Sofia Rojas Ruiz

Title

The Role of Powerful Radio Jets in the Host Galaxy of a Quasar in the First Gyr of the Universe

Abstract

High-redshift quasars can shed light on the co-evolution of central supermassive black holes and their host galaxies in the very early universe. Observational constraints on radio jet and interstellar medium feedback processes are still very limited at redshifts z>2. We investigate the radio-loud quasar P352-15 near the end of Reionization at redshift z~6. This quasar is the most powerful radio emitter with direct evidence of a kpc-scale radio jet (~1.6 kpc) at these high redshifts. I will present the results on the spectral energy distribution of this quasar at millimeter (far-infrared in the rest-frame) and radio observations. The millimeter continuum emission for radio-quiet quasars at these redshifts has usually been interpreted as cold dust and is modeled as a modified black body. However, the analysis on this radio-loud quasar shows that it is not possible to model the millimeter measurements as cold dust alone. I will present evidence of the strong radio synchrotron emission in this source affecting the dust-dominated continuum emission in the millimeter, and implying a break in the synchrotron spectrum. I will further portray the big picture in a dedicated study for the first time on measuring different jet lifetimes based on rest-UV/Optical and radio observations of this quasar. Thus, constraining the black hole - host galaxy formation and jet ejection mechanisms of a quasar in the first Gyr of the universe.

Sofía Rojas Ruiz | Curriculum Vitae

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Education

- **International Max Planck Research School - Heidelberg (IMPRS-HD)**
  Natural Sciences Ph.D. in Astrophysics *2019 – Present*
  "Accreting supermassive black holes in the first billion years: impact on their environments from parsecs to mega-parsecs"
- **The University of Texas at Austin**
  B.S. Astronomy & B.S. Physics, GPA:3.52 *2015 – 2019*
- **Corazonista School - Bogotá, Colombia**
  High School GPA:3.96 *2007 – 2013*

Previous Employment

- **The University of Texas at Austin (UT Austin)**
  Undergraduate Research Assistant *2016 – 2019*
  Search for galaxies at z∼8-10 in the HST-BoRG survey under the supervision of Dr. Steven Finkelstein.
- **Max Planck Institute for Astronomy**
  Summer Research Intern *Summer 2018*
  Analyzed varying chemical abundances in nuclear star clusters with Dr. Nadine Neumayer and Dr. Nikolay Kacharov.
- **The National Radio Astronomy Observatory**
  Summer Research Intern *Summer 2017*
  Analyzed and mapped star formation in different areas of LIRG-type interacting galaxies under the supervision of Dr. Eric Murphy.

Research Projects

- **Spectral Energy Distribution of an Extreme Radio Quasar at z∼6** **Dr. Eduardo Bañados**
  Max Planck Institute for Astronomy - Heidelberg *2019-2021*
  Analyzed ALMA, NOEMA, and GMRT data to study the influence of jets in the host galaxy of an extreme radio-loud QSO at z∼6 with evidence of extended radio lobes.
- **Finding Galaxies at z=8-10 with the Hubble Space Telescope** **Dr. Steven Finkelstein**
  The University of Texas at Austin *2016-2019*
  Reduced HST imaging data, used Source Extractor and EAZY to perform photometric detections of galaxies at redshifts 8-10.
- **Investigating Chemical Abundances in Nuclear Star Clusters** **Dr. Nadine Neumayer**
  Max Planck Institute for Astronomy *Summer 2018*
  Fit synthetic model spectra generated with MOOG to integrated light spectra from X-Shooter/VLT of the nuclear star clusters in six nearby galaxies.
- **Star formation tracing in Infrared-Bright Interacting Galaxies** **Dr. Eric Murphy**
  The National Radio Astronomy Observatory *Summer 2017*
  Analyzed Mid-Infrared spectra to find PAH features, molecular hydrogen, and characteristic AGN compounds in eight LIRG interacting galaxies.
- **HETDEX (Hobby-Eberly Telescope Dark Energy Experiment) Dr. S. Finkelstein, Dr. K. Gebhardt**
  The University of Texas at Austin *Summer 2016*
  Tested the first spectrographs for the HETDEX project by running calibrations and using QFitsView to find Lyman-Alpha galaxies at redshifts 2-4.
- **Measuring the Color-Magnitude Diagram of M67** **Dr. Michael Montgomery**
  The University of Texas at Austin *Spring 2016*
  Took images of M67 with the 0.8m telescope at McDonald observatory and performed PSF photometry to analyze Color-Magnitude diagrams.

