Blazars, Fast Radio Bursts and Unidentified γ-ray Sources

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Abstract

The activity of our group in 2018 focused on finalizing a white paper for the LSST Cadence Optimization for our science case. We joined two task forces organized within the "Transients and Variable Stars" (TVS) Science Collaboration, one of which dealing with selecting variability characterization parameters to include in the LSST catalogs. We tested several statistical methods on blazar light curves built with data from the Whole Earth Blazar Telescope and other available databases with the aim of finding distinctive properties that will allow us to recognize new blazars among the LSST variable sources. In particular, we are working to obtain SDSS lightcurves to apply these methods on a complete sample. We prepared a database that will be populated by LSST data on blazars to make their exploitation more efficient. Finally, we developed an LSST-Italia WEB site, which will collect useful information and facilitate collaboration among the people involved.

1 Quintuplet Information 2018

- Claudia M. Raiteri (PI), ricercatore astronomo, INAF-OATo

- Barbara Balmaverde, ricercatore (from December 1st), INAF-OATo

- Maria Isabel (Maribel) Carnerero Martin, post-doc, INAF-OATo

- Filippo D'Ammando, ricercatore (from December 1st), INAF-IRA

- Chiara Righi, dottoranda, INAF-OAB

Co-PI:
Elena Pian, dirigente di ricerca, INAF-OASBo
Andrea Possenti, primo ricercatore, INAF-OAC

2 Quintuplet Information 2019

- Claudia M. Raiteri (PI), ricercatore astronomo, INAF-OATo

- Barbara Balmaverde, ricercatore, INAF-OATo

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1. **Scientific Collaborations:**

All the members of the quintuplet joined the "Transients and Variable Stars" (TVS) Science Collaboration and two TVS task forces:
"Deep Drilling Fields and Minisurvey proposals planning"
"Review variability characterization parameters planned for the Level 1 and Level 2 LSST catalogs"; Maribel is serving as spokesperson for this task force

3 Scientific Activity

The major effort of our group this year was devoted to figure out the best observing strategy for LSST that can optimize the scientific return for our science cases: blazars, fast radio bursts (FRB) and unidentified γ-ray sources. We have submitted a white paper in answer to the LSST Cadence Optimization call that proposes: i) the adoption of a reference filter that would allows us to obtain a well-sampled light curve without the need of colour correction; ii) the use of two snapshots with different exposure times during every visit to avoid saturation of bright/flaring sources, iii) the adoption of a rolling cadence to get better-sampled light curves during some periods of time, lasting at least 18 months; iv) the possibility to ask for Target of Opportunity (ToO) observations triggered by the detection of high-energy neutrinos likely coming from blazars, v) a minisurvey conducted in "Star Trail" observing mode, where the shift to this mode occurs during the second visit to a given field if saturation of selected objects (blazars) is detected during the first visit.

We are working to identify variability diagnostic methods that can distinguish blazars from other variable sources, in particular quasars. We built optical light curves of known blazars using data coming from the monitoring campaigns organized by the Whole Earth Blazar Telescope[1] (WEBT), whose leadership is at the Torino Observatory. We complemented these data with data publicly available from the Steward Observatory, the Catalina Real-Time Transient Survey (CRTS), the Small and Moderate Aperture Research Telescope System (SMARTS) and the Katzman Automatic Imaging Telescope (KAIT). We applied various diagnostic tests on these lightcurves to compare blazar variability properties with those of quasars and stars. The goal is to find distinctive features that will allow to identify new blazars among the LSST variable sources. The first results indicate that methods like the one proposed by Butler & Bloom (2011) and De Cicco et al. (2015) can give positive results for the most active objects, while they fail to separate blazars from quasars in the other cases (see figures below). We are now analysing Sloan Digital Sky Survey (SDSS) images of the Stripe 82 sky region to derive photometry of all known blazars inside it and build their light curves. We will then have a complete sample on which we will perform a variability analysis that will be compare with the results obtained by MacLeod et al. (2011) on quasars in the same zone.

We have prepared a database with MySQL and CakePHP with one entry for each of the ~ 4700 known blazars, including all those that will be seen by LSST, in view of populating it with LSST data as soon as they become available. The database provides basic information on the source and on each observation stored, and statistics on the variability properties. It can show plots of the light curves and can run analysis programs on them, to calculate e.g. colour indices, Structure Function, Discrete Correlate Function. Implementation of other tools is in progress. The aim of the database is to make the use of LSST data more efficient.

Finally, we developed a WEB site under WordPress for LSST-Italia. The goal is to collect useful information and facilitate collaboration among the people involved.

