Suruj Jyoti Das

Postdoktor i evolutionen av primordiala magnetfält

Ref nr: SU FV-4638-25-53

Datum för ansökan: 2026-01-20 20:57

Födelsedatum	1995-12-04
E-post	surujjd@gmail.com
Kön	Man

Frågor

1. *Nuvarande sysselsättning (ange huvudsaklig sysselsättning)*
Anställd vid lärosäte utanför Sverige

2. *Högsta examen*
Doktors-/licentiatsexamen

3. *Från vilket land har du din högsta examen?*
Indien

4. *Har du din högsta examen från Stockholms universitet?*
Nej

5. *Ange datum när du tog din doktorsexamen*
2023-07-29

6. *NUVARANDE ANSTÄLLNING. Ange arbetsplats och jobbtitel samt när anställningen påbörjades..*
Postdoctoral Researcher (January 2024-present),
Particle Theory and Cosmology Group,
Center for Theoretical Physics of the Universe,
Institute for Basic Science,
Daejeon, Republic of Korea.

7. *REFERENSER. Ange namn, telefon och e-post för 2–3 referenspersoner som kan komma att kontaktas.*
Dr. Debasish Borah, 0361-2583563, dborah@iitg.ac.in
Dr. Konstantinos Dimopoulos, k.dimopoulos1@lancaster.ac.uk
Dr. Nobuchika Okada, (205) 348-2837, okadan@ua.edu

8. *SPRÅKKUNSKAPER. Beskriv kort dina språkkunskaper.*
English

9. *FORSKNINGSPLAN/PROJEKTPLAN. Bifoga din plan som beskriver det tilltänkta projektet.*
researchstatement_suruj_Nordita.pdf

10. *DOKTORSEXAMEN ELLER MOTSVARANDE. Ange doktorsexamen med ämne och lärosäte.*
Ph.D. in Physics,
Thesis Title: Production of Dark Matter and Baryon Asymmetry in Non-standard Cosmologies,
Place: Indian Institute of Technology Guwahati, India

11. *EXAMENSBEVIS ELLER MOTSVARANDE. Bifoga examensbevis.*
Suruj_PhD_Degree_Original.pdf

Suruj Jyoti Das

Postdoktor i evolutionen av primordiala magnetfält

Ref nr: SU FV-4638-25-53

Datum för ansökan: 2026-01-20 20:57

Eget uppladdat CV

January 20, 2026

Dr. Suruj Jyoti Das
Particle Theory and Cosmology Group,
Center for Theoretical Physics of the Universe,
Institute for Basic Science,
Daejeon, Republic of Korea, 34126.
Email: surujjd@gmail.com
Phone: +82 1021873961

Nordic Institute for Theoretical Physics (Nordita),
Roslagstullsbacken 23, 10691 Stockholm, Sweden.

Subject: Application for Postdoctoral Fellow in Primordial magnetic field evolution

Dear members of the hiring committee,

I am writing to express my strong interest in the postdoctoral fellow position with **Dr. Axel Brandenburg**, in primordial magnetic field evolution within the project "**COSMOMAG**". I obtained my Ph.D. in 2023, and am currently a postdoctoral researcher at the Institute for Basic Science, South Korea.

My research has been at the interface of **particle physics and cosmology**, primarily focusing on different aspects of **cosmic inflation**, **(primordial) black holes (PBH)**, **dark matter**, **axion physics**, and **baryogenesis**, with an emphasis on finding unique imprints of these **Beyond Standard Model** (BSM) physics on **Gravitational Waves** (GW). I have investigated potentially detectable GW spectrum across a broad frequency range (nHz-kHz), with additional complementary signatures of these new physics in particle physics, cosmology and astrophysics experiments.

