Curriculum Vitae

Michael Y. Grudić

NASA Hubble Fellow

Carnegie Observatories
813 Santa Barbara St
Pasadena, CA 91101, USA

mgrudic@carnegiescience.edu
(626) 484-9037
https://mikegrudic.github.io

Research Interests

Theoretical astrophysics ∘ Numerical simulations ∘ HPC ∘ Star and galaxy formation ∘ Star clusters: origins, properties, dynamics, IMF ∘ Stellar feedback ∘ Software ∘ Interstellar medium: physics, chemistry, observations

Education

Ph.D. in Physics *2014-2019*
California Institute of Technology (Caltech), Pasadena, CA
Dissertation: *The Role of Stellar Feedback in Star Cluster Formation*
Adviser: Dr. Philip F. Hopkins

B.Sc. (Honours) in Physics and Applied Mathematics *2009-2014*
Memorial University of Newfoundland (MUN), St. Johns, NL, Canada
Dissertation: *Gravitational Scattering in the Relativistic Kepler Problem*
Adviser: Dr. John Lewis

Professional Experience

NASA Hubble Fellow, Carnegie Observatories, Pasadena, CA *Sept 2021-present*
CIERA Postdoctoral Fellow, Northwestern University, Evanston, IL *Sept 2019-Aug 2021*

Academic Honors

Caltech Robert F. Christy Prize for Outstanding Doctoral Thesis in Theoretical Physics *2019*
Caltech James A. Cullen Memorial Fellowship for Excellence in Physics *2017*
MUN Medals for Excellence in both Physics and Applied Mathematics *2014*
Daniel Freeman Memorial Scholarship *2014*
Lou Visentin Award *2014*
NSERC Undergraduate Summer Research Award *2011-2013*
Mrs. E.D. Matthews Memorial Scholarship in Mathematics and Statistics *2013*
MUN Faculty of Science Deans Book Prize (Physics) *2013*
Dr. S. W. Brekon Scholarship in Physics *2012-2013*
Flight 491 Legacy Scholarship *2011-2013*
MUN Faculty of Science Dean's List *2011-2013*

Competitive Computing Awards

Frontera LRAC: *STARFORGE: Simulating star formation with realistic physics and feedback* – 60M CPU-h to date (PI) *2021-2023*
Frontera Pathways: *Exploring the Physical Ingredients of Star Formation with Simulations* – 14M CPU-h (PI) *2020-2021*
XSEDE AST190018: *Simulating the Life of a GMC* – 28M CPU-h (co-PI) *2020-2021*

Selected Scientific Presentations

Bash Symposium, University of Texas, Austin, TX. Invited seminar.	*2023*
Columbia University Astronomy Colloquium, Columbia University, New York, NY.	*2023*
Surveying the Milky Way, Caltech, Pasadena, CA. Contributed talk.	*2023*
MODEST-23, Northwestern University, Evanston, IL. Contributed talk.	*2023*
Great Lakes Clusters & Streams Workshop, University of Michigan, Ann Arbor, MI. Contributed talk.	*2023*
Santa Cruz Galaxy Workshop, UC Santa Cruz, Santa Cruz, CA. Invited talk.	*2023*
SF Clumps and Clustered Starbursts Across Cosmic Time, MIAPbP, Garching, Germany. Invited review.	*2022*
Illuminating Galaxy Formation with Ancient Globular Star Clusters, Aspen, CO. Contributed talk.	*2022*
Our Galactic Ecosystem, Lake Arrowhead, CA. Contributed talk.	*2022*
Harvard-Smithsonian Center for Astrophysics Seminar, Harvard University (virtual).	*2022*
University of São Paulo Institute of Astronomy Seminar, São Paulo University (virtual).	*2021*
Los Alamos Astrophysics Seminar, Los Alamos National Laboratory (virtual).	*2021*
236th AAS Meeting (virtual). Invited talk.	*2020*
Star Clusters: from the Milky Way to the Early Universe, Bologna. Contributed talk.	*2019*
Princeton SFIR Seminar, Princeton University, Princeton, NJ.	*2018*
MPA Cosmology Seminar, Max Planck Institute for Astrophysics, Garching, Germany.	*2018*
Formation of Globular Clusters at High and Low Redshift, Sexten, Italy. Invited opening keynote.	*2018*
Multi-scale Physics of SF & Feedback During Galaxy Formation, Heidelberg, Germany. Invited talk.	*2018*
UT Austin Theory Seminar, University of Texas, Austin, TX.	*2018*
231st AAS Meeting, Washington, D.C.. Contributed talk and poster.	*2018*
CITA Seminar, Canadian Institute for Theoretical Astrophysics, Toronto, ON, Canada.	*2017*
230th AAS Meeting, Austin, TX. Contributed talk.	*2017*
Galaxy Formation and Evolution in Southern California, Caltech, Pasadena, CA, USA. Contributed talk.	*2016*

