Paul O. Hayne

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Summary I am an assistant professor of astrophysical and planetary sciences at the University of Colorado, Boulder. My research focuses on the surfaces and atmospheres of icy planets and moons. I develop computational models and use the latest observational data to better understand these planetary bodies. Teaching, mentoring, and public engagement are also fundamental to my work.

Positions Held

University of Colorado, Boulder
Assistant Professor, January 2018 – present
Astrophysical & Planetary Sciences Department, and
Laboratory for Atmospheric & Space Physics

NASA – Jet Propulsion Laboratory, California Institute of Technology
Research Scientist, 2012 – 2017

California Institute of Technology
Postdoctoral Scholar, 2011 – 2012
Division of Geological & Planetary Sciences (with Oded Aharonson)

Education

University of California, Los Angeles
Ph.D., Geophysics & Space Physics, 2010 (Advisor: David A. Paige)

Stanford University
M.S., Geophysics, 2005 (Advisors: Norman H. Sleep & Jack J. Lissauer)
B.S., Geophysics, 2003

Mission Involvement

NASA Europa Clipper
Co-Investigator (2017–present) and *Investigation Scientist* (2015–2018)
Europa Thermal Emission Imaging System (E-THEMIS)

NASA Mars Reconnaissance Orbiter
Co-Investigator (2017–present) and *Affiliate* (2007–2016)
Mars Climate Sounder

NASA Lunar Flashlight
Co-Investigator (2012–present)

NASA Lunar Reconnaissance Orbiter
Co-Investigator (2011–present)
Diviner Lunar Radiometer Experiment

Science Team Affiliate: **NASA Dawn at Ceres** (2016–present) and
NASA/ESA Cassini-Huygens Mission to Saturn (2006–2014)

Visiting Appointments

Lawrence Livermore National Laboratory
Visiting Scientist (2017)
Planetary Defense Program / Weapons and Complex Integration (WCI)

Weizmann Institute of Science, Israel
Visiting Scientist (2015, 2016)
The Helen Kimmel Center for Planetary Science

Leadership & Service

Keck Institute for Space Studies, California Institute of Technology
Study Co-Lead
2017–2018: Unlocking the Climate Record Stored within Mars' Polar Layered Deposits
2013–2014: New Approaches to Lunar Ice Detection and Mapping

American Astronomical Society, Division for Planetary Sciences
Member of the Federal Relations Subcommittee (2017–present)
Local Organizing Committee, Annual Meeting (2016)
Panelist, Annual Meeting (2015)

American Geophysical Union
Session Organizer (Mars Atmosphere), Annual Meeting (2014–2017)

Young Scientists for Planetary Exploration
Co-founder (2012) and *Co-leader* (2012–present)
World-wide advocacy organization for early-career planetary scientists

Ad Astra Academy
Co-founder and Co-leader, Ad Astra - Brazil (2015–2016)
Science and exploration program for school-aged students in developing countries

NASA Science Mission Directorate
Review Panel Member (2012–present)

National Research Council – Space Studies Board
Raconteur, Planetary Science Decadal Survey (2009–2010)

Earth & Space Sciences Student Organization, UCLA
President (2007–2008)

Stanford Astronomical Society
President (2002–2004)

Referee for major scientific journals:
Journal of Geophysical Research
Geophysical Research Letters
Icarus
Astrophysical Journal
Planetary & Space Science
Advances in Space Research
Space Science Reviews
Geology
Science Advances

Honors & Awards

2013 *NASA Group Achievement Award*, Diviner Lunar Radiometer science team
2011 *NASA Group Achievement Award*, Mars Climate Sounder science team
2010 *Best Student Paper Award*, NASA Lunar Science Forum
2010 *NASA Group Achievement Award*, Diviner Lunar Radiometer operations team
2010 *NASA Group Achievement Award*, Diviner Lunar Radiometer science team
2008 *Simon Latimer Award for Service*, UCLA
2006 *Graduate Fellowship*, Institute of Geophysics and Planetary Physics
2006 *Chancellor's Prize*, UCLA
2003 *Graduate Fellowship*, Dept. of Geophysics, Stanford University
2001 *Summer Research Fellowship*, Dept. of Physics, Stanford University

Teaching

University of Colorado, Boulder
ASTR 3720: Planets and their Atmospheres (Spring, 2018)
Professor for upper-division undergraduate course (84 students)

