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FOLLOW-UPS TO FERMI GBM GAMMA-RAY BURSTS

V. Connaughton,[1] A. Goldstein,[2] and M. S. Briggs[1]

RESUMEN

El Monitor de Rayos Gamma (GBM) de Fermi, ha estado detectando 240 Estallidos de Rayos Gamma (GRBs) por año desde 2008, 40-45 de ellos GRBs cortos. GBM es un instrumento de fuentes transitorias de todo cielo en rayos X duros que opera entre 8 keV y 40 MeV (Meegan et al. 2009). GBM localiza las fuentes triangulando la posición más probable basándose en tasas de conteo en detectores con distintas orientaciones al cielo. Las posiciones de los GRBs son diseminadas usando avisos en la Red de Coordenadas de GRB (GCN). Aquí reportamos un análisis de más de 300 localizaciones de GRB para las cuales se conocen posiciones más precisas. Incertidumbres sistemáticas de $2-4^\circ$ afectan a casi el 90% de las localizaciones de GBM (68% de nivel de confianza), con efectos sistemáticos más grandes para el 10% restante. Estos componentes sistemáticos son añadidos en cuadratura a las incertidumbres estadísticas de $1-\sim 10^\circ$ y son facilitados como mapas de probabilidad a la comunidad de seguimiento en una hora o menos después del disparo del GRB. El intermediario "Palomar Transient Factory" ha utilizado estos mapas para detectar tres posluminiscencias usando la información de posición del GBM.

ABSTRACT

The Fermi Gamma-Ray Burst Monitor (GBM) has been detecting 240 Gamma-Ray Bursts (GRBs) per year since 2008, 40-45 of them per year short GRBs. GBM is an all-sky transient monitor of the hard X-ray sky operating between 8 keV and 40 MeV (Meegan et al. 2009). GBM localizes sources by triangulating the most likely source position based on observed count rates in detectors with different orientations to the sky. GRB locations are disseminated using GRB Coordinate Network (GCN) notices. We report here an analysis of over 300 GBM localizations for which more accurate positions were known. Systematic uncertainties of about $2-4^\circ$ affect about 90% of GBM localizations (68% confidence level), with larger systematic effects for the remaining 10%. These systematic components are added in quadrature to the statistical uncertainties of $1-\sim 10^\circ$ and provided as probability maps to the follow-up community an hour or less after the GRB trigger. The intermediate Palomar Transient Factory has used these maps to detect three GRB afterglows using the GBM positional information.

Key Words: gamma-ray bursts: general — methods: statistical

1. FERMI GBM LOCALIZATIONS OF GRBS

GBM triggers on a GRB when count rates in two or more of its 14 detectors significantly exceed background levels on one or more timescales from 16 to 4096 ms, usually in the 50 - 300 keV energy range. Other triggering energy ranges provide sensitivity to a variety of transient phenomena: solar flares and soft gamma-ray repeaters at the low end and terrestrial gamma-ray flashes at higher energies.

Source localization is done by minimizing χ^2 on a grid of 41168 points on the sky, comparing the observed background-subtracted count rates in each of the detectors with model rates obtained by convolving the detector response with representative GRB spectra. Locations are produced on-board, by the flight software, and on the ground, from data downlinked within seconds of the GRB trigger (ground-auto) or with a larger data set and human intervention (human-in-the-loop, or HitL). Flight software and ground-auto locations are distributed as GCN notices from $10-\sim 45$ s following the trigger, with ground-auto locations being significantly more accurate. The HitL locations have latencies from 20 min to over an hour following the trigger and are also distributed as GCN notices. The suite of localizations, from flight software to human-in-loop, allows the follow-up community to optimize their observation strategy, with wide-field instruments, capable of rapid response but shallow coverage, more suited to chasing the automated locations, and more sensitive instruments that are less capable of covering large sky areas waiting for the HitL locations.

[1]University of Alabama in Huntsville, 320 Sparkman Drive, Huntsville, AL 35899, USA.

[2]NASA Postdoctoral Program fellow, NASA Marshall Space Flight Center, AL 35899, USA.

