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Ulysses/BATSE Observations of Cosmic Gamma-Ray Bursts

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ABSTRACT

The gamma-ray burst detector aboard the ESA-NASA Ulysses spacecraft, in operation since November 1990, has detected numerous gamma-bursts in conjunction with the BATSE experiment aboard the Compton Observatory. We present initial results on burst locations for three events (April 21, May 2, and May 3 1991) obtained by arrival time analysis, and compare them with the BATSE locations. The arrival time analysis annuli have typical widths of 5'. Our preliminary analysis indicates that both experiments are likely to have unresolved systematic errors, but that further work will improve the location accuracy substantially.

INTRODUCTION

The Ulysses gamma-burst experiment is the farthest point from Earth in the 3rd Interplanetary Network (presently consisting of a cluster of near-earth spacecraft including the Compton Observatory, with Pioneer Venus Orbiter and Ulysses as interplanetary spacecraft). A full description of the Ulysses mission and its investigations is currently in press (see, e.g., Hurley et al., 1991). Briefly, the burst detectors are two NaI(Tl) hemispherical crystals, 3 mm thick by 51 mm in diameter, coupled to two photomultiplier tubes. They cover the energy range from about 20 to 150 keV, using fast memories to record gamma-bursts with up to 8 ms resolution. They achieve a sensitivity of around 10^{-6} ergs/cm^{2}s, view 4π sr., and have a duty cycle exceeding 90%. Because the Ulysses mission passes by Jupiter and out of the plane of the ecliptic, the Earth-Ulysses baseline is the longest that has ever been achieved for gamma-ray burst studies, and the resulting localization accuracy is of the order of arcminutes or less. Here we discuss the intial results obtained for the localization of 3 events which occurred shortly after the launch of the Compton Observatory.

OBSERVATIONS

The three events we present here are among the very first dozen or so found in an initial search of the Compton and Ulysses data; they occurred on April 21, 1991 around 09:14 UT, on May 2, 1991 around 22:37 UT, and on May 3, 1991 around 07:04 UT (Earth-crossing times). Pioneer

Venus Orbiter may have recorded a rate increase at the time of the first event, but was off during the second and third bursts (J. Laros, private communication). However, the May 3 burst was also observed by the COMPTEL (Schonfelder, 1991) and EGRET (Schneid, 1991) experiments. The Compton Observatory/Ulysses distances ranged from about 1380 to 1520 light-seconds for these observations.

In each case, we have used the BATSE and Ulysses time histories to construct an annulus of arrival directions. The assumed timing uncertainties used were ±300 ms, with an approximately equivalent amount of uncertainty assumed for the Ulysses spacecraft location, taken from predict orbit tapes. Both of these uncertainties can be considerably reduced: the final timing to perhaps ±50 - 100 ms., and the spacecraft position to a completely negligible amount. Thus the widths of the annuli will eventually shrink by a factor of up to 6, to the <1' range.

