# Sarah C. Millholland

MIT Kavli Institute for Astrophysics and Space Research sarah.millholland@mit.edu 77 Massachusetts Avenue, Building 37, Room 611 www.sarahmillholland.com Cambridge, Massachusetts 02139 Research Exoplanet detection & characterization; demographics & orbital architectures of planetary systems; planetary dynamics and celestial mechanics; planetary atmospheres Interests **EDUCATION** July 2016 - May 2020 Yale University, New Haven, CT Ph.D. in Astronomy, May 2020 Thesis: Data-Driven Dynamics of Planetary Systems Advisor: Prof. Greg Laughlin M.S., M.Phil. in Astronomy, May 2018 Sept. 2015 – June 2016 UC Santa Cruz, Santa Cruz, CA Pursuit of Ph.D. in Astronomy & Astrophysics (transferred after completing first year) University of Saint Thomas, Saint Paul, MN Sept. 2011 - May 2015 **B.S.** in Physics; **B.A.** in Mathematics, May 2015 Summa Cum Laude **POSITIONS** Assistant Professor July 2022 – present Department of Physics, Massachusetts Institute of Technology NASA Sagan Fellow July 2020 - June 2022 Department of Astrophysical Sciences, Princeton University NSF Graduate Research Fellow 2017 - 2020Department of Astronomy, Yale University Advisor: Prof. Greg Laughlin Graduate Student Researcher 2015 - 2017Department of Astronomy, Yale University (2016 – 2017) Department of Astronomy & Astrophysics, UCSC (2015 – 2016) Advisor: Prof. Greg Laughlin AWARDS - Brouwer Prize ("awarded to Yale astronomy graduates for 2021 contributions of unusual merit to any branch of astronomy") - Lyman Spitzer Jr. Postdoctoral Fellowship, Princeton University 2023 - 2025- NASA Hubble Fellowship Program (NHFP) Sagan Fellowship 2020 - 2023- Tinsley Award ("best paper by a Yale astronomy graduate 2018 student"; for Millholland & Laughlin 2017b) - DDA/AAS Raynor L. Duncombe Prize for Student Research 2018 - Yale Conference Travel Fellowship 2017 2017 - 2020- NSF Graduate Research Fellowship - Summer Sagan Workshop Travel Award 2016 - UCSC Regents Fellowship 2015 - NSF Graduate Research Fellowship Honorable Mention 2015 2014 - 2015- Barry M. Goldwater Scholarship (national science scholarship) - Smith Academic Scholarship 2014 - 20152013 - 2014, 2014 - 2015- Danger Mathematics Scholarship

|            | - UST Collaborative Inquiry Research Scholarship      | 2014                    |
|------------|---|-------------------------|
|            | - Walczak Mathematics Scholarship                     | 2013 - 2014             |
|            | - B. John Barry Academic Scholarship                  | 2012 - 2013             |
|            | - UST Endowed Scholarship                             | 2011-2015               |
|            |   |                         |
| Teaching   | - Teaching Fellow, Planets and Stars, Yale University | Spring 2017             |
| Experience | - Teaching Fellow, Physics of Planetary Systems, UCSC | Spring 2016             |
|            | - Teaching Fellow, Overview of the Universe, UCSC     | Fall 2016               |
|            | - Teaching Assistant, Modern Physics, UST             | Springs 2014, 2015      |
|            | - Observatory Lab Instructor, Introduction to         | Fall 2012 – Spring 2015 |

#### MENTORING EXPERIENCE

- Nicole Gountanis, Princeton undergraduate student, Fall 2021 (Junior Project)
- Joshua Zou, Princeton undergraduate student, Summer 2021 (Undergraduate Summer Research Program)

Astronomy, UST and the UST Observatory

- David Jensen, Princeton undergraduate student, Fall 2020 (Junior Project)
- Samantha Berek, Yale undergraduate student, 2018 2020 ("Astro Sib" Mentorship Program)
- Adrian Kulesza, Yale undergraduate student, Spring 2019 (research project in "Astrophysics Research Methods")
- Rachel Cohen, Yale undergraduate student, Spring 2019 (research project in "Astrophysics Research Methods")
- Marguerite Epstein-Martin, Yale undergraduate student, 2017 2018 (co-advised with Greg Laughlin)

