

PhD name: Stefano Giarratana

PhD Cycle: 36

Tutor: Dr. Marcello Giroletti

RESEARCH PROJECT:

The structure and evolution of gamma-ray bursts: mapping multi-frequency and multi-messenger events at high angular resolution

Context

Gamma-Ray Bursts (GRBs) pinpoint the explosion of a massive star (long-duration GRB) or the merger of two compact objects (short-duration GRB). Regardless their different origin, a highly magnetized neutron star or a stellar mass black hole is eventually produced. This central engine launches two oppositely directed relativistic jets, whose emission is usually divided into prompt and afterglow phases. While the short-lived prompt emission is generated by magnetic reconnections or by internal shocks within the jet, a long-lived (from days to weeks, months or even years) afterglow emission, extending from γ -rays down to the radio band, is produced when the expanding jets interact with the circum-burst material that surrounds the progenitor.

Radio observations, and in particular Very Long Baseline Interferometry (VLBI), proved to be a unique tool to investigate the afterglow phase of GRBs, to directly measure the superluminal expansion and the centroid displacement of the outflow, and to constrain its size. Moreover, the high angular resolution achieved with VLBI is fundamental to distinguish the compact afterglow emission from contaminating diffuse components within the host galaxy.

Goals

Within this scientific framework, the aim of the PhD is to characterize and constrain the jet, the circum-burst medium and the progenitor properties. To achieve these goals we want to study both single events and the statistical properties of GRB afterglows. On the one hand, we want to trace and model the multi-wavelength light curve of nearby events in order to infer the global (the isotropic-equivalent energy, the circum-burst density, ...) and the microphysical (the electron distribution index, the fractions of internal energy retained by the magnetic field and the electrons) parameters. Together with the afterglow itself, we are also interested in GRB host galaxies, whose characterization can constrain the nature of the progenitor. In this case VLBI techniques are needed to resolve the different emitting components within the galaxy.

On the other hand, a link between the prompt and the afterglow properties of GRB is tantalizing: albeit previous statistical studies on radio afterglows have been performed by Chandra & Frail (2012), who found that only 30% of GRBs have a detected radio afterglow, this work was sensitivity limited. Recent upgrades in radio facilities (such as the JVLA) could allow us to increase the number of detected events and to test possible overlooked correlations.

Results

In the first year I have coordinated an international team with experts from the INAF/OABrera (Italy), the University of Oxford (UK), the JIVE (The Netherlands) and the University of Barcelona (Spain) to successfully model the multiwavelength light curve of GRB 201015A, which was the less luminous event among the five GRBs ever detected at very high energies.

During a systematic search for late radio emission from GRB afterglows, I have detected the host galaxy of GRB 200716C in the archival data from the VLASS, NVSS and FIRST surveys of the VLA, and from the LOw Frequency ARray. Since all the available data are limited in sensitivity and angular resolution, we have requested and obtained two observations at 1.6 and 5 GHz with the European VLBI Network, in order to fully resolve the galaxy and finally discern the presence of an AGN from an extreme star formation rate. Finally, I have extended the BAT6 sample (Salvaterra et al. 2012, Pescalli et al. 2015) and searched for late time radio emission from the selected sources in the VLASS surveys of the VLA. Nevertheless, to improve the results of Chandra & Frail (2012) a larger sample is still required; thus we are currently reconsidering our selection criteria.

Prospects

Future efforts will be devoted to

- (i) characterize the host galaxy of GRB 200716C;
- (ii) characterize the host galaxy of GRB 170817A (the first multi-messenger event ever detected);
- (iii) trace the light curve of remarkably interesting GRBs, for which I have already submitted (as PI or Co-PI) observing proposals to be triggered;
- (iv) revise and further extend the radio afterglow sample to perform statistical studies.