Teaching

Graduate Teaching Assistant, Caltech *2014-2019*
∘ Analog Electronics Lab (Ph 5) ∘ Sophomore Experimental Physics Lab (Ph 6, 7) ∘ Computational Physics Lab (Ph 20, 21, 22)

Undergraduate Teaching Assistant, MUN *2012-2014*
∘ General Physics I: Mechanics ∘ General Physics II: Waves, Oscillations and Electromagnetism ∘ Mathematics Help Centre ∘ Engineering Help Centre

Personal tutor in mathematics, physics, and chemistry at secondary and post-secondary levels *2008-2012*

Outreach

Active in astronomy outreach since 2012, incl. outreach programs at University of Toronto, Caltech, Northwestern University, and Carnegie Observatories, and collaboration with Mannheim Planetarium and University of Arizona. **Activities:** ∘ Public lectures (speaking and volunteering), including Astronomy On Tap ∘ Public observing sessions, sidewalk astronomy ∘ Special events for transits, eclipses ∘ Presentations to K-12 students about astronomy and careers in STEM ∘ Planetarium and multi-media audiovisual presentations using educational simulation renderings

Academic Service

- Frequent referee for peer-reviewed journals including MNRAS(L), ApJ(L), A&A Letters, Nature Astronomy, and Journal of Open Source Software.
- Invited reviewer for grant programs: NSF AAG, NASA FINESST.

Publications

Submitted

[1] **Grudić, M. Y.** and Hopkins, P. F. "The opacity limit." *arXiv e-prints*, arXiv:2308.16268, August 2023. doi:10.48550/arXiv.2308.16268.

[2] **Grudić, M. Y.**, Offner, S. S. R., Guszejnov, D., Faucher-Giguère, C.-A., and Hopkins, P. F. "Does God play dice with star clusters?" *arXiv e-prints*, arXiv:2307.00052, June 2023. doi:10.48550/arXiv.2307.00052.

[3] Xu, D., Offner, S., Gutermuth, R., **Grudić, M. Y.**, Guszejnov, D., and Hopkins, P. "Predicting the Radiation Field of Molecular Clouds using Denoising Diffusion Probabilistic Models." *arXiv e-prints*, arXiv:2309.05811, September 2023. doi:10.48550/arXiv.2309.05811.

Student Project Research Notes

[1] Lue, A., Guszejnov, D., Offner, S. S. R., and **Grudić, M. Y.** "Evolution of the Gas Density in a Simulated Star-forming Cloud with Stellar Feedback." *Research Notes of the American Astronomical Society*, 5, 10, 225, October 2021. doi:10.3847/2515-5172/ac2d37.

[2] Piperno, E., Guszejnov, D., Offner, S. S. R., and **Grudić, M. Y.** "Comparing Methods to Identify GMCs in Simulated Galaxies." *Research Notes of the American Astronomical Society*, 4, 1, 14, January 2020. doi:10.3847/2515-5172/ab7022.

Refereed Articles

[1] Foley, M. M., Goodman, A., Zucker, C., Forbes, J. C., Konietzka, R., Swiggum, C., Alves, J., Bally, J., Soler, J. D., Großschedl, J. E., Bialy, S., **Grudić, M. Y.**, Leike, R., and Enßlin, T. "A 3D View of Orion. I. Barnard's Loop." ApJ, 947, 2, 66, April 2023. doi:10.3847/1538-4357/acb5f4.

[2] **Grudić, M. Y.**, Hafen, Z., Rodriguez, C. L., Guszejnov, D., Lamberts, A., Wetzel, A., Boylan-Kolchin, M., and Faucher-Giguère, C.-A. "Great balls of FIRE - I. The formation of star clusters across cosmic time in a Milky Way-mass galaxy." MNRAS, 519, 1, 1366–1380, February 2023. doi:10.1093/mnras/stac3573.

[3] Guszejnov, D., Raju, A. N., Offner, S. S. R., **Grudić, M. Y.**, Faucher-Giguère, C.-A., Hopkins, P. F., and Rosen, A. L. "Effects of the environment on the multiplicity properties of stars in the STARFORGE simulations." MNRAS, 518, 3, 4693–4712, January 2023. doi:10.1093/mnras/stac3268.

