SCIENTIFIC OBJECTIVES OF THE ORIENTED SCINTILLATION SPECTROMETER EXPERIMENT

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ABSTRACT

The Oriented Scintillation Spectrometer Experiment (OSSE) will undertake a broad range of scientific observations in the 0.05 - 10 MeV energy region. These include observations of supernovae and SN remnants, novae, collapsed objects (neutron stars, black holes, and white dwarfs), other galactic discrete and diffuse emissions, gamma-ray burst sources, active galactic nuclei, solar flares, and the opportunity for a partial or complete sky survey. OSSE will provide a line gamma-ray sensitivity of 2-5 x 10^{-5} photons/cm^{-2}-s for a 10^6-second observation and a corresponding continuum sensitivity of < 5 x 10^{-3} Crab. For the initial sky survey comprised of two-week viewing periods, OSSE will undertake detailed investigations of about 50 targets per year. Examples of the capabilities of OSSE to meet several of these scientific objectives are discussed and the tentative observation program for the first 15 months of the mission is presented. Opportunities for Guest Investigations using OSSE are also discussed.

INTRODUCTION

The Oriented Scintillation Spectrometer Experiment (OSSE) includes four identical actively-shielded scintillation detectors designed to undertake observations in the 0.05-10.0 MeV energy range. Additional capabilities for gamma-ray and neutron observations above 10 MeV are also available. For a review of the instrument and its operational capabilities see Johnson et al. (1989). Table 1 is a summary of the OSSE instrumental characteristics. In this paper we discuss the capabilities of OSSE to undertake observations of discrete galactic sources, diffuse galactic emission, the Galactic Center region, extragalactic sources, and the opportunities for performing a sky survey. Other scientific goals of OSSE are covered in other papers in these proceedings. Specifically, nucleosynthetic sources (supernovae and novae) are discussed in the papers by Leising et al. (1989) and Clayton (1989). The capabilities of OSSE for observations of solar flares and gamma-ray bursts are covered by Matz et al. (1989).

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TABLE 1: OSSE INSTRUMENTAL CHARACTERISTICS

Energy range	0.05 - 10 MeV γ-rays 10-200 MeV (γ-rays and neutrons)
Spectral Resolution	8.2% @ 0.66 MeV 3.8% @ 6.13 MeV
Time Resolution	4 s (full spectral mode) 0.125 ms (pulsar EBE mode) 4 ms (pulsar rate mode)
Field-of-view	$3.8^\circ \times 11.4^\circ$ FWHM @ 0.51 MeV
Line Sensitivity (3σ)	$2 - 5 \times 10^{-5}$ γ/cm^2-s
Continuum Sensitivity (3σ)	~0.005 Crab (> 0.1 MeV) ~0.05 Crab (> 1.0 MeV)
Observing Plan	2 - week GRO pointings two-source/orbit capability

The initial 15-month period of GRO scientific observations will be devoted to a sky survey (for the EGRET and COMPTEL instruments). The sky survey will consist of sequential two-week periods with the observatory maintaining a fixed 3-axis orientation in inertial space. During each period, OSSE will typically undertake observations of two sources: one source near the spacecraft Z-axis, and another source near the spacecraft X-axis when the Z-axis source is occulted by the Earth. During each two-week period, about 5×10^5 seconds of observing time will be devoted to each source (including the required background observations). The sensitivity for line γ-rays for a 10^6-second observation is shown by Johnson et al. (1989). Note that achieving this sensitivity will require two standard two-week observing periods during the sky survey period. Longer observing periods may be available after the sky survey is completed.

OSSE SCIENTIFIC OBJECTIVES

OSSE will undertake a broad range of scientific investigations. These are listed in Table 2. As indicated previously, other papers in these proceedings discuss several of the OSSE scientific objectives. In this paper the capabilities for undertaking selected objectives are discussed. These include: (1) discrete galactic sources; (2) the Galactic Center region; (3) diffuse ^{26}Al and positron annihilation emission from the galactic plane; and (4) studies of active galactic nuclei (AGN's) and 5) a brief dicussion of an OSSE sky survey.

