Julian B. Muñoz

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RESEARCH INTERESTS

I am a broadly trained astrophysicist working at the intersection of cosmology and particle physics. I am best known for my work on 21 cm and dark matter. I have developed theoretical models to probe the dark sector with data from cosmic dawn and reionization, and used them to search for dark matter within the HERA collaboration as well as HST and JWST observations. My work also uses other cosmic data, such as the LSS, CMB, and fast radio bursts, to search for new physics in our universe.

RESEARCH EXPERIENCE

2023- **Assistant Professor,** Department of Astronomy, University of Texas at Austin, TX.

2020-22 **Clay Fellow,** Harvard-Smithsonian Center for Astrophysics, Cambridge, MA

2017-20 **Postdoctoral Fellow,** Department of Physics, Harvard University, Cambridge, MA.

EDUCATION

2017 **Ph.D. in Physics,** Johns Hopkins University, USA. "*New Cosmological Probes for Old Fundamental Questions*". Advisor: Marc Kamionkowski.

2013 **Graduado en Física** (Bachelor's in Physics), Complutense University of Madrid, Spain.

PRESENTATIONS

Colloquia
"Cosmic Dawn: The Next Frontier", MIT, Cornell, UT Austin Astronomy, UT Physics, CITA, SLAC, Dartmouth, EuCAPT, Clay Lecture, McGill, UNC Chapel Hill (2021-23).
"Cosmology with the 21-cm line", ETH Zurich (2020).
"Did LIGO detect dark matter?" Harvard BHI (2017).

Selected Invited Talks
"Understanding the First Galaxies" SALF VIII, 21cmGS workshop, UC Berkeley, (2021-23)
"Light Relics beyond $N_{\rm eff}$", GGI, Aspen (2021).
"Small scales and high-z with the 21-cm line", Seminar at Cornell, CERN, YITP, PSU, Perimeter, Yale, NYU, IFT, Weizmann, MIT, UT Austin, USC, BGU, Cambridge, Geneva, Stanford, Caltech, BSM Pandemic, Columbia Theory, PCTS workshop, Structure Seminar, BCTP, UNM, Minnesota (2020-22).

FUNDING

NASA Hubble Fellowship Program (PI) "*Improving Our Understanding of Cosmic Dawn*"
\$300k (2020, declined in favor of Clay)
XSEDE (Co-I) "*Unveiling Cosmic Dawn with HERA*"
2M core hours (2020)
NASA Hubble Space Telescope (Co-I) "*Quasars with small proximity zones*"
11 orbits (2021)

FELLOWSHIPS & AWARDS

MIT Kavli Fellowship (declined), NASA Hubble Fellowship (declined), 5-year Clay Fellowship (2020).
Dan David Prize Scholar 2017 ($15k).
EJ Rhee travel award 2016 ($1k)
Pitt PACC travel award 2017 ($0.5k).
Spanish Ministry of Education Research Fellowship 2012 (€4k).
Summer Fellowship at the Instituto Astrofísico de Canarias 2012 (€2k).

TEACHING & ADVISING EXPERIENCE

Teaching Assistant, Johns Hopkins University

Responsibilities included grading, supervising group discussions and laboratories, holding office hours, and developing assignments and exams.

- Physics 103. Fall 2013 (taught by David E. Kaplan).
- Physics 104. Spring 2014 (taught by Tim Heckman).
- Graduate Quantum Mechanics. Fall 2015 (taught by Marc Kamionkowski).
- Stars and the Universe. Spring 2016 (taught by Adam Riess).

Guest lecturer

Basics of 21-cm cosmology, Ay98 at Harvard, Fall 2018 and 2019 (taught by Xingang Chen). Substitute lectures for Quantum Mechanics and Cosmology at JHU and Harvard, respectively.

Advising Experience

W. Linda Xu (graduate student at Harvard Physics->Postdoc Berkeley), since 2018, 3 papers.
Nick Deporzio (graduate student at Harvard Physics), since 2018, 2 papers.
Nash Sabti (graduate student at King's College London->Postdoc JHU), since 2019, 3 papers.
Misha Rashkovetskyi (graduate student at Harvard Astronomy), 2020, 1 paper.
Dashon Jones (undergraduate at the Smithsonian Latino Initiative Program), summer 2022.