[4] Hopkins, P. F., Gurvich, A. B., Shen, X., Hafen, Z., **Grudić, M. Y.**, Kurinchi-Vendhan, S., Hayward, C. C., Jiang, F., Orr, M. E., Wetzel, A., Kereš, D., Stern, J., Faucher-Giguère, C.-A., Bullock, J., Wheeler, C., El-Badry, K., Loebman, S. R., Moreno, J., Boylan-Kolchin, M., and Quataert, E. "What causes the formation of discs and end of bursty star formation?" MNRAS, 525, 2, 2241–2286, October 2023. doi:10.1093/mnras/stad1902.

[5] Hopkins, P. F., Nadler, E. O., **Grudić, M. Y.**, Shen, X., Sands, I., and Jiang, F. "Novel conservative methods for adaptive force softening in collisionless and multi-species N-body simulations." MNRAS, August 2023. doi:10.1093/mnras/stad2548.

[6] Hopkins, P. F., Wetzel, A., Wheeler, C., Sanderson, R., **Grudić, M. Y.**, Sameie, O., Boylan-Kolchin, M., Orr, M., Ma, X., Faucher-Giguère, C.-A., Kereš, D., Quataert, E., Su, K.-Y., Moreno, J., Feldmann, R., Bullock, J. S., Loebman, S. R., Anglés-Alcázar, D., Stern, J., Necib, L., Choban, C. R., and Hayward, C. C. "FIRE-3: updated stellar evolution models, yields, and microphysics and fitting functions for applications in galaxy simulations." MNRAS, 519, 2, 3154–3181, February 2023. doi:10.1093/mnras/stac3489.

[7] Rodriguez, C. L., Hafen, Z., **Grudić, M. Y.**, Lamberts, A., Sharma, K., Faucher-Giguère, C.-A., and Wetzel, A. "Great balls of FIRE II: The evolution and destruction of star clusters across cosmic time in a Milky Way-mass galaxy." MNRAS, 521, 1, 124–147, May 2023. doi:10.1093/mnras/stad578.

[8] Shi, Y., Kremer, K., **Grudić, M. Y.**, Gerling-Dunsmore, H. J., and Hopkins, P. F. "Hyper-Eddington black hole growth in star-forming molecular clouds and galactic nuclei: can it happen?" MNRAS, 518, 3, 3606–3621, January 2023. doi:10.1093/mnras/stac3245.

[9] **Grudić, M. Y.**, Guszejnov, D., Offner, S. S. R., Rosen, A. L., Raju, A. N., Faucher-Giguère, C.-A., and Hopkins, P. F. "The dynamics and outcome of star formation with jets, radiation, winds, and supernovae in concert." MNRAS, 512, 1, 216–232, May 2022. doi:10.1093/mnras/stac526.

[10] Guszejnov, D., **Grudić, M. Y.**, Offner, S. S. R., Faucher-Giguère, C.-A., Hopkins, P. F., and Rosen, A. L. "Effects of the environment and feedback physics on the initial mass function of stars in the STARFORGE simulations." MNRAS, 515, 4, 4929–4952, October 2022. doi:10.1093/mnras/stac2060.

[11] Guszejnov, D., Markey, C., Offner, S. S. R., **Grudić, M. Y.**, Faucher-Giguère, C.-A., Rosen, A. L., and Hopkins, P. F. "Cluster assembly and the origin of mass segregation in the STARFORGE simulations." MNRAS, 515, 1, 167–184, September 2022. doi:10.1093/mnras/stac1737.

[12] Hopkins, P. F., Wellons, S., Anglés-Alcázar, D., Faucher-Giguère, C.-A., and **Grudić, M. Y.** "Why do black holes trace bulges (& central surface densities), instead of galaxies as a whole?" MNRAS, 510, 1, 630–638, February 2022. doi:10.1093/mnras/stab3458.

[13] Lane, H. B., **Grudić, M. Y.**, Guszejnov, D., Offner, S. S. R., Faucher-Giguère, C.-A., and Rosen, A. L. "Less wrong: a more realistic initial condition for simulations of turbulent molecular clouds." MNRAS, 510, 4, 4767–4778, March 2022. doi:10.1093/mnras/stab3739.

[14] **Grudić, M. Y.** "Accelerating self-gravitating hydrodynamics simulations with adaptive force updates." MNRAS, 507, 1, 1064–1071, October 2021. doi:10.1093/mnras/stab2208.

