

Ruben Fedriani



Title

Revealing a clustered region of massive star formation through NIR jets using VLT instruments

Abstract

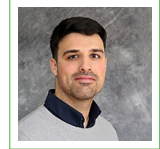
Massive stars play crucial roles in determining the physical and chemical evolution of galaxies. They shape their environment from early in their protostellar phase when they blast the surrounding with powerful jets, up until their violent deaths in the form of supernova. However, they form deeply embedded in their parental clouds, making it challenging to directly observe these stars and immediate environments. Notwithstanding, their massive outflows can extend several parsecs and since accretion and ejection processes are intrinsically related, they can provide crucial information about the processes governing massive star formation.

In this talk, I will present the IRAS 18264-1152 high-mass star-forming complex and reveal the jets through NIR spectro-imaging. We observe the molecular hydrogen (H₂) NIR jets in the K-band (1.9-2.5 μ m) obtained with the integral field units VLT/SINFONI and VLT/KMOS. We compare the geometry of the NIR outflows with that of the associated molecular outflow, probed by CO(2-1) emission mapped with the SMA. The spectro-imaging analysis focuses on the H₂ jets, for which we derived visual extinction, temperature, column density, area, and mass. The intensity, velocity, and excitation maps based on H₂ emission strongly support the existence of a protostellar cluster in this region, with at least two (but up to four) different large-scale outflows, found through the NIR and radio observations. This multi-wavelength comparison also allows us to derive a stellar density of 4000 stars pc⁻³ showing that relatively low number density region can harbour massive protostars. In conclusion, our study reveals the presence of several outflows driven by young sources from a forming cluster of young massive stars. Moreover, the derived stellar number density together with the geometry of the outflows suggest that massive stars can form in a relatively ordered manner in this cluster.

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Curriculum Vitae

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Education

- Oct 2015–
Jan 2020 **PhD in Astrophysics, Star Formation**, *Dublin Institute for Advanced Studies and University College Dublin (Ireland)*, Viva defended on January 2020, access to the thesis: <https://researchrepository.ucd.ie/handle/10197/11654>.
- Sept 2014–
Sept 2015 **Master in Astrophysics**, *University Complutense of Madrid (Spain)*.
- Sept 2009–
Jul 2014 **Bachelor in Mathematics**, *University of Cadiz (Spain), University of Saarland (Germany), and University Complutense of Madrid (Spain)*.

Work Experience

- Apr 2021–
present **Marie Skłodowska-Curie Actions Fellow (MSCA-IF) in Star Formation**,
CHALMERS UNIVERSITY OF TECHNOLOGY, Gothenburg (Sweden).
- Nov 2019–
Mar 2021 **Chalmers Initiative on Cosmic Origins Postdoctoral Fellow in Star Formation**,
CHALMERS UNIVERSITY OF TECHNOLOGY, Gothenburg (Sweden).
- Jan 2015–
Jan 2017 **Second year Physics Laboratories Demonstrator**,
UNIVERSITY COLLEGE DUBLIN, Dublin.
- Feb 2015–
Sept 2015 **ESAC Trainee at the European Space Astronomy Centre (ESAC)**,
EUROPEAN SPACE AGENCY, Madrid.
Search for bright nearby M dwarfs with Virtual Observatory tools.
- Sept 2009–
Sept 2015 **Tutor in an academy teaching Mathematics**.
Tutors student individually and in groups during office hours outside of class.
- April 2014 **Volunteer in XVIII Mathematics Spring Contest**,
UNIVERSITY COMPLUTENSE OF MADRID, Madrid.

