing timescales, one can begin to infer something about the geometry of the source. Similar observations covering a variety of other events will be required to piece together a coherent picture of the GRB phenomena. COMPTEL-RBR's rapid (~minutes) broadcast of ~1°-2° localizations are key to allowing other instruments to respond during this interesting time.

2. The COMPTEL Rapid Burst Response System

We propose to continue our effort to upgrade and maintain the Rapid γ-ray Burst Response (RBR) program of COMPTEL, CGRO's 1-30 MeV imaging telescope (Schönfelder et al. 1993). This semi-automated system broadcasts ~1°-2° localizations of MeV-bright GRBs in the COMPTEL FoV to a world-wide network of ground and space-based observatories. It does so within ~8-12 min of burst onset under good conditions (cf. GRB 990123, Figure 2) or within ~45 min for a burst requiring manual intervention (cf. GRB~980329, Figure 1). MeV light-curves and positions are also posted on the internet. We have partially completed the process of upgrading the RBR system. These improvements will ultimately provide a more robust system with a response time in the range ~2-4 minutes. Eventually, the system will automatically combining COMPTEL location contours with those of the BATSE-LOCBURST, RXTE/ASM, and (in longer timescale) the IPN timing arcs. These last two sources give narrow (~arc-minutes) but long (~degrees) position error boxes for which the COMPTEL data can provide valuable constraints. In general, for most astrophysical studies, the nominal FoV of COMPTEL is considered to extend to ~30° from the pointing direction, where the photon detection efficiency is down to ~50% of its maximum (on-axis) value. This provides a FoV of ~1 sr. Since many GRBs are associated with very high fluxes, COMPTEL is actually capable of imaging GRBs that are as far as ~60° from the pointing direction (c.f., GRB 990123). Thus, the effective FoV for bright GRBs is much larger, more like ~π sr.

3. The Role of the COMPTEL Rapid Burst Response System

We have surveyed users of the COMPTEL RBR products. We find that there are three main uses of our rapidly produced data products.

3.1. As a trigger for prompt high energy observations: Observers associated with CGRO-OSSE, ASCA, ALEXIS, Ulysses, and RXTE are currenty signed up on our broadcast list. OSSE uses these data to help insure an on-target observation for repointing during the initial decay phase of the burst (E. Grove, 1996, private communication; Matz et al. 1997). At X-ray energies, BACODINE (~10°) or BATSE/Huntsville-RBR (LocBurst) positions (~2°), by themselves, are too large for good AXAF or ASCA coverage. However, even moderate COMPTEL locations plus ASM or IPN (e.g. GRB 980124, Fig. 1) provide sufficiently accurate positions. Also, for scanning observations such as with RXTE/PCA ToO's, a smaller sized error box to raster effectively reduces response time and increases the on-source time (T. Takeshima 1998 private communication). There would therefore be a higher probability of catching the event while it was still X-ray bright, and possible to see some excess variability above any power-law decay envelope (e.g. Connors and Hueter 1998; Piro et al. 1998). Tighter positions help, as well, when analyzing the RXTE/ASM flux and variability of any long-term glow in the interesting time directly after the burst.

