Charles J. Law – Curriculum Vitae

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EDUCATION

Ph.D., Astronomy and Astrophysics 2018 – Present
Harvard University, Cambridge, MA
Thesis: *Chemical Complexity at High Spatial Resolution during Star and Planet Formation*
Advisor: Karin I. Öberg

M.A., Astronomy and Astrophysics May 2021
Harvard University, Cambridge, MA

B.A., Physics and Astrophysics 2013 – 2017
Secondary Concentration: Computer Science
Magna Cum Laude with Highest Honors
Harvard University, Cambridge, MA
Thesis: *Carbon Chain Molecules Toward Embedded Low-Mass Protostars*
Advisor: Karin I. Öberg

RESEARCH INTERESTS

I am broadly interested in exploring chemical complexity in space, with a particular focus on (sub)millimeter interferometry. I use high spatial resolution observations to understand the chemistry and physics of the star and planet formation process, including toward low-mass and embedded protostars, massive young stellar objects, and protoplanetary disks.

HONORS & AWARDS

- NSF Graduate Research Fellowship 2019 – Present
  Supports outstanding graduate students in NSF-supported science disciplines
- Honorable Mention, Chambliss Astronomy Achievement Award Student Prize 2020
- Smithsonian Astrophysical Observatory Research Fellowship 2017
- Leo Goldberg Prize in Astronomy, Harvard University 2017
  Departmental award for an exceptional undergraduate senior astronomy thesis
- Thomas Temple Hoopes Prize, Harvard University 2017
  College-wide award for an outstanding undergraduate senior thesis
- Phi Beta Kappa, Harvard University 2017
- Frederick Tarantino Memorial Scholarship Award, Universities Space Research Assoc. 2016
  National designation for astrophysics research potential
- Harvard College PRISE Research Fellowship 2016
- Detur Book Prize, Harvard University 2014
  Awarded to outstanding first-year students
- John Harvard Scholar, Harvard University 2014
  Awarded to top 5% of first-year students

PUBLICATIONS

Author of 28 publications (refereed or under review), including 8 as first author. A full listing of my publications can be found on ADS.

First Author

1. **Law, C.J.**, Loomis, R. A., Teague, R. et al. MAPS III. Characteristics of Radial Chemical Substructures, *ApJS*, under review.
2. **Law, C.J.**, Teague, R., Loomis, R. A. et al. MAPS IV. Emission Surfaces and Vertical Distribution of Molecules, *ApJS*, under review.
3. **Law, C. J.**, Zhang, Q., Öberg, K. I., Galván-Madrid, R., Keto, E., Liu, H., Ho, P. T. P. 2021, Subarcsecond Imaging of the Complex Organic Chemistry in Massive Star-Forming Region G10.6-0.4, *ApJ*, 909, 214
4. **Law, C. J.**, Milisavljevic, D., et al., (+10 coauthors). 2020, Three-dimensional Kinematic Reconstruction of the Optically-Emitting, High-Velocity, Oxygen-Rich Ejecta of Supernova Remnant N132D, *ApJ*, 894, 73
5. **Law, C. J.**, Zhang, Q., Ricci, L., Petitpas, G., M. J. Jiménez-Donaire, Ueda, J., Lu, X., Dunham, M. M. 2018, Submillimeter Array Observations of Extended CO (J = 2 - 1) Emission in Interacting Galaxy NGC 3627, *ApJ*, 865, 17
6. **Law, C. J.**, Öberg, K. I., Bergner, J. B., Graninger, D. 2018, Carbon Chain Molecules Toward Embedded Low-Mass Protostars, *ApJ*, 863, 88
7. **Law, C. J.**, Ricci, L., Andrews, S. M., Wilner, D. J., Qi, C. 2017, An SMA Continuum Survey of Circumstellar Disks in the Serpens Star-Forming Region, *AJ*, 154, 255
8. **Law, C. J.**, Milisavljevic, D., et al. (+9 coauthors). 2017, TRES Survey of Variable Diffuse Interstellar Bands, *MNRAS*, 470, 2835