California Institute of Technology
Ge 151: Planetary Surfaces (2011)
Guest Lecturer for graduate course (∼6 students)

University of California, Los Angeles
ESS 10: Exploring Mars (2008)
Teaching Assistant and Guest Lecturer for undergraduate course (60 students)

Stanford University
Geophysics 150: Physics of the Earth (2004, 2005)
Teaching Assistant for graduate course (∼6 students)
Physics 50: Observational Astronomy (2002, 2003)
Teaching Assistant for undergraduate course (∼20 students)

Mentoring

Laboratory for Atmospheric and Space Physics
Mentor
2018–present: Carlos Eytan Gary Bicas (U. Colorado)

Caltech Summer Undergraduate Research Fellows (SURF)
Mentor
2017: James Haber (Cornell University)
2015: Léa Bonnefoy (Cornell University)
2014: Clifford Watkins (Carleton College)
2011: Michael Lauria (Caltech)

Maximizing Student Potential (MSP)
Mentor
2015–2018: Jose Martínez Camacho (Citrus College → Cal-Poly University)

Caltech Postdoctoral Fellows at JPL
Mentor
2017–2018: Dr. Quentin Vinckier (*co-mentor* with Dr. R. Glenn Sellar)
2016–2018: Dr. Catherine M. Elder

External Grants

2018–2021 *Boulders on Bennu: Modeling Thermal Emission from Boulders for Yarkovsky Effect and Thermal Inertia Investigations*
PI: P. Hayne (Science PI: C. Elder)
NASA OSIRIS-REx Participating Scientist Program / $346,000

2013–2019 *Lunar Flashlight Science Investigation*
PI: B. Cohen (Co-I: P. Hayne)
NASA Advanced Exploration Systems / ∼$400,000 for P. Hayne

2017–2018 *Unlocking the Climate Record Stored within Mars' Polar Layered Deposits*
PI: P. Hayne
W. M. Keck Institute for Space Studies / $50,000

2016–2018 *Lunar Reconnaissance Orbiter Extended Mission 3*
PI: D. Paige (Co-I: P. Hayne)
NASA Discovery Program / ∼$600,000 allocation for P. Hayne

2016–2018 *Mars Reconnaissance Orbiter Extended Mission 4*
PI: J. T. Schofield (Co-I: P. Hayne)
NASA Mars Program / ∼$300,000 allocation for P. Hayne

2015–2018 *Inter-seasonal and Inter-annual Surface Dust Fluxes on Mars*
PI: P. Hayne (Science PI: S. Piqueux)
NASA Mars Data Analysis Program / $330,690

2015–2018 *Europa Thermal Emission Imaging System*
PI: P. Christensen (Co-I: P. Hayne)
NASA Europa Clipper Mission / ∼$30,000 allocation for P. Hayne

2013–2017 *Volatile Regolith Thermal Investigation Consortium for Exploration and Science (VORTICES)*
PI: A. Rivkin (Co-I: P. Hayne)
NASA Solar System Exploration Research Virtual Institute / ∼$120,000

2014–2016 *Thermal Infrared Observations of the Moon during Lunar Eclipse*
PI: P. Lucey (Co-I: P. Hayne)
NASA Planetary Astronomy / $142,810 allocation for P. Hayne

2013–2014 *Development of Large Format Rad-Hard Focal Plane Arrays and Readouts for Thermal Radiometer for Europa Clipper Mission*
PI: M. Kenyon (Co-I: P. Hayne)
Instrument Concepts for Europa Exploration / $16,460 allocation for P. Hayne

2013–2014 *New Approaches to Lunar Ice Detection and Mapping*
PI: P. Hayne
W. M. Keck Institute for Space Studies / $50,000

Invited Lectures

2018	Applied Physics Laboratory, Johns Hopkins University
2017	Lawrence Livermore National Laboratory
2017	University of Colorado, Boulder
2016	Lunar & Planetary Institute
2016	Weizmann Institute of Science (Israel)
2015	International Space Exploration Coordination Group,
2015	NASA Exploration Science Forum
2015	University of California - Santa Cruz
2014	SETI Institute
2013	Lunar & Planetary Institute
2012	California Institute of Technology
2012	NASA – Jet Propulsion Laboratory

Professional Affiliations

American Astronomical Society - Division for Planetary Sciences
American Geophysical Union
European Geosciences Union
Asia Oceania Geosciences Society
Geochemical Society
Sigma Xi

Skills & Training

Remote sensing & spacecraft instrumentation
Spectroscopy (ultraviolet through submillimeter)
Thermal imaging and radiometry

Modeling and Numerical Simulation
Heat transfer (thermal modeling)
Radiative transfer for planetary atmospheres and surfaces
Geophysical inversion
Transient and stochastic phenomena

Computer programming languages
Proficient/expert: `C/C++, Python, MATLAB, IDL, bash, c-shell`
Familiar: `Fortran 90/95, awk, javascript`, etc.