# Refereed **Publications** (\*=STUDENT SUPERVISED BY S.C.M.)

#### First author

- 14. Millholland, S., He, M., & Zink, J. "Edge-of-the-Multis: Evidence for a Transition in the Outer Architectures of Compact Multi-Planet Systems." 2022, AJ, 164, 72
- 13. Millholland, S. & Winn, J. "Split Peas in a Pod: Intra-System Uniformity of Super-Earths and Sub-Neptunes." 2021, ApJL, 920, L34
- 12. Millholland, S., He, M., Ford, E., et al. "Evidence for a Non-Dichotomous Solution to the Kepler Dichotomy: Mutual Inclinations of Kepler Planetary Systems from Transit Duration Variations." 2021, AJ, 162, 166
- 11. Millholland, S. & Spalding, C. "Formation of Ultra-Short-Period Planets by Obliquity-Driven Tidal Runaway." 2020, ApJ, 905, 71
- 10. Millholland, S., Petigura, E., & Batygin, K. "Tidal Inflation Reconciles Low-Density Sub-Saturns with Core Accretion." 2020, ApJ, 897, 7
- 9. Millholland, S. "Tidally Induced Radius Inflation of Sub-Neptunes." 2019, ApJ, 886, 72
- 8. Milholland, S. & Batygin, K. "Excitation of Planetary Obliquities Through Planet-Disk Interactions." 2019, ApJ, 876, 119
- 7. Milholland, S. & Laughlin, G. "Obliquity-Driven Sculpting of Exoplanetary Systems." 2019, Nature Astronomy, 3, 424
- 6. Millholland, S. & Laughlin, G. "Obliquity Tides May Drive WASP-12b's Rapid Orbital Decay." 2018, ApJL, 869, L15
- 5. Millholland, S., Laughlin, G., Teske, J., et al. "New Constraints on Gliese 876 - Exemplar of Mean-Motion Resonance." 2018, AJ, 155, 106
- 4. Milholland, S., Wang, S., & Laughlin, G. "Kepler Multi-Planet Systems Exhibit Unexpected Intra-system Uniformity in Mass and Radius." 2017, ApJL, 849, L33

- 3. Millholland, S. & Laughlin, G. "Supervised Learning Detection of Sixty Non-Transiting Hot Jupiter Candidates." 2017, AJ, 154, 83
- 2. Millholland, S. & Laughlin, G. "Constraints on Planet Nine's Orbit and Sky Position within a Framework of Mean-motion Resonances." 2017, AJ, 153, 91
- 1. Millholland, S., Wang, S., & Laughlin, G. "On the Detection of Non-Transiting Hot Jupiters in Multiple Planet Systems." 2016, ApJL, 823, L7

#### Second author

- 5. \*Jensen, D. & Millholland, S. "Inferred Properties of Planets in Mean-Motion Resonances are Biased by Measurement Noise." 2022, AJ, accepted
- 4. Weiss, L., Millholland, S., Petigura, E., Adams, F., Batygin, K., Bloch, A., & Mordasini, C. "Architectures of Compact Multi-planet Systems: Diversity and Uniformity." 2022, Protostars and Planets VII book chapter, arXiv: 2203.10076
- 3. Lillo-Box, J., **Millholland, S.**, & Laughlin, G. "Follow-up of Non-Transiting Planets Detected by Kepler: Confirmation of Three Hot Jupiters and Validation of Three Other Planets." 2021, A&A, 654, 9
- Spalding, C. & Millholland, S. "Stellar Oblateness versus Distant Giants in Exciting Kepler Planet Mutual Inclinations." 2020, AJ, 160, 105
- 1. Adams, A. D., **Millholland, S.**, & Laughlin, G. "Signatures of Obliquity in Thermal Phase Curves of Hot Jupiters." 2019, AJ, 158, 3

