# DIEGO J. MUÑOZ, PhD

## Computational Astrophysicist

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**RESEARCH INTERESTS**

Planet formation, accretion disks, gas dynamics, binary black holes, planetary dynamics, numerical methods, hydrodynamics, $N$-body techniques, interferometry, Bayesian inference

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**EMPLOYMENT**

**Northern Arizona University** Flagstaff, AZ
Assistant Profesor — Aug 2023- present

**Northwestern University** Evanston, IL
Research Assistant Profesor — July 2021- Aug 2023

**Universidad Adolfo Ibañez** Santiago, Chile
Assistant Profesor — July 2021- Aug 2023

**Northwestern University** Evanston, IL
CIERA Postdoctoral Fellow / RCSA Cottrell Prize Fellow — Nov 2017 - July 2021

**University of Arizona** Tucson, AZ /
**Technion - Israel Institute of Technology** Haifa, Israel
Visiting Researcher, Steward Observatory/Physics Department — Sep 2016 - Oct 2017

**Cornell University**, Ithaca, NY
Research Associate, Department of Astronomy — Sep 2013 - Aug 2016

**Harvard University**, Cambridge, MA
Graduate Research Assistant, Astronomy Department — 2006-2013

**Universidad de Chile**, Santiago, Chile
Research Assistant, Astronomy Department — 2004-2006

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**EDUCATION**

**Harvard University**, Cambridge, MA
**PhD, Astronomy & Astrophysics**. — August 2013
**AM, Astronomy**. — 2008

**Universidad de Chile**, Santiago, Chile
**MSc, Astronomy**. — 2006
**BS, Astrophysics**. — 2004

**AWARDS**

**Cottrell Fellowship of the Research Corporation** (2020-21)

**CIERA Fellowship** (2017-20)

**Gliese Fellowship (Germany, declined)** (2017)

**FONDECYT National Fellow (Chile, declined)** (2015)

**Fulbright Scholar** (2006-2010)

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**RESEARCH EXPERIENCE**

- Discovered a mechanism of outward binary migration.
- Developed hierarchical Bayesian formalism to combine observations of stellar obliquity
- Derived analytical criteria for the modified evolution of the secular three-body problem under additional forces

• Studied the interaction of circumstellar disks with embedded planets using Lagrangian/Eulerian code AREPO
• Developed techniques for massively parallel hydrodynamics on large computer clusters
• Studied random walks in gravitational systems in the context of the Solar System
• In depth experience with finite volume methods for hyperbolic equations and symplectic methods for Hamiltonian systems
• Designed software for analysis and visualization of large sets of simulation data
• Analyzed polarimetric interferometric data at submillimeter wavelengths
• Experience in error analysis and time-series analysis of radio-wavelengths observations
• Investigated the formation of stars in massive molecular complexes
• Designed software for image processing and data mining

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## TEACHING EXPERIENCE

**Univ. Adolfo Ibañez**, Santiago, Chile
• *Waves and Thermodynamics* (Fall 2022) • *Waves and Thermodynamics* (Fall 2021)
**Northwestern University**, Evanston, IL
Guest lecturer in *Computational Methods of Physics* (Prof. Sasha Tchekhovskoy, Spring 2018)
**Cornell University**, Ithaca, NY
Guest lecturer in *Radiation Processes* (Prof. Dong Lai, Fall 2013)
**Harvard University**, Cambridge, MA
Teaching Fellow
• *Radio Astronomy*, (Prof. James Moran, Fall 2009) • *Radiative Processes in Astrophysics*, (Prof. Ramesh Narayan, Fall 2008) • *Cosmic Connections*, (Prof. David Charbonneau, Fall 2007)
**Universidad de Chile**, Santiago, Chile
Teaching Assistant
• *General Astronomy* (Profs. Diego Mardones, Fall 2005 and María Teresa Ruíz, Spring 2005) • *Introduction to Contemporary Physics* (Profs. Simón Casassus, Fall 2003 and Sebastián López, Spring 2004)