Co-Authored Publications

1. Öberg K. I., et al. (incl. **Law, C. J.**). MAPS I. Program Overview and Highlights, *ApJS*, accepted
2. Czekala, I., et al. (incl. **Law, C. J.**). MAPS II. CLEAN Strategies for Synthesizing Images of Molecular Line Emission in Protoplanetary Disks, *ApJS*, accepted
3. Zhang, K., Booth, A., **Law, C. J.**, et al. MAPS V. CO Gas Distributions, *ApJS*, under review
4. Guzmán, V. V., Bergner, J. B., **Law, C. J.**, et al. MAPS VI. Distribution of the Small Organics HCN, C_2H, and H_2CO, *ApJS*, under review
5. Bosman, A. D., et al. (incl. **Law, C. J.**). MAPS VII. Sub-stellar O/H and C/H and super-stellar C/O in Planet Feeding Gas, *ApJS*, under review
6. Alarcón, F., et al. (incl. **Law, C. J.**). MAPS VIII. Gap Chemistry in AS 209: Gas Depletion or Chemical processing?, *ApJS*, under review
7. Ilee, J. D., et al. (incl. **Law, C. J.**). MAPS IX. Distribution and Properties of the Large Organic Molecules HC_3N, CH_3CN, and c-C_3H_2, *ApJS*, under review
8. Cataldi, G., et al. (incl. **Law, C. J.**). MAPS X. Distributions of Deuterated Molecules, *ApJS*, under review
9. Bergner, J. B., Öberg, K. I., Guzmán, V. V., **Law, C. J.**, et al. MAPS XI. CN and HCN as Tracers of Photochemistry in Disks, *ApJS*, under review

10. Le Gal, R., et al. (incl. **Law, C. J.**). MAPS XII. Inferring the C/O and S/H Ratios in Protoplanetary Disks with Sulfur Molecules, *ApJS*, under review
11. Aikawa, Y., et al. (incl. **Law, C. J.**). MAPS XIII. HCO^+ and Disk Ionization, *ApJS*, under review
12. Sierra, A., et al. (incl. **Law, C. J.**). MAPS XIV. Revealing Disk Substructures in Multi-wavelength Continuum Emission, *ApJS*, accepted
13. Bosman, A. D., et al. (incl. **Law, C. J.**). MAPS XV. Tracing Proto-planetary Disk Structure within 20 au, *ApJS*, under review
14. Booth, A., et al. (incl. **Law, C. J.**). MAPS XVI. Characterizing the impact of the molecular wind on the evolution of the HD 163296 system, *ApJS*, under review
15. Calahan, J., et al. (incl. **Law, C. J.**). MAPS XVII. Determining the 2D Thermal Structure of HD 163296, *ApJS*, under review
16. Teague, R., et al. (incl. **Law, C. J.**). MAPS XVIII. Kinematic Substructure in the Disks of HD 163296 and MWC 480, *ApJS*, under review
17. Huang, J., et al. (incl. **Law, C. J.**). MAPS XIX. Spiral Arms, a Tail, and Diffuse Structures Traced by CO toward the GM Aur Disk, *ApJS*, under review
18. Schwarz, K., et al. (incl. **Law, C. J.**). MAPS XX. The Massive Disk Around GM Aurigae, *ApJS*, under review
19. Sano, H., et al. (incl. **Law, C. J.**). 2020, ALMA CO Observations of Gamma-Ray Supernova Remnant N 132D in the Large Magellanic Cloud: Possible Evidence for Shocked Molecular Clouds Illuminated by Cosmic-Ray Protons, *ApJ*, 902, 53
20. Le Gal, R., et al. (incl. **Law, C. J.**). 2020, A 3mm chemical exploration of small organics in Class I YSOs *ApJ*, 898, 131

PRESS

1.	INAF Bulletin on the 3D reconstruction of SNR N132D	April 2020
2.	SMA Newsletter on SMA observations of NGC 3627	January 2019

TALKS

I have given a total of 22 talks, including 4 invited talks and 5 public talks.

1.	Contributed, Emerging Researchers in Exoplanet Science	May 2021
2.	**Invited**, Origins Seminar, University of Arizona	May 2021
3.	Contributed, Space Telescope, 2021 Spring Symposium	April 2021
4.	Contributed, Five years after HL Tau: a new era in planet formation	December 2020
5.	Contributed, Harvard-Heidelberg Star Formation Workshop	December 2020
6.	Contributed, Astrochemical Frontiers	June 2020
7.	*Public Talk*, North Shore Amateur Astronomy Club	June 2020
8.	*Public Talk*, Gloucester Area Astronomy Club	May 2020
9.	*Public Talk*, Beacon Hill Seminar	March 2020
10.	Seminar, SMA Talk, CfA	February 2020
11.	Contributed, New England Star Formation Meeting, UConn	January 2020
12.	Contributed, 235th AAS, Honolulu, HI	January 2020

