INTRODUCTION

The final report of the latest Astrophysics Senior Review (August, 1998) clearly indicated that the extended CGRO mission was, in large part, motivated by the recognition that "CGRO will be an important observational tool during the upcoming solar maximum." The report went on to say that, "except for solar observations, the potential for new discoveries is diminishing" and that the observation of solar flares will be important "with the full suite of instruments, particularly when HESSI and ACE are flying." (ACE is already in orbit, collecting data on Solar Energetic Particles in interplanetary space. HESSI is scheduled for launch in mid-2000.) COMPTEL provides unique capabilities for studying both 0.1-30 MeV solar flare γ-rays (using data from both its telescope mode and burst mode data streams) and 20-200 MeV solar flare neutrons. In fact, COMPTEL is the only instrument that will be available during the next solar maximum to provide detailed solar flare neutron measurements. With the next solar maximum expected to take place during the 18 month period of Cycle 9, it is imperative that we maximize our exposure to the Sun during this time. Long, uninterrupted exposures to the Sun offer many advantages over the use of Target-of-Opportunities (ToO's), including: 1) providing good background measurements both before and after each flare; 2) minimzing the loss of data due to delays in declaring and implementing a ToO (which can take several days); and 3) providing data on possible quiet-time or low-level solar emissions. Our proposal provides several means of achieving prolonged solar exposures with COMPTEL (as well as OSSE and EGRET) while, at the same time, providing valuable and uncompromised non-solar data. The principle part of our proposal is to observe the Sun during three prolonged (6 week) observations that also provide improved all-sky coverage for COMPTEL. In addition, we propose several strategies for further solar observations during Cycle 9. Collectively, these proposals are designed to make the best overall use of CGRO during the next solar maximum, with the goal of achieving at least 9 months on the Sun.

SOLAR FLARE OBSERVATIONS

CGRO was launched on the declining phase of the last cycle. Nonetheless, the CGRO instruments gathered a wealth of solar flare data during solar cycle 22 and demonstrated the ability to significantly contribute to the field of high-energy solar physics. Most of the exciting results came from observations of a single active region in June of 1991. Many new phenomena were revealed, including: 1) the extended high-energy phase of flares that lasts for several hours, providing evidence of prolonged particle acceleration; 2) spectral changes in the proton population at the Sun as seen in a variable γ-ray spectrum; 3) "repeatability" of γ-ray intensity-time profiles in three successive flares indicating a persistent magnetic field structure; 4) the first composite γ-ray spectrum of a flare extending from 50 keV to 1 GeV, along with the spectrum of 10-100 MeV neutrons; 5) new information from OSSE measurements of the 4 June 1991 flare about the accelerated-particle spectra and composition and about the ambient plasma at the flare site (see e.g. Kanbach et al. 1993, Rank et al. 1996, Murphy et al. 1997, Share et al. 1997). Based on these observations we now believe that there are two distinct mechanisms or phases for accelerating ions to γ-ray producing energies and that it is likely that some trapping of the energetic ions is taking place late in the flare. We also believe that γ-ray production high in the corona can be significant. We have seen evidence of an extremely soft proton spectrum embedded between hard and intense spectra in the 11 June 1991 flare. However, since all the June 1991 flares originated from the same active region and were of a similar structure, they certainly do not represent an unbiased selection of events. By observing a larger sample of intense flares we will be able to separate specific properties of the June 1991 flares from properties which are inherent to large flares in general.

During the next two years, solar activity should reach the peak of its current cycle – solar cycle 23 (Figure 1). The instruments on CGRO have an opportunity once again to make significant contributions to high energy solar physics. During Cycle 9 we propose to obtain long duration solar observations with both COMPTEL and OSSE and to provide the opportunity for observations by EGRET. Long, uninterrupted exposures to the Sun offer many advantages over the use of ToO's. These include:

• Good background measurements for COMPTEL observations of solar flares come from an average of data collected 15 orbits before the flare and 15 orbits after the flare. These data must be collected with the spacecraft fixed in attitude and the instruments operating in a fixed mode. Prolonged solar observations insure that good background measurements ae made.

• Although the ToO approach for obtaining solar flare data has its merits, it also has several drawbacks. The transit of a particular active region across the solar disk takes ~2 weeks. Under ideal circumstances, an active region emerging from behind the limb could trigger a ToO within 1-2 days. With reduced FOT coverage, several days may then pass before the spacecraft is successfully repointed, leaving only a few days or perhaps a week of observation

time for a particular active region. For example, in June of 1991, when the Sun was declared a ToO, only 3 (2) out of 6 X-class flares were observed by COMPTEL (EGRET) during a single active region transit.