#### Other co-author

- 8. Zhao, L., Kunovac, V., Brewer, J., Llama, J., Millholland, S., et al. [11 total] "Measured Spin-Orbit Alignment of Ultra-Short Period Super-Earth 55 Cancri e." 2022, Nature Astronomy, submitted
- Stefansson, G., Mahadevan, S., Petrovich, C., Winn, J., Kanodia, S., Millholland,
   S., et al. [37 total] "The Warm Neptune GJ 3470b has a Polar Orbit." 2022, ApJL,
   931, L15
- Azari, A., Biersteker, J., Dewey, R., Doran, G., et al. including Millholland, S. [16 total] "Integrating Machine Learning for Planetary Science: Perspectives for the Next Decade." 2021, BAAS, 53, 128 (white paper)
- 5. Davis, A., Wang, S., Jones, M., Eastman, J., Günther, M., Stassun, K., et al. including **Millholland**, S. [51 total] "TOI 564 b and TOI 905 b: Grazing and Fully Transiting Hot Jupiters Discovered by TESS." 2020, AJ, 160, 229
- Bryan, M., Chiang, E., Bowler, B. P., Morley, C. V, Millholland, S., Blunt, S., Ashok, K. B., Nielsen, E., Ngo, H., Mawet, D., Knutson, H. A. "Obliquity Constraints on an Extrasolar Planetary-Mass Companion." 2020, AJ, 159, 181
- Wang, S., Jones, M., Shporer, A., Fulton, B. J., Paredes, L. A., Trifonov, T., Kossakowski, D., Eastman, J., Redfield, S., Günther, M. N., Kreidberg, L., Huang, C. X., Millholland, S., et al. [60 total] "HD 202772Ab: A Transiting Hot Jupiter Around a Bright, Mildly Evolved Star in a Visual Binary Discovered by TESS." 2019, AJ, 157, 51
- 2. Becker, J. C., Khain, T., Hamilton, S. J., Adams, F. C., Gerdes, D. W., Zullo, L., Franson, K., **Millholland**, S., et al. [66 total] "Discovery and Dynamical Analysis of an Extreme Trans-Neptunian Object with a High Orbital Inclination." 2018, AJ, 156, 81
- Janvier, M., Savcheva, A., Pariat, E., Tassev, S., Millholland, S., Bommier, V., McCauley, P., McKillop, S., Dougan, F. "Evolution of Flare Ribbons, Electric Currents and Quasi-separatrix Layers During an X-class Flare." 2016, A&A, 591, A141

### Observing Programs

- Keck I, HIRESr, "Non-Transiting Hot Jupiters: Hidden Companions to Known Exoplanets", 2020B, 2 nights, Co-I (PI: Malena Rice)
- ORM, STELLA/SES, "Radial velocity confirmation of non-transiting planets from Kepler" 2020B, 40 hrs, Co-I (PI: Jorge Lillo-Box)
- Keck I, HIRESr, "Non-Transiting Hot Jupiters: Hidden Companions to Known Exoplanets", 2020A, 2 nights, Co-I (PI: Songhu Wang)
- Keck I, HIRESr, "Are Hot Jupiters Dynamically Hot?", 2020A, 2 nights, Co-I (PI: Songhu Wang)
- Keck I, HIRESr, "Non-Transiting Hot Jupiters: Hidden Companions to Known Exoplanets", 2019B, 4 nights, Co-I (PI: Songhu Wang)
- CAHA, CAFE, "Radial velocity confirmation of non-transiting planets from Kepler" 2019B, 5 nights, Co-I (PI: Jorge Lillo-Box)
- Keck I, HIRESr, "Do Multi-planet Systems Share Alignment with Their Parent Stars?", 2018A, 1 night, Co-I (PI: Songhu Wang)