Refereed Publications

- December
2021 **A.R. Costa-Silva, R. Fedriani, J.C Tan, et al. 2021, A&A, accepted.**
NIR jets from a clustered region of massive star formation. Morphology and composition in the IRAS 18264–1152 region.
ADS entry: <https://ui.adsabs.harvard.edu/abs/2021arXiv211204463C/abstract>
- January 2020 **R. Fedriani, A. Caratti o Garatti, M. Koutoulaki, et al. 2020, A&A, 663, A128.**
Mirror, mirror on the outflow cavity wall. Near-infrared CO overtone disc emission of the high-mass YSO IRAS 11101-5829.
ADS entry: <https://ui.adsabs.harvard.edu/abs/2020A%26A...633A.128F>
- August 2019 **R. Fedriani, A. Caratti o Garatti, S.J.D. Purser, et al. 2019, Nature Communications, 10, 3630.**
Measuring the ionisation fraction in a jet from a massive protostar.
Online entry: <https://www.nature.com/articles/s41467-019-11595-x>
- May 2018 **R. Fedriani, A. Caratti o Garatti, D. Coffey, et al. 2018, A&A, 616, A126.**
Parsec-scale jets driven by high-mass young stellar objects. Connecting the au- and the parsec-scale jet in IRAS 13481-6124.
ADS entry: <https://ui.adsabs.harvard.edu/abs/2018A%26A...616A.126F>
- January 2021 **M. Koutoulaki, , R. Garcia Lopez, A. Natta, R. Fedriani; et al. A&A, 645, A50.**
The GRAVITY Young Stellar Object survey III. The CO overtone emission in 51 Oph at sub-au scales.
ADS entry: <https://ui.adsabs.harvard.edu/abs/2021A%26A...645A..50G>

- August 2020 **R. Garcia-Lopez, A. Natta, A. Caratti o Garatti, T.P. Ray, R. Fedriani, et al. 2020, Nature, 584, 547-550.**
A measure of the size of the magnetospheric accretion region in TW Hydrae.
Online entry: <https://www.nature.com/articles/s41586-020-2613-1>
- August 2020 **C. Stock, A. Caratti o Garatti, P. McGinnis, R. Garcia Lopez, S. Antonucci, R. Fedriani, and T. P. Ray; et al. A&A, 643, A181.**
Investigating episodic accretion in a very low-mass young stellar object.
ADS entry: <https://ui.adsabs.harvard.edu/abs/2020A%26A...643A.181S>
- August 2020 **M. Liu, J.C. Tan, J.M. De Buizer, Y. Zhang, E. Moser, M.T. Beltrán, J.E. Staff, K.E.I. Tanaka, B. Whitney, V. Rosero, Y.L. Yang, and R. Fedriani, ApJ, 905, 75.**
The SOFIA Massive (SOMA) Star Formation Survey. III. From Intermediate- to High-mass Protostars.
ADS entry: <https://ui.adsabs.harvard.edu/abs/2020ApJ...904...75L>
- March 2020 **A. Caratti o Garatti, R. Fedriani, R. Garcia-Lopez, et al. 2020, A&A, 635 L12.**
The GRAVITY young stellar object survey. II. First spatially resolved observations of the CO bandhead emission in a high-mass YSO.
ADS entry: <https://ui.adsabs.harvard.edu/abs/2020A%26A...635L..12G>
- March 2019 **M. Koutoulaki, S. Facchini, C.F. Manara, A. Natta, R. Garcia-Lopez, R. Fedriani, et al. A&A, 625, A49.**
Exploring the dimming event of RW Aur A through multi-epoch VLT/X-Shooter spectroscopy.
ADS entry: <https://ui.adsabs.harvard.edu/abs/2019A%26A...625A..49K>

