

Vera Gluscevic

Curriculum Vitae

University of Southern California
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Research Interests

Cosmological and astrophysical probes of new physics; fundamental nature of dark matter and dark energy; dark matter direct detection; cosmic microwave background theory and analysis; near-field cosmology; 21-cm cosmology; forward modeling and inference in physics.

Appointments

- 2019–Present **University of Southern California, Department of Physics and Astronomy, Los Angeles, CA**
- Gabilan Assistant Professor
- 2018–2019 **University of Florida, Department of Physics, Gainesville, FL**
- Assistant Professor (deferral - on leave)
- 2018–2019 **Princeton University, Department of Physics, Princeton, NJ**
- Visiting Research Scholar
- 2013–2018 **Institute for Advanced Study, Princeton, NJ**
- Postdoctoral Member
 - Eric Schmidt Fellow (2016-2018)
 - Maternity leave (summer 2013; spring 2017)

Education

- June 2013 **Ph.D. in Astrophysics, California Institute of Technology, Pasadena, CA**
- Thesis: *CMB as a Probe of New Physics and Old Times*.
 - Adviser: Prof. Marc Kamionkowski.
- June 2007 **B.S. in Astrophysics, University of Belgrade, Belgrade, Serbia**
- Award “Prof. Zaharije Brkic” (for the best student in class of 2007).
 - Faculty for Mathematics Award for Excellence in Studies (2004; 2005).
 - Serbian Ministry of Education and Faculty for Mathematics Excellence Award (2006).

Service and Leadership

- 2020–Present **NASA PhysPAG**
- NASA Physics of the Cosmos Program Analysis Group (PhysPAG) member of the Executive Committee and Co-chair of the Cosmic Structures Science Interest group.
- 2018–Present **Simons Observatory Collaboration**
- Analysis pipeline development co-lead (2018-2020)
 - Likelihood and Theory working group co-lead (2018-2020)

- 2018–Present **CMB-S4 Collaboration**, *community-wide effort to design the next-generation ground-based cosmic microwave background experiment*
- Member of the Science Council (2018-2020)
 - Lead of the Dark Matter working group (2018-2020)
- 2021 **Snowmass21**, *particle physics community planning process*
- **Principal author of a Letter of Interest** “Cosmic Probes of Dark Matter Interactions: Challenges for Theory and Analysis”, submitted to Snowmass Cosmic Frontiers working group, August 2020.
- 2019 **Astro2020 Decadal Survey**, *community input coordination*
- **Principal author of science white paper** “Cosmological Probes of Dark Matter Interactions: The Next Decade”, submitted to the National Academies, March 2019 [ArXiv:1903.05140].
 - Key contributor to four science white papers, submitted to the National Academies, March 2019. (https://sites.nationalacademies.org/SSB/CurrentProjects/SSB_185159)
 - Key contributor to three project white papers (Simons Observatory, CMB-S4, PICO).
- 2021–Present **USC Physics and Astronomy Climate Committee**, chair.
- 2019/2020 **USC Diversity, Equity, and Inclusion Caucus**, member.
- 2015–2018 **IAS Committee on Diversity**, member.
- 2016, 2020, **NSF astrophysics grant proposal review**, panelist.
- 2020 **NASA grant proposal review**, panelist.
- 2013–Present **Journal referee**: Physical Review D, Physical Review Letters, Journal of Cosmology and Astroparticle Physics.

Organization

- 2019–Present USC Women in Physics, founder.
- 2019–Present USC CosmoLab, founder and organizer.
- Aug. 2021 COSMO21 conference (online), invited co-convener.
- 2021–Present USC Astrophysics Seminar, co-organizer.
- 2019/2020 USC Physics and Astronomy Colloquium, organizer.
- Aug. 2019 COSMO19 conference in Aachen, Germany, invited co-convener.
- Jun 2019 AAS meeting-in-a-meeting on Dark Matter, St. Louis, MO, organizer.
- 2014-2015 IAS Informal Seminar, organizer.
- 2012-2013 “CMB Tea” meetings for Caltech Cosmology Group, founder and organizer.