Although I have not previously worked on magnetic fields directly, over the past few years, I have gained experience working on aspects of BSM physics in the early Universe, and am **familiar with early Universe dynamics that could play a role in the magnetic field generation and evolution**. I am also an associate member of the **Indian Pulsar Timing Array (InPTA)** collaboration. In parallel to exploring the above rich phenomenology through various particle physics models in the early Universe, over the last few months **with InPTA**, I have also become **acquainted with pulsar observation techniques, along with the preliminary data reduction and processing involved**. I intend to accelerate significantly along this learning trajectory, focusing on using PTA data to probe BSM physics, with **magnetic fields as a complementary search direction**.

Hence, this postdoctoral position, as part of the project *"COSMOMAG"* is timely and would provide me with the necessary platform, especially to explore the close **interconnections** between different research areas in the early Universe, along with my GW search route. My research interests and plans (more details in my Research Statement), related to (a) cosmic inflation, axion physics, baryogenesis & reheating, (b) exploiting **GW anisotropies** as a tool for probing new physics, can have close connections with magnetic fields. I believe I can learn the necessary skills and prerequisites required for numerical analysis, including the **PENCIL** code, and contribute significantly to this project. Collaborations with other members of this project, especially **Dr. Chiara Caprini**, would also help me in my **gravitational wave analysis**.

With a strong background in theoretical physics and phenomenology of the early Universe, focused around BSM physics and cosmological GW sources; along with my recent involvement in a GW experiment collaboration (InPTA), I believe this position aligns well with my ongoing and planned research trajectory. This exposure, focused on primordial magnetic fields, with members covering broad research topics in particle cosmology, would be beneficial considering BSM physics and modified gravity (MG) ideas that can be probed with **multimessenger search** in cosmology, astrophysics and particle physics experiments. I have enclosed my **CV** with **Publication List**, **Research statement** and have provided the contact details of **three references**.

Thank you very much for considering my application. I am happy to provide additional information or to discuss my plans in an interview at your convenience.

Sincerely,
Suruj Jyoti Das.

Particle Theory and Cosmology Group,
Center for Theoretical Physics of the Universe,
Institute for Basic Science,
Daejeon, Republic of Korea, 34126.
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Dr. Suruj Jyoti Das, Post-Doctoral Researcher

Research Interests

- **Axion Physics.**
- **Baryon Asymmetry.**
- **Cosmic Inflation.**
- **Dark Matter.**
- **Primordial Black Holes.**
- **Primordial Gravitational Waves.**
- **PTA searches for Gravitational Waves.**

Personal Information

Date of Birth	04/12/1995.
Citizenship	Indian.
Languages	English (fluent), Hindi (native), Assamese (native).

Academic Timeline

2024-present **Post-Doctoral Researcher**, Institute for Basic Science, Daejeon, Republic of Korea.

2023 **Visitor**, Tata Institute of Fundamental Research, Mumbai, India.

2018–2023 **Ph.D. in Physics**, Indian Institute of Technology, Guwahati, India.

- Thesis title: "*Production of Dark Matter and Baryon Asymmetry in Non-standard Cosmologies (Defended on July 29, 2023)*", under supervision of Dr. Debasish Borah.

2016–2018 **M.Sc. in Physics**, Indian Institute of Technology, Hyderabad, India.

- M.Sc. Thesis: "*Holographic Computational Complexity as a Measure for the Multiverse*", under supervision of Dr. Shubho Roy.
- CGPA : 8.16 /10.
- Area of Specialization : Gravitation and Cosmology, Classical/Quantum Field Theory, Particle Physics, Data Science Analysis.
- Other experience : Data Science Analysis Project on *LIGO data analysis*.

2013–2016 **B.Sc. Physics Honors**, Cotton College State University, Guwahati, India.

- CGPA : 8.28 /10.

2011–2013 **Senior Schooling**, Don Bosco Senior Secondary School, Guwahati, India.

- Board: Central Board of Secondary Education, India.
- % Marks Obtained : 86 %.

2011 **Schooling completed**, Don Bosco Senior Secondary School, Guwahati, India.

- Board: Central Board of Secondary Education, India.
- CGPA : 9.2 /10.

Experiments

- Associate member of **Indian Pulsar Timing Array (InPTA)** Experiment, since November 2024.