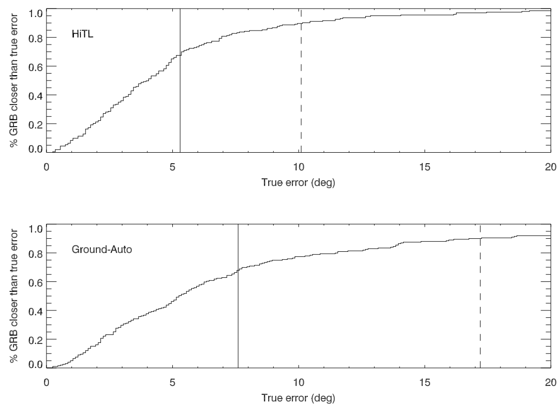

Fig. 1. Accuracy of GBM localizations. The cumulative distributions show the fraction of GBM localizations as a function of offset in degrees from a known GRB location. The solid and dashed vertical lines show, respectively, the containment radius for 68% and 90% of the reference positions. The top panel is for the HitL locations, the bottom for the latest ground-auto location.

We use 203 GRBs localized by *Swift*, LAT, INTEGRAL, MAXI and SuperAGILE to analyze the accuracy of GBM GRB localizations. Figure 1 shows the fraction of GRBs as a function of the distance from the known position for the HitL and ground-auto locations, regardless of the reported uncertainty on the localization. It can be seen that 68% of the ground-auto locations lie within 7.6° of the true position, with 90% within about 17°. The more refined HitL positions are significantly more accurate, with 68% within 5.2° of the true position and 90% within 10°, at the cost of a longer latency of at least 20 minutes. If one considers the reported statistical uncertainties, then for both the ground-auto and the HitL localizations, the 68% uncertainty regions contain the true position ∼40% of the time and the 95% uncertainty regions contain 70% of the GRB positions. This implies there is a systematic component to the total uncertainty on the calculated burst position.

2. SYSTEMATIC AND TOTAL ERRORS ON GBM LOCALIZATIONS

A Bayesian approach to find a model characterizing the systematic uncertainties (Briggs et al. 1999) was then applied to the GRBs with reference locations (including an additional 109 GRBs with triangulations from the InterPlanetary Network). A preference was found for a model that puts about 90% of GRB localizations in a core with a systematic uncertainty modeled by a Gaussian centered on

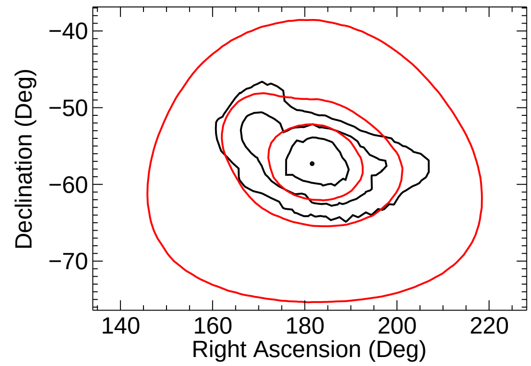

Fig. 2. Probability map for the localization of GRB 080714745, with the statistical uncertainty contours (black) overplotted with the total uncertainty using the best model defined in Connaughton et al. (2014). The contours are 68%, 95%, and 99.8% confidence level regions around the χ^2 minimum from the GBM localization process.

$3.7° \pm 0.2°$. The tail is modeled by a Gaussian centered on $14.3° \pm 2.5°$. We find a dependence for the systematic error in the core of the sample on the burst geometry in the spacecraft frame. Bursts from directions along the $\pm Y$ axes have smaller errors ($2.3° \pm 0.4°$) than those incident along the $\pm X$ axes ($4.1° \pm 0.3°$), with the fraction of GRBs in the core and the errors in the tail similar for both geometries (Connaughton et al. 2014).

The geometry-dependent core-plus-tail systematic error model has been convolved with the statistical uncertainty from the χ^2-minimization process to produce probability maps for each GRB localized by GBM since January 2014. Figure 2 shows an example of the maps with the contours containing the 68%, 95%, and 99.8% probability for a GRB with a large statistical uncertainty. These maps and the ASCII data for the probability contours populating them are now uploaded to the Fermi Science Support Center upon production of the HitL location [3]

REFERENCES

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M. S. Briggs et al., 1999, ApJS, 503, 122
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[3] `http://heasarc.gsfc.nasa.gov/FTP/fermi/data/gbm/triggers/yyyy/bnyymmddfff/quicklook/` where yyyy, mm, dd, fff are the year, month, day, and fraction of day for the GRB trigger e.g., `http://heasarc.gsfc.nasa.gov/FTP/fermi/data/gbm/triggers/2014/bn140122597/quicklook/glg_locplot_all_bn140122597.png`.