



## Laura Schaefer

Assistant Professor of Earth and Planetary Sciences and, by courtesy, of Geophysics

Earth & Planetary Sciences

 Curriculum Vitae available Online

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### Bio

#### BIO

Laura joined the department of Geological Sciences in January 2019 as an Assistant Professor. Laura received her Bachelor's from Washington University in St. Louis in 2002. She remained for several years at Washington University as a research assistant in Earth and Planetary Sciences, where she studied planetary atmospheres and their formation. In 2011, Laura began graduate school at the Harvard-Smithsonian Center for Astrophysics and received her PhD in Astronomy in 2016. Her thesis work focused on volatile cycles on rocky exoplanets, metal-silicate differentiation and atmosphere formation. In fall of 2016, Laura joined the School of Earth and Space Exploration at Arizona State University as a postdoctoral scholar where she worked on projects related to the evolution of mantle oxidation state and magma ocean evolution, as well as volatile cycles on planetesimals as a member of the NASA Psyche team.

#### ACADEMIC APPOINTMENTS

- Assistant Professor, Earth & Planetary Sciences
- Assistant Professor (By courtesy), Geophysics

#### HONORS AND AWARDS

- Gabilan Faculty Fellow, Stanford University (2020-2021)

#### PROFESSIONAL EDUCATION

- PhD, Harvard University , Astronomy & Astrophysics (2016)
- B.A., Washington University in St. Louis , Earth and Planetary Science (2002)

#### LINKS

- Personal Site: <http://web.stanford.edu/~lkschaef/>
- Research Group Site: <https://planets.stanford.edu/>

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### Research & Scholarship

#### CURRENT RESEARCH AND SCHOLARLY INTERESTS

I study atmosphere-interior exchange on rocky planets, both within our Solar System and beyond. I'm interested in the initial outgassed atmospheres of rocky planets and their evolution with time due to external factors and due to interaction with the solid planet. During planet formation, all the materials that make a planet are intimately mixed together, so the physical and chemical processes of accretion and differentiation can have long term effects on the composition of both the atmosphere and the interior. I study these early processes using a combination of magma ocean, atmospheric and internal

structure models. The presence of extant magma oceans on some hot rocky exoplanets provide a window into the early planet differentiation processes of the Solar System.

In the Solar System, I have particular interest in understanding the atmospheric evolution of Venus and Jupiter's moon Io, which both may have experienced significant volatile loss, likely through very different mechanisms. These planets are excellent proxies for the rocky exoplanets that will be observable in the near-term with new telescopes like the James Webb Space Telescope.

I am also interested in understanding the conditions of early atmospheric formation that may help or hinder the origins of life both within the Solar System and on exoplanets. Long-term interactions of atmosphere and interior will also influence the stability of habitable conditions on rocky exoplanets and are therefore vital to understand as astronomical observations of these planets become more feasible.

## Teaching

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### COURSES

#### 2024-25

- Formation and Dynamics of Planets: EPS 119, EPS 219 (Aut)
- Introduction to Planetary Science: EPS 124, ESS 125, GEOPHYS 124 (Spr)

#### 2023-24

- Geochemical Thermodynamics: EPS 164, EPS 264 (Win)
- Planetary Science Reading: EPS 127, EPS 227, GEOPHYS 126, GEOPHYS 226 (Win)

#### 2022-23

- Departmental Seminar in Geological Sciences: GEOLSCI 290 (Aut, Spr)
- Formation and Dynamics of Planets: GEOLSCI 119, GEOLSCI 219, GEOPHYS 109, GEOPHYS 209 (Aut)
- Introduction to Planetary Science: ESS 125, GEOLSCI 124, GEOPHYS 124 (Spr)
- Planetary Science Reading: GEOLSCI 127, GEOLSCI 227, GEOPHYS 126, GEOPHYS 226 (Aut, Win)

#### 2021-22

- Atmospheric Evolution of Rocky Planets: GEOLSCI 125, GEOLSCI 225 (Win)
- Departmental Seminar in Geological Sciences: GEOLSCI 290 (Spr)
- Geochemical Thermodynamics: GEOLSCI 164, GEOLSCI 264 (Aut)
- Planetary Science Reading: GEOLSCI 127, GEOLSCI 227, GEOPHYS 126, GEOPHYS 226 (Aut, Win)