Experience in InPTA

- Took part in **Evaluation of Median DM** (Dispersion Measure) for the Cycle 48 InPTA Observation, subsequently used for Cycle 49 Observations.
- **Secondary observer** for a BAND 3 ($300 - 500$ MHz) Cycle 48 InPTA observation on 16 May, 2025 and subsequent **Data Reduction** & **Processing** using Automated/Semi-Automated *PINTA*.
- Took part in **Evaluation of Median DM** (Dispersion Measure) for the Cycle 47 InPTA Observation, subsequently used for Cycle 48 Observations.
- Took part in **Auditing** of Reduced Data of the Cycle 47 InPTA Observation.
- **Secondary observer** for a BAND 3 ($300 - 500$ MHz) Cycle 47 InPTA observation on 27 December, 2024 and subsequent **Data Reduction** & **Processing** using Automated/ Semi-Automated *PINTA*.

Other qualifications and achievements

- Qualified Graduate Aptitude Test in Engineering (GATE) Exam conducted by Indian Institute of Technology (IITs) in 2019, with **All India Rank 1284**.
- Achieved Lectureship (LS) conducted by Council of Scientific and Industrial Research (CSIR), India in December 2018, with **All India Rank 21** in LS Category.
- Qualified Joint Admission to M.Sc. (JAM) Exam conducted by Indian Institute of Technology (IITs) in 2016, with **All India Rank 237**.

Computational Skills

- Computer languages : C++ (basic), Fortran (basic), Python.
- Scientific software: Mathematica, LaTeX.
- Particle Physics, Cosmology tools/package : micrOMEGAs, CalcHEP, FeynRules, HEALPix, COSMOLattice (Preliminary).
- Boltzmann codes: (GW)CLASS.