Teaching

- Spring 2021, **The Universe (ASTR 100)**, *General Education Course*, Department of Physics
 Fall 2021, and Astronomy, University of Southern California, CA
 Spring 2022

- Spring 2020 **Cosmology (ASTR 424)**, *Upper-division course for undergraduates*, Department of Physics and Astronomy, University of Southern California, CA
- Summer 2010 **Forces and Rocketry**, *Summer course*, Wilson Middle School in Pasadena, CA
- 2008-2011 **Teaching assistant**, *California Institute of Technology*
- Ay101: *Physics of Stars*, Fall 2008, Prof. L. Hillenbrand.
 - Prepared solutions, held office hours, graded problem sets.
 - Ay21: *Galaxies and Cosmology*, Winter 2008, Prof. C. Steidel.
 - Held office hours, graded problem sets, organized material reviews.
 - Ay1: *The Evolving Universe*, Spring 2009, Prof. N. Scoville.
 - Section Instructor: *Astrobiology*.
 - Ph1: *Introductory Course in Newtonian Mechanics*, Fall 2009, Prof. J. Zmuidzinas.
 - Graded problem sets and quizzes.
 - Ph1: *Introductory Course in Newtonian Mechanics*, Fall 2010, Prof. J. Zmuidzinas.
 - Section instructor.

Student Mentoring

- 2019–Present **Ph.D. thesis adviser**
Wendy Crumrine, Aryan Rahimieh, George (Trey) Driskell, Adam He, Isabella Johansson (master student)
- 2019–Present **Undergraduate student project advisor**
Karime Maamari (USC, class of 2020), Dimple Sarnaaik (USC, class of 2021), David Nguyen (USC, class of 2021), Brenda Zhou (USC, class of 2021), Resherle Verna (USC, class of 2020), Christian Glover (USC, class of 2020), Connor Powers (USC, class of 2021), Francisco Silva Pavon (USC, class of 2021, capstone project), Praayas Aggarwal (USC, class of 2021, capstone project), Arjun Bamba (USC, class of 2022, capstone project), Shuxing Fang (USC, class of 2022, capstone project), Nyal McCrea (Central Washington University, NSBP-Simons program 2021)
- 2016-2020 **External project advisor (graduate students)**
Jack Lashner (USC, 2020), Ethan Nadler (Stanford, 2019), Zack Li (Princeton, 2017/18), Samuel Witte (UCLA, 2016)
- Summer 2015-2018 **Undergraduate Summer Research Program (USRP)**, *Department of Astrophysical Sciences, Princeton University*, Student Project Adviser
- Aizhan Akhmetzhanova (*Non-linearities in interacting cosmologies*; Summer/Fall 2018.)
 - Emery Trott (*CMB- S_4 sensitivity to dark matter interactions*; Summer 2017.)
 - Katelyn Neese (*Annual modulation as a model-selection tool*; Summer/Fall 2015.)
- 2011-2013 **Astronomy peer mentoring program**, *California Institute of Technology*
- Mentored junior grad students: Melodie Kao, Io Kleiser.
- Summer 2010 **Summer Undergraduate Research Fellowship (SURF) Program**, *California Institute of Technology*
- Co-advised student: Jason Sanders (*Constraining cosmic birefringence with AGN*.)

Outreach

- June 2020 Physics Festival, USC, panelist

- January 2020 Students for the Exploration and Development of Space, USC, talk: *The cosmological hunt for dark matter.*
- March 2018 IAS After Hours Conversations, talk: *Did we discover evidence for dark matter collisions at the dawn of first stars?*
- October 2016 Lunch with a Member, talk for the Friends of the IAS: *Cosmic microwave background: a cosmologist's discovery tool.*
- March 2016 IAS After Hours Conversations, talk: *What is dark matter?*
- September 2015 IAS Staff Welcome Reception, presentation on current research.
- December 2014 Princeton Amateur Astronomer's Association (AAAP), public talk: *How do you "catch" dark matter?*
- August 2013 Public lecture, Belgrade Planetarium, Serbia: *Glow of the past: Story of the CMB (Sjaj prošlosti: Prica o mikrotalasnoj kosmičkoj pozadini).*
- Spring 2012 "The 2012 Venus Transit at Caltech" public outreach program: volunteer.
- Summer 2009 "Letenka" astronomy summer camp, Fruska Gora, Serbia: Invited consultation session for Serbian undergraduates interested in studying abroad.
- 2003-2013 Magazine "Astronomija" for popularization of Astronomy and Science, Novi Sad, Serbia: columnist and foreign correspondent.
- 2001-2003 Belgrade Public Observatory and Planetarium, Serbia: junior assistant.

