Fermi Gamma-Ray Burst Monitor Analysis of the Hard X-Ray / Soft Gamma-Ray Sky Using the Earth Occultation Technique

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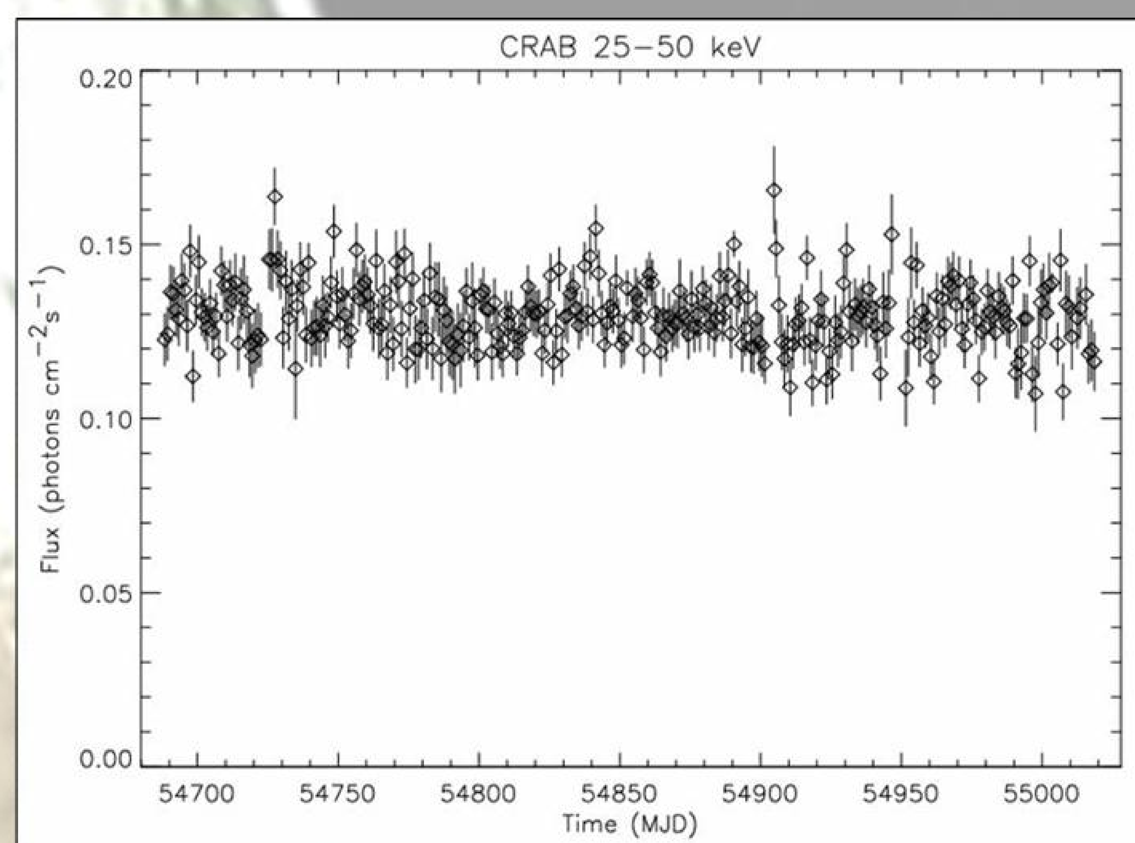
1. Abstract