3.2. As a trigger for near real-time, wide field of view, optical, IR or TeV searches: Prior to GRB 990123, we had made simple estimates of optical/IR fluxes associated with the burst itself following Kazanas, Titarchuk & Hua (1998)'s outline of GRB spectral evolution, and extrapolating from X-rays assuming a bright burst (fluence ~10^{5}-10^{-4} ergs cm^{2}), plus a standard spectral shape, including a power-law with (photon) indices below a few keV of ~2-3 (e.g. Connors & Hueter 1998). These gave rough estimates of durations on the order of 3-30 minutes, and intensities around magnitudes 15-18 in the optical and IR, assuming negligible extinction (which in any case should not affect the IR bands). Although the experience with GRB 990123 demonstrates that the coincident optical emission can be much brighter, even this lower limit – during the burst – is in the range now detectable by current rapid optical systems. New and notable among these is the Planetary Systems/Microlensing Network, recently upgraded to include both the 74" Mt. Stromlo and a 1.5~M at Boyden Observatory, South Africa; with field diameters ~1° (S. Rhie). Other recently upgraded fast systems include the LOTIS (Park and Ott); ROTSE (Lee and Akerlof); JPL's NEAT CCD camera; the APT (Grossan et al.); the large European Optical Network (Hudec et al.); and the upgraded BOOTES system (Castro-Tirado). The excitement of chasing γ-ray bursts in near-real time has brought not only this cross-fertilization from powerful telescope systems developed for other purposes, but also small telescopes at undergraduate (and other) colleges where the prime motive is education. For some of these the response time can be relatively fast (~15 minutes, Wheaton College Observatory, T. Barker); and it also serves the purpose of more public outreach. This is an aspect of science that the public can understand and participate in at some level. Several Cerenkov telescopes such as HEGRA also have burst observing programs and fields of view well-matched to that of COMPTEL's error boxes.

3.3. As a "heads-up", plus background information for bursts measured with more precise positions at other wavelengths: Currently, observers at Haystack, NRAO, Owens Valley, the VLA, Westerbork, the Mullard observatory, and the BIMA array are signed up on the distribution list. Some use the smaller COMPTEL positions for scanning observations. Others report they wait for tighter position constraints but use the COMPTEL data products as background information; or survey a COMPTEL position only if it is particularly bright or otherwise interesting. For slower or small field of view optical sites, including Palomar, CTIO, ESO, HST and Lick Observatory, observers report the use is similar.

4. RECENT RESULTS

CGRO-COMPTEL's telescope has detected 39 bursts since its launch in April 1991, an average of ~5 events per year. During the past 12 months, the COMPTEL-RBR system was triggered 77 times, with five of those triggers leading to positive detections. Some of the latest events are described below.

GRB 980124, Moderate detection localized in 8 minutes: This event was about 20° off-axis, and bright enough so that about sixty 0.75-30 MeV burst photons were detected in the first peak, which lasted about 14 seconds. The first and second peaks are both visible in the COMPTEL 0.1-1.6 MeV (Burst-mode low range) and 0.6-10 MeV (Burst-mode high range), with the second barely visible in telescope-mode (0.75-30 MeV) light-curve. This was a possible RXTE ToO for which the combined COMPTEL and BATSE position contours would have been used. However appropriate RXTE schedulers could not be located in time.

GRB 980329, Faint detection localized in 45 minutes: Although bright for BATSE (Briggs et al. 1998, IAUC 6856), this was a weak COMPTEL detection (33 events, about 4.3 sigma) at about 40° off-axis, for which manual intervention was required for the time-interval selection. The position was broadcast world-wide ~45 minutes after burst onset. The COMPTEL light-curves are shown in Figure 1a. This was a spectacularly bright BeppoSAX WFC event (Fronterra et al. 1998, IAUC 6853) with a subsequent X-ray afterglow detection ('t Zand et al. 1998, IAUC 6854); and R, I and K band detections (Djorgovski et al. 1998, GCN 41; Klose 1998, IAUC 6864; Larkin et al. 1998, GCN 44; repectively) as well as radio (Taylor et al., GCN 40). In Figure 1b we display the combined CGRO-COMPTEL and BATSE-LOCBURST location contours (systematic errors included), with the IPN timing arc (K. Hurley et al. via GCN) and the BeppoSAX position ('t Zand et al. 1998). Although the final radio and IR detections were based on much tighter BeppoSAX and IPN positions, IR/optical observer S. Klose (1998 private communication) noted the COMPTEL positions "are nevertheless useful, as they are considerably faster than BeppoSAX messages." Radio observer D. Frail (1998 private communication) comments "The BATSE light curves, the IPN/COMPTEL/BATSE positions are all useful to have when working on a well-localized RXTE or BeppoSAX burst."

