

Debnandini Mukherjee

POSTDOCTORAL RESEARCH ASSISTANT

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Main Research interest

Gravitational wave physics and data analysis: Analysis of Advanced LIGO-Virgo data to search for gravitational waves from black holes and other compact objects in binary systems and using such observations to enrich our knowledge of astrophysics. Also, development of low-latency searches for massive black holes and early warning systems for their multi-messenger observations, for the upcoming LISA mission.

Education

PhD. Physics

University of Wisconsin-Milwaukee, USA

LEONARD E PARKER CENTER FOR GRAVITATION COSMOLOGY & ASTROPHYSICS (CGCA)

August 2012 - May 2018

- Advisor: Dr. Patrick R. Brady
- Dissertation: Search for compact object coalescences and understanding their significance using data from Advanced LIGO
- Area of study: Gravitational wave physics and data analysis
- key achievements: Helped develop the IMBH search in O1 with LIGO and analysed data for O1, Designed the all-sky template bank for O2 and analysed data for the LIGO-Virgo GstLAL pipeline, Developed IMBH search for the LIGO GstLAL pipeline for O2, investigation of compact object population distributions in proposed mass gaps, helped with astrophysical rate computations for GWs including GW170817

Master of Science (M.Sc), Physics

Delhi, India

UNIVERSITY OF DELHI

July 2009 - June 2011

Bachelor of Science (B.Sc), Honours, Physics

Delhi, India

UNIVERSITY OF DELHI

July 2006 - June 2009

Work

Postdoctoral Research Assistant, Physics

University of Alabama Huntsville &

NASA-Marshall Space Flight Center

THE CENTER FOR SPACE PLASMA AND AERONOMIC RESEARCH (CSPAR)

August 2021 - Present

- Supervisor: Dr. Tyson Littenberg
- Projects: Development of a low-latency search for gravitational waves from massive black holes for the LISA mission and setting up an early warning alert system for such mergers. Development of matched filter based searches for LIGO-Virgo-KAGRA data analysis, with emphasis on intermediate mass black holes (IMBHs).
- Area of study: Gravitational wave physics and data analysis
- achievements: Development of early warning search pipeline for LISA massive black holes, Designing of IMBH search for the LIGO GstLAL pipeline for O4

Postdoctoral Scholar, Physics

INSTITUTE FOR GRAVITATION AND THE COSMOS (IGC)

Pennsylvania State University, USA

July 2019 - August 2021

- Supervisor: Dr. Chad Hanna
- Project: Search for gravitational waves from Intermediate Mass Black Hole (IMBH) Binaries, early warning detection of binary neutron star mergers and real-time data quality inference
- Area of study: Gravitational wave physics and data analysis
- achievements: Development of early warning search pipeline for O3 for LIGO-Virgo, Developed IMBH search for the LIGO GstLAL pipeline for O3, co-chaired IMBH search group within LIGO-Virgo, analysed LIGO-Virgo O3 data and served as author and paper manager of IMBH O3 all-sky search paper

Postdoctoral Fellow, Physics

INDIAN INSTITUTE OF TECHNOLOGY (IIT)-BOMBAY

Mumbai, India

January 2019 - June 2019

- Supervisor: Dr. Archana Pai
- Project: Search for gravitational waves from Intermediate Mass Black Hole (IMBH) Binaries
- Area of study: Gravitational wave physics and data analysis
- achievements: Developed IMBH search for the LIGO GstLAL pipeline for O2, analysed LIGO-Virgo O2 data and served as author of IMBH O2 all-sky search paper

Research Experience

LIGO-Virgo-KAGRA Collaboration

MEMBER

LVK Collaboration

Dec 2014 - Present

- Main working groups: Compact Binary Coalescence (CBC), Gstreamer and LIGO Algorithm Library based search (GstLAL), Intermediate Mass Black hole Binary (IMBHB) search group, Rates and populations
- **IMBHB (CBC) chair** (May 2019 - July 2021)