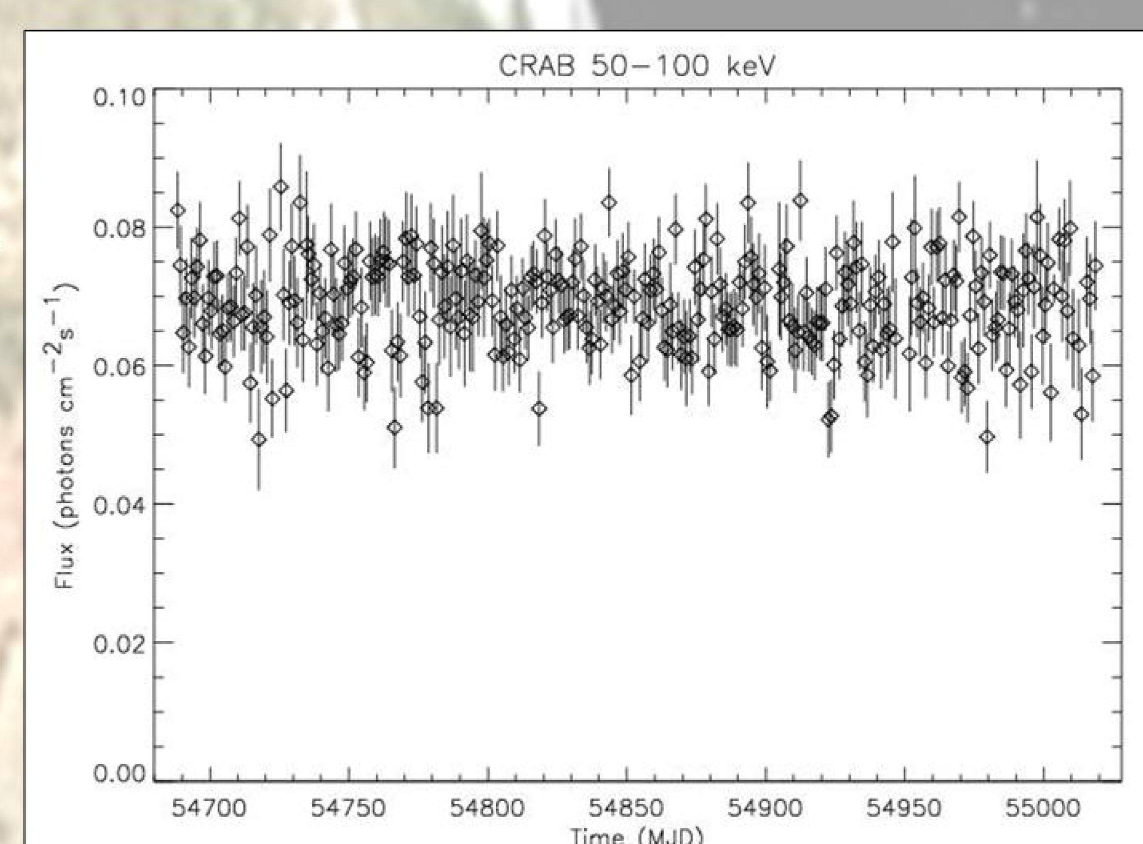
In astronomy, the term occultation is used to describe an event in which a source object is blocked from view by another object that passes between the source and an observer. Such events are important because they provide a direct and easy means for accurately determining the fluxes of sources. In our research, the hard X-ray / soft gamma-ray sky was monitored using the Earth occultation technique (EOT). This process makes use of the fact that sources are continuously occulted by the Earth due to the regular orbits of observational satellites. As a result, *steps* in the measured count rates are observed both before and after source objects are occulted. The count rates in our research were measured by two different Gamma-Ray Burst Monitor (GBM) detectors on-board the Fermi satellite. The sodium iodide (NaI) scintillation detectors monitored the energy range from approximately 8 keV to approximately 1 MeV while the bismuth germanate (BGO) scintillation detectors covered the range from approximately 150 keV to approximately 30 MeV. By fitting the detector backgrounds and measuring the differences in count rates before and after occultation, fluxes of the occulted sources were able to be determined. In addition, light curves for the individual sources were able to be produced allowing us to compare our results with those from other instruments and evaluate the effectiveness of the EOT.