WORKSHOPS, CONFERENCES & MEETINGS

Contributed Talks:

12 - 14 July 2021 EVN mini-Symposium and Users' meeting
Contributed Talk: *"GRB 201015A: characterization of a Radio afterglow with EVN and e-MERLIN"*

4 - 8 October 2021 The Third National Workshop on the SKA Project - The Italian Route to the SKAO revolution
Accepted Abstract for a contributed Talk: *"High-resolution and high-sensitivity wanted: the impact of SKA on GRBs"*

Attended workshops, conferences and meetings:

November 2020 - June 2021 IRA Coffee Talks
Talks hosted by IRA

November 2020 - June 2021 Astrophysics Talks
Talks hosted by IRA, OAS and DIFA

November 2020 - June 2021 Joint Astrophysical Colloquium
Talks hosted by IRA, OAS and DIFA

January 2021 - July 2021 Weekly PHD Seminars
Talk: *"GRB 201015A: Characterization of a radio afterglow with Very Long Baseline Interferometry"*

October 2020 Chandra Frontiers in Time-Domain Science
Seminar hosted by Chandra X-ray Center

2-6 November 2020 CASA-VLBI workshop 2020
Workshop hosted by Jive

5 November 2020 *"The structure of the galactic thick disks"*
Seminario Generale OA Arcetri with speaker Dr. Marie Martig (Liverpool John Moores, UK)

11 November 2020 *"The TOPoS project and other methods to select metal-poor candidates"*
OATS & UNITS Seminar with speaker Elisabetta Caffau (Observatoire de Paris/Meudon)

12 November 2020 *"Gaia: the Dynamic Sky in 3D"*
Game Changers Online Seminars with speaker Prof. Anthony Brown (Leiden University)

18-19 November 2020 HERMES-SP/TP 1st Scientific Workshop: Astrophysics with CubeSats
Workshop hosted by HERMES SCIENCE TEAM

16 December 2020 *"Gaia: Early Data Release 3, mission status, and science highlights from the second data release"*
Christmas Lecture with speaker Prof. Anthony Brown (Leiden University)

19 January 2021 *"The Italian FRB Network: from the lowest frequencies to the highest energies"*
Colloquium hosted by INAF-OAC with speaker Dr. Maura Pilia (INAF-OAC)

5 February 2021 *"How to give a scientific presentation"*
Lecture by Prof. Marco Viceconti

9 February 2021 *"Accretion behaviour during binary star formation"*
Hypatia Colloquium with speaker Dr. Rajika Kuruwita

22 February 2021 *"Towards a Physics of Time"*
OATo Seminar with speaker Dr. Luigi Foschini

23 February 2021 *"Gamma-Ray Astronomy: The Cross-Road between Physics and Astrophysics"*
Quid Ulta Colloquium with speaker Dr. Razmik Mirzoyan (Max Planck Institute for Physics, Munich)

15 - 19 March 2021 A precursor view of the SKA sky
Virtual workshop hosted by the SKA Telescope Team

23 - 26 March 2021 Theseus Conference
Hosted by the Theseus Team

29 March 2021 *"Shadows and Photon Rings: Imaging Supermassive Black Holes with the Event Horizon Telescope"*
EVN Online Seminar with speaker Michael Johnson (Harvard Smithsonian Center for Astrophysics)

12 - 17 April 2021 Ninth International Fermi Symposium
Virtual symposium hosted by the Fermi Gamma-Ray Space Telescope Team

13 April 2021 *"Einstein Telescope: a next generation gravitational wave detector"*
Colloquium hosted by INAF-OAC with speaker Dr. Alessandro Cardini (INFN-Cagliari)

19 May 2021 *"The sharpest view of the radio Universe: VLBI - Connecting Astronomers Worldwide"*
EVN Online Seminar with speaker Dr. Marcello Giroletti (INAF-IRA)

16 June 2021 *"Astroseismic ages for galactic archaeology: strengths and limitations"*
IAPS Web Seminar Series with speaker Prof. Andrea Miglio

23 - 25 June 2021 Second edition of Gravi-Gamma workshop
Virtual workshop hosted by INFN

1 July 2021 *"LVK Webinar - Gravitational waves from neutron star - black hole coalescences"*

9 July 2021 *"Tying the Sky to the Ground"*
EVN Online Seminar with speaker Dr. Ivan Marti-Vidal (University of Valencia)

