Curriculum Vitae

Swetha Bhagwat

EPSRC Stephen Hawking Fellow
University of Birmingham
Edgbaston, Birmingham
United Kingdom B15 2SQ

Email : infn.swethabhagwat@gmail.com

Research Interests - Gravitational Wave Physics and astrophysics, Tests of fundamental physics using gravitational wave observations, General Theory of Relativity; Astrophysical Interpretation with Gravitational Wave; Black-Hole & Neutron Star Physics; Primordial black holes; Testing Strong Gravity with Observations; LIGO Data Analysis; Development of Waveform and Analysis Tools for LISA/3G Gravitational Wave Detectors; Testing GR with LISA Data; Application of Machine Learning to Gravitational Waves Data Analysis; Bias in parameter inference due to signal and noise models; Understanding Fundamental Interactions with Neutron Star Observations and Black-Hole Ringdown; Numerical Relativity & its Interface with the Gravitational Waves; Gravitational Waveform Source Modelling; Black-Hole Perturbation Theory;.

References -

1. Prof Duncan Brown (*Syracuse University*) dabrown@syr.edu
2. Prof Paolo Pani (*La Sapienza University of Rome*) paolo.pani@uniroma1.it
3. Patricia Schmidt (*University of Birmingham*) pschmidt@star.sr.bham.ac.uk
4. Prof Stefan Ballmer (*Syracuse University*) sballmer@syr.edu

Education and Academic Positions

- **EPSRC Stephen Hawking Fellow** **Mar 2022 - ongoing**
  University of Birmingham, Edgbaston, Birmingham, United Kingdom, B15 2SQ
- **Postdoctoral researcher** **Mar 2019 - Mar 2022**

  Department of Physics, Sapienza University of Rome, Rome, Italy
  Research Group: Member of the DarkGRA project, led by Prof. Paolo Pani
- **Doctor of Philosophy in Physics (Ph.D)** **Aug 2013 - Mar 2019**

  Department of Physics, Syracuse University, New York, USA
  Advisor: Prof. Duncan Brown
  PhD Thesis Title : Towards probing the strong field gravity using binary black-hole ringdowns
- **Integrated Bachelors and Masters of Science (BS-MS)** **May 2008 - Jul 2013**

Indian Institute of Science Research and Education (IISER), Pune, India
Host for Thesis: Inter-University Centre for Astronomy and Astrophysics (IUCAA), Pune, India
Advisors: Prof. Sanjeev Dhurandhar & Prof. Sanjit Mitra
Master's Thesis Title : Data analysis techniques in gravitational wave astronomy

Memberships in Scientific Collaboration

- **Core member of the LISA consortium** **2019 - ongoing**
  Working Group: Fundamental Science with LISA
- **Member of the ET OSB** **2021 - ongoing**
  Key Areas: Fundamental Science with ET
- **Core member of LIGO Scientific Collaboration (LSC)** **2013 - 2018**
  Source waveform modelling and data analysis of CBC signals
- Associated to the IndIGO consortium (Indian Gravitational Wave efforts) **2014 - ongoing**

Awards

- Stephen Hawking Fellowship, 2022
- 2016 Special Breakthrough Prize in Fundamental Physics as a core member of LIGO Scientific Collaboration for the discovery of the first gravitational wave from binary black-hole system.
- 2016 Gruber Cosmology Prize as a core member of LIGO Scientific Collaboration, the discovery of the first gravitational wave from binary black-hole system.

Teaching and Mentoring Experiences

- Co-mentoring two 4th year students at University of Birmingham for their undergraduate the thesis project on 'Comparing various ringdown analysis pipelines'. **Fall of 2022**
- Leading and designing a 15 week citizen astronomy course within open science collective organisation called 'One Sky' **Summer of 2022**
- Astronomy-101: Our Corner of the Universe - Syracuse University in the **Fall of 2013**
- Astronomy-104: Stars, Galaxies and the Universe - Syracuse University in the **Summer of 2014**

Current Leadership Roles

- Leading the writing of Blue book section for science case of test of strong field gravity in ET consortium.
- Coordinator of Astronomy in the city for University of Birmingham

Publications

Short Author Publications

1. C. Pacilio., **S. Bhagwat** *Identifying modified theories of gravity using binary black-hole ringdowns* (This manuscript is submitted in Physical Review D (PRD)) PrePrint: arXiv:2301.02267

2. X. J. Forteza, **S. Bhagwat**, S. Kumar, P. Pani *A novel ringdown amplitude-phase consistency test* Phys. Rev. Letters, 130.021001

