OSSE OBSERVATIONS OF ACTIVE GALACTIC NUCLEI

W. Neil Johnson
Naval Research Laboratory
Washington DC

ABSTRACT

The Oriented Scintillation Spectrometer Experiment (OSSE) has been designed to address a broad range of scientific objectives through gamma ray observations in the 0.05 - 10 MeV energy range. A significant number of these observations shall be directed to the study of Active Galactic Nuclei (AGN). The characteristics of the OSSE instrument and the current observation plans are discussed. Examples of the scientific issues which OSSE expects to address are provided.

INTRODUCTION

The Oriented Scintillation Spectrometer Experiment (OSSE), one of four experiments on NASA's Gamma Ray Observatory Satellite, has been designed to undertake comprehensive gamma-ray observations in the 0.05 to 10 MeV energy range. The instrument incorporates four actively-shielded NaI(Tl)-CsI(Na) phoswich detectors which have 3.8° x 11.4° fields of view defined by tungsten collimators. The characteristics of OSSE are summarized in Table 1; a more complete description of the instrument and its capabilities can be found in Johnson *et al.* (1989).

OSSE's relatively small field of view dictates the approach to AGN observations which will consist of long exposures to specific AGN targets. The AGN targets shall be selected from an OSSE catalog of interesting AGNs which has been developed primarily from AGN observations by HEAO-1, HEAO-2, and EXOSAT in the X-ray band. The nominal exposure will be two weeks on a given source. OSSE uses offset pointing for background measurements to reduce systematic errors associated with orbital background effects. The OSSE target AGN will generally be in the fields of view of the other GRO instruments permitting coordinated observations over six decades in gamma ray energy. However, OSSE's orientation control system permits observations outside the fields of view of COMPTEL and EGRET; this capability will be used on orbital time scales to observe a second target (perhaps an AGN) while the co-aligned instrument viewing direction is occulted by the Earth. Consequently, OSSE will usually study two target sources per two-week interval, or approximately 52 targets per year. Thus, over the expected lifetime of GRO (possibly greater than 5 years), OSSE will have observed as many as 100 AGNs. Examples of the expected scientific results of such observations are presented below.

Table 1.
OSSE SUMMARY

Detectors	
Aperture Area (total):	2620 cm^2
Effective Area:	1920 cm^2 at 0.511 MeV
Field-of-View:	$3.8^\circ \times 11.4^\circ$ FWHM
Energy Resolution:	8.2% at 0.661 MeV
	3.8% at 6.13 MeV
Time Resolution:	4 sec in normal mode
	0.125 msec in pulsar mode
	4 msec in burst mode
Experiment Sensitivities (10^6 sec)	
0.1 - 10 MeV Line γs	~ 2 - 5 x 10^{-5} γ $cm^{-2}s^{-1}$
0.1 - 1 MeV Continuum	0.005 x Crab
1 - 10 MeV Continuum	0.05 x Crab
Gamma Ray Bursts	1 x 10^{-7} erg cm^{-2}
Solar Flare Line γs (10^3 sec flare)	1 x 10^{-3} γ $cm^{-2}s^{-1}$
Solar Flare Neutrons (>10 MeV)	5 x 10^{-3} n $cm^{-2}s^{-1}$

AGNS AND THE COSMIC DIFFUSE BACKGROUND

Surveys of AGN in the X-ray band show that they emit a significant fraction of their power in X rays and above. Consequently, the contribution of the summed emission from unresolved AGNs to the X-ray diffuse background has been a topic of interest since Setti and Woltjer (1973) first suggested that quasars would contribute much of the X-ray background if the X-ray to optical flux ratio observed for 3C273 was typical for quasars in general. The HEAO-1 and HEAO-2 missions have provided X-ray surveys which indicate that in the 2 - 10 keV range AGNs contribute ~20% of the observed cosmic diffuse background (Piccinotti *et al.* 1982).