Outreach

Member of the graduate-student outreach group at JHU (2014-17): Lectures at Pikesville High, JHU physics fair, demonstrations at Coppin State, and Baltimore city middle schools.
Contributor to the Boston non-profit Science for the Public (2018), and Astronomy on Tap (2019).
Advisor, SAO Latino Initiative Program REU (2022).

PROFESSIONAL SERVICE

Reviewing

Panelist, NSF AAG (USA), ERC *Synergy* (EU), and *FONDECYT* (Chile).
PRL, PRD, ApJ, ApJ Lett., JCAP, MNRAS, Phys.Rept., Nat. Astronomy, & Nat.Comm.

White Papers

Contributor CMB-S4 science book, thirteen Astro2020 and six Snowmass 2021 white papers.
Contact person, four LOIs, one RFI, and speaker in the Snowmass 2021 meeting.

Professional Duties

Organizer, high-energy physics seminar, Harvard University (2018-2019).
Member, ITC postdoctoral selection committee (2021).
Coordinator, DM theory group, Hydrogen epoch of reionization array (HERA) experiment.
Developer, 21cmvFAST, RelicFast, GALLUMI, and 21cmFAST(v3).

PUBLICATIONS

Total number of publications: 48
Total number of citations: >3100 (including preprints: >5000)
h-index: 30; citations/paper: 67 (including preprints: 73)

Selected

1. **J. B. Muñoz**
   An Effective Model for the Cosmic-Dawn 21-cm Signal.
   Submitted to MNRAS. ArXiv: 2302.08506.

2. HERA collaboration (incl. **J. B. Muñoz**, I led the IGM and dark-matter constraints)
   Improved Constraints on the 21 cm EoR Power Spectrum and the X-Ray Heating of the IGM with HERA Phase I Observations
   ApJ, in press (2023). ArXiv: 2210.04912.

3. **J. B. Muñoz**
   A Standard Ruler at Cosmic Dawn
   Phys. Rev. Lett. 123, 131301 (2019). ArXiv: 1904.07868 **– Editor's Choice.** (>50 citations)

4. **J. B. Muñoz** and A. Loeb
   A small amount of mini-charged dark matter could cool the baryons in the early Universe.
   Nature 557 no.7707, 684 (2018). ArXiv: 1802.10094. (>250 citations)

5. **J.B. Muñoz**, E.D. Kovetz, L. Dai, and M. Kamionkowski
   Lensing of Fast Radio Bursts as a Probe of Compact Dark Matter.
   Phys. Rev. Lett. 117, 091301 (2016). ArXiv: 1605.00008 **– Editor's Choice.** (>150 citations)

Additional (*Student co-supervised)

6. C. Mason, **J. B. Muñoz**, B. Greig, A. Mesinger, J. Park
   `21cmfish`: Fisher-matrix framework for fast parameter forecasts from the cosmic 21-cm signal.
   Submitted to MNRAS. ArXiv: 2212.09797.

7. X. Wu*, **J. B. Muñoz**, and D. J. Eisenstein
   Non-parametric Lagrangian biasing from the insights of neural nets
   Submitted to JCAP. ArXiv: 2212.08095.

8. M. Montero^, **J. B. Muñoz**^, G. Obied^ **(^Alphabetical)**
   Swampland bounds on dark sectors.
   MNRAS 514 2, 2010 (2022). ArXiv: 2201.07249.

9. J. Mirocha, **J. B. Muñoz**, S. Furlanetto, A. Liu, and A. Mesinger
   A galaxy-free phenomenological model for the 21-cm power spectrum during reionization.
   MNRAS 514 2, 2010 (2022). ArXiv: 2201.07249.

10. **J. B. Muñoz**, Y. Qin, A. Mesinger, S. Murray, B. Greig, and C. Mason
    The Impact of the First Galaxies on Cosmic Dawn and Reionization.
    MNRAS 511 3, 3657 (2022). ArXiv: 2110.13919.

11. N. Sabti[*], **J. B. Muñoz**, and D. Blas
Measurements of the Clustering of Matter with the High-Redshift Galaxy UVLF.
Astrophys.J.Lett. 928 2, L20 (2022). ArXiv: 2110.13161 – **Featured in AAS Nova**

12. N. Sabti[*], **J. B. Muñoz**, and D. Blas
GALLUMI: A Galaxy Luminosity Function Pipeline for Cosmology and Astrophysics.
Phys.Rev.D 105 4, 043518 (2022). ArXiv: 2110.13168.