### STANFORD ADVISEES

#### Doctoral Dissertation Reader (AC)

Thom Chaffee

#### Doctoral Dissertation Advisor (AC)

Matthew Reinhold, Andrea Zorzi

#### Doctoral (Program)

Chase Alvarado-Anderson, Matthew Reinhold, Monica Vidaurri, Andrea Zorzi

## Publications

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### PUBLICATIONS

- **Toward a Self-consistent Evaluation of Gas Dwarf Scenarios for Temperate Sub-Neptunes** *ASTROPHYSICAL JOURNAL*  
Rigby, F. E., Pica-Ciamarra, L., Holmberg, M., Madhusudhan, N., Constantinou, S., Schaefer, L., Deng, J., Lee, K. M., Moses, J. I.  
2024; 975 (1)
- **Ferric Iron Evolution During Crystallization of the Earth and Mars** *JOURNAL OF GEOPHYSICAL RESEARCH-PLANETS*  
Schaefer, L., Pahlevan, K., Elkins-Tanton, L. T.  
2024; 129 (9)
- **Outgassing Composition of the Murchison Meteorite: Implications for Volatile Depletion of Planetesimals and Interior-atmosphere Connections for Terrestrial Exoplanets** *PLANETARY SCIENCE JOURNAL*  
Thompson, M. A., Telus, M., Edwards, G., Schaefer, L., Dhaliwal, J., Dreyer, B., Fortney, J. J., Kim, K.  
2023; 4 (10)
- **No thick carbon dioxide atmosphere on the rocky exoplanet TRAPPIST-1 c.** *Nature*  
Zieba, S., Kreidberg, L., Ducrot, E., Gillon, M., Morley, C., Schaefer, L., Tamburo, P., Koll, D. D., Lyu, X., Acuña, L., Agol, E., Iyer, A. R., Hu, et al  
2023
- **A primordial atmospheric origin of hydrospheric deuterium enrichment on Mars** *EARTH AND PLANETARY SCIENCE LETTERS*  
Pahlevan, K., Schaefer, L., Elkins-Tanton, L. T., Desch, S. J., Buseck, P. R.  
2022; 595
- **The effects of bulk composition on planetesimal core sulfur content and size** *ICARUS*  
Bercovici, H. L., Elkins-Tanton, L. T., O'Rourke, J. G., Schaefer, L.  
2022; 380
- **The Air Over There: Exploring Exoplanet Atmospheres** *ELEMENTS*  
Schaefer, L. K., Parmentier, V.  
2021; 17 (4): 257-263
- **Composition of terrestrial exoplanet atmospheres from meteorite outgassing experiments** *NATURE ASTRONOMY*  
Thompson, M. A., Telus, M., Schaefer, L., Fortney, J. J., Joshi, T., Lederman, D.  
2021
- **Water on Hot Rocky Exoplanets** *ASTROPHYSICAL JOURNAL LETTERS*  
Kite, E. S., Schaefer, L.  
2021; 909 (2)
- **Atmosphere Origins for Exoplanet Sub-Neptunes** *ASTROPHYSICAL JOURNAL*  
Kite, E. S., Fegley, B., Schaefer, L., Ford, E. B.  
2020; 891 (2)
- **Observations, Meteorites, and Models: A Preflight Assessment of the Composition and Formation of (16) Psyche** *JOURNAL OF GEOPHYSICAL RESEARCH-PLANETS*  
Elkins-Tanton, L. T., Asphaug, E., Bell, J. F., Bercovici, H., Bills, B., Binzel, R., Bottke, W. F., Dobb, S., Lawrence, D. J., Marchi, S., McCoy, T. J., Oran, R., Park, et al  
2020; 125 (3): e2019JE006296
- **Probing space to understand Earth** *Nature Reviews Earth & Environment*  
Lapôtre, M. G., O'Rourke, J. G., Schaefer, L. K., Siebach, K. L., Spalding, C., Tikoo, S. M., Wordsworth, R. D.  
2020; 1: 170-181
- **The Composition of Rocky Planets** *Planetary Diversity: Rocky planet processes and their observational signatures*  
Unterborn, C., Schaefer, L., Krijt, S.  
IOP Publishing.2020: 5-1 - 5-52
- **Superabundance of Exoplanet Sub-Neptunes Explained by Fugacity Crisis** *ASTROPHYSICAL JOURNAL LETTERS*