At higher energies, the HEAO-1 mission observed the spectra of 12 AGN out to an energy of ~100 keV (Rothschild *et al.* 1983). These Seyfert galaxies had similar spectra which were well represented by power law model with photon index of ~1.6. Rothschild *et al.* (1983) use the AGN luminosity function from the 2 - 10 keV range (Piccinotti *et al.* 1982) with their average AGN high energy spectrum to estimate the AGN contribution to the cosmic diffuse background above 10 keV. Their result is shown in Figure 1 which displays the observed diffuse background and two estimates of the integrated AGN contribution with differing assumptions on the lower bound of the luminosity function used in the integral.

As can be seen in the figure, the hardness of the observed AGN spectra causes the AGN contribution to the diffuse background to grow with energy until it reaches and/or exceeds the observed diffuse background somewhere in

ORIGINAL PAGE IS
OF POOR QUALITY

the 100 keV to 4 MeV range. A softening or break in the spectra of AGN likely occurs in this energy range to prevent the integrated AGN flux from exceeding the gamma ray diffuse background. Above ~500 keV only four AGNs have been observed mainly by balloon experiments (see Bassani and Dean 1983). However, OSSE should be able to measure the spectra of ~ 30 - 100 AGNs in this energy range and thereby observe any softening in the spectra which would provide information on the AGN contribution to the γ ray diffuse background and perhaps provide insight into the fundamental energy source in AGNs. The OSSE observations of this number of AGNs might also provide a greater understanding of the differences in Type I and II Seyferts. If the main difference in these types is dust opacity, at γ-ray energies the dust may become optically thin so that both types have similar γ-ray characteristics. Figure 2 displays the OSSE sensitivity for 10^6 sec observations along with some of the AGNs measured by HEAO-1 and two high energy γ-ray measurements.

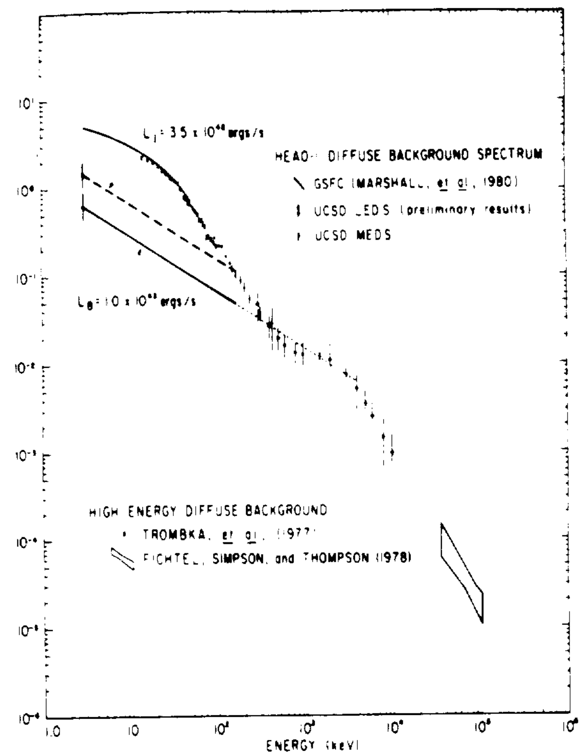

Figure 1. AGN Contribution to Diffuse Background (from Rothschild et al. 1983). Two estimates for the integrated power law contribution from unresolved Seyferts are displayed.

AGN TEMPORAL VARIABILITY

Active galactic nuclei have demonstrated temporal variability in X rays on time scales of days to months. Intensity variations by factors of 2 - 100 have been reported. At gamma-ray energies there are many fewer observations and, consequently, only variations of NGC 4151 have been reported (Perotti *et al.* 1981). The time scales of the variations are generally taken as evidence for association of the emission with the central power source of the AGN. The model of accretion onto a massive black hole provides some interesting predictions which OSSE can address in its observations of AGN. One example of the variability is in the form of Penrose Compton Scattering (PCS) transients as proposed by Leiter and Boldt (1989).

