Erwin T. Lau

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Education

- Ph.D., Astronomy & Astrophysics, University of Chicago, Chicago, IL, USA, 2010
- M.S., Astronomy & Astrophysics, University of Chicago, Chicago, IL, USA, 2006
- B.S., Astronomy and General Physics, University of Michigan, Ann Arbor, MI, USA, 2004
- B.S.E., Engineering Physics, University of Michigan, Ann Arbor, MI, USA, 2004

Research Experience

- University of Miami, Department of Physics
  Postdoctoral Associate, Jan 2018–present
  Advisor: Nico Cappelluti
- Yale University, Department of Physics, Yale Center for Astronomy & Astrophysics
  Associate Research Scientist, 2015–2017
  Postdoctoral Associate, 2011–2015
  Advisor: Daisuke Nagai
- Shanghai Astronomical Observatory, Key Laboratory for Research in Galaxies and Cosmology
  Postdoctoral Fellow, 2010–2011
  Advisor: Xiaohu Yang
- University of Chicago, Department of Astronomy & Astrophysics
  Graduate Research Assistant, 2005–2010
  Advisor: Andrey V. Kravtsov
- University of Michigan, Department of Physics
  Undergraduate Research Assistant, 2003–2004
  Advisor: Tim A. McKay

References

Prof. Nico Cappelluti (Postdoc Advisor)	University of Miami	ncappelluti@miami.edu
Prof. Daisuke Nagai (Postdoc Advisor)	Yale University	daisuke.nagai@yale.edu
Prof. Andrey V. Kravtsov (Thesis Advisor)	University of Chicago	andrey@oddjob.uchicago.edu
Prof. Paolo Coppi (Collaborator)	Yale University	paolo.coppi@yale.edu
Dr. Alexey Vikhlinin (Collaborator)	Smithsonian Astrophysical Observatory	alexey@cfa.harvard.edu

Progamming Languages and Astronomical Software Experiences

- Proficient in C/C++, python, and Fortran. Working knowledge with IDL and MATLAB
- Proficient in generating and analyzing synthetic X-ray data sets with instrumental responses (Chandra, Lynx, Athena, Hitomi, ROSAT) with own code and publicly available codes (e.g., pyXSIM, SOXS).
- Experience in analyzing real X-ray data sets (Chandra, ROSAT) with XSPEC.
- Experience in using CFITSIO in handling and manipulating HEASARC FITS files with C, Fortran.
- Experience in improving speed and scalability of code with algorithm changes and with parallel programming (MPI and OpenMP) in C and Fortran.
- Experience in analyzing big data sets.
- Experience in integrating C/C++ code with python.
- Experience with creating and using SQL database.
- Experience with collaborative software development with git and mercurial.
- Operating systems: UNIX/Linux, OSX, Windows
- Webpage development with HTML and CSS

Research Interests

Computational and theoretical modeling of galaxy clusters and their observational signatures in X-ray and microwave. Statistical analysis of large data sets in simulations and observations. Astronomical software development. Physical processes in the intracluster medium. Diffuse emissions from the Large-scale Intergalactic Medium. Galaxy clusters as cosmological probes.

Awards

XSEDE Computing Research Allocation TG-AST190003, "Simulating Cosmic Weather in Galaxy Clusters" , 45k node hours

Professional Activities and Academic Services

Referee for:

- The Astrophysical Journal
- The Monthly Notices of the Royal Astronomical Society
- Astronomy & Astrophysics
- Research in Astronomy & Astrophysics

Peer Reviewer, *Chandra* Cycle 20 Peer Review, 2018
Organizer, Cosmology Seminar at Yale University, 2012–2014

Professional Societies

Member, American Astronomical Society
Member, International Astronomical Union

Selected Invited Talks

2019/6	INAF-OAS, Bologna, Italy, Cluster Talk
2017/9	Yale University, CT, USA, Astronomy Colloquium
2017/2	Rochester Institute of Technology, Rochester, NY, USA, Astrophysics Colloquium
2017/1	Kavli Institute for the Physics and Mathematics of the Universe, Kashiwa, Japan, Astrophysics Seminar
2017/1	Academia Sinica Institute of Astronomy and Astrophysics, Taipei, Taiwan, Special Seminar
2016/1	Shanghai Astronomical Observatory, Shanghai, China, Special Seminar
2016/1	Kavli Institute for Astronomy and Astrophysics, Peking University, Beijing, Lunch Seminar
2015/9	Kavli Institute for the Physics and Mathematics of the Universe, Kashiwa, Japan, Astrophysics Lunch Talk
2015/3	University of Hong Kong, Hong Kong, Physics Seminar
2014/3	University of Michigan, Ann Arbor, MI, USA, Cluster Seminar
2013/10	Brown University, Providence, RI, USA, Astrophysics Seminar
2012/8	Shanghai Astronomical Observatory, Shanghai, China, Cosmology Seminar
2012/4	Yale University, New Haven, CT, USA, Cosmology Seminar
2010/3	University of Colorado, Boulder, CO, USA, Cluster Seminar