TABLE 2: OSSE SCIENTIFIC OBJECTIVES

Supernovae
Novae
Neutron Stars
Black Holes (Stellar)
Black Holes (Massive)
White Dwarf Stars
Galactic Center Region
Interstellar Medium
Diffuse Galactic Emission
Galactic Plane Survey
Pulsars
Gamma Ray Transients/Bursts
Active Galactic Nuclei
Solar Flares
Study of Specific High-Energy Gamma-Ray Sources (e.g. Geminga)
Sky Survey (Partial or Complete)

1. Discrete Galactic Sources

OSSE will be used to investigate many discrete galactic sources. These investigations will include studies of objects which have not previously been detected in the γ-ray energy range and a survey of the galactic plane to be largely completed during the first two years of the mission. This survey should result in observation of several new sources which can be further studied using dedicated observations later in the GRO mission. Also included will be candidate objects that are known from previous hard x-ray and γ-ray observations, but which can now be observed with much higher sensitivity. For example, with this improved sensitivity we will search for line features in the gamma-ray spectra of neutron stars in accreting binary systems. The gravitational red-shift of spectral features emitted from a neutron star surface, e.g. Her X-1, along with the mass determined from the binary nature, will provide important information on the equation of state of neutron star matter.

OSSE will also observe known (Crab and Vela) and expected gamma-ray pulsars to further elucidate the properties of these systems, i.e. location and mechanism for γ-ray emission, magnetic field strength from cyclotron line observations, and studies of pulsar properties vs. period, $\dot{p}$, age, and magnetic field. These studies will characterize the emission from other young pulsars as well as search for the suggested MeV emission associated with low-mass binary systems in which old, rapidly rotating pulsars are evaporating their companion (e.g. PSR 1951+20). For a more complete review of GRO pulsar investigations see Taylor (1989) and references therein.

2. Galactic Center Region

The Galactic Center region apparently contains several hard X-ray sources (Skinner et al. 1989), one perhaps coincident with Sgr-A West, and also apparently includes a variable point source of positron annihilation radiation (Leventhal et al. 1989, Riegler et al. 1981). The intensity observed by HEAO-C1 in the fall of 1979 was $(1.85 \pm .21) \times 10^{-3}\ \gamma/cm^2\text{-}s$, but had decreased to $(0.65 \pm .27) \times 10^{-3}\ \gamma/cm^2\text{-}s$ in the Spring of 1980 (Reigler et al. 1981). Upper limits confirming the decrease were reported by Leventhal et al. (1986) and Paciesas et al. (1982). Recently, the GSFC/Bell/Sandia group has observed he source "on" again (Leventhal et al. 1989). With a 3σ sensitivity of ~ 5 x 10^{-5} γ/cm^2-s and the opportunity for multiple observations of the Galactic Center region, OSSE should make definitive measurements of any variable point source of 0.51 MeV radiation at the levels reported earlier.

If such a variable point source exists, a determination of the location is the next important objective. Much theoretical speculation has involved the presumption that the source is associated with a massive object at the Galactic Center. Recently, McClintock and Leventhal (1989) have suggested, based on temporal correlations with X-ray observations, that the X-ray pulsar GX1+4 is the source of the variable 0.51 MeV emission. We have performed simulations of OSSE scans of the Galactic Center region to determine the capability of OSSE to locate a 0.511 MeV point source. We assumed contributions from the following 0.51 MeV sources: a broad, diffuse emission along the galactic plane with intensity of 2.0 x 10^{-3} γ/cm^2-s-rad, a point source at GX1742-29 with an intensity of 10^{-3} γ/cm^2-s, and a point source at GX1+4 with an intensity of 10^{-4} γ/cm^2-s. Using four scans at position angles separated by 45° (see Figure 1), we find that, for a 10^6-second observation, OSSE will be able to locate a strong point source (10^{-3} γ/cm^2-s, 50σ detection) to within 0.2 degrees and a weak point source (10^{-4} γ/cm^2-sec, 5σ detection) to within 0.5 degrees. This capability, combined with OSSE plans for repeated observations of the Galactic Center region, should do much to resolve the reality and origin of the 0.51 MeV emission from the Galactic Center.