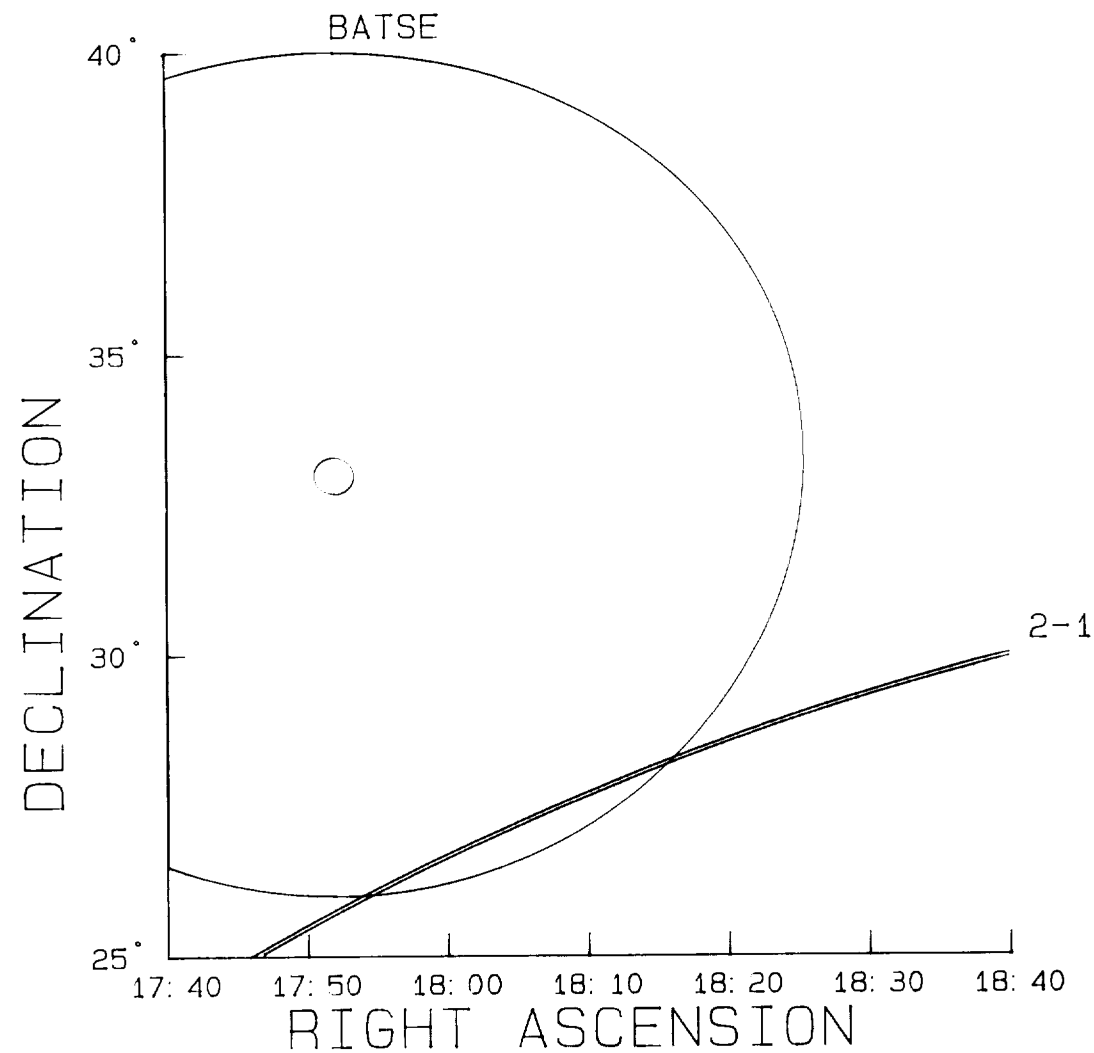

Figure 1. Sky map for the April 21, 1991 burst. "2-1" is the Ulysses-BATSE annulus. Two BATSE error circles are also indicated; the inner circle takes only the formal statistical errors into account, while the outer circle is for estimated systematic errors.

Figures 1 and 2 show the regions around the BATSE locations of the April 21 and May 2 events, and Figure 3, for the May 3 event, includes the COMPTEL error box (Schonfelder, 1991). In all cases, two BATSE error boxes are shown, one taking only the formal statistical errors into account, and the other, estimated systematic errors. The Ulysses-BATSE annuli include the uncertainties mentioned above; the resulting annulus widths are around 4', 3', and 6' in these figures, respectively.

