

Alejandro Cruz Osorio

Instituto de Astronomía, Universidad Nacional Autónoma de México
Ciudad de México – México

✉ aosorio@astro.unam.mx • 🌐 <https://itp.uni-frankfurt.de/osorio/index.html>
Nationality: Mexican Date of birth: April 17 of 1984

Research Interests

Relativistic Astrophysics : Extragalactic Relativistic Jets – Shadows – Multiwavelength Emission – Accretion onto Compact Objects – General Relativistic Magnetohydrodynamics. General Relativity: Gravitational waves – Neutron and Quark Stars. Nonthermal Particle Acceleration.

Experience

Investigador Asociado C <i>Instituto de Astronomía, Universidad Nacional Autónoma de México, México.</i>	Aug.2023–Jul.2025
Postdoctoral Fellow in Relativistic Astrophysics <i>Institut für Theoretische Physik, Goethe Universität Frankfurt, Germany. MENTOR: Luciano Rezzolla</i>	2019–2023
Postdoctoral Fellow in Numerical Relativity <i>Departament d'Astronomia i Astrofísica, Universitat de València, Spain. MENTOR: José A. Font Roda.</i>	2017–2019
Postdoctoral Fellow in Relativistic Astrophysics <i>Institut Für Theoretische Physik, Goethe Universität Frankfurt, Germany. MENTOR: Luciano Rezzolla</i>	2016–2017
Postdoctoral Fellow in Astronomy <i>Instituto de Astronomía, Universidad Nacional Autónoma de México, México. MENTOR: F. Sánchez.</i>	2015–2016
Full time interim professor <i>Dep. of Computational Systems, Instituto Tecnológico Superior de los Ríos, México</i>	Aug.2014–Feb.2015

Education

Ph.D. in Physics <i>Institute of Physics and Mathematics, UMSNH, México</i> Numerical implementation of the relativistic magnetohydrodynamics	2010-2014
M.Sc. in Physics <i>Institute of Physics and Mathematics, UMSNH, México</i> Numerical solution of the wave equation in Minkowski and Schwarzschild space-times in a domain containing the future infinite null	2008-2010
B.Sc in Physics-Mathematics <i>Faculty of Physical-Mathematical Sciences, UMSNH, México</i> Tracking null radial geodesics of spherically symmetric space-times.	2002-2008

Languages

Nahuatl: Native	Spanish: Native
English: Full professional proficiency	German: Basic

Awards and Recognitions

EHT Early Career Award 2022: For the outstanding contribution of Theoretical Modeling of Sagittarius A*. The Event Horizon Telescope collaboration. Dec. 2022

Wissenschaftspreis der Frankfurter Physik 2022 (Science Award of Frankfurt Physics 2022): Department of Physics Goethe University Frankfurt and Walter Greiner Gesellschaft zur Förderung der physikalischen Grundlagenforschung, Frankfurt, Germany. Jul. 2022

2016–2022 SNI I: National Researchers System Recognition by the National Council of Science and Technology (CONACYT ¹), México. First period: Jan 2016 – Dec 2018. Second period: Jan 2019 – Dec 2022. Third period: Jan 2023 –

Research Grants

2024–2026: Project CBF2023-2024-1102 – Sombras de Agujeros Negros y Jets Relativistas como laboratorios para probar teorías de la gravedad, propiedades del plasma en discos de acreción y la aceleración de partículas Ciencia Básica y de Frontera 2023-2024 (CONAHCYT)

2022–2025 Marie Curie Horizon Europe Staff Exchange action 2022 (NewFunFiCO): Fundamental Fields and Compact Objects: new opportunities, funding 276 000 Euros, **Before:co-PI of Germany branch. Now: Co-PI of Mexican branches.**

2021–2023 JETSET-ERC Fellowship: Institut Für Theoretische Physik, Goethe Universität.

2019–2021 Black Hole Cam-EHT Fellowship: Institut Für Theoretische Physik, Goethe Universität.

2017–2019 CONACYT Postdoc abroad Fellowship: at Universitat de València.

2016–2017 ExaHyPE-Horizon 2020 EU Fellowship: Institut Für Theoretische Physik, Goethe Universität.

2015–2017 DGAPA postdoc Fellowship: at Institute of Astronomy, UNAM

2008–2010 Fellowship for Ph.D. studies: at the Institute of Physics and Mathematics, UMSNH ², granted by the Mexican Council of Science CONACyT.

2010–2014 Fellowship for M.Sc studies: at the Institute of Physics and Mathematics, UMSNH, granted by the Mexican Council of Science CONACyT.

Grants of computational time allocation

Co-PI Estudio de la emisión electromagnética en multifrecuencias de Blazares: Comparación teórica-observacional LAMOD-UNAM cluster. 1 Million CPU-hours. 2023-2024.

PI Evolución de discos magnetizados alrededor de agujero negro LAMOD-UNAM cluster. 0.5 Million CPU-hours. 2023-2024.

PI of the project Long-term simulations of magnetized disks and jets around supermassive black-hole binaries in General Relativity HAWK cluster, High-Performance Computing Center Stuttgart, Stuttgart, Germany. 100 Millions CPU-hours. 2023-2024.

PI of the project Large-scale numerical-relativity simulations of tilted black hole-torus system, project-ID: FI-2019-2-0043, 3 Millions CPU-hours, Estimated cost: 2959 euros, Cluster: Barcelona Supercomputing center-MareNostrum 4.

Microphysical aspects of binary neutron star mergers (BNSMIC), HAWK cluster, High-Performance Computing Center Stuttgart, Stuttgart, Germany. **100 Millions CPU-hours.** PI Luciano Rezzolla.