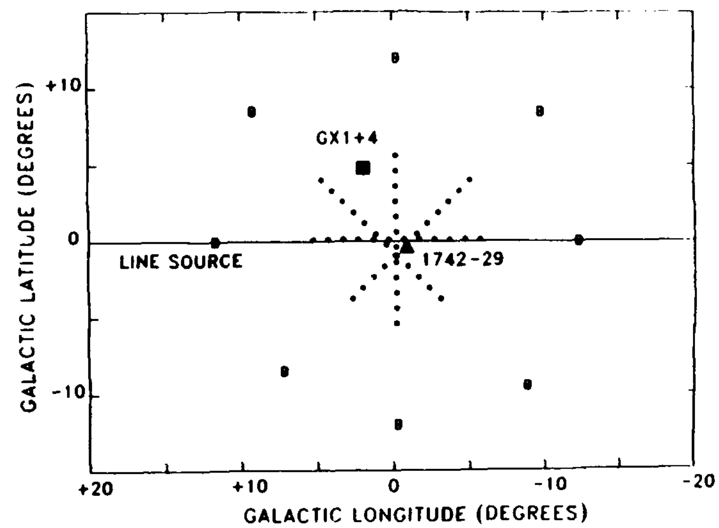

Figure 1. Simulated scans of the Galactic Center region to locate hypothetical 0.51 MeV point sources. Dotted lines indicate scan directions; B's indicate background measurements. See text for details of simulation.

3. Diffuse Galactic Emission

Diffuse emissions from the galactic plane have excited much theoretical activity and are a major observational objective. HEAO-C1 (Mahoney et al. 1984) and SMM (Share et al. 1985) have reported ^{26}Al emission from the general region of the

Galactic Center, and SMM has observed a steady 0.51 MeV emission which is also attributed to diffuse emission. The origin of the ^{26}Al has been the subject of considerable debate, with supernovae, novae, and Wolf-Rayet stars suggested as candidate sources. A fraction of the positron radiation is also attributed to ^{26}Al decay, however the bulk of it likely comes from other long-lived positron emitters, ^{56}Co, ^{44}Sc, ^{22}Na produced in supernovae or novae (Lingenfelter and Ramaty 1989) or from electromagnetic processes near compact objects. Since these diffuse emissions arise from a large number of sources, a determination of their origin (e.g. ^{26}Al) must come from measurements of the spatial distribution of the emission and by comparison with model distributions for the several types of sources. Leising and Clayton (1985), and Purcell (1989) have made such analyses for nova and supernova distributions. Using the angular distribution models for novae and supernovae from Leising and Clayton (1985) normalized to the SMM observatons as described in Purcell (1989), a simulation of OSSE observations of ^{26}Al along the galactic plane was performed. The results of these simulations are shown in Figure 2. In this analysis, the angular response of the OSSE instrument has been convolved with the assumed ^{26}Al distributions. It has been further assumed that the ^{26}Al observations were obtained by undertaking measurements with the long direction of the OSSE 3.8° x 11.4° field-of-view parallel to the galactic plane, and with background measurements obtained at ± 5° latitude. It is seen that OSSE has the sensitivity to differentiate the novae and supernovae models through a few observations at selected galactic longitudes. A more thorough study will be achieved by performing a complete survey of the galactic plane within ± 10° latitude with the ~ 4° resolution provided by OSSE, and comparing the results with the expected angular distributions for various sources. Identification of ^{26}Al sources and of the radial dependence of $^{26}Al/^{27}Al$ in the galactic disk also has important implications for the origin of the solar system because of the puzzling ^{26}Mg isotopic anomalies (Clayton and Leising 1987).