Template bank based offline search for gravitational waves

(GstLAL)

GstLAL group, LIGO

Oct 2015 - Present

- Analysis of data from the 1st observation run (O1) and 2nd observation run (O2) of LIGO-Virgo and improvement of the search for the third observing run (O3)

Search for Intermediate Mass Black Hole Binaries

(IMBH SEARCH)

IMBH group, LIGO-Virgo

Dec 2015 - Present

- Searching advanced LIGO-Virgo data for intermediate mass binaries, improving the search by including precession and contributions from higher order modes and finding astrophysical distributions of IMBHs.

Estimation of astrophysical Rates and Populations

Rates + GstLAL groups, LIGO-Virgo

Feb 2017--Present

- Calculating rates of detections of binary coalescences, and using such to constrain theoretically predicted astrophysics.

LISA Consortium

MEMBER

NASA (LISA Mission)

June 2022 - Present

- Developing a low-latency search pipeline to detect gravitational wave signals from massive black hole binaries and an early alert system for multi-messenger observations of such sources.

Relevant Skills

Programming Languages: Python, C, C++, Pascal

Experience with using and improving data analysis packages and pipelines used by LIGO. Also experience with LATE χ and Git.

Outreach and services

Public Outreach activities :

- As a member of Coffee Shop Astrophysics at UW Milwaukee, helped prepare and give a number of astro-related public talks.
- Astro Break Talks: Talks given at the Manfred Olson Planetarium (UW Milwaukee).
- Astro club : 20 minute talks given to an audience of undergraduate physics majors.
- LIGO-India Outreach Week - Vigyan Samagam, Nehru Science Centre - May 27 to June 02, 2019. Talk: "Things we have seen in gravitational waves!! Search for compact object coalescences and their interpretation using Advanced LIGO-Virgo"
- Gravitational Wave summer camp - Penn State - June 22 to June 24, 2021: Helped organize the summer camp and gave talks/lessons to the participating local high school students. This was organized in collaboration with Sci-U, the science education and outreach group on campus.
- The International Space Weather Camp (ISWC) - July 17, 2023: Talk "Searching for giants and dwarves: searches for compact objects"
- Rural enrichment talk in India organized by Cheenta Academy for Gifted Students - January 27, 2024: An online outreach talk delivered mainly to rural, underprivileged school students in West Bengal, India "Searching for giants and dwarves: a tale of searches for compact objects"

Reviews:

- LIGO PnP Review of Impact of eccentricity on the gravitational wave searches for binary black holes: High mass case (Antoni Ramos-Buades et al.)
- LIGO PnP Review of Targeted Sub-threshold Search for Strongly-lensed Gravitational-wave Events (Alvin K. Y. Li et al.)

Other Services:

- APS (American Physical Society) Conference of Undergraduate Women in Physics (CuWIP) January 20 - 22, 2023. Panel and speaker for "How to navigate male-dominated spaces"
- During my postdoc at Penn State, I have been part of PAW+ (Physics and Astronomy for Women and other minorities), a group dedicated to motivate diversity and representation in Physics
- I have also played an active role at conferences in organizing events beneficial to students (for example, a career counseling workshop organized in Aspen winter conference 2022).
- part of Women in Physics lunch meetings group at University of Wisconsin Milwaukee (2017)
- Guest at radio program on women in STEM directed at high school girls (station KDNK, Carbondale, Colorado at 4:30 MST, Jan 25, 2022)
- Poster judge for Postdoc Appreciation Week 2019 at Penn State

Selected Honours and Awards

Physics Research Excellence Award

UNIVERSITY OF WISCONSIN MILWAUKEE

Milwaukee

Aug 2012--May 2018

Special Breakthrough Prize in Fundamental Physics

December 4, 2016

Awarded to the members of the LIGO-Virgo collaboration who were part of the team responsible for the first ever detection of gravitational waves