Conference Presentations

2019/6	XMM Workshop on Extended X-ray Sources, ESAC, Madrid, Spain
2019/1	223th AAS meeting, Seattle, WA, USA
2018/12	“Miami 2018: Topical Physics Conference”, Fort Lauderdale, FL, USA
2018/10	“Accretion Histories of AGN Workshop”, Miami, FL, USA
2018/7	“Alpine Cosmology Workshop 2018”, Alagna Valsesia, Italy
2018/6	“AGN Feeding and Feedback”, Sesto, Italy
2017/8	“From Chandra to Lynx: Taking the Sharpest X-ray Vision Fainter and Farther”, Cambridge, MA, USA
2016/12	“Galaxy clusters: Physics Laboratories and Cosmological Probes”, Cambridge, UK
2015/6	“ICM Physics and Modelling”, Max Planck Institute for Astrophysics, Garching, Germany
2015/3	“Astroparticle View of Galaxy Clusters”, Hiroshima University, Hiroshima, Japan
2015/3	“SnowCluster 2015”, Snowmass, UT, USA
2014/6	“Cluster Paris 2014”, Paris, France
2013/3	“SnowCluster 2013”, Snowmass, UT, USA
2012/11	Galaxy Cluster Workshop, Ringberg, Germany
2012/8	28th IAU General Assembly, Beijing, China
2012/6	220th AAS Meeting, Anchorage, AK, USA
2012/3	“Turbulence in Cosmic Structure Formation”, ASU, Tempe, AZ, USA
2011/9	“Cosmology with X-ray and SZE Observations of Galaxy Clusters”, Huntsville, AL, USA
2011/3	“Astrophysics and Cosmology with Galaxy Clusters”, KITP, Santa Barbara, CA, USA
2010/7	“From Massive Galaxy Formation to Dark Energy”, IPMU, Kashiwa, Chiba, Japan
2010/6	10th “Great Lakes Cosmology Workshop”, Chicago, IL, USA
2010/1	215th AAS meeting, Washington, DC, USA
2007/2	“Clusters of Galaxies as Cosmological Probes”, Aspen, CO, USA

Mentoring and Teaching

Co-supervised undergraduate and graduate students with Prof. Daisuke Nagai at Yale University, and Prof. Nico Cappelluti at the University of Miami.

Guanhua Chen: UMiami Undergrad (2019-now)
Project: "Semi-Analytic Modeling of X-ray and SZ Cross Power Spectra of Galaxy Clusters and Groups

Luis Fernando: Yale Undergrad (2016 - 2017)
Junior Project: "Modeling HST-COS Observations of Galaxy Cluster Outskirts"

Emil Öhman: Yale Undergrad (2015 - 2017)
Junior Project: "High resolution modeling of gas properties in galaxy cluster outskirts"
Senior Project: "Nature of gas streams and cold fronts in cosmological simulations of galaxy clusters"

Mari Kawakatsu: Yale Undergrad (2016 - 2017)
Senior Project: "Improving Galaxy Cluster Mass Measurements with Machine Learning Techniques"

Julia Menzel: Yale Undergrad (2015 - 2016)
Senior Project: "Streaming gas motions in galaxy clusters"

Joshua Burt, Yale Grad Student, Physics (2014-2015)
Summer Project: "Finding Gas Filaments in the Outskirts of Galaxy Clusters"

Christopher Cappiello: Yale Undergrad (2013 - 2015)
Awarded DeForest Pioneer Prize in Physics, Yale University, 2015
Senior Project: "Shapes of Galaxy Clusters"

Maya Fishbach: Yale Undergrad (2013 - 2015)
Awarded Howard L. Schultz Prize in Physics, Yale University, 2015
Senior Project: "Evolution of the filamentary gas flows in simulated galaxy clusters"
Junior Project: "Cluster Merger Simulations with Self-Interacting Dark Matter"

Hendrik Kits van Heyningen: Yale Undergrad (2013-2014)
Awarded DeForest Pioneer Prize in Physics, Yale University, 2014
Senior Project: "Modified Gravity & Dark Energy in Spherical Collapse Model"

