

Laura Schaefer
CURRICULUM VITAE

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PROFESSIONAL POSITIONS

Assistant Professor Department of Geological Sciences Stanford University	2019 – present
Postdoctoral Research Associate School of Earth and Space Exploration Arizona State University	2016 – 2018
Graduate Student Department of Astronomy Harvard University	2011 – 2016
Research Assistant Department of Earth & Planetary Sciences Washington University, St. Louis	2002 – 2011

EDUCATION

Harvard University, Department of Astronomy Doctorate of Philosophy (PhD) <i>Dissertation:</i> The Atmosphere-Interior Connection: Rocky Planets as Linked Chemical Systems <i>Advisor:</i> Dimitar Sasselov	Oct. 2016
Washington University, Department of Earth & Planetary Sciences Bachelor of Arts (BA)	May 2002

AWARDS & SCHOLARSHIPS

Smith Family Graduate Science and Engineering Fellowship Harvard University	2011 – 2012
Bok Center Certificate of Distinction in Teaching Harvard University	Spring 2013 & Spring 2015
Courtney Werner Memorial Prize (for academic excellence) Washington University	May 2002

REFERREED PUBLICATIONS

26. Wu, J., Desch, S.D., **Schaefer, L.**, Elkins-Tanton, L.T., Pahlevan, K. and Buseck, P.R. (2018) Origin of Earth's Water: chondritic inheritance plus nebular ingassing and storage of hydrogen in the core. *J. Geophys. Res. Planets*, 123, 2691-2712.
25. **Schaefer, L.** & Elkins-Tanton, LT. (2018). Magma oceans as a critical stage in the tectonic development of rocky planets. *Phil. Trans. Roy. Soc. A*, 376: 20180109.
24. Wordsworth, R.D., **Schaefer, L.**, & Fischer, R.A. 2017. Redox evolution via gravitational differentiation on low mass planets: implications for biosignatures, water loss and habitability. *ApJ*, 155, 195.
23. Jacobson, N. S., Kulis, M., Radoman-Shaw, B., Harvey, R., Myers, D. L., **Schaefer, L.**, & Fegley, B. Jr. 2017. Thermodynamic constraints on the lower atmosphere of Venus. *ACS Earth Space Chem.*, 1, 422-430.
22. **Schaefer, L.** & Fegley, B., Jr. (2017) Redox states of initial atmospheres outgassed on rocky planets and planetesimals. *ApJ*, 843, 120.
21. **Schaefer, L.**, Jacobsen, S., Petaev, M., Remo, J., & Sasselov, D. (2017) Metal-silicate partitioning during core formation on rocky super-Earth exoplanets. *ApJ*, 835, 234.
20. **Schaefer, L.** Wordsworth, R. D., Berta-Thompson, Z., & Sasselov, D. (2016) Predictions of the atmospheric composition of GJ 1132 b. *ApJ*, 829, 63.
19. Kite, E., Fegley, B., Jr., **Schaefer, L.** & Gaidos, E. (2016) Atmosphere-interior exchange on hot rocky exoplanets. *ApJ*, 828, 80.
18. Fegley, B., Jr., Jacobson, N. S., Williams, K. B., Plane, J.M.C., **Schaefer, L.**, & Lodders, K. (2016) Solubility of rock in steam atmospheres of planets. *ApJ*, 824, 80.
17. Vanderburg, A. et al. (2015) A disintegrating minor planet transiting a white dwarf. *Nature*, 526, 546–549.
16. **Schaefer, L.** & Sasselov, D. (2015) Persistence of oceans on Earth-like planets. *ApJ*, 801, 40.
15. Lupu, R.E., Zahnle, K., Marley, M. S., **Schaefer, L.** et al. (2014). The atmospheres of Earth-like planets after giant impact events. *ApJ*, 784, 27.
14. **Schaefer, L.**, Lodders, K. & Fegley, B., Jr. (2012) Vaporization of the Earth: Application to Exoplanet Atmospheres. *ApJ*, 755, 41.
13. Miguel, Y., Kaltenegger, L., Fegley, B., & **Schaefer, L.** (2011) Compositions of Hot Super-Earth Atmospheres: Exploring Kepler Candidates. *ApJL*, 742, L19.
12. Léger, A., et al. (2011). The extreme physical properties of the CoRoT-7b super-Earth. *Icarus*, 213, 1-11.
11. **Schaefer, L.** & Fegley, B., Jr. (2011). Atmospheric Chemistry of Venus-like Exoplanets. *ApJ*, 729, 6.
10. **Schaefer, L.** & Fegley, B., Jr. (2010). Chemistry of Atmospheres Formed during Accretion of the Earth and Other Terrestrial Planets. *Icarus*, 208, 438-448.
9. **Schaefer, L.** & Fegley, B., Jr. (2010) Volatile Element Chemistry during Metamorphism of Ordinary Chondritic Material. *Icarus*, 205, 483-496.
8. **Schaefer, L.** & Fegley, B., Jr. (2009). Chemistry of Silicate Atmospheres of Evaporating Super-Earths. *Astrophys. J. Lett.* 703, L113-L117.
7. **Schaefer, L.** & Fegley, B., Jr. (2007) Outgassing of Ordinary Chondritic Material and Some of its Implications for the Chemistry of Asteroids, Planets, and Satellites. *Icarus* 186, 462-483.

