

Curriculum Vitae
Michael Y. Grudić

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Research Interests

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

Professional Experience

NASA Hubble Fellow, Carnegie Observatories, Pasadena, CA
CIERA Postdoctoral Fellow, Northwestern University, Evanston, IL

Sept 2021-present
Sept 2019-Aug 2021

Education

Ph.D. in Physics 2014-2019
California Institute of Technology (Caltech), Pasadena, CA
Dissertation: *The Role of Stellar Feedback in Star Cluster Formation*, advised by 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*, advised by Dr. John Lewis

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 majors	2014
Daniel Freeman Memorial Scholarship	2014
Lou Visentin Award	2014
NSERC Undergraduate Summer Research Award	2011-2013
MUN Faculty of Science Deans Book Prize (Physics)	2013
Dr. S. W. Brekon Scholarship in Physics	2012-2013
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

<u>Bash Symposium</u> , University of Texas, Austin, TX. Invited review.	2023
<u>Columbia University Astronomy Colloquium</u> , Columbia University, New York, NY.	2023
<u>Surveying the Milky Way</u> , Caltech, Pasadena, CA. Contributed talk.	2023

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

In Review

- [1] Bruel, T., Rodriguez, C. L., Lamberts, A., **Grudić, Michael Y.**, Hafen, Z., and Feldmann, R. “Great Balls of FIRE III: Modeling Black Hole Mergers from Massive Star Clusters in Simulations of Galaxies.” *arXiv e-prints*, arXiv:2311.14855, November 2023.
- [2] **Grudić, M. Y.** and Hopkins, P. F. “The opacity limit.” *arXiv e-prints*, arXiv:2308.16268, August 2023.
- [3] Hopkins, P. F., **Grudić, M. Y.**, Su, K.-Y., Wellons, S., Angles-Alcazar, D., Steinwandel, U. P., Guszejnov, D., Murray, N., Faucher-Giguere, C.-A., Quataert, E., and Keres, D. “FORGE'd in FIRE: Resolving the End of Star Formation and Structure of AGN Accretion Disks from Cosmological Initial Conditions.” *arXiv e-prints*, arXiv:2309.13115, September 2023.
- [4] Hopkins, P. F., Squire, J., Su, K.-Y., Steinwandel, U. P., Kremer, K., Shi, Y., **Grudić, M. Y.**, Wellons, S., Faucher-Giguere, C.-A., Angles-Alcazar, D., Murray, N., and Quataert, E. “FORGE'd in FIRE II: The Formation of Magnetically-Dominated Quasar Accretion Disks from Cosmological Initial Conditions.” *arXiv e-prints*, arXiv:2310.04506, October 2023.

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.
- [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.

Refereed Articles

- [1] Farias, J. P., Offner, S. S. R., Grudić, M. Y., Guszejnov, D., Rosen, A. L., and STARFORGE Team. “Stellar populations in STARFORGE: the origin and evolution of star clusters and associations.” *MNRAS*, 527, 3, January 2024.
- [2] Hennebelle, P. and **Grudić, M. Y.** “The Physical Origin of the Stellar Initial Mass Function.” *ARA&A*, 2024.
- [3] Crowe, S., Fedriani, R., Tan, J. C., Whittle, M., Zhang, Y., Garatti, A. C. o., Farias, J. P., Gautam, A., Telkamp, Z., Rothberg, B., **Grudić, M. Y.**, Andersen, M., Cosentino, G., Garcia-Lopez, R., Rosero, V., Tanaka, K., Pinna, E., Rossi, F., Miller, D., Agapito, G., Plantet, C., Ghose, E., Christou, J., Power, J., Puglisi, A., Briguglio, R., Brusa, G., Taylor, G., Zhang, X., Mazzoni, T., Bonaglia, M., Esposito, S., and Veillet, C. “Near-Infrared Observations of Outflows and YSOs in the Massive Star-Forming Region AFGL 5180.” *arXiv e-prints*, arXiv:2311.11909, November 2023.
- [4] 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.
- [5] **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, February 2023.
- [6] **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, accepted for publication in Open Journal of Astrophysics*, arXiv:2307.00052, June 2023.

- [7] 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, January 2023.
- [8] 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, October 2023.
- [9] 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.
- [10] 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, February 2023.
- [11] Millstone, S., Gutermuth, R., Offner, S. S. R., Pokhrel, R., and **Grudić, M. Y.** “Co-Evolution of Stars and Gas: Using Analysis of Synthetic Observations to Investigate the Star-Gas Correlation in STARFORGE.” *arXiv e-prints, accepted for publication in ApJ*, arXiv:2310.11544, October 2023.
- [12] 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, May 2023.
- [13] 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, January 2023.
- [14] Xu, D., Offner, S. S. R., Gutermuth, R., **Grudić, Michael Y.**, Guszejnov, D., and Hopkins, P. F. “Predicting the Radiation Field of Molecular Clouds Using Denoising Diffusion Probabilistic Models.” *ApJ*, 958, 1, 97, November 2023.
- [15] **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, May 2022.
- [16] 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, October 2022.
- [17] 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, September 2022.
- [18] 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, February 2022.
- [19] 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, March 2022.
- [20] **Grudić, M. Y.** “Accelerating self-gravitating hydrodynamics simulations with adaptive force updates.” *MNRAS*, 507, 1, October 2021.
- [21] **Grudić, M. Y.** and Gurvich, A. “pytreegrav: A fast Python gravity solver.” *The Journal of Open Source Software*, 6, 68, 3675, December 2021.
- [22] **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, September 2021.

- [23] **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, September 2021.
- [24] 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, April 2021.
- [25] Shi, Y., **Grudić, M. Y.**, and Hopkins, P. F. “The mass budget for intermediate-mass black holes in dense star clusters.” MNRAS, 505, 2, August 2021.
- [26] **Grudić, M. Y.**, Boylan-Kolchin, M., Faucher-Giguère, C.-A., and Hopkins, P. F. “The universal acceleration scale from stellar feedback.” MNRAS, 496, 1, July 2020.
- [27] **Grudić, M. Y.** and Hopkins, P. F. “A general-purpose time-step criterion for simulations with gravity.” MNRAS, 495, 4, July 2020.
- [28] 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, November 2020.
- [29] 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, August 2020.
- [30] 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, February 2020.
- [31] 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, January 2020.
- [32] 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, April 2020.
- [33] 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.
- [34] 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, May 2020.
- [35] **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, September 2019.
- [36] **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, September 2019.
- [37] **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, March 2019.
- [38] Hopkins, P. F. and **Grudić, M. Y.** “Numerical problems in coupling photon momentum (radiation pressure) to gas.” MNRAS, 483, 3, March 2019.
- [39] **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, November 2018.

- [40] **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, April 2018.
- [41] Guszejnov, D., Hopkins, P. F., and **Grudić, M. Y.** “Universal scaling relations in scale-free structure formation.” *MNRAS*, 477, 4, July 2018.
- [42] 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, October 2018.
- [43] 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, October 2018.
- [44] 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, March 2018.
- [45] 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.