An analysis of the redshift and fluence data collected by the Fermi satellite's GBM and LAT instruments

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Abstract

The gamma-ray bursts (GRBs) detected by the Fermi satellite's GLAST Burst Monitor (GBM) and Large Area Telescope (LAT) are divided into two samples: those with measured redshifts and those without. Here we study only the peak-fluxes and fluences of GRBs with known redshifts. It is shown that the inverse behavior – predicted by Mészáros A., Řípa J. and Ryde F., 2011, A&A, 529, A55 – may happen for the Fermi data.

Inverse behavior of the peak-flux and fluence: Theory and the Swift satellite

In the article Mészáros A., Řípa J. and Ryde F. (A&A, 529, A55, 2011) a remarkable property of the gamma-ray bursts (GRBs) was found. It can be briefly explained as follows (for details see the mentioned paper).

Given a GRB with measured peak-flux *P(z)* (with dimension of $ph/(cm^2 s)$ – where "ph" means photon). If the object has a redshift z, then its isotropic peak-luminosity *L(z)* (in units of *ph/s*) is related to the peak-flux by the expression

$$P(z) = \frac{(1+z)L(z)}{4\pi D_l(z)^2}$$

where $D_l(z)$ is the luminosity distance of the object.

An instrument measures the peak-flux at an interval $E_1 < E < E_2$, where E_1 and E_2 are the limiting photon energies given by the instrument, and E is the measured energy of the photon. Then the peak-luminosity must be taken from the interval $E_1(1+z)$ and $E_2(1+z)$, not simply from E_1 and E_2.

The same relation is also expected for the fluence if it has the dimension erg/cm^2.

It is standard cosmology that $D_l(z)$ increases with the redshift. For the exact formula, see Carroll et al., 1992, ARA&A., 20, 499, Eqs. 23-25.

But, on the other hand, it is also possible that *L(z)* is increasing with *z*. In Mészáros et al. (2011) it is argued that in some cases *L(z)* can increase faster than $D_l(z)^2/(1+z)$ and hence **an "inverse" behavior can occur: an apparently fainter GRB can be at a smaller redshift than a brighter one.**

This theoretical expectation was shown to happen in Swift's data. But from Fermi's data only 6 GRBs were used because at that time those were the only ones available from Fermi's database with known redshifts.

Here, we use a much wider data set from Fermi to study this inverse behavior.

The sample

For the period from 11 June 2008 (launch of Fermi satellite) to 11 June 2017, 41 GRBs were observed by Fermi with known redshifts.