Publications

[1] **Cruz-Osorio, A., Gonzalez-Juarez, A., Guzman, F. S., & Lora-Clavijo, F. D.** Numerical solution of the wave equation on particular space-times using CMC slices and scri-fixing conformal compactification. *Rev. Mex. Fis.*, 56:456–468, pages 456–468. 2010

CONACYT: Consejo Nacional de Ciencia y Tecnología

UMSNH: Universidad Michoacana de San Nicolás de Hidalgo

- [2] **Cruz-Osorio**, A., Lora-Clavijo, F. D., & Guzmán, F. S., Jul. 2010, in *American Institute of Physics Conference Series*, Vol. 1256, *Gravitational Physics: Testing Gravity from Submillimeter to Cosmic*, ed. H. A. Morales-Tecotl, L. A. Urena-Lopez, R. Linares-Romero, & H. H. Garcia-Compean, pages 311–317
- [3] Lora-Clavijo, F. D., **Cruz-Osorio**, A., & Guzmán, F. S. Evolution of a massless test scalar field on boson star space-times. *Phys. Rev. D*, **82(2)**:023005, page 023005. Jul. 2010
- [4] **Cruz-Osorio**, A., Guzmán, F. S., & Lora-Clavijo, F. D. Scalar field dark matter: behavior around black holes. *Journal of Cosmology and Astroparticle Physics*, **2011(6)**:029, page 029. Jun. 2011
- [5] **Cruz-Osorio**, A., Lora-Clavijo, F. D., & Guzmán, F. S. Is the flip-flop behaviour of accretion shock cones on to black holes an effect of coordinates? *Mon. Not. R. Astron. Soc.*, **426(1)**:732–738, pages 732–738. Oct. 2012
- [6] **Cruz-Osorio**, A., Lora-Clavijo, F. D., & Guzmán, F. S., Jul. 2013, in *American Institute of Physics Conference Series*, Vol. 1548, *IX Mexican School on Gravitation and Mathematical Physics: Cosmology for the XXIst Century: Gravitation and Mathematical Physics Division of the Mexican Physical Society DGFMSMF*, ed. L. A. Uren-López, R. Becerril-Bárceñas, & R. Linares-Romero, pages 323–327
- [7] Lora-Clavijo, F. D., Guzmán, F. S., & **Cruz-Osorio**, A. PBH mass growth through radial accretion during the radiation dominated era. *Journal of Cosmology and Astroparticle Physics*, **2013(12)**:015, page 015. Dec. 2013
- [8] Lora-Clavijo, F. D., **Cruz-Osorio**, A., & Guzmán, F. S. CAFE: A New Relativistic MHD Code. *Astrophys. J., Supp.*, **218(2)**:24, page 24. Jun. 2015
- [9] Lora-Clavijo, F. D., **Cruz-Osorio**, A., & Moreno Méndez, E. Relativistic Bondi-Hoyle-Lyttleton Accretion onto a Rotating Black Hole: Density Gradients. *Astrophys. J., Supp.*, **219(2)**:30, page 30. Aug. 2015
- [10] González-Avilés, J. J., **Cruz-Osorio**, A., Lora-Clavijo, F. D., & Guzmán, F. S. Newtonian CAFE: a new ideal MHD code to study the solar atmosphere. *Mon. Not. R. Astron. Soc.*, **454(2)**:1871–1885, pages 1871–1885. Dec. 2015
- [11] **Cruz-Osorio**, A., & Lora-Clavijo, F. D. Non-axisymmetric relativistic wind accretion with velocity gradients on to a rotating black hole. *Mon. Not. R. Astron. Soc.*, **460(3)**:3193–3201, pages 3193–3201. Aug. 2016
- [12] **Cruz-Osorio**, A., Sánchez-Salcedo, F. J., & Lora-Clavijo, F. D. Relativistic Bondi-Hoyle-Lyttleton accretion in the presence of small rigid bodies around a black hole. *Mon. Not. R. Astron. Soc.*, **471(3)**:3127–3134, pages 3127–3134. Nov. 2017
- [13] Becerra-Vergara, E. A., Mojica, S., Lora-Clavijo, F. D., & **Cruz-Osorio**, A. Anisotropic quark stars with an interacting quark equation of state. *Phys. Rev. D*, **100(10)**:103006, page 103006. Nov. 2019
- [14] Arroyo-Chávez, G., **Cruz-Osorio**, A., Lora-Clavijo, F. D., Campuzano Vargas, C., & García Mora, L. A. Neutron and quark stars: constraining the parameters for simple EoS using the GW170817. *Astrophys Space Sci.*, **365(2)**:43, page 43. Feb. 2020
- [15] **Cruz-Osorio**, A., Gimeno-Soler, S., & Font, J. A. Non-linear evolutions of magnetized thick discs around black holes: dependence on the initial data. *Mon. Not. R. Astron. Soc.*, **492(4)**:5730–5742, pages 5730–5742. Mar. 2020
- [16] **Cruz-Osorio**, A., & Rezzolla, L. Common-envelope Dynamics of a Stellar-mass Black Hole: General Relativistic Simulations. *Astrophys. J.*, **894(2)**:147, page 147. May 2020
- [17] Event Horizon Telescope Collaboration, Akiyama, K., Algaba, J. C., et al. First M87 Event Horizon Telescope Results. VII. Polarization of the Ring. *Astrophys. J. Lett.*, **910(1)**:L12, page L12. Mar. 2021