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## ADVISING EXPERIENCE

• Luciano Godoi (MSc student, UAI, 2022-) *Binary populations*
• Magdalena Siwek (Grad student, Harvard, 2021-22) *Circumbinary disks* (co-adv. Hernquist)
• Jeremy Rath (Grad student, Northwestern, 2019-23) *Disk eccentricity* (co-adv. Lithwick)
• Adam Dempsey (Grad student, Northwestern, 2018-20) *Accretion disks* (co-adv. Lithwick)
• Evgeni Grishin (Grad student, Technion, 2016-17) *Dynamics of triples* (co-adv. Perets)
• Ryan Miranda (Grad student, Cornell, 2015-17) *Circumbinary disk simulations* (co-adv. Lai)
• Bin Liu (Grad student, USTC/Cornell, 2013-14) *Suppression of extreme orbital evolution in triple systems with short range forces* (co-adv. Lai)
• Michael Hammer (Undergrad, Cornell, 2013-14) *Long-term stability of circumbinary planets at high inclination* (co-adv. Lai)

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## SERVICE

• LOC *APS Conference for Undergraduate Women in Physics* (Evanston IL, Jan 2019)
• Referee for *The Astronomical Journal*, *Monthly Notices of the Astronomical Society*, *Astrophysical Journal Letters*, *The Astrophysical Journal*, *Astronomy & Astrophysics*, *SciPost*
• Panel member at Chandra Cycle 16 Review Panel (June 2014)
• SOC and LOC for *Emerging Researchers in Exoplanet Science II*, (Ithaca, NY, May 2016)
• External reviewer for NASA Review Panel (July 2017)
• Participant at NASA Review Panel (August 2017, August 2018)

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## GRANTS

• **2024-27 "Building and Detecting Dust Enshrouded Planets"** (23-XRP23_2-0121) **Co-I (PI Kratter), $476K**
• **2023-27 "Plataforma de Cómputo para Deep Learning basada en NVIDIA DGX A100"** (Fondequip Grant EQM220152, Chile) **Co-I , $357 K**

• **2023-25 "Planets in Long-Lived Accretion Disks"** (22-XRP22_2-0001) **Co-I (PI Lithwick), $410K**
• **2022-23 "Electromagnetic Signatures of Massive Black Hole Binaries"** (Seed Funds Grant, UAI Chile) **PI, $15K**
• **2022-25 "Formation and Dynamics of Planets in Distorted Disks"** (Fondecyt Regular 1220361, Chile) **PI, $140K**
• **2022-25 "GPU-accelerated Astrophysics: from planet-formation to gravitational wave astrophysics"** (Fondo QUIMAL Astronomy) **Co-PI , $150K**
• 2021-25 "Stellar Dynamics and Stellar Collisions in Star-by-Star Models of Nuclear Star Clusters" (21-ATP21-0144) Collab (PI Rodriguez)
• 2020-24 "Relativistic Simulations of Accreting Neutron Stars" (80NSSC21K1746) Collab (PI Parfrey)
• **2017-21 "Orbital Evolution in Multi-star Systems"** (17-ATP17-0070) **Co-I (PI Kratter), $495K**
• 2015-19 "Origin of exoplanets within and around binary stars" (15-XRP15_2-0010) Collab (PI Rafikov)

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## Technical Skills

**Programming**
Python (fluent), C (fluent), C++ (intermediate), Unix bash script (fluent), SQLite (basic)
**Statistical Modeling**
Hierarchical Bayesian inference, Time Series, Spectral (Fourier/wavelet) Analysis, MCMC Parameter Estimation, PCA, Feature Engineering, Decision Trees, Clustering
**Numerical Techniques**
Partial and ordinary differential equations, Monte Carlo, visualization/ray tracing
**Tools**
Unix/Linux, Latex, OpenMPI, Git, NumPy, SciPy, scikit-learn, Pandas

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## Organizations/ Outreach

• Co-organizer, mentor and lecturer at the *Research Experiences in Astronomy at CIERA for High School Students* program (REACH) at Northwestern University (2021-)
• Regular presenter at *Ask an Astronomer* events at the Adler Planetarium (2019-)
• Creator and admin of spanish-language science blog http://laformadelatierra.com
• Science in the News Boston: board member, AV coordination and lecturer, Lecture: "The Box in a (Pretty Big) Box: From Cells to Galaxies Using Supercomputers" Oct 24th, 2012 (lecture video https://vimeo.com/57476524)
• Contributed article: "Astronomy: The Gateway Science" (*Policylab* ) http://www.policylab.org/2013/05/18/astronomy-the-gateway-science/
• Contributed art: http://www.policylab.org/2013/06/12/312/ (*Policylab* )