- Kite, E. S., Fegley, B., Schaefer, L., Ford, E. B.  
2019; 887 (2)
- **Hydrogen isotopic evidence for early oxidation of silicate Earth** *EARTH AND PLANETARY SCIENCE LETTERS*  
Pahlevan, K., Schaefer, L., Hirschmann, M. M.  
2019; 526
  - **Absence of a thick atmosphere on the terrestrial exoplanet LHS 3844b.** *Nature*  
Kreidberg, L. n., Koll, D. D., Morley, C. n., Hu, R. n., Schaefer, L. n., Deming, D. n., Stevenson, K. B., Dittmann, J. n., Vanderburg, A. n., Berardo, D. n., Guo, X. n., Stassun, K. n., Crossfield, et al  
2019
  - **Magma oceans as a critical stage in the tectonic development of rocky planets** *PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY A-MATHEMATICAL PHYSICAL AND ENGINEERING SCIENCES*  
Schaefer, L., Elkins-Tanton, L. T.  
2018; 376 (2132)
  - **Origin of Earth's Water: Chondritic Inheritance Plus Nebular Ingressing and Storage of Hydrogen in the Core** *JOURNAL OF GEOPHYSICAL RESEARCH-PLANETS*  
Wu, J., Desch, S. J., Schaefer, L., Elkins-Tanton, L. T., Pahlevan, K., Buseck, P. R.  
2018; 123 (10): 2691–2712
  - **Redox Evolution via Gravitational Differentiation on Low-mass Planets: Implications for Abiotic Oxygen, Water Loss, and Habitability** *ASTRONOMICAL JOURNAL*  
Wordsworth, R. D., Schaefer, L. K., Fischer, R. A.  
2018; 155 (5)
  - **PLANETARY SCIENCE A steamy proposal for Martian clays** *NATURE*  
Schaefer, L.  
2017; 552 (7683): 37–38
  - **Thermodynamic Constraints on the Lower Atmosphere of Venus** *ACS EARTH AND SPACE CHEMISTRY*  
Jacobson, N. S., Kulis, M., Radoman-Shaw, B., Harvey, R., Myers, D. L., Schaefer, L., Fegley, B.  
2017; 1 (7): 422–30
  - **Redox States of Initial Atmospheres Outgassed on Rocky Planets and Planetesimals** *ASTROPHYSICAL JOURNAL*  
Schaefer, L., Fegley, B.  
2017; 843 (2)
  - **Metal-silicate Partitioning and Its Role in Core Formation and Composition on Super-Earths** *ASTROPHYSICAL JOURNAL*  
Schaefer, L., Jacobsen, S. B., Remo, J. L., Petaev, M. I., Sasselov, D. D.  
2017; 835 (2)
  - **PREDICTIONS OF THE ATMOSPHERIC COMPOSITION OF GJ 1132b** *ASTROPHYSICAL JOURNAL*  
Schaefer, L., Wordsworth, R. D., Berta-Thompson, Z., Sasselov, D.  
2016; 829 (2)
  - **ATMOSPHERE-INTERIOR EXCHANGE ON HOT, ROCKY EXOPLANETS** *ASTROPHYSICAL JOURNAL*  
Kite, E. S., Fegley, B., Schaefer, L., Gaidos, E.  
2016; 828 (2)
  - **SOLUBILITY OF ROCK IN STEAM ATMOSPHERES OF PLANETS** *ASTROPHYSICAL JOURNAL*  
Fegley, B., Jacobson, N. S., Williams, K. B., Plane, J. C., Schaefer, L., Lodders, K.  
2016; 824 (2)
  - **A disintegrating minor planet transiting a white dwarf** *NATURE*  
Vanderburg, A., Johnson, J., Rappaport, S., Bieryla, A., Irwin, J., Lewis, J., Kipping, D., Brown, W. R., Dufour, P., Ciardi, D. R., Angus, R., Schaefer, L., Latham, et al  
2015; 526 (7574): 546–49
  - **THE PERSISTENCE OF OCEANS ON EARTH-LIKE PLANETS: INSIGHTS FROM THE DEEP-WATER CYCLE** *ASTROPHYSICAL JOURNAL*