Benjamin Elder, Yale Grad Student, Physics (2012-2013)
First Year Project: "Cosmological Simulations with Self-Interacting Dark Matter"

Dan Steinbrook: Yale Undergrad (Summer 2012)
Summer Project: "Effects of $f(R)$ gravity on the Shapes of Galaxy Clusters"

Elizabeth Peng: Yale Undergrad (2011-2012)
Senior Project: "Mock ASTRO-H Simulations of Galaxy Clusters"

Graduate Teaching Assistant, University of Chicago, 2004–2005, 2007

Refereed Publications

1. Shirasaki, M., **Lau, E. T.**, Nagai, D., *Probing Cosmology and Cluster Astrophysics with Multi-Wavelength Surveys I. Correlation Statistics*, 2020, MNRAS, 491, 235, arXiv:1909.02179

2. Chen, H., Avestruz, C., Kravtsov, A V., **Lau, E. T.**, Nagai, D., *Imprints of mass accretion history on the shape of the intracluster medium and the $T_X - M$ relation*, 2019, MNRAS, 490, 2380 arXiv:1903.08662

3. Shi, X., Nagai, D., **Lau, E. T.**, *Multiscale analysis of turbulence evolution in the density-stratified intracluster medium*, 2018, MNRAS, 481, 1075 arXiv:1806.05056

4. Shirasaki, M., **Lau, E. T.**, Nagai, D., *Modelling Baryonic Effects on Galaxy Cluster Mass Profiles*, 2018, MNRAS, 477, 2804, arXiv:1711.06366

5. ZuHone, J. A., Kowalik, K.; Öhman, E., **Lau, E.**, Nagai, D., *The Galaxy Cluster Merger Catalog: An Online Repository of Mock Observations from Simulated Galaxy Cluster Mergers*, 2018, ApJS, 234, 4, arXiv:1609.04121

6. Zinger, E., Dekel, A., Birnboim, Y., Nagai, D., **Lau, E.**, Kravtsov, A. V., *Cold Fronts and Shocks Formed by Gas Streams in Galaxy Clusters*, 2018, MNRAS, 476, 56, arXiv:1609.05308

7. Ota, N., Nagai, D., **Lau, E. T.**, *Constraining hydrostatic mass bias of galaxy clusters with high-resolution X-ray spectroscopy*, 2018, PASJ, 70, 51, arXiv:1507.02730

8. **Lau, E. T.**, Gaspari, M., Nagai, D., Coppi, P., *Physical Origins of Gas Motions in Galaxy Cluster Cores: Interpreting Hitomi Observations of the Perseus Cluster*, 2017, ApJ, 849, 54, arXiv:1705.06280

9. Tchernin, C., Eckert, D., Ettori, S., Pointecouteau, E.. Paltani, S., Molendi, S., Hurier, G., Gastaldello, F., **Lau, E. T.**, Nagai, D., Roncarelli, M.. Rossetti, M., *The XMM Cluster Outskirts Project (X-COP): Physical conditions to the virial radius of Abell 2142*, 2016, A&A, 595, A42, arXiv:1606.05657

10. Avestruz, C., Nagai, D., **Lau, E. T.**, *Stirred, not Clumped: Evolution of Temperature Profiles in the Outskirts of Galaxy Clusters*, 2016, ApJ, 833, 227, arXiv:1605.01723

11. Shirasaki, M., Nagai, D., **Lau, E. T.**, *Covariance in the Thermal SZ-Weak Lensing Mass Scaling Relation of Galaxy Clusters*, 2016, MNRAS, 460, 3913, arXiv:1603.08609

12. Shi, X., Komatsu, E., Nagai, D., **Lau, E. T.**, *Analytical model for non-thermal pressure in galaxy clusters - III. Removing the hydrostatic mass bias*, 2016, MNRAS, 455, 2936, arXiv:1507.04338

13. Sembolini, F. , Yepes, G., Pearce, F. R., Knebe, A., Kay, S. T., Power, C., Cui, W., Beck, A. M., Borgani, S., Dalla Vecchia, C., Davé, R., Elahi, P. J., February, S., Huang, S., Hobbs, A., Katz, N., **Lau, E.**, McCarthy, I. G., Murante, G., Nagai, D., Nelson, K., Newton, R. D. A., Perret, V., Puchwein, E., Read, J. I., Saro, A., Schaye, J., Teyssier, R.,Thacker, R. J., *nIFTy galaxy cluster simulations - I. Dark matter and non-radiative models*, 2016, MNRAS, 457, 2063, arXiv:1503.06065

