

# Harsha Suresh Bhat

Chargé de Recherche de Classe Normale, CNRS

École Normale Supérieure, Paris

Laboratoire de Géologie, 24 Rue Lhomond, 75005, Paris, France

## ► PERSONAL INFORMATION

Email: [harsha.bhat@ens.fr](mailto:harsha.bhat@ens.fr) Nationality: Indian Website: <https://harshasbhat.github.io>

## ► EDUCATION

École Normale Supérieure, France	H. D. R. <sup>†</sup>	Supershear Earthquakes	2021/01
Harvard University, USA	Ph. D.*	Mechanical Sciences	2007/06
Harvard University, USA	M. S.	Engineering Sciences	2002/06
NITK, India	B. E.	Civil Engineering	2001/06

<sup>†</sup> Habilitation à Diriger des Recherches \* Supervised by Prof. J. R. Rice & Dr. R. Dmowska

## ► CURRENT POSITION

École Normale Supérieure, France	2016/05 ► Present	CNRS Research Scientist
California Institute of Technology, USA	2018/12 ► Present	Visiting Professor in Aeronautics

## ► PAST POSITIONS

Institut de Physique du Globe de Paris, France	2012/01 ► 2016/05	CNRS Research Scientist
University of Southern California, USA	2010/03 ► 2011/12	Asst. Professor (Research)
University of Southern California, USA	2007/11 ► 2010/03	Post Doctoral Fellow
California Institute of Technology, USA	2007/11 ► 2010/03	Visitor in Aeronautics
Harvard University, USA	2007/05 ► 2007/10	Post Doctoral Fellow
Harvard University, USA	2001/11 ► 2007/05	Grad. Research Associate

## ► FUNDING & GRANTS<sup>†</sup>

- 2021-2025 ► 2M€ ERC Consolidator Grant, PERSISMO (Grant No. 865411)
- 2018-2018 ► 25k€ ENS Actions Incitatives
- 2017-2017 ► 6k€ TelluS INSU - action ALEAS

## ► HONORS AND AWARDS

- 2018 CNRS Award for Doctoral Supervision and Research
- 2018 Grand Prix Michel Gouilloud Schlumberger, French Academy of Sciences
- 2006 Harvard University Certificate of Distinction in Teaching
- 2004 Harvard University Certificate of Distinction in Teaching
- 2003 Harvard University Certificate of Distinction in Teaching

## ► TEACHING ACTIVITIES†

- |  |   |
|--|---|
| 1) Mécanique des Milieux Continus              | 8) Complex and Fourier Analysis                 |
| 2) Active Faults : Geometry                    | 9) Computational Solid and Structural Mechanics |
| 3) Seismic Ruptures and Scaling Laws           | 10) Solid Mechanics                             |
| 4) Introduction to Rock Physics                | 11) Introduction to the Mechanics of Solids     |
| 5) Mathematical Methods in the Sciences        | 12) Mechanics of Fracture                       |
| 6) Environmental Risks and Disasters           | 13) Advanced Geomechanics                       |
| 7) Ordinary and Partial Differential Equations | 14) Mécanique de la Fracturation                |

† Classes taught with various colleagues at Harvard, Caltech, IPGP and ENS

## ► ORGANISATION OF SCIENTIFIC MEETINGS

- June 2019: Coupled Processes In Fracture Propagation In Geo-Materials: From Hydraulic Fractures To Earthquakes: CISM Advanced School, Udine, Italy
- April 2015: Seismological Society of America, Multiscale Modeling and Characterization of Fragmentation and Damage Patterns in Fault Zones
- December 2014: American Geophysical Union, Fault Zone Properties And Processes During Dynamic Ruptures

## ► INSTITUTIONAL RESPONSIBILITIES

- 2018 Onwards: Team Leader of Faults & Earthquakes Group, ENS (11 Researchers, 8 postdocs and 8 PhD students)
- 2018-2019: Co-organizer of the Internal Seminar, ENS