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## Colloquia, Invited Talks and Conference Presentations

• **LSU Physics Colloquium**- Baton Rouge, LA (March 2023)
• **UT-Dallas Physics Colloquium**- Richardson, TX (February 2023)
• **NAU Astronomy and Planetary Science Colloquium**- Flagstaff, AZ (February 2023)
• **HUJI astrophysics seminar**- Jerusalem, Israel (remote, December 2022)
• NANOGrav Fall Meeting- Contributed Talk: *A Revised Paradigm of Binary-Disk Interaction*, Milwaukee, WI (October 2022)
• MPIA Planet Formation Group Meeting - Heidelberg Germany (remote, May 2022)
• **CIERA Astrophysics Seminar** - Evanston, IL (April 2022)
• KITP Program BINARY22- Key participant (March-April 2022)
• Distorted Astrophysical Discs - Contributed Talk: *Long-Lived Eccentric Modes in Circumbinary Disks*, Cambridge, UK (May 2021)
• TrEnDy3 - Contributed Talk: *Eccentric Black Hole Mergers from Evection Resonances in AGN Disks*, Evanston, IL (March 2021)

• Exploring supermassive black holes - **Invited Talk**: *Hydrodynamic Simulations of Circumbinary Disks*, Princeton, NY (October 2020)
• Growing Black Holes: Accretion and Mergers - **Invited Review Talk**: *Migration of Supermassive Black Hole Binaries*, Kathmandu , Nepal (April 2020, suspended due to COVID)
• Great Barriers in Planet Formation - Contributed Talk: *Circumbinary accretion: challenges for the formation of close binaries and circumbinary planets*, Palm Cove, Australia (July 2019)
• Astrophysical Dynamics - **Invited Talk**: *Hydrodynamics of Circumbinary Accretion*, Shanghai, China (July 2019)
• **Astronomy Colloquium** - Lowell Observatory , Flagstaff, AZ (October 2018)
• Triple Evolution and Dynamics 2 - Contributed Talk: *Circumbinary disks and the formation of coplanar triples*, Leiden, Netherlands (September 2018)
• **Astrophysics Seminar** - University of Chicago, Chicago, IL (June 2018)
• **Astronomy Colloquium** - University of Wisconsin - Madison , Madison, WI (January 2018)
• Exoplanets and Planet Formation 2017 - **Invited Talk**: *Accreting Circumbinary Disks: a Link Between Star and Planet Formation*, Shanghai, China (December 2017)
• Chicago-area exoplanet meeting '17 - Contributed Talk: *Planetary Engulfment as a Trigger for White Dwarf Pollution*, Chicago, IL (December 2017)
• **Astrophysics Colloquium** - CCA Flatiron Institute, New York, NY (November 2017)
• Numerical Simulations of Planet-Disc Interactions - Contributed Talk: *Orbital Migration with Steady Accretion: Binaries and Massive Planets*, Cuernavaca, Mexico (November 2017)
• Origins Seminar - University of Arizona, Tucson, AZ (September 2017)
• Planets beyond the main sequence - Contributed Talk: *Planetary Engulfment as a Trigger for White Dwarf Pollution* , Haifa, Israel (March 2017)
• ERES II - Contributed Talk: *The formation efficiency of close-in planets via Lidov-Kozai migration*, Ithaca, NY (June 2016)
• Extreme Solar Systems III - Contributed Talk: *Survival of Planet Around Shrinking Binaries*, Kona, HI (December 2015)
• **Theory Colloquium** - University of Arizona , Tucson, AZ (November 2015)
• Theory Seminar - CITA , Toronto, ON (October 2015)
• Group discussion leader: Circumbinary planets - SPF-1 , Tucson, AZ (March 2015)
• **Astronomy Colloquium** - Cornell University , Ithaca, NY (October 2014)
• Astrophysics Lunch - Cornell University , Ithaca, NY (September 2013)
• Theory Lunch Talk - University of Maryland , College Park, MD (November 2012)
• TUNA Lunch Talk - NRAO, Charlottesville, VA (November 2012)
• Star and Planet Formation Seminar - STScI , Baltimore, MD (November 2012)
• Astronomy Group Meeting - Carnegie DTM , Washington, DC (November 2012)
• Exoplanet Seminar - NASA Goddard Space Flight Center, Greenbelt, MD (November 2012)
• Seminar - DARK Cosmology Centre, Copenhagen, Denmark (August 2012)