• The instruments can be operated in the same mode during the whole period. Upon the notification of a solar flare by BATSE, the OSSE detectors can be slewed, if necessary, to acquire solar data. The EGRET spark chamber can likewise be switched on to collect a few hours of potentially very important data. COMPTEL will be operated in a mode that continuously accomodates solar and non-solar science simultaneously. No re-orientation of the satellite is required, keeping operational efforts to a minimum.

• Even if no major flare occurs, long solar observations allow us to study low-level emissions from the Sun. The most interesting candidates for such emissions include: 1) 2.2 MeV emission as a signature of a steady-state population of accelerated ions (e.g., Harris et al. 1992); and 2) nuclear line emissions from (relatively) long-lived radioactive isotopes produced in solar flares, such as the lines from ^{56}Co and ^{22}Na (e.g., Kuzhevskii 1982). COMPTEL studies of quiet-time solar emissions (McConnell et al. 1997) have so far set only upper limits.

• Both COMPTEL and EGRET have detected M-class flares. It would be useful to study the low-level emissions from an ensemble of such smaller flares by summing the weak signals from the individual flares.

THE COMPTEL SKY SURVEY

Independent of the solar observations, the proposed pointings will support the effort to generate a more uniform distribution of COMPTEL exposure throughout the entire sky. A principle objective of the COMPTEL experiment is to map out and study the large-scale Galactic emission, both diffuse and from discrete sources. These studies involve both continuum and line emissions. Although the full dataset from the COMPTEL mission continues to improve as time goes on, there are still limitations due to the variation in quality and coverage of the data. It is this issue that we hope to address with the proposed observations. Improved coverage of the full sky by COMPTEL will have potentially important implications for several on-going studies, including those related to diffuse continuum emission from the galactic plane, diffuse line emission at 1.8 MeV from radioactive ^{26}Al, line emission at 1.16 MeV from the decay of ^{44}Ti in recent supernovae, and line emission at 2.22 MeV from neutron capture on hydrogen. Improved sky coverage may also have an impact on attempts to search for anisotropies in the cosmic diffuse γ-ray background.

PROPOSED CGRO OBSERVATIONS

To date, the accumulated COMPTEL exposure to the sky is very non-uniform. Areas along the galactic plane have been observed repeatedly with a maximum exposure of 95 effective days in the Crab region. The two regions with the lowest overall exposure (~33 days each) are those near (l, b) = (175°, -60°) and (l, b) = (255°, +20°). Most of the exposure in these regions results from adjacent observations with the large FoV of COMPTEL. By chance, these regions lie near the ecliptic. We propose three sets of 6 × 1-week observations following the Sun through these sky regions.

The Sun moves through these regions each year in April and August. The Sun must always be kept within 7° of the x/z-plane to be accessible for OSSE by either the z-axis pointing or by aligning the OSSE scan plane along the ecliptic. For the EGRET spark chamber it is best to have the Sun not further than 15° from the center of the FoV. We have put together a sequence of observations designed to allow COMPTEL, OSSE and EGRET to observe the Sun. The proposed observations are shown graphically in Figure 3. The proposed observations increase the exposure at (l, b) = (175°, -58°) from 32.5 days to 45 days and at (l, b) = (255°, +20°) from 34 to 36 days. These observations are tightly constrained by the EGRET requirement to be within 15° of the Sun. If this requirement were to be removed (providing only COMPTEL and OSSE observations), then we would have much greater flexibility in our planning. The removal of the EGRET constraint would allow for significantly improved exposure coverage for COMPTEL, but would lose the potential for doing important solar science with EGRET.

A similar proposal was accepted for inclusion in CGRO Cycle 8 observations (CGRO-98-034, “Completion of the COMPTEL Sky Survey Combined with Long Duration Solar Observations”, PI: H. Steinle). A total of six weeks were scheduled during the initial Cycle 8 timeline. Three of those weeks have already been re-allocated to a ToO observation of GRS 1915+105. Unfortunately, solar activity during the remaining three weeks was quite low, with only one significant flare – an M1.9 flare on 03-May-1999 that triggered the COMPTEL Rapid Burst Response (RBR) system. The limited observation time also means that our efforts to smooth out the full-sky exposure met with limited success.