- [18] Event Horizon Telescope Collaboration, Akiyama, K., Algaba, J. C., et al. First M87 Event Horizon Telescope Results. VIII. Magnetic Field Structure near The Event Horizon. *Astrophys. J. Lett.*, **910(1)**:L13, page L13. Mar. 2021
- [19] Goddi, C., Martí-Vidal, I., Messias, H., et al. Polarimetric Properties of Event Horizon Telescope Targets from ALMA. *Astrophys. J. Lett.*, **910(1)**:L14, page L14. Mar. 2021
- [20] EHT MWL Science Working Group, Algaba, J. C., Anzarski, J., et al. Broadband Multi-wavelength Properties of M87 during the 2017 Event Horizon Telescope Campaign. *Astrophys. J. Lett.*, **911(1)**:L11, page L11. Apr. 2021
- [21] Narayan, R., Palumbo, D. C. M., Johnson, M. D., et al. The Polarized Image of a Synchrotron-emitting Ring of Gas Orbiting a Black Hole. *Astrophys. J.*, **912(1)**:35, page 35. May 2021
- [22] Kocherlakota, P., Rezzolla, L., Falcke, H., et al. Constraints on black-hole charges with the 2017 EHT observations of M87*. *Phys. Rev. D*, **103(10)**:104047, page 104047. May 2021
- [23] **Cruz-Osorio**, A., Gimeno-Soler, S., Font, J. A., De Laurentis, M., & Mendoza, S. Magnetized discs and photon rings around yukawa-like black holes. *Phys. Rev. D*, **103(12)**:124009, page 124009. Jun. 2021
- [24] **Cruz-Osorio**, A., Lora-Clavijo, F. D., & Herdeiro, C. GW190521 formation scenarios via relativistic accretion. *Journal of Cosmology and Astroparticle Physics*, **2021(07)**:032, page 032. Jul. 2021
- [25] Janssen, M., Falcke, H., Kadler, M., et al. Event Horizon Telescope observations of the jet launching and collimation in Centaurus A. *Nature Astronomy*, **5**:1017–1028, pages 1017–1028. Jul. 2021
- [26] **Cruz-Osorio**, A., Fromm, C. M., Mizuno, Y., et al. State-of-the-art energetic and morphological modelling of the launching site of the M87 jet. *Nature Astronomy*, **6**:103–108, pages 103–108. Jan. 2022
- [27] Satapathy, K., Psaltis, D., Özel, F., et al. The Variability of the Black Hole Image in M87 at the Dynamical Timescale. *Astrophys. J.*, **925(1)**:13, page 13. Jan. 2022
- [28] Fromm, C. M., **Cruz-Osorio**, A., Mizuno, Y., et al. Impact of non-thermal particles on the spectral and structural properties of M87. *Astronomy and Astrophysics*, **660**:A107, page A107. Apr. 2022
- [29] Event Horizon Telescope Collaboration, Akiyama, K., Algaba, J. C., Alberdi, A., & Alef, W. First Sagittarius A* Event Horizon Telescope Results. I. The Shadow of the Supermassive Black Hole in the Center of the Milky Way. *Astrophys. J. Lett.*, **930(2)**:L12, page L12. May 2022
- [30] Event Horizon Telescope Collaboration, Akiyama, K., Algaba, J. C., Alberdi, A., & Alef, W. First Sagittarius A* Event Horizon Telescope Results. II. EHT and Multiwavelength Observations, Data Processing, and Calibration. *Astrophys. J. Lett.*, **930(2)**:L13, page L13. May 2022
- [31] Event Horizon Telescope Collaboration, Akiyama, K., Algaba, J. C., Alberdi, A., & Alef, W. First Sagittarius A* Event Horizon Telescope Results. III. Imaging of the Galactic Center Supermassive Black Hole. *Astrophys. J. Lett.*, **930(2)**:L14, page L14. May 2022
- [32] Event Horizon Telescope Collaboration, Akiyama, K., Algaba, J. C., Alberdi, A., & Alef, W. First Sagittarius A* Event Horizon Telescope Results. IV. Variability, Morphology, and Black Hole Mass. *Astrophys. J. Lett.*, **930(2)**:L15, page L15. May 2022
- [33] Event Horizon Telescope Collaboration, Akiyama, K., Algaba, J. C., Alberdi, A., & Alef, W. First Sagittarius A* Event Horizon Telescope Results. V. Testing Astrophysical Models of the Galactic Center Black Hole. *Astrophys. J. Lett.*, **930(2)**:L16, page L16. May 2022
- [34] Event Horizon Telescope Collaboration, Akiyama, K., Algaba, J. C., Alberdi, A., & Alef, W. First Sagittarius A* Event Horizon Telescope Results. VI. Testing the Black Hole Metric. *Astrophys. J. Lett.*, **930(2)**:L17, page L17. May 2022

- [35] Farah, J., & Event Horizon Telescope Collaboration. Selective Dynamical Imaging of Interferometric Data. *Astrophys. J. Lett.*, **930(2)**:L18, page L18. May 2022
- [36] Wielgus, M., & Event Horizon Telescope Collaboration. Millimeter Light Curves of Sagittarius A* Observed during the 2017 Event Horizon Telescope Campaign. *Astrophys. J. Lett.*, **930(2)**:L19, page L19. May 2022
- [37] Georgiev, B., & Event Horizon Telescope Collaboration. A Universal Power-law Prescription for Variability from Synthetic Images of Black Hole Accretion Flows. *Astrophys. J. Lett.*, **930(2)**:L20, page L20. May 2022
- [38] Broderick, A., & Event Horizon Telescope Collaboration. Characterizing and Mitigating Intraday Variability: Reconstructing Source Structure in Accreting Black Holes with mm-VLBI. *Astrophys. J. Lett.*, **930(2)**:L21, page L21. May 2022
- [39] Röder, J., **Cruz-Osorio**, A., Fromm, C. M., et al., Jan. 2022, in *European VLBI Network Mini-Symposium and Users' Meeting 2021*, page 24
- [40] Issaoun, S., Wielgus, M., & Event Horizon Telescope Collaboration. Resolving the inner parsec of the blazar J1924–2914 with the Event Horizon Telescope. *Astrophys. J.*, **934(2)**:21, page 21. Jul. 2022
- [41] Broderick, A., Pesce, D., Gold, R., et al. The Photon Ring in M87*. *Astrophys. J.*, **935(1)**:61, page 61. Aug. 2022
- [42] Meringolo, C., **Cruz-Osorio**, A., Rezzolla, L., & Servidio, S. Microphysical Plasma Relations from Special-relativistic Turbulence. *Astrophys. J.*, **944(2)**:122, page 122. Feb. 2023
- [43] Jorstad, S., Wielgus, M., Lico, R., et al. The Event Horizon Telescope Image of the Quasar NRAO 530. *Astrophys. J.*, **943(2)**:170, page 170. Feb. 2023
- [44] Röder, J., **Cruz-Osorio**, A., Fromm, C. M., et al. Probing the spacetime and accretion model for the Galactic Center: Comparison of Kerr and dilaton black hole shadows. *Astronomy and Astrophysics*, **671**:A143, page A143. Mar. 2023
- [45] Prather, B. S., Dexter, J., Moscibrodzka, M., et al. Comparison of Polarized Radiative Transfer Codes Used by the EHT Collaboration. *Astrophys. J.*, **950(1)**:35, page 35. Jun. 2023
- [46] **Cruz-Osorio**, A., Rezzolla, L., Lora-Clavijo, F. D., et al. Bondi-Hoyle-Lyttleton accretion onto a rotating black hole with ultralight scalar hair. *Journal of Cosmology and Astroparticle Physics*, **2023(8)**:057, page 057. Aug. 2023
- [47] Torne, P., Liu, K., Eatough, R. P., et al. A search for pulsars around sgr a* in the first event horizon telescope data set. *The Astrophysical Journal*, **959(1)**:14, page 14. nov 2023
- [48] Kocherlakota, P., Narayan, R., Chatterjee, K., **Cruz-Osorio**, A., & Mizuno, Y. Toward General Relativistic Magnetohydrodynamics Simulations in Stationary Nonvacuum Spacetimes. *Astrophys. J. Lett.*, **956(1)**:L11, page L11. Oct. 2023
- [49] Event Horizon Telescope Collaboration, Akiyama, K., Alberdi, A., et al. First M87 Event Horizon Telescope Results. IX. Detection of Near-horizon Circular Polarization. *Astrophys. J. Lett.*, **957(2)**:L20, page L20. Nov. 2023
- [50] Roelofs, F., Johnson, M. D., Chael, A., et al. Polarimetric Geometric Modeling for mm-VLBI Observations of Black Holes. *Astrophys. J. Lett.*, **957(2)**:L21, page L21. Nov. 2023
- [51] Mpisketzis, V., Duqué, R., Nathanail, A., **Cruz-Osorio**, A., & Rezzolla, L. Impact of anisotropic ejecta on jet dynamics and afterglow emission in binary neutron-star mergers. *Mon. Not. R. Astron. Soc.*, **527(3)**:9159–9175, pages 9159–9175. Jan. 2024