## Publications (total citations: 2195 / 1st+2nd author citations: 1103/ h-index: 20)

scholar.google.com/citations?user=USL3xkMAAAAJ

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SUBMITTED AND PUBLISHED (*STUDENT PAPER)

31. *Espinoza-Retamal et al "The Aligned Orbit of the Eccentric Proto Hot Jupiter TOI-3362b". *The Astrophysical Journal* (2023) (submitted) (arxiv:2309.03306)

30. *Rath, J., **Muñoz, D. J.**, Lithwick, Y.
"Steady-State Warped Disks". *The Astrophysical Journal* (2023) (submitted)

29. Sedaghati, E., Jordán, A., Brahm, R., **Muñoz, D. J.**, Petrovich, C. and Hobson, M.
"Orbital Alignment of the Eccentric Warm Jupiter TOI-677b". *The Astronomical Journal* (2023) 166 (3), 130

28. Lai, D and **Muñoz, D. J.**
"Circumbinary Accretion: From Supermassive Binary Black Holes to Circumbinary Planets". *Annual Review of Astronomy and Astrophysics* (2023) Volume 61, Issue , pp. 517-560

27. Sedaghati, E., Jordán, A., Brahm, R., **Muñoz, D. J.**, Petrovich, C. and Hobson, M.
"Orbital Alignment of the Eccentric Warm Jupiter TOI-677b". *The Astronomical Journal* (2023) 166 (3), 130

26. Brahm, R., et al. "Three long period transiting giant planets from *TESS*" *The Astrophysical Journal* (2023) (in press)

25. **Muñoz, D. J.**, Stone, N.C., Petrovich, C., and Rasio, F.A.
"Eccentric Mergers of Intermediate-Mass Black Holes from Evection Resonances in AGN Disks". *Physical Review D* (2022) (in press) (arXiv:2204.06002)

24. *Siwek, M., Weinberger, R., **Muñoz, D. J.**, and Hernquist, L.
"Preferential Accretion and Circumbinary Disk Precession in Eccentric Binary Systems". *Monthly Notices of the Astronomical Society* (2022) (in press) (arXiv:2203.02514)

23. *Dempsey, C., **Muñoz, D. J.**, and Lithwick, Y.
"Outward Migration of Super Jupiters '. *The Astrophysical Journal Letters* (2021) 918 (2) L36

22. **Muñoz, D. J.**, and Lithwick, Y.
"Long-lived Eccentric Modes in Circumbinary Disks". *The Astrophysical Journal* (2020) 905 (2), 106

21. **Muñoz, D. J.** and Petrovich, C.
"Kozai Migration Naturally Explains the White Dwarf Planet WD1856b". *The Astrophysical Journal Letters* (2020) 904 (1) L3

20. Petrovich, C., **Muñoz, D. J.**, Kratter, K., and Malhotra, R.
"A disk-driven resonance as the origin of close-in planets with high inclinations". *The Astrophysical Journal Letters* (2020) 902 (1) L5

19. *Dempsey, A., **Muñoz, D. J.**, and Lithwick, Y.
"Inner Boundary Condition in Quasi-Lagrangian Simulations of Accretion Disks". *The Astrophysical Journal Letters* (2020) 892 (2) L29

18. **Muñoz, D. J.**, Lai, D., Kratter, K. and Miranda, R.
"Circumbinary accretion from finite and infinite disks". *The Astrophysical Journal* (2020) 889 (2), 114