# SEMINARS & COLLOQUIA (\*=INVITED)

- \* Astrophysics Colloquium, Chalmers University of Technology, May 2022
- \* Astronomy Colloquium, University of Wisconsin-Madison, March 2022
- \* Stellar Astrophysics Center Seminar, Aarhus University, November 2021
- \* Astronomy Colloquium, California Institute of Technology, October 2021
- \* Astronomy Colloquium, Columbia University, October 2021
- \* Astronomy Colloquium, University of Rochester, September 2021
- \* Astrophysics Seminar, Astrophysical Fluid Dynamics Group at DAMTP, University of Cambridge, May 2021
- \* Astronomy Colloquium, University of California Los Angeles, March 2021
- \* Center for Integrative Planetary Science Seminar, University of California Berkeley, March 2021
- \* Exoplanets and Protoplanetary Disks Research Group Talk, Imperial College London, March 2021
- \* Canadian Institute for Theoretical Astrophysics Seminar, University of Toronto, March 2021
- \* Center for Astrophysical Sciences Seminar, Johns Hopkins University, Feb. 2021
- \* Astronomy Seminar, Carnegie Earth and Planets Laboratory, Feb. 2021
- \* Astrophysics Colloquium, Massachusetts Institute of Technology, Feb. 2021
- \* Colloquium, Center for Computational Astrophysics, Flatiron Institute, Oct. 2020
- \* JILA Astrophysics Seminar, University of Colorado Boulder, Oct. 2020
- \* JPL Exoplanet Journal Club Talk, NASA Jet Propulsion Laboratory, Aug. 2020
- \* Special Seminar, Climate and Space Sciences and Engineering, University of Michigan, Feb. 2020
- \* Cosmos Seminar, The University of Texas at Austin, Oct. 2019
- \* Institute for Theory and Computation Seminar, Harvard University, Oct. 2019
- Friday Lunch Time Astrophysics Seminar, University of California Santa Cruz, Oct. 2019
- Tuesday Lunch Talk, University of California Los Angeles, Oct. 2019
- Astronomy Tea Talk, California Institute of Technology, Oct. 2019
- Exoplanet Tea Talk, Massachusetts Institute of Technology, Sept. 2019
- \* Planetary Lunch Seminar, Cornell University, Sept. 2019
- Astronomy Seminar, Columbia University, Sept. 2019
- Star and Planet Formation Seminar, University of Michigan, March 2019
- Exoplanet Lunch Seminar, Princeton University, Feb. 2019
- \* Center for Exoplanets & Habitable Worlds Seminar, Penn State University, Feb. 2019

- \* Extrasolar Planets Seminar, NASA Goddard Space Flight Center, April 2018
- \* Planetary Science Seminar, California Institute of Technology, Dec. 2017
- \* Stars & Planets Seminar, Harvard-Smithsonian Center for Astrophysics, Nov. 2017
- Exoplanet Pizza Lunch, Harvard-Smithsonian Center for Astrophysics, March 2017

#### Conference Talks

- "Edge-of-the-Multis: Evidence for Truncation of the Outer Architectures of Compact Multiple-Planet Systems." Exoplanets IV Conference, Las Vegas, Nevada, May 2022
- "Edge-of-the-Multis: Evidence for Truncation of the Outer Architectures of Compact Multiple-Planet Systems." Division of Dynamical Astronomy Meeting, Flatiron Institute, New York, New York, April 2022
- "A 3D View of Planetary Orbital Architectures." 2021 NHFP Symposium, virtual conference, October 2021
- "Evidence for a Non-Dichotomous Solution to the Kepler Dichotomy." AAS Meeting #238, virtual conference, June 2021
- "Evidence for a Non-Dichotomous Solution to the Kepler Dichotomy." Division of Dynamical Astronomy Meeting, virtual conference, May 2021
- "Testing Obliquity-Driven Sculpting of Exoplanetary Systems with PLATO." PLATO ESP Workshop on Planetary Interiors and System Architectures, virtual conference, November 2020
- "Formation of Ultra-Short-Period Planets by Obliquity-Driven Tidal Runaway." 2020 NHFP Symposium, virtual conference, September 2020
- "Formation of Ultra-Short-Period Planets by Obliquity-Driven Tidal Runaway." Division of Dynamical Astronomy Meeting, virtual conference, August 2020
- "The Role of Tidal Inflation in Explaining Sub-Saturn Structures." Boston Area Exoplanet Science Meeting #7, virtual conference, April 2020
- "Obliquity-Driven Sculpting of Exoplanetary Systems." AAS Meeting #235, Honolulu, HI, January 2020
- "Tidally-Induced Radius Inflation of Sub-Neptunes." Extreme Solar Systems IV, Reykjavik, Iceland, August 2019
- "Tidally-Induced Radius Inflation of Sub-Neptunes." Emerging Researchers in Exoplanet Science (ERES) V, Cornell University, Ithaca, NY, June 2019
- "Excitation of Planetary Obliquities Through Planet-Disk Interactions." Division of Dynamical Astronomy Meeting, Boulder, CO, June 2019
- "Obliquity Tides and their Role in Understanding the Kepler Planet Period Ratio Distribution." Kepler & K2 Science Conference V, Glendale, CA, March 2019
- "The Surprising Role of Obliquity Tides in Short-Period Exoplanets." Boston Area Exoplanet Science Meeting #5, Boston University, Boston, MA, January 2019
- "Consequences of Large Planetary Obliquities in Extrasolar Systems." 2018 CT Exoplanets Meeting, Wesleyan University, Middletown, CT, July 2018
- "Obliquity-Driven Sculpting of Exoplanetary Systems." Emerging Researchers in Exoplanet Science (ERES) IV, Pennsylvania State University, State College, PA, June 2018
- "On f for 9." Planet Nine Workshop, California Institute of Technology, Pasadena, CA, May 2018
- "On the Obliquities of Planets in Close-in, Coplanar Systems." Division of Dynamical Astronomy Meeting, San Jose, CA, April 2018
- "New Constraints on the Multi-Resonant Planetary System, Gliese 876." Numerical Integration Methods in Planetary Science, University of Toronto at Scarborough, Toronto, Ontario, August 2017
- "Constraints on Planet Nine in a Mean-Motion Resonant Framework." Numerical Integration Methods in Planetary Science, University of Toronto at Scarborough, Toronto, Ontario, August 2017