The inverse behavior of the bursts recorded by Fermi: Peak-flux

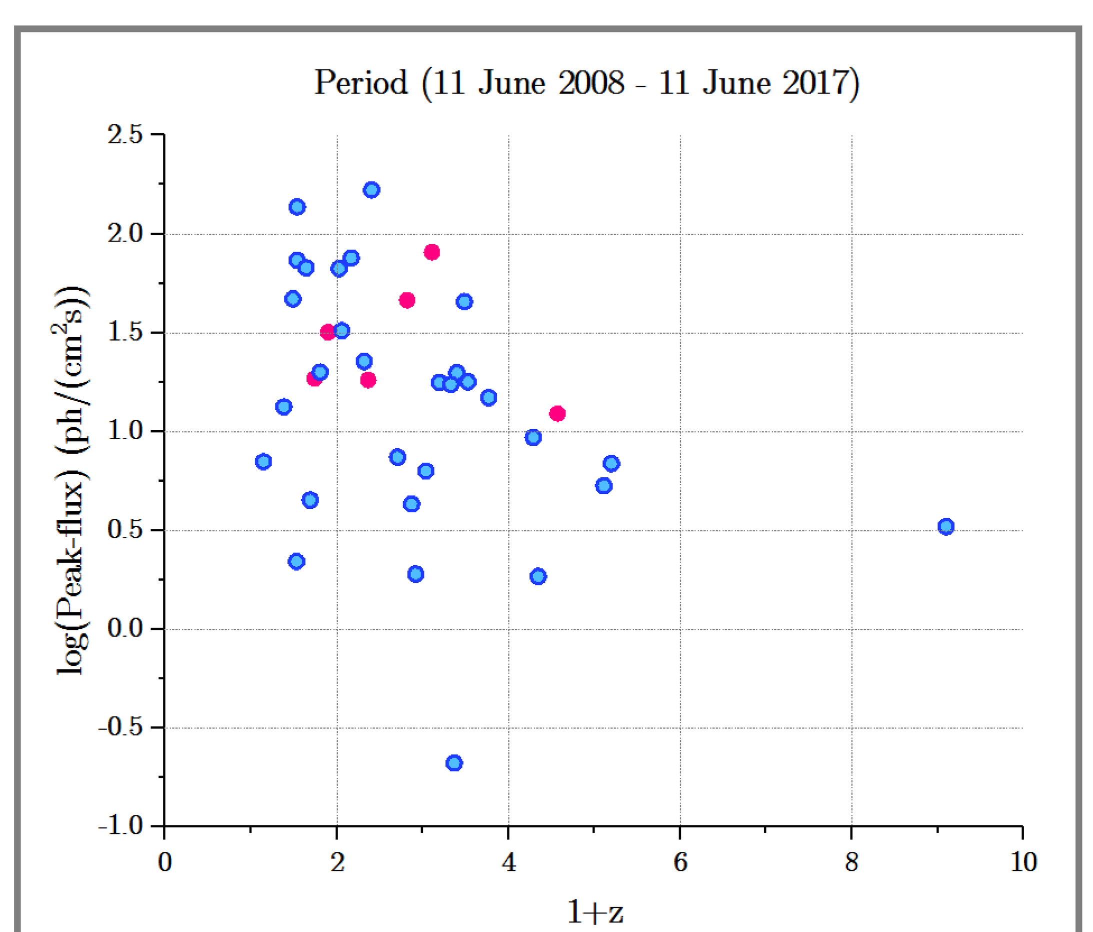

Figure 1: GRB peak-flux data with redshifts collected from the Fermi satellite between 11 June 2008 and 11 June 2017. The 6 GRBs from A&A, 529, A55, 2011 are highlighted.

If the relation were $L(z) = const.$, then on the figure one would see a clear decreasing tendency proportional to $log[(1+z)/D_l(z)^2]$.