Mission formulation experience
Team-X, NASA Jet Propulsion Laboratory
Team-A, NASA Jet Propulsion Laboratory
Capture Lead Training, NASA Jet Propulsion Laboratory
Co-I on proposals to NASA's *Discovery* and *New Frontiers* programs
PI on instrument proposals to NASA mission programs

Additional training
Astrobiology Winter School and Field Course (2011)
NASA Astrobiology Institute and Hawaii Institute for Astronomy
International Astrobiology Summer School (2008)
NASA Astrobiology Institute and Universidad Internacional Menéndez Pelayo, Spain
PADI Open Water Diver scuba certification (50+ dives)
Eagle Scout (1998), BSA Troop 676, Issaquah, WA

Publications: Refereed Journal Articles

Number of peer-reviewed papers: 31 (as of March, 2018)
h-index: 14 (Web of Science), 17 (Google Scholar)
Total citations: 594 (Web of Science), 1,009 (Google Scholar)

2018

1. Heavens, N. G., Kleinböhl, A., Chaffin, M. S., Halekas, J. S., Kass, D. M., **Hayne, P. O.**, McCleese, D. J., Piqueux, S., Shirley, J. H., & Schofield, J. T. (2018), Hydrogen escape from Mars enhanced by deep convection in dust storms, *Nature Astronomy, 2*, 126–132. doi: 10.1038/s41550-017-0353-4.

2017

2. **Hayne, P. O.**, Bandfield, J. L., Siegler, M. A., Vasavada, A. R., Ghent, R. R., et al. (2017), Global regolith thermophysical properties of the Moon from the Diviner Lunar Radiometer Experiment, *J. Geophys. Res., 122*, 2371–2400. doi: 10.1002/2017JE005387

3. Elder, C. M., **Hayne, P. O.**, Bandfield, J. L., Ghent, R. R., Williams, J.-P., Donaldson Hanna, K. L., & Paige, D. A. (2017), Young lunar volcanic Features: Thermophysical properties and formation, *Icarus, 290*, 224–237. doi: 10.1016/j.icarus.2017.03.004

4. Mitri, G., Postberg, F., Soderblom, J. M., ..., **Hayne, P. O.**, et al. (2017), Explorer of Enceladus and Titan (E^2T): Investigating ocean worlds' evolution and habitability in the solar system, *Planetary and Space Science*, doi: 10.1016/j.pss.2017.11.001

5. Landis, M. E., Byrne, S., Schörghofer, N., Schmidt, B. E., **Hayne, P. O.**, Castillo-Rogez, J., ... Russell, C. T. (2017), Conditions for sublimating water ice to supply Ceres' exosphere, *J. Geophys. Res., 122*, 1984–1995. doi: 10.1002/2017JE005335

6. Davies, A. G., Gunapala, S., Soibel, A., Ting, D., Rafol, S., Blackwell, M., **Hayne, P. O.**, & Kelly, M. (2017), A novel technology for measuring the eruption temperature of silicate lavas with remote sensing: Application to Io and other planets, *J. Volcanology & Geothermal Res., 343*, 1–16. doi: 10.1016/j.jvolgeores.2017.04.016

7. Fisher, E. A., Lucey, P. G., Lemelin, M., Greenhagen, B. T., Siegler, M. A., Mazarico, E., Aharonson, O., Williams, J-P., **Hayne, P. O.**, Neumann, G. A., Paige, D. A., Smith, D. E., & Zuber, M. T. (2017), Evidence for surface water ice in the lunar polar regions using reflectance measurements from the Lunar Orbiter Laser Altimeter and temperature measurements from the Diviner Lunar Radiometer Experiment, *Icarus, 292*, 74–85. doi: 10.1016/j.icarus.2017.03.023