13. *Public Talk*, Union County College/AAI, NJ — December 2019
14. Contributed, Science with the Submillimeter Array: Present and Future — October 2019
15. Contributed, ISMS, 74th, Champaign-Urbana, IL — June 2019
16. Contributed, SNRs II, Chania, Crete, Greece — June 2019
17. Seminar, Exoplanet Pizza Lunch, CfA — May 2019
18. **Invited**, ALMA Community Day, MIT — April 2019
19. **Invited**, ALMA Community Day, CfA — April 2019
20. Seminar, High Energy Phenomena Seminar, CfA — February 2019
21. **Invited**, SMA Advisory Committee Meeting, CfA — July 2018
22. *Public Talk*, Gloucester Area Astronomy Club — September 2018

CONFERENCE CONTRIBUTIONS

Author of 12 conference contributions, including 7 as primary contributor.

1. Milisavljevic, D. (+5 coauthors; incl. **Law, C. J.**), "Visualization and Collaborative Exploration of Complex Multi-dimensional Data Among Distant Individuals using Virtual Reality," American Astronomical Society, Meeting #237 (Poster)
2. Plucinsky, P. P. on behalf of N132D Legacy Team (incl. **Law, C. J.**), "A Chandra Legacy Observation of N132D," American Astronomical Society, Meeting #235 (Poster)
3. Milisavljevic, D., **Law, C. J.,** (+8 coauthors) "Three-Dimensional Kinematic Reconstruction of the Optically-Emitting, High-Velocity, Oxygen-Rich Ejecta of Supernova Remnant N132D," American Astronomical Society, Meeting #235 (Poster)
4. **Law, C. J.**, Zhang, Q, Öberg, K., Galván-Madrid, R., Keto, E., Ho, P., Liu, H. 2020, "An ALMA Sub-arcsecond View of Outflows, Ionized Gas, and Spatially-Extended Complex Organic Chemistry in OB Cluster-forming Region G10.6-0.4," ALMA Special Session at American Astronomical Society, Meeting #235 (Poster)
5. Plucinsky, P. P. on behalf of the N132D Legacy Team (incl. **Law, C. J.**), "A Chandra Legacy Observation of the LMC SNR N132D," 20 Years of Chandra Science Symposium (Poster)
6. **Law, C. J.**, Zhang, Q, Öberg, K., Galván-Madrid, R., Keto, E., Ho, P., Liu, H. 2019, "Sub-arcsecond Imaging of the Complex Organic Chemistry in Massive Star-forming region G10.6-0.4," Harvard-Heidelberg Star Formation Workshop 2019: Linking Observations and Simulations (Intro Talk & Poster)
7. **Law, C. J.**, Zhang, Q, Öberg, K., Loomis, R., Galván-Madrid, R., Keto, E., Ho, P., Liu, H. 2019, "ALMA Observations of Nitrile Chemistry in the Massive Star-forming Region G10.6-0.4," American Astronomical Society, Meeting #233 (Poster)
8. **Law, C. J.**, Ricci, L., Andrews, S. M., Wilner, D. J., Qi, C. 2018, "SMA Continuum Survey of Circumstellar Disks in Serpens," SPF2 (Poster)
9. **Law, C. J.**, Öberg, K. I., Bergner, J. B., Graninger, D. 2017, "Carbon Chains Toward Embedded Low-Mass Protostars," Harvard-Heidelberg Star Formation Workshop 2017: Star Formation Across the Universe (Intro Talk & Poster)
10. **Law, C. J.**, Ricci, L., Andrews, S. M., Wilner, D. J., Qi, C. 2017, "SMA Continuum Survey of Circumstellar Disks in Serpens," American Astronomical Society, Meeting #230 (Poster)

11. Johansen, S., Crabtree, K., **Law, C. J.**, Milisavljevic, D. 2017, "Potential Line Structure Variability in DIB Features Observed in Pathfinder TRES Survey," International Symposium on Molecular Spectroscopy, 72nd Meeting (Talk)
12. **Law, C. J.**, Milisavljevic, D., Crabtree, K., Johansen, S., Patnaude, D. 2017, "TRES Survey of Variable Diffuse Interstellar Bands," American Astronomical Society, Meeting #229 (Poster)

OBSERVING EXPERIENCE & PROPOSALS

PI of 8 programs and Co-I on an additional 19 programs for access to observing facilities such as the SMA, 6.5m Magellan telescope, VLA, ALMA, HST, and JWST.

