

Rodrigo Carvajal

Last-year PhD student in Astronomy and Astrophysics at the Instituto de Astrofísica e Ciências do Espaço (IA), in the University of Lisbon (FCUL), working on the identification and characterisation of Radio Galaxies and on the implementation of Machine Learning tools to detect and study them in large-area radio surveys.

Education

Instruction

- 2019 – **PhD in Astronomy and Astrophysics**, *Faculdade de Ciências, Universidade de Lisboa*, Lisbon, Portugal
- 2024 Project: The First Radio Galaxies in the Universe. Supervisors: J. Afonso, I. Matute, H. Messias.
- 2016 – **MSc in Astrophysics**, *Pontificia Universidad Católica de Chile*, Santiago, Chile
- 2019 Thesis: Stacking UV-selected Lyman-Break Galaxies in the ALMA Frontier Fields¹ (Maximum distinction). Supervisor: F. E. Bauer.
- 2007 – **Licenciado en Ciencias (BSc equivalent)**, *Universidad de Chile*, Santiago, Chile, *Astronomy (Distinction, no thesis required)*
- 2014

Prizes and Awards

- 2019 **PhD::SPACE Fellowship**, *Instituto de Astrofísica e Ciências do Espaço*, Lisbon, Portugal
The Doctoral Network in Space Sciences (PhD::SPACE) is a program funded by the Fundação para a Ciência e a Tecnologia (MEC, Portugal) to support PhD Fellowships in Space Sciences.
- 2017 **Teaching Assistant Scholarship**, *Pontificia Universidad Católica de Chile*, Santiago, Chile
This scholarship, awarded by the Pontificia Universidad Católica de Chile, grants students full exemption from payment of tuition fees and provides subsistence allowance to students.
- 2007 – **Beca Universidad de Chile**, *Universidad de Chile*, Santiago, Chile
- 2010 Beca Universidad de Chile covers tuition and fee of undergraduate programs for the duration of studies.

Research Experience

- Jan 2019 – **Research Assistant**, *Institute of Astrophysics, Pontificia Universidad Católica de Chile*, Santiago, Chile
- Oct 2019 Imaged and analysed ALMA data for project “Hunting for redshifts of faint DSFGs in A2744”.
- Aug 2015 – **Research Assistant**, *Institute of Astrophysics, Pontificia Universidad Católica de Chile*, Santiago, Chile
- Mar 2019 Used image enhancement techniques to improve quality of ALMA observations and study objects with low signal-to-noise ratio. Worked under supervision of Prof. Franz Bauer and Jorge González.
- Jan 2014 – **Research Assistant**, *Joint ALMA Observatory (JAO)*, Santiago, Chile
- Mar 2015 Studied Mars’ atmosphere and produce profiles for temperature, and wind speed using ALMA observations. Worked under supervision of Dr. Rüdiger Kneissl and Dr. David Rabanus, from JAO.
- Aug 2013 – **Research Assistant**, *Departament of Astronomy, Universidad de Chile*, Santiago, Chile
- Oct 2013 Studied differences from outer structures of lensing galaxies through absorbed light of far quasars. Worked under supervision of Prof. Sebastián López.
- Mar 2013 **Research Assistant**, *Departament of Astronomy, Universidad de Chile*, Santiago, Chile
- May 2013 Searched quasars pairs at small distances over catalogue of more than 100 000 objects (SDSS-DR9 Quasar Catalog. Pâris et al. 2012). Worked under supervision of Dr. Isabelle Pâris.
- Mar 2012 **Research Assistant**, *Departament of Astronomy, Universidad de Chile*, Santiago, Chile
- Jul 2012 Confirmed influence of thermal-broadening Doppler parameter in turbulent broadening in Intergalactic Medium. Worked under supervision of Prof. Sebastián López.
- May 2012 **Research Assistant**, *Departament of Astronomy, Universidad de Chile*, Santiago, Chile
- Jul 2012 Measured correlation for results of Voigt curve-fitting procedures in metallic species absorption lines from far quasar emission. Worked under supervision of Prof. Sebastián López.
- Aug 2011 – **Research Assistant**, *Departament of Astronomy, Universidad de Chile*, Santiago, Chile
- Dec 2011 Determined influence of thermal-broadening Doppler parameter in turbulent broadening in Intergalactic Medium. Worked under supervision of Prof. Sebastián López.