13. X. Wu[*], **J. B. Muñoz**, and D. J. Eisenstein
A fully Lagrangian, non-parametric bias model for dark-matter halos
JCAP 02 02, 002 (2022). ArXiv: 2109.13948.

14. HERA collaboration (incl. **J. B. Muñoz**, I led Secs. 4 and 7 on IGM and dark-matter constraints)
HERA Phase I Limits on the Cosmic 21-cm Signal: Constraints on Astrophysics and Cosmology During the Epoch of Reionization
*Ap*J 924, 51 (2021). ArXiv: 2108.07282.

15. M. Rashkovetskyi[*], **J. B. Muñoz**, D. J. Eisenstein, and C. Dvorkin
Small-scale Clumping at Recombination and the Hubble Tension
Phys.Rev.D 104 10, 103517 (2021). ArXiv: 2108.02747.

16. W.L. Xu[*], **J. B. Muñoz**, and C. Dvorkin
Cosmological Constraints on Light (but Massive) Relics
Phys.Rev.D 105 9, 095029 (2022). ArXiv: 2107.09664.

17. S. Hotinli, T. Binnie, **J. B. Muñoz**, B. Dinda, and M. Kamionkowski
Probing compensated isocurvature with the 21-cm signal during cosmic dawn
Phys.Rev.D 104 6, 063536 (2021). ArXiv: 2106.11979.

18. A. Ray, R. Laha, **J. B. Muñoz**, and R. Caputo
Closing the gap: Near future MeV telescopes can discover asteroid-mass primordial black holes
Phys.Rev.D 104 2, 023516 (2021). ArXiv: 2102.06714.

19. **J. B. Muñoz**, S. Bohr, F.Y. Cyr-Racine, J. Zavala, and Mark Vogelsberger
ETHOS: Impact of Dark Acoustic Oscillations on Cosmic Dawn
Phys.Rev.D 103 4, 043512 (2021). ArXiv: 2011.05333.

20. S. Murray, B. Greig, A. Mesinger, **J. B. Muñoz**, Y. Qin, J. Park, and C. Watkinson
21cmFASTv3: A Python-integrated C code for 3D realizations of the cosmic 21cm signal.
JOSS 5(54), 2582. ArXiv: 2010.15121.

21. N. Sabti[*], **J. B. Muñoz**, and D. Blas
First Constraints on Small-Scale Non-Gaussianity from UV Galaxy Luminosity Functions.
JCAP 01 010 (2021). ArXiv: 2009.01245.

22. J. Flitter, **J. B. Muñoz**, and E. Kovetz
Outliers in the LIGO Black Hole Mass Function from Coagulation in Dense Clusters.
MNRAS 507 1, 743 (2020). ArXiv: 2008.10389

23. W.L. Xu[*], N. Deporzio[*], **J. B. Muñoz**, and C. Dvorkin
Accurately Weighing Neutrinos with Cosmological Surveys.
Phys.Rev.D 103 2, 023503 (2021). ArXiv: 2006.09395.

24. N. Deporzio*, W.L. Xu*, **J. B. Muñoz**, and C. Dvorkin
Finding eV-scale Light Relics with Cosmological Observables.
Phys.Rev.D 103 2, 023504 (2021). ArXiv: 2006.09380.

25. **J. B. Muñoz** and F.Y. Cyr-Racine
Cosmic Variance of the 21-cm Global Signal.
Phys.Rev.D 103 2, 023512 (2021). ArXiv: 2005.03664.

26. R. Laha^, **J. B. Muñoz**^, and T. Slatyer^ **(^Alphabetical)**
INTEGRAL constraints on primordial black holes and particle dark matter.
Phys.Rev.D 101,123514 (2020). ArXiv: 2004.00627 – **INTEGRAL paper of the month** (>150 cit.)

27. Y. Qin, A. Mesinger, J. Park, B. Greig, and **J. B. Muñoz**
A tale of two sites I: Inferring the properties of minihalo-hosted galaxies from current observations.
MNRAS 495 1, 123 (2020) ArXiv: 2003.04442.

