

Dr. Shang-Min Tsai

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University of California, Earth and Planetary Sciences

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RESEARCH INTERESTS

Chemistry and dynamics of exoplanet atmospheres | biosignatures and habitability

EMPLOYMENT

11.2022 - present Postdoctoral Scholar, University of California, Riverside

12.2018 - 10.2022 Postdoctoral Researcher (ERC funded), University of Oxford

EDUCATION

10.2014 - 9.2018 Ph.D., Astrophysics, University of Bern

11.2012 - 6.2014 Research Assistant, Academia Sinica Institute of Astronomy and Astrophysics

11.2011 - 10.2012 Military Service in the Air Force (conscription)

9.2008 - 6.2011 M.Sc, Astrophysics, National Taiwan University (NTU)

9.2004 - 6.2008 B.Sc., Physics, National Taiwan University

CODE DEVELOPMENT

Lead developer:

VULCAN: Open-Source, photochemical kinetics model for planetary and exoplanetary atmospheres
(widely used by the community including several JWST Cycle 1 & 2 programs)

<https://github.com/exoclimate/VULCAN>

Mini-Chemical module for GCMs and retrieval frameworks

https://github.com/shami-EEG/mini_chem

Contributor

HELIOS: GPU-accelerated, radiative transfer model
(contributed to the convection and chemistry modules)

https://github.com/shami-EEG/HELIOS_VULCAN

THOR: GPU-accelerated, 3-D general circulation model
(contributed to the radiative-transfer and disequilibrium chemistry modules)

<https://github.com/exoclimate/THOR>

AWARDS

2023 Second place at UCReEarly Career Scientist Symposium Oral presentations

2019 Philosophy and science Faculty Award at University of Bern

2018 Heinrich Greinacher award for the doctoral thesis "Chemical Kinetics on Exoplanet Atmospheres"

2018 SSAA MERAC Funding and Travel Award

PUBLICATION

1st Author:

Tsai S.-M., Lee E.K.H., Powell D., Gao P., Zhang X., Moses J. I. et al. (2023), Photochemically-produced SO₂ in the atmosphere of WASP-39b, *Nature*, 617, 483

Tsai S.-M., Steinrueck M., Parmentier V., Lewis N., Pierrehumbert R. (2023) The climate and compositional variation of the highly eccentric planet HD 80606 b – the rise and fall of carbon monoxide and elemental sulfur, *MNRAS*, 520, 3

Tsai S.-M., Moses J. I., Powell D., Lee E.K.H., Day-night Transport Induced Chemistry And Clouds On WASP-39b I: Gas-phase Composition, submitted to *ApJL*

Tsai S.-M., Mendonça, J.M., Tan X., et al., Global Chemical Transport on Hot Jupiters: Insights from 2D VULCAN photochemical model, submitted to *ApJ*

Tsai S.-M., Lee E.K.H., Pierrehumbert R. (2022) A Mini Chemical Scheme with Net Reactions for 3D GCMs I: Thermochemical Kinetics, *A&A*, 664, A82

Tsai S.-M., Innes H., Lichtenberg T., Malik M., Chubb K., Pierrehumbert R. (2021) Inferring Shallow Surfaces on sub-Neptune Exoplanets with JWST, *ApJL*, 922, L27

Tsai S.-M., Malik M., Kitzmann D., Lyons, James R., Fateev A., Lee E.K.H., Heng K. (2021) A Comparative Study of Atmospheric Chemistry with VULCAN, *ApJ*, 923, 264

Tsai S.-M., Kitzmann D., Lyons J. R., Mendonça, J.M., Grimm S. L., Heng K. (2018) Towards Consistent Modeling of Atmospheric Chemistry and Dynamics in Exoplanets: Validation of Chemical Relaxation Method, *ApJ*, 862, 31

Tsai S.-M., Lyons J. R., Grosheintz L., Rimmer P. B., Kitzmann, D., Heng K. (2017) VULCAN: An Open-Source, Validated Chemical Kinetics Python Code for Exoplanetary Atmospheres, *ApJS*, 228, 20

Tsai S.-M., Dobbs-Dixon, I. & Gu P.-G. (2014) 3D Structures of equatorial waves and the resulting superrotation in the atmosphere of a tidally locked hot Jupiter, *ApJ*, 793, 141

2nd Author:

Lee E.K.H., **Tsai S.-M.**, Hammond M., Tan X. A Mini Chemical Scheme with Net Reactions for 3D GCMs II.: 3D thermochemical modelling of WASP-39b and HD 189733b, *A&A*, A110, 13

Innes H., **Tsai S.-M.**, Pierrehumbert, R. T. (2023) The Runaway Greenhouse Effect on Hycean Worlds, *ApJ*, 953, 168