- "Supervised Learning Detection of Sixty Non-Transiting Hot Jupiter Candidates."
   Kepler & K2 Science Conference IV, NASA Ames Research Center, Moffett Field,
   CA, June 2017
- "Supervised Learning Detection of Sixty Non-Transiting Hot Jupiter Candidates." Emerging Researchers in Exoplanet Science (ERES) III, Yale University, New Haven, CT, June 2017
- "Supervised Learning Detection of Sixty Non-Transiting Hot Jupiter Candidates." 2017 CT Exoplanets Meeting, Wesleyan University, Middletown, CT, May 2017
- "Constraints on Planet Nine in a Mean-Motion Resonant Framework." 2017 Aspen Winter Conference, Formation and Dynamical Evolution of Exoplanets, Aspen, CO, March 2017

#### Conference Posters

- Millholland, S., Petigura, E., & Batygin, K. "Tidal Inflation Reconciles Low-Density Sub-Saturns with Core Accretion." Exoplanets III Conference, virtual conference, July 2020
- Adams, A., Millholland, S. & Laughlin, G. "Detecting Planet Obliquity in Thermal Phase Curves." Summer Sagan Workshop, Pasadena, CA, July 2018
- Millholland, S. & Laughlin, G. "Obliquity-Driven Sculpting of Exoplanetary Systems."
   Exoplanets II Conference, Cambridge, UK, July 2018
- Millholland, S., Laughlin, G., Butler, P., et al. "New Dynamical Constraints on the Multi-Resonant System, GJ 876." Summer Sagan Workshop, Pasadena, CA, July 2016
- Millholland, S., Laughlin, G., Burt, J., et al. "A Search for Non-Transiting Hot Jupiters with Transiting Super-Earth Companions." Exoplanets I Conference, Davos, Switzerland, July 2016
- Millholland, S. & Ruch, G. "An Analysis of the Fixed Star Approximation in Transit Light Curve Models." IAU General Assembly, Meeting #29, id.2255909, Honolulu, HI, August 2015
- Millholland, S., Savcheva, A. & DeLuca, E., "Magnetic Field Modeling of Complex, Flare Producing Active Regions." American Geophysical Union Fall Meeting, abstract #SH13A-4079, San Francisco, CA, December 2014
- Milholland, S., Maruyama, N., Maute, A., et al. "Modeling Sudden Stratospheric Warming Events Using the Ionosphere-Plasmasphere Electrodynamics Model." American Geophysical Union Fall Meeting, abstract #SA23A-2034, San Francisco, CA, December 2013
- Milholland, S. & Ruch, G., "Modeling and Fitting Exoplanet Transit Light Curves." AAS Meeting #221, id.343.10, Long Beach, CA, January 2013

### Web Blog Publications

- "Tilting Planets and Sculpting Orbits", invited guest post by S. Millholland at *Nature Research Behind the Paper*, March 2019. (Click here to follow link.)