- [52] Moriyama, K., **Cruz-Osorio**, A., Mizuno, Y., et al. Future Prospects for Constraining Black Hole Spacetime: Horizon-scale Variability of Astrophysical Jets. *Astrophys. J.*, **960(2)**:106, page 106. Jan. 2024
- [53] Event Horizon Telescope Collaboration, Akiyama, K., Alberdi, A., et al. The persistent shadow of the supermassive black hole of M 87. I. Observations, calibration, imaging, and analysis. *Astronomy and Astrophysics*, **681**:A79, page A79. Jan. 2024
- [54] Paraschos, G. F., Kim, J. Y., Wielgus, M., et al. Ordered magnetic fields around the 3C 84 central black hole. *Astronomy and Astrophysics*, **682**:L3, page L3. Feb. 2024
- [55] Event Horizon Telescope Collaboration, Akiyama, K., Alberdi, A., et al. First Sagittarius A* Event Horizon Telescope Results. VII. Polarization of the Ring. *Astrophys. J. Lett.*, **964(2)**:L25, page L25. Apr. 2024
- [56] Event Horizon Telescope Collaboration, Akiyama, K., Alberdi, A., et al. First Sagittarius A* Event Horizon Telescope Results. VIII. Physical Interpretation of the Polarized Ring. *Astrophys. J. Lett.*, **964(2)**:L26, page L26. Apr. 2024
- [57] Chabanov, M., **Cruz-Osorio**, A., Ecker, C., et al., Apr. 2024, in *High Performance Computing in Science and Engineering '22, Springer Nature Switzerland*, ed. W. E. Nagel, D. H. Kröner, & M. M. Resch, page 19
- [58] Zhang, M., Mizuno, Y., Fromm, C. M., Younsi, Z., & **Cruz-Osorio**, A. Impacts of nonthermal emission on the images of a black hole shadow and extended jets in two-temperature GRMHD simulations. *Astronomy and Astrophysics*, **687**:A88, page A88. Jul. 2024
- [59] Gimeno-Soler, S., Pimentel, O. M., Lora-Clavijo, F. D., **Cruz-Osorio**, A., & Font, J. A. Magnetized tori with magnetic polarization around Kerr black holes: Variable angular momentum disks. *Phys. Rev. D*, **110(2)**:023023, page 023023. Jul. 2024
- [60] Raymond, A. W., Doeleman, S. S., Asada, K., et al. First very long baseline interferometry detections at 870 m. *The Astronomical Journal*, **168(3)**:130, page 130. aug 2024
- [61] Sanchez-Bermudez, J., Cruz-Osorio, A., Barrera-Ballesteros, J. K., Alberdi, A., & Schödel, R., Aug. 2024, in *Society of Photo-Optical Instrumentation Engineers (SPIE) Conference Series, Vol. 13095, Optical and Infrared Interferometry and Imaging IX*, ed. J. Kammerer, S. Sallum, & J. Sanchez-Bermudez, page 1309519
- [62] Imbrogno, M., Meringolo, C., Servidio, S., et al. Long-lived Equilibria in Kinetic Astrophysical Plasma Turbulence. *Astrophys. J. Lett.*, **972(1)**:L5, page L5. Sep. 2024
- [63] Algaba, J. C., Baloković, M., Chandra, S., et al. Broadband multi-wavelength properties of M87 during the 2018 EHT campaign including a very high energy flaring episode. *Astronomy and Astrophysics*, **692**:A140, page A140. Dec. 2024
- [64] Baczkó, A.-K., Kadler, M., Ros, E., et al. The putative center in NGC 1052. *Astronomy and Astrophysics*, **692**:A205, page A205. Dec. 2024

Teaching and Mentoring

Graduated students.....

Giuseppe Riveccio (M.Sc. in Physics)	17.11.2023
<i>Università degli Studi di Napoli Federico II, Italy</i>	<i>co-supervisor: Mariafelicia De Laurentis</i>
Tracking hotspots around Sgr A*	
Mauricio Ortiz (M.Sc. in Astrophysics) with Summa cum laude	04.09.2023
<i>Institut für Theoretische Physik, University of Cologne, Germany</i>	<i>co-supervisor: Claus Kiefer</i>
General Relativistic Magnetohydrodynamic Simulations of Relativistic Jets Interacting with Stellar Winds	

- Jan Röder (M.Sc. in Astrophysics) with Summa cum laude** **14.04.2020**
Institut für Theoretische Physik, Goethe Universität Frankfurt, Germany *co-supervisor: Luciano Rezzolla*
 Comparison of Kerr and dilaton black hole shadows: Impact of non-thermal emission
- Luis García (B.Sc. in Physic)[14]** **12.03.2019**
Faculty of Physics, UNAM, México
 Quark star using MIT bag model
- Griselda Arroyo Chávez (B.Sc. in Physic) with "Mención Honorífica" [14]** **26.01.2018**
Faculty of Physics, Universidad Veracruzana, México *co-supervisor: C. Campuzano*
 Observational and numerical comparability of neutron stars models using a polytropic EoS