¹Thesis text available at <https://repositorio.uc.cl/handle/11534/22335>

Jan 2011 **Research Assistant**, *Departament of Astronomy, Universidad de Chile*, Santiago, Chile
Worked in project “A study of the Molecular Properties of the Vela Molecular Ridge (Coud C)” searching possible clumps using data from Mopra Radio Telescope. Worked under supervision of Dr. Nadia Lo.

Referred Articles

- Carvajal, R., Matute, I., Afonso, J., Norris, R. P., Luken, K. J., Sánchez-Sáez, P., Cunha, P., Humphrey, A., et al. “**Selection of Powerful Radio Galaxies with Machine Learning**”. In: *A&A* (2023). Accepted.
- Humphrey, A., Cunha, P. A. C., Paulino-Afonso, A., Amarantidis, S., Carvajal, R., Gomes, J. M., Matute, I., and Papaderos, P. “**Improving machine learning-derived photometric redshifts and physical property estimates using unlabelled observations**”. In: *MNRAS* 520.1 (Mar. 2023), pp. 305–313. doi: 10.1093/mnras/stac3596.
- Miranda, H., Pappalardo, C., Papaderos, P., Afonso, J., Matute, I., Lobo, C., Paulino-Afonso, A., Carvajal, R., et al. “**An investigation of the star-forming main sequence considering the nebular continuum emission at low-z**”. In: *A&A* 669, A16 (Jan. 2023), A16. doi: 10.1051/0004-6361/202244390.
- Carvajal, R., Matute, I., Afonso, J., Amarantidis, S., Barbosa, D., Cunha, P., and Humphrey, A. “**Exploring New Redshift Indicators for Radio-Powerful AGN**”. In: *Galaxies* 9.4 (Oct. 2021), p. 86. doi: 10.3390/galaxies9040086.
- Pappalardo, C., Cardoso, L. S. M., M. Gomes, J., Papaderos, P., Afonso, J., Breda, I., Humphrey, A., Scott, T., et al. “**Self-consistent population spectral synthesis with FADO. II. Star formation history of galaxies in spectral synthesis methods**”. In: *A&A* 651, A99 (July 2021), A99. doi: 10.1051/0004-6361/202039792.
- Carvajal, R., Bauer, F. E., Bouwens, R. J., Oesch, P. A., González-López, J., Anguita, T., Aravena, M., Demarco, R., et al. “**The ALMA Frontier Fields Survey. V. ALMA Stacking of Lyman-Break Galaxies in Abell 2744, Abell 370, Abell S1063, MACSJ0416.1-2403 and MACSJ1149.5+2223**”. In: *A&A* 633, A160 (Jan. 2020), A160. doi: 10.1051/0004-6361/201936260.
- González-López, J., Bauer, F. E., Aravena, M., Laporte, N., Bradley, L., Carrasco, M., Carvajal, R., Demarco, R., et al. “**The ALMA Frontier Fields Survey. III. 1.1 mm emission line identifications in Abell 2744, MACSJ 0416.1-2403, MACSJ 1149.5+2223, Abell 370, and Abell S1063**”. In: *A&A* 608, A138 (Dec. 2017), A138. doi: 10.1051/0004-6361/201730961.
- Laporte, N., Bauer, F. E., Troncoso-Iribarren, P., Huang, X., González-López, J., Kim, S., Anguita, T., Aravena, M., et al. “**The ALMA Frontier Fields Survey. II. Multiwavelength Photometric analysis of 1.1 mm continuum sources in Abell 2744, MACSJ0416.1-2403 and MACSJ1149.5+2223**”. In: *A&A* 604, A132 (Aug. 2017), A132. doi: 10.1051/0004-6361/201730628.
- González-López, J., Bauer, F. E., Romero-Cañizales, C., Kneissl, R., Villard, E., Carvajal, R., Kim, S., Laporte, N., et al. “**The ALMA Frontier Fields Survey. I. 1.1 mm continuum detections in Abell 2744, MACS J0416.1-2403 and MACS J1149.5+2223**”. In: *A&A* 597, A41 (Jan. 2017), A41. doi: 10.1051/0004-6361/201628806.