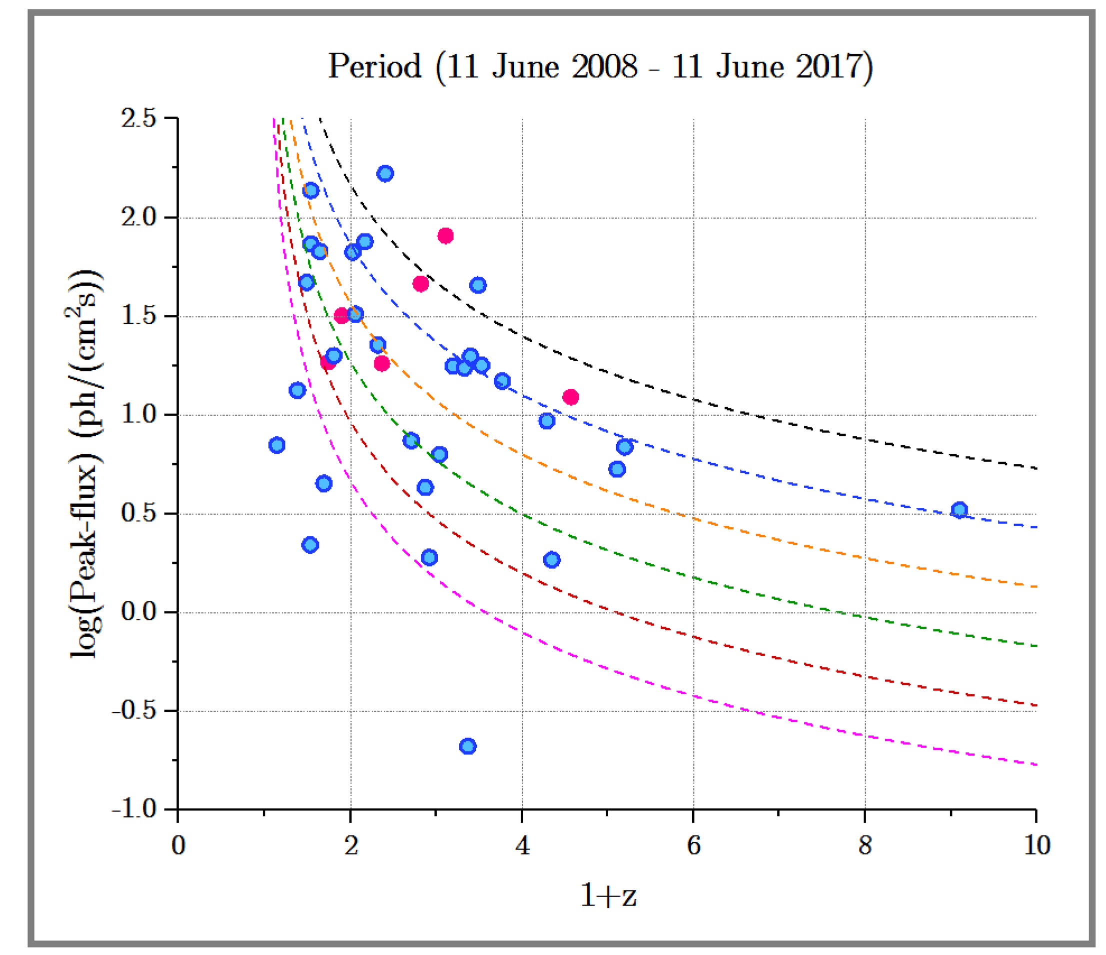

Figure 2: The dotted lines show the decreasing of $\log[(1+z)/D_l(z)^2]$ for the simplest cosmological model with $\Omega_M = 1$ and $\Omega_\Lambda = 0$.

The inverse behavior of the bursts recorded by Fermi: Fluence

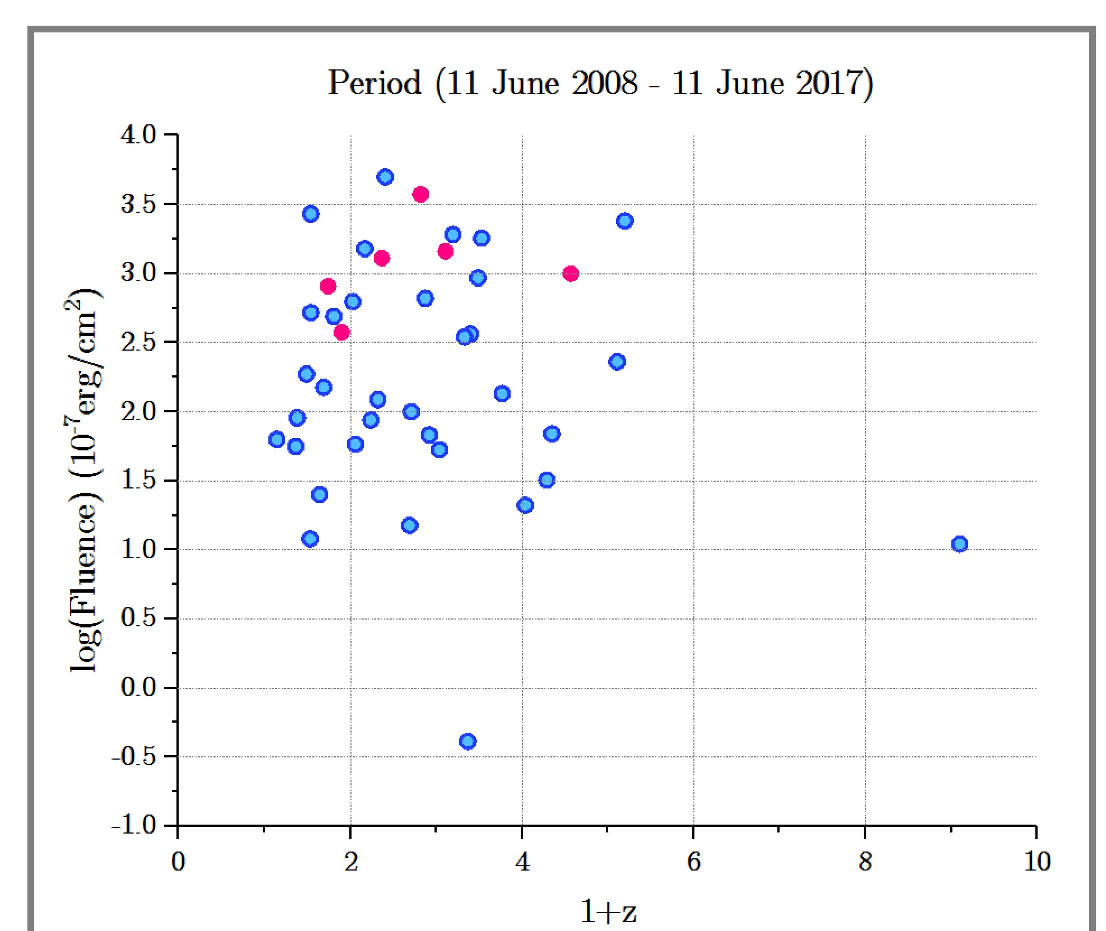

Figure 3: GRB fluence data with redshifts collected from the Fermi satellite between 11 June 2008 and 11 June 2017. The 6 GRBs from A&A, 529, A55, 2011 highlighted.

