Cristobal Bordiu

Title

A molecular window into the mass loss history of Luminous Blue Variables

Abstract

Luminous Blue Variables represent a very short stage in the life of some massive stars, characterized by significant variability, dense and steady winds, and occasional mass eruptions that rip off the outer stellar layers. By virtue of these processes, LBVs are often surrounded by large and heterogeneous circumstellar structures, like the remarkable Homunculus Nebula around Eta Car, that contain the evolutionary footprint of the parent star.

Therefore, these nebulae have been comprehensively studied at optical, infrared and radio wavelengths, resulting in a very accurate portrait of their dust and ionized gas content. However, a crucial piece of the puzzle is missing: a possible molecular counterpart. Such a component was overlooked for decades, but now we know that, under certain conditions, molecules can thrive in the hostile outskirts of LBV stars, despite the hot temperatures and strong UV fields. By investigating this molecular component at (sub)millimeter wavelengths, we can complete the mass-loss record of these challenging sources, learning about the mechanisms behind the eruptions and disclosing their chemical peculiarities.

This talk will present the most remarkable findings of a search for molecular gas associated with Galactic LBV stars, focusing on a series of previously undetected warm molecular rings. These structures, displaying unmistakable signs of CNO-processed material, suggest an evolutionary connection that extends beyond the LBV phase. We will discuss the origin of these structures and the role of LBVs as molecular polluters, shedding light on how the most massive stars contributed to the chemical enrichment of the early Universe.

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Professional experience

Osservatorio Astrofisico di Catania (INAF)   **Catania (ITALY)**
Research Fellow   *Mar 2020–present*
Hired by the H2020 NEANIAS project, working on the development of cloud-based analysis pipelines for astronomical data, in the context of the European Open Source Cloud (EOSC). The services implemented are particularly tailored to the needs of SKA precursors, using novel source extraction techniques and machine learning algorithms. As a member of the Galactic Science Radio Group, taking active part in the scientific exploitation of SKA precursor continuum survey data (ASKAP, MeerKAT), with a special emphasis on the late evolutionary stages of massive stars.

Telefónica (Eleven Paths)   **Madrid (SPAIN)**
Software Engineer   *Mar 2014–Mar 2020*
Member of a six people team with the goal of researching and developing software solutions. In particular, taking part in the development of a cybersecurity cloud service focused on automated persistent penetration testing for preventive detection of security breaches and threats that could pose a risk to customers' infrastructure. Traversal role in the team, involved in the design, implementation and testing of different aspects of the service, from the business logic to the presentation layer.

Telefónica (Eleven Paths)   **Madrid (SPAIN)**
Talentum Startups intern   *Dec 2013–Feb 2014*
Three-month internship at the software development department.

Academic background

Universidad Complutense de Madrid   **Madrid (SPAIN)**
Ph.D. in Astrophysics, cum laude   *2016–2021*
Research carried out as a member of the Department of Astrophysics of the Centro de Astrobiología (INTA-CSIC), under supervision of Dr. J. Ricardo Rizzo.
Thesis: *Interplay between evolved massive stars and their circumstellar medium: a (sub) millimetre view of Luminous Blue Variable mass loss.*

Universidad Internacional de Valencia   **Valencia (SPAIN)**
M.Sc. in Astronomy and Astrophysics   *2014–2015*
Master thesis: *Study of the Keplerian rotation of the circumstellar disk around TW Hydrae based on ALMA data.*

Politechnika Wrocławska   **Wrocław (POLAND)**
Erasmus exchange student   *2012–2013*
Member of the Erasmus exchange program at Faculty of Electronics and Computer Science.

Universidad de Oviedo   **Oviedo (SPAIN)**
B.Sc. in Telecommunication Engineering   *2008–2014*
Final project: *Diagnosis of interfering radio stations in FM broadcasting.*

List of publications

Peer-reviewed publications...

[8] Leto, P., Trigilio, C., Krticka, J., et al., 2021, *A scaling relationship for non-thermal radio emission from ordered magnetospheres: from the top of the main sequence to planets.* MNRAS, Vol. 507, pp. 1979-1998

[7] Riggi, S., **Bordiu**, C., Vitello, F., et al., 2021, *Astronomical source finding services for the CIRASA visual analytic platform.* Astronomy and Computing, Vol. 37, 100506

[6] Umana, G., Trigilio, C., Ingallinera, A., et al., 2021, *A first glimpse at the Galactic plane with the ASKAP: the SCORPIO field.* MNRAS, Vol. 506, pp. 2232-2246

[5] Riggi, S., Umana, G., Trigilio, C., et al., 2021, *Evolutionary map of the Universe (EMU): Compact radio sources in the SCORPIO field towards the Galactic Plane.* MNRAS, Vol. 502, pp. 60-79

[4] **Bordiu**, C., Bufano, F., Cerrigone, L., et al., 2021, *A warm molecular ring in AG Car: composing the mass-loss puzzle.* MNRAS, Vol. 500, pp. 5500-5514

[3] **Bordiu**, C., & Rizzo, J. R., 2019. *The peculiar chemistry of the inner ejecta of Eta Carina.* MNRAS, Vol. 490, pp.1570-1580

[2] Rizzo, J. R., Ritacco, A., & **Bordiu**, C., 2019. *NIKA2 observations around LBV stars: emission from stars and circumstellar material.* EPJ Web Conf., 228 (2020) 00023

[1] **Bordiu**, C., Rizzo, J. R., & Ritacco, A., 2019. *A slowly expanding torus associated with the candidate LBV MGE 042.0787+00.5084.* MNRAS, Vol. 482, pp.1651-1663

Other publications...