Publications

- Rojas-Ruiz, Sofía; Bañados, Eduardo; Neeleman, Marcel et al. **2021,** *The Impact of Powerful Jets on the Far-infrared Emission of an Extreme Radio Quasar at z∼6* , The Astrophysical Journal, 920, 150
- Rojas-Ruiz, Sofía; Finkelstein, Steven L.; Bagley, Micaela B. et al. **2020,** *Probing the Bright End of*

the Rest-frame Ultraviolet Luminosity Function at z = 8-10 with Hubble Pure-parallel Imaging, The Astrophysical Journal, 891, 146

- Tacchella, Sandro et al. (Rojas-Ruiz, Sofía 16^{th} of 21 authors) **2021,** *On the Stellar Populations of Galaxies at $z = 9 - 11$: The Growth of Metals and Stellar Mass at Early Times,* arXiv:2111.05351
- Finkelstein, Steven L. et al. (Rojas-Ruiz, Sofía 21^{st} of 24 authors) **2021,** *A Census of the Bright z=8.5-11 Universe with the Hubble and Spitzer Space Telescopes in the CANDELS Fields,* arXiv:2106.13813
- Connor, Thomas et al. (Rojas-Ruiz, Sofía 7^{th} of 11 authors) **2021,** *Enhanced X-Ray Emission from the Most Radio-powerful Quasar in the Universe's First Billion Years,* The Astrophysical Journal, 911,120

Talks

- **Interactions of Radio Jets and Interstellar Medium in an Extreme Radio-loud Quasar in the First Gyr of the Universe**
  Rojas Ruiz, S., Bañados, E., Neeleman, M. et al.
  - European Astronomical Society Annual Meeting (EAS), Leiden, Netherlands (Virtual) *2021*
  - Galaxy Coffee at the Max Planck Institute for Astronomy, Heidelberg, Germany *2021*
  - Astronomy Seminar, Universidad de Los Andes, Colombia *2021*
  - Orígenes Seminar, Universidad de Antioquia, Colombia *2021*
- **Search for Bright Galaxies at z=8-10 with the Hubble Space Telescope**
  Rojas Ruiz, S., Finkelstein, S., Bagley, M. B. et al.
  - 'Black Holes and Galaxies at the Edge of the Universe', Ringberg Castle, Germany *2020*
  - TMT Seminar, European Southern Observatory, Chile (ESO-Santiago) *2020*
  - Galaxy Coffee at Max Planck Institute for Astronomy, Heidelberg, Germany *2019*
  - Astronomy on Tap - Bogotá, Colombia *2018*
  - Extragalactic Seminar at The University of Texas at Austin *2017*
  - Texas Astronomy Undergraduate Research Symposium *2016*

Poster Presentations

- **Investigating the Mpc-scale Environment around the $z \sim 7.54$ Quasar ULAS J1342+0928**
  Rojas Ruiz, S., Mazzucchelli, C., Bañados,E., et al.
  - 'Formation and Evolution of Galaxy Clusters Across Cosmic Time',
    XXXII Canary Islands Winter School of Astrophysics, La Laguna, Tenerife, Spain. *2021*
- **The Host Galaxy of an Extreme Radio Quasar at $z \sim 6$**
  Rojas Ruiz, S., Bañados, E., Neeleman, M., et al.
  - Extragalactic jets on all scales - launching, propagation, termination, MPIA and IIT Indore, Virtual *2021*
  - Summer All Zoom Epoch of Reionization Astronomy Conference (SAZERAC) *2020*
- **Search for Bright Galaxies at z=8-10 with the Hubble Space Telescope.**
  Rojas Ruiz, S., Finkelstein, S., Bagley, M. B. et al.
  - 'First Light School': Stars, Galaxies and Black Holes in the Epoch of Reionization, Brazil *2019*
  - 'Barefoot Reionization': Exploring the first billion years of the Universe, Australia *2019*
  - 233rd American Astronomical Society (AAS), #233, id. 144.03 *2019*
  - Board of Visitors Meeting, UT Austin *2018*
  - Frank N. Bash Symposium, UT Austin *2017*
  - College of Natural Sciences Research Forum, UT Austin *2016*
- **Infrared-Bright Interacting Galaxies.**
  Rojas Ruiz, S., Murphy, E. J., Armus, L., Smith, J.D.T., Bradford, C.M., Stierwalt, S. *2018*
  231th American Astronomical Society (AAS), #231, id. 251.07

Awards

Research Funding

- ***European Southern Observatory Science Support Discretionary Fund (ESO-SSDF)*** *Fall 2020*
  Awarded to an ESO-Chile Fellow and a student visitor to complete a research project.
- ***IMPRS Fellowship for PhD at International Max Planck Research School - Heidelberg*** *Spring 2019*
  Awarded every year to the most outstanding applicant to fund the full studies of the Ph.D. (4 years).