[15] **Grudić, M. Y.** and Gurvich, A. "pytreegrav: A fast Python gravity solver." *The Journal of Open Source Software*, 6, 68, 3675, December 2021. doi:10.21105/joss.03675.

[16] **Grudić, M. Y.**, Guszejnov, D., Hopkins, P. F., Offner, S. S. R., and Faucher-Giguère, C.-A. "STARFORGE: Towards a comprehensive numerical model of star cluster formation and feedback." MNRAS, 506, 2, 2199–2231, September 2021. doi:10.1093/mnras/stab1347.

[17] **Grudić, M. Y.**, Kruijssen, J. M. D., Faucher-Giguère, C.-A., Hopkins, P. F., Ma, X., Quataert, E., and Boylan-Kolchin, M. "A model for the formation of stellar associations and clusters from giant molecular clouds." MNRAS, 506, 3, 3239–3258, September 2021. doi:10.1093/mnras/stab1894.

[18] Guszejnov, D., **Grudić, M. Y.**, Hopkins, P. F., Offner, S. S. R., and Faucher-Giguère, C.-A. "STARFORGE: the effects of protostellar outflows on the IMF." MNRAS, 502, 3, 3646–3663, April 2021. doi:10.1093/mnras/stab278.

[19] Shi, Y., **Grudić, M. Y.**, and Hopkins, P. F. "The mass budget for intermediate-mass black holes in dense star clusters." MNRAS, 505, 2, 2753–2763, August 2021. doi:10.1093/mnras/stab1470.

[20] **Grudić, M. Y.**, Boylan-Kolchin, M., Faucher-Giguère, C.-A., and Hopkins, P. F. "The universal acceleration scale from stellar feedback." MNRAS, 496, 1, L127–L132, July 2020. doi:10.1093/mnrasl/slaa103.

[21] **Grudić, M. Y.** and Hopkins, P. F. "A general-purpose time-step criterion for simulations with gravity." MNRAS, 495, 4, 4306–4313, July 2020. doi:10.1093/mnras/staa1453.

[22] Gurvich, A. B., Faucher-Giguère, C.-A., Richings, A. J., Hopkins, P. F., **Grudić, M. Y.**, Hafen, Z., Wellons, S., Stern, J., Quataert, E., Chan, T. K., Orr, M. E., Kereš, D., Wetzel, A., Hayward, C. C., Loebman, S. R., and Murray, N. "Pressure balance in the multiphase ISM of cosmologically simulated disc galaxies." MNRAS, 498, 3, 3664–3683, November 2020. doi:10.1093/mnras/staa2578.

[23] Guszejnov, D., **Grudić, M. Y.**, Hopkins, P. F., Offner, S. S. R., and Faucher-Giguère, C.-A. "Can magnetized turbulence set the mass scale of stars?" MNRAS, 496, 4, 5072–5088, August 2020. doi:10.1093/mnras/staa1883.

[24] Guszejnov, D., **Grudić, M. Y.**, Offner, S. S. R., Boylan-Kolchin, M., Faucher-Giguère, C.-A., Wetzel, A., Benincasa, S. M., and Loebman, S. "Evolution of giant molecular clouds across cosmic time." MNRAS, 492, 1, 488–502, February 2020. doi:10.1093/mnras/stz3527.

[25] Hopkins, P. F., **Grudić, M. Y.**, Wetzel, A., Kereš, D., Faucher-Giguère, C.-A., Ma, X., Murray, N., and Butcher, N. "Radiative stellar feedback in galaxy formation: Methods and physics." MNRAS, 491, 3, 3702–3729, January 2020. doi:10.1093/mnras/stz3129.

[26] Ma, X., **Grudić, M. Y.**, Quataert, E., Hopkins, P. F., Faucher-Giguère, C.-A., Boylan-Kolchin, M., Wetzel, A., Kim, J.-h., Murray, N., and Kereš, D. "Self-consistent proto-globular cluster formation in cosmological simulations of high-redshift galaxies." MNRAS, 493, 3, 4315–4332, April 2020. doi:10.1093/mnras/staa527.

[27] Rodriguez, C. L., Kremer, K., **Grudić, M. Y.**, Hafen, Z., Chatterjee, S., Fragione, G., Lamberts, A., Martinez, M. A. S., Rasio, F. A., Weatherford, N., and Ye, C. S. "GW190412 as a Third-generation Black Hole Merger from a Super Star Cluster." ApJ, 896, 1, L10, June 2020. doi:10.3847/2041-8213/ab961d.