GRB 980707, localized in ~1 hour despite computer problems. GRB 980707 triggered CGRO-BATSE while COMPTEL computer systems at UNH were in the midst being upgraded to the Solaris operating system. Nevertheless an initial COMPTEL position was reported about an hour from burst onset. Roughly two dozen 0.75-30 MeV photons were detected in a short spike lasting 0.23 seconds. This signal provided a 7 σ detection, despite being 47°off-axis.

GRB 990123, Bright detection localized in 12 minutes: This event was of great scientific importance due to the observation by ROTSE of coincident 9th magnitude optical emission (Akerloff et al. 1999). Above an MeV, the burst lasted about 45 seconds. The COMPTEL RBR system responded to this event, with its first results distributed ~12 minutes after the BATSE trigger. This initial result, which was distributed about 20 minutes prior to the distribution of the BATSE-LOCBURST position, had a significance of 8σ. This first COMPTEL result was based, however, only an initial, relatively small, precursor. This precursor can be seen in Figure 2a, where we show the CGRO-COMPTEL light curves from both the burst mode data and the telescope mode data. A more complete analysis of the event, incorporating events from the entire burst and distributed several hours later, improved the detection to a level of ~10σ. The size of the final COMPTEL 1σ eror box was about 2° × 4°, as can be seen in Figure 2b, which also shows the final BeppoSAX position and IPN timing arc. The COMPTEL detection was rather extraordinary, given that the burst location was 58° from the COMPTEL axis. A much smaller (and more symmetric) error box would have been obtained had the burst occurred closer to the COMPTEL pointing direction. The burst demonstrates the much larger effective FoV that COMPTEL provides for intense GRBs.

5. Summary

The COMPTEL-RBR system is a key component of a strongly interdependent rapid response network (GCN). The GCN demonstrated a crucial role in the observational history of GRB 990123. We request suppport to continue this service, and to continue our upgrade efforts. These upgrade efforts, which should largely be completed by the end of Cycle 8, should lead to the dissemination of high-level data products with ~2-4 minutes of the burst trigger. The specific improvements include the use of an improved algorithm for defining the burst time interval and the use of more effective software languages (e.g., Fortran rather than IDL). More importantly, we plan to remove a large fraction of the RBR software from the COMPTEL-COMPASS software system, eliminating a large amount of unnecessary overhead. This step would also permit us to install the software directly onto the COMPTEL GSE computer, streamlining the data transfer process. These changes are expected to have a significant impact on the RBR response time. The requested funding ($10,000) will be used to support these on-going activities at UNH.

6. References

Akerlof, C., et al., 1999, Nature, in press.
Briggs, M. et al., 1999, Ap.J., in press.
Connors, A. & Heuters, G., Ap.J., 501, 307.
Kazanas, D., Titarchuk, L., & Hua, X.-M., 1998, Ap.J., 493, 708.
Mészáros, P. & Rees, M. 1997, Ap.J., 476, 232.
Pilla, R. & Loeb, A., 1998, Ap.J., 494, L167.
Schönfelder, V., et al., 1993, Ap.J.S., 86, 629.
Share, G. et al., 1999, BAAS.