SCHEDULING OF OTHER CYCLE 9 OBSERVATIONS

COMPTEL has demonstrated on several ocassions its ability to study intense γ-ray bursts at very large off-axis angles. The most recent such example is that of GRB 990123, which was observed by COMPTEL at 58° off-axis (Briggs et al., 1999). In addition, the COMPTEL FoV for neutrons is significantly larger than that for photons. Although smaller off-axis angles (< 20° - 30°) would certainly be preferred, it is clear that useful solar science might also be achieved even at large off-axis angles. We therefore request that other CGRO observations be scheduled, whenever possible, to include the Sun within 50° (or, more preferrably, within 20°) of the COMPTEL pointing direction. We propose to work with the CGRO timeline committee to include this general constraint on all CGRO observations to maximize the COMPTEL exposure to the Sun. The scheduling should also incorporate observations with OSSE (c.f., proposal entitled "OSSE Observations in Solar Cycle 23", PI: R. Murphy).

One specific opportunity is offered by proposal CGRO-99-007 ("Galactic Central Radian Deep Exposure", PI: V. Schönfelder). This proposal requests a very deep (45 week) exposure of the central radian of the galaxy. Since the Sun lies within 50° of the galactic center between roughly November 1 and February 15, a substantial fraction of that exposure could be carried out during a time in which the Sun is well-placed within the COMPTEL FoV. In particular, such observations could be planned for the time frame between 01-Dec-1999 to 15-Feb-2000 and again between 1-Nov-2000 and 15-feb-2001, providing a total of six months exposure to the Sun.

A second opportunity comes from proposal CGRO-99-012 ("Large-Scale Mapping of the Gamma-Ray Sky", PI: V. Schönfelder). This proposal requests deep exposures along the galactic plane at l = 135° (10 weeks) and at l = 250° (15 weeks). Although these points lie 40° – 50° from the ecliptic, scheduling these deep pointings when the Sun is nearby could nonetheless place the Sun within 50° of the COMPTEL pointing direction (or perhaps even closer). As stated above, observations of solar flares at such large off-axis angles may still be of great value. To a large extent, these observations dovetail with those that we are proposing here.

SUMMARY

COMPTEL and OSSE are both operating normally. For COMPTEL, a new observing mode has recently been implemented that maximizes the return from both solar and non-solar science simultaneously. The new configuration is based on experience from the major flares of 1991 and is designed to have little, if any, effect on the instrument response for non-solar observations. At the same time, it will improve the data aquisition capabilities (i.e., improved livetime) compared to the 1991 solar observations, in particular for observing the impulsive phase of large flares. Although the sensitivity of the EGRET spark chamber has now degraded considerably, it is still sufficient for measuring transient events like solar flares. Since the Sun will be in the FOV continuously during the proposed observations, we propose to switch on the EGRET spark chamber for several hours whenever a major flare occurs. Data (with limited time resolution) would also be continuously available from the EGRET-TASC. Details of the triggering of EGRET by a BATSE-derived signal can be found in a cycle 9 solar flare ToO proposal submitted by Bertsch et al. HESSI is expected to be launched in mid-2000 and can be expected to provide valuable complementary observations, especially at hard X-ray and low-energy γ-ray energies. The imaging capabilities of HESSI will provide important constraints on the interpretation of data collected by CGRO and the high-quality data from CGRO will likewise provide important constraints on the interpretation of data from HESSI.

Both survey and flare observations will be analyzed by the experienced teams from EGRET, OSSE, and COMPTEL. The pointings are very favorable for the survey, since both observed regions are far from the orbital poles and away from the galactic plane (useful for more reliable background modeling). The requested funding level of $15,000 will be used to support the analysis of COMPTEL data at UNH.

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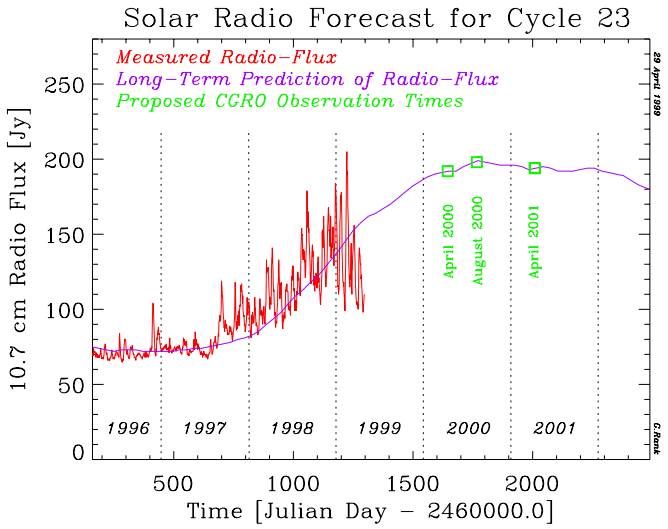

