COMPTEL upper limits for the 56Co γ-rays from SN1998bu

R Georgii
Max-Planck-Institut für extraterrestriche

S Pluschke
Max-Planck-Institut für extraterrestrische Physik

R Diehl
Max-Planck-Institut für extraterrestriche

W Collmar
Max-Planck-Institut für extraterrestriche Physik

G G. Lichti
Max-Planck-Institut für extraterrestrische Physik

See next page for additional authors

Recommended Citation

COMPTEL upper limits for the 56Co γ-rays from SN1998bu Georgii, R. and Plüschke, S. and Diehl, R. and Collmar, W. and Lichti, G. G. and Schönfelder, V. and Bloemen, H. and Knödlseder, J. and McConnell, M. and Ryan, J. and Bennett, K., AIP Conference Proceedings, 510, 49-53 (2000), DOI:http://dx.doi.org/10.1063/1.1303172

Authors

R Georgii, S Pluschke, R Diehl, W Collmar, G G. Lichti, V Schonfelder, H Bloemen, J Knodlseder, Mark L. McConnell, James M. Ryan, and K Bennett

COMPTEL upper limits for the 56 Co γ-rays from SN1998bu

R. Georgii, S. Plüschke, R. Diehl, W. Collmar, G. G. Lichti, V. Schönfelder, H. Bloemen, J. Knödlseder, M. McConnell, J. Ryan, and K. Bennett

Citation: AIP Conference Proceedings **510**, 49 (2000); doi: 10.1063/1.1303172
View online: http://dx.doi.org/10.1063/1.1303172
View Table of Contents: http://scitation.aip.org/content/aip/proceeding/aipcp/510?ver=pdfcov
Published by the AIP Publishing

COMPTEL upper limits for the ^{56}Co γ-rays from SN1998bu

R. Georgii*, S. Plüschke*, R. Diehl*, W. Collmar*, G.G. Lichti*, V. Schönfelder*, H. Bloemen†, J. Knödlseder‡, M. McConnell‖, J. Ryan‖ and K. Bennett¶

*Max-Planck-Institut für extraterrestrische Physik, Postfach 1603, 85740 Garching, Germany
†SRON, Sorbonnelaan 2, 3584 CA Utrecht, The Netherlands
‡CESR (CNRS/UPS), 9, av. du Colonel-Roche, 31028 Toulouse Cedex, France
‖Space Science Center, University of New Hampshire, Durham, NH 03824, USA
¶Astrophysics Division, ESTEC, ESA, 2200 AG Noordwijk, The Netherlands

Abstract. The type Ia supernova SN 1998bu in M96 was observed by COMPTEL for a total of 88 days starting 17 days after the detection of the SN. A special mode improving the low-energy sensitivity was invoked. We obtained images in the 847 keV and 1238 keV lines of ^{56}Co using an improved point-spread function for the low-energies. We do not detect SN1998bu. Sensitive upper limits at both energies constrain the standard supernova model for this event.

INTRODUCTION

On May 9.9 UT SN1998bu was discovered in M96 (NGC 3368) [14]. From wide-band spectrograms it was classified to be of the type Ia [1]. From a prediscovery observation [3] and an estimation for maximum blue light of $t_{Bmax} = 10952.7 \pm 0.5$ TJD (i.e. May 19), P. Meikle [10] estimates the date of the explosion to be May 2.0 $\pm$ 1.0 UT (i.e. TJD 10935 $\pm$ 1). The Cepheid distance to M96 is about 11 Mpc.

Observations of SNe in the optical and neighbouring bands concentrate on information on the light curves from such events. However, due to the creation of the optical photons long after the initial explosion most information of the initial state of a SN-explosion is lost. Therefore a distinction of the various SN-explosion scenarios via their optical light curves alone is very difficult. On the contrary, through the observation of SN in the γ-ray line regime, information from much earlier states in the explosion can be obtained. Considerable differences in the predicted spectra of different SN models, for example the He-Cap or detonation model, exist [6]. They can be used to discriminate between the models and to decide about the extend of mixing in the SN-explosion.