Teaching

- 2025-1 Introducción al cómputo intensivo para astrónomos, MSc. in Astrophysics program, IA-UNAM, México.
- 2025-1 Introducción a la astrofísica relativista, SI, MSc. in Astrophysics program, IA-UNAM, México.
- 2024-2 Modelado de la emision de AGNs con jet, SI, MSc. in Astrophysics program, IA-UNAM, México.
- 2024-2 Numerical Relativistic Magnetohydrodynamics, MSc. in Astrophysics program, IA-UNAM, México.
- 2024-2 Relativity, Science Faculty (Physic), UNAM, México.
- 2024-1 Quantum Mechanics, M. Sc. in Astrophysics program, IA-UNAM, México.
- 2022-2 Hydrodynamics and Magnetohydrodynamics, M. Sc. in Physics program, summer semester, Institute of Theoretical Physics, Goethe-Universität Frankfurt, Germany. [Notes here](#)
- 2016 Relativity, Science Faculty (Physic), UNAM, México.
- 2015 Electrodynamics, M. Sc. in Astrophysics program, Institute of Astronomy-UNAM, México.
- 2015 Hydrodynamics in general relativity, M. Sc. in Astrophysics program, Institute of Astronomy-UNAM, México.
- 2014 General Physics, Department of Computer Systems Engineering, Instituto Tecnológico Superior de los Ríos, México.
- 2014 Fluid mechanics, Environmental Engineering, Instituto Tecnológico Superior de los Ríos, Tabasco, México.
- 2014 Transport phenomena, Environmental Engineering, Instituto Tecnológico Superior de los Ríos, México.
- 2014 Graduation Seminar. Master in Nutritional, Universidad de Morelia, Michoacán, México.
- 2014 Statistics II. Masters in Nutritional, Universidad de Morelia, Michoacán, México.
- 10-13 Mathematics I, Faculty of Biology, Universidad Michoacana de San Nicolás de Hidalgo, Michoacán, México.
- 10-13 Physics, Faculty of Biology, Universidad Michoacana de San Nicolás de Hidalgo, Michoacán, México.
- 2010 Thermodynamics, Faculty of Electrical Engineering, Universidad Michoacana de San Nicolás de Hidalgo, Michoacán, México.

Tutoring

- 2022 General Relativity, Winter semester, Professor: Dr. Luciano Rezzolla, Goethe-Universität Frankfurt, Germany.
- 2021 Proseminar on Astrophysics, summer semester, Professor: Dr. Laura Sagunski and Dr. Jürgen Schaffner Bielich, Goethe-Universität Frankfurt, Germany.
- 2021 Einführung in die Programmierung für Physiker (Introduction to programming for physicists), winter semester, Professor of the course: Dr. Eberhard Engel, Goethe-Universität Frankfurt, Germany.

Talks

Invited talks – Conferences

Modelado de sombras de agujeros negros supermasivos

Invited Lecture, XV Taller de la División de Gravitación y Física-Matemática-SMF, León, Guanajuato, México. Oct. 21-24 2024

Agujeros Negros

Invited Lecture, Primera Escuela de Verano, Observatorio Astronómico Nacional Tonantzintla 2024, Tonantzintla, Puebla, México. Jun. 30-Jul. 5 2024

Using ngVLA to probe gravity, plasma properties and particle acceleration

Invited Talk, First Mexican meeting in route to the Next Generation VLA, Morelia, México. Sep. 25-27 2023

Interpretando la imagen de la sombra de Sagitario A* utilizando relatividad general

Plenary Talk, LXV Congreso Nacional de Física, Zacatecas, México. Oct 4 2022

Shadow of the supermassive black hole in M87

Review Talk, Growing Black Holes: Accretion & Mergers In memory of Sergio Colafrancesco Kathmandu, Nepal, May 15-20, 2022

GW190521 formation scenarios via relativistic accretion

Engineering Week, Faculty of Higher Studies "Aragón" -UNAM, Mexico City, México. October 28th 2021.

Seminars

Sombras de agujeros negros: Un nuevo horizonte para las teorías de la gravedad

Seminario de Astrofísica del INAOE,

Tonantzintla, Puebla, México. Sep 20, 2024.

Testing modified theory of gravity with shadows

Seminario del Departamento de Gravitación y Teoría de Campos del ICN, UNAM

CDMX, México. Sep 12, 2024.

Relativistic Jets as laboratory to test gravity, particle acceleration and plasma properties

Seminario "Jesús Reyes Corona", Instituto de Física, Benemérita Universidad Autónoma de Puebla, Puebla, México. Feb 23, 2024.

Modelando la sombra de un agujero negro supermasivo: M87* y SgrA*

Seminario del departamento de Física, Facultad de Ciencias, UNAM, México. Feb 09, 2024.

An update on the supermassive black hole shadow M87*

Coloquio del Instituto de Astronomía, UNAM, México. Jan 24, 2024.

Jets relativistas bajo el microscopio: Efectos de la microfísica en la emisión electromagnética

Seminar group DAEC, Institute of Astronomy-UNAM, Mexico City, México. Nov 23th 2023.

Acceleration of non-thermal particles from turbulent plasmas

Coloquio del Instituto de Ciencias Físicas, UNAM, Cuernavaca, Morelos, Mexico. Jan 27, 2023.

Interpretando la imagen de la sombra de Sagitario A* utilizando relatividad general

Seminario del Dep. de Física, Universidad Autónoma Metropolitana Iztapalapa, México. Oct 7 del 2022

Interpretación teórica de la sombra del agujero negro supermasivo Sagitario A*

Coloquio del Instituto de Astronomía, UNAM, Mexico. Oct 6, 2022.

SgrA*: Our own black hole at the heart of the Milky Way

Seminario del Instituto de Física y Matemáticas/Facultad de Ciencias Físico-Matemáticas de la UMSNH

Morelia, Michoacán, México. May 27 2022

Jets relativistas:

Mecanismo de generación, aceleración de partículas y emisión electromagnética en multi-frecuencias

Coloquio del Instituto de Astronomía, UNAM, Mexico. May 11, 2022.