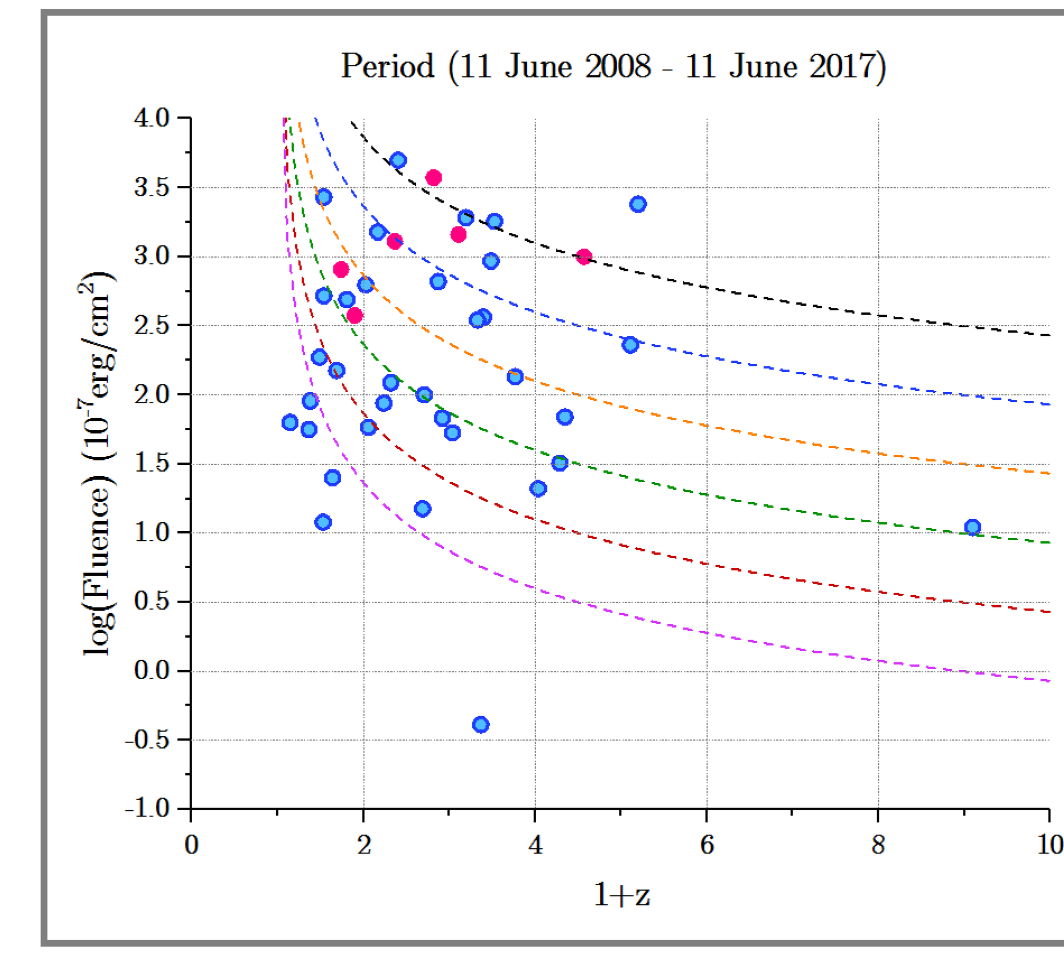

Figure 4: The dotted lines show the decreasing of $\log[(1+z)/D_l(z)^2]$ for the simplest cosmological model with $\Omega_M = 1$ and $\Omega_\Lambda = 0$.

Fermi Satellite

Figure 5: Artist's rendering of NASA's Fermi satellite. (Source: NASA)

Conclusion

The expected trend of inverse behavior is mainly seen for the fluences plotted in Figures 3 and 4. For the peak-fluxes this is not so obvious.

References

1. Mészáros A., Řípa J., Ryde F., 2011, A&A, 529, A55
2. Carroll et al., 1992, ARA&A, 30, 499