## ► LANGUAGES

English – Native | French – Conversant | Hindi – Fluent | Kannada – Native

## ► REVIEWING ACTIVITIES

American Geophysical Union   Seismological Society of America   International Journal of Fracture  
Geological Society of America   Science   Nature   Journal of the Mechanics and Physics of Solids  
European Journal of Mechanics - A/Solids   Earth and Planetary Science Letters   Geophysical Research Letters  
Journal of Structural Geology   Proceedings of the National Academies of Science, USA  
Geology   Geophysical Journal International   Journal of Applied Mechanics   National Science Foundation  
European Research Council   Nature Communications   Nature Geoscience  
Science Advances

## ► STUDENTS & POSTDOCS

### Undergraduate Students : 6 weeks long research internship

- **Phillipe Danre (2017)** Étude de l'impact des marées sur le glissement sismique et asismique des failles actives (Co-advised with Dr. R. Jolivet, ENS)
- **Hugo Lestrelin (2019)** Theoretical investigation of radiation from a size distribution of fractures (Co-advised with Dr. L. Bruhat, ENS)
- **Roxane Ferry (2019)** Understanding the relationship between Slow Slip accélération observed in natural and synthetic GPS (Co-advised with Dr. J. Jara, ENS)

### Masters Students : 4-6 month long research internship

- **Sonia Fliss (2003)** Fault branching and rupture directivity (Co-advised with Prof. J. R. Rice & Dr. R. Dmowska, Harvard)
- **Marion Olives (2004)** Finite fault branches and rupture dynamics: Is it time to look more carefully at fault maps? (Co-advised with Prof. J. R. Rice & Dr. R. Dmowska, Harvard)
- **Aurelie Baudet (2004)** Finite element modeling of laboratory experiments on impact and shear rupture of pre-faulted specimens (Co-advised with Prof. J. R. Rice & Dr. E. L. Templeton, Harvard)
- **Lucile Bruhat (2012)** Near-field radiation from stopping ruptures (Co-advised with Prof. J.-P. Vilotte, IPGP)
- **Thibaut Perol (2013)** Micromechanics Based Permeability Evolution In Brittle Materials At High Strain Rates
- **Kurama Okubo (2014)** The effect of waste water injection on earthquake nucleation in damaged fault zones
- **Victor Barolle (2015)** Metastable phase transformation in the mantle: Evolution of a spinel inclusion into olivine
- **Eleni Kolokytha (2015)** Understanding the role of temperature evolution in the frictional behavior of fault zone and its effect on the seismic cycle (Co-advised with Dr. M. Y. Thomas)
- **Luc Illien (2018)** Multiseismic phase characterization in laboratory rock deformation experiments, a Numerical and Experimental study (Co-advised with Dr. N. Brantut)
- **Nicolas Mercury (2018)** Modélisation physique de réseaux complexes de failles afin de déterminer l'origine de la loi de Gutenberg-Richter (Co-advised with Dr. J-A Olive)
- **Phillipe Danre (2019)** Nonlinear dynamics of faults subjected to periodic loads (Co-advised with Dr. R. Jolivet, ENS)
- **Jinhui Cheng (2020)** Analyze modes of slip and related synthetic GPS based on quasi-dynamic earthquake cycle modelling in complex fault networks
- **Roxane Ferry (2021)** Unraveling the mechanisms of earthquakes in 'quiet' regions (Co-advised with Prof. E. Calais and Prof. M. Ghill)

### PhD students : Co-supervised

- **Michael Mello (2012)** Identifying the unique ground motion signatures of supershear earthquakes: Theory and experiments, *Caltech*, Main Advisor : Prof. A. J. Rosakis  
Currently Teaching Professor at Caltech
- **Jonathan Mihaly (2013)** Investigation of hypervelocity impact phenomena using real-time concurrent diagnostics, *Caltech*, Main Advisor : Prof. A. J. Rosakis  
Currently at JPL
- **François X. Passelègue (2014)** Étude Expérimentale de la Rupture Sismique, *École Normale Supérieure de Paris*, Main Advisors : Prof. R. Madariaga & Dr. A. Schubnel  
Currently Ambizione Energy fellow at EPFL
- **Vahe Gabuchian (2015)** Experimental investigation of thrust fault rupture mechanics, *Caltech*, Main Advisor : Prof. A. J. Rosakis  
Currently Research Scientist at Caltech
- **Marshall Alan Rogers-Martinez (2019)** Source mechanics of near-field s-wave generation from explosive sources, *Univ. South. Calif.*, Main Advisor : Prof. C. G. Sammis