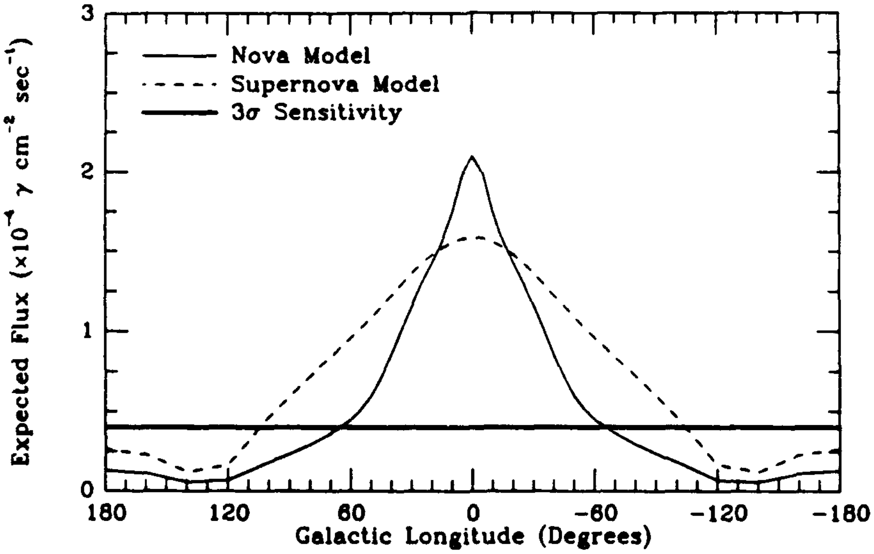

Figure 2. Simulated OSSE responses to diffuse galactic ^{26}Al γ-ray emission based on model novae and supernovae distributions. The OSSE response incorporated the measured angular response at 1838 keV using a ^{88}Y source. The OSSE 3σ sensitivity is also shown, indicating the capability to distinguish between models with OSSE observations at selected galactic longitudes.

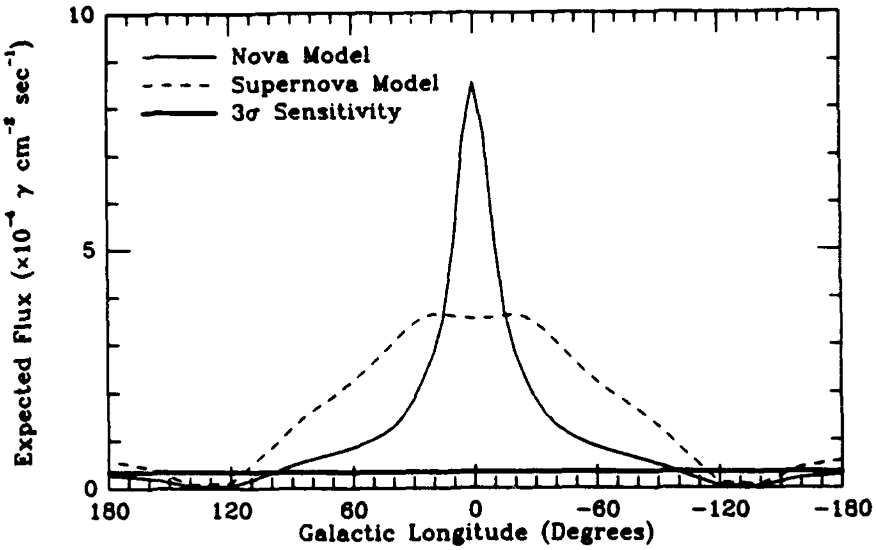

Figure 3. Simulated OSSE responses to diffuse galactic 0.51 MeV γ-ray emission using model distributions as in Figure 2.

Figure 3 presents a similar analysis for OSSE observations of a diffuse 0.51 MeV emission from the galactic plane. See also the paper by Dupraz et al. (1989) in these proceedings.

Cosmic ray interactions with the interstellar medium will also produce diffuse line and continuum emissions likely to be observed by OSSE. Detectable fluxes of line γ-rays associated with proton interactions with interstellar material carbon, oxygen, iron, nitrogen etc. are expected to display features at 4.4, 6.1, 0.847 and 1.238, and 1.63 MeV respectively (Ramaty, Kozlovsky and Lingenfelter 1979). These observations will provide a measurement of the low-energy (10 - 100 MeV) cosmic ray flux in the Galaxy. The SMM spectrometer has obtained a preliminary measurement of the first detailed continuum spectrum of the Galactic Center region (Harris et al., 1989). This continuum emission is most likely associated with galactic electron bremsstrahlung with a contribution from inverse Compton emission. An OSSE objective will be to confirm this spectrum and determine the angular distribution, thereby providing new information on the cosmic ray electron spectrum vs. location in the Galaxy.

