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Hunting the gamma-ray emission from Fast Radio Burst with Fermi-LAT

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Summary. — Fast Radio Bursts (FRBs) are one of the most exciting new mysteries in astrophysics. Their origin is still unknown, but recent observations seem to link them to soft gamma repeaters and, in particular, to magnetar activity. Taking advantage of more than 12 years of the Fermi Large Area Telescope (LAT) data, we perform a search for gamma-ray emission from all the reported repeating and non-repeating FRBs. In this talk we present the preliminary results of our study and we discuss their implications for the predictions of gamma-ray emission from this class of sources.

1. – Introduction

Fast Radio Bursts (FRBs) are bright (typical fluences of 2 Jy ms) and short-duration (few ms or less) emissions at frequencies of about 1 GHz, caused by some high-energy astrophysical processes not yet understood. Since their discovery only over a decade ago in 2007 [1], few thousand FRBs have been reported so far [2, 3]. In particular, an increasing number of FRBs exhibit repeating bursts random in time, and two of them show a periodic pattern in their activity cycle: FRB 180916 [4] and FRB 121102 [5, 6]. For FRB 180916 a periodicity of 16.35 ± 0.15 days was detected, with 38 bursts recorded

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between September 16, 2018, and February 4, 2020, arriving in a 5.4-day phase window, while 50% of the bursts arriving in a 0.6-day phase window. Regarding FRB 121102, there is only an indication that it might be a periodic repeating FRB. No clear indications for physically different populations distinguishing repeating and non-repeating sources have been obtained so far.

Many recent studies are focused on understanding the FRB progenitors. The short duration of FRBs favours models involving compact objects such as strongly magnetized neutron stars (magnetars) and massive black holes [7]. In 2020, an FRB-like event was associated for the first time with a Soft Gamma Repeater (SGR 1935+2154) and, in particular, to a Galactic magnetar [8]. Recently, a magnetar giant flare (MGF) in the Sculptor galaxy was also detected in high-energy gamma rays, at GeV energies, [9], which motivates the search for gamma-ray counterparts of the known FRBs. In the last years, few searches at gamma-ray energies for FRBs counterparts have been performed without any significant detection [10-13], which were based on a few dozen FRBs.

Thanks to over 12 years of data collected by the *Fermi* Large Area Telescope (LAT), and to more than one thousand published FRBs, we aim to perform the largest and deepest systematic search for gamma-ray emission from all the reported repeating and non-repeating bursts.

2. – Fermi-LAT analysis

We selected a sample of more than 1000 FRBs including: 535 repeating and non-repeating FRBs reported in the first CHIME/FRB catalog [3]; 230 bursts from the 20 repeating FRBs reported by the CHIME/FRB Collaboration([1]) as of June 15, 2021, including 73 bursts from the periodic FRB 180916; 235 bursts from FRB 121102 collected by [5]; 118 events from the FRBCAT([2]) [2]. In addition, we included the first FRB from the Galactic magnetar flare located in SGR 1935+2154. Our sample consists of 1025 FRBs events, including 560 non-repeating FRBs and 465 bursts from 22 repeating FRBs. Last year, for the first time, an FRB-like event (DM = 332.7206) was associated to a Galactic magnetar, SGR 1935+2154, located at a distance of 12.5 kpc [8, 14]. In this work we focus on the preliminary results on the search of high-energy emission from the periodic FRB 180916.

The LAT is a gamma-ray telescope sensitive to photons in the 20 MeV–1 TeV energy range. It consists of a high-resolution converter tracker to measure the incident gamma ray direction, a CsI(Tl) crystal calorimeter for energy measurement and an anti-coincidence detector to identify gamma-rays from the cosmic ray background [15]. Thanks to its wide-field of view, it is able to cover the entire sky in ~ 3 hours, making it a very suitable γ-ray detector to study transient sources and in particular FRBs. We analysed the Fermi-LAT data of each individual source in our sample by using a standard likelihood analysis. The Test Statistic TS([3]) was used to determine whether a source is detected (TS > 25). We analysed each individual burst in time windows ranging from few seconds to one thousand seconds centred on the arrival time of the FRB. We also

([1]) `http://www.chime-frb.ca/repeaters`.
([2]) `https://frbcat.org`.
([3]) The test statistic (TS) is the logarithmic ratio of the likelihood $\mathcal{L}$ of a model with the source being at a given position in a grid to the likelihood of the model without the source, $\mathrm{TS} = 2\log\frac{\mathcal{L}_{\mathrm{src}}}{\mathcal{L}_{\mathrm{null}}}$.