14. **Lau, E. T.**, Nagai, D., Avestruz, C., Nelson, K., Vikhlinin, A., *Mass Accretion and its Effects on the Self-similarity of Gas Profiles in the Outskirts of Galaxy Clusters*, 2015, ApJ, 806, 86, arXiv:1411.5361

15. Avestruz, C., Nagai, D., **Lau, E. T.**, Nelson, K., *Non-Equilibrium Electrons in the Outskirts of Galaxy Clusters*, 2015, ApJ, 808, 176, arXiv:1410.8142

16. Rasia, E., **Lau, E. T.**, Borgani, S., Nagai, D., Dolag K., Avestruz, C., Granato, G. L., Mazzotta, P., Murante, G., Nelson, K., Ragone-Figueroa, C., *Temperature Structure of the Intra-Cluster Medium from SPH and AMR simulation*, 2014, ApJ, 791, 96, arXiv:1406.4410

17. Zhuravleva, I., Churazov, E., Schekochihin, A. A., **Lau, E. T.**, Nagai, D., Gaspari, M., Allen, S. W., Nelson, K., Parrish, I. J. *The relation between gas density and velocity power spectra in galaxy clusters: qualitative treatment and cosmological simulations* 2014, ApJL, 788, L13, arXiv:1404.5306

18. Gaspari, M., Churazov, E., Nagai, D., **Lau, E. T.**, Zhuravleva, I., *The relation between gas density and velocity power spectra in galaxy clusters: high-resolution hydrodynamic simulations and the role of conduction*, 2014, A&A, 569, A67, arXiv:1404.5302

19. Nelson, K., **Lau, E. T.**, Nagai, D., *Hydrodynamic Simulation of Non-thermal Pressure Profiles of Galaxy Clusters*, 2014, ApJ, 792, 25, arXiv:1404.4636

20. Avestruz, C., **Lau, E. T.**, Nagai, D., Vikhlinin, A., *Testing X-ray Measurements of Galaxy Cluster Outskirts with Cosmological Simulations*, 2014, ApJ, 797, 117, arXiv:1404.4634

21. Wang, L., Yang, X., Shen, S., Mo, H. J., van den Bosch., F. C., Luo, W., Wang, Y., **Lau, E. T.**, Wang, Q. D., Kang, X., Li, R., *Measuring the X-ray luminosities of SDSS DR7 clusters from RASS*, 2014, MNRAS, 439, 611, arXiv:1312.7417

22. Harvey, D., Tittley, E., Massey, R., Kitching, T. D., Taylor, A., Pike, S. R., Kay, S. .T., **Lau, E. T.**, & Nagai, D., *On the cross-section of Dark Matter using substructure infall into galaxy clusters*, 2014, MNRAS, 441, 404, arXiv:1310.1731

23. Nelson, K., **Lau, E. T.**, Nagai, D., Rudd, D. H., & Yu, L., *Weighing Galaxy Clusters with Gas. II. On the Origins of Hydrostatic Mass Bias in ΛCDM Galaxy Clusters*, 2014, ApJ, 782, 107, arXiv:1308.6589

24. Nagai, D., **Lau, E. T.**, Avestruz, C., Nelson, K., & Rudd, D. H., *Predicting Merger-Induced Gas Motions in ΛCDM Galaxy Clusters*, 2013, ApJ, 777, 137, arXiv:1307.2251

25. **Lau, E. T.**, Nagai, D., & Nelson, K., *Weighing Galaxy Clusters with Gas. I. On the Methods of Computing Hydrostatic Mass Bias*, 2013, ApJ, 777, 151, arXiv:1306.3993

26. Khedekar, S., Churazov, E., Kravtsov, A., Zhuravleva, I., **Lau, E. T.**, Nagai, D., & Sunyaev, R., *Bias from gas inhomogeneities in the pressure profiles as measured from X-ray and Sunyaev-Zeldovich observations*, 2013, MNRAS, 431, 954, arXiv:1211.3358

27. Zhuravleva, I., Churazov, E., Kravtsov, A., **Lau, E. T.**, Nagai, D., & Sunyaev, R., *Quantifying properties of ICM inhomogeneities*, 2012, MNRAS, 428, 3274, arXiv:1210.6706