Gruber Cosmology Prize

July 2016

Awarded to the members of LIGO-Virgo collaboration who were part of the team responsible for the first ever detection of gravitational waves

Teaching Experience

Art and Science of Teaching Physics

Physics 610

PEDAGOGICAL TRAINING

Fall 2012

- Course on teaching physics

General Physics Laboratory I

Physics 121

TEACHING ASSISTANT

Fall 2012 - Summer 2013, Spring 2014 - Fall 2015

- Non-calculus Lab

Physics for health professionals

Physics 110

TEACHING ASSISTANT

Fall 2013

- Discussion session

Lab Physics I

Physics 214

TEACHING ASSISTANT

Spring 2017, Fall 2017

- Calculus-based Lab

Conferences, presentations, meetings and invited talks

Gravitational waves and LIGO

Marquette University, Milwaukee

INVITED TALK

March 2017

Talk given to a class of physics undergraduates

Listening to the Universe with Gravitational Waves!

SINP, Kolkata

INVITED TALK

September 2018

Searching for the Giants: Search for Intermediate Mass Black Holes in the 3rd Observing Run of Advanced LIGO-Virgo

KAGRA International Workshop (KIW8-virtual)

INVITED TALK

July 7-9, 2021

Of Giants and Dwarfs: A Template-based Search for Intermediate Mass Binaries and Other Stories

MIT/Caltech LIGO Labs Seminar

INVITED TALK

February 18, 2021

Gravitational Wave Physics and Astronomy Workshop (GWPAW)

TALK

Cape Cod, MA

June 2016

- Searching for intermediate mass black hole binaries using Advanced LIGO

American Physical Society April Meeting (APS April 2017)

TALK

Washington DC

January 2017

- Towards an extended binary black hole search using advanced LIGO: from stellar to intermediate mass

Global Relay of Observatories Watching Transients Happen (GROWTH)

TALK

Milwaukee, WI

October 2017

- Using data from Advanced LIGO to make astrophysical statements: what the search for compact objects have to say

Graduate Student Research Symposium for Math, Engineering and the Natural Sciences

TALK

Milwaukee, WI

October 2016

- Search for gravitational waves using advanced LIGO

LIGO-Virgo Collaboration March/September meeting (LVC-meeting)-2020

TALK

Zoom

March, September 2020

- Update on GstLAL preparation for IMBH search in O3

American Physical Society April Meeting (APS April 2020)

TALK

online presentation

April Virtual meeting 2020

- A Template Based Search for Intermediate Mass Black Hole Binaries: Advanced LIGO-Virgo in its 3rd observing run

American Physical Society April Meeting (APS April 2021)

TALK

online presentation

April Virtual meeting 2021

- A Template Based Search for GW190521 and other Intermediate Mass Black Hole Binaries

Aspen Winter Conference on GW Sources

TALK

Aspen Center For Physics, Aspen, CO

January 2022

- Searching for the Giants: Search for Intermediate Mass Black Holes in the 3rd Observing Run of Advanced LIGO-Virgo

LISA symposium 2022

TALK

virtual

July 2022

- Towards Early Alerts for the Giants: developing a low-latency search for LISA massive black holes

APS April 2023

TALK

Minneapolis, MN

April 2023

- Early warning search for LISA massive black holes

3 Minute Thesis Competition

3 MINUTE TALK

Milwaukee, WI

April 2018

- Listening to the Universe Using Gravitational Waves detected by LIGO

Postdoc Appreciation Week

VIRTUAL LIGHTNING TALK

Penn State

September 2020

- Finding Gargantuan Black Holes Using Gravitational Waves

LIGO-Virgo Collaboration March meeting (LVC-meeting)-2017

POSTER

Pasadena, CA

March 2017

- Source-dependent template-weighting methods to evaluate compact binary coalescence rates
- presented by Debnandini Mukherjee, Shasvath Kapadia, Heather Fong