CP510, *The Fifth Compton Symposium,* edited by M. L. McConnell and J. M. Ryan

The sensitivity of existing γ-ray instruments, mainly the instruments on-board CGRO (OSSE and COMPTEL), limits the observations of type Ia SN to such events which occur at distances well below 15 Mpc. Consequently, only one SN of type Ia, SN1991T, was marginally detected with COMPTEL [11]. SN1998bu opens a second opportunity for line searches in SN, since according to some of the models it should be observable with the sensitivities of COMPTEL and OSSE in the Cepheid adopted distance of 11 Mpc.

COMPTEL observations of SN1998bu started on TJD 10952, 17 days after the explosion. Due to the late start of the observations and due to the low sensitivity of COMPTEL for low energies, we missed the decay of the 750 keV and 812 keV lines of ^{56}Ni (τ = 8.8 d). The observations were performed for a total of 88 days with the aim to detect the 847 keV and 1238 keV lines of the daughter nuclei ^{56}Co (τ = 112 d) .

ANALYSIS AND RESULTS

In order to obtain a higher sensitivity at lower energies the observations were performed in the so-called "low mode", where the threshold of the D2 modules were considerably lowered (For a detailed description of COMPTEL see [12]). In the "low mode" most of the thresholds are well below 650 keV, the software threshold in the standard COMPTEL analysis and show a considerable spread. Therefore a homogeneous software threshold at this value for all D2 detectors is no longer a good choice, since we would lose low-energy sensitivity in those modules with low thresholds. On the contrary the hardware thresholds of the D1 modules all lie in a narrow range below 50 keV, thus allowing to use this value as software threshold for all D1 detectors. Therefore the D2 modules were separated in groups with similar thresholds. A new point-spread function (PSF) was calculated, adding up the individual PSFs for each of these groups weighted with the number of the members in each group. Furthermore another PSF was derived from simulations where each module was simulated with its correct hardware threshold. The standard and the two new PSFs were then applied to 3 days worth of Crab low-mode data fortuitously collected during a observation of Geminga. Using the two new PSFs we clearly detect Crab with 5.1 σ of 847 keV, compared to only 3.02 σ with the standard PSF. For the 1238 keV line the values are 1.6 σ and 0.63 σ, respectively. This result reflects that most D2 modules are now sensitive below the standard 650 keV software threshold used for the standard analysis, resulting in a larger sensitivity for the 847 keV line. Since no major difference was found between the added PSF and the simulated one, in the further analysis only the simulated PSF was used, since it reflects the correct treatment of the threshold of each module.

Unfortunately we are not able to make use of the full sensitivity gain in the 847 keV line, due to the low threshold of some D2 modules, we start to see the 511 keV line leading to a very high background. To eliminate this, two approaches are possible, the spectral analysis and the imaging analysis.

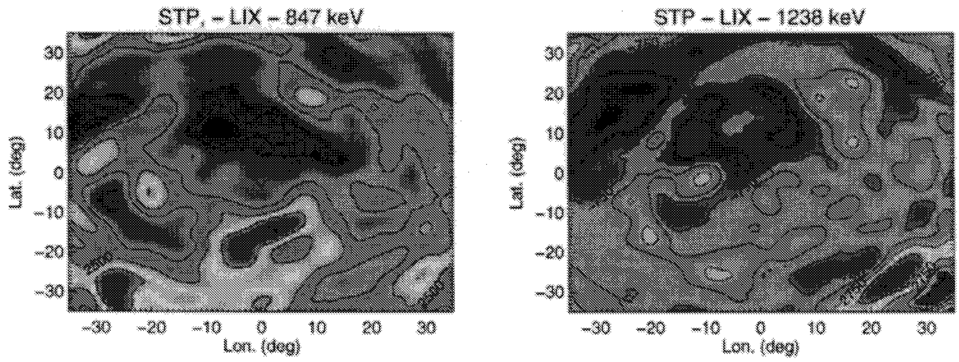

FIGURE 1. Flux map of the SN1998bu region in 847 keV (left) and 1238 keV (right). The SN position is marked by a diamond. The contour levels are in units of 10^{-8} photons/(cm^2 sec). The 1σ contour level corresponds to 2900 for the left and 1600 for the right map, respectively.