One final example is the probability for detection of recent galactic supernovae through the observation of a ^{44}Ti feature at 1.146 MeV. OSSE should be able to detect optically unobserved supernova which have occurred within 10 kpc within the last ~ 200 years (Kurfess 1988; Clayton 1989)

4. Extragalactic Sources

OSSE will make major contributions to the study of active galactic nuclei. It is well known from hard X-ray observations (see Rothschild et al. 1983) that AGN's typically have very hard spectra (photon index ≃ -1.6) in the energy region up to 100 keV. In the high-energy gamma-ray region surveyed by SAS-II and COS-B, only 3C273 has been observed. This result, along with upper limits on several other sources, make it clear that bolometric spectra of AGN's peak in the 0.1 - 10

MeV interval and so can be studied by OSSE. Figure 4 compares extrapolated hard X-ray spectra of several AGN's with the OSSE continuum sensitivity. It is evident that OSSE should detect a significant number of AGN's. We expect to observe 30-50 AGN's with greater than 5σ significance at several hundred keV under the assumption that typical AGN spectra (α = -1.6) extend to these energies.

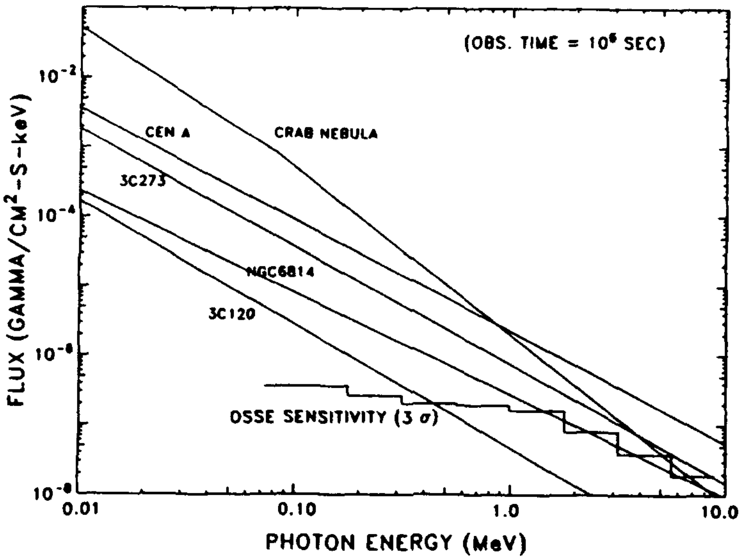

Figure 4. Comparison of OSSE continuum sensitivity and extrapolation of hard X-ray emission of several AGN's into the OSSE energy range.

Of specific interest will be OSSE results on the energy spectra and time variability of AGN's. OSSE will provide high quality spectra of the stronger AGN's, and thereby impose constraints on the emission mechanisms (e.g. synchrotron self-compton, Penrose process) and physical conditions in the source regions. (E.g. spectral evidence for pair creation opacity which can be used to define size and energy densities in the source regions).

For the stronger sources, OSSE will also enable studies of temporal variability on time scales from several hours to years. For example, OSSE should be capable of detecting strong sources such as NGC4151, Cen A and MCG 8-11-11 at the 10σ level in 10^4 seconds in the 50 - 300 keV region and at the 3σ level at 1 MeV. Thus, short term variability on time scales of hours and correlations of these variabilities with X-ray, optical, and radio observations should place severe constraints on models for the central power source in AGN's (see e.g. Leiter and Boldt, 1989).

5. Sky Survey

As indicated earlier, an OSSE objective during the first two phases of the mission is to undertake a survey of the galactic plane. With the modest OSSE field-of-view, this will require considerable observation time and may extend into following phases of the mission.

OSSE was not designed as a survey instrument, but with an extended mission of 5-10 years, a partial or complete sky survey can be considered. It would take about 500 pointed observations with OSSE to complete a full survey. Clearly, only ~ 10^5 s per observation could be obtained if a full sky survey were to be completed in a reasonable period of time. The scientific value of such a survey will be considered as part of the scientific review process for phases 3 and 4 of the mission. We propose that undertaking such a survey involve both OSSE team scientists and selected Associate Investigators as discussed below.