LIGO-Virgo Collaboration March meeting (LVC-meeting)-2018

POSTER

Sonoma, CA

March 2018

- Does the Supernova (SN) Mass Gap Really Exist? Using data from advanced LIGO to inspect the limits of the hypothesized SN mass gap
- presented by Debnandini Mukherjee, prepared in consultation with Shasvath Kapadia, Jolien Creighton, Sarah Caudill, others

American Astronomical Society Virtual Meeting (AAS January 2021)

IPOSTER

online presentation

Virtual meeting 2021

- A Template-based Search for GW190521 and other Intermediate Mass Black Hole Binaries

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IPOSTER

online presentation

Virtual meeting, July 2021

- A Template-based Search for Intermediate Mass Black Hole Binaries in LIGO-Virgo's 3rd Observation Run

Physics and Astrophysics at the Extreme III (PAX III) meeting

MEETING

State College, PA

February 2018

- Organized at the Penn State University

Physics and Astrophysics at the Extreme IV (PAX IV) meeting

MEETING

Pune, India

August 2018

- Organized at IUCAA, India

GstLAL Face to Face

FACE TO FACE MEETING

State College, PA

February 2018

- Organized at The Penn State University

GstLAL Face to Face

FACE TO FACE MEETING

Pasadena, CA

May 2022

- Organized at Caltech

Low latency boot camp

EM FOLLOW-UP

Boston, MA

September 30 - October 04, 2019

- Organized at MIT

References Available to Contact

Dr. Tyson Littenberg

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PHONE: 2569617833

Research Astrophysicist

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Dr. Jolien Creighton

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UW-MILWAUKEE, KENWOOD INTERDISCIPLINARY RESEARCH COMPLEX, ROOM 4077, 3135 N
MARYLAND AVE, MILWAUKEE, WI 53211, PHONE: 4142292907

Professor CGCA

✉ jolien.creighton@ligo.org

Dr. Chad Hanna

PENN STATE, 104 DAVEY LAB 253 UNIVERSITY PARK, PA 16802, PHONE: (814) 865-2924

*Assistant Professor of Physics & Astronomy
and Astrophysics*

✉ crh184@psu.edu

Dr. Patrick Brady

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UW-MILWAUKEE, KENWOOD INTERDISCIPLINARY RESEARCH COMPLEX, ROOM 4160, 3135 N
MARYLAND AVE, MILWAUKEE, WI 53211, PHONE: 4142296508

Professor & Director CGCA

✉ patrick.brady@ligo.org

Publications

SHORT AUTHOR LIST PAPERS:

