SEARCH FOR A RADIO COUNTERPART TO GRB 940301 WITH WESTERBORK

L.O. HANLON* and K. BENNETT
Astrophysics Division, ESTEC, Noordwijk, The Netherlands
T. GALAMA
Astronomical Institute 'Anton Pannekoek', Amsterdam, The Netherlands
and
T. A. TH. SPOELSTRA
NFRA Radio Observatory, Dwingeloo, The Netherlands

Abstract. The COMPTEL instrument onboard the *Compton* Gamma–Ray Observatory imaged the bright gamma–ray burst GRB 940301 within 1.6 hours of the event, with a mean 1σ error radius of 1.5°. The error region was subsequently refined by combining the COMPTEL location with the arc derived from differences in the event arrival time at the Ulysses and BATSE detectors. Westerbork observations of the COMPTEL error region began on March 4 1994 at 21 cm, however coverage of the refined position was not obtained until 32 days after the GRB occurrence, by which time the operating wavelength had changed to 92 cm. We have constrained the level of variability of sources within the triangulation arc-COMPTEL 2σ error box region to be less than 40 mJy (5σ upper limit) at 92 cm 41 days after the burst.

Key words: Gamma–ray bursts – Counterparts – Radio

1. Introduction

The sources of gamma–ray bursts (GRBs), the most prolific yet short-lived species in the γ–ray sky, remain unknown. To date there has been no confirmed detection of a GRB at longer wavelengths, making determination of their distance highly model dependent. Historically, searches for GRB counterparts have principally employed two strategies - deep searches for quiescent counterparts to accurately localised events [1] and serendipitous simultaneous searches using, for example, meteor patrol plates [2]. The latest counterpart search technique is to begin observations within hours or days of the event, using rapidly determined positions from BATSE via the BACODINE system (~10° error radius) [3] or from COMPTEL via the Rapid Response Network (~2.5° error radius) [4]. Such flaring and/or fading emission has been predicted at all wavelengths from a variety of mechanisms [5]. Of particular relevance for the present study is the prediction of transient radio emission resulting from the interaction of relativistic ejecta with the interstellar medium [6].

We report here preliminary results from a search for a radio counterpart to GRB 940301 using the Westerbork Synthesis Radio Telescope (WSRT).

* Also: University College, Dublin

The WSRT is an E–W array consisting of 10 fixed and 4 moveable parabolic dishes, each 25 m in diameter. Of the five operating wavelengths, 6 cm, 21 cm and 92 cm are the most commonly used. The theoretical continuum sensitivity at these wavelengths is 0.07 mJy, 0.05 mJy and 0.5 mJy per beam respectively, for a full 12 hour observation. The field sizes (Half Power Beam Width, HPBW) are relatively large ($0.17°$, $0.6°$ and $2.6°$ for the quoted wavelengths) which makes the WSRT a potentially valuable facility for the rapid surveying of GRB error boxes.

2. Observations and Data Reduction

The COMPTEL instrument onboard the *Compton* Gamma–Ray Observatory imaged the bright gamma–ray burst GRB 940301 within 1.6 hours of the event, with a mean 1σ error radius of $1.5°$ [7]. The error region was subsequently refined by combining the COMPTEL location with the arc derived from differences in the event arrival time at the Ulysses and BATSE detectors. This burst is of particular interest since there is evidence to suggest it is a repetition of a previously detected GRB [7, 8].

Westerbork observations of the COMPTEL error region began on March 4, 1994 at 21 cm. However, coverage of the refined position was not obtained until 32 days after the GRB occurrence, by which time the operating wavelength had changed to 92 cm (Figure 1).

The 92 cm (349.5 MHz) broadband data contain eight bands of bandwidth 5 MHz. Ten observations, ranging in duration from 1h49m to 6h01m were obtained in the period from April 2 1994 to June 25 1994.

We report here results of the analysis from the earliest 92 cm observations which have been analysed in detail. A source model, containing $\sim$300 sources was constructed by combining two $\sim$6 hour observations (from April 2 and June 25) in order to have good coverage of the $u - v$ plane. Although eight frequency bands are in principle available for analysis, only three were usable for the selected observations, due to interference. The source model is complete down to a flux level of 12.5 mJy. This source model was then subtracted from the observation of April 11, where the noise level in the map was $\sim$1.5 mJy.