3. **S. Bhagwat**, C. Pacilio., E. Barausse, P. Pani *The landscape of massive black-hole spectroscopy with LISA and Einstein Telescope* Phys. Rev. D 105, 124063

4. **S. Bhagwat**, C. Pacilio. *Merger-Ringdown Consistency: A New Test of Strong Gravity using Deep Learning .* Phys. Rev. D 104, 024030

5. **S. Bhagwat**, V. De Luca, G. Franciolini, P. Pani and A. Riotto. *The Importance of Priors on LIGO-Virgo Parameter Estimation: the Case of Primordial Black Holes.* JCAP: 10.1088/1475-7516/2021/01/037

6. X. J. Forteza, **S. Bhagwat**, P. Pani and V. Ferrari. *On the spectroscopy of binary black hole ringdown using overtones and angular modes.* Phys. Rev. D 102, 044053

7. **S. Bhagwat**, X. Forteza, P. Pani, V. Ferrari. *Ringdown overtones, black hole spectroscopy and, no-hair theorem tests.* Phys.Rev.D 101 (2020) 4, 044033

8. **S. Bhagwat**, M. Cabero, C. D. Capano, B. Krishnan, D. A. Brown. *Detectability of the subdominant mode in a binary black hole ringdown.* Phys.Rev.D 102 (2020) 2, 024023

9. E. Maggio, A. Testa, **S. Bhagwat**, P. Pani *Analytical model for gravitational-wave echoes from spinning remnants.* Phys.Rev.D 100 (2019) 6, 064056

10. S. Panda, **S. Bhagwat**, J. Suresh, S. Mitra *Stochastic gravitational wave background mapmaking using regularised deconvolution.* Phys.Rev.D 100 (2019) 4, 043541

11. **S. Bhagwat**, M Okounkova, S. W. Ballmer, D. A. Brown, M Giesler, S. Sheel and S. Teukolsky. *On choosing the start time of binary black hole ringdown.* Phys.Rev.D 97 (2018) 10, 104065

12. **S. Bhagwat**, D. A. Brown, and S. W. Ballmer. *Spectroscopic analysis of stellar mass black-hole mergers in our local universe with ground-based gravitational wave detectors.* Phys.Rev.D 94 (2016) 8, 084024, Phys.Rev.D 95 (2017) 6, 069906 (erratum)

13. P. Kumar, K. Barkett, **S. Bhagwat**, N. Afshari, D. A. Brown, G. Lovelace, M. A. Scheel, and B. Szilagyi. *Accuracy and precision of gravitational-wave models of inspiraling neutron star-black hole binaries with spin: Comparison with matter-free numerical relativity in the low-frequency regime.* Phys.Rev.D 92 (2015) 10, 102001

14. T. Dal Canton, **S. Bhagwat**, S. V. Dhurandhar, and A. Lundgren. *Effect of sine-Gaussian glitches on searches for binary coalescence.* Class.Quant.Grav. 31 (2014) 015016

Authorships & substantial contributions towards LISA consortium Publications:

- *Prospects for Fundamental Physics with LISA* arXiv:2001.09793
- *New Horizons for Fundamental Physics with LISA* arXiv:2205.01597

Authorships & substantial contributions towards ET Observational Science Board:

- *COBA: Cost-benefit analysis for Einstein Telescope configurations. (document in internal review)*
- *Blue-book for science case with Einstein Telescope. (document in prep)*

Authorships and substantial contributions towards LIGO Scientific Collaboration Papers

Contributing to the LSC collaboration as a core member, I am a co-author of all the publication produced by the LSC collaboration from 2013 till 2018 including the first detection of Gravitational Wave from binary black holes system, *Phys. Rev. Lett. 116, 061102 (2016)* and from binary neutron star system, *Phys. Rev. Lett. 119, 161101 (2017)*. I have co-authored $\sim$ 80 papers in this duration and I have worked extensively in the LIGO-Virgo collaboration leading efforts in gravitational wave data analysis during LIGO's first few gravitational wave detections. Here is a list of my responsibilities/contributions within the LIGO Scientific collaboration.

- Developed and performed the residue test on GW150914 data, a version of which was later adapted as fig 1 in GW150914 discovery paper.
- Active team member of code-developers for one of LIGO's major data analysis and search pipelines called `PyCBC`.
- Responsible for implementation of family of binary black hole signal models into LIGO analysis library (*specifically, time-domain post-newtonian waveforms — Taylor-T4 and T2*) and for reviewing binary neutron star signal models implementations (*like SEOBNRv4 and Taylor-F2 tidal*), which were/are being used in parameter estimation of GW events by the LVK collaboration.
- Active contributors towards modules in the post-merger singal (ringdown) analysis used for BH spectroscopy within the `PyCBC` code repository.
- Led studies towards effects of data conditioning on the analysis pipelines.
- Performed many outreach activities for the collaboration during the discovery era.