Invited Talks/Workshops (Recent)

- Apr. 2022 Novel Hidden Sectors: From Colliders to Cosmology Invited Participation, Garching, Germany
- Apr. 2022 Theoretical Particle Physics Seminar, Melbourne, Australia (via Zoom).
- Oct. 2021 Racontres the Blois Conference, France, invited plenary talk, turned down invitation due to COVID-19 travel restrictions.
- Oct. 2021 Perimeter Institute Astrophysics Seminar (via zoom); Title: *Dark matter interactions throughout cosmic history.*
- Aug. 2021 Summer workshop on Dark Matter, Aspen, selected participant.
- Jul. 2021 International School of Astroparticle Physics (ISAPP) "DARK MATTER: from theory to detection," Vienna, Austria (via zoom); Title: *Dark matter cosmology.*
- May 2021 XIV International Conference on Interconnections between Particle Physics and Cosmology (via zoom); Title: *Dark matter interactions.*
- May 2021 TRIUMF Astrophysics Seminar (via zoom); Title: *Dark matter interactions.*
- Apr. 2021 DKM LSST, Vera Rubin Observatory dark matter meeting (via zoom); Title: *Dark matter interactions.*
- Mar. 2021 OKC Colloquium, Stockholm (via zoom); Title: *Dark matter throughout cosmic history.*

- Mar. 2021 Astronomy Colloquium, UC Riverside (via zoom); Title: *Dark matter throughout cosmic history.*
- Dec. 2020 Astronomy Seminar, UC Davis (via zoom); Title: *Dark matter interactions throughout cosmic history.*
- Nov. 2020 Cal State LA, Astronomy Colloquium (via zoom); Title: *Dark matter interactions throughout cosmic history.*
- Oct. 2020 Workshop on Global 21-cm signal, plenary talk, Cambridge, UK (via zoom); Title: *Dark matter interactions throughout cosmic history.*
- Oct. 2020 XIX Serbian Astronomy Conference, plenary talk; Title: *Dark matter interactions throughout cosmic history.*
- Oct. 2020 Caltech/JPL Cosmology Seminar; Title: *Dark matter interactions.*
- Aug. 2020 Cosmology Seminar, Fermilab; Title: *Dark matter interactions.*
- Jul. 2020 Invited follow-on visit, KITP, Santa Barbara (cancelled due to COVID); Title: *Millicharged dark matter on small scales.*
- Jun. 2020 News from the Dark, Workshop (by invitation), Strasbourg, France (via Zoom, due to COVID); Title: *Dark matter interactions throughout cosmic history.*
- May 2020 Invited plenary talk, 32nd Rencontres de Blois - Particle Physics and Cosmology Conference, Chateau de Blois, France (cancelled due to COVID); Title: *Astrophysical Probes of Dark Matter.*
- Mar. 2020 UCLA Dark Matter 2020 conference (cancelled due to COVID); Title: *Astrophysical probes of dark matter.*
- Mar. 2020 Cosmology/Astrophysics Seminar, South Methodist University (via Zoom, due to COVID); Title: *Dark matter throughout cosmic history.*
- Mar. 2020 Invited participant, Lighting new Lampposts for Dark Matter and Beyond the Standard Model, Simons Center Program (cancelled trip due to COVID)
- Feb. 2020 Colloquium, Mitchell Institute, Texas A&M University; Title: *Dark matter throughout cosmic history.*
- Feb. 2020 Theory Thursday, Carnegie Observatories, Pasadena; Title: *Satellites as probes of dark matter.*
- Dec. 2019 KITP Seminar, UCSB; Title: *Dark matter throughout cosmic history.*
- Nov. 2019 Astronomy Colloquium, UCLA; Title: *Dark matter throughout cosmic history.*
- Oct. 2019 2nd Global 21-cm signal, Workshop, McGill University; Title: *Dark matter throughout cosmic history.*
- Oct. 2019 Working group lead status report, CMB-S4 collaboration meeting; Title: *Dark Universe.*
- Aug. 2019 LSST Dark Matter Workshop, University of Chicago; Title: *Cosmological probes of dark matter interactions.*

- Jun. 2019 New Directions in the Search for Light Dark Matter Particles, Conference, Fermilab; Title: *Cosmological probes of dark matter interactions*.
- Jan. 2019 Dunlap Institute Colloquium, University of Toronto; Title: *Dark matter throughout cosmic history*.