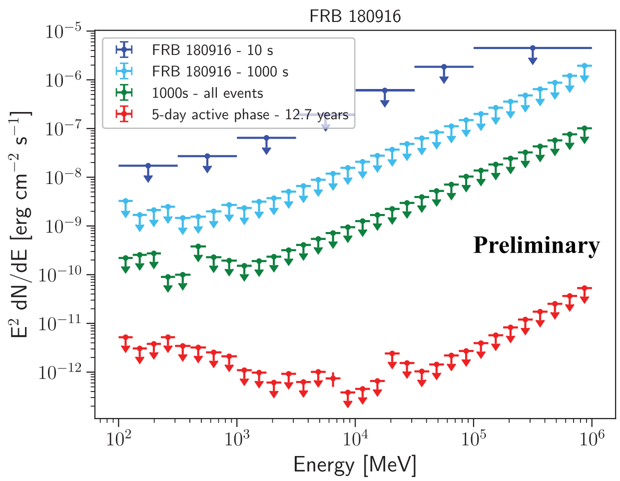

Fig. 1. – Fermi-LAT spectrum of the periodic FRB 180916.

analysed the 12.7 years (August 5, 2008 – April 5, 2021) of Fermi-LAT data to search for a possible new steady gamma-ray source. For the repeating FRBs, we also searched for a cumulative signal from all the intervals when bursts have been reported. We therefore used a folding analysis procedure, combining together 1000 seconds time intervals of all the events from a FRB source. For the periodic FRB 180916, the folding analysis was performed by considering both the 0.6-day and 5.4-day phase windows, corresponding to the windows on which 50% and 100% of the events have been detected, respectively [4]. We also performed a stacking analysis of all FRBs, in order to investigate the general properties of the population of the FRB sources [16].

The analysis was performed using the Fermipy package([4]), based on the Fermi Science Tools version 11-07-00. We selected events in the energy range 100 MeV–1 TeV, with zenith angle smaller than 90° and within $< 15°$ from the FRB source. We used the P8R3_SOURCE_V2 instrument response functions. Each Region of Interest was modeled including the known point-like and extended LAT sources in the 4FGL-DR2 catalog [17], the Galactic diffuse and isotropic emission([5]) and a point-like source to model the FRB source. Since we did not find any detection from this latter source, we derived an upper limit on the gamma-ray energy flux at 95% confidence level, assuming a power-law spectral model with spectral photon index of -2.

For the periodic FRB 180916, we obtained energy flux upper limits of $7.8 \cdot 10^{-8}$ and $1.4 \cdot 10^{-9}$ erg cm^{-2} s^{-1} from the analysis performed on the 10 second and 1000 second time intervals centred on the first observed burst (MJD = 58377.42972096) respectively. The folding analysis provided more stringent upper limits of $1.7 \cdot 10^{-10}$ erg cm^{-2} s^{-1} from the folding of the 73 detected bursts and $2.3 \cdot 10^{-12}$ erg cm^{-2} s^{-1} from the 5.4-day active phase windows on the 12.7 years data sample. Finally, differential flux upper limits in energy bins were derived and are shown in fig. 1. Although we did not find any detection, we provide the so-far most stringent upper limits on the gamma-ray emission from the FRB 180916 source during its 5.4-day active-phase window.

([4]) `http://fermipy.readthedocs.io/en/latest/`.
([5]) `https://fermi.gsfc.nasa.gov/ssc/data/access/lat/BackgroundModels.html`.

3. – Conclusions

FRBs are one of the most intriguing topics in astronomy of the last decade. Although their origin is still unclear, recent observations seem to associate them to Soft Gamma Repeaters and, in particular, to Galactic magnetars.

We report here the preliminary results of the search for high-energy emission from the periodic FRB 180916 ($z = 0.0337$). Although in our analysis we did not find any detection, we provide the so-far most stringent upper limits on the gamma-ray emission from the FRB 180916 source during its 5.4-day active-phase window ($L_{\gamma\text{-ray}} < 7.5 \times 10^{42}$ erg s^{-1}). Our results provide crucial information on constraining the origin of FRBs and modelling their emission mechanisms.

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