Hammond M., **Tsai S.-M.**, Pierrehumbert, R. T. (2020) The Equatorial Jet Speed on Tidally Locked Planets. I. Terrestrial Planets, *ApJ*, 901, 78

Heng K., & **Tsai S.-M.** (2016) Analytical Models of Exoplanetary Atmospheres. III. Gaseous C-H-O-N Chemistry with Nine Molecules, *ApJ*, 829, 104

Selected Co-authored:

Bean, J. L., Xue Q., August P., Lunine, J., Zhang, M., Thorngren, D., **Tsai S.-M.** et al (2023) High atmospheric metal enrichment for a Saturn-mass planet, *Nature*, 618, 43

- Lee E.K.H., Tan X., **Tsai S.-M.** (2023) Dynamically coupled kinetic chemistry in brown dwarf atmospheres I. Performing global scale kinetic modelling, *MNRAS*, 523, 3
- Lee E.K.H., Prinoth B., Kitzmann D., **Tsai S.-M.**, Hoeijmakers J., Borsato N., Heng K. (2022) The Mantis Network II: examining the 3D high-resolution observable properties of the UHJs WASP-121b and WASP-189b through GCM modelling, *MNRAS*, 517, 1
- The JWST Transiting Exoplanet Community Early Release Science Team; Ahrer E.-M., Alderson L., Batalha N. M., et. al. (2022) Identification of carbon dioxide in an exoplanet atmosphere, *Nature*, 614, 649
- Lee E.K.H., Parmentier V., Hammond M., Grimm S.L., Kitzmann D., Tan X., **Tsai S.-M.**, Pierrehumbert R. (2021) Simulating gas giant exoplanet atmospheres with EXO-FMS: comparing semigrey, picket fence, and correlated-k radiative-transfer schemes, *MNRAS*, 506, 2
- Mills F. P., Moses J. I., Gao P., **Tsai S.-M.** (2021) The Diversity of Planetary Atmospheric Chemistry, *Space Sci Rev* 217, 43
- Baxter C., Desert J.-M., **Tsai S.-M.**, Todorov, K. O., Bean, J.L., Deming D., Parmentier V., Fortney, J. J., Line, M., Thorngren D., Pierrehumbert R. T., Burrows A., Showman A. P. (2021) Evidence for disequilibrium chemistry from vertical mixing in hot Jupiter atmospheres. A comprehensive survey of transiting close-in gas giant exoplanets with warm-Spitzer/IRAC, *A&A*, 648, A127
- Louca A., Miguel Y., **Tsai S.-M.**, Froning C. S., Loyd R.O.P., France K., The impact of time-dependent stellar activity on exoplanet atmospheres, accepted for publication in *MNRAS*
- Dash S., Majumdar L., Willacy K., **Tsai S.-M.**, Turner N., Rimmer P. et al., Linking atmospheric chemistry of the hot Jupiter HD 209458b to its formation location through spectroscopy, *ApJ*, 932, 20
- Lichtenberg, T., Bower, D. J., Hammond, M., Boukrouche, R., Sanan, P., **Tsai S.-M.**, Pierrehumbert, R. T. (2021) Vertically resolved magma ocean-protatmosphere evolution with varying primary absorbers, *JGR*, 126, 2
- Arcangeli, J. ; Desert, J. -M. ; Parmentier, V. ; Tsai, S. -M. ; Stevenson, K. B. (2021) A new approach to spectroscopic phase curves. The emission spectrum of WASP-12b observed in quadrature with HST/WFC3, *A&A*, 646, A94
- Lee, E. K. H., Casewell S. L., Chubb, K. L., Hammond, M., Tan, X., Tsai, **Tsai S.-M.**, Pierrehumbert, R. T. (2020) Simplified 3D GCM modelling of the irradiated brown dwarf WD 0137-349B, *MNRAS*, 496, 4
- Drummond B., Hebrard E., Mayne N. J., Venot O., Ridgway R. J., Changeat Q., **Tsai S.-M.**, Manners, J., Tremblin, P., Abraham, N. L., Sing, D., Kohary, K. (2020) Implications of three-dimensional chemical transport in hot Jupiter atmospheres: results from a consistently coupled chemistry-radiation-hydrodynamics model, *A&A*, 636, A68
- Deitrick R., Mendonça J. M., Schroffenegger U., Grimm S. L., **Tsai S.-M.**, Heng K. (2020) THOR 2.0: Major Improvements to the Open-Source General Circulation Model, *ApJS*, 248, 30
- Malik, M., Kitzmann, D., Mendonça, J.M., Grimm L. S., Marleau, G.-D., Linder E., **Tsai S.-M.**, Heng K. (2019) Self-luminous and irradiated exoplanetary atmospheres explored with HELIOS, *AJ*, 157
- Mendonça, J.M., **Tsai S.-M.**, Malik M., Grimm L. S., Heng K. (2018) Three-Dimensional Circulation Driving Chemical Disequilibrium in WASP-43b, *ApJ*, 869, 107
- Kitzmann, D., Heng, K., Rimmer, P. B., Hoeijmakers H. J., **Tsai S.-M.**, Malik M., Lendl M., Deitrick R. & Demory B.-D. (2018) The Peculiar Atmospheric Chemistry of KELT-9b, *ApJ*, 863, 183
- Oreshenko M., Lavie B., Grimm L. S., **Tsai S.-M.**, Malik M., Demory B.-D., Mordasini C., Alibert Y., Benz W., Trotta R., & Heng K. (2017) Retrieval Analysis of the Emission Spectrum of WASP-12b: Sensitivity of Outcomes to Prior Assumptions and Implications for Formation History, *ApJL*, 847, L3
- Malik, M., Grosheintz, L., Mendonça, J.M., Grimm S. L., Lavie B., Kitzmann D., **Tsai S.-M.**, Burrows A., Kreidberg L., Bedell M., Bean J. L., Stevenson K. B., Heng K. (2017) HELIOS: An Open-source, GPU-accelerated Radiative Transfer Code For Self-consistent Exoplanetary Atmospheres, *AJ*, 153, 56
- Heng, K., Lyons, J.R., & **Tsai S.-M.** (2016) Atmospheric Chemistry for Astrophysicists: A Self-consistent Formalism and Analytical Solutions for Arbitrary C/O, *ApJ*, 816, 96