- ***Student Researcher Award, UT Office of Undergraduate Research*** *Spring 2019*
  Two fellowships awarded yearly to students in all areas of research to advance and showcase their projects.
- ***Undergraduate Research Fellowship, UT Office of Undergraduate Research*** *Spring 2018*
  Financial support for a research project conducted at the university.
- ***John W. Cox Endowment for the Advanced Studies in Astronomy*** *Summer 2016*
  Awarded to develop a research project at the Astronomy Department during the summer.
- ***FRI Summer Research Fellowship*** *Summer 2016*
  Awarded to a freshman student developing a summer research project at the College of Natural Sciences.

Scholarships

- ***Ralph Cutler Greene Endowed Scholarship, UT Astronomy Department*** *Spring 2019*
  Awarded annually to an outstanding senior astronomy student entering their final year.
- ***General ISSS Financial Aid, UT International Office*** *Fall 2016-Spring 2019*
  Awarded every year in cash assistance to international students who demonstrate financial need.
- ***Melvin J. Rieger Scholarship Fund in Physics, UT Physics Department*** *Fall 2018-Spring 2019*
  Endowed scholarship awarded every academic year to an outstanding physics student.
- ***Jeannie Hunter Hackett Memorial Scholarship, PART - Austin Chapter*** *Spring 2018*
  Awarded every year to an outstanding UT Austin junior or senior from Latin America.
- ***College of Natural Sciences out-of-state tuition waiver*** *Fall 2016-Spring 2018*
  Waiver allowing non-resident of Texas students to pay one year of tuition at in-state rates.
- ***Thomas and Elizabeth Merner Scholarship, College of Natural Sciences*** *Fall 2017-Spring 2018*
  Awarded to students in financial need and with strong academic performance
- ***Brian M. Welch Endowed Memorial Scholarship, College of Natural Sciences*** *Fall 2016-Spring 2017*
  Offered to students in the College of Natural Sciences with a minimum 3.0 GPA.
- ***Abel Family Scholarships in Physics, UT Physics Department*** *Fall 2016-Spring 2017*
  Awarded to outstanding students in the Physics Department

Honors

- ***Astronomy Departmental Honors, UT Austin.*** *Spring 2019*
  Awarded to students presenting a written and oral thesis in astronomy and who have a GPA above 3.50.
- ***Graduate Physics Departmental Honors, UT Austin*** *Spring 2019*
  Awarded to students graduating with a thesis in physical sciences and a GPA above 3.50.
- ***Graduate of Distinction in Research, College of Natural Sciences, UT Austin*** *Spring 2019*
  Awarded to students who demonstrated excellence in the area of Research during their career.
- ***College of Natural Sciences Aspire Professor's Choice Awards*** *Spring 2018*
  Awarded every year to honor excellent Black and LatinX students nominated by their professors.
- ***College of Natural Sciences Aspire Research Excellence Award*** *Spring 2017*
  Awarded every year to honor the research accomplishments of Black and LatinX students.
- ***Honors in IV Colombian Astronomy Olympiad*** *2013*
  Received 4th place at the national competition and was selected to participate in the Latin American Olympiad.
- ***Bronze Medal in V Latin American Olympiad of Astronomy and Astronautics*** *2013*
  Awarded every year to students from Latin America participating in this competition.
- ***High School Valedictorian, Corazonista School Bogotá*** *2013*
  Awarded to one graduating student with the best academic record during the periods of 6th to 11th grades.

Research Skills

Research Classes

- **AST 376: Observational Methods in Astronomy** **Dr. Finkelstein, Dr. Kraus**
  Used the 0.9m and 2.7m telescopes at McDonald Observatory to obtain and analyze data for projects in different areas of astronomy. *Fall 2018*
- **AST 210K: FRI-White Dwarfs** **Dr. Michael Montgomery**
  Gained experience analyzing light curves of white dwarfs using Fourier transforms, and MESA software for simulations of stellar evolution. *Spring 2016*
- **AST 376R: A Practical Introduction to Research** **Dr. Shardha Jogee**
  Learned to use the Linux/Mac OSX operating systems, used IRAF/PyRAF and DS9 software for analysis of nearby galaxies with different morphologies. *Fall 2015*

Software and Programming Skills

- Use of LaTeX and programming experience with the Interactive Data Language (IDL), Python, and Mathematica for array manipulations, reading multi-dimensional catalogs, statistical analyses, and plotting.
- Reduction and analysis of interferometry data with ***GILDAS*** *and* ***CASA.***
- Performance of photometry in images using ***Source Extractor***.
- Application of the ***EAZY*** program "Easy and Accurate Z(photometric redshifts) from Yale" to find photometric redshifts of galaxies.
- Utilization of Software ***CUBISM*** (Cube Builder for IRS Spectral Mapping) and ***SMART*** (Spectroscopy Modeling Analysis and Reduction Tool) to reduce and analyze Mid-Infrared spectra from galaxies.
- Use of the code ***MOOG*** to generate synthetic spectra for analyzing the chemical composition of stars.