PI

1. Connecting scaling laws between exoplanets and young disks
   Submillimeter Array 2021A-S003 *4 B-ranked Tracks*
2. Jet-like, IR-bright Ejecta in O-rich LMC Supernova Remnant N132D
   Magellan Baade 6.5m, FIRE, 2021B *3 Nights*
3. Connecting scaling laws between exoplanets and young disks
   Submillimeter Array 2020A-S028 *4 B-ranked Tracks**
4. Jet-like, IR-bright Ejecta in O-rich LMC Supernova Remnant N132D
   Magellan Baade 6.5m, FIRE, 2020B *4 Nights**
5. Searching for Ionized Accretion Flows around 0.1 pc Scale Clusters with O-Type Stars
   ALMA, Cycle 7 *14.8 hours, C-ranked**
6. Jet-like, Si-rich ejecta in O-rich LMC Supernova Remnant N132D
   Magellan Baade 6.5m, FIRE, 2019B *3 Nights*
7. Formation of O Stars by Accretion of Ionized Gas
   Very Large Array 2019A-228 *11 hours, A-ranked*
8. Searching for Ionized Accretion Flows around 0.1 pc Scale Clusters with O-Type Stars
   Submillimeter Array 2018B+2019A *8 B-ranked Tracks*

**not observed due to pandemic-related observatory closures*

Co-I

1. Mapping the Delivery of Material to a Planet-forming Disk
   GBT, 21B-065, Priority B+ *(PI: J. Huang)* *11.75 hours*
2. Detecting a Young 2 Jupiter Mass Planet Embedded in the Disk of HD 163296
   JWST, MIRI/Coronagraphy, Cycle 1 GO, ID: 2153 *(PI: G. Cugno)* *7.8 hours*
3. The Chemistry of Planet Formation: A JWST-ALMA Survey of 4 Planet-Forming Disks
   JWST, MIRI/MRS, Cycle 1 GO, ID: 2025 *(PI: K. Öberg)* *12.8 hours*
4. Distinguishing between envelope and embedded disk chemistry of Class I YSOs
   NOEMA Winter 2020, W20AJ *(PI: R. Le Gal)* *B-ranked*
5. A Unique Opportunity to Measure the Continuum Optical Depth of a Protoplanetary Disk via Background Illumination
   IRAM 30m 2020A, No. 140-20 *(PI: I. Czekala)* *A-ranked*

6. Sulfur Chemistry in Planet-forming Disks
   Submillimeter Array 2020A-S018 *(PI: R. Le Gal)* — *5 A-ranked Tracks*
7. Distinguishing between envelope and embedded disk chemistry of Class I YSOs
   NOEMA Summer 2020, S20AH *(PI: R. Le Gal)* — *B-ranked*
8. Resolving ionized accretion flow toward most massive O-type stars
   ALMA Cycle 7 *(PI: Q. Zhang)* — *B-ranked*
9. A Serpens disk survey: exploring planet formation in an unexplored region
   ALMA Cycle 7 *(PI: N. van der Marel)* — *B-ranked*
10. The Center of Expansion and Age of Supernova Remnant N132D
    HST Cycle 27, 15818 *(PI: D. Milisavljevic)* — *3 Orbits*
11. Exploratory survey of Class I YSO chemistry
    IRAM 30m 2019A, No. 014-19 *(PI: R. Le Gal)* — *B-ranked*
12. Variable Diffuse Interstellar Bands
    Shane 3m 2019A *(PI: K. Crabtree)* — *5 Nights*
13. Variable Diffuse Interstellar Bands
    Gemini 2019A *(PI: D. Milisavljevic)* — *5 hours*
14. Searching for Ionized Accretion Flows around the Cluster with O-Type Stars
    Very Large Array, 2019A *(PI: Q. Zhang)* — *B-ranked*
15. A Pilot Wideband Chemical Survey of Class I Protostellar Disks
    Submillimeter Array 2018B+2019A *(PI: J. Huang)* — *4 A- + 4 B-ranked Tracks*
16. The Chemistry of Planet Formation
    ALMA Cycle 6, Large Program *(PI: K. Öberg)* — *A-ranked; 131 hours*
17. Variable Diffuse Interstellar Bands
    Shane 3m 2018B *(PI: K. Crabtree)* — *5 Nights*
18. WIYN Survey of Variable Diffuse Interstellar Bands
    WIYN 3.5m 2018A *(PI: D. Milisavljevic)* — *1.5 Nights*
19. Hectochelle Survey of Cygnus OB2
    MMT 6.5 m 2016B *(PI: D. Milisavljevic)* — *0.5 Nights*

Observing Experience:

- SMA, 15 nights (July 14 – 18, 2016; Dec. 14 – 18, 2017; June 21 – 25, 2018)
- FIRE+Baade, 6.5m Magellan telescope, 2.5 nights (Dec. 13 – 15, 2019)
- MMT, 1 night [*remote*] (Dec. 2, 16, 2016)