- Debnandini Mukherjee, Sarah Caudill, et al. Template bank for spinning compact binary mergers in the second observation run of Advanced LIGO and the first observation run of Advanced Virgo , *arXiv:1812.05121v2 [astro-ph.IM]*, *Phys. Rev. D* 103, 084047 (2021), <https://doi.org/10.1103/PhysRevD.103.084047>
- Debnandini Mukherjee et al. A low-latency search pipeline for LISA massive black holes to send out early alerts for electromagnetic follow up, *draft under progress*
- Debnandini Mukherjee et al. A template-based search for intermediate mass black holes in LIGO-Virgo's 4th observing run, *draft under progress*
- Surabhi Sachdev,...,Debnandini Mukherjee, et al. The GstLAL Search Analysis Methods for Compact Binary Mergers in Advanced LIGO's Second and Advanced Virgo's First Observing Runs , *arXiv:1901.08580 [gr-qc]*
- Chad Hanna,...,Debnandini Mukherjee, et al. Fast evaluation of multi-detector consistency for real-time gravitational wave searches , *arXiv:1901.02227 [gr-qc]*, *Phys. Rev. D* 101, 022003 (2020), <https://doi.org/10.1103/PhysRevD.101.022003>
- Ryan Magee,...,Debnandini Mukherjee, et al. Sub-threshold binary neutron star search in Advanced LIGO'S first observing run , *arXiv:1901.09884 [gr-qc]*, *Ryan Magee et al 2019 ApJL* 878 L17, <https://doi.org/10.3847/2041-8213/ab20cf>
- Shasvath J. Kapadia,...,Debnandini Mukherjee, et al. A self-consistent method to estimate the rate of compact binary coalescences with an Poisson mixture model , *arXiv:1903.06881 [astro-ph.HE]*, *Shasvath J Kapadia et al 2020 Class. Quantum Grav.* 37 045007, <https://doi.org/10.1088/1361-6382/ab5f2d>
- Patrick Godwin,...,Debnandini Mukherjee, et al. Incorporation of Statistical Data Quality Information into the GstLAL Search Analysis , *arXiv:2010.15282 [gr-qc]*
- Surabhi Sachdev,...,Debnandini Mukherjee, et al. An early warning system for electromagnetic follow-up of gravitational-wave events , *arXiv:2008.04288 [astro-ph.HE]*, *Surabhi Sachdev et al 2020 ApJL* 905 L25, <https://doi.org/10.3847/2041-8213/abc753>
- Kipp Cannon,...,Debnandini Mukherjee, et al. GstLAL: A software framework for gravitational wave discovery , *arXiv:2010.05082 [astro-ph.IM]*, <https://doi.org/10.1016/j.softx.2021.100680>
- Chiwai Chan,...,Debnandini Mukherjee, et al. Improving the background estimation technique in the GstLAL inspiral pipeline with the time-reversed template bank , *arXiv:2009.03025 [astro-ph.IM]*
- Cody Messick,...,Debnandini Mukherjee, et al. Automating the Inclusion of Subthreshold Signal-to-Noise Ratios for Rapid Gravitational-Wave Localization , *arXiv:2011.02457 [astro-ph.IM]*
- Sio Sakon,...,Debnandini Mukherjee, et al. Template bank for compact binary mergers in the fourth observing run of Advanced LIGO, Advanced Virgo, and KAGRA , *arXiv:2211.16674 [gr-qc]*
- Leo Tsukada,...,Debnandini Mukherjee, et al. Improved ranking statistics of the GstLAL inspiral search for compact binary coalescences , *arXiv:2305.06286 [astro-ph.IM]*, *Leo Tsukada et al. Phys. Rev. D* 108, 043004 – Published 3 August 2023, <https://doi.org/10.1103/PhysRevD.108.043004>
- Becca Ewing,...,Debnandini Mukherjee, et al. Performance of the low-latency GstLAL inspiral search towards LIGO, Virgo, and KAGRA's fourth observing run, *arXiv:2305.05625 [gr-qc]*
- Chad Hanna,...,Debnandini Mukherjee, et al. Binary tree approach to template placement for searches for gravitational waves from compact binary mergers , *arXiv:2209.11298 [gr-qc]*, *Chad Hanna et al. Phys. Rev. D* 108, 042003 – Published 14 August 2023, <https://doi.org/10.1103/PhysRevD.108.042003>

MAJOR CONTRIBUTIONS TO COLLABORATION-WIDE (LVK) PAPERS

- B.P Abbot,...D. Mukherjee, et al. GW170817: Observation of Gravitational Waves from a Binary Neutron Star *Inspirals* *Phys. Rev. Lett.* 119, (2017) 161101 : Calculation of astrophysical rate of Binary Neutron Stars (sec. V, A)
- Helped with the gstreamer based GstLAL offline search over Advanced LIGO's 1st, 2nd and 3rd observation run data. Also helped with improvements in search template banks and mechanisms. This contributes to a number of collaboration wide papers, including the ones declaring discovery of events and the GW catalogs (select few of which are listed below).
- B.P Abbot,...D. Mukherjee, et al. Search for intermediate mass black hole binaries in the first and second observing runs of the Advanced LIGO and Virgo network *Phys. Rev. D* 100, 064064 : Helped with the rates analysis runs for IMBHB search paper for O1-O2.
- B.P Abbot,...D. Mukherjee, et al. GW190521: A Binary Black Hole Merger with a Total Mass of $150 M_{\odot}$ *Phys. Rev. Lett.* 125, 101102 (2020) : GstLAL Analysis for IMBH O3 event discovery paper
- B.P Abbot,...D. Mukherjee, et al. Search for intermediate mass black hole binaries in the third observing run of Advanced LIGO and Advanced Virgo *AA* 659, A84 (2022), *arXiv:2105.15120 [astro-ph.HE]* : part of the paper writing team, paper co-manager and conducted the GstLAL Analysis (as lead) for IMBH O3 all sky paper