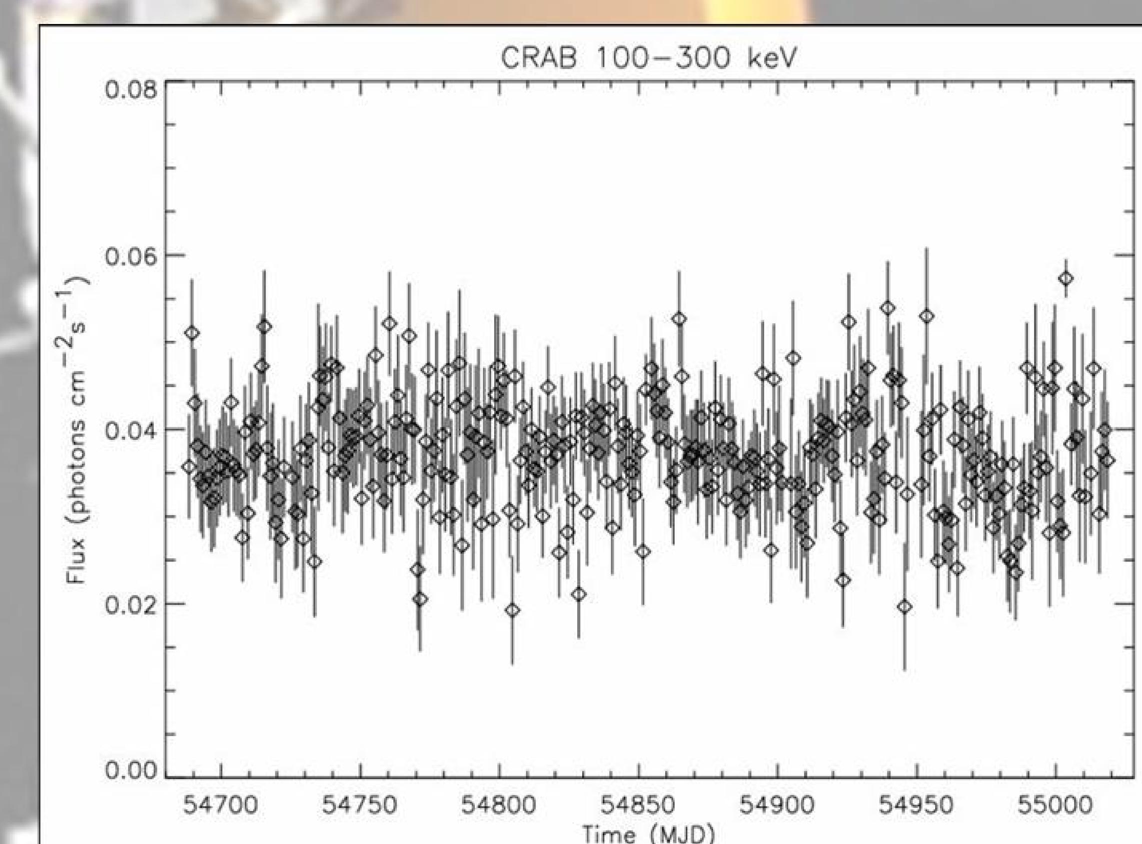
2. Purpose

- The purposes of GBM include, but are not limited to, the following:
  - Complementing the Large Area Telescope (LAT), also on-board Fermi, in its observations of gamma-ray bursts and other transient sources;
  - Providing a better understanding of the physical processes that result in X-ray and gamma-ray emission.
- The purposes for studying occultations include, but are not limited to, the following:
  - Detecting outbursts and flares that pointed satellites miss;
  - Letting other research teams know when the states of sources have changed;
  - Allowing correlated observations to be made with other wavelength bands (pointed observations may be made by more sensitive instruments in other wavebands when a source is in an "interesting" state);
  - Discovering new sources of gamma-ray emission.

Source Being Occulted by the Earth







The plots above were generated using 10 months of data collected by the NaI detectors on GBM. Each point represents a daily flux value obtained by averaging all of the flux values for a source found in a given day. The source above was the Crab Pulsar, a relatively young neutron star. As illustrated by the graphs, the pulsar is still detectable in the 100-300 keV energy range.