# OUTREACH TALKS AND

Yale Young Global Scholars Research Showcase (http://globalscholars.yale.edu),
 Yale University, June & July 2022 (virtual talks)

### PUBLICATIONS - Exploring Science, Yale University, August 2020 (virtual talk)

- Yale Young Global Scholars Research Showcase, Yale University, July 2019 (talk)
- Institute for Learning in Retirement, Albertus Magnus College, October 2018 (talk)
- Yale Young Global Scholars Research Showcase, Yale University, June & July 2018 (talks)
- Leitner Family Observatory & Planetarium, February 2018 (talk)
- Pathways Summer Scholars Program Science Café (http://pathwayssummerscholars.yale.edu), Yale University, July 2017 (talk)

- Yale Young Global Scholars Research Showcase, Yale University, July 2017 (talk)
- Pathways Summer Scholars Enrichment Workshop, Yale University, July 2017 (talk & workshop)
- Yale Open Labs Science Café (http://theopenlabs.org), Yale University, April 2017 (talk)
- 9th Annual Women in Leadership Conference, Yale University, February 2017 (invited panel member)
- "The Search for Planet Nine", a publication for the Hartford Courant News in Education series, Science Matters!, January 2017 (article)
- LAMAT REU Program, UC Santa Cruz, July 2016 (talk)
- "Reading Scientific Literature", LAMAT REU Program, UC Santa Cruz, June 2016 (workshop)
- Public Observing Night, University of St. Thomas Observatory, March 2013 (talk & public observing)
- Minnesota Optical Society Meeting, March 2013 (talk)

## Professional ACTIVITIES & SERVICE

#### Reviews

- Referee for Nature Astronomy, AJ, ApJ, ApJL, PSJ, A&A, MNRAS, PASP
- Proposal reviewer, NSF Astronomy & Astrophysics Program
- Proposal reviewer, NASA Exoplanets Research Program
- External reviewer, Canada-France-Hawaii Telescope
- External reviewer, OPTICON Telescope Transnational Access

#### Organizing Committees

| - Committee member, Division of Dynamical Astronomy Committee    | ee 2021 –        |
|--|------------------|
| - Organizer, Princeton Planetary Dynamics Reading Group          | 2020 -           |
| - Scientific Organizing Committee Member,                        | 2022             |
| Division of Dynamical Astronomy 53rd Annual Meeting              |                  |
| - Scientific Organizing Committee Member,                        | 2017, 2019, 2021 |
| Emerging Researchers in Exoplanet Science (ERES)                 |                  |
| Conference III (Yale), V (Cornell) and VI (virtual)              |                  |
| - Organizing committee, UCSC astronomy prospective student visit | 2015             |

#### Diversity & Inclusion Involvement

| - Co-organizer, Seminar Series on Equity, Diversity and Inclusion | 2020 - 2021 |
|---|-------------|
| for the Departments of Physics and Astrophysics at Princeton      |             |
| - Committee member, Improving equity and inclusion in graduate    | e 2020      |
| admissions at the Department of Astrophysics at Princeton         |             |
| - Organizer, Panel Discussion at Emerging Researchers in          | 2019        |
| Exoplanet Science V: "Diversity & Inclusion in Astronomy"         |             |

#### Professional Affiliations & Mentorship

- Member, American Astronomical Society
- Member, Division of Dynamical Astronomy of the AAS - Mentor, Goldwater Scholar Community Mentorship Program
- Mentor, DDA Mentorship Program 2021 -2021 -

2021 -

- Mentor, Princeton Astrophysics Mentorship Program

# SELECTED OUTREACH

| - Yale Open Labs (http://theopenlabs.org)    | 2016 - 2018 |
|--|-------------|
| Committee chair for Science Café Talk Series | 2017 - 2018 |
| Executive board member                       | 2016 - 2017 |

Organizer of Yale Young Global Scholars Program visits to the Astro. Department (http://globalscholars.yale.edu)
 Public Night Volunteer, Lick Observatory

Summer 2016

2012 - 2015

- Astronomy Public Night Leader, UST Observatory

SELECTED MEDIA COVERAGE

- **Tilted planets** (Millholland & Laughlin 2019) featured in Scientific American, Sky & Telescope, Popular Science, Science Daily, Live Science, Space.com, Yale News.
- Intra-system uniformity (Millholland et al. 2017) featured in AAS Nova, Nature Research Highlights.
- Machine learning detection of hot Jupiters (Millholland & Laughlin 2017b) featured in National Geographic, Sky & Telescope, FOX 61 Connecticut News (television), University of St. Thomas News, Yale News.
- Featured subject for University of St. Thomas television and online advertisements