3. Results and Conclusion

After subtraction of the source model from the April 11 observation, no source remained within the intersection of the BATSE-Ulysses triangulation annulus and the COMPTEL 2σ error box (Figure 1) above a level of 10 mJy. Since our model was not complete down to this level, it is not clear that the remaining weak sources are indeed variable, since they may have been present in the observations used to generate the source model. Therefore we

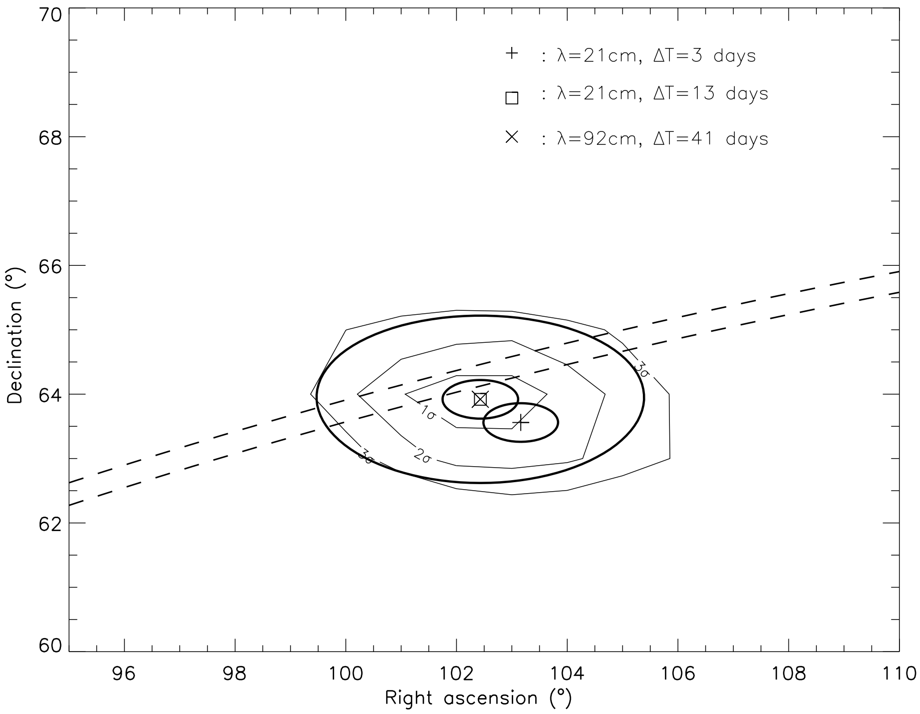

Fig. 1. WSRT coverage of the error box of GRB 940301. The labelled contours are the confidence levels obtained by COMPTEL. The dashed lines are the extrema of the triangulation arc from BATSE-Ulysses [9]. The boldly outlined regions are the WSRT HPBW fields, centred on the plus, box and cross symbols.

can, at the moment, only place a conservative upper limit on the level of variability of sources within the region of interest of ∼40mJy, 41 days after the burst. This estimate includes a correction by a factor of two for primary beam attenuation. Our result is consistent with the upper limit of 100 mJy at 74 cm obtained for this event with the DRAO Synthesis Telescope [10].

Assuming isotropic emission, the model of Paczyński and Rhoads [6] predicts a radio flare for GRB 940301 with a peak flux of 1.4 mJy at 92 cm, 212 days after the event for a source distance of 0.5 Gpc. Placing the source at 10^{-4} Gpc results in a peak flux of 12 mJy at a time delay of 0.04 days. Our result cannot therefore impose any constraints on this model.

We will continue to search for a possible radio counterpart on the basis of source variability by comparing different observations, using the same source model for each observation.

Other tools at our disposal include determination of spectral indices, for evidence of unusual spectral behaviour and measurement of source polarisation.

Acknowledgements

We are grateful to the Westerbork Observatory staff for carrying out the observations. LH acknowledges an EC fellowship and ESA/ESTEC for use of research facilities

References

1. Schaefer, B.E.: 1992, In C. Ho, R.I. Epstein, and E.E. Fenimore, eds., *Gamma Ray Bursts: Observations, Analyses and Theories*, Cambridge University Press, Cambridge, 107–111.
2. Hudec, R.: 1993, *Astro. Lett. and Communications* **28**, 359.
3. Barthelmy, S.D., Cline, T.L., Gehrels, N., *et al.*: 1994, In G.J. Fishman, J.J. Brainerd, and K. Hurley, eds., *Gamma Ray Bursts: AIP Proceedings* **307**, New York, 643.
4. Kippen, R.M., Connors, A., Macri, J., *et al.*: 1994, In G.J. Fishman, J.J. Brainerd, and K. Hurley, eds., *Gamma Ray Bursts: AIP Proceedings* **307**, New York, 418.
5. Schaefer, B.E.: 1994, In G.J. Fishman, J.J. Brainerd, and K. Hurley, eds., *Gamma Ray Bursts: AIP Proceedings* **307**, American Institute of Physics, New York, 382.
6. Paczyński, B. and Rhoads, J.E.: 1993, *Astrophys. J.* **418**, L5.
7. Kippen, R.M., Bennett, K., Connors, A., *et al.*: 1995, *Astron. Astrophys.* **293** L5.
8. Hanlon, L.O., Hermsen, W., Kippen, R.M. *et al.*: 1995, *Astron. Astrophys.* **296**, L41.
9. Hurley, K., Fishman, G., Kouveliotou, C. *et al.*: 1994, *IAU Circular 5944*.
10. Frail, D.A., Kulkarni, S., Hurley, K.C. *et al.*: 1994, *Astrophys. J.* **437**, L43.