Currently Engineer at Joby Aviation

- **Samson Marty (2020)** High frequency radiation and foreshocks during laboratory earthquakes, *École Normale Supérieure de Paris*, Main Advisor : Dr. A. Schubnel  
Currently Post Doctoral Fellow at Penn. State
- **Joseph Michael Flores Cuba (2020–)** Main Advisors : Dr. M. Y. Thomas & Prof. L. Jolivet

### PhD students : Main Supervisor

- **Pierre Romanet (2017)** Fast algorithms to model quasi-dynamic earthquake cycles in complex fault networks, *Institut de Physique du Globe de Paris* Co-Advisor : Prof. R. Madariaga  
Currently Post Doctoral Fellow at Univ. Tokyo
- **Kurama Okubo (2018)** Earthquakes in fault networks and dynamic off-fault fracture networks developed during earthquakes, *Institut de Physique du Globe de Paris* Co-Advisor : Dr. Y. Klinger  
Currently Research Scientist at NIED, Japan
- **Claudia Hulbert (2018–)** Machine learning techniques for event identification and simulation of earthquake cycles, Co-Advisors : Dr. R. Jolivet & Dr. A. Schubnel
- **Jinhui Cheng (2021–)** ERC PERSISMO

### Post Doctoral Associates

- **Marion Y. Thomas (2014-2016)** Dynamic damage and earthquake ruptures, Co-Advisor : Dr. Y. Klinger  
– (2018) Earthquake cycles accounting for off-fault damage, Prestige Marie-Curie Fellow  
Currently CNRS Research Scientist at Sorbonne Université
- **Lisa Gordeliy (2019)** Hydraulic Fracturing Co-Advisor : Prof. B. Lecampion  
Currently Post Doctoral fellow at Ecole Polytechnique
- **Lucile Bruhat (2018–2019)** Dynamics of subduction zone earthquakes, Prestige Marie-Curie Fellow  
– (2020–) Dynamics of subduction zone earthquakes and Tsunamigenesis, LRC Yves Rocard Prestige Fellow
- **Michelle Almakari (2021–)** ERC PERSISMO
- **Carlos Villafuerte (2021–)** ERC PERSISMO

### ► BOOKS

Thomas, M. Y., T. M. Mitchell, and H. S. Bhat, eds. (2017b). "Fault Zone Dynamic Processes : Evolution of Fault Properties During Seismic Rupture, *Geophysical Monograph 227*". American Geophysical Union (AGU). doi: 10.1002/9781119156895.

Bizzarri, A. and H. S. Bhat, eds. (2012). "The mechanics of faulting: From laboratory to earthquakes". Research Signpost.

### ► MANUSCRIPTS

Publications in peer reviewed international journals including Nature, Nature Communications and Science; edited volumes, theses and book chapters . h-index of 22 with an average of 149 citations per year since 2012.