Figure 1: The forecast of the solar 10.7 cm radio flux is useful as a global indicator of solar activity. Cycle 23 is expected to peak around the year 2000 (during cycle 9) on a slightly higher level than the preceding cycle 22, although the most recent radio data suggests a lower-than-expected level of activity at this point of the solar cycle. (Forecast data and measurements provided by NOAA.) The dates of our proposed observations are indicated by squares.

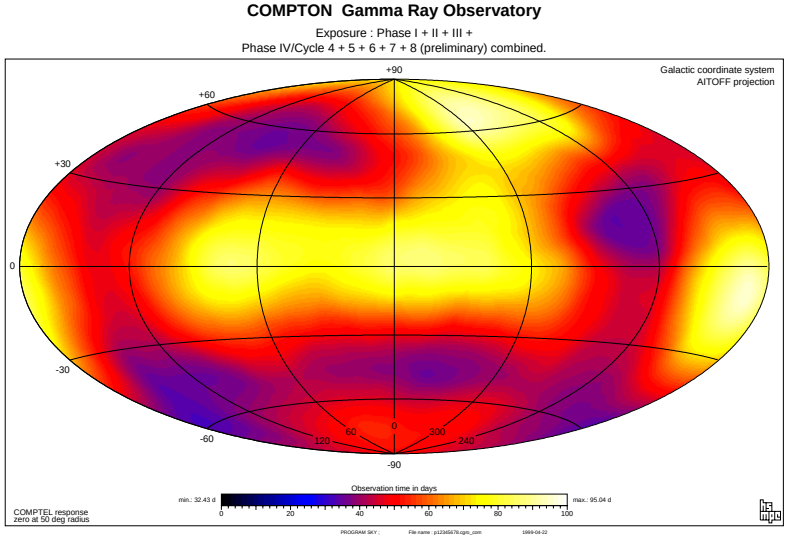

Figure 2: Total sky exposure for COMPTEL through the end of the current cycle 8 observations (based on the latest cycle 8 timeline). Two regions having relatively low exposure are those near (225°, +20°) and near (175°, -60°). Since these regions lie near the ecliptic, it is possible to improve the overall exposure in these regions while maximizing the COMPTEL exposure to the Sun.

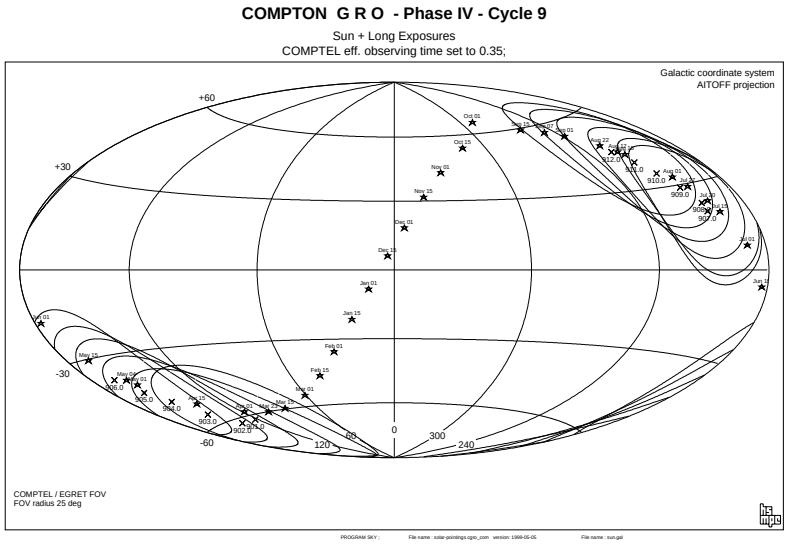

Figure 3: A plot showing the proposed COMPTEL exposures. The exposures are indicated by circles with a radius of 25°, which somewhat underestimates the true effective FoV of COMPTEL, since COMPTEL has ocassionally studied intense γ-rays bursts that are 60° off-axis. The location of the Sun, at 15-day intervals, is shown by a series of stars.

SUMMARY OF PREVIOUS CGRO WORK

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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
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