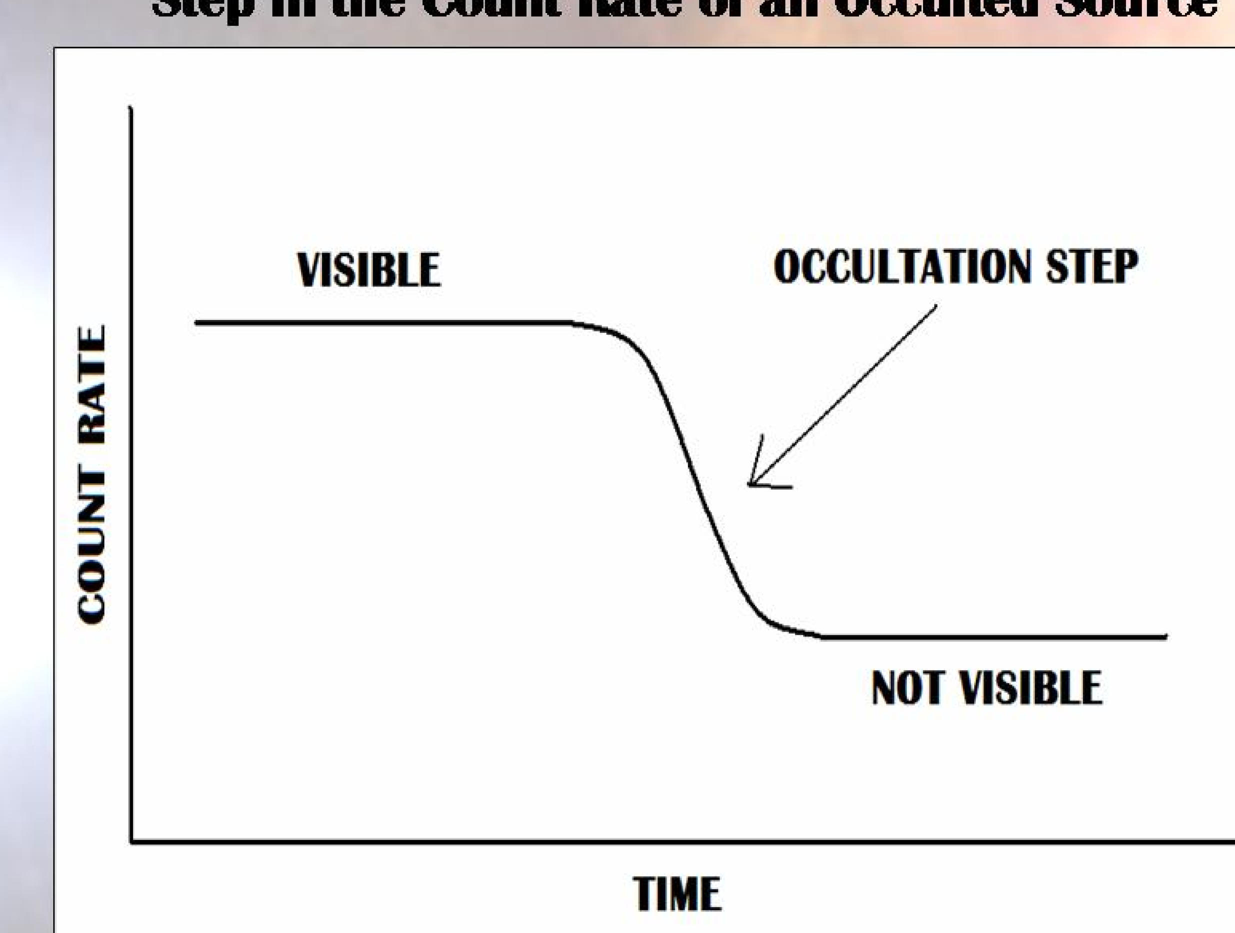
3. Advantages

- The EOT provides an easy way for determining the fluxes of sources. GBM is able to measure count rates of sources without any sort of imaging like coded masks or focusing optics.
- GBM is an all-sky monitor, meaning that it views the entire unocculted sky at any instant. This characteristic allows GBM to observe unpredictable events that other imaging and collimated instruments miss.
- GBM is able to *look back in time* for flaring events reported by other instruments. This fact is important because GBM can view data at the time of the flare even if it occurred years earlier.
- GBM is the only all-sky monitor that detects energies well above 100 keV. For this reason it is able to observe high-energy sources that other instruments are not sensitive to.

4. Methodology

- The time at which a source will be Earth-occulted is computed using an oblate Earth model, the spacecraft position in time, and the direction to the source from the spacecraft.
- Once the occultation time is known, a window of data is chosen from the NaI detectors that see the source to within 60 degrees of face on (90 degrees of face on for the BGOs). Data is collected approximately 120 seconds before and after the occultation step (see diagram below) and fit with a variety of models.
- Once the best fit to the data is determined using a chi-square test, the data (still in count rates) from all included detectors is converted to flux using another model and various computations.
- This technique is used for both the NaI detectors as well as the BGO detectors albeit with different energy bands depending on the detector type.

Step in the Count Rate of an Occulted Source



5. Conclusions

- The EOT provides a direct and easy method for determining the flux of transient sources because it does not require imaging.
- By using the EOT a better understanding of the physical processes that drive the observed X-ray and gamma-ray emission can be gained.
- By producing light curves for a variety of sources and comparing the results with those from other instruments it is possible to evaluate the effectiveness of the EOT.
- Because GBM is an all-sky monitor and capable of observing at energies well above 100 keV, the spacecraft is able to detect unpredictable outbursts, energetic flares, and new sources of gamma-ray emission.

Acknowledgments: Special thanks to Dr. Colleen A. Wilson-Hodge and the entire GBM team at the National Space Science and Technology Center (NSSTC). Also special thanks to Dr. Frank Six, Dr. Gerald Carr, and the entire NASA Academy at Marshall Space Flight Center (MSFC).