Contributed Talks

- Nov 2022 **Ensemble Machine Learning for Radio Galaxy detections**, *SPARCS XI. 2022 meeting of the SKA Pathfinders Radio Continuum Surveys (SPARCS)*, IDIA - Inter-university Institute for Data Intensive Astronomy, South Africa
- Sep 2022 **Ensemble Machine Learning for the Extraction of High-Redshift Radio Galaxies**, *XXXII Encontro Nacional de Astronomia e Astrofísica (ENAA)*, Faculty of Sciences - University of Lisbon, Lisbon, Portugal
- Jul 2022 **Searching for High-z Radio Galaxy Detections with Ensemble Machine Learning**, *EMU International Virtual Meeting*, Evolutionary Map of the Universe - Online event
- Feb 2022 **Prediction of distant Radio Galaxies candidates with Machine Learning**, *Jornadas Doutorais (Doctoral Day) from the Department of Physics*, Faculty of Sciences - University of Lisbon, Lisbon, Portugal
- Feb 2022 **High-redshift Radio Galaxies candidates prediction with ensemble Machine Learning**, *SAZERAC SIPS: Learning the high-redshift Universe*, online event
- Jan 2022 **Prediction of high-redshift Radio Galaxy candidates with ensemble Machine Learning**, *XVII SOCHIAS Meeting. 2022 meeting of the Chilean Society of Astronomy*, online event, Chile
- Nov 2021 **Using ensemble Machine Learning to predict high-redshift Radio Galaxy detections**, *SPARCS X 2021. 2021 meeting of the SKA Pathfinders Radio Continuum Surveys (SPARCS)*, online event, IDIA - Inter-university Institute for Data Intensive Astronomy. South Africa
- Nov 2021 **Obtaining High-redshift Radio Galaxy candidates with Machine Learning**, *Internal Workshop of the Institute of Astrophysics and Space Sciences (IA-ON8)*, IA - University of Coimbra, Portugal
- Oct 2021 **Using a series of Machine Learning Models for the detection of high-redshift Radio Galaxy candidates**, *Debating the potential of Machine Learning in astronomical surveys*, IAP Colloquium, Institut d'Astrophysique de Paris, France
- Aug 2021 **Using Machine Learning to identify high-redshift Radio Galaxy candidates**, *50th Young European Radio Astronomers Conference*, online event, IRAM

- Mar 2021 **Exploring new redshift indicators for radio-powerful AGNs**, *RGCW: A new window on the radio emission from galaxies, clusters and cosmic web*, online event, Italy
- Oct 2020 **Searching for the earliest AGN in the radio sky**, *Internal Workshop of the Institute of Astrophysics and Space Sciences (IA-ON7)*, online event, Porto, Portugal
- Mar 2020 **The first Radio Galaxies in the Universe**, *Jornadas Doutorais (Doctoral Day) from the Department of Physics*, Faculty of Sciences - University of Lisbon, Lisbon, Portugal
- Dec 2017 **Stacking in the ALMA Frontier Fields**, *Distant Galaxies from the Far South*, Bariloche, Argentina

Invited Talks or Seminars

- Jun 2021 **Developing a ML pipeline to detect high-redshift Radio Galaxy candidates**, *Machine Learning in Astronomy Group – SPARCS*, Western Sydney University. Sydney, Australia
- May 2021 **Explaining Machine Learning Models: SHAP, IA** – *Galaxies Machine Learning Club*, Porto, Portugal
- Jul 2020 **Stacking UV-selected Lyman-Break Galaxies in the ALMA Frontier Fields**, *Instituto de Astrofísica e Ciências do Espaço*, Lisbon, Portugal
- Jun 2019 **Stacking UV-selected Lyman-Break Galaxies in the ALMA Frontier Fields**, *ESO*, Santiago, Chile

Posters

- Jul 2023 **Ensemble Machine Learning for the prediction of Radio AGN in multi-survey data**, *Encontro Ciência '23: Encontro com a Ciência e Tecnologia em Portugal*, Aveiro, Portugal
- Feb 2023 **Radio Galaxy prediction with multi-survey data and ensemble Machine Learning**, *Coordinated Surveys of the Southern Sky*, ESO, Garching, Germany
- Sep 2022 **Searching for Radio Galaxy detections with ensemble Machine Learning**, *VLA Sky Survey in the Multiwavelength Spotlight*, NRAO, Socorro, NM. U.S.A.
- May 2022 **Radio Galaxy detection prediction with ensemble Machine Learning**, *International Conference on Machine Learning for Astrophysics – ML4Astro*, Catania, Italy
- May 2022 **Finding high-redshift Radio Galaxies with Machine Learning**, *Encontro Ciência '22: Encontro com a Ciência e Tecnologia em Portugal*, Lisbon, Portugal
- Sep 2021 **Detection of high-redshift Radio Galaxies using Machine Learning models**, *Encontro Nacional de Astronomia e Astrofísica*, online event, Portugal
- Jun 2021 **Using Machine Learning to look for high-redshift Radio Galaxies**, *Encontro Ciência '21: Encontro com a Ciência e Tecnologia em Portugal*, Lisbon, Portugal
- Mar 2021 **Exploring new redshift indicators for radio-powerful AGNs**, *A precursor view of the SKA Sky*, online event, The SKA Observatory
- Nov 2020 **Mining the radio sky toward the earliest AGN**, *Encontro Ciência '20: Encontro com a Ciência e Tecnologia em Portugal*, Lisbon, Portugal
- Sep 2020 **Mining the radio sky toward the earliest AGN**, *Encontro Nacional de Astronomia e Astrofísica*, online event, Portugal
- Mar 2015 **Mapping the winds on Mars. Test study (master project) for planetary atmospheric monitoring with ALMA**, *Ground and space observatories: a joint venture to planetary science*, Santiago, Chile

