GRB 090102:
enigmatic explosion from the edge of the universe

Peter Sims – P.Sims@warwick.ac.uk

Supervisors: Andrew Levan – A.J.Levan@warwick.ac.uk
Karl Svensson - k.m.svensson@warwick.ac.uk

Abstract

Detected on the 2nd of January 2009, Gamma Ray Burst 090102 was declared a burst of special interest by NASA's Swift team. X-ray and optical lightcurves of the afterglow have been produced and analysed to establish the energy of the burst. The energy released in the burst, if emitted equally in all directions would be $E_{iso} = 2\times10^{53}$ erg which is approaching the rest mass energy of the Sun. An achromatic break in the emission is not visible for at least the first 70 days subsequent to the initial detection of the burst. This leads to a calculation of the total energy of the burst as $E_\gamma \geq 7\times10^{51}$ erg potentially making GRB 090102 the most energetic burst ever observed.

I. Introduction and Theory

Figure 1: artists impression of gamma-ray burst emission [1] showing a blue hypergiant star having shed it's outer layers and twin jets of plasma emanating from a black hole collapsed at the centre of the star. Gamma-rays radiate out from the jets.

A gamma-ray burst (shown in figure 1) is an intense flash of high energy photons ($E > 10^5$ eV) associated with extremely energetic explosions in distant galaxies. GRBs can be separated into two categories - long and short duration - based on the length of time for which the burst progresses. These two types of burst have different characteristics and are thought to derive from different classes of astronomical event. GRB 090102 falls into the long burst category and as such is predicted to originate in the collapse of the core of an extremely massive star.

The initial transient burst of gamma rays lasts only a matter of seconds but as the shock wave collides with the dust and gas of the interstellar medium (ISM), a longer-lived "afterglow" (shown in figure 2) is formed emitting less energetic radiation including x-rays ultraviolet and visible light.