Some seminal papers I have co-authored –

- *Observation of Gravitational Waves from a Binary Black Hole Merger* , Phys. Rev. Lett. 116, 061102 (2016)
- *Tests of General Relativity with GW150914*, Phys. Rev. Lett. 116, 221101 (2016)
- *Properties of the Binary Black Hole Merger GW150914*, Phys. Rev. Lett. 116, 241102 (2016)
- *Astrophysical Implications of the Binary Black-Hole Merger GW150914*, Astrophys. J. Lett. 818, L22 (2016)
- *GW151226: Observation of Gravitational Waves from a 22-Solar-Mass Binary Black Hole Coalescence* , Phys. Rev. Lett. 116, 241103 (2016)
- *GW170608: Observation of a 19 Solar-mass Binary Black Hole Coalescence* , Astrophys. J. Lett. 851, L35
- *GW170817: Observation of Gravitational Waves from a Binary Neutron Star Inspiral*, Phys. Rev. Lett. 119, 161101 (2017)
- *Multi-Messenger Observations of a Binary Neutron Star Merger* , Astrophys. J. Lett. 848, L12 (2017)
- *GW170104: Observation of a 50-Solar-Mass Binary Black Hole Coalescence at Redshift 0.2* , Phys. Rev. Lett. 118, 221101 (2017)

Research Activities

Conference Organisation

- Organized the *Primordial Black Holes confront LIGO/Virgo data* workshop at the Sapienza University of Rome in Feb,2021.

Upcoming Research activities

- Colloquium on "Tests of Gravity" at University of Nottingham (early Nov) (Invited)

Invited Talks and Seminars

- *Black holes and gravitational wave*
  (Institute of Physics, Public Seminar)
  University of Birmingham, UK **Nov 2022**
- *Importance of Amplitude and phases in ringdown tests*
  (Invited Seminar)
  La Sapienza University of Rome, Italy **Oct 2022**
- *The massive black-hole spectroscopy with next generation detector*
  (Invited Colloquium)
  Inter-University Centre for Astronomy and Astrophysics (IUCAA), Pune, India **Dec 2021**
- *The landscape of massive black-hole spectroscopy with LISA*
  (Invited Talk)
  Online, Hosted by LISA consortium **Jan 2022**
- *Testing GR with LIGO and LISA*
  (Invited Seminar)
  Online, Hosted Bar-Ilan University **Sep 2021**
- *Merger-ringdown consistency test*
  (Invited Talk)
  Online, Hosted by Central European Institute for Cosmology and Fundamental Physics **May 2021**
- *Testing fundamental physics in the era of gravitational-wave astronomy*
  (Tenure Track Job Seminar)
  Online, Hosted by Goethe University Frankfurt **Mar 2020**
- *On ringdown overtones, black hole spectroscopy and no hair theorem tests*
  (Invited Talk)
  Max Planck Institute for Gravitational Physics (Albert Einstein Institute), Hannover **Oct 2019**
- *Gravitation waves from binary neutron stars*
  (Invited for Panel)
  Physics and Astrophysics at the Extreme (PAX), Pisa Italy **May 2019**
- *On the binary black hole ringdowns for testing gravity*
  (Invited Seminar)
  Inter-University Centre for Astronomy and Astrophysics (IUCAA), Pune, India **Oct 2018**
- *Ringdowns and strong gravity close to the event horizon*
  (Invited Colloquium)
  The Sapienza University of Rome **Apr 2018**
- *On the start time of binary black-hole ringdown*
  (Invited Seminar)
  Perimeter Institute, **Nov 2017**
- *Probing the strong gravity regime with black-hole ringdowns*
  (Invited Seminar)
  TAPIR seminar, Caltech **Sep 2017**
- *Ringdown and it's data analysis - An overview*
  (Invited for Panel)
  Physics and Astrophysics at the Extreme (PAX) Workshop, Nikhef, Netherlands, **Aug 2017**

Extended Academic Visits

- Max Planck Institute for Gravitational Physics (Albert Einstein Institute), Germany **Oct 2019**