6. **Schaefer, L.** & Fegley, B., Jr. (2005) Silicon Tetrafluoride on Io. *Icarus* 179, 252-258.
5. **Schaefer, L.** & Fegley, B., Jr. (2005) Predicted Abundances of Carbon Compounds in Volcanic Gases on Io. *ApJ* 618, 1079-1085.
4. **Schaefer, L.** & Fegley, B., Jr. (2005) Alkali and Halogen Chemistry in Volcanic gases on Io. *Icarus* 173, 454-468.
3. **Schaefer, L.** & Fegley, B., Jr. (2004) Application of an Equilibrium Vaporization Model to the Ablation of Chondritic and Achondritic Meteoroids. *Earth, Moon and Planets* 95, 413-423. doi:10.1007/s11038-005-9030-1.
2. **Schaefer, L.** & Fegley, B., Jr. (2004) Heavy Metal Frost on Venus. *Icarus* 168, 215-219.
1. **Schaefer, L.** & Fegley, B., Jr. (2004) A Thermodynamic Model of High Temperature Lava Vaporization on Io. *Icarus* 169, 216-241.

MISCELLANEOUS PUBLICATIONS

1. Del Genio, A., Brain, D., Noack, L., **Schaefer, L.** (2018). The inner Solar System's habitability through time. In: Planetary Astrobiology, (ed., Meadows, V., Arney, G., des Marias, D., Schmidt, B.), Univ. AZ Press, in review.
2. **Schaefer, L.** (2017) All Steamed Up: Making Martian Clays. *Nature*, 552, 37-38.
3. **Schaefer, L.** & Fegley, B., Jr. (2014) Atmospheric composition of Hadean-early Archean Earth: The importance of CO: Comment. *Geol. Soc. Am. Spec. Papers*, 504, 29-31.
4. Fegley, B., Jr. & **Schaefer, L.** (2012) Chemistry of the Earth's earliest atmosphere. pg. 71 – 90, In: *The Atmosphere – History* (ed., J. Farquhar, D. Canfield, and J. Kasting), Vol 13 *Treatise on Geochemistry*, (eds. H. D. Holland and K. K. Turekian) Elsevier Science, 2nd ed.
5. Zahnle, K., **Schaefer, L.** & Fegley, B., Jr. (2010) Earth's Earliest Atmospheres. in *The Origins of Life* (D Deamer, J. Szostak, eds.) Cold Spring Harbor Perspectives in Biology, 2:a004895.
6. Fegley, B., Jr. & **Schaefer, L.** (2010). Cosmochemistry. In *Principles and Perspectives in Cosmochemistry: Lecture Notes of the Kodai School on 'Synthesis of Elements in Stars' held at Kodaikanal Observatory, India* (eds. A. Goswami, B. E. Reddy) Springer-Verlag, Berlin, pp. 347-378.
7. Fegley, B., Jr. & **Schaefer, L.** (2010). Cosmochemistry of the Biogenic Elements C, H, N, O, and S. In *Astrobiology: Emergence, Search and Detection of Life* (eds. V. A. Basiuk). Am. Sci. Publishers. pg. 23-49.
8. **Schaefer, L.** & Fegley, B., Jr. (2007) Chemistry and Composition of Planetary Atmospheres, pp. 187-207. In *Chemical Evolution Across Space and Time From the Big Bang to Prebiotic Chemistry* (eds. L. Zaikowski and J. M. Friedrich), ACS Symposium Series 981, Oxford Univ. Press.
9. Kargel, J. S., Carlson, R., Davies, A., Fegley, B. Jr., and 20 others (2003) Extreme volcanism on Io : Latest insights at the end of Galileo era. *EOS Trans. AGU* 84, 313, 318.