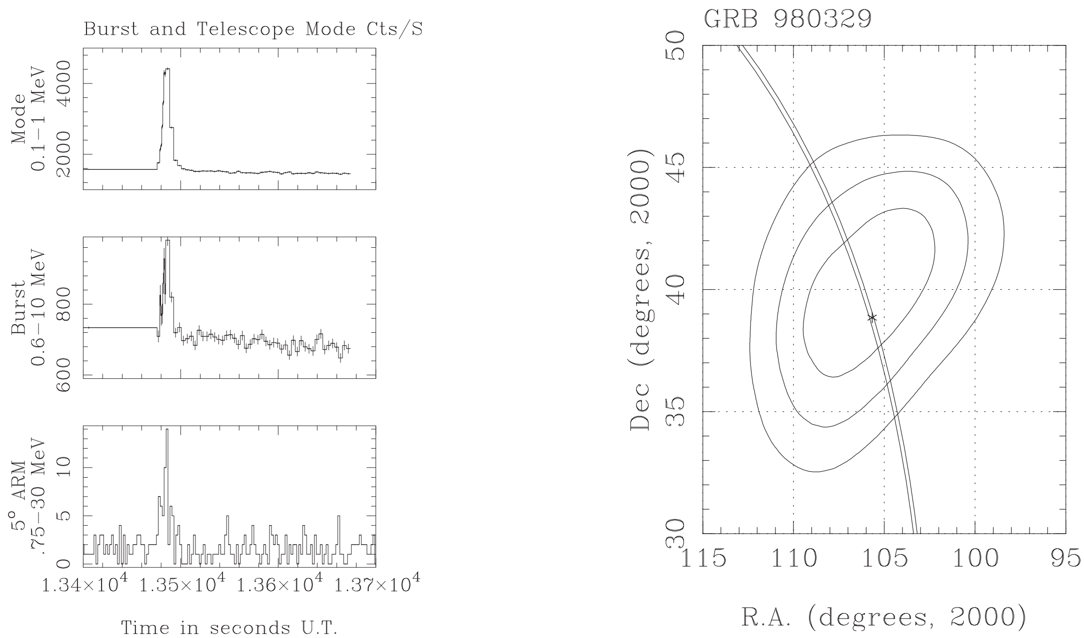

Figure 1: a) CGRO-COMPTEL telescope light-curves for GRB 980329. From top to bottom: 0.3-1.6 MeV (burst-mode, low range); 0.6–10 MeV (burst-mode, high range); and 0.75-30 MeV (telescope-mode) in counts per second. b) Combined COMPTEL+BATSE 1, 2, and 3σ position contours for GRB 980329, systematics included. Ulysses/BATSE IPN timing arc is superposed. The star in the center marks the best BeppoSAX position.