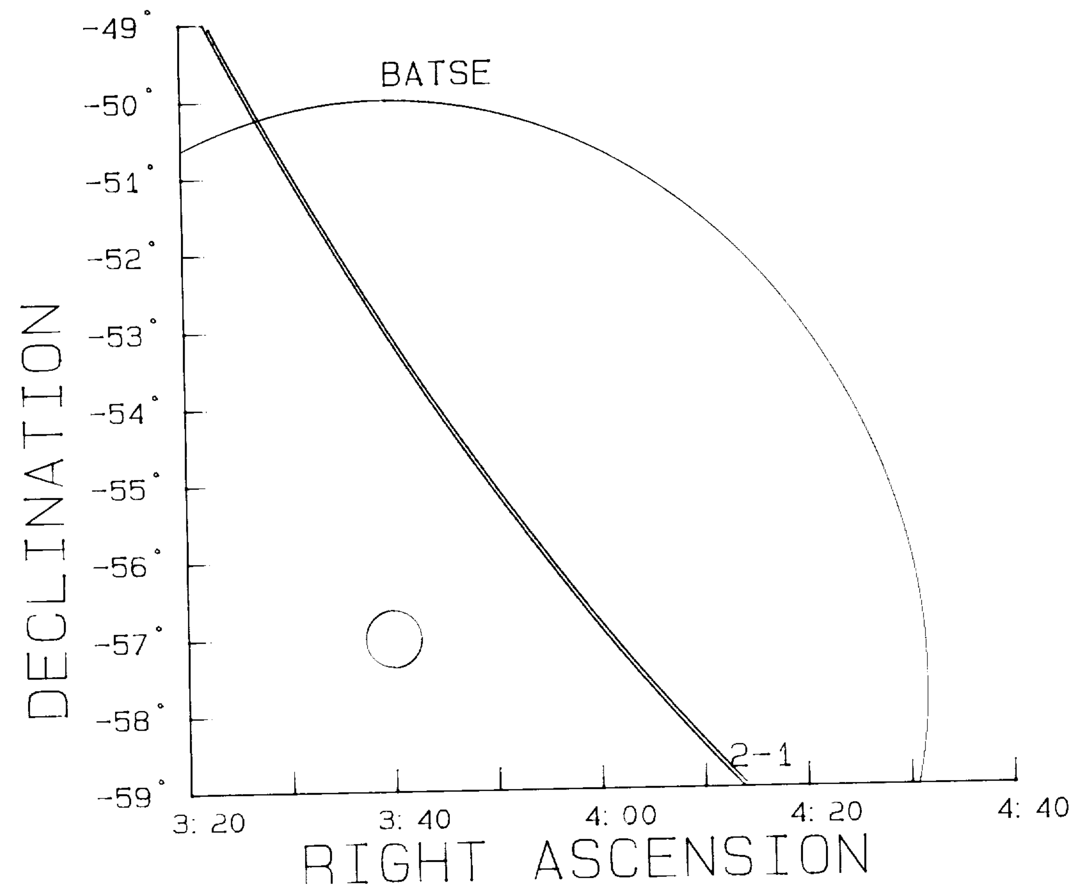

Figure 2. Sky map for the May 2, 1991 event. "2-1" is the Ulysses-BATSE annulus. Two BATSE error circles are also shown; the inner circle includes only statistical errors, while the outer circle is for estimated systematic errors.

DISCUSSION AND CONCLUSION

The initial results presented here indicate that the centers of the error boxes obtained by the BATSE experiment alone are up to several degrees from the Ulysses/BATSE arrival time annuli. We attribute these differences to unresolved systematic errors. In the case of BATSE, these include the effects of atmospheric and spacecraft scattering, which can be corrected by semi-empirical modeling. In the case of Ulysses, they include spacecraft location uncertainties and systematic timing errors. Both of these can be reduced considerably: the spacecraft range is now known to an accuracy of several kilometers, and the right ascension and declination to about 500 nanoradians. The timing is currently verified to an accuracy of around 100 ms, and ultimately can be demonstrated to be accurate to about 1/10th this amount. An annulus-only location does not determine a unique position for the BATSE error box, but rather, only a minimum error. We are currently localizing a number of PVO/BATSE/Ulysses bursts to resolve this uncertainty.

