PRESS RELEASE

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THE GAMMA RAY BURST THEORY MEETS OBSERVATIONS: THE BIRTH OF NEW STANDARD CANDLES

GRBs as Standard candles: observations vs. theory

Boulder, Co, September 17, 2020

A study presenting the most comprehensive analysis to date of Gamma-Ray Bursts (GRBs) detected by the Neil Gehrels Swift Observatory (Swift) has been presented in a new article accepted in the Astrophysical Journal Supplements Series (https://arxiv.org/abs/2009.06740). The analysis was performed by an international team led by Dr. hab. Maria Giovanna Dainotti, Assistant Professor at Jagiellonian University in Krakow, Poland and concurrently serving as an Affiliate Research Scientist at Space Science Institute in Boulder, Colorado, USA, and as a mentor of the U.S. Department of Energy's Science Undergraduate Laboratory Internships (SULI) program at Stanford University, USA. The lead authors of the paper are Gokul Srinivasaragavan, an undergraduate senior attending the California Institute of Technology, and Dr. Dainotti, his mentor during the SULI program. This work enjoyed the support from SULI at SLAC National Accelerator Laboratory, California, USA.

GRBs are the most powerful high-energy events known in the Universe. They are thought to be produced through either the merger of two neutron stars or a neutron star and a black hole, or the collapse of a massive star, with masses 20 times larger than the mass of the Sun. In a few seconds, during their initial burst of gamma ray photons called the prompt emission phase, GRBs emit the same amount of energy the Sun releases over its entire lifetime. Because of their extremely high energies, they are detectable at cosmological distances, with the furthest being detectable to very shortly after the Big Bang, very close to the origin of the universe.

The three-dimensional analysis by Srinivasaragavan & Dainotti et al. has pinpointed the link between observational traits of the GRBs and how they are naturally connected to their physical properties, without assuming them beforehand. This is a huge step ahead in opening a new route for GRBs to be used as standard candles - objects with known luminosities that can be calculated through well-established relationships among luminosities and other properties that are independent from the distance.

More specifically, the work by Srinivasaragavan & Dainotti et al. analyzes 455 GRBs detected by Swift from both an astrophysical point of view in terms of their emission mechanisms and progenitor environments, as well as from a cosmological point of view. This study boosts the process of making GRBs into astronomical standard candles. This allows us to calculate astronomical distances. The furthest accredited standard candles to this day are the Supernovae Ia, but the great advantage to using GRBs is that they can be observed at much further distances (13.2 billion light years) than the SNe Ia (11 billion light years for SNe Ia).

GRBs are interesting to study as both singular events as well as in larger statistical studies, the latter being the topic of this paper. The prompt emission phase (usually in gamma-rays) of GRBs usually lasts from few seconds to thousands of seconds. The subsequent afterglow phase last anywhere from seconds to even years after the initial prompt emission, and it is observed in different wavelengths from X-rays all the way down to radio. GRBs vary dramatically in their physical origins and progenitor environments, which has made the process of making them standard candles very challenging. Indeed, scientists are still struggling in finding common features within their properties. However, it has been shown that about 50% of GRBs observed by Swift display a flat "plateau" emission in their X-ray light curves. The study published by Srinivasaragavan & Dainotti et al. focused on GRBs that display this characteristic "plateau" emission, see Fig. 1.