28. **Lau, E. T.**, Nagai, D., Kravtsov, A. V., Vikhlinin,, A., & Zentner, A. R., *Constraining Cluster Physics with the Shape of X-Ray Clusters: Comparison of Local X-Ray Clusters Versus ΛCDM Clusters*, 2012, ApJ, 755, 116, arXiv:1201.2168

29. Eckert, D., Vazza, F., Ettori, S., Molendi, S. Nagai, D., **Lau, E. T.**, Roncarelli, M., Rossetti, M., Snowden, S. L., & Gastaldello, F., *The Gas Distribution in the Outer Regions of Galaxy Clusters*, 2012, A&A, 541, A75, arXiv:1111.0020

30. **Lau, E. T.**, *Characterizing Galaxy Clusters with Gravitational Potential*, 2011, ApJ, 736, 145, arXiv:1009.2124

31. Nagai, D., & **Lau, E. T.**, *Gas Clumping in the Outskirts of ΛCDM Clusters*, 2011, ApJL, 731 L10, arXiv:1103.0280

32. **Lau, E. T.**, Nagai, D., Kravtsov, A. V., & Zentner, A. R., *Shapes of Gas, Gravitational Potential and Dark Matter in ΛCDM Clusters*, 2011, ApJ, 734, 93, arXiv:1003.2270

33. Shaw, L. D., Nagai, D., Bhattacharya, S., **Lau, E. T.**, *Impact of Cluster Physics on the Sunyaev-Zel'dovich Power Spectrum*, 2010, ApJ, 725, 1452, arXiv:1006.1945

34. **Lau, E. T.**, Nagai, D., & Kravtsov, A. V., *Effects of Baryon Dissipation on the Dark Matter Virial Scaling Relation*, 2010, ApJ, 708, 1419, arXiv:0908.2133

35. **Lau, E. T.**, Kravtsov, A. V., & Nagai, D., *Residual Gas Motions in the Intracluster Medium and Bias on the Hydrostatic Mass Profile*, 2009, ApJ, 705, 1129, arXiv:0903.4895

36. Becker, M. R., McKay, T. A., Koester, B., Wechsler, R. H., Rozo, E., Evrard, A., Johnston, D., Sheldon, E., Annis, J., **Lau, E.**, Nichol, R., & Miller, C., *The Mean and Scatter of the Velocity Dispersion–Optical Richness Relation for maxBCG Galaxy Clusters*, 2007, ApJ, 669, 905, arXiv:0704.3614

Publications under review

1. Tchernin C., **Lau, E. T.**, Stapelberg, S., Hug, D., Bartelmann, M., *Characterizing galaxy clusters by their gravitational potential: systematics of cluster potential reconstruction*, 2019, A&A, submitted

Unrefereed Publications

1. Simionescu, A.; Ettori, S.; Werner, N.; Nagai, D.; Vazza, F.; Akamatsu, H.; Pinto, C.; de Plaa, J.; Wijers, N.; Nelson, D.; Pointecouteau, E.; Pratt, G. W.; Spiga, D.; **Lau, E.**; Rossetti, M.; Gastaldello, F.; Biffi, V.; Bulbul, E.; den Herder, J. W.; Eckert, D. Fraternali, F.; Mingo, B.; Pareschi, G.; Pezzulli, G.; Reiprich, T. H.; Schaye, J.; Walker, S. A.; Werk, J., *Voyage through the Hidden Physics of the Cosmic Web*, 2019, White paper submitted in response to ESA's Voyage 2050 Call, arXiv:1908.01778

2. Walker, S.; Nagai, D.; Simionescu, A.; Markevitch, M.; Akamatsu, H.; Arnaud, M.; Avestruz, C.; Bautz, M.; Biffi, V.; Borgani, S.; Bulbul, E.; Churazov, E.; Dolag, K.; Eckert, D.; Ettori, S.; Fujita, Y.; Gaspari, M.; Ghirardini, V.; Kraft, R.; **Lau, E. T.**; Mantz, A.; Matsushita, K.; McDonald, M.; Miller, E.; Mroczkowski, T.; Nulsen, P.; Okabe, N.; Ota, N.; Pointecouteau, E.; Pratt, G.; Sato, K.; Shi, X.; Tremblay, G.; Tremmel, M.; Vazza, F.; Zhuravleva, I.; Zinger, E.; ZuHone, J., *Unveiling the Galaxy Cluster - Cosmic Web Connection with X-ray observations in the Next Decade*, 2019, Astro2020: Decadal Survey on Astronomy and Astrophysics, science white papers, no. 218; Bulletin of the American Astronomical Society, Vol. 51, Issue 3, id. 218, arXiv:1903.04550