2016

8. Piqueux, S., Kleinböhl, A., **Hayne, P. O.**, Heavens, N. G., Kass, D. M., McCleese, D. J., ... & Shirley, J. H. (2016), Discovery of a widespread low–latitude diurnal CO_2 frost cycle on Mars, *J. Geophys. Res., 121*, 1174-118. doi: 10.1002/2016JE005034

9. Greenhagen, B. T., Neish, C. D., Williams, J. P., Cahill, J. T., Ghent, R. R., **Hayne, P. O.**, ... & Bandfield, J. L. (2016), Origin of the anomalously rocky appearance of Tsiolkovskiy crater, *Icarus, 273*, 237–247. doi: 10.1016/j.icarus.2016.02.041

10. Bennett, K. A., Horgan, B. H., Gaddis, L. R., Greenhagen, B. T., Allen, C. C., **Hayne, P. O.**, ... & Paige, D. A. (2016), Complex explosive volcanic activity on the Moon within Oppenheimer crater, *Icarus, 273*, 296–314. doi: 10.1016/j.icarus.2016.02.007

11. Bonnefoy, L. E., A. G. Hayes, **P. O. Hayne**, et al. (2015), Compositional and spatial variations in Titan dune and interdune regions from Cassini VIMS and RADAR, *Icarus, 270*, 222–237, doi:10.1016/j.icarus.2015.09.014

2015

12. **Hayne, P. O.**, and Oded Aharonson (2015), Thermal stability of ice on Ceres with rough topography, *J. Geophys. Res., 120*, 1567–1584, doi: 10.1002/2015JE004887

13. Heavens, N. G., Cantor, B. A., **Hayne, P. O.**, et al. (2015), Extreme detached dust layers near Martian volcanoes: Evidence for dust transport by mesoscale circulations forced by high topography, *Geophys. Res. Lett., 42*, 10, 3730–3738. doi: 10.1002/2015GL064004

14. **Hayne, P. O.**, A. R. Hendrix, E. Sefton-Nash, P. G. Lucey, K. D. Retherford, J-P. Williams, et al. (2015), Evidence for exposed water ice in the Moon's south polar regions from Lunar Reconnaissance Orbiter ultraviolet albedo and temperature measurements, *Icarus, 255*, 58–69, doi:10.1016/j.icarus.2015.03.032

15. Glotch, T. D., Bandfield, J. L., Lucey, P. G., **Hayne, P. O.**, et al. (2015), Formation of lunar swirls by magnetic field standoff of the solar wind, *Nature Communications, 6*. doi: 10.1038/ncomms7189

16. Piqueux, S., Kleinböhl, A., **Hayne, P. O.**, Kass, D. M., Schofield, J. T., & McCleese, D. J. (2015), Variability of the Martian seasonal CO2 cap extent over eight Mars Years, *Icarus*, doi:10.1016/j.icarus.2014.10.045

17. Bandfield, J. L., **Hayne, P. O.**, Williams, J. P., Greenhagen, B. T., & Paige, D. A. (2015), Lunar surface roughness derived from LRO Diviner Radiometer observations, *Icarus, 248*, 357–372. doi: 10.1016/j.icarus.2014.11.009

2014

18. **Hayne, P. O.**, McCord, T. B., & Sotin, C. (2014), Titan's surface composition and atmospheric transmission with solar occultation measurements by Cassini VIMS, *Icarus, 243*, 158–172. doi: 10.1016/j.icarus.2014.08.045

19. **Hayne, P. O.**, D. A. Paige, N. G. Heavens (2014), The role of snowfall in forming the seasonal ice caps of Mars: Models and constraints from the Mars Climate Sounder, *Icarus 231*, 122–130. doi: 10.1016/j.icarus.2013.10.020

20. Ghent, R. R., **Hayne, P. O.**, Bandfield, J. L., Campbell, B. A., Allen, C. C., Carter, L. M., & Paige, D. A. (2014), Constraints on the recent rate of lunar ejecta breakdown and implications for crater ages, *Geology, 42*(12), 1059–1062. doi: 10.1130/G35926.1

21. Bandfield, J. L., E. Song, **P. O. Hayne**, B. D. Brand, R. R. Ghent, A. R. Vasavada, D. A. Paige (2014), Lunar cold spots: Granular flow features and extensive insulating materials surrounding young craters, *Icarus 231*, 221–231. doi: 10.1016/j.icarus.2013.12.017