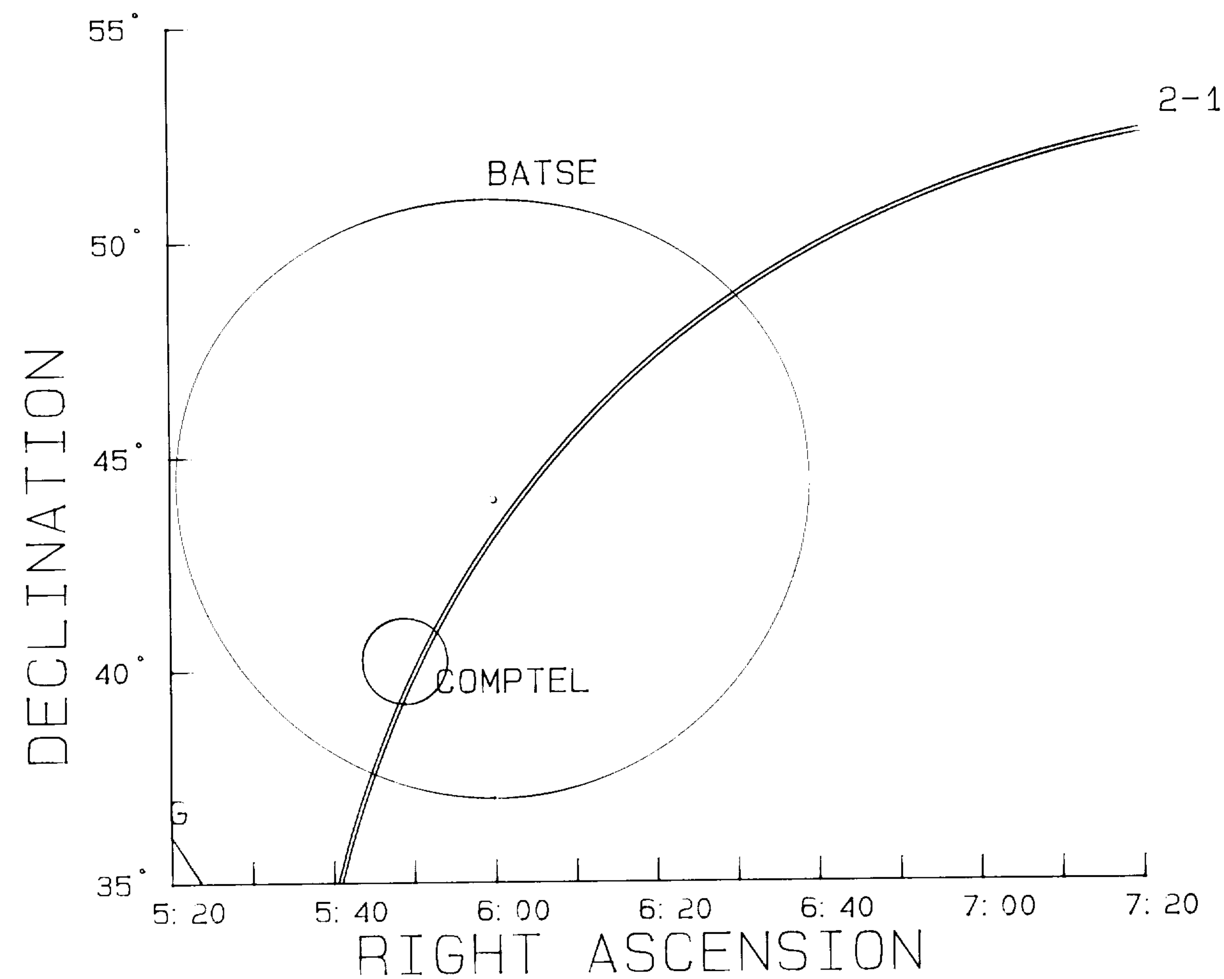

Figure 3. Sky map for the May 3, 1991 burst. "2-1" indicates the Ulysses/BATSE arrival time annulus. Two BATSE and one COMPTEL (Schonfelder, 1991) error boxes are indicated. The inner BATSE error circle takes only formal statistical errors into account; the outer circle is for estimated systematic errors. "G" is the galactic plane.

ACKNOWLEDGMENTS

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