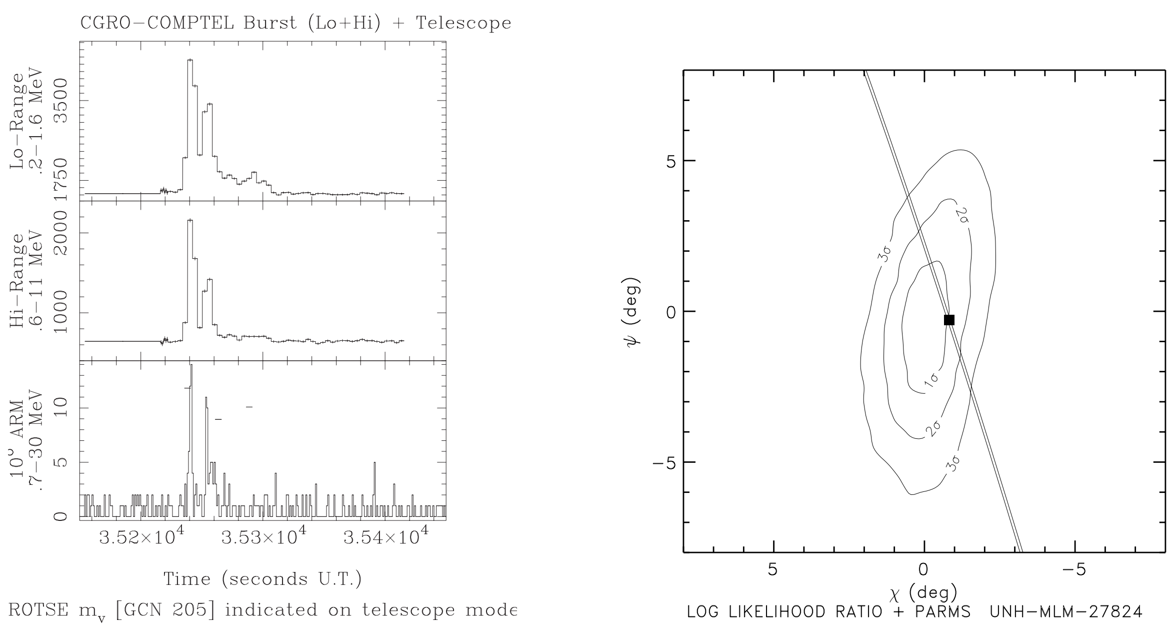

Figure 2: a) CGRO-COMPTEL light-curves for GRB 990123. From top to bottom: 0.3-1.6 MeV (burst-mode, low range); 0.6-10 MeV (burst-mode, high range); and 0.75-30 MeV (telescope-mode) in counts per second. b) Combined COMPTEL 1, 2, and 3σ position contours for GRB 990123, along with the Ulysses/BATSE IPN timing arc is superposed. The square marks the best BeppoSAX position.

SUMMARY OF PREVIOUS CGRO WORK
Dr. Mark McConnell
Research Associate Professor
University of New Hampshire

Approved CGRO Guest Investigations

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"
Cycle 7	"Exploring the Gamma-Ray Sky at 2.2 MeV"
Cycle 7	"COMPTEL Observations of Soft X-Ray Transients"
Cycle 8	"Broad Band Gamma-Ray Spectra of Cygnus X-1"
Cycle 8	"COMPTEL Studies of Gamma-Ray Bursts at MeV Energies"
Cycle 8	"COMPTEL Observations of X-Ray Transients"
Cycle 8	"CGRO Observations of the 2.2 MeV Source Candidate RE J0317-853"

Partial list of CGRO-Related Publications :

COMPTEL OBSERVATIONS OF X-RAY BINARIES
M. McConnell, K. Bennett, W. Collmar, A. Connors, R. van Dijk, D. Forrest, W. Hermsen, J. Ryan, V. Schönfelder, H. Steinle, and A. Strong, 1993, Proc. 23rd Internat. Cosmic Ray Conf., Calgary, 1, 192.

COMPTEL OBSERVATIONS OF CYGNUS X-1
M. McConnell, A. Connors, D. Forrest, J. Ryan, W. Collmar, R. Diehl, V. Schönfelder, H. Steinle, A. Strong, H. Bloemen, R. van Dijk, W. Hermsen, L. Kuiper, B. Swanenburg and C. Winkler, 1993, in AIP Conf. Proc. 280, Compton Gamma-Ray Observatory, ed. M. Friedlander, N. Gehrels & D.J. Macomb (New York: AIP), p. 335.

OBSERVATIONS OF CYGNUS X-1 BY COMPTEL DURING 1991
M. McConnell, D. Forrest, J. Ryan, W. Collmar, V. Schönfelder, H. Steinle, A. Strong, R. van Dijk, W. Hermsen, and K. Bennett, 1994, Ap. J., 424, 933.

MEV EMISSION FROM THE BLACK-HOLE CANDIDATE GRO J0422+32 MEASURED WITH COMPTEL
R. van Dijk, H. Bloemen, W. Hermsen, W. Collmar, R. Diehl, J. Greiner, G.G. Lichti, V. Schönfelder, A. Strong, K. Bennett, L. Hanlon, C. Winkler, **M. McConnell**, and J. Ryan, 1994, in AIP Conf. Proc. 304, The Second Compton Symposium, ed. C.E. Fichtel, N. Gehrels, & J.P. Norris (New York: AIP), p. 197.

RECENT RESULTS FROM COMPTEL OBSERVATIONS OF CYGNUS X-1
M. McConnell, D. Forrest, J. Ryan, W. Collmar, V. Schönfelder, H. Steinle, A. Strong, R. van Dijk, W. Hermsen, K. Bennett, and R. Much, 1994, in AIP Conf. Proc. 304, The Second Compton Symposium, ed. C.E. Fichtel, N. Gehrels, & J.P. Norris (New York: AIP), p. 230.