22. Ingersoll, R. V., Pratt, M. J., Davis, P. M., Caracciolo, L., Day, P. P., **Hayne, P. O.**, ... & Hendrix, E. D. (2014), Paleotectonics of a complex Miocene half graben formed above a detachment fault: The Diligencia basin, Orocopia Mountains, southern California, *Lithosphere, 6*(3), 157–176. doi: 10.1130/L334.1

2013

23. Barnes, J. W., B. J. Buratti, E. P. Turtle, J. Bow, P. A. Dalba, J. Perry, R. H. Brown, S. Rodriguez, S. Le Mouelic, K. H. Baines, C. Sotin, R. D. Lorenz, M. J. Malaska, T. B. McCord, R. N. Clark, R. Jaumann, **P. O. Hayne**, et al. (2013), Precipitation-Induced Surface Brightenings Seen on Titan by Cassini VIMS and ISS, *Planetary Science, 2*, p. 1. doi: 10.1186/2191-2521-2-1

2012

24. **Hayne, P. O.**, D. A. Paige, J. T. Schofield, D. M. Kass, A. Kleinböhl, N. G. Heavens, and D. J. McCleese (2012), Carbon dioxide snow clouds on Mars: South polar winter observations by the Mars Climate Sounder, *J. Geophys. Res., 117*, E08014, doi: 10.1029/2011JE004040

25. Vasavada, A. R., J. L. Bandfield, B. T. Greenhagen, **P. O. Hayne**, et al. (2012), Lunar Equatorial Surface Temperatures and Regolith Properties from the Diviner Lunar Radiometer Experiment, *J. Geophys. Res. 117*, E00H18. doi: 10.1029/2011JE003987

2010

26. **Hayne, P. O.**, B. T. Greenhagen, M. C. Foote, M. A. Siegler, A. R. Vasavada, and D. A. Paige (2010), Diviner Lunar Radiometer Observations of the LCROSS Impact, *Science, 330*, 477. doi: 10.1126/science.1197135

27. Paige, D. A., M. A. Siegler, J. A. Zhang, **P. O. Hayne**, et al. (2010), Diviner Observations of Cold Traps in the Lunar South Polar Region: Spatial Distribution and Temperature, *Science 330*, 479. doi: 10.1126/science.1187726

28. Greenhagen, B. T., P. G. Lucey, M. B. Wyatt, T. D. Glotch, C. C. Allen, J. A. Arnold, J. L. Bandfield, N. E. Bowles, K. L. Hanna, **P. O. Hayne**, E. Song, I. R. Thomas, and D. A. Paige (2010), Global Silicate Mineralogy of the Moon from the Diviner Lunar Radiometer, *Science 329*, 1507. doi: 10.1126/science.1192196

29. McCord, T. B., Hansen, G. B., Combe, J-P., & **P. O. Hayne** (2010), Hydrated minerals on Europa's surface: An improved look from the Galileo NIMS investigation, *Icarus 209*, 639–650. doi: 10.1016/j.icarus.2010.05.026

2009

30. Barnes, J. W., ..., **P. O. Hayne**, et al. (2009), VIMS Spectral Mapping Observations of Titan during the Cassini Prime Mission, *Planet. and Space Sci., 57*, 1950–1962. doi: 10.1016/j.pss.2009.04.013

2008

31. McCord, T. B., **P. Hayne**, et al. (2008), Titan's surface: Search for spectral diversity and composition using the Cassini VIMS investigation, *Icarus, 194*, 212–242. doi: 10.1016/j.icarus.2007.08.039

Publications: Book Chapters & Reports

1. Aharonson, O., A. Hayes, **P. O. Hayne**, R. Lopes, A. Lucas, J. T. Perron, (2012), Titan's Surface Geology, in: C. G. Mueller-Wodarg, T. Cravens and E. Lellouch (Ed.), *Titan: Surface, Atmosphere and Magnetosphere*, Cambridge University Press, Cambridge, UK.

2. **Hayne, P. O.**, A. P. Ingersoll, D. A. Paige, & 32 co-authors (2014), "New approaches to lunar ice detection and mapping," *Keck Institute for Space Studies Report.* [PDF]

Publications: Commentaries

1. **Hayne, P. O.** (2013), Abandoned frontier, *Nature Geosci., 6(3)*, 155-156. doi: 10.1038/ngeo1753