Electromagnetic emission from relativistic jets:

Modeling the launching and high energy emission using GRMHD simulations

Seminar, Instituto Avanzado de Cosmología, Mexico. April 1, 2022.

Multiwavelength emission of M87 jet from GRMHD simulations

Seminario "Dr. Jesús Reyes Corona", Instituto de Física—UAP, Mexico. February 4th 2022.

Understanding multi-wavelength emission of M87 jet using general relativistic MHD simulations

AstroLunch, The Netherlands Institute for Radio Astronomy, Netherlands. January 26th 2022.

Modeling Radiation Emission of M87 Jet with GRMHD Simulations

Dep. of Gravitation and Field theory seminar, Institute of Nuclear Physic-UNAM, México. Sep. 30th 2021.

General relativistic simulations of the common-envelope evolution

Physics Department Seminar, Universidad de la Sapienza Roma, Roma, Italy. March 17th, 2021.

Electromagnetic emissions from relativistic jets and magnetized disks

Multidisciplinary seminar, Facultad de ciencias,

Universidad Autónoma del Estado de México, Toluca, México. November 26th 2020

Relativistic Fluid Accretion Around a Black Hole

AstroCoffee seminar, Institute for Theoretical Physics, Goethe University,

Frankfurt, Germany. May 9th 2017

Fix Mesh Refinement in Cartesian coordinates

Institute of Astronomy-UNAM, Mexico City, México. June 14th 2016.

"Newton (Siglo XVII)—Diplomado en Astrofísica"

Institute of Astronomy-UNAM, Mexico City, México. May 12th 2016.

"Relativistic Bondi-Hoyle accretion onto rotating black holes using CAFE code

Seminar of National Institute of Astrophysics, Optics and Electronics(INAOE)

Tonantzintla, Puebla, México. March 4th 2016.

Primordial black holes as seeds of supermassive black holes

Seminar of the Faculty of Physics, Universidad Veracruzana, Veracruz, México. February 4th 2016.

Relativistic accretion of supersonic winds around rotating black holes

Seminar group DATA, Institute of Astronomy-UNAM, Mexico City, México. January 19th 2016.

Contributed Talks

High Performance Computing in Relativistic Astrophysics

1er BootCamp: Introducción a la Programación Científica IA-UNAM

CDMX, México, Jul. 30 2024

Influence of Initial Accretion Disc properties on GRMHD Simulation Outcomes

The Event Horizon Telescope Collaboration meeting 2024

CDMX, México, May. 29 - 24 2024

Relativistic jets as laboratory to test gravity, particle acceleration, and plasma properties. *Workshop on Fundamental Fields and Compact Objects: New Opportunities, ICF-UNAM, Morelos, México, Oct 4th - 6th 2023*

Multi-wavelength emission of M87 jet using self-consistent electron-to-proton temperature
Workshop on Kinetic Models of Relativistic Plasmas, Trinity College, Dublin, Ireland, Feb. 27 – March.2, 2023.

Non-thermal emission at event horizon and jet launching scales
New Generation Event Horizon Telescope Meeting 2022. June 22-25 2022.

Modeling the limb brightening of M87 jet: Effects of electron temperature and magnetic energy
Event Horizon Telescope Meeting 2022. June 19-22 2022.

Modeling MWL emission with GRMHD and GRRT simulations
Event Horizon Telescope Meeting 2021. December 6-10 2021.

Non-thermal emission in SANE and MAD GRMHD simulations
Event Horizon Telescope SgrA Theory Symposium 2020. September 4th 2020.*

Non-linear evolution of magnetized-torus-BH: Comparison between magnetic field approaches
689. WE-Heraeus-Seminar on Accretion in strong gravity, Bad Honnef, Germany. February 4-8 2019.

Evolution of a Magnetized Thick disk around a highly rotating black hole
The European Einstein Toolkit meeting 2018, Lisbon, Portugal. September 13th 2018.

Consistent construction of a magnetised accretion disc around a highly rotating black hole
Spanish-Portuguese Relativity Meeting 2018, Palencia, Spain. September 4th 2018.

Special and General relativistic magnetohydrodynamics in ExaHyPE
ExaHyPE council Meeting, Garching, Germany. April 3th 2017.

CAFE a new relativistic MHD code
28th Texas Symposium on Relativistic Astrophysics, Geneva, Switzerland. December 2015.

Relativistic Bondi-Hoyle Accretion onto a Rotating Black Hole: Density Gradients
X Mexican School on Gravitation and Mathematical Physics, Playa del Carmen, México. December 2014.

Morelia, a new special relativistic MHD code
X workshop of the DGFm, Hidalgo, México. December 2013.

Morelia, a new special relativistic MHD code
XXV National Congress of Astronomy, Mexico city, México. November 2013.

Flip-flop instability of the shock cone in Bondi-Hoyle accretion
IX Mexican School on Gravitation and Mathematical Physics, Guadalajara, México. December 2012.

Flip-flop instability in the wind accretion around a rotating black hole
LV National Congress of Physics, Morelia, México. October 2012.

Bondi-Hoyle accretion onto Schwarzschild and Kerr black holes
XXIV National Congress of Astronomy, Guadalajara, México. September 2011.

Solution of a scalar field on a background of Schwarzschild containing the null infinity future
LIII Congress of Physics, Veracruz, México. October 2010.

Numerical solution of the wave equation on space-times with scri-fixing conformal compactifications
VIII Mexican School on Gravitation and Mathematical Physics of the DGFm-SMF, Playa del Carmen, México. December 10th 2009

Poster Sessions.....

A model for M 87 SED using a General Relativistic Radiative Transfer code

XV Taller de la División de Gravitación y Física-Matemática-SMF, León, Guanajuato, México. Oct. 21-24 2024. Authors: Donaldo Mora, Erika Benitez, Alejandro Cruz Osorio

Gravitational Waves From Long-Time Evolution Of Tilted Thick Disc Around A Rotating Black Hole

22nd International Conference on General Relativity and Gravitation-13th Edoardo Amaldi Conference on Gravitational Waves, València, Spain. July 7th-12th 2019.

Stellar winds effect in Bondi-Hoyle accretion around Schwarzschild black hole

3rd Karl Schwarzschild Meeting - Gravity and the Gauge/Gravity Correspondence, Frankfurt, Germany. July 24th-28th 2017.