SEMINARS AND COLLOQUIA

<i>Atmosphere-Mantle feedbacks: importance of mantle oxidation state</i> University of Arizona, Lunar and Planetary Laboratory Colloquium	September 2018
<i>Differentiation Sets the Stage: core formation and mantle redox state</i> Carnegie Institute, Dept. Terrestrial Magnetism Seminar	July 2018
<i>Ghosts of Atmospheres Past: modeling atmosphere formation and evolution on rocky planets</i> University of Central Florida, Physics Colloquium	April 2018
<i>Differentiation Sets the Stage: core formation and mantle redox state</i> Cornell University, Planetary Sciences Seminar	February 2018
<i>Ghosts of Atmospheres Past: modeling atmosphere formation and evolution on rocky planets</i> Cornell University, Astronomy Colloquium	February 2018
<i>Atmosphere-Mantle feedbacks: importance of mantle oxidation state</i> Stanford University – Geology Colloquium	January 2018
<i>Atmosphere-Mantle feedbacks: importance of mantle oxidation state</i> McGill University – Physics Colloquium	January 2018
<i>Feeling Hot, Hot, Hot! Magma Ocean Evolution on Rocky Exoplanets</i> University of Arizona – Origins NExSS Seminar	May 2017
<i>Ghosts of Atmospheres Past: modeling atmosphere formation and evolution on rocky planets</i> University of Boulder, APS Colloquium	February 2017
<i>Coupled Atmosphere-Interior Evolution Models for Rocky (exo)Planets</i> GeoSci Seminar, University of Chicago	April 2016
<i>Finding oceans on Earth-like exoplanets</i> Arizona State University	January 2016
<i>Finding oceans on Earth-like exoplanets</i> Planetary Science Seminar, JPL	April 2015
<i>Formation of the Earth and its Earliest Atmospheres</i> St. Louis Astronomical Society	December 2005