Funding:

- Harvard Data Science Initiative Research Fund, Regularized Maximum Likelihood Imaging: A New Method for Detecting Planets ($9,700; Collaborator, PI: R. Teague)
- NRAO Student Observing Support, VLA 2019A, 2019 ($33,601; Advisor: Q. Zhang)
- ALMA Student Observing Support, ALMA Cycle 4, 2016 ($9,000; Advisor: Q. Zhang)

COLLABORATIONS

Molecules with ALMA at Planet-forming Scales (MAPS) 2018 – Present
PI: Karin I. Öberg; co-PIs: Yuri Aikawa, Edwin A. Bergin, Viviana V. Guzmán, Catherine Walsh
ALMA Cycle 6 Large Program to comprehensive survey the chemistry of five protoplanetary disks at high spatial resolution (~15 au)

N132D Chandra Legacy Team 2019 – Present
PI: Paul P. Plucinsky
Chandra Cycle 20 Large Program to obtain legacy observations of N132D at unprecedented depth/integration time (900 ks)

TEACHING

- Python Workshop instructor, SAO Latino Initiative Program [*expected*] Aug. 16, 2021
  "Scientific Computing with SciPy"
- Co-Instructor, Introduction to Scientific Programming in Python (CSCI P-14320). [*expected*] Summer 2021
- TF, Interstellar Medium and Star Formation (AY203). Harvard University. Spring 2021
- TF, Introduction to Scientific Programming in Python (CSCI P-14320). Summer 2019, 2020
  Harvard Summer School, Pre-College Program
- TF, Stellar and Planetary Astronomy (AY16). Harvard University. Spring 2020
- TF, Physics I (Lab): Mechanics, Elasticity, Fluids, and Diffusion (PHYS E-1axl). Fall 2017
  Harvard Extension School.

OUTREACH

- Course Coordinator, Beacon Hill Seminar Spring 2021, Fall 2021 [*expected*]
  Organized the "Unveiling the Cosmos" weekly seminar; featured in community newspaper
  ["Harvard-Smithsonian Center makes impact with outreach to lifelong learners" in Wicked Local]

- Astronomy Advisor to Harvard Undergraduate Science Olympiad 2018 – 2020
  Served multiple roles including Astronomy Rules-Writer (Spring 2020) and Event Supervisor (Fall 2018)

- Astrobites Contributing Author Jan 2019 – Present
  Author and editor of the "reader's digest" version of recent astronomy papers with a wide audience.
  A full list of authored posts (12) can be found here; three of which were featured on AAS Nova:
  Salt and Hot Water around Massive Protostars
  Spectral Line Survey Reveals New Molecules in Two Protoplanetary Disks
  A New Window into Prebiotic Nitrogen Chemistry in Protoplanetary Disks

- AAS Astronomy Ambassador Jan 2019 – Present
- Presenter, Flipped Science Fair, John F. Kennedy School June 2018, May 2019
- Speaker, Astrophysics Lecture Series, Cambridge Rindge and Latin School Mar 2018
  Led a hands-on astronomy lecture and activity about molecules in space

- Observatory Night Volunteer, CfA Fall 2017 – Present
- Seminar Leader, Harvard Summit for Young Leaders in China Aug 2017
  Designed course curriculum and taught a weeklong astronomy seminar to
  Chinese high school students in Shanghai; handled aspects of residential life

PROFESSIONAL SERVICE & LEADERSHIP

Referee: A&A, A&A Letters, ApJ, ApJS	2018 – Present
Junior Member, American Astronomical Society	Apr 2017 – Present
Co-Organizer, Grad School Visitation Days	Spring 2020
Co-Organizer, Student-Faculty Lunch Series	Spring 2020
Member, Astronomical Society of the Pacific	Jan 2019 – Jan 2020
Treasurer & Founding Member, Harvard Astrophysical Society	Nov 2015 – May 2017

MENTORING

Sage Crystian, Harvard Undergraduate — Summer 2021

Co-advised with K. Öberg; summer research project mapping vertical gas structures in protoplanetary disks using ALMA data

Prabidhik KC, Harvard Undergraduate — Spring 2020 – Present

Co-advised with Q. Zhang; independent research project on the chemistry of MYSOs and UC HII regions using using SMA data

Devin Sullivan, Harvard Undergraduate — Fall 2019

Co-advised with K. Öberg; Junior Thesis (AY98) on the distribution of HCN gas in protoplanetary disks using using ALMA data