28. **J. B. Muñoz**, C. Dvorkin, and F.Y. Cyr-Racine
Probing the Small-Scale Matter Power Spectrum with Large-Scale 21-cm Data (>50 citations)
Phys.Rev. D 101, 063526 (2020). ArXiv: 1911.11144.

29. **J. B. Muñoz**, V. Ravi, and A. Loeb
Periodic Fast Radio Bursts from Young Neutron Stars.
ApJ 890 162 (2020), ArXiv: 1909.00004.

30. D. Jyoti, **J. B. Muñoz**, R. Caldwell, and M. Kamionkowski
Cosmic Time Slip: Testing Gravity on Supergalactic Scales with Strong-Lensing Time Delays
Phys.Rev. D 100, 043031 (2019). ArXiv: 1906.06324.

31. **J. B. Muñoz**
Robust Velocity-induced Acoustic Oscillations at Cosmic Dawn
Phys.Rev. D 100, 063538 (2019). ArXiv: 1904.07881 **– Editor's Choice.** (>50 citations)

32. C. Zeng, E.D. Kovetz, X Chen, Y. Gong**, J. B. Muñoz,** and M. Kamionkowski
Searching for Oscillations in the Primordial Power Spectrum with CMB and LSS Data
Phys.Rev. D 99, 043517 (2019). ArXiv: 1812.05105.

33. **J. B. Muñoz** and A. Loeb
Finding the Missing Baryons with FRBs and Sunyaev-Zeldovich Maps
Phys.Rev. D 98, 103518 (2018). ArXiv: 1809.04074.

34. **J. B. Muñoz** and C. Dvorkin
Efficient Computation of Galaxy Bias with Neutrinos and Other Relics.
Phys.Rev. D 98, 043503 (2018). ArXiv: 1805.11623.

35. **J. B. Muñoz,** C. Dvorkin and A. Loeb
21-cm Fluctuations from Charged Dark Matter.
Phys. Rev. Lett. 121, 121301 (2018). ArXiv: 1804.01092. (>80 citations)

36. A.M. Dizgah, H. Lee, **J. B. Muñoz** and C. Dvorkin
Galaxy Bispectrum from Massive Spinning Particles.
JCAP 1805, 013 (2018). ArXiv: 1801.07265. (>50 citations)

37. **J. B. Muñoz** and A. Loeb
Constraints on Dark Matter-Baryon Scattering from the Temperature Evolution of the Intergalactic Medium.
JCAP 1711, 043 (2017). ArXiv: 1708.08923.

38. **J.B. Muñoz** and M. Kamionkowski
Large-Distance Lens Uncertainties and Time-Delay Measurements of H_0.
Phys.Rev. D 96, 103537 (2017). ArXiv: 1708.08454.

39. T. L. Smith, **J.B. Muñoz**, R. Smith, K. Yee, and D. Grin
Baryons still trace dark matter: probing CMB lensing maps for hidden isocurvature.
Phys.Rev. D 96, 083508 (2017). ArXiv 1704.03461.

40. **J.B. Muñoz**, E. D. Kovetz, A. Raccanelli, M. Kamionkowski, and J. Silk
Towards a measurement of the spectral runnings.
JCAP 1705, 032 (2017). ArXiv 1611.05883. (>50 citations)

41. P.D. Meerburg, M. Münchmeyer, **J.B. Muñoz**, and X. Chen
Prospects for Cosmological Collider Physics.
JCAP 1703, 050 (2017). ArXiv: 1610.06559. (>90 citations)

42. I. Cholis, E.D. Kovetz, Y. Ali-Haïmoud, S. Bird, M. Kamionkowski
J.B. Muñoz, and A. Raccanelli.
Orbital eccentricities in primordial-black hole binaries.
Phys. Rev. D 94, 084013 (2016). ArXiv: 1606.07437. (>100 citations)

43. A. Raccanelli, E.D. Kovetz, S. Bird, I. Cholis, and **J.B. Muñoz**
Determining the progenitors of merging black-hole binaries.
Phys. Rev. D 94, 023516 (2016). ArXiv: 1605.01405. (>50 citations)

44. M. Shiraishi, **J.B. Muñoz**, M. Kamionkowski, and A. Raccanelli
Violation of statistical isotropy and homogeneity in the 21-cm power spectrum.
Phys.Rev. D 93, 103506 (2016) . ArXiv: 1603.01206.