Penrose Compton Scattering (Figure 3) occurs in the ergosphere around a Kerr black hole when blue shifted photons from the accretion disk scatter off of infalling electrons and escape with increased energy as high as 2.7 MeV. The emission is beamed relative to the accretion disk and the spectrum of the emitted gamma rays is essentially flat from 300 keV to ~ 3 MeV with a kinematic cut-off controlled by the electron rest mass. Leiter and Boldt (1989)

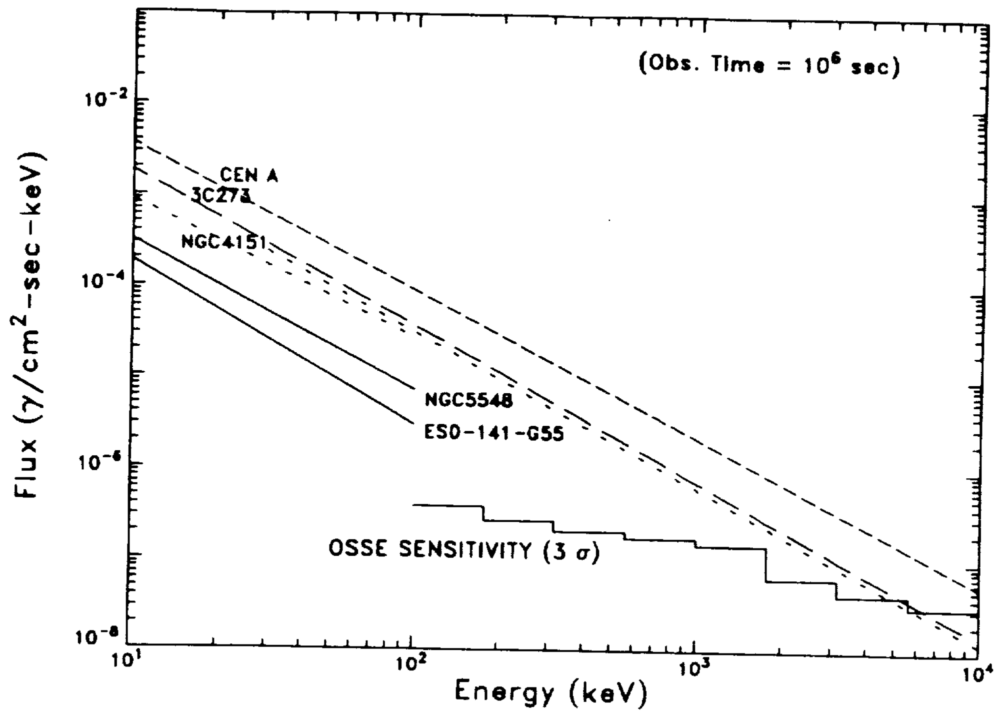

Figure 2. OSSE continuum sensitivity and X-ray and gamma-ray measurements of several AGN.

have suggested this mechanism as an alternate explanation for the "bump" in the diffuse background spectrum at a few MeV (see Figure 1). The duration of a PCS gamma-ray transient is associated with the time required for a plasma blob in the accretion disk to cross the Penrose target region and is on the order of hours.

Leiter (1980) predicts that for NGC 4151 PCS transients of 2.2 hour duration with few percent duty cycle should be observed. These individual outbursts from NGC 4151 in the 300 keV - 3 MeV range should be detectable by OSSE. Detection of these events from several AGN displaying the same cutoff energy would not only confirm the Penrose Compton Scattering theory but also address the possibility of the PCS explanation for the MeV "bump" in the diffuse background spectrum.