Teaching Experiences

2022 Teaching assistant for the Second Year B.Tech General Physics Laboratory course PH210 at IIT Guwahati.

2021 Teaching assistant for the M.Sc. General Physics Laboratory course PH511 at IIT Guwahati.

2020 Teaching assistant for the Second Year B.Tech Classical Mechanics course PH203 at IIT Guwahati.

2020 Teaching assistant for the M.Sc. Advanced Physics Laboratory course PH516 at IIT Guwahati.

2019 Teaching assistant for the Fourth Year B.Tech Advanced Physics Laboratory course PH417 at IIT Guwahati.

2019 Teaching assistant for the First Year B.Tech Physics Laboratory course PH110 at IIT Guwahati.

List of Publications

- **(24)** Revisiting wideband pulsar timing measurements, Abhimanyu Susobhanan, Avinash Kumar Paladi, Réka Desmecht et al. **arXiv:2512.01288 [astro-ph.IM]** (under review) [contributed to observation and subsequent reduction & processing of the data used for the analysis in this paper, for MJD: 60671, 60811].
- **(23)** Leptogenesis and neutrino mass with one right-handed neutrino and Higgs inflaton, Disha Bandyopadhyay, Debasish Borah, Suruj Jyoti Das, Nobuchika Okada, **arXiv: 2508.10103 [hep-ph]** (under review).
- **(22)** Hunting for heavy Z' with IceCube neutrinos and gravitational waves, Basabendu Barman, Arindam Das, Suruj Jyoti Das, Marco Merchand, **Phys. Rev. D 112, 035035**.
- **(21)** Flipped Rotating Axion Non-minimally Coupled to Gravity: Baryogenesis and Dark Matter, Chao Chen, Suruj Jyoti Das, Konstantinos Dimopoulos, Anish Ghoshal, **Eur. Phys. J.C 85 (2025) 8, 898**.
- **(20)** Cogenesis by a sliding pNGB with symmetry non-restoration, Eung Jin Chun, Suruj Jyoti Das, Minxi He, Tae Hyun Jung, Jin Sun, **Phys.Rev.D 112 (2025) 9, 095002**.
- **(19)** Leptogenesis, primordial gravitational waves, and PBH-induced reheating, Basabendu Barman, Suruj Jyoti Das, Md Riajul Haque, Yann Mambrini, **Phys. Rev. D 110, 043528.**
- **(18)** Cogenesis of baryon and dark matter with PBH and QCD axion, Debasish Borah, Nayan Das, Suruj Jyoti Das, Rome Samanta, **Phys.Rev.D 110 (2024) 11, 115013** .
- **(17)** Dark matter from phase transition generated PBH evaporation with gravitational waves signatures, Debasish Borah, Suruj Jyoti Das, Indrajit Saha, **Phys.Rev.D 110 (2024) 3, 035014.**
- **(16)** Imprint of inflationary gravitational waves and WIMP dark matter in pulsar timing array data, Debasish Borah, Suruj Jyoti Das, Rome Samanta, **JCAP 03 (2024) 031.**
- **(15)** Scale of Dirac leptogenesis and left-right symmetry in the light of recent PTA results, Basabendu Barman, Debasish Borah, Suruj Jyoti Das, Indrajit Saha, **JCAP 10 (2023) 053**.
- **(14)** Thermalised dark radiation in the presence of PBH: $\Delta N_{\rm eff}$ and gravitational waves complementarity, Nayan Das, Suruj Jyoti Das, Debasish Borah, **Phys.Rev.D 108 (2023) 9, 095052.**
- **(13)** Baryon asymmetry from dark matter decay, Debasish Borah, Suruj Jyoti Das, Rishav Roshan, **Phys.Rev.D 108 (2023) 7, 075025.**
- **(12)** Imprint of PBH domination on gravitational waves generated by cosmic strings, Debasish Borah, Suruj Jyoti Das, Rishav Roshan, Rome Samanta, **Phys.Rev.D 108 (2023) 2, 023531**.
- **(11)** Affleck-Dine Cogenesis of Baryon and Dark Matter, Debasish Borah, Suruj Jyoti Das, Nobuchika Okada, **JHEP 05 (2023) 004**.
- **(10)** Gravitational wave signatures of PBH-generated baryon-dark matter coincidence, Basabendu Barman, Debasish Borah, Suruj Jyoti Das, Rishav Roshan, **Phys.Rev.D 107 (2023) 9, 095002**.
- **(9)** PBH-infused seesaw origin of matter and unique gravitational waves, Debasish Borah, Suruj Jyoti Das, Rome Samanta, Federico R. Urban, **JHEP 03 (2023) 127**.
- **(8)** Probing high scale seesaw and PBH generated dark matter via gravitational waves with multiple tilts, Debasish Borah, Suruj Jyoti Das, Rishav Roshan, **Nucl.Phys.B 1002 (2024) 116528**.

- **(7)** Cogenesis of Baryon Asymmetry and Gravitational Dark Matter from primordial black holes, Basabendu Barman, Debasish Borah, Suruj Jyoti Das, Rishav Roshan, **JCAP 08 (2022) 068**.
- **(6)** Probing WIMP Dark Matter via Gravitational Waves Spectral Shapes, Debasish Borah, Suruj Jyoti Das, Abhijit Kumar Saha, Rome Samanta, **Phys.Rev.D 106 (2022) 1, L011701**.
- **(5)** Non-thermal Origin of Asymmetric Dark Matter from Inflaton and Primordial Black Holes, Basabendu Barman, Debasish Borah, Suruj Jyoti Das, Rishav Roshan, **JCAP 03 (2022) 03, 031**.
- **(4)** Thermal keV neutrino dark matter in minimal gauged B-L model with cosmic inflation, Debasish Borah, Suruj Jyoti Das, Abhijit Kumar Saha, **Phys.Rev.D 106 (2022) 5, 055010**.
- **(3)** Low scale leptogenesis and dark matter in the presence of primordial black holes, Suruj Jyoti Das, Devabrat Mahanta, Debasish Borah, **JCAP 11 (2021) 019**.
- **(2)** Gravitational origin of dark matter and Majorana neutrino mass with non-minimal quartic inflation, Debasish Borah, Suruj Jyoti Das, Abhijit Kumar Saha, **Phys.Dark Univ. 33 (2021) 100858**.
- **(1)** Cosmic Inflation in Minimal $U(1)_{B-L}$ Model: Implications for (Non) Thermal Dark Matter and Leptogenesis, Debasish Borah, Suruj Jyoti Das, Abhijit Kumar Saha, **Eur.Phys.J.C 81 (2021) 2, 169**.