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[1]http://www.oato.inaf.it/blazars/webt/
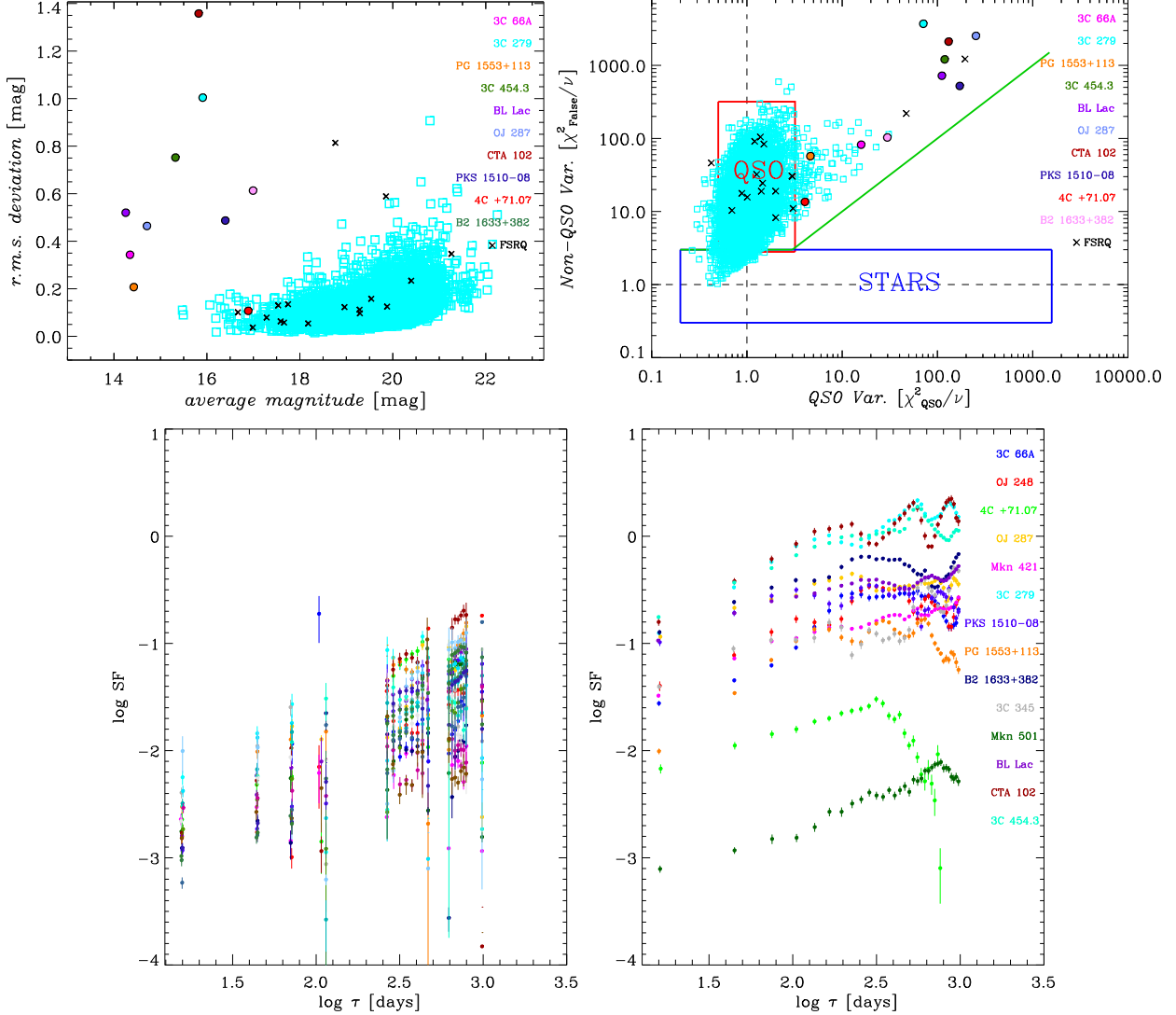
Top-left: Results of the variability analysis according to the De Cicco et al. (2015) method. The light curve r.m.s. is plotted as a function of magnitude. Cyan squares represent the QSO analysed by MacLeod et al. (2011), the black crosses marking the FSRQs[2] in their sample. The coloured circles represent the objects in our blazar sample. Only one of them, the high-redshift FSRQs 4C 71.07, together with almost all FSRQs in the MacLeod et al. sample, are located in the QSO region. The reason is that their emission is dominated by the big blue bump due the accretion disc light, as in normal QSO.
Top-right: Results of the variability analysis according to the Butler & Bloom (2011) method, aimed at separating Stars (blue region) from QSO (red region). Symbols as in the left panel.
Bottom-left: Structure Function of the best-sampled QSO analysed by MacLeod et al. (2011)
Bottom-right: Structure Function of the objects in our blazar sample

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[2]Flat Spectrum Radio Quasars (FSRQs) are one of the two blazar classes, the other being the BL Lac objects.