In the spectral analysis, a software cut at 600 keV in the D2 modules is used to suppress the 511 keV line background. At the SN-position and at different positions on a grid around the SN position (the positions on the grid allow to obtain off-source spectra) residual spectra, using data from a 3^0 cone in the 3-dimensional data-space as a "source spectrum" and data from a 3^0 - 7^0 cone mantle as "background spectrum" are produced. Subsequently a template Gaussian, with a width corresponding to the instrumental energy resolution, is used to obtain line intensities for both γ-ray lines at every position of the grid. Using this method, no significant difference between the source and the off-source positions can be seen. We derive 2σ upper limits in the following way: histograms for both lines using the fitted intensities from all positions of the grid are derived. The width of the distribution is then interpreted as a measure of the statistical and systematic uncertainty of the method. Together with information on the exposure and the effective area this yields a 2σ upper flux limit of $4.1 \cdot 10^{-5}$ photons/(cm^2 sec) for the 847 keV line and $2.3 \cdot 10^{-5}$ photons/(cm^2 sec) for the 1238 keV line.

In the imaging analysis a $\bar{\varphi}$ cut (see [12]) of 40^0 maximum is applied. Using the simulated PSF and the $\bar{\varphi}$ cut, the two maps for the two γ-ray energies (shown in figure 1) are produced using a maximum-likelihood method. Again it can clearly be seen that there is no signal from the supernova. The 2σ upper limits can be derived as follows: From the histogram of all fluxes in the maps in figure 1 the FWHMs are determined, assuming a Gaussian distribution. Using the Bayesian method described in [4], which also accounts for the systematic and statistical uncertainties, 2σ upper limits of $5.8 \cdot 10^{-5}$ photons/(cm^2 sec) for the 847 keV line and of $3.2 \cdot 10^{-5}$ photons/(cm^2 sec) for the 1238 keV line are found.

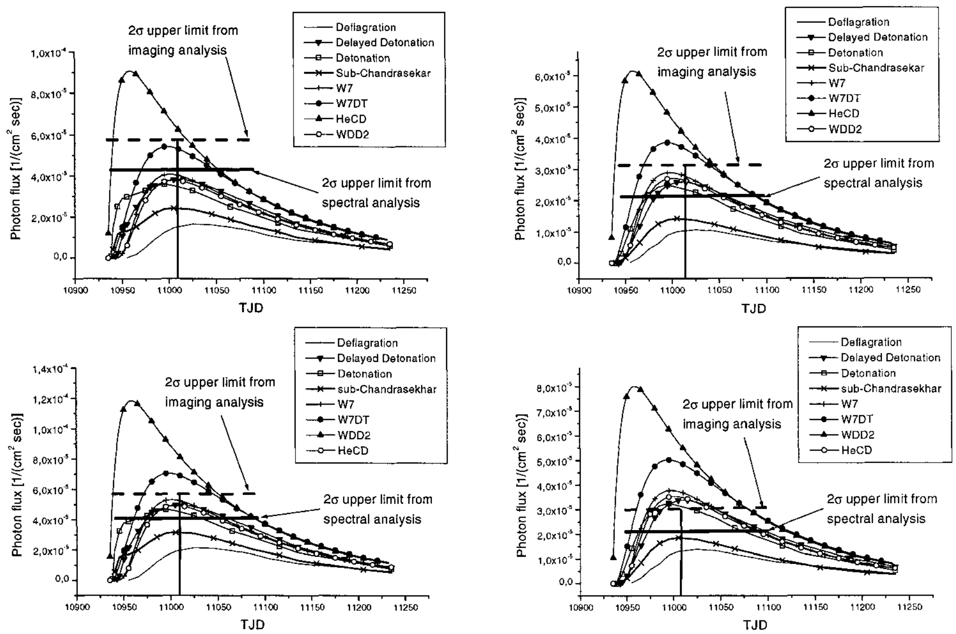

FIGURE 2. The model fluxes for the 847 keV (left) and for the 1238 keV (right) line for different models versus time after the explosion. The upper row is for a distance of 11.3 Mpc, the lower for a distance of 9.9 Mpc.