External funding

- NASA Astrophysics Theory Program (ATP). PI, "Cosmological Signals of Light Dark Matter: New Predictions and Connections" awarded \$545,084 for 3 years, starting Fall 2022 (Grant No. 21-ATP21-0135).
- NSF Astro-particle and Cosmology solicitation. Single-PI, "Probing Dark Matter throughout Cosmic History" awarded \$225,000 for 3 years, starting Fall 2020; Grant No. PHY-2013951.

Peer-Reviewed Publications

Below are listed all peer-reviewed publications which V. Gluscevic led or for which she was a key contributor. Advisees (students or postdocs) are indicated by an asterisk. Senior collaborators are indicated by underline, and their roles explained in footnotes.

- Nguyen, D. V.^{*}, Sarnaaik, D.^{*}, Boddy, K. K., Nadler, E. O.^{*}, **Gluscevic, V.** 2021. Observational constraints on dark matter scattering with electrons. *Physical Review D* 104. doi:10.1103/PhysRevD.104.103521
- Nadler, E. O.^{*} and 68 colleagues (DES Collaboration) including **Gluscevic, V.** as external key contributor 2021. Constraints on Dark Matter Properties from Observations of Milky Way Satellite Galaxies. *Physical Review Letters* 126. doi:10.1103/PhysRevLett.126.091101
- Maamari, K.^{*}, **Gluscevic, V.**, Boddy, K. K., Nadler, E. O.^{*}, Wechsler, R. H.¹ 2021. Bounds on Velocity-dependent Dark Matter-Proton Scattering from Milky Way Satellite Abundance. *The Astrophysical Journal* 907. doi:10.3847/2041-8213/abd807
- Nadler, E. O.^{*}, **Gluscevic, V.**, Boddy, K. K., Wechsler, R. H.¹ 2019. Constraints on Dark Matter Microphysics from the Milky Way Satellite Population. *The Astrophysical Journal* 878. doi:10.3847/2041-8213/ab1eb2
- Li, Z.^{*}, **Gluscevic, V.**, Boddy, K. K., Madhavacheril, M. S. 2018. Disentangling dark physics with cosmic microwave background experiments. *Physical Review D* 98. doi:10.1103/PhysRevD.98.123524
- Boddy, K. K., **Gluscevic, V.**, Poulin, V., Kovetz, E. D., Kamionkowski, M.², Barkana, R.³ 2018. Critical assessment of CMB limits on dark matter-baryon scattering: New treatment of the relative bulk velocity. *Physical Review D* 98. doi:10.1103/PhysRevD.98.123506
- Kovetz, E. D., Poulin, V., **Gluscevic, V.**, Boddy, K. K., Barkana, R.³, Kamionkowski, M.² 2018. Tighter limits on dark matter explanations of the anomalous EDGES 21 cm signal. *Physical Review D* 98. doi:10.1103/PhysRevD.98.103529
- Boddy, K. K., **Gluscevic, V.** 2018. First cosmological constraint on the effective theory of dark matter-proton interactions. *Physical Review D* 98. doi:10.1103/PhysRevD.98.083510

¹E. Nadler's Ph.D. adviser; V. Gluscevic led the project.

²PI of group that included Boddy, Poulin, and Kovetz at the time.

³Senior collaborator of Kamionkowski group.