OSSE OBSERVATION PLAN

A primary objective of the initial phases of the GRO mission is to undertake a full sky survey with the wide field-of-view COMPTEL and EGRET instruments. This will be accomplished with a series of two-week viewing periods during which the Z-axis of the spacecraft (coincident with the axis of the COMPTEL and EGRET fields-of-view) will be oriented at a sequence of celestial positions to provide nearly uniform coverage at the completion of the survey. During each viewing period, the OSSE intent is to undertake observations of a source at or near the spacecraft Z-axis and another source near the spacecraft X-axis (see Johnson et al. 1989). Other requirements which are incorporated into the overall viewing program are to observe 8-10 high priority targets during the first several months of the mission, and to observe selected sources (Galactic Center and SN1987A) for 2 viewing periods each during the first year of the mission.

With these requirements, and with consideration for other requirements and constraints imposed by the GRO spacecraft, the GRO Time Line Panel is developing an observation program for the sky survey phase, currently planned to be a 15-month period. The final observation plan is to be developed 6-months prior to launch, which is currently scheduled for mid-1990.

Table 3 lists a preliminary plan for OSSE observations during the sky survey period. This plan is provided to indicate the priorities and characteristics of the OSSE observation program, and is not to be taken as indicative of the final plan which will be modified to reflect the actual launch date and other

TABLE 3: PRELIMINARY VIEWING PROGRAM

Viewing Period	Z-axis target	X-axis target
1	Crab	III Zw2
2	Vela Pulsar	3C120
3	Cyg X-1	NGC 1275
4	SN1987A	PSR1509-58
5	G0+0	SN1987A
6	SS433	Cyg X-3
7	3C 273	MCG-8-11-11
8	Her X-1	NGC 4151
9	NGC4151	MK421
10	Cen A	0620-00
11	Sco X-1	3C273
12	G60+0	Her X-1
13	NGC1275	MK421
14	SN1987A	Cen A

TABLE 3: PRIELIMINARY VIEWING PROGRAM (con't)

15	G320-40	Rho Oph
16	G0+0	3C273
17	G342+0	NGC5506
18	G180+35	M87
19	G220+0	Eta Car
20	G0-45	G0+0
21	G240-40	Rho Oph
22	G0-90	G25+0
23	G60-45	MK590
24	G115+0	M82
25	G120-45	SN1987A
26	G0+60	M87
27	G120+45	M31
28	Cen X-3	NGC 2110
29	G220-45	2CG135+01
30	G160-45	GEMINGA
31	G140+15	3C390.3

considerations which impact OSSE objectives in the near future. This plan includes three observations of the galactic center region (during which scans at different position angles will be undertaken for purposes of location of sources as described in Section III). Four observations of SN1987A and multiple observations of at least 8 other sources including several AGN's are also planned.

OSSE SCIENCE TEAMS

For purposes of planning OSSE scientific observations and data analysis, OSSE investigators have selected membership on science area teams. These teams have responsibilities for the detailed planning and analysis associated with activities in their respective areas. Team leaders have been selected who have responsibility for ensuring the orderly implementation, coordination, and analysis required in their respective areas. Table 4 is a list of the current OSSE Science Teams and Team Leaders.

TABLE 4: OSSE SCIENCE TEAMS

SCIENCE TEAM	TEAM LEADER
Explosive Objects	Leising
Diffuse Galactic Emission	Purcell
Galactic Center Region	Jung
Pulsars	Ulmer
Discrete Galactic Sources (X-ray Binaries)	Ulmer
Discrete Galactic Sources (Wolf-Rayet, Cataclysmic Variables)	Leising
Extragalactic Sources	Strickman
Cosmic Bursts/Transients	Matz
Solar Flares	Murphy
Sky Survey	Kurfess
Background	Kinzer

OSSE GUEST INVESTIGATOR PROGRAM

Bunner (1989) has outlined the Guest Investigator opportunities for GRO. For OSSE, there are opportunities for Associate Investigators during the first year of the mission, with an increasing number of GI's expected during phases 2, 3, and 4. Since the observing program for the first year of the mission will be defined 6 months prior to launch and prior to selection of the initial GI's, the early opportunities on OSSE will not involve selection of OSSE Targets, but will relate to analysis activities on planned targets, collaboration with OSSE Co-I's on development of data analysis tools, participation on selected PI/GI teams discussed below, or use of OSSE data for objectives not planned by OSSE Co-I's.