Supervision Experience

- May 2021–
July 2021 **Main supervisor of a Chalmers Astrophysics & Space Science Summer (CASSUM) Research Fellowship project 2021.** *Needles in a Cosmic Haystack - A Near-IR Search for YSOs around Massive Protostars.* Student: Ethan Duncan (Arizona State University)
- May 2021–
July 2021 **Main supervisor of a Chalmers Astrophysics & Space Science Summer (CASSUM) Research Fellowship project 2021.** *Near-infrared H₂ outflows through IFU observations: the massive star forming region IRAS 18264-1152.* Student: Ana Silva (University of Hertfordshire)
- Feb 2021–
May 2021 **Co-supervisor of the final bachelor theses of 12 undergraduates separated in 4 groups of 3 students.** *Massive Star Fireworks.* Students: Group 1: Nora Malmquist, Victor Gustafsson, Max Tapia molander; Group 2: Ludvig Askbom, Axel Lind, Emma Ulberstad; Group 3: Alva Kinman, Carl Larsson, Oskar Olander; Group 4: Mattias Wiklund Karin Hult, Johanna Brinkmalm (Chalmers University of Technology)
- May 2020–
July 2020 **Main supervisor of a Chalmers Astrophysics & Space Science Summer (CASSUM) Research Fellowship project 2020.** *New Views of the IRAS16562-3959 High-Mass Protostar and its Jets with Hubble and Friends.* Student: Ethan Duncan (Arizona State University)
- May 2020–
July 2020 **Main supervisor of a Chalmers Astrophysics & Space Science Summer (CASSUM) Research Fellowship project 2020.** *Studying NIR jets driven by high-mass protostars: morphology and composition in the IRAS18264-1152 region.* Student: Ana Silva (University of Hertfordshire)

Referee Experience

- October 2018 **ESO Distributed Peer Review Experiment:** *Review of 8 proposal for observing time as a part of the DPR Experiment.*

Projects as PI

- March 2021 **ESO Proposal for Observing Time.** *Peering into the Heart of Massive Star Birth with KMOS.* VLT/KMOS 24h, Program ID: 108.223D. Role: Write proposal, design observations, prepare phase II and Observing blocks.
- September 2017 **ESO Proposal for Observing Time.** *Revealing the dominant component in High-Mass Young Stellar Objects primary jets.* VLT/SINFONI 8h, Program ID: 0103.C-0363. Role: Write proposal, design observations, prepare phase II and Observing blocks.

Projects as co-PI

- 2021-2022 **JWST Proposal for Observing Time.** *Initial Mass Function in the Lowest Metallicity Protocluster in the Galaxy.* NIRCam/Imaging 2.8h. Role: Help in designing observations and give comments to draft.
- 2nd semester 2021 **LBT Proposal for Observing Time.** *Revealing the NIR view of massive protostellar jets III.* LBT/LUCI 10h, Program ID: UV-2021B-005. Role: Write proposal, design observations, prepare phase II and Observing blocks.
- 1st semester 2021 **LBT Proposal for Observing Time.** *Revealing the NIR view of massive protostellar jets II.* LBT/LUCI 5h, Program ID: UV-2021A-006. Role: Write proposal, design observations, prepare phase II and Observing blocks.
- 2nd semester 2020 **LBT Proposal for Observing Time.** *Revealing the NIR view of massive protostellar jets I.* LBT/LUCI 6h, Program ID: UV-2020B-004. Role: Write proposal, design observations, prepare phase II and Observing blocks.
- 1st semester 2020 **LBT Proposal for commissioning AO-science.** *Peering into the SOUL of NIR Jets.* LBT/LUCI+AO 1h, Program ID: UV-2020B-501. Role: Write proposal, design observations, prepare phase II and Observing blocks.
- September 2019 **ESO Proposal for Observing Time.** *Disclosing the inner structure of HMYSOs with GRAVITY/VLTI.* VLTI/GRAVITY 16h, Program ID: 0104.C-0425. Role: Revise proposal.

Observing Experience

- 2020-2021 **Service mode Observer in Large Binocular Telescope (LBT)** in Mount Graham (Arizona, USA) with twin 8m telescopes: *Revealing the NIR view of massive protostellar jets.*
- December 2018 **Visitor Observer in Telescopio Nazionale Galileo (TNG)** in La Palma (Canary Island, Spain) with 3.6 m telescope: *Resolving the Inner Structure of Proto-Planetary Discs: a Combined GIARPS/TNG-GRAVITY/VLTI Survey.*
- Feb 2018–Sept 2018 **Service mode in European Southern Observatory (ESO)** in Paranal (Chile) with 8.0 m telescope: *Revealing the dominant component in High-Mass Young Stellar Objects primary jets.*
- April 2015 **Visitor Observer in Centro Astronómico Hispano Alemán (CAHA)** in Calar Alto (Almería, Spain) with 2.2 m telescope: *Low-resolution spectroscopy of new nearby M-dwarfs discovered with Virtual Observatory tools.*