CONFERENCE ABSTRACTS

*contributed talk, **invited talk, †advisee

1. †H. Bercovici, L. T. Elkins-Tanton, **L. Schaefer**. 2019. The effect of bulk composition on the behavior of sulfur during core formation. Lunar & Planetary Science Conference, Houston, TX.
2. S.J. Desch, J.G. O'Rourke, **L. Schaefer**, T.G. Sharp, D.L. Schrader. 2019. Diamonds in ureilites from Mars. Lunar & Planetary Science Conference, Houston, TX.
3. ****L. Schaefer**. 2018. Combined redox evolution of magma oceans due to disproportionation, ferric iron partitioning, and atmospheric oxidation. American Geophysical Union Fall Meeting, Washington, D.C.
4. ****L. Schaefer**. 2018. Atmosphere-mantle volatile exchange throughout planetary evolution. Comparative Climatology of Terrestrial Planets 3. Houston, TX.
5. ****L. Schaefer**. 2018. Secondary atmospheres: composition and evolution during magma ocean phase. Gordon Research Conference: Deep Carbon Science in the Context of Geologic Time. Bryant College, RI.
6. **L. Schaefer**, L.T. Elkins-Tanton, K. Pahlevan. 2018. Ferric iron production in magma oceans and evolution of mantle oxidation state. Differentiation workshop, Pasadena, CA.
7. ***L. Schaefer**, L.T. Elkins-Tanton. 2018. The formation of terrestrial planets. Royal Society workshop: Earth dynamics and the development of plate tectonics. London, England.
8. ****L. Schaefer**. 2018. Redox state of early rocky planet atmospheres and interaction with magma oceans. DTA Symposium VIII: Challenge to Super-Earths and their Atmospheres --- Where do they come from? National Astronomical Observatory of Japan.
9. ****L. Schaefer**. 2018. Effect of water outgassing on magma ocean redox state. Water during Planet Formation and Evolution Workshop. University of Zurich.
10. ***L. Schaefer**, L.T. Elkins-Tanton, K. Pahlevan. 2017. Redox evolution in magma oceans due to ferric/ferrous iron partitioning. American Geophysical Union Fall Meeting, New Orleans, LA.
11. K. Pahlevan, **L. Schaefer**, S.J. Desch, L.T. Elkins-Tanton. 2017. A massive hydrogen-rich Martian greenhouse recorded in D/H. American Geophysical Union Fall Meeting, New Orleans, LA.
12. ***L. Schaefer**, L.T. Elkins-Tanton. 2017. The effects of accretionary impacts on the compositions of rocky planets. Accrete workshop, Nice, Fr.
13. N. S. Jacobson, M. J. Kulis, B. Radoman-Shaw, R. Harvey, D. Myers, **L. Schaefer**, B. Fegley, Jr. 2017. Thermodynamic modeling of the lower Venusian atmosphere. Venus Modeling Workshop, Cleveland, OH.
14. ***L. Schaefer** 2017. Atmospheric loss of rocky elements from M dwarf habitable zone planets. Astrobiology Science Conference, Mesa, AZ.
15. ***L. Schaefer** 2017. Oxygen fugacity evolution of magma oceans on planetesimals and protoplanets. 48th Lunar & Planetary Science Conference, Houston, TX.
16. K. Pahlevan, **L. Schaefer**, L. Elkins-Tanton, S. Desch, S. Karato. 2017. Hydrogen isotopic fractionation in the terrestrial magma ocean. 48th Lunar & Planetary Science Conference, Houston, TX.
17. ***L. Schaefer**, R. Wordsworth, Z. Berta, D. Sasselov 2017. Atmosphere-magma ocean modeling of GJ 1132 b. 229th American Astronomical Society Meeting, Grapevine, TX.