4 - 7 August 2021 The Past, Present, and Future of the VLA: Celebrating 40 years
Virtual workshop hosted by the VLA Telescope Team

15 September 2021 *"Towards precision calorimetry of black hole accretion"*
Rome Joint Astrophysical Colloquium with speaker Prof. Rob Fender (University of Oxford)

PhD SCHOOLS

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INTERNAL COURSES

30 November - 2 December 2020 Bologna, Italy - *"The Interstellar medium"*

19 - 23 April 2021 Bologna, Italy - *"Gamma Ray Bursts: from observations to physical properties"*

5 - 14 May 2021 Bologna, Italy - *"Writing, talking and presenting Science"*

ISA LECTURES

15 December 2020 *"Translating texts which do not exist. Pseudo-originality, multistable figures, and Fortini's literary reception of Heine and Brecht"*
Battistini Lecture by Dr. Irene Fantappiè (Institut für Romanische Philologie, Freie Universität Berlin, Germany)

19 January 2021 *"Extreme events: how to describe and predict them using mathematical theories"*
Lecture by Prof. Sandro Vaienti (University of Toulon, France)

RESEARCH PERIOD ABROAD

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COMPETITIVE TELESCOPE/COMPUTER TIME ALLOCATIONS

"*SRGe J195057.5+672122: smoking gun of a nearby off-axis afterglow?*"

VLA 20B-420, PI Marcello Giroletti

We have been awarded four hours in the L, S, C, X, Ku bands.

"*GRB 201015A: an extreme short gamma-ray burst with a luminous radio afterglow?*"

e-MERLIN proposal, PI Marcello Giroletti

We have been awarded four epochs at 5 GHz.

"*Resolving the structure of binary mergers with VLBI observations*"

INAF Radio Telescopes proposal, PI Marcello Giroletti

Accepted proposal

"*Jet structure from neutron star mergers discovered through kilonovae*"

EVN proposal EG117, PI Marcello Giroletti

Accepted proposal. We have been awarded of five 12h-long observations.

"*Exceptional star formation or an hidden AGN in the host of a short GRB?*"

EVN + e-MERLIN E21B020, PI Stefano Giarratana

Accepted proposal

"*Resolving the jets of GRB afterglows*"

VLBA 22A-158, PI Marcello Giroletti

(Waiting for the evaluation)

"*Is the magnetic field in GRB ejecta quenched by the Reverse shock?*"

VLA 22A-184, PI Stefano Giarratana

(Waiting for the evaluation)

OTHER RELEVANT ACTIVITIES

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PUBLICATIONS

"GRB 201015A: VLBI observations of the less luminous Gamma-Ray burst ever detected at Very High Energy"

S. Giarratana, L. Rhodes, B. Marcote, R. Fender, G. Ghirlanda, M. Giroletti, L. Nava, J. M. Paredes, M. E. Rivasio and M. Ribó (in prep.)

1 October 2020 "VLASS constraints on the radio afterglow of the GRB afterglow/hypernova candidate SRGe J195057.5+672122"
The Astronomers' Telegram #14059

B. Marcote (JIVE), M. Giroletti (INAF), G. Migliori (INAF), **S. Giarratana**

20 November 2020 "GRB 201015A radio afterglow with e-MERLIN"
GCN Circular #28939

S. Giarratana, M. Giroletti (INAF/IRA), B. Marcote (JIV-ERIC), G. Ghirlanda (INAF/OABrera), M. Ribó (Univ. of Barcelona), J.M. Paredes (Univ. of Barcelona)

11 Decemeber 2020 "GRB 201015A: 5-GHz radio afterglow detection with the EVN"
GCN Circular #29028

B. Marcote (JIVE), M. Ribó (Univ. of Barcelona), J. M. Paredes (Univ. of Barcelona), M. Giroletti (INAF/IRA), **S. Giarratana** (Univ. of Bologna, INAF/IRA), G. Ghirlanda (INAF/OABrera)