Google Scholar ID: ZHskR34AAAAJ ORCID: 0000-0003-0361-1854

- Thomas, M. Y. and H. S. Bhat (2021). "Combined effects of fault roughness and off-fault damage on earthquake dynamics". *in prep.*
- Romanet, P., H. S. Bhat, S. Chaillat, and R. Madariaga (2021). "Fast algorithms to model quasi-dynamic earthquake cycles in complex fault networks". *to be subm. J. Geophys. Res.*
- Marty, S., H. S. Bhat, J. Aubry, E. Fukuyama, R. Madariaga, and A. Schubnel (2021). "Dominantly Aseismic Nucleation of Laboratory Earthquakes: A Quantitative Investigation". *to be subm. J. Geophys. Res.*
- Jara, J., L. Bruhat, S. Antoine, K. Okubo, M. Y. Thomas, Y. Klinger, R. Jolivet, and H. S. Bhat (2021). "Signature of supershear transition seen in damage and aftershock pattern". *to be submitted.*
- Amlani, F., H. S. Bhat, W. J. F. Simons, A. Schubnel, C. Vigny, A. J. Rosakis, J. Efendi, A. Elbanna, and H. Z. Abidin (2021). "Supershear shock front contributions to the tsunami from the 2018  $M_w$  7.5 Palu earthquake". *subm. Nat. Geosci.*
- Elbanna, A., M. Abdelmeguid, X. Ma, F. Amlani, H. S. Bhat, C. Synolakis, and A. J. Rosakis (2021). "Anatomy of Strike Slip Fault Tsunami-genesis". *Proc. Natl. Acad. Sci. USA*. DOI: <https://doi.org/10.31223/X57G72>.
- Bhat, H. S. (2021). "Supershear Earthquakes". PhD thesis. Habilitation à Diriger des Recherches, Ecole Normale Supérieure.
- Thomas, M. Y. and H. S. Bhat (2020). "Loi de friction et modélisation numérique du cycle sismique". in *Le Cycle Sismique*. Ed. by F. Rolandone. ISTE Editions.
- Jeandet-Ribes, L., N. Cubas, H. S. Bhat, and P. Steer (2020). "Response of a single fault to transient normal stress change, and implications of large erosional events on the seismic cycle". *Geophys. Res. Lett.* 47.e2020GL087631. DOI: 10.1029/2020GL087631.
- Jolivet, R., M. Simons, Z. Duputel, J.-A. Olive, H. S. Bhat, and Q. Bletery (2020). "Interseismic Loading of Subduction Megathrust Drives Long-Term Uplift in Northern Chile". *Geophys. Res. Lett.* 47.8, e2019GL085377. DOI: 10.1029/2019GL085377.
- Okubo, K., E. Rougier, Z. Lei, and H. S. Bhat (2020). "Modeling earthquakes with off-fault damage using the combined finite discrete element method". *J. Comp. Part. Mech.* DOI: 10.1007/s40571-020-00335-4.
- Okubo, K., H. S. Bhat, E. Rougier, S. Marty, A. Schubnel, Z. Lei, E. E. Knight, and Y. Klinger (2019). "Dynamics, radiation and overall energy budget of earthquake rupture with coseismic off-fault damage". *J. Geophys. Res.* 124. DOI: 10.1029/2019JB017304.
- Marty, S., F. X. Passelègue, J. Aubry, A. Schubnel, H. S. Bhat, and R. Madariaga (2019). "Origin of high-frequency radiation during laboratory earthquakes". *Geophys. Res. Lett.* 46. DOI: 10.1029/2018GL080519.
- Aubry, J., F. X. Passelègue, D. Deldicque, F. Girault, S. Marty, A. Lahfid, H. S. Bhat, J. Escartin, and A. Schubnel (2018). "Frictional heating processes and energy budget during laboratory earthquakes". *Geophys. Res. Lett.* 45. DOI: 10.1029/2018GL079263.
- Klinger, Y. et al. (2018). "Earthquake damage patterns resolve complex rupture processes". *Geophys. Res. Lett.* DOI: 10.1029/2018GL078842.
- Cruz-Atienza, V. M., C. D. Villafuerte, and H. S. Bhat (2018). "Rapid tremor migration and pore-pressure waves in subduction zones". *Nat. Commun.* 9.1, p. 2900. DOI: 10.1038/s41467-018-05150-3.
- Thomas, M. Y. and H. S. Bhat (2018). "Dynamic evolution of off-fault medium during an earthquake: a micromechanics based model". *Geophys. J. Int.* 214.2, pp. 1267–1280. DOI: 10.1093/gji/ggy129.
- Romanet, P., H. S. Bhat, R. Jolivet, and R. Madariaga (2018). "Fast and slow earthquakes emerge due to fault geometrical complexity". *Geophys. Res. Lett.* DOI: 10.1029/2018GL077579.
- Gabuchian, V., A. J. Rosakis, H. S. Bhat, R. Madariaga, and H. Kanamori (2017). "Experimental evidence that thrust earthquake ruptures might open open faults". *Nature* 545.336–339. DOI: 10.1038/nature22045.