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- Schaefer, L., Sasselov, D.  
2015; 801 (1)
- **THE ATMOSPHERES OF EARTHLIKE PLANETS AFTER GIANT IMPACT EVENTS** *ASTROPHYSICAL JOURNAL*  
Lupu, R. E., Zahnle, K., Marley, M. S., Schaefer, L., Fegley, B., Morley, C., Cahoy, K., Freedman, R., Fortney, J. J.  
2014; 784 (1)
  - **Atmospheric composition of Hadean-early Archean Earth: The importance of CO: Comment**  
Schaefer, L., Fegley, B., Shaw, G. H.  
GEOLOGICAL SOC AMER INC.2014: 29–31
  - **VAPORIZATION OF THE EARTH: APPLICATION TO EXOPLANET ATMOSPHERES** *ASTROPHYSICAL JOURNAL*  
Schaefer, L., Lodders, K., Fegley, B.  
2012; 755 (1)
  - **COMPOSITIONS OF HOT SUPER-EARTH ATMOSPHERES: EXPLORING KEPLER CANDIDATES** *ASTROPHYSICAL JOURNAL LETTERS*  
Miguel, Y., Kaltenecker, L., Fegley, B., Schaefer, L.  
2011; 742 (2)
  - **The extreme physical properties of the CoRoT-7b super-Earth** *ICARUS*  
Leger, A., Grasset, O., Fegley, B., Codron, F., Albarede, F., Barge, P., Barnes, R., Cance, P., Carpy, S., Catalano, F., Cavarroc, C., Demangeon, O., Ferraz-Mello, et al  
2011; 213 (1): 1–11
  - **ATMOSPHERIC CHEMISTRY OF VENUS-LIKE EXOPLANETS** *ASTROPHYSICAL JOURNAL*  
Schaefer, L., Fegley, B.  
2011; 729 (1)
  - **Earth's Earliest Atmospheres** *COLD SPRING HARBOR PERSPECTIVES IN BIOLOGY*  
Zahnle, K., Schaefer, L., Fegley, B.  
2010; 2 (10): a004895
  - **Chemistry of atmospheres formed during accretion of the Earth and other terrestrial planets** *ICARUS*  
Schaefer, L., Fegley, B.  
2010; 208 (1): 438–48
  - **Volatile element chemistry during metamorphism of ordinary chondritic material and some of its implications for the composition of asteroids** *ICARUS*  
Schaefer, L., Fegley, B.  
2010; 205 (2): 483–96
  - **Cosmochemistry**  
Fegley, B., Schaefer, L., Goswami, A., Reddy, B. E.  
SPRINGER.2010: 347–77
  - **CHEMISTRY OF SILICATE ATMOSPHERES OF EVAPORATING SUPER-EARTHS** *ASTROPHYSICAL JOURNAL LETTERS*  
Schaefer, L., Fegley, B.  
2009; 703 (2): L113–L117
  - **Chemistry and Composition of Planetary Atmospheres**  
Schaefer, L., Fegley, B., Zaikowski, L., Friedrich, J. M.  
AMER CHEMICAL SOC.2008: 187–207
  - **Outgassing of ordinary chondritic material and some of its implications for the chemistry of asteroids, planets, and satellites** *ICARUS*  
Schaefer, L., Fegley, B.  
2007; 186 (2): 462–83
  - **Application of an equilibrium vaporization model to the ablation of chondritic and achondritic meteoroids**  
Schaefer, L., Fegley, B.  
SPRINGER.2005: 413–23

- **Silicon tetrafluoride on Io** *ICARUS*  
Schaefer, L., Fegley, B.  
2005; 179 (1): 252–58
- **Alkali and halogen chemistry in volcanic gases on Io** *ICARUS*  
Schaefer, L., Fegley, B.  
2005; 173 (2): 454–68
- **Predicted abundances of carbon compounds in volcanic gases on Io** *ASTROPHYSICAL JOURNAL*  
Schaefer, L., Fegley, B.  
2005; 618 (2): 1079–85
- **A thermodynamic model of high temperature lava vaporization on Io** *ICARUS*  
Schaefer, L., Fegley, B.  
2004; 169 (1): 216–41
- **Heavy metal frost on Venus** *ICARUS*  
Schaefer, L., Fegley, B.  
2004; 168 (1): 215–19