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CORRELATED OPTICAL OBSERVATIONS WITH BATSE/CGRO ON SCO X-1

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Introduction

The Burst and Transient Source Experiemnt (BATSE) instrument on the Compton Gamma-Ray Observatory consists of two banks of eight instruments referred to as the Large Area Detectors (LADs) and the Spectroscopic Detectors (SDs). Each LAD crystal is 50.8 cm in diameter by 1.27 cm thick while for a SD these values are 12.7 cm in diameter by 7.62 cm in diameter. Both the LADs and SDs are NaI(Tl) scintillation detectors. The LADs and SDs are situated on the CGRO spacecraft so as to provide all sky coverage for both sets of detectors. The SDs have the ability to measure energies in the 8-16 keV range whereas the minimum energy at which the LADs operate is near 20 keV.

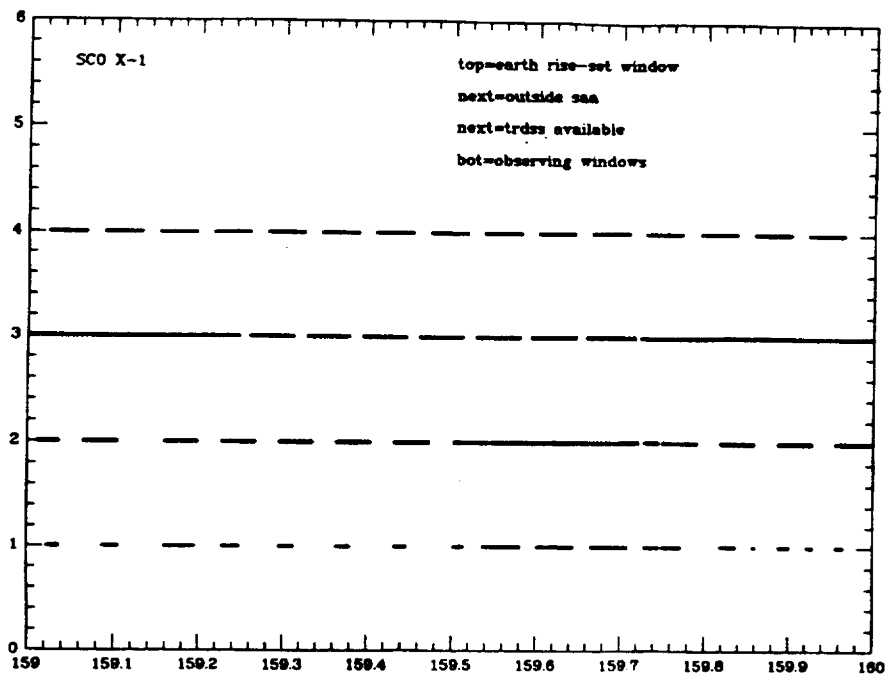
Sco X-1 is the brightest continuous X-ray source in the sky. It is believed to consist of a low mass star orbiting and transfering mass onto a neutron star. It is representative of a class of similar objects referred to as low mass X-ray binaries (LMXB). Because Sco X-1 serves as the proto-type of this class of X-ray emitters and since its detectable emission is so large, it warrants extended study.

One of the most fruitful techniques of studing a LMXB system is by simultaneously monitoring its emission at a variety of different wavelengths. These correlated datasets can be used to probe the source environment, investigate emission mechanisms, and examine the mass transfer process itself. In principle, the BATSE SDs have the capability of providing a nearly continuous 8-16 keV record of Sco X-1 activity. The aim of this study was to investigate the feasibility of using the BATSE SDs along with simultaneous optical measurements to study this source.

Observational Considerations

In order to obtain simultaneous ground-based optical data with BATSE, three satellite related constraints must be considered. Satellite observations are only possible (1) when Sco X-1 is unobscured by the earth, (2) when the satellite is outside the South Altantic Anomaly (SAA), and (3) when TDRSS is available to transmit data to ground-based facilities. Each of these constraints influences the extent of the joint optical/high energy observational windows. An example of this is shown in figure 1. From top to bottom, the solid lines indicate when Sco X-1 is observable by CGRO, when the satellite is outside of the SAA, when TDRSS communication is available, and finally the extent of the simultaneous optical and 8-16 keV windows. Typically, notification of guaranteed TDRSS availability proceed the actual observational dates by a only few days. SAA passage times are available for up to two week intervals and earth rise, set times can be predicted to an accuracy of about 30 seconds one week prior to a desired date of joint observations. The ability to plan joint observations is thus limited to a few days prior to the actual observational date by the TDRSS notification time.