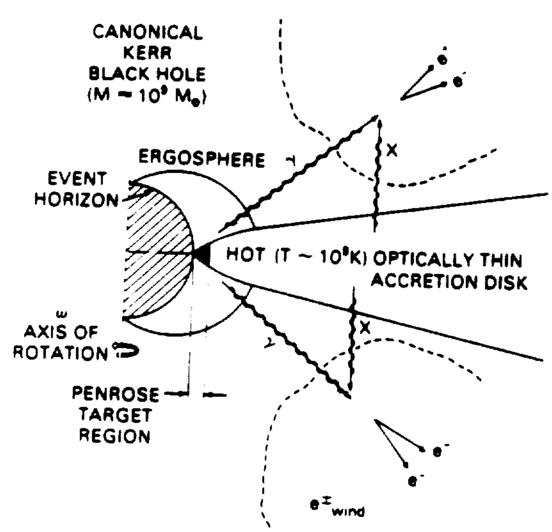

Figure 3. Penrose Compton Scattering of gamma rays from accretion disk around a Kerr black hole. From Leiter and Boldt (1989).

OBSERVATION PLAN

The observing plan for GRO is determined well in advance with scientific priorities identified by the GRO science teams, the GRO Users Group, and the user community via the GRO Guest Investigator Program. The primary objective of the initial 15 months of the GRO mission is to provide a full sky survey with the EGRET and COMPTEL broad field of view instruments. This shall consist of ~30 two-week observations designed to give uniform sky coverage. For each observation period, OSSE will select two targets from its catalogs for study. The desire for uniform sky coverage provides ample opportunity for OSSE observations of AGN. Table 2 summarizes the OSSE AGN targets which are currently planned for the first 15 months of the mission. The final observing plan for GRO depends on the actual launch date so that this list of AGNs will likely undergo minor changes until the launch date of GRO is fixed. The final plan is expected to be available two months before launch. OSSE expects to make significant contributions to the understanding of AGNs from the observations of these 20 sources as well as from many other sources in the subsequent years of the GRO mission.

TABLE 2.
OSSE AGN Targets
(1st 15 months of GRO Mission)

Target	Class[1]	Target	Class[1]
M82	2	PKS 2155-304	3
CEN A	1	MRK 590	1
3C 273	4	3C 390.3	1
M87	1	3C 120	1
NGC 5548	1	MCG 8-11-11	1
NGC 4151	1	PKS 0521-365	3
3C 317	1	MRK 279	1
NGC 1275	1	MRK 421	3
III ZW2	1	NGC 5506	2
MRK 335	1	ESO-141-G55	1

[1]Classes: 1) Type 1 Seyferts, Radio Gal; 2) Type 2 Seyferts, Starburst, NELG; 3) BL Lacs; 4) Quasars

REFERENCES

Bassani, L., A.J. Dean 1983, *Space Sci. Rev.*, **35**, 367.

Johnson, W.N., *et al.* 1989, *Proceedings of the Gamma Ray Observatory Science Workshop*, NASA/GSFC, 2-22.

Leiter, D. 1980, *Astron. Astrophys.*, **89**, 370.

Leiter, D., E. Boldt 1989, *Proceedings of the Gamma Ray Observatory Science Workshop*, NASA/GSFC, 4-14.

Perotti, A., *et al.* 1981, *Ap. J. (Letters)*, **247**, L63.

Piccinotti, G., R.F. Mushotzky, E.A. Boldt, S.S. Holt, F.E. Marshall, P.J. Serlemitsos, R.A. Shafer 1982, *Ap. J.*, **253**, 485.

Rothschild, R.E., R.F. Mushotzky, W.A. Baity, D.E. Gruber, J.L. Matteson, L.E. Peterson 1983, *Ap. J.*, **269**, 423.

DISCUSSION

Chuck Dermer:

Please comment on a recent reanalysis of SAS-2 data by Young and Yu (Ap.J. 330, L5, 1988), in which they claim detections of 129 quasars and 7 seyfert galaxies.

Carl Fichtel:

There seems to be no solid justification for these claims in the SAS-2 data. You may wish to refer to the SAS-2 catalog. Added comment by David Thompson - the statistics of the SAS-2 catalog are too small to support such detections, in many cases involving only a few photons.

Extragalactic Diffuse Radiation