PROJECTS

- PI** in International Space Science Institute (ISSI) International Team (2023) : *3-D Chemical Kinetics Model Benchmark for Hot Jupiter Atmospheres*
- co-I** in JWST 3171: *Red Dwarfs and the Seven Giants: First Insights into the Atmospheres of Giant Exoplanets around M-dwarf Stars* (PI: Dr. Shubham Kanodia)
- co-I** in JWST 4082: *Putting it all Together: Dynamics and Chemistry Probed Through Transmission Spectroscopy of a Cloud-Free Exoplanet* (PI: Michael Radica)
- co-I** in JWST DDT 2784: *MIRI LRS follow up on SO₂ detection in WASP-39b* (PI: Dr. Diana Powell, Dr. Elspeth Lee)
- Foreign collaborator**¹ NASA Habitable Worlds proposal 22-HW22.2-0031: *How To Identify Exoplanet Surfaces Using Atmospheric Trace Species in Super-Earth Atmospheres* (PI: Prof. Xinting Yu)
- co-I** in JWST GO 2784: *Unveiling the Nature of the Impossible Planets* (PI: Dr. Peter Gao)
- co-PI** in ISSI International Team (2018) (PI: Dr. Benjamin Drummond) : *An intercomparison of 1D chemical kinetics codes for exoplanet atmospheres*
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PRESENTATIONS

- Invited Talks

Planetary Science Lunch Seminar: *The atmosphere of gas giants near and far*, 29 March 2023, Caltech, US

ESP (Exoclines Simulation Platform) Summer School, Guarda Val, Switzerland – 12-14 June 2019

Astrophysics seminar at University of Exeter, 14 March 2019

- Selected Contributed Talks

Revealing Atmospheric Chemistry of Exoplanets with JWST, Exeter, UK, 27 June 2023

Direct Evidence of Photochemistry in an Exoplanet Atmosphere, AAS 241 meeting, Seattle, US, 9 Jan 2023

The evolution and stability of CO₂-CH₄-H₂O atmospheres, Rocky Worlds II, Oxford, UK, 4-8 July 2022

Compositional Variations of the Highly Eccentric Planet HD 80606b, Europlanet Science Congress, online, 13 – 24 September 2021

Toward 3D photochemical modelling of exoplanet atmospheres, Exoplanets II, Cambridge, UK – 5 June 2018

TEACHING/SUPERVISING/PUBLIC OUTREACH

Co-supervising Ziyu Huang (2022 – Present) University of Southern California

Co-supervising Amy Louca (2020 – 2021) Leiden University

– Louca, Miguel, Tsai, et al. (2023), *The impact of time-dependent stellar activity on exoplanet atmospheres*, MNRAS, 521, 3

Co-supervising Thomas Drant (2021) IPSL, University of Paris Saclay, France

Supervising Ailsa Campbell (summer student, 2022) University of Oxford

Tutor MPhys C5 Physics of Atmospheres and Oceans Spring 2019

– *teaching problem sets*

¹not affiliated with a US institute at the time of application

Astrobitess Author

2017 – 2018

Teaching Assistant University of Bern Fall 2017

Fluid Dynamics by Kevin Heng

- *devising and delivering teaching sessions on problem sets*

COMMUNITY SERVICE

Referee for AAS, MNRAS, A&A etc. journals

Non-panelist reviewer for NASAXRP23 proposals

Distributed Peer Review for ESO Period 113