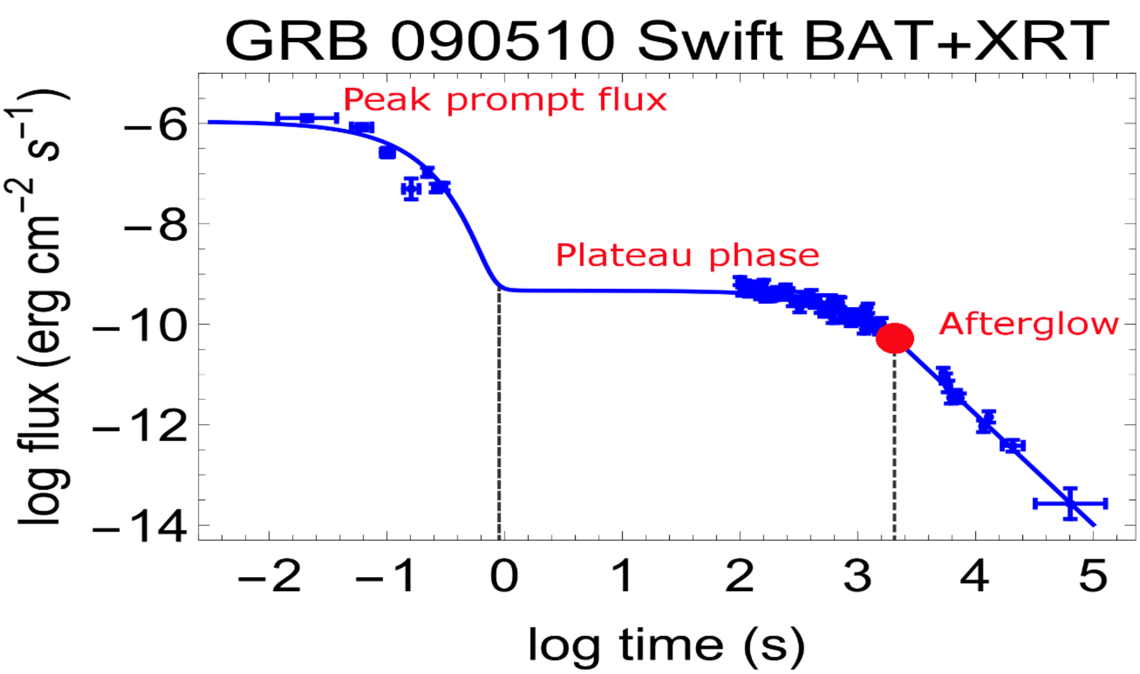

Fig.1 The light curve of GRB 090510 with the regions of prompt emission, plateau and afterglow marked.

This study describes a new method to standardize GRBs in terms of their progenitor environments. The team tested a set of theoretical relationships that determine if these extreme objects are most likely produced in a constant density interstellar medium (ISM) environment or a wind ejected by its progenitor star. The team succeeded in determining the majority of the GRBs' environment conditions in their data sample (GRB types are shown with different colors and shapes in Fig. 2 according to their observational features). They tested several features using the 3D Fundamental Plane relation (the grey region in Fig. 2). They discovered that GRBs falling under a fast cooling regime (when electrons cool down rapidly) are the closest to the 3D Fundamental Plane relation than ever before seen in the literature. Indeed, the closer GRBs are to the Plane, the more they can be used as standard candles with greater precision. Before this paper, Dr. Dainotti and collaborators searched for selection of a standard set of GRBs done by segregating observational classes. This is the first time that the standard set comes naturally from assuming a particular theory. Thus, this new method of classifying GRBs through their astrophysical environments and cooling regimes is a novel key to turn GRBs into standard candles.

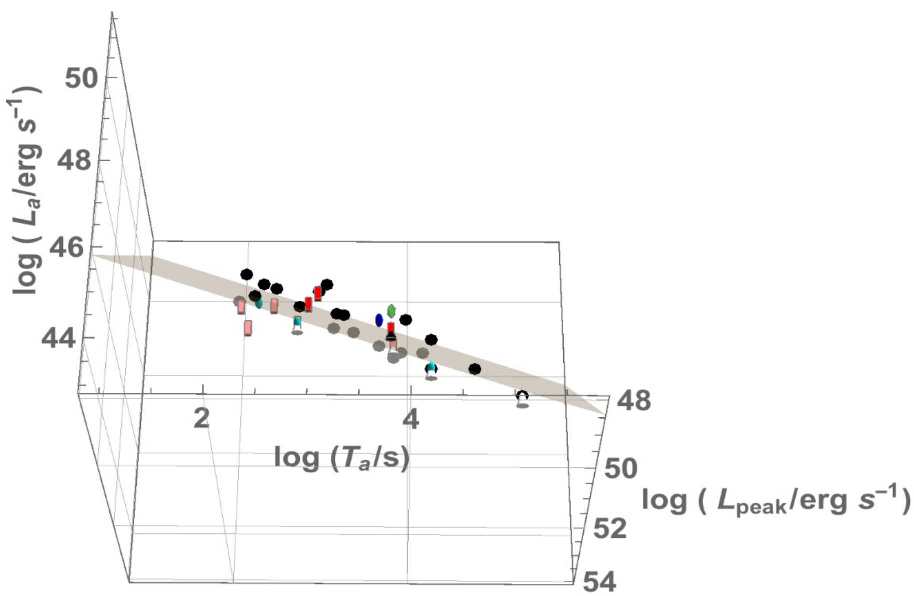

Fig. 2 The 3D Fundamental Plane relation, shown by the grey zone, for the sample of GRBs that happen in a fast cooling regime with a wind environment. The three parameters are at the end of the flat part of the plateau, T_a, the maximum luminosity during the prompt emission and luminosity at the end of the plateau phase.

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