- **Gluscevic, V.**, Boddy, K. K. 2018. Constraints on Scattering of keV-TeV Dark Matter with Protons in the Early Universe. *Physical Review Letters* 121. doi:10.1103/PhysRevLett.121.081301
- **Gluscevic, V.**, Venumadhav, T., Fang, X., Hirata, C.⁴, Oklopčić, A., Mishra, A. 2017. New probe of magnetic fields in the pre-reionization epoch. II. Detectability. *Physical Review D* 95. doi:10.1103/PhysRevD.95.083011
- Venumadhav, T., Oklopčić, A., **Gluscevic, V.**, Mishra, A., Hirata, C. M.⁴ 2017. New probe of magnetic fields in the preionization epoch. I. Formalism. *Physical Review D* 95. doi:10.1103/PhysRevD.95.083010
- Witte, S. J.* , **Gluscevic, V.**, McDermott, S. D. 2017. Prospects for distinguishing dark matter models using annual modulation. *Journal of Cosmology and Astroparticle Physics* 2017. doi:10.1088/1475-7516/2017/02/044
- **Gluscevic, V.**, Gresham, M. I.⁵, McDermott, S. D., Peter, A. H. G.⁵, Zurek, K. M.⁵ 2015. Identifying the theory of dark matter with direct detection. *Journal of Cosmology and Astroparticle Physics* 2015. doi:10.1088/1475-7516/2015/12/057
- Peter, A. H. G.⁶, **Gluscevic, V.**, Green, A. M.⁷, Kavanagh, B. J., Lee, S. K. 2014. WIMP physics with ensembles of direct-detection experiments. *Physics of the Dark Universe* 5, 45–74. doi:10.1016/j.dark.2014.10.006
- **Gluscevic, V.**, Peter, A. H. G.⁸ 2014. Understanding WIMP-baryon interactions with direct detection: a roadmap. *Journal of Cosmology and Astroparticle Physics* 2014. doi:10.1088/1475-7516/2014/09/040
- **Gluscevic, V.**, Kamionkowski⁹, M., Hanson, D. 2013. Patchy screening of the cosmic microwave background by inhomogeneous reionization. *Physical Review D* 87. doi:10.1103/PhysRevD.87.047303
- **Gluscevic, V.** 2013. CMB as a Probe of New Physics and Old Times. Ph.D. Thesis.
- **Gluscevic, V.**, Hanson, D., Kamionkowski, M.⁹, Hirata, C. M.¹⁰ 2012. First CMB constraints on direction-dependent cosmological birefringence from WMAP-7. *Physical Review D* 86. doi:10.1103/PhysRevD.86.103529
- Caldwell, R. R.¹⁰, **Gluscevic, V.**, Kamionkowski, M.⁹ 2011. Cross-correlation of cosmological birefringence with CMB temperature. *Physical Review D* 84. doi:10.1103/PhysRevD.84.043504
- **Gluscevic, V.**, Barkana, R.⁸ 2010. Statistics of 21-cm fluctuations in cosmic reionization simulations: PDFs and difference PDFs. *Monthly Notices of the Royal Astronomical Society* 408, 2373–2380. doi:10.1111/j.1365-2966.2010.17293.x
- **Gluscevic, V.**, Kamionkowski, M.⁹ 2010. Testing parity-violating mechanisms with cosmic microwave background experiments. *Physical Review D* 81. doi:10.1103/PhysRevD.81.123529
- **Gluscevic, V.**, Kamionkowski, M.⁹, Cooray, A.¹⁰ 2009. Derotation of the cosmic microwave background polarization: Full-sky formalism. *Physical Review D* 80. doi:10.1103/PhysRevD.80.023510

⁴Senior adviser of the project.

⁵Senior collaborator of V. Gluscevic from different institution; V.G. led the project as a postdoc.

⁶Led review paper and invited co-authors.

⁷Invited co-author.

⁸Advised V. Gluscevic on project.

⁹Ph.D. adviser of V. Gluscevic.

¹⁰Senior contributing collaborator; paper led by V. Gluscevic.

Peer-Reviewed Large-Collaboration Publications

Below are listed peer-reviewed publications to which V. Gluscevic made minor contributions as a member of a large collaboration.