- Thomas, M. Y., H. S. Bhat, and Y. Klinger (2017a). "Effect of Brittle off-fault Damage on Earthquake Rupture Dynamics". in *Fault Zone Dynamic Processes : Evolution of Fault Properties During Seismic Rupture, Geophysical Monograph 227*. Ed. by M. Y. Thomas, H. S. Bhat, and T. M. Mitchell. American Geophysical Union (AGU), pp. 255–280. doi: 10.1002/9781119156895.ch14.
- Passelègue, F. X., S. Latour, A. Schubnel, S. Nielsen, H. S. Bhat, and R. Madariaga (2017). "Precursory Processes during Laboratory Earthquakes". in *Fault Zone Dynamic Processes : Evolution of Fault Properties During Seismic Rupture, Geophysical Monograph 227*. Ed. by M. Y. Thomas, H. S. Bhat, and T. M. Mitchell. American Geophysical Union (AGU). Chap. 12, pp. 229–242. doi: 10.1002/9781119156895.ch12.
- Perol, T. and H. S. Bhat (2016). "Micromechanics based permeability evolution in brittle materials at high strain rates". *Pure Appl. Geophys.* Pp. 1–12. doi: 10.1007/s00024-016-1354-4.
- Passelègue, F. X., A. Schubnel, S. Nielsen, H. S. Bhat, D. Deldicque, and R. Madariaga (2016). "Dynamic rupture processes inferred from laboratory microearthquakes". *J. Geophys. Res.* 121. doi: 10.1002/2015JB012694.
- Mello, M., H. S. Bhat, and A. J. Rosakis (2016). "Spatiotemporal properties of sub-Rayleigh and supershear rupture velocity fields : Theory and Experiments". *J. Mech. Phys. Solids* 93, pp. 153–181. doi: 10.1016/j.jmps.2016.02.031.
- Vallage, A, Y Klinger, R Grandin, H. S. Bhat, and M Pierrot-Deseilligny (2015). "Inelastic surface deformation during the 2013 Mw 7.7 Balochistan, Pakistan, earthquake". *Geology* 43.12, pp. 1079–1082. doi: 10.1130/G37290.1.
- Frank, W. B., N. M. Shapiro, A. L. Husker, V Kostoglodov, H. S. Bhat, and M Campillo (2015). "Along-fault pore-pressure evolution during a slow-slip event in Guerrero, Mexico". *Earth Planet. Sc. Lett.* 413, pp. 135–143. doi: 10.1016/j.epsl.2014.12.051.
- Siriki, H., H. S. Bhat, X. Lu, and S. Krishnan (2015). "A Laboratory Earthquake-Based Stochastic Seismic Source Generation Algorithm for Strike-Slip Faults". *Bull. Seism. Soc. Am.* 105.4, pp. 2250–2273. doi: 10.1785/0120140110.
- Mello, M., H. S. Bhat, A. J. Rosakis, and H. Kanamori (2014). "Reproducing The Supershear Portion Of The 2002 Denali Earthquake Rupture In Laboratory". *Earth Planet. Sc. Lett.* 387, pp. 89–96. doi: 10.1016/j.epsl.2013.11.030.
- Passelègue, F. X., A. Schubnel, S. Nielsen, H. S. Bhat, and R. Madariaga (2013). "From Sub-Rayleigh to Supershear Ruptures During Stick-Slip Experiments on Crustal Rocks". *Science* 340.6137, pp. 1208–1211. doi: 10.1126/science.1235637.
- Bhat, H. S., A. J. Rosakis, and C. G. Sammis (2012). "A Micromechanics Based Constitutive Model For Brittle Failure at High Strain Rates". *J. Appl. Mech.* 79.3. doi: 10.1115/1.4005897.
- Bhat, H. S., C. G. Sammis, and A. J. Rosakis (2011). "The Micromechanics of Westerley Granite at Large Compressive Loads". *Pure Appl. Geophys.* 168.12, pp. 1–18. doi: 10.1007/s00024-011-0271-9.
- Bhat, H. S., R. L. Biegel, A. J. Rosakis, and C. G. Sammis (2010). "The Effect of Asymmetric Damage on Dynamic Shear Rupture Propagation II: With Mismatch in Bulk Elasticity". *Tectonophysics* 493.3, pp. 263–271. doi: 10.1016/j.tecto.2010.03.016.
- Biegel, R. L., H. S. Bhat, C. G. Sammis, and A. J. Rosakis (2010). "The Effect of Asymmetric Damage on Dynamic Shear Rupture Propagation I: No Mismatch in Bulk Elasticity". *Tectonophysics* 493.3, pp. 254–262. doi: 10.1016/j.tecto.2010.03.020.
- Mello, M., H. S. Bhat, A. J. Rosakis, and H. Kanamori (2010). "Identifying the unique ground motion signatures of supershear earthquakes: Theory and experiments". *Tectonophysics* 493, pp. 297–326. doi: 10.1016/j.tecto.2010.07.003.
- Templeton, E. L., H. S. Bhat, R. Dmowska, and J. R. Rice (2010). "Dynamic rupture through a branched fault configuration at Yucca Mountain and resulting ground motions". *Bull. Seism. Soc. Am.* 100.4, pp. 1485–1497. doi: 10.1785/012009012110.1785/0120090121.