Figure 1



Measuring the 8-16 keV Sco X-1 Signal Strength

Because of space limitations this section will deal only with the acquisition of the Sco X-1 8-16 keV data. This can be measured in two different fashions. The most straight forward procedure involves measuring the step in the received signal as Sco X-1 rises and sets over the Earth's limb. This is the procedure used by the BATSE team to measure the flux detected by the LADs for a number of astronomically interesting sources. An extension of this procedure to a SD is fairly straight forward. We have written a number of software programs that measure the Sco X-1 step size in the SD flux data. In addition to these values, the flux during the interval between earth rise and earth set can be approximately measured. In order for this information to be obtained, one must subtract the 8-16 keV background signal from the observed flux. Two techniques were developed for this purpose. The first technique models the background using a 3rd order polynomial fit in terms of the cosine of the angle between the detector normal and the center of the earth. In principle this procedure should work quite well because the cosmic 8-16 keV radiation is highly modulated by earth blockage and is the major background contributor. If flux measurements are available over a significant portion of the orbit prior to the rise of Sco X-1, this procedure indeed allows one to estimate and thus subtract the background contribution during those times when Sco X-1 is in the field of view of a SD.

The second technique for subtracting the background is less model sensitive but relies upon the assumption that over the course of a few hours, the cosmic background 8-16 keV radiation remains constant within orbital position. This assumption essentially states that one can use a past orbit to predict the background contribution in a subsequent orbit. If the time span is only a few hours, this assumption appears to be valid. A second, more dangerous, assumption must also be made as part of this technique. That is, that during some orbits the 8-16 keV emission from Sco X-1 is constant. This latter assumption has been tested using BATSE SD data and appears to be valid. Background subtraction is then accomplished by using an orbit which shows no Sco X-1 activity as a reference and subtracting it from a nearby orbit in which Sco X-1 is active. The flux level of the subtracted signal can then be adjusted using the measured Sco X-1 step size from the reference orbit.

Results and Conclusions

Figures 2 and 3 show the correlated optical and BATSE 8-16 keV SD signal for the days TDJ 8791 and 8811. The optical data (top portion of each figure) shows that during these periods Sco X-1 was in a flaring state. The BATSE 8-16 keV light curve (bottom portion of each figure) closely tracks the optical data.There appears to be a slight time delay (seconds) between the two light curves in the sense that the optical activity follows the higher energy signal. This is what one would expect if the optical signal represents reprocessed high energy photons, presumably from an accretion disk surrounding the neutron star. If the optical signal indeed arises from an accretion disk, then one might also expect the optical signal to be smeared (of longer time duration) than the high energy signal. At this point data analysis is not sufficiently advanced to state whether this smearing is present or not. A second interesting feature seen in both figures is that the optical and high energy continuum radiations are not correlated. This may be due to inadequacies in the background subtraction model which veil this correlation or it may be due to the fact that optical continuum variations reflect a longer term response to the high energy variations.

Figure 2

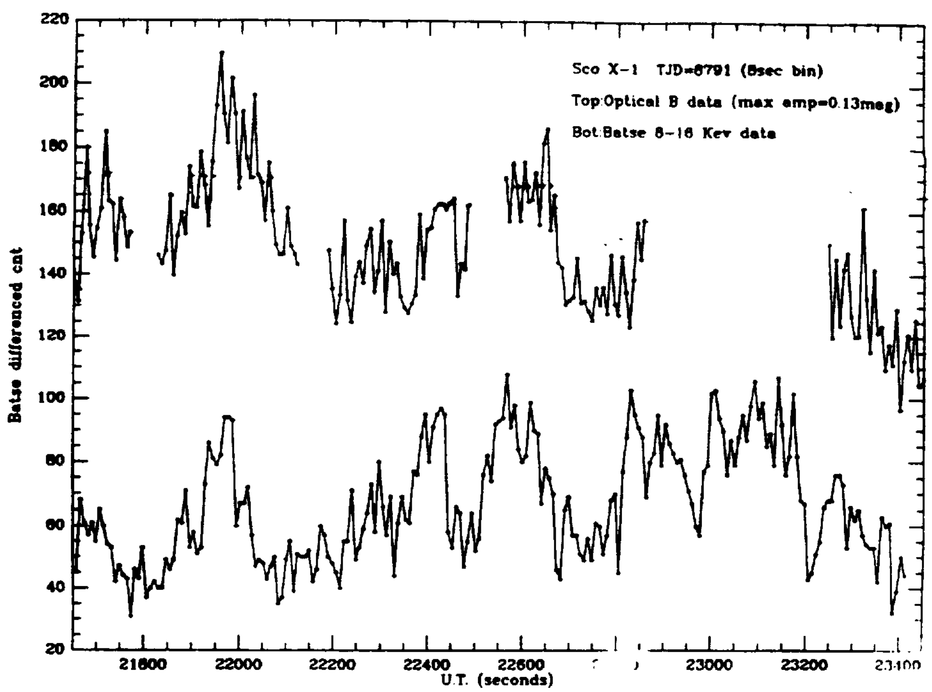


Figure 3