- Hill, J. C. and 41 colleagues (ACT Collaboration) including **Gluscevic, V.** 2021. The Atacama Cosmology Telescope: Constraints on Pre-Recombination Early Dark Energy. arXiv:2109.04451; submitted to PRD
- Li, Y. and 32 colleagues (ACT Collaboration) including **Gluscevic, V.** 2021. Constraining Cosmic Microwave Background Temperature Evolution With Sunyaev-Zel'Dovich Galaxy Clusters from the Atacama Cosmology Telescope. The Astrophysical Journal 922. doi:10.3847/1538-4357/ac26b6
- Aiola, S. and 140 colleagues (ACT Collaboration) including **Gluscevic, V.** 2020. The Atacama Cosmology Telescope: DR4 maps and cosmological parameters. Journal of Cosmology and Astroparticle Physics 2020. doi:10.1088/1475-7516/2020/12/047
- Choi, S. K. and 138 colleagues (ACT Collaboration) including **Gluscevic, V.** 2020. The Atacama Cosmology Telescope: a measurement of the Cosmic Microwave Background power spectra at 98 and 150 GHz. Journal of Cosmology and Astroparticle Physics 2020. doi:10.1088/1475-7516/2020/12/045
- Madhavacheril, M. S. and 55 colleagues (ACT Collaboration) including **Gluscevic, V.** 2020. Atacama Cosmology Telescope: Component-separated maps of CMB temperature and the thermal Sunyaev-Zel'dovich effect. Physical Review D 102. doi:10.1103/PhysRevD.102.023534
- Namikawa, T. and 53 colleagues (ACT Collaboration) including **Gluscevic, V.** 2020. Atacama Cosmology Telescope: Constraints on cosmic birefringence. Physical Review D 101. doi:10.1103/PhysRevD.101.083527
- Ade, P. and 249 colleagues (Simons Observatory Collaboration) including **Gluscevic, V.** 2019. The Simons Observatory: science goals and forecasts. Journal of Cosmology and Astroparticle Physics 2019. doi:10.1088/1475-7516/2019/02/056

White Papers

Below are listed white papers or non-refereed e-print science books to which V. Gluscevic contributed.

- The CMB-S4 Collaboration et al., including **Gluscevic, V.** 2020. CMB-S4: Forecasting Constraints on Primordial Gravitational Waves. arXiv:2008.12619
- Grin, D. and 7 colleagues including **Gluscevic, V.** 2019. Gravitational probes of ultra-light axions. Bulletin of the American Astronomical Society 51.
- Simon, J. and 11 colleagues including **Gluscevic, V.** 2019. Dynamical Masses for a Complete Census of Local Dwarf Galaxies. Bulletin of the American Astronomical Society 51.
- Mantz, A. and 181 colleagues including **Gluscevic, V.** 2019. The Future Landscape of High-Redshift Galaxy Cluster Science. Bulletin of the American Astronomical Society 51.
- Bechtol, K. and 178 colleagues including **Gluscevic, V.** 2019. Dark Matter Science in the Era of LSST. Bulletin of the American Astronomical Society 51.

- Chluba, J. and 100 colleagues including **Gluscevic, V.** 2019. Spectral Distortions of the CMB as a Probe of Inflation, Recombination, Structure Formation and Particle Physics. Bulletin of the American Astronomical Society 51.
- Green, D. and 138 colleagues including **Gluscevic, V.** 2019. Messengers from the Early Universe: Cosmic Neutrinos and Other Light Relics. Bulletin of the American Astronomical Society 51.
- **Gluscevic, V.** and 18 colleagues 2019. Cosmological Probes of Dark Matter Interactions: The Next Decade. Bulletin of the American Astronomical Society 51.
- Sehgal, N. and 24 colleagues including **Gluscevic, V.** 2019. Science from an Ultra-Deep, High-Resolution Millimeter-Wave Survey. Bulletin of the American Astronomical Society 51.
- Abazajian, K. and 224 colleagues including **Gluscevic, V.** 2019. CMB-S4 Science Case, Reference Design, and Project Plan. arXiv:1907.04473
- Hanany, S. and 81 colleagues including **Gluscevic, V.** 2019. PICO: Probe of Inflation and Cosmic Origins. arXiv:1902.10541
- Drlica-Wagner, A. and 99 colleagues including **Gluscevic, V.** 2019. Probing the Fundamental Nature of Dark Matter with the Large Synoptic Survey Telescope. arXiv:1902.01055.
- Abazajian, K. N. and 85 colleagues including **Gluscevic, V.** 2016. CMB-S4 Science Book, First Edition. arXiv:1610.02743.

Computer Skills and Code

python, cython, C, Mathematica, MATLAB. Packages: MultiNest, HEALPix, CAMB, 21CMFast, CosmoMC, CLASS, Monte Python. Open source code available at <https://github.com/veragluscevic/>.

References

Prof. Marc Kamionkowski (kamion@pha.jhu.edu)
 Prof. Jo Dunkley (jdunkley@princeton.edu)
 Prof. Annika Peter (peter.33@osu.edu)
 Prof. Robert Caldwell (robert.r.caldwell@dartmouth.edu)