18. E. S. Kite, B. Fegley, Jr., **L. Schaefer**, E. Gaidos 2016. Volcanism on Magma Planets: Extreme Volcanism is Regulated by Planet Mass, Temperature, and Initial Composition. 47th Lunar and Planetary Science Conference, Houston, TX.
19. **L. Schaefer**, D. Sasselov 2015. Atmospheres of partially differentiated super-Earth exoplanets. 47th Division of Planetary Sciences Meeting, National Harbor, MD.
20. ***L. Schaefer**, D. Sasselov. 2015 Persistence of oceans on Earth-like planets. 225th American Astronomical Society Meeting, Seattle, WA.
21. ****L. Schaefer**, B. Fegley, Jr. 2014. Chemical Equilibrium Models of the Redox State of Earth's Earliest Atmosphere. 24th Goldschmidt Conference, Sacramento, CA.
22. Y. Miguel, L. Kaltenegger, B. Fegley, Jr., **L. Schaefer** 2012. Composition of Rocky Hot Super-Earth Atmospheres. EGU Vienna, Austria.
23. B. Fegley, Jr., L. Schaefer, K. Lodders. 2012. Chemistry of the Moon-Forming Impact. 219th American Astronomical Society Meeting, Austin, TX.
24. M. S. Marley, K. Cahoy, B. Fegley, Jr., **L. Schaefer**, K J. Zahnle, K. Lodders, 2011. Thermal Emission Spectra of Post-Giant-Impact Earths. American Geophysical Union Fall Meeting, San Francisco, CA.
25. ****L. Schaefer**, B. Fegley, Jr. K. Lodders. 2011. Atmospheric Formation of Rocky Terrestrial Planets, American Geophysical Union Fall Meeting, San Francisco, CA.
26. ****L. Schaefer**. 2011. Hadean Atmosphere of the Early Earth. Geological Society of America Annual Meeting, Pardee Symposium.
27. ***L. Schaefer**, K. Lodders, B. Fegley, Jr. 2011. Equilibrium Chemistry of the Atmospheres of Scorched Rocky Exoplanets. 217th American Astronomical Society Meeting, Seattle, WA.
28. ***L. Schaefer**, K. Lodders, B. Fegley, Jr. 2010. Equilibrium Chemistry of the Atmospheres of Hot Earth-like Exoplanets, 42nd Division of Planetary Sciences Meeting, Pasadena, CA.
29. **L. Schaefer**, B. Fegley, Jr. 2010. Atmospheric Chemistry of Hot Earth-like Exoplanets. II. Lithophile Elements Na, K, Fe, Si, Mg, Al, Ca and Ti. 73rd Meteoritical Society Meeting, New York, NY.
30. B. Fegley, Jr., **L. Schaefer** 2010. Atmospheric Chemistry of Hot Earth-like Exoplanets. I. The Major Volatile Elements H, C, N, O and S. 73rd Meteoritical Society Meeting, New York, NY.
31. ****L. Schaefer**, B. Fegley, Jr. 2010. Atmospheres of Hot Terrestrial Exoplanets, UCF Winter Workshop: Exoplanets for Planetary Scientists, Orlando, FL.
32. **L. Schaefer**, B. Fegley, Jr. 2009. Fractional Vaporization of Hot Earth-like Exoplanets. 72st Meteoritical Society Meeting, Nancy, France
33. B. Fegley, Jr., **L. Schaefer** 2008. Silicate Atmosphere and Clouds of Hot Earth-like Exoplanets. 72st Meteoritical Society Meeting, Nancy, France.
34. **L. Schaefer**, B. Fegley, Jr. 2008. Chemistry During Accretion of the Earth. II. Rock-forming Elements in the "Steam" Atmosphere. 71st Meteoritical Society Meeting, Matsue, Japan.
35. B. Fegley, Jr., **L. Schaefer** 2008. Chemistry During Accretion of the Earth. I. Volatiles in the "Steam" Atmosphere. 71st Meteoritical Society Meeting, Matsue, Japan.
36. B. Fegley, Jr., **L. Schaefer** 2007. Chemistry of Earth's Putative Steam Atmosphere. American Geophysical Society Meeting Fall Meeting, San Francisco, CA.

37. **L. Schaefer**, B. Fegley, Jr. 2007. Trace Element Chemistry During Metamorphism on Ordinary Chondrite Parent Bodies. 38th Lunar and Planetary Science Conference, Houston, TX.
38. **L. Schaefer**, B. Fegley, Jr. 2006. Thermal Outgassing of Ordinary Chondritic Material - II. Sensitivity Studies. 69th Meteoritical Society Meeting, Zurich, Switzerland.
39. B. Fegley, Jr., **L. Schaefer** 2006. Thermal Outgassing of Ordinary Chondritic Material - I. Nominal Model Results. 69th Meteoritical Society Meeting, Zurich, Switzerland.
40. B. Fegley, Jr., **L. Schaefer** 2005. Spectroscopic Signatures of the Accretion of Earth-like Exoplanets. 37th Division of Planetary Sciences Meeting, Cambridge, UK.
41. **L. Schaefer**, B. Fegley, Jr., 2005. A Reducing Atmosphere From Out-gassing of the Early Earth. 37th Division of Planetary Sciences Meeting, Cambridge, UK.
42. **L. Schaefer**, B. Fegley, Jr. 2004. Chemistry of Carbon Gases in Volcanic Gases on Io. 36th Division of Planetary Sciences Meeting, Louisville, KY.
43. B. Fegley, Jr., **L. Schaefer** 2004. Silicon Tetrafluoride on Io. 36th Division of Planetary Sciences Meeting, Louisville, KY.
44. **L. Schaefer**, B. Fegley, Jr. 2004. Volatile Element Geochemistry in the Lower Atmosphere of Venus. 35th Lunar and Planetary Science Conference, Houston, TX.
45. **L. Schaefer**, B. Fegley, Jr. 2003. Metallic Snow in the Venusian Highlands. 35th Division of Planetary Sciences Meeting, Monterey, CA.
46. B. Fegley, Jr., **L. Schaefer**. 2003. An explanation of the SO₂ profile on Venus from the Vega 1 and 2 UV spectrometers. Division of Planetary Sciences Meeting, Monterey, CA.
47. J. S. Kargel, B. Fegley, Jr., **L. Schaefer**. 2003. Ceramic Volcanism on Refractory Worlds: The Cases of Io and Chondrite CAIs. 34th Lunar and Planetary Science Conference, Houston, TX.
48. **L. Schaefer**, B. Fegley, Jr. 2003. Volcanic Origin of Alkali Halides on Io. 34th Lunar and Planetary Science Conference, Houston, TX.
49. B. Fegley, Jr., **L. Schaefer**, J. S. Kargel. 2003. Vapor Pressure, Vapor Composition and Fractional Vaporization of High Temperature Lavas on Io. 34th, Lunar and Planetary Science Conference, Houston, TX.
50. **L. Schaefer** & B. Fegley, Jr. 2002. Vaporization of high temperature magmas on Io, 34th Division of Planetary Sciences Meeting, Birmingham, AL.