During the first portion of the mission, high priority will be given to refining the mission operations and data analysis procedures for OSSE, including development of the optimum instrument configurations for undertaking different types of observations, understanding the several orbital background phenomena which produce systematic effects and which must be understood in order to perform reliable scientific analysis, and fine tuning data analysis procedures. All of these must be accomplished before a full Guest Investigator program for OSSE can be undertaken in the second year of the mission and beyond. Therefore, in phase 1 some priority will be given to selection of Assoicate Investigators with interests in supporting the PI team in meeting the above objectives.

The scientific objectives related to the diffuse galactic plane emission, the sky survey, and solar flares are areas for which special consideration is given with respect to GI participation and long term data rights. GI's interested in participating in these areas are encouraged to propose to become members of a combined PI/GI Science Team which will have overall responsibility for undertaking the associated observations and will have data analysis rights to the acquired data. This approach is adopted for the survey objectives because of their complexity and their long-term nature, the necessity for coordinated planning of the surveys with the other OSSE objectives, coordinated planning with the Time Line panel, and the requirement for a detailed understanding of the instrumental response. For the diffuse emission from the Galaxy, it is expected that a complete survey of the galactic plane region could take up to 100 OSSE pointings (equivalent to two years observing time). This undertaking will require detailed understanding of the OSSE operations and instrument acquired by the OSSE team during the mission. It will be initiated during the first two phases of the mission, but will extend into phases 3 and 4 for its completion. Therefore, GI participation for the general survey is best realized as participating members of the Galactic Diffuse Emission Science Area Team.

Likewise, plans for a partial or complete sky survey with the OSSE instrument would require a major observing program. For example, to complete a full sky survey to a sensitivity limit 3-4 times higher than the limiting sensitivity for a 10^6-s observing period would require 2-4 years. OSSE was not designed to be a sky survey instrument. Although the plans for an extended mission permit consideration of a partial or complete sky survey, it is not obvious that such a program represents the best utilization of the OSSE instrument. This Science Area team must justify such a program though the peer review process.

Finally, the phase 1 and phase 2 periods of the mission occur at the peak of the solar cycle #22. Since most of this time is PI-allocated observing time, GI opportunities will be made available by adding GI's to the Solar Flare Science Team.

GI's are encouraged to propose for phase 1 opportunities which relate to mission requirements for optimizing OSSE operational and data analysis procedures, participating in one of the Science Area Teams identified above, collaborating on one or more of the planned observations identified in the phase 1 observing program, or proposing observations and/or analysis not currently planned. Preference for the limited phase 1 opportunities will be given to those GI proposals which support the OSSE phase 1 objectives listed above. GI's that propose to participate on a Science Area Team or collaborate on other activities currently planned by the OSSE PI team should emphasize the specific experience and expertise that they will bring to the proposed activity.

There are also opportunities to work with the OSSE science teams and with OSSE data if the investigator does not require financial support from NASA. In this case, referred to as the Invited Investigator, a prospective investigator should contact the OSSE Principal Investigator (J. Kurfess) or one of the Science Team leaders listed in Table 4 to explore opportunities available. The prospective investigator should indicate those specific areas of interest and expertise.

GI opportunities and planned PI/GI teams are summarized in Table 5.

TABLE 5: OSSE GUEST INVESTIGATOR PROGRAM

GI OPPORTUNITIES

Phase 1:	Associate Investigators work as members of selected joint PI/GI teams, pre-planned first year observations, and data analysis techniques
Phase 2:	Associate Investigators propose observations
	Independent Investigator analyze Level 2 data
	PI/GI Teams
Phase 3/4:	Associate and Independent Investigator propose observations
	PI/GI Teams

SELECT GI/PI TEAMS

Galactic Plane Survey

Partial/Full Sky Survey

Solar Physics

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