4 Scientific and technical deliverables

- We have contributed to the LSST TVS RoadMap Document[3]

- We have submitted a white paper on our science case for the LSST Survey Strategy Optimization: "Blazars and Fast Radio Bursts with LSST" by C.M. Raiteri, M.I. Carnerero, B. Balmaverde, F. D'Ammando, C. Righi, A. Possenti, E. Pian, A. Capetti, M. Villata, M. Giroletti, P. Romano, A. Stamerra, F. Tavecchio, S. Vercellone

- We have also contributed to another white paper: "Unveiling the Rich and Diverse Universe of SubsecondAstrophysics through LSST Star Trails" by David Thomas, Steven Kahn, Federica Bianco, Zeljko Ivezíc, Claudia M. Raiteri, Andrea Possenti, John Peterson, Colin Burke, Robert Blum, George Jacoby, Steve Howell, Grzegorz Madejski

- We have developed a database to organize LSST data for blazar studies, which can be adapted to serve also other scientific cases (Done by Maribel, with comments/suggestions by the others)

- We have developed a website for LSST-INAF (Done by Maribel, with comments/suggestions by the others)

White papers are posted on arXiv following the TVS chairs' suggestion.

1. **List of attached documents:** The two white papers by Raiteri et al. and Thomas et al.

5 Other information

- June 11-15 Meeting "Half a Century of Blazars and Beyond". Claudia was in the SOC, Maribel in the LOC. All quintuplet members attended. We presented a poster on "A blazar science case for the Large Synoptic Survey Telescope (LSST)" by M.I. Carnerero Martin, C.M. Raiteri, B. Balmaverde, F. D'Ammando, C. Righi.

- June 13 During the free half-day of the Torino Meeting, we had a brainstorming session on LSST at the Torino Observatory to organize our activities. All quintuplet members attended.

- April 9–1 LSST TVS Workshop 2018 in Napoli (http://eventi.na.astro.it/lsst-tvs-2018/). Barbara and Maribel attended. Maribel presented the blazar science case.

- June 4–8 LSST TVS Survey Strategy Proposal Preparation WorkshopMeeting at Lehigh University, PA, USA (https://lsst-tvssc.github.io/DDFMS_meeting_2018.html). Barbara attended and learned how to use MAF.

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[3]https://www.authorea.com/users/45/articles/281328-lsst-tvs-roadmap-document-draft-in-progress?access_token=NLF5iQX2Tn-gb1hAarEisA

- September 17–19 Mini-workshop on "Metric Analysis Framework (MAF) for LSST" at the Torino Observatory. It was organized by Barbara and Maribel and attended by Claudia and Filippo, together with Ilaria Musella, Maria Teresa Botticella, Roberto Silvotti, Rosaria Bonito.

  The aim of the workshop was that Barbara taught how to use MAF to the others and assisted them in practical sessions. Moreover, we discussed on the white papers for LSST Cadence Optimization and tried to find common observing strategies to propose.

  During the Meeting we also organized a "choral" conference "Science with The Large Synoptic Survey Telescope (LSST). Opening a Window of Discovery on the Dynamic Universe" for the colleagues of the Osservatorio Astronomico and Istituto di Fisica di Torino, with speakers covering different science cases for LSST.

- October 8–10 Meeting "LSST-Large Synoptic Survey Telescope - Special Programs Workshop" in Palermo (https://indico.ict.inaf.it/event/741/overview). Attended by Claudia and Maribel, who gave the following talks:

  "New website and database for LSST-INAF" by M.I. Carnerero,

  "Blazars with LSST" by C.M. Raiteri,

  "Highlights from the Turin MAF workshop" by M.I. Carnerero (invited)

- November 4–10 XXX Canary Islands Winter School of Astrophysics "Big Data analysis in astronomy" (http://www.iac.es/winterschool/2018/). Attended by Maribel, who presented a poster on "A blazar science case for the Large Synoptica Survey Telescope (LSST)"

- We participate regularly to the TVS Intercontinental telecons on BlueJeans organized by Federica Bianco and Rachel Street every 2 weeks at 17:30 Rome time.

- We actively discuss issues on the Slack and Community LSST forums.

- We organize skype telecon for internal discussion

6   References

Blutler & Bloom 2011, AJ, 141, 93
De Cicco et al. 2015, A&A, 574, A112
MacLeod et al. 2011, ApJ, 728, 26