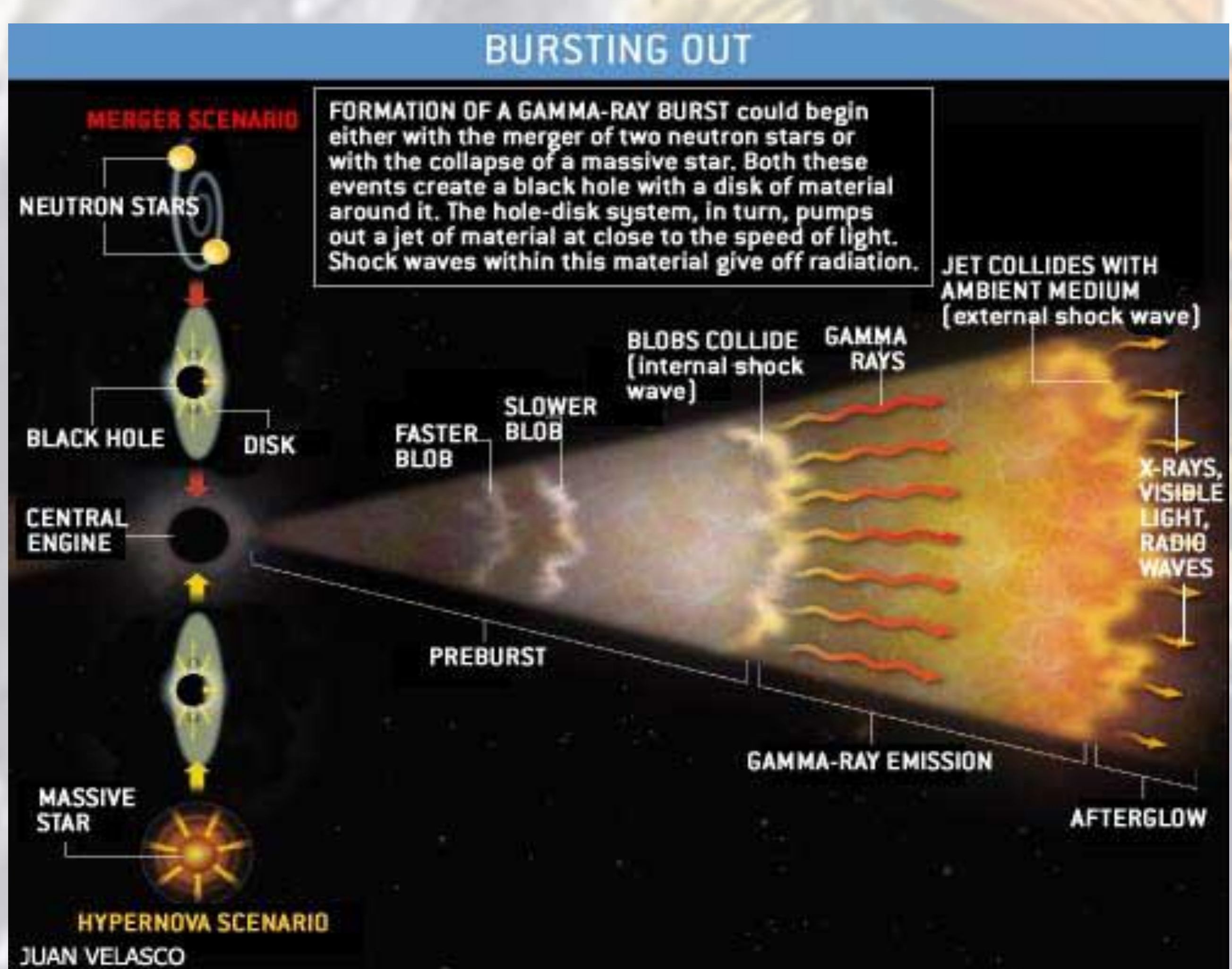

Figure 2: A schematic representation of the progression of events during a GRB [2]. Illustrated to the right is the afterglow emission, generated by energy transfer in external shocks as the jet encounters the ISM.

II. GRB 090102

GRB Model

The 'canonical fireball model' presents a likely explanation for the origin of the afterglow of long duration bursts such as GRB 090102. This model predicts a phenomena know as an 'achromatic jet-break' [3] in the afterglow emission which entails a simultaneous broadband reduction in the intensity of the light from the afterglow after a period known as the break time. It can be shown that this break time is correlated with the opening angle of the jet, [4] and this in turn can be used to calculate the total energy of the burst.