- The Sapienza University of Rome, Italy **Oct-Nov 2018**
- Inter-University Center of Astronomy and Astrophysics, IUCAA, India **Aug-Sep 2018**
- Max Planck Institute for Gravitational Physics (Albert Einstein Institute), Germany **Feb 2018**
- California Institute of Technology **Sep 2017**

Contributed Talks in Conferences

- *Ringdown modelling and test of GR with future detectors*
  Black holes, gravitational waves and fundamental physics (GWverse) **May 2021**
- *About the modes and tones of black hole ringdowns*
  The 13th International LISA Symposium **Sep 2020**
- *On black hole spectroscopy using binary black hole ringdown*
  3rd meeting of the GWVerse COST action **Jan 2019**
- *Ringdown overtones and black hole spectroscopy*
  Texas 2019: Symposium on Relativistic Astrophysics **Dec 2019**
- *Multimodal analysis with Binary Black hole ringdowns*
  Amaldi-GR22 conference **Jul 2019**
- *Spectroscopic analysis of stellar mass black-hole mergers with ground-based gravitational wave detectors*
  APS April Meeting, 2017, Washington DC **Jan 2017**
- *Prospects of Spectroscopic Analysis of Black Hole Ringdown*
  Midwest Relativity Meeting, Perimeter Institute **Oct 2016**
- *Accuracy and precision of gravitational-wave models of inspiraling neutron star-black hole binaries with spin*
  APS April Meeting, 2016, Salt Lake City **Apr 2016**
- *Comparison of gravitational-wave models of inspiraling neutron star-black hole binaries*
  International Conference on Gravitation and Cosmology, Indian Institute of Science Education and Research, Mohali **Dec 2015**

Schools, Workshops and Conference Attended

- Machine Learning in GW search: g2net next challenges, University of Pisa **Sep 2022**
- BH Ringdown Workshop, Flatiron Institute **Feb 2022**
- PCCP Workshop Series : Bayesian Deep Learning for Cosmology and Gravitational Waves
  APC laboratory, Université de Paris **Mar 2020**
- The Future of Gravitational-Wave Astronomy
  International Centre for Theoretical Sciences **Aug 2019**
- The International School on Gravity from Earth to Space,
  University of Urbino **May 2019**
- Strong Gravity & Binary Dynamics with Gravitational Wave Observations, (StronG-BaD),
  Univ. of Mississippi **Feb 2017**
- Physics and Astrophysics at the Extreme (PAX) Workshop, State College, PA **Dec 2016**
- Unifying Tests of General Relativity Workshop, Caltech **Jul 2016**
- LSC-Virgo March 2016 Meeting, Pasadena, California **Mar 2016**
- Theoretical and Computational Astrophysics Networks (TCAN), Cornell University **Sep 2015**
- *Low mass ER6 analysis and software injection study*
  LSC-Virgo March 2015 Meeting, Pasadena, California **Mar 2015**
- *Accuracy and precision of gravitational-wave models of inspiraling neutron star-black hole binaries with spin*
  Numerical and Analytical Relativity & Data Analysis (NRDA), Cal. State., Fullerton **Aug 2014**

- Numerical Relativity School, International Centre for Theoretical Sciences (ICTS) **Jun 2013**
- Gravitational Wave Physics and Astronomy Workshop (GWPAW), Hannover **Jun 2012**
- Lecture series on gravitational wave data analysis, Joint workshop by IISER & IUCAA **Fall 2012**

Outreach Activities

- Leading and developing an online astronomy course called One Sky as a part of Open science collective to reach out to underprivileged high schools in developing countries.
- Leading the coordination of Astronomy in the city at Birmingham.
- Recently joined the editorial team of LIGO-magazine.
- Developing sci-art initiative including participating in 1^{st} and 2^{nd} International Gravitational Waves Outreach Group Meeting (IGRAV) in 2019 and 2020 with intentions to get better involved in Art and Science outreach working group.
- Have contributed to the organisation of Women in Physics day at the Sapienza University of Rome (2019)
- Have participated actively in organising and conducting physics stalls during the the local Press Conference at Syracuse University held for the announcement for detection of first GW from binary neutron stars, GW170817 (2017).
- An outreach colloquium at Hartwick College on **The discovery of GW150914**, in Oneonta NY, (Invited) (2016).
- Presentation of **Numerical simulation of GW150914** at the local Press Conference at Syracuse University held for the announcement for detection of first GW from binary black hole system, GW150914. (2016)
- Have been a member of Women in Physics group in Syracuse and have contributed in organising the conferences for undergraduate women in Physics (CUWiP), Syracuse Chapter (2016).