Telescope Experience

Observing Proposals Led

- ***James Webb Space Telescope (JWST) Cycle 1 GO*** **(Rojas–Ruiz Co-PI)**
  "Spectroscopic Confirmation and Characterization of Bright Galaxies at z∼9".
  Awarded 18.2 hours with NIRSpec/Fixed slit from the JWST TAC.

- ***Very Large Array (VLA)*** **(Rojas–Ruiz PI)**
  "Constraining the Synchrotron Lifetime of an Extreme Radio Quasar at Redshift 6".
  Awarded 5.00 hours at Priority A from the NRAO TAC.

Observing time

- The MPG/ESO 2.2m Telescope, La Silla Observatory.
- Keck 1 Telescope with the MOSFIRE spectrograph, W.M Keck Observatory.
- The 2.7m, 0.8m, and 0.9m telescopes at McDonald Observatory.
- The Mayall 4-meter telescope at Kitt Peak National Observatory.
- The 40-ft radio telescope at Green Bank Observatory.

Work with data from

- *Hubble* Space Telescope data (WFC3/UVIS and WFC3/IR Instruments.)
- *Spitzer* Space Telescope IRS data.
- *VLT* X-Shooter integrated light spectral data.
- *NOEMA* and *ALMA* interferometry data.

Teaching Experience

- **Heidelberg University, Germany**
  Tutor of the class 'Introduction to Astronomy and Astrophysics' *Winter 2021*
  Prepared classes of additional material on topics of Galactic and Extragalactic Astronomy. Specifically presented research on nuclear star clusters, dwarf galaxies and Dark Matter, galaxy clusters and lensing, and galaxies and quasars in the Epoch of Reionization. Also helped students reviewing and clarifying the homework exercises.

- **Mentoring Program for Future Colombian Astronomers**
  Red de Estudiantes Colombianos de Astronomía (RECA) *2020 – 2021*
  Mentored students in pursuit of doctoral education in Astronomy overseas. Helped them prepare for the TOEFL English test, guided application materials, gathered funding resources and supported the student until successful acceptance to high-quality astronomy programs in Europe. https://recaastronomia.wixsite.com/website-5/mentores

- **Heidelberg University, Germany**
  Tutor of Advanced Lab F36: 'Wavefront analysis with a Shack-Hartmann wavefront sensor.' *Summer 2020*
  Prepared short quizzes for the preparation of the lab, instructed and graded students on the development of the experiment.

- **The University of Texas at Austin**
  Undergraduate Learning Assistant of "AST 301: Introduction to Astronomy" *Fall 2016*
  Collaborated on preparing activities to teach this class targeted for non-science majors and helped them prepare for exams.

Service to the Community

- *Referee for the Astrophysical Journal* *2021*
- *Committee Organizer of the Network of Colombian Astronomy Students* *2021*
  (Red Estudiantes Colombianos Astronomía - RECA) https://recaastronomia.wixsite.com/website-5
- *Leader of RECA - Education Node, Colombia* *2021*
  https://recaastronomia.wixsite.com/website-5/educación

University Involvement

- *Student advisor of the Texas Institute for Discovery Education in Science (TIDES) Board* *2017-2019*
- *Astronomy Students Association, UT elected Webmaster* *2016-2017*
- *Student in the Freshman Research Initiative stream "Exploring the Universe with White Dwarfs"* *2016*
- *Undergraduate Women in Physics, UT chapter member* *2015-2019*
- *Society of Physics Students, UT chapter member* *2015*

Extracurricular Activities

- *Co-Organizer of Astronomy on Tap Bogotá, Colombia* *2017-2018*
- *Stargazing with Newtonian telescope* *2007-present*
- *Build Hydraulic Rockets* *3 yrs*
- *Outreach volunteer of the Colombian Astronomy Association "ACDA"* *4 yrs*
- *Salsa dancing* *15 yrs*
- *Play tennis and soccer* *10 yrs*
- *Play soccer* *2 yrs*
- *Languages: Spanish (Native), English (Fluent), and German (A2.2 level).*

References

- *Dr. Eduardo Bañados, MPIA, Heidelberg* *Email: banados@mpia.de*
- *Dr. Steven Finkelstein, UT Austin* *Email: stevenf@astro.as.utexas.edu*
- *Dr. Nadine Neumayer, MPIA, Heidelberg* *Email: neumayer@mpia.de*
- *Dr. Eric Murphy, NRAO, Charlottesville, VA* *Email: emurphy@nrao.edu*