[28] Yu, S., Bullock, J. S., Wetzel, A., Sanderson, R. E., Graus, A. S., Boylan-Kolchin, M., Nierenberg, A. M., **Grudić, M. Y.**, Hopkins, P. F., Kereš, D., and Faucher-Giguère, C.-A. "Stars made in outflows may populate the stellar halo of the Milky Way." MNRAS, 494, 2, 1539–1559, May 2020. doi:10.1093/mnras/staa522.

[29] **Grudić, M. Y.** and Hopkins, P. F. "The elephant in the room: the importance of the details of massive star formation in molecular clouds." MNRAS, 488, 2, 2970–2975, September 2019. doi:10.1093/mnras/stz1820.

[30] **Grudić, M. Y.**, Hopkins, P. F., Lee, E. J., Murray, N., Faucher-Giguère, C.-A., and Johnson, L. C. "On the nature of variations in the measured star formation efficiency of molecular clouds." MNRAS, 488, 2, 1501–1518, September 2019. doi:10.1093/mnras/stz1758.

[31] **Grudić, M. Y.**, Hopkins, P. F., Quataert, E., and Murray, N. "The maximum stellar surface density due to the failure of stellar feedback." MNRAS, 483, 4, 5548–5553, March 2019. doi:10.1093/mnras/sty3386.

[32] Hopkins, P. F. and **Grudić, M. Y.** "Numerical problems in coupling photon momentum (radiation pressure) to gas." MNRAS, 483, 3, 4187–4196, March 2019. doi:10.1093/mnras/sty3089.

[33] **Grudić, M. Y.**, Guszejnov, D., Hopkins, P. F., Lamberts, A., Boylan-Kolchin, M., Murray, N., and Schmitz, D. "From the top down and back up again: star cluster structure from hierarchical star formation." MNRAS, 481, 1, 688–702, November 2018. doi:10.1093/mnras/sty2303.

[34] **Grudić, M. Y.**, Hopkins, P. F., Faucher-Giguère, C.-A., Quataert, E., Murray, N., and Kereš, D. "When feedback fails: the scaling and saturation of star formation efficiency." MNRAS, 475, 3, 3511–3528, April 2018. doi:10.1093/mnras/sty035.

[35] Guszejnov, D., Hopkins, P. F., and **Grudić, M. Y.** "Universal scaling relations in scale-free structure formation." MNRAS, 477, 4, 5139–5149, July 2018. doi:10.1093/mnras/sty920.

[36] Guszejnov, D., Hopkins, P. F., **Grudić, M. Y.**, Krumholz, M. R., and Federrath, C. "Isothermal Fragmentation: Is there a low-mass cut-off?" MNRAS, 480, 1, 182–191, October 2018. doi:10.1093/mnras/sty1847.

[37] Hopkins, P. F., Wetzel, A., Kereš, D., Faucher-Giguère, C.-A., Quataert, E., Boylan-Kolchin, M., Murray, N., Hayward, C. C., Garrison-Kimmel, S., Hummels, C., Feldmann, R., Torrey, P., Ma, X., Anglés-Alcázar, D., Su, K.-Y., Orr, M., Schmitz, D., Escala, I., Sanderson, R., **Grudić, M. Y.**, Hafen, Z., Kim, J.-H., Fitts, A., Bullock, J. S., Wheeler, C., Chan, T. K., Elbert, O. D., and Narayanan, D. "FIRE-2 simulations: physics versus numerics in galaxy formation." MNRAS, 480, 1, 800–863, October 2018. doi:10.1093/mnras/sty1690.

[38] Kim, J.-h., Ma, X., **Grudić, M. Y.**, Hopkins, P. F., Hayward, C. C., Wetzel, A., Faucher-Giguère, C.-A., Kereš, D., Garrison-Kimmel, S., and Murray, N. "Formation of globular cluster candidates in merging proto-galaxies at high redshift: a view from the FIRE cosmological simulations." MNRAS, 474, 3, 4232–4244, March 2018. doi:10.1093/mnras/stx2994.

[39] Foucart, F., Buchman, L., Duez, M. D., **Grudić, M. Y.**, Kidder, L. E., MacDonald, I., Mroue, A., Pfeiffer, H. P., Scheel, M. A., and Szilagyi, B. "First direct comparison of nondisrupting neutron star-black hole and binary black hole merger simulations." Phys. Rev. D, 88, 6, 064017, September 2013. doi:10.1103/PhysRevD.88.064017.