Optical and X-ray Data Analysis

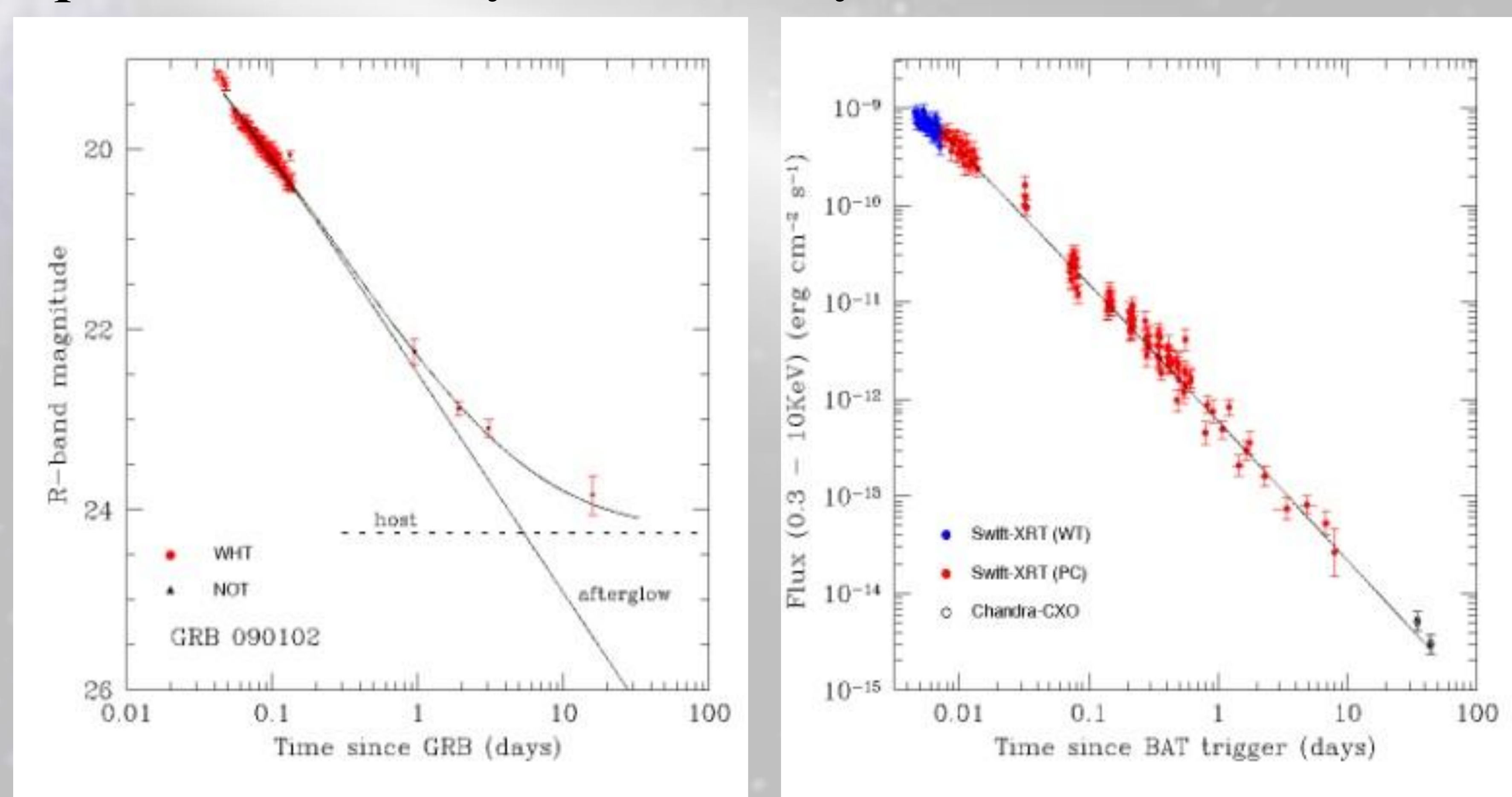

Figure 3: Shows the optical and x-ray lightcurves of the afterglow of GRB 090102 on the left and right respectively [5]. The optical lightcurve is derived from data obtained using the WHT and NOT ground based observatories as well as the Hubble Space Telescope. The x-ray light curve is created using data obtained from Swift XRT and Chandra CXO

The optical and x-ray lightcurves (shown in figure 3) were used to determine that there is no achromatic break present in the afterglow of GRB 090102 for at least 70 days subsequent to the initial detection of the burst. This implies a 15 opening angle of the jet yielding a value of $E_\gamma \geq 7\times10^{51}$ erg, and makes GRB 090102 one of the most energetic bursts detected to date (see fig 4).

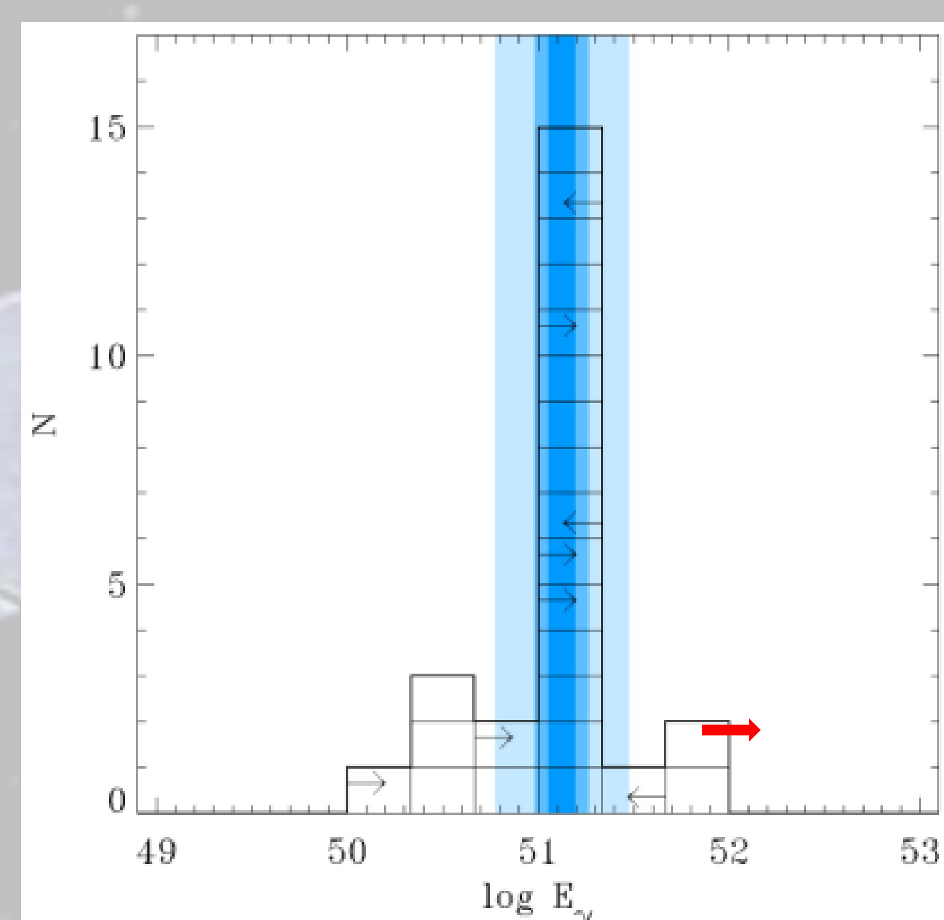

Figure 4: Histogram of GRB energies (*E*) with three equal logarithmic spacing's per decade. The red arrow shows the energy of GRB 090102.

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References:

[1] http://www.nasa.gov/centers/goddard/news/topstory/2003/0319hete.html
[2] http://www.astro.psu.edu/~niel/astro130/astro130.html
[3] D.A.Frail , S. R. Kulkarni, et al., 2001, The Astronomical Journal, 562 55
[4] R. Sari, et al. 1998, The Astronomical Journal 497 17
[5] A. J. Levan, P. Sims , K. Svensson, et al., The late time light curve of GRB 090102