Wind accretion on a Schwarzschild black hole in slab symmetry

LIV National Congress of Physics 2011, Yucatán, México. October 2011

Basic tests of general relativity hydrodynamics codes

VII School of the Gravitation and Mathematical Physics Division of the Mexican Physical Society, Playa del Carmen, México. December 2006.

Lectures at Workshops.....

Numerical methods for the study of relativistic astrophysics

Workshop on Numerical Relativity, Faculty of Physics, University of Veracruz, Xalapa, Veracruz. November 18th-20th 2015.

Introduction to programming in Fortran 90

18 anniversary of the Instituto Tecnológico Superior de los Ríos, Tabasco, México. November 26th & 27th 2014.

The science of science fiction

First Multidisciplinary Academic Week of the Instituto Tecnológico Superior de los Ríos, Tabasco, México. November 17th & 18th 2014.

Outreach

Ondas Gravitacionales <i>Octubre Mes de la Astronomía, Sociedad Astronómica Queretana, Queretaro, México. Oct. 17 2024.</i>	Talk
Sombras cósmicas con el EHT, un telescopio del tamaño de la tierra <i>Los Caminos de la Astronomía OAN-Tonantzintla, Tonantzintla, Puebla, México. Oct. 10 2024.</i>	Talk
Sombras Cósmicas: El agujero negro en el centro de nuestra galaxia <i>Noche de Museos, Palacio de la Autonomía-UNAM, Mexico city, México. April 24th 2024.</i>	Talk
¡Agujeros Negros fantásticos y Como Encontrarlos! <i>Noche de las Estrellas, Institute of Astronomy-UNAM, Mexico city, México. November 25th 2023.</i>	Talk
La primera imagen de la sombra del agujero negro en el centro de nuestra galaxia <i>Conversatorio en el Museo de Arte e Historia de Guanajuato, Leon, Guanajuato, México. Oct 14th 2023.</i>	Talk
Agujeros negros y como encontrarlos sin morir en el intento <i>Seminario de Estudiantes del Posgrado en Astrofísica., UNAM, Ciudad de México, México. February 22th 2022.</i>	Talk
Siluetas en la oscuridad: El agujero negro en el corazón de la Vía Láctea <i>Seminario del Club de Ciencias "Johann Carl Friedrich Gauss", Facultad de Ingeniería Universidad Autónoma de Chihuahua. Chihuahua, México. November 10th 2022.</i>	Talk
Telescopio del Horizonte de Eventos - El centro de la Vía Láctea <i>CONACYT, Mexico. August 2022.</i>	Interview
Physik an der Goethe-Universität: Auszeichnung für herausragende Forschung <i>(Physics at the Goethe University: Award for outstanding research)</i> <i>Goethe Universität, Frankfurt am Main, Germany. July 08th 2022.</i>	Post
Congratulations to Dr. Cruz-Osorio, laureate of the 2022 Frankfurt Physics Prize! <i>Goethe Universität, Frankfurt am Main, Germany. July 08th 2022.</i>	Post
Astronomers reveal first image of the black hole at the heart of our galaxy <i>Event Horizon Telescope-Mexico, May 12th 2022.</i>	Press Conference
Panelist of EHT Conference(Mexico) – YouTube <i>Simulando los chorros del agujero negro de M87, Minute 1:55:00</i> <i>Coffee Break: Señal y Ruido, November 12th 2021, Spain.</i>	Podcast
Coffee Break (YouTube) Ep341: Gravitondas; Monopolos; Fluidos en Roca Porosa; Agua en Galaxias; Agujeros Negros, Minute 2:08:35 <i>Wie Schwarze Löcher ihren Jet zünden</i> <i>UniReport Nr.6, Goethe Universität, Frankfurt am Main, Germany. December 9th 2021.</i>	Press
Jet from giant galaxy M87: Computer modelling explains black hole observations <i>Goethe Universität, Frankfurt am Main, Germany. November 04th 2021.</i>	Press Release
Nature Astronomy Press Release has 119 replicas in 36 countries. <i>Der Astrophysiker Alejandro Cruz Osorio im Porträt</i> <i>UniReport Nr.5, Goethe Universität, Frankfurt am Main, Germany. October 12th 2017.</i>	Press
The first image of a supermassive hole <i>"Jornadas de Ciencia y Matemáticas", Center for research and teaching of mathematics, Morelia, México. October 13th 2020.</i>	Talk
A supermassive black hole as the engine of our galaxy <i>Astronomical Society of Mexico, Mexico city, México. March 30th 2016.</i>	Talk
A supermassive black hole at the center of our galaxy! <i>Night of Stars, Institute of Astronomy-UNAM, Mexico city, México. November 28th 2015.</i>	Talk
Talking with Astronomers <i>Night of Stars, Institute of Astronomy-UNAM, Mexico city, México. November 28th 2015.</i>	Talk
What is a black hole? <i>Feast of Sciences and Humanities, UNAM UNIVERSUM-Museum, Mexico city, México. October 17th 2015.</i>	Talk
LIGHT: our eyes throughout the universe <i>22 National Week of Science and Technology, International Year of Light, Instituto Tecnológico Superior Huichapan, Hidalgo, México. October 12th 2015.</i>	Talk
Nota sobre magnetohidrodinámica <i>Radio UNAM 96.1 FM, Programa: Primer Movimiento min:1:54, Mexico city, México. June 28th 2016. http://goo.gl/S6YzX7</i>	Radio
UNAM estudia el universo con el uso de códigos numéricos <i>El Universal, Mexico city, México. June 20th 2016. http://goo.gl/CcGB6z</i>	Press
Códigos numéricos para la Astrofísica <i>Agencia informativa CONACYT, Mexico city, México. May 16th 2016.</i>	Press

Academic Service

Organizing committee

- **Founder and Chair of AstroLunch: Astrofísica Relativista**, Instituto de Astronomía-UNAM, 2024, Sep. 2024 – Now, CDMX, México.