- Harris, R. A. et al. (2009). "The SCEC/USGS dynamic earthquake rupture code verification exercise". *Seismol. Res. Lett.* 80.1. DOI: 10.1785/gssr1.80.1.119.
- Sammis, C. G., A. J. Rosakis, and H. S. Bhat (2009). "Effects of Off-fault Damage on Earthquake Rupture Propagation: Experimental Studies". *Pure Appl. Geophys.* 166. DOI: 10.1007/s00024-009-0512-3.
- Templeton, E. L., A. Baudet, H. S. Bhat, R. Dmowska, J. R. Rice, A. J. Rosakis, and C. E. Rousseau (2009). "Finite Element Simulations of Dynamic Shear Rupture Experiments and Dynamic Path Selection Along Kinked and Branched Faults". *J. Geophys. Res.* B08304. DOI: 10.1029/2008JB006174.
- Dunham, E. M. and H. S. Bhat (2008). "Attenuation of radiated ground motion and stresses from three-dimensional supershear ruptures". *J. Geophys. Res.* 113.B08319. DOI: 10.1029/2007JB005182.
- Bhat, H. S., R. Dmowska, G. C. P. King, Y. Klinger, and J. R. Rice (2007a). "Off-fault damage patterns due to supershear ruptures with application to the 2001  $M_w$  8.1 Kokoxili (Kunlun) Tibet earthquake". *J. Geophys. Res.* B06301. DOI: 10.1029/2006JB004425.
- Bhat, H. S., M. Olives, R. Dmowska, and J. R. Rice (2007b). "Role of fault branches in earthquake rupture dynamics". *J. Geophys. Res.* B11309. DOI: 10.1029/2007JB005027.
- Bhat, H. S. (2007). "Role of Geometric Complexities and Off-Fault Damage in Dynamic Rupture Propagation". PhD thesis. Harvard University.
- Fliss, S., H. S. Bhat, R. Dmowska, and J. R. Rice (2005). "Fault branching and rupture directivity". *J. Geophys. Res.* B06312. DOI: 10.1029/2004JB003368.
- Bhat, H. S., R. Dmowska, J. R. Rice, and N. Kame (2004). "Dynamic slip transfer from the Denali to Totschunda faults, Alaska: Testing theory for fault branching". *Bull. Seism. Soc. Am.* 94, S202–S213. DOI: 10.1785/0120040601.