Invited talks

- December 2021 **Seminar at Instituto de Astrofísica de Andalucía.** Granada (Spain). *'Lighthouse Piercing Through the Storm Clouds in Massive Star Formation'*. <https://youtu.be/p0S8i2p6pUI>
- November 2019 **Seminar at Observatorio Astronómico Nacional.** Madrid (Spain). *'Protostellar Jets driven by High-Mass Protostars'*.
- November 2019 **Seminar at Centre for Astrobiology.** Torrejón de Ardoz, Madrid (Spain). *'Massive Star Formation'*.
- November 2019 **Seminar at Universidad de Cádiz.** Cádiz (Spain). *'Desvelando los secretos de la formación estelar'*.
- March 2019 **Planet-Forming Disks. A workshop to honor Antonella Natta.** Villa Vigoni, Como (Italy). *'Massive protostellar jets as a tool for understanding the ejection and accretion processes in HMYSOs'*.
- February 2019 **Seminar at the Chalmers University of Technology.** Gothenburg (Sweden). *'A glimpse into High-Mass Star Formation. A near-IR perspective on the role of protostellar jets'*.
- December 2018 **Seminar at the Instituto de Astrofísica de Canarias (IAC).** Tenerife (Spain). *'The formation of high mass young stellar objects and the importance of their massive protostellar jets'*.
- November 2018 **Seminar at the Osservatorio Astrofisico di Arcetri (INAF).** Arcetri (Italy). *'The formation of massive (proto)stars and the role of their jets'*.

Conferences and Summer Schools

Conferences

- June 2021 **European Astronomical Society Meeting 2021**. Leiden-Zoom.
ePoster Contribution: *'Peering into the heart of massive protostars. The SOMA near-infrared survey.'*
- May 2021 **CICO-VICO-CASSUM Spring 2021 Workshop**. Zoom.
Talk Contribution: *'A (massive) light in the dark.'*
- December 2020 **Chalmers-Virginia Initiative on Cosmic Origins (CICO-VICO) Fall 2020 Workshop**. Zoom.
Talk Contribution: *'The SOMA near-infrared survey. Imaging and spectroscopy at the heart of massive protostars.'*
- March 2020 **Virginia Initiative on Cosmic Origins (VICO) Science day**. Charlottesville (Virginia, USA). Talk
Contribution: *'From low- to high-mass protostars: Measuring the ionisation fraction in a jet from a massive young stellar object.'*
- February 2020 **Chalmers Initiative on Cosmic Origins (CICO) Science day**. Gothenburg (Sweden). Talk
Contribution: *'Mirror, mirror on the outflow cavity wall.'*
- September 2019 **Irish National Astronomy Meeting (INAM) 2019**. Armagh (Northern Ireland).
Talk Contribution: *'Mirror, mirror on the outflow cavity wall.'*
- October 2018 **Take a Closer Look. European Southern Observatory (ESO)**. Garching (Germany). Poster
Contribution: *'Revealing the true nature of jets in high-mass young stellar objects.'*
- September 2018 **Irish National Astronomy Meeting (INAM) 2018**. Birr (Ireland).
Talk Contribution: *'Protostellar jets revealing the physical processes of high-mass star formation using ESO/VLT instruments.'*
- July 2018 **XIII Reunión Científica de la Sociedad Española de Astronomía (SEA)**. Salamanca (Spain).
Poster Contribution: *'Protostellar jets revealing the physical processes of high-mass star formation.'*
- September 2017 **Irish National Astronomy Meeting (INAM) 2017**. Dublin (Ireland).
Talk Contribution: *'On the connection between the au-scale and the parsec-scale jet in high-mass young stellar objects.'*
- April 2017 **Multi-Scale Star Formation (MSSF)**. Morelia (Mexico). Poster Contribution: *'IRAS 13481-6124: A High-Mass Young Stellar Object driving a parsec-scale jet.'*
- September 2016 **Irish National Astronomy Meeting (INAM) 2016**. Dublin (Ireland).
Poster Contribution: *'IRAS 13481-6124: A Massive Young Stellar Object driving a parsec-scale jet.'*