Observation Experience

- Nov 2022 **NIKA2 and EMIR instruments**, *30m Pico Veleta Radio Telescope*, IRAM, Spain, One-week observation run under pooled observations scheme.
- Feb 2013 **MagE instrument**, *6.5m Magellan-Clay Telescope*, LCO, Chile, One-night observation run under the supervision of Dr. Isabelle Pâris.

Teaching Experience

- Mar 2013 **Universidad de Chile**, *Teaching Assistant FI1001. Introduction to Newtonian Physics*, Department of Physics, Santiago, Chile. Professor: Sebastián López
- Jul 2013
- Mar 2013 **Universidad de Chile**, *Teaching Assistant EI2001. Project Workshop*, School of Engineering, Santiago, Chile. Professor: S. López. Practical course to teach students how to characterize the CCD at the University Observatory.
- Jul 2013
- Mar 2012 **Universidad de Chile**, *Teaching Assistant AS3004–AS758. Intergalactic Medium*, Department of Astronomy, Santiago, Chile. Professor: S. López
- Jul 2012

Student Supervision

- Jul 2023 **Instituto de Astrofísica e Ciências do Espaço**, *Co-supervision of BSc and MSc students' Summer Internships*, Faculdade de Ciências - Universidade de Lisboa, Lisbon, Portugal
With main supervisors (B. Arsioli and I. Matute) we guided five students (L. Rodrigues, G. Monteiro, A. Correia, D. Barreta, and T. Melo) on project "Multifrequency Analysis and Machine Learning for the most powerful quasars in the Universe".
- Sep 2022 – Feb 2023 **Universidade de Lisboa**, *Co-supervision of BSc student*, Faculdade de Ciências, Lisbon, Portugal
Helped main supervisor (I. Matute) guiding J. Bagagem on project "Connecting galaxies photometry with Super-Massive Black Hole (SMBH) properties: A machine learning approach".
- Sep 2021 – Feb 2022 **Universidade de Lisboa**, *Co-supervision of BSc student*, Faculdade de Ciências, Lisbon, Portugal
Helped main supervisor (I. Matute) guiding J. Lopes on project "Modelling Active Galactic Nuclei with Machine Learning".
- Sep 2021 – Jan 2022 **Universidade de Lisboa**, *Co-supervision of BSc student*, Faculdade de Ciências, Lisbon, Portugal
Helped main supervisor (I. Matute) guiding B. Resendes on project "Identifying and characterizing AGN in next-generation radio surveys with machine learning".
- Jul 2021 **Instituto de Astrofísica e Ciências do Espaço**, *Co-supervision of students' Summer Internships*, Faculdade de Ciências - Universidade de Lisboa, Lisbon, Portugal
Helped main supervisor (I. Matute) guiding four students (J. Sandrin, P. Ferreira, P. Rodrigues, and A. Monteiro) on project "Identifying and characterizing AGN in next-generation radio surveys using machine and deep learning".
- Jul 2021 **Instituto de Astrofísica e Ciências do Espaço**, *Co-supervision of students' Summer Internships*, Faculdade de Ciências - Universidade de Lisboa, Lisbon, Portugal
Helped supervisor (J. Afonso) guiding four students (A. Labib, M. E. Pimentel, L. Barroso, and J. Rato) on project "The 200: exploring the most active supermassive black holes in the first Gyr of the Universe".
- Sep 2020 – Feb 2021 **Universidade de Lisboa**, *Co-supervision of BSc student*, Faculdade de Ciências, Lisbon, Portugal
Helped main supervisor (I. Matute) guiding I. Tiago on project "Understanding triggering Radio emission from AGNs (Machine Learning)".
- Jul 2020 **Universidade de Lisboa**, *Co-supervision of BSc student*, Faculdade de Ciências, Lisbon, Portugal
Helped the main supervisor (J. Afonso) guiding L. Piscarreta on studying radio and X-ray emission of high-redshift AGN.