THE BLACK-HOLE CANDIDATE GRO J0422+32: MEV EMISSION MEASURED WITH COMPTEL
R. van Dijk, K. Bennett, W. Collmar, R. Diehl, W. Hermsen, G.G. Lichti, **M. McConnell**, J. Ryan, V. Schönfelder, A. Strong, J. van Paradijs, and C. Winkler, 1995, Astron. Astrophys., 296, L33.

SEARCH FOR MEV EMISSION FROM THE X-RAY BINARY CYG X-3
W. Collmar, **M. McConnell**, K. Bennett, R. van Dijk, W. Hermsen, V. Schönfelder, and H. Steinle, 1995, Proc. 24rd Internat. Cosmic Ray Conf., Rome, 2, 170.

HARD X-RAY POLARIMETRY OF SOLAR FLARES WITH BATSE
M. McConnell, D. Forrest, W.T. Vestrand, and M. Finger, 1996, in AIP Conf. Proc. 374, High Energy Solar Physics, ed. R. Ramaty, N. Mandzhavidze & X.-M. Hua (New York, AIP), p. 368.

GAMMA-RAY OBSERVATIONS OF GRO J1655-40
R.A. Kroeger, M.S. Strickman, J.E. Grove, P. Kaaret, E. Ford, B.A. Harmon, and **M. McConnell**, 1996, Astron. Astrophys. Suppl., 120, C117.

A SURVEY OF GALACTIC BLACK HOLE CANDIDATES AT MEV ENERGIES - PRELIMINARY RESULTS
M. McConnell, K. Bennett, H. Bloemen, W. Collmar, R. van Dijk, W. Hermsen, R. Much, J. Ryan, V. Schönfelder, H. Steinle, and A. Strong, 1996, Astron. Astrophys. Suppl., 120, C149.

THE RESPONSE OF THE CGRO COMPTEL DETERMINED FROM MONTE CARLO SIMULATION STUDIES
J.G. Stacy, R.M. Kippen, S.C. Kappadath, **M. McConnell**, D. Morris, R. Miller, A. Connors, B. Hersh, J. Ryan, J. Macri, G. Simpson, V. Schönfelder, H. Steinle, R. van Dijk, and O.R. Williams, 1996, Astron. Astrophys. Suppl., 120, C691.

THE RESPONSE OF THE CGRO COMPTEL DETERMINED FROM MONTE CARLO SIMULATION STUDIES
J.G. Stacy, R.M. Kippen, S.C. Kappadath, **M. McConnell**, D. Morris, R. Miller, A. Connors, B. Hersh, J. Ryan, J. Macri, G. Simpson, V. Schönfelder, H. Steinle, R. van Dijk, and O.R. Williams, 1996, Astron. Astrophys. Suppl., 120, C691.

USING BATSE TO MEASURE GAMMA-RAY BURST POLARIZATION
M. McConnell, D.J. Forrest, W.T. Vestrand, and M. Finger, 1996, in AIP Conf. Proc. 384, Gamma Ray Bursts, 3rd Huntsville Symposium, ed. C. Kouveliotou, M.F. Briggs & G.J. Fishman (New York: AIP), p. 851.

COMPTEL OBSERVATIONS OF GRO J1655-40
R. van Dijk, K. Bennett, C. Winkler, H. Bloemen, W. Hermsen, R. Diehl, V. Schönfelder, **M. McConnell**, and J. Ryan, 1997, Proceedings of the 2nd INTEGRAL Workshop, “The Transparent Universe”, ESA SP-382, p. XXX.

LATEST COMPTEL RESULTS ON GALACTIC BLACK HOLE CANDIDATES
M. McConnell, K. Bennett, W. Collmar, R. van Dijk, D. Forrest, W. Hermsen, R. Much, J. Ryan, V. Schönfelder, H. Steinle, and A. Strong, 1997, Adv. Space Research, 19, No. 1, 25.