45. S. Bird, I. Cholis, **J.B. Muñoz**, Y. Ali-Haïmoud, M. Kamionkowski, E.D. Kovetz, A. Raccanelli, and A.G. Riess.
Did LIGO detect dark matter?
Phys. Rev. Lett. 116, 201301 (2016). ArXiv: 1603.00464 – **Featured in Physics.** (>950 citations)

46. **J.B. Muñoz**, D. Grin, L. Dai, M. Kamionkowski, and E.D. Kovetz
Search for Compensated Isocurvature Perturbations with Planck Power Spectra.
Phys.Rev. D 93, 043008 (2016). ArXiv: 1511.04441.

47. **J.B. Muñoz**, E.D. Kovetz, and Y. Ali-Haïmoud
Heating of Baryons due to Scattering with Dark Matter During the Dark Ages.
Phys.Rev. D 92, 083528 (2015). ArXiv: 1509.00029. (>125 citations)

48. **J.B. Muñoz**, Y. Ali-Haïmoud, and M. Kamionkowski
Primordial non-gaussianity from the bispectrum of 21-cm fluctuations in the dark ages.
Phys.Rev. D 92, 083508 (2015). Arxiv: 1506.04152 – **Editor's Choice.** (>90 citations)

49. **J.B. Muñoz** and M. Kamionkowski
Equation-of-State Parameter for Reheating.
Phys.Rev. D 91, 043521 (2015). ArXiv: 1412.0656. (>150 citations)

50. **J. Muñoz-Bermejo**, A. Asensio Ramos, and C. Allende Prieto
A PCA approach to stellar effective temperatures.
Astronomy & Astrophysics 553, A95 (2013). ArXiv: 1303.7218. (Undergraduate project as summer intern at the Instituto Astrofísico de Canarias.)

Selected white papers
Snowmass 2021-23

1. A. Drilica-Wagner et al. (including **J.B. Muñoz**)
Report of the Topical Group on Cosmic Probes of Dark Matter for Snowmass (arXiv: 2209.08215).
2. K. Boddy et al. (including **J.B. Muñoz**)
Astrophysical and Cosmological Probes of Dark Matter (arXiv: 2203.06380).
3. K. Bechtol et al. (including **J.B. Muñoz**)
Dark Matter Physics from Halo Measurements (arXiv: 2203.07354).
4. M. Alvarez et al. (including **J.B. Muñoz**)
Cosmological Simulations and Modeling (arXiv: 2203.07347).
5. C. Dvorkin et al. (including **J.B. Muñoz**)
The Physics of Light Relics (arXiv: 2203.07943).
6. S. Bird et al. (including **J.B. Muñoz**)
Primordial Black Hole Dark Matter (arXiv: 2203.08967).
7. S. Aiola et al. (including **J.B. Muñoz**)
CMB-HD White Paper (arXiv: 2203.05728).

Astro2020 (Decadal)

8. V. Ravi et al. (including **J.B. Muñoz**)
Fast Radio Burst Tomography of the Unseen Universe (arXiv:1903.06535).
9. A. Liu et al. (including **J.B. Muñoz**)
Cosmology with the Highly Redshifted 21cm Line (arXiv:1903.06240).
10. S. Furlanetto et al. (including **J.B. Muñoz**)
Fundamental Cosmology in the Dark Ages with 21-cm Line Fluctuations (arXiv:1903.06240).
11. V. Gluscevic et al. (including **J.B. Muñoz**)
Cosmological Probes of Dark Matter Interactions: The Next Decade (arXiv:1903.05140).
12. C. Dvorkin et al. (including **J.B. Muñoz**)
Neutrino Mass from Cosmology: Physics Beyond the Standard Model (arXiv:1903.03689).
13. J.O. Burns et al. (including **J.B. Muñoz**)
Dark Cosmology: Dark Matter & Exotic Physics in the Dark Ages using 21-cm (arXiv:1902.06147).

Others:

14. A. Loeb and **J.B. Muñoz**
The First Stars May Shed Light on Dark Matter (Invited viewpoint for PRL, arXiv:1807.01531).
15. K.A. Abazajian et al. (including **J.B. Muñoz,** I lead one of the parameter-forecasting teams)
CMB-S4 Science Book, First Edition (arXiv:1610.02743).