- **Chair of the LOC of the EHT Collaboration Meeting summer 2024**, Unidad de Posgrado-UNAM, 2024 May 19th-24th, Ciudad de México.
- **Co-chair of the "Arcadio Poveda's" Colloquium**, IA-UNAM, Sep.2023 – Now
- **SOC of the First Mexican meeting in route to the Next Generation VLA**, IRyA-UNAM, Michoacán, México, 25th-27th Sep 2023.
- **Chair of the AstroCoffee seminar**, Institut für Theoretische Physik, Johann Wolfgang Goethe Universität Frankfurt, Oct.2020 – Sep.2022
- **EHT Sgr A* Theory Busy Days (2020-Q4)**, Event Horizon Telescope Collaboration, Nov 30th – Dec 4th 2021.
- **First Student Meeting 2014**, Instituto Tecnológico Superior de los Ríos, November 20th 2015, Tabasco, México.
- **Basic Electronics Conference-Workshop**, Faculty of Science Physics and Mathematics-UMSNH, April 28th & 29th 2006, Morelia, México.
- **1^o Regional Meeting of Optic**, September 19th-23th 2005, Morelia, México.

Journal Reviewer.....

- Astrophysical Journal
- American Journal of Physics ³
- Revista Mexicana de Física
- MDPI-Universe ⁴
- Referee at DiRAC-cluster England: Astronomy, Particle Physics and Nuclear Physics

Synod & Examiner.....

Synod committee of Thesis Defence:

- *PhD thesis*. Fernando Josue Ureña Mena, Multifrequency study of Very High Energy emitter Active Galactic Nuclei observed with HAWC, 03.Dec.2024, INAOE, México.
- *Master thesis*. Omar Vilchis Alcántar, Unveiling the Magneto-ionic structures of the radio relic of MACS07+3745, 28.Nov.2024, IRyA-UNAM, México.
- *Bachelor thesis*. Enrique Galicia Pineda, Modelado de estrellas compactas con el programa Aztekas, 15.April.2024, Facultad de Ciencias UNAM, México.
- *Bachelor thesis*. Fernando Vázquez Chávez, Orbitas estelares como herramienta para estudiar la naturaleza del espacio-tiempo, 04.March.2024, Facultad de Ciencias UNAM, México.
- *Bachelor thesis*. German David Prada Méndez, Análisis del espectro de emisión proveniente de un toro magnetizado alrededor de singularidades desnudas con deformación cuadrupolar (17.February.2023), Faculty of Physics, Universidad Industrial de Santander, Colombia.
- *Bachelor thesis*. Jennyfer Camila Acevedo Muñoz, Análisis numérico de la interacción del sistema agujero negro – campo escalar en un espacio-tiempo dinámico (17.February.2023), Faculty of Physics, Universidad Industrial de Santander, Colombia.
- *Master thesis*. Juan Manuel Velásquez Cadavid, Simulation of the intensity map in magnetically polarized accretion disks around Kerr black holes (13.October.2022), Master of Applied Mathematics, Faculty of Physics, Universidad Industrial de Santander, Colombia.
- *Bachelor thesis*. Cédric Jockel, Modelling of plasma accretion onto black hole mimickers (20.October.2021), Institut für Theoretische Physik, Johann Wolfgang Goethe -Universität Frankfurt am Main, Germany.
- *Bachelor thesis*. Jose Miguel Amado Dugarte, Numerical study of relativistic magnetohydrodynamic laminar currents in a magnetically polarized fluid (21.July.2021), Faculty of Physics, Universidad Industrial de Santander, Colombia.
- *Master thesis*. Jan Röder, Comparison of Kerr and dilaton black hole shadows: Impact of non-thermal emission (13.April.2021), Institut für Theoretische Physik, Johann Wolfgang Goethe -Universität Frankfurt am Main, Germany.
- *Master thesis*. Manuel Eduardo de la Cruz Hernández, Modelling of work surfaces in 1D astrophysical jets at the relativistic strong shock limit (31.June.2019), Institute of Astronomy, UNAM, México.
- *Master thesis*. Alejandro Aguayo Ortiz, A direct Primitive Variable Recovery Scheme for hyperbolic conservative equations (27.Jul.2018), Institute of Astronomy, UNAM, México.

Examiner of Thesis Project:

- *Bachelor project*. German David Prada Méndez, Análisis del espectro de emisión proveniente de un toro magnetizado alrededor de singularidades desnudas con deformación cuadrupolar (22.August.2022), Faculty of Physics, Universidad Industrial de Santander, Colombia.
- *PhD project*. Gustavo Magallanes Guijón, December 3, 2021, Statistical and computational methods in inference binary black holes, PhD on Astrophysics program of the Institute of Astronomy, UNAM, México.
- *Master project*. Juan Manuel Velásquez Cadavid, Simulation of the intensity map in magnetically polarized accretion

American Journal of Physics 87, 330 (2019). <https://doi.org/10.1119/1.5096895>

Universe 2021, 7(2), 22; <https://doi.org/10.3390/universe7020022>

disks around Kerr black holes (04.December.2020), Master of Applied Mathematics, Faculty of Physics, Universidad Industrial de Santander, Colombia.

Tutor commettee:

- *PhD.* Daniel Núñez Trigueros, (2025-1 – now), Astrophysics program of the IA-UNAM, México.
- *Master.* Jeoshua Alejandro Licea Garcia (2025-1 – now), Physics program of the IA-UNAM, México.
- *Master.* Axel Morales Buendía (2025-1 – now), Physics program of the IA-UNAM, México.
- *PhD.* David Barrero González (2024-2 – now), Astrophysics program of the IA-UNAM, México.
- *PhD.* Juan José Zaldívar Vázquez (2024-1 – now), Astrophysics program of the INAOE, México.
- *Master.* Yael Morales Venegas (2025-1 – now), Astrophysics program of the IA-UNAM, México.
- *Master.* César Orlando Navarrete Zavala (2024-2 – now), Astrophysics program of the IA-UNAM, México.
- *Master.* Anthony Brandon Arenas Martínez (2024-2–now), Astrophysics program of the IA-UNAM, México.
- *Master.* Inti Ernesto Chávez Ménez (2024-2), Astrophysics program of the IA-UNAM, México.
- *Master.* Donaldo Emilio Mora (2024-1 – now), Astrophysics program of the IA-UNAM, México.
- *PhD.* Alejandro Aguayo Ortiz (2018 –2021), Astrophysics program of the IA-UNAM⁵, México.

Computer skills

Languages: Fortran, Python, C/C++

Code Development: CAFE, BHAC, BHOSS

High Performance: OpenMP, MPI, AMR, FMR

Codes: Einstein Toolkit, ehtim