A SEARCH FOR MEV GAMMA-RAY EMISSION FROM THE QUIET-TIME SUN
M.L. McConnell, K. Bennett, A. MacKinnon, R. Miller, G. Rank, J. Ryan, and V. Schönfelder, 1997, Proc. 25th Internat. Cosmic Ray Conf., Durban (South Africa), 1, 13.

COMPTEL ALL-SKY IMAGING AT 2.2 MEV
M.L. McConnell, K. Bennett, H. Bloemen, R. Diehl, S. Fletcher, W. Hermsen, J. Ryan, V. Schönfelder, J.G. Stacy, A. Strong, and R. van Dijk, 1997, Proc. 25th Internat. Cosmic Ray Conf., Durban (South Africa), 3, 393.

GALACTIC BLACK HOLE BINARIES: HIGH ENERGY RADIATION
J.E. Grove, J.E. Grindlay, B.A. Harmon, X.-M. Hua, D. Kazanas, and **M. McConnell**, 1997, in AIP Conf. Proc. 410, The 4th Compton Symposium on Gamma-Ray Astronomy and Astrophysics, ed. C.D. Dermer, M.S. Strickman, & J.D. Kurfess (New York: AIP), p. 122.

THE MEV SPECTRUM OF CYGNUS X-1 AS OBSERVED WITH COMPTEL
M. McConnell, J.M. Ryan, W. Collmar, V. Schönfelder, H. Steinle, A. Strong, H. Bloemen, W. Hermsen, L. Kuiper, K. Bennett, R. van Dijk, and R. Much, 1997, in AIP Conf. Proc. 410, The 4th Compton Symposium on Gamma-Ray Astronomy and Astrophysics, ed. C.D. Dermer, M.S. Strickman, & J.D. Kurfess (New York: AIP), p. 829.

A SEARCH FOR GAMMA-RAY FLARES FROM BLACK-HOLE CANDIDATES ON TIME SCALES OF ~1.5 HOURS
R. van Dijk, K. Bennett, R. Diehl, V. Schönfelder, H. Bloemen, W. Hermsen, **M. McConnell**, and J.M. Ryan, 1997, in AIP Conf. Proc. 410, The 4th Compton Symposium on Gamma-Ray Astronomy and Astrophysics, ed. C.D. Dermer, M.S. Strickman, & J.D. Kurfess (New York: AIP), p. 967.

COMPTEL ALL-SKY IMAGING AT 2.2 MEV
M. McConnell, J. Ryan, S. Fletcher, R. Diehl, V. Schönfelder, A. Strong,H. Bloemen, W. Hermsen, K. Bennett, and R. van Dijk, 1997, in AIP Conf. Proc. 410, The 4th Compton Symposium on Gamma-Ray Astronomy and Astrophysics, ed. C.D. Dermer, M.S. Strickman, & J.D. Kurfess (New York: AIP), p. 1099.

OBSERVATIONS OF GRB 990123 BY THE COMPTON GAMMA-RAY OBSRVATORY
M.S. Briggs, D.L. Band, R.M. Kippen, R.D. Preece, C. Kouveliotou, J. van Paradijs, G.H. Share, R.J. Murphy, S.M. Matz, A. Connors, C. Winkler, **M.L. McConnell**, J.M. Ryan, O.R. Williams, C.A. Young, B. Dingus, J.R. Catelli, and R.A.M.J. Wijers, 1999, submitted to Ap.J.

THE MEV GAMMA-RAY SPECTRUM OF CYGNUS X-1
M. McConnell, J.M. Ryan, W. Collmar, V. Schönfelder, H. Steinle, A. Strong, H. Bloemen, W. Hermsen, L. Kuiper, K. Bennett, B. Phlips, and J.C. Ling, 1999, to be presented at the 26th International Cosmic Ray Conference.

THE MEV SPECTRUM OF CYGNUS X-1
M. McConnell, J.M. Ryan, W. Collmar, V. Schönfelder, H. Steinle, A. Strong, H. Bloemen, W. Hermsen, L. Kuiper, K. Bennett, R. van Dijk, and R. Much, 1999, Ap. J., in preparation.