SELECTED LIST OF OTHER COLLABORATION-WIDE (LVK) PAPERS

- B.P Abbot,...D. Mukherjee, et al. GWTC-3: Compact Binary Coalescences Observed by LIGO and Virgo During the Second Part of the Third Observing Run, *arXiv:2111.03606 [gr-qc]*
- B.P Abbot,...D. Mukherjee, et al. GWTC-2: Compact Binary Coalescences Observed by LIGO and Virgo During the First Half of the Third Observing Run, *Phys. Rev. X* 9, 031040 (2019), *arXiv:2010.14527 [gr-qc]*
- B.P Abbot,...D. Mukherjee, et al. GWTC-1: A Gravitational-Wave Transient Catalog of Compact Binary Mergers Observed by LIGO and Virgo during the First and Second Observing Runs, *Phys. Rev. X* 9, 031040 (2019), *arXiv:1811.12907*
- B.P Abbot,...D. Mukherjee, et al. Search for sub-solar mass ultracompact binaries in Advanced LIGO's first observing run, *Phys. Rev. Lett.* 121, 231103 (2018)
- B.P Abbot,...D. Mukherjee, et al. GW170814: A Three-Detector Observation of Gravitational Waves from a Binary Black Hole Coalescence, *Phys. Rev. Lett.* 119, (2017) 141101
- B.P Abbot,...D. Mukherjee, et al. GW170104: Observation of a 50-Solar-Mass Binary Black Hole Coalescence at Redshift 0.2, *Phys. Rev. Lett.* 118, (2017) 221101
- B.P Abbot,...D. Mukherjee, et al. Search for intermediate mass black hole binaries in the first observing run of Advanced LIGO, *Phys. Rev. D* 96, 022001 (2017)
- B.P Abbot,...D. Mukherjee, et al. Upper limits on the rates of binary neutron star and neutron star - black hole mergers from Advanced LIGO's first observing run, *Astrophys. J. Lett.* 832, L21 (2016)
- B.P Abbot,...D. Mukherjee, et al. The basic physics of the binary black hole merger GW150914, *Annalen der Physik* 529, 1600209 (2017)
- B.P Abbot,...D. Mukherjee, et al. Binary black hole mergers in the first Advanced LIGO observing run, *Phys. Rev. X* 6, 041015 (2016)
- B.P Abbot,...D. Mukherjee, et al. GW151226: Observation of Gravitational Waves from a 22-Solar-Mass Binary Black Hole Coalescence, *Phys. Rev. Lett.* 116, 241103 (2016)
- B.P Abbot,...D. Mukherjee, et al. Observation of Gravitational Waves from a Binary Black Hole Merger, *Phys. Rev. Lett.* 116, 061102 (2016)
- B.P Abbot,...D. Mukherjee, et al. GW150914: First results from the search for binary black hole coalescence with Advanced LIGO, *Phys. Rev. D* 93, 122003 (2016)

- B.P Abbot,...D. Mukherjee, et al. Astrophysical Implications of the Binary Black-Hole Merger GW150914, *Astrophys. J. Lett.* 818, L22 (2016)
- B.P Abbot,...D. Mukherjee, et al. The rate of binary black hole mergers inferred from Advanced LIGO observations surrounding GW150914, *Astrophys. J. Lett.* 833, L1 (2016)