[4] **Bordiu**, C., Bufano, F., Sciacca, E., et al., 2020, *Astronomical research in the next decade: trends, barriers and needs in data access, management, visualization and analysis.* Proceedings of Astronomical Data Analysis Software and Systems (ADASS) XXX Conference.

[3] Sciacca, E., Krokos, M., Becciani, U., et al., 2020, *Novel EOSC Services for Space Challenges: The NEANIAS first outcomes.* Proceedings of Astronomical Data Analysis Software and Systems (ADASS) XXX Conference.

[2] Sciacca, E., Vitello, F., Riggi, S., et al., 2020, *Astrophysics visual analytics services on the European Open Science Cloud.* Proceedings of SPIE, Vol. 11452

[1] **Bordiu**, C., Rizzo, J. R., & Ritacco, A., 2019. *Tracing back the mass loss history of MGE042.0787+00.5084.* Highlights on Spanish Astrophysics X, 400

Conferences and workshops

- **IAA-CSIC Severo Ochoa School on Machine Learning, Big Data and Deep Learning in Astronomy (online, 2021).** Workshop on the current trends in the application of machine learning and deep learning techniques in astrophysical science cases.
- **SMA Interferometry School (online, 2021).** Workshop on fundamentals of radio interferometry, with a special emphasis on the Submillimiter Array (SMA). Presentation of a science case that led to a successful standard proposal: *Peering into the heart of the LBV MWC930.*
- **X Spanish Virtual Observatory School (La Laguna, 2017).** Technical school on Virtual observatory tools and methods for information extraction from large astronomical catalogs. Presentation of a science case: *Finding evolved massive stars with VO.*

National and International Conferences..

- **SOFIA Science Series: Evolved Stars and their Circumstellar Environments (online, 2021)**. Oral contribution: *Molecular gas: the forgotten ingredient of LBV ejecta.*
- **Statistical Methods and Machine Learning in the Space Sciences (online, 2021)**. Oral contribution: *Towards a modern unsupervised machine learning approach to the analysis of astrophysical images.*
- **Astronomical Data Analysis Software and Systems (ADASS) XXX (online, 2020)**. Oral contribution: *Astronomical research in the next decade: trends, barriers and needs in data access, management, visualization and analysis.*
- **European Astronomical Society Annual Meeting (online, 2020)**. Two oral contributions: *A molecular window to the past - mass loss archaeology of very massive stars* and *NEANIAS - Tackling the challenges of future astronomy.*
- **XIII Scientific Meeting of the Spanish Astronomical Society (Salamanca, 2018).** Poster Contribution: *Tracing back the mass-loss history of MGE042.0787+00.5084.*

Public Seminars...

- *A (sub) millimetre view of Luminous Blue Variables: molecules and mass loss.* Centro de Astrobiología, (Madrid, Oct. 2021)
- *Looking for molecular gas around evolved massive stars.* Jornadas de Doctorandos, Universidad Complutense de Madrid (Madrid, Dec. 2017)
- *The ALMA view of the protoplanetary disk of TW Hydrae.* Centro de Astrobiología, (Madrid, Dec. 2016)

Research skills

General competences:: Expertise in mapping, calibration, line and continuum radio data reduction, line identification, radiative transfer modelling. Experience with single-dish radiotelescopes and interferometers.

Proposal preparation: Seven accepted proposals as PI, at different radio and IR facilities and instruments, namely APEX, IRAM 30m, GTC, ATCA and SMA for a total of more than 80 hours of granted observing time.

Observational experience: Experience planning observations at different telescopes, both in visitor and service mode. More than 30 hours of in-situ observations at IRAM 30m.

Data reduction and analysis: Able to reduce multi-wavelength data in both imaging and spectroscopic mode. Experience with multiple instruments, e.g. ALMA, APEX, ATCA, SMA. Knowledge of common data reduction procedures for radio single-dish and interferometric data (e.g. CLEANing, self-calibration). Experience with multiple data reduction packages, for continuum and spectral line data, e.g. MIRIAD, CASA, GILDAS.

Data Modelling: Able to produce synthetic models of different astrophysical environments: disk, shells, nebulae under LTE and non-LTE conditions. Expertise with radiative transfer codes and line modelling software (LIME, RADEX). Simulation of single-dish and interferometric observations on synthetic datasets; optimization and model fitting.

Astronomical instrumentation: Engineering background. Able to understand engineering problems in Radio Astronomy.

Machine learning: Expertise in Machine Learning algorithms and their application to astrophysics problems, with a particular focus on unsupervised learning and clustering techniques.

Computer skills

Software Development: Expertise developing client-server applications. Able to work with different technologies applying good programming practices and producing efficient code.
- Software life cycle.
- RESTful services, design patterns (MVC).
- Version control and code review systems, issue tracking and collaborative tools (git).

Cloud technologies: Experience developing and deploying web services in cloud infrastructures (Amazon Web Services, Microsoft Azure). Knowledge of virtualization and containerization technologies (Docker, Kubernetes).

Operating systems: Unix; MacOS; Microsoft Windows.

Astronomy packages: GILDAS, MIRIAD, CASA, Astropy and related libraries.

Programming: C# (.NET), Python, SIC, HTML, JavaScript. Frameworks: ASP.NET MVC, Django (web development); scikit-learn, TensorFlow (Machine Learning).

Languages

Spanish: Mother tongue

English: Fluent writing and speaking   *Cambridge Advanced certificate (2011)*

Italian: Intermediate writing and speaking