17. **Muñoz, D. J.**, Miranda, R., and Lai, D.
"Hydrodynamics of circumbinary accretion: Angular momentum transfer and binary orbital evolution". *The Astrophysical Journal* (2019), 817(1), 84

16. **Muñoz, D. J.** and Perets, H.
"Statistical Trends in the Obliquity Distribution of Exoplanet Systems". *The Astronomical Journal* (2018), 156(6), 253

15. *Miranda, R., **Muñoz, D. J.** and Lai, D.
"Viscous hydrodynamics simulations of circumbinary accretion discs: variability, quasi-steady state, and angular momentum transfer". *Monthly Notices of the Astronomical Society* (2017), 466 (1), 1170-1191

14. Petrovich, C. and **Muñoz, D. J.**
"Planetary Engulfment as a Trigger for White Dwarf Pollution". *The Astrophysical Journal* (2017), 834(2), 116

13. **Muñoz, D. J.** and Lai, D.
"Pulsed Accretion onto Eccentric and Circular Binaries". *The Astrophysical Journal* , (2016), 827(1), 43

12. **Muñoz, D. J.**, Lai, D. and Liu, B.
"On the formation efficiency of close-in planets via Lidov-Kozai migration: analytic calculations". *Monthly Notices of the Astronomical Society*, (2016) 460, 1086-1093

11. Pakmor, R., Springel, V., Bauer, A., Mocz, P., **Muñoz, D. J.**, Ohlmann, S.T., Schaal, K. and Zhu, C.
"Improving the convergence properties of the moving-mesh code AREPO". *Monthly Notices of the Astronomical Society*, (2016) 445, 1134-1143

10. **Muñoz, D. J.** and Lai, D.
"Survival of planets around shrinking stellar binaries". *Proceedings of the National Academy of Science*, (2015) 112 (30), 9264-9269

9. *Liu, B., **Muñoz, D. J.** and Lai, D.
"Suppression of extreme orbital evolution in triple systems with short range forces". *Monthly Notices of the Astronomical Society*, (2015) 447, 747-764

8. **Muñoz, D. J.**, Kratter, K., Springel, V. and Hernquist, L.
"Stellar orbit evolution in close circumstellar disk encounters". *Monthly Notices of the Astronomical Society*, (2015) 446, 2010-2029

7. **Muñoz, D. J.**, Kratter, K., Vogelsberger, M., Hernquist, L. and Springel, V.
"Planet-disc interaction on a freely moving mesh". *Monthly Notices of the Astronomical Society*, (2014) 445, 3475-3495

6. Salyk, C., Pontoppidan, K., Corder, S., **Muñoz, D. J.**, Zhang, K., and Blake, G.
"ALMA observations of the T Tauri binary system AS 205: evidence for molecular winds and/or binary interactions". *The Astrophysical Journal*, (2014) 792, 68-81

5. **Muñoz, D. J.**, Springel, V., Marcus, R., Vogelsberger, M., and Hernquist, L. "Multi-Dimensional Compressible Viscous Flow on a Moving Voronoi Mesh". *Monthly Notices of the Astronomical Society* (2013) 428, 254-279.

4. **Muñoz, D. J.**, Marrone, D. P., Moran, J. M., and Rao, R. "The Circular Polarization of Sagittarius A* at Submillimeter Wavelengths," *The Astrophysical Journal*, (2012) 745, 115-128.

3. Hicken, M. et al. "CfA3: 185 Type Ia Supernova Light Curves from the CfA" *The Astrophysical Journal*, (2009) 700(1), 331-357

2. Marrone, D. P., Baganoff, F. K., Morris, M. R., Moran, J. M., Ghez, A. M., Hornstein, S. D., Dowell, C. D., **Muñoz, D. J.**, Bautz, M. W., Ricker, G. R., and 7 coauthors "An X-Ray, Infrared, and Submillimeter Flare of Sagittarius A." *The Astrophysical Journal*, (2008) 682, 373-383.

1. **Muñoz, D. J.**, Mardones, D., Garay, G.; Rebolledo, D., Brooks, K., and Bontemps, S. "Massive Clumps in the NGC 6334 Star-forming Region." *The Astrophysical Journal*, (2007) 668, 906-917.