Summer Schools

- October 2018 **ICCUB School on Protoplanetary Disks in Young Stellar Objects**. Barcelona (Spain). Talk
Contribution: *'Why are massive protostellar jets important in the study of HMYSOs?'*
- May 2016 **Summer School on Astrophysical Jets**. Corsica (France). Poster Contribution: *'IRAS 13481-6124: A Massive Young Stellar Object driving a parsec-scale jet.'*
- November 2014 **Eighth Spanish Virtual Observatory (SVO) School**. Centro de Astrobiología, Madrid (Spain).

Outreach

- April 2021 **Talk at the International Science Festival**. Gothenburg (Sweden) and the world through zoom.
The secrets of star formation and its fireworks. <https://program.vetenskapsfestivalen.se/activity/index/987/2021-04-17>
- Jan 2020–
Feb 2021 **Noble Prize Museum 'Help a Scientist' Project**.
Co-leader of the project *The Star Hunt* producing the booklet and preparing the exercises for over a 1200 Swedish high school students. <https://nobelprizemuseum.se/en/education/stjarnjakten/>
- February 2021 **Lecture at the Association of Astronomical Youth in Gothenburg (GAUSS)**. Gothenburg (Sweden). *'A journey through star formation and its fire works.'* https://www.youtube.com/watch?v=2Lx_fxAT_4w

- Jan 2021 **Participation on a TV debate**
Part of debating group talking about the possibility of living in Mars. *Onda Cadiz, El Palenque.*
<https://youtu.be/3PZ322fJysc>
- September 2019 **Interview for nobbot, tecnología para las personas.** *Rubén Fedriani: ha nacido una estrella y él sabe cómo.* <https://www.nobbot.com/personas/ruben-fedriani-estrellas-astrofisica/>
- September 2019 **Dublin Culture Night.** Dunsink Observatory, Dublin (Ireland).
Talk Contribution: *A Journey through Star Formation.*
- September 2017 **Dublin Culture Night.** Dunsink Observatory, Dublin (Ireland).
Talk Contribution: *Star Formation and the James Webb Space Telescope.*
- December 2016 **University College Dublin Transition Week.** Dunsink Observatory, Dublin (Ireland). Talk Contribution: *Transition Year Students 2016.*

Prizes and Awards

- May 2021 **Stiftelsen Wilhelm och Martina Lundgrens Vetenskapsfond.** Chalmers University of Technology (Sweden). Attracted funds 22 500 SEK. URL: <https://wmlundgren.se/>
- April 2021 **Marie Curie Individual Fellowship 'SMART'.** Chalmers University of Technology (Sweden). Attracted funds 203 852 euros
- June 2017 **Award to Academic Merit Capitán de Navío Martín Oar 'Virgen del Carmen'** Asociación Cultural Santiago, Cantabria (Spain). Attracted funds 600 euros

Memberships

- April 2021 **International Astronomical Union (IAU)** Junior member. <https://www.iau.org/administration/membership/individual/19918/>
- April 2021 **Asociación de Científicos Españoles en Suecia (ACES)** Member.
- July 2018 **Sociedad Española de Astronomía (SEA)** Junior member.
- July 2018 **European Astronomical Society (EAS)** Junior member.

Personal Skills and Competences

Technical

Knowledge of a Unix-based operating system. Experience in programming and mathematics software: Python, R, C++, Mathematica, MatLab, LaTeX, IDL, Iraf. Knowledge of VO tools: ALADIN, TOPCAT, STILTS, VOSA. Knowledge of Microsoft Office and similar free software. Knowledge in European Southern Observatory (ESO) pipelines, such as, *gasgano*.

Professional

Dedicated team member who works well in multicultural environments. Excellent public speaking and interpersonal skills in both professional and academic environments. Driven worker adapts easily to multidisciplinary environments.

Languages

- Primary language Spanish
- Other Languages Fluency in English