INTERPRETATION AND CONCLUSIONS

For the comparison of our upper limits, the distance to the SN plays a essential role. Interestingly the host galaxy M96 had already a HST-Cepheid-determinated distance of 11.6 $\pm$ 0.9 Mpc [13], later revised to 11.3 $\pm$ 0.9 Mpc [5] , leaving SN1998bu as one of seven SN being observed in galaxies with a Cepheid distance. However, a distance determination based on Planetary Nebulae (PN) suggests a distance as close as 9.6 $\pm$ 0.6 Mpc [2]. This points to a distance which would be compatible with a Cepheid distance of 9.9 Mpc resulting from recently discussed correction in the distance ladder scale [9].

In figure 2 expected model fluxes for a distance of 11.3 Mpc and 9.9 Mpc to M96 are plotted versus the time after the explosion and are compared to the 2σ upper limits obtained for both lines. The models are taken from Isern et al. [7] and from Kumagai et al. [8] and are scaled to the adopted distances. In figure 3 the expected maximal model fluxes are plotted versus distance in Mpc and are compared to the upper limit of the spectral analysis.

From these figures it can be seen, that we can exclude the HeCD and the W7DT model for SN1998bu: the upper limits are below the peak flux for both lines and distances. For the distance of 9.9 Mpc most other models would be inconsistent

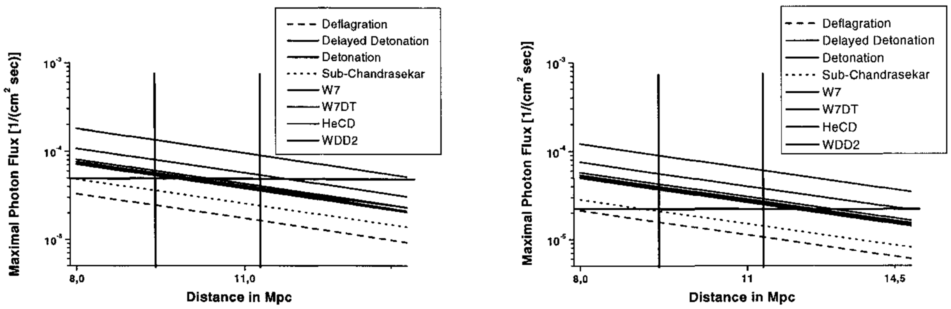

FIGURE 3. The model fluxes for the 847 keV (left) and the 1238 keV line (right) versus distance. The horizontal solid line represents the spectral upper limits. The solid vertical lines show the two different Cepheid distances of 9.9 Mpc and 12.3 Mpc, respectively.

with the 1238 keV measurement only, but be still marginally consistent with the 847 keV flux. The deflagration model and the Sub-Chandrasekar model are consistent with our line measurements for this distance.

In summary we favour the deflagration model and the Sub-Chandrasekar model for SN 1998bu and regard the HeCD model as rather improbable (Otherwise the amount of ^{56}Ni in the outer region of the progenitor CO-white dwarf should be much smaller then predicted by the current model). For detonation models a smaller mixing has to be assumed in order to be compatible with the results of the analysis presented here.

REFERENCES

1. K. Ayani et al. and P. Meikle, IAU Circ. No, **6905**, 1998.
2. Feldmeier, J.J., Ciardullo, R. and Jacoby, G.H., Ap.J. **479**, 231–243, 1997.
3. Fraranda ,C. and Skiff, B.A., IAU Circ. No. **6905**, 1998.
4. Georgii et al., Proc. 2^{nd} INTEGRAL workshop, ESA **SP-382**, 51–54, 1997.
5. Hjorth, J. and Tanvir, N.R., Ap.J. **482**, 68–74, 1997.
6. Höflich, P., Wheeler, J.C. and Khokhlov, A., APJ **492**, 228–245, 1998.
7. priv. communication.
8. priv. communication.
9. Manoz E. et al., astro-ph/9908140, 1999.
10. Meikle, P. and Hernandez, M., astro-ph/990256, 1999.
11. Morris, D.J. et al., Proc. of the 4^{th} Compton Symposium, AIP Conf. proc. **410**, 1084–1088, 1997.
12. Schönfelder et al., Ap.J. Suppl. Ser. **86**, 657–692, 1993.
13. Tanvir, N.R., Shanks, T., Ferguson, H.C. and Robinson, D.R.T., Nature **377**, 27–31, 1995.
14. Villi, M., IAU Circ. No. **6899**, 1998.