MISSION INVOLVEMENT

Psyche: Mission to a Metal World
Affiliate Team Member

May 2017 – present

PROFESSIONAL MEMBERSHIPS

American Geophysical Union
American Astronomical Society
Division of Planetary Sciences of the AAS

TEACHING EXPERIENCE

Teaching Fellow

Spring 2015

Astronomy 189 – Exoplanet Systems

Harvard University, Professor Dave Charbonneau

Responsibilities: produce homework solutions, grade homework and exams, run homework help sessions involving code debugging, office hours.

Head Teaching Fellow

Spring 2014

Science of the Physical Universe 30 – Life as a Planetary Phenomenon

Harvard University, Professor Dimitar Sasselov

Responsibilities: lead teaching meetings for course staff, order and organize all course materials, write all biweekly homework sets, weekly lab section handouts and exams, lead weekly student section, assist other teaching fellows in their weekly sections, grade homeworks and exams, assign weekly reading assignments, and update course website

Teaching Fellow

Spring 2013

Science of the Physical Universe 30 – Life as a Planetary Phenomenon

Harvard University, Professor Dimitar Sasselov

Responsibilities: teach a weekly student review and laboratory section (15 students), grade homework and exams, hold office hours

STUDENT MENTORING

Kevin Hubbard

January 2017- present

2nd yr graduate student, Arizona State University

Project: Formation of Ni-Cu-PGE ores on Mars through sulfide saturation

SERVICE

Outstanding Student Poster Award Judge American Geophysical Union Fall Meeting	2017
Conant Prize Judge The Conant Prize is awarded to students in General Education STEM courses for innovative projects or essays. Projects are submitted by course instructors for consideration for the prize and ranked by a panel of current or former GenEd teaching fellows.	Spring 2015 Fall 2014 Spring 2014 Fall 2013
Harvard Astronomy Department Peer Mentor	2015 - 2016
AAS Chambliss Judge for undergraduate posters	January 2015
Exoplanet Pizza Lunch Co-organizer, biweekly lunch talk series on exoplanets	2015 - 2016
Planetary Journal Club Co-organizer, biweekly joint Astronomy – Earth & Planetary Sciences journal club	2015 - 2016

REVIEWER

Journals: American Mineralogist, Astrophysical Journal, Astrophysical Journal Letters, Comptes Rendus Geoscience, Earth and Planetary Science Letters, Geophysical Research Letters, Icarus, Nature, Nature Astronomy, Physics of Earth and Planetary Interiors

Funding Agencies: NASA (various programs)

PUBLIC ENGAGEMENT

Carnegie Institute of Science Public Lecture (Panelist) Habitability: What Earth and the inner planets can teach us about the search for life on rocky planets.	December 2018
Dean of Science Public Lecture (Panelist) Reaching Proxima b, our closest exoplanet	December 2016
Science in the News Fall Seminar Earth Formation – the Making of Planet Earth.	October 2013
Science in the News Spring Seminar Sailing the Seas of Alien Worlds: The fate of oceans on rocky planets.	April 2015