Outreach

- Aug 2023 **IX Escuela Ecuatoriana de Astronomía y Astrofísica**, (*IX Ecuadorian School of Astronomy and Astrophysics*), Quito, Ecuador
Prepare and present one of the lectures, titled "Looking for galaxies in a Universe of data".
- Oct 2021 **Festival Internacional de Ciência (FICA)**, Oeiras, Lisbon, Portugal
Answer questions about observatories in the stand of the Instituto de Astrofísica e Ciências do Espaço.

Working Experience

- 2013 – 2019 **Tourist guide**, *Observatorio Astronómico Andino (OAA)*, Santiago, Chile
Guide visitors (tourists) through the observatory. This includes showing them the main characteristics of the night sky and answer their questions referring to Astronomy and Astrophysics. This work could be done in both Spanish and English.

Attendance to Meetings, Conferences, Schools, or Workshops

- May 2022 **18th Synthesis Imaging Workshop**, Remote workshop, National Radio Astronomy Observatory. Socorro, NM. U.S.A.
- Apr-May 2022 **SKilled, Innovative & Entrepreneurial Scientists**, Hybrid workshop, Instituto de Astrofísica e Ciências do Espaço. Coimbra, Portugal
- Feb 2022 **SKA regional centre training event. Hands-on Containerization**, Online event, Science User Engagement (SUE) group of the SKA Regional Centre Steering Committee
- Dec 2021 **Cosmology in the Radio Sky: Prospects and Challenges in the Square Kilometre Array Observatory era**, Online course, Instituto de Astrofísica e Ciências do Espaço
- Dec 2020 **Machine Learning in Science & Engineering**, Online event, Columbia University - Data Science Institute
- Dec 2020 **SOCHIAS (Chilean Society of Astronomy) annual meeting**, Pucón, Chile
- Nov 2020 **Exploiting Archives for Radio Astronomy in the SKA-era**, Lisbon, Portugal
- Jun 2020 **European Astronomical Society Annual Meeting**, Leiden, Netherlands

Mar 2019 **ALMA Community Day (Cycle 7 Proposing Workshop)**, *ALMA Joint Observatory (JAO)*, Santiago, Chile
Jan 2011 **SOCHIAS (Chilean Society of Astronomy) annual meeting**, Santiago, Chile

■ Participation in Projects

Jan 2022 – **Finding Lyman-alpha emitters through machine learning (Encontrando emissores de Lyman-alpha através de aprendizagem máquina)**, *PTCRIS: EXPL/FIS-AST/1085/2021*, Funding: Fundação para a Ciência e a Tecnologia, Portugal, P.I. A Paulino-Afonso
Jun 2023

■ Memberships

Evolutionary Map of the Universe (EMU)

Square Kilometre Array Observatory (SKAO), *Extragalactic Continuum Science Working Group*

SKA Pathfinders Radio Continuum Surveys Working Group (SPARCS)

■ Service

Jul 2022 **Chair of KS8 session**, *EMU International Virtual Meeting*, Evolutionary Map of the Universe – Online event
Sep 2022 – **Co-organiser Journal Club discussions**, *Galaxies Research Group*, Instituto de Astrofísica e Ciências do Espaço, Weekly meetings to discuss relevant articles and topics.
Jul 2023

■ Technical Skills

Coding

- Python. Intermediate level.
- C. Intermediate level.
- Java. Intermediate level.
- Matlab. Intermediate level.
- \LaTeX . Intermediate level.
- Mathematica. Basic level.
- Bash scripting. Basic level.

Software Skills

- Common Astronomy Software Application (CASA) package. Intermediate level.
- Tool for operations on catalogues and tables (TOPCAT). Intermediate level.
- Gnuplot. Intermediate level.
- ESO-MIDAS. Basic level.
- Image Reduction and Analysis Facility (IRAF). Basic level.
- The Atmospheric Radiative Transfer Simulator (ARTS). Basic level.
- SAOImage DS9. Basic level.
- EsoRex. Basic level.

Languages

- **Spanish**. Native speaker.
- **English**. IELTS Academic 7.5 (Good User).
- **Portuguese**. Basic knowledge.

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Last update: August, 2023.