Conference Proceedings

- **(2)** Signatures of High-Scale Seesaw and PBH Generated DarkMatter in Gravitational Waves with Multiple Tilts, Debasish Borah, Suruj Jyoti Das, Rishav Roshan, Proceedings of 25th DAE-BRNS High Energy Physics Symposium, **Springer Proc.Phys. 304 (2024) 783-785**.
- **(1)** Dark Matter and Leptogenesis in Minimal $U(1)_{B-L}$ Model with Nonminimal Quartic Inflation, Debasish Borah, Suruj Jyoti Das, Abhijit Kumar Saha, Proceedings of 24th DAE-BRNS High Energy Physics Symposium, **Springer Proc.Phys. 277 (2022) 737-741**.

Talks/Posters/Visits

- Visited **ICCUB**, Barcelona during November 13-14, 2025, and delivered a talk titled "Phenomenology of Rotating axions: Baryogenesis & Dark Matter".
- Invited talk titled "Affleck-Dine origins of Baryons, Dark Matter and Inflation" at the **10th IBS-IFT Workshop**, held in IFT, Madrid during November 10-13, 2024.
- Visited **IPARCOS, UCM**, Madrid during November 6-7, 2025, and delivered a talk titled "Phenomenology of Rotating axions: Baryogenesis & Dark Matter".
- Visited the **TRIUMF Theory Department** during July 14-16, 2025 and delivered a talk titled "Phenomenology of Rotating axions: Baryogenesis & Dark Matter"
- Presented a talk titled "Flipped rotating axion non-minimally coupled to gravity: Baryogenesis & Dark Matter" at the **19th Dark Side of the Universe (DSU 2025) workshop**, held at Université de Montreal, Canada, from July 7-11 2025.
- Invited talk titled "Phenomenology of Rotating pNGBs: Baryogenesis & Dark Matter" at the **7th CUBES (Chirality in the Universe Beyond the Electroweak Scale) Workshop**, held in Gurye, South Korea during April 25-28, 2025.
- Invited talk titled "Cogenesis by pNGB" at the **9th IBS-IFT Workshop**, held in IBS, Daejeon, South Korea during November 5-14, 2024.

- Presented a poster titled "Gravitational Leptogenesis and Primordial Gravitational Waves during PBH-induced reheating" in the **Kashiwa Dark Matter and Cosmology Symposium 2024**, held in IPMU, Japan during 28 October-01 November 2024.
- Presented a talk titled "Cogenesis by a sliding pNGB with symmetry non-restoration" in the **COSMO 2024** conference held in Kyoto University, Japan during 21-25 October 2024.
- Presented a poster titled "Probing Miracle-less WIMP Dark Matter via Gravitational Waves Spectral Shapes" in the **4th DMNet Symposium** held in IBS, Daejeon, South Korea during 5-7 September 2024.
- Presented a talk titled "Cogenesis by a sliding pNGB with symmetry non-restoration", in the **Light Dark World 2024, 9th meeting of the annual Light Dark World International Forum series**, held at the Korea Advanced Institute of Science and Technology in Daejeon during 12 August-15 August, 2024.
- Visited **University of Southampton** during 26 June-28 June 2024 and presented a talk titled "Exploring cogenesis through pNGB Dynamics and PBH-induced Reheating" in Seminar.
- Visited **University of Lancaster** during 21 June-25 June 2024 and presented a talk titled "Exploring cogenesis through pNGB Dynamics and PBH-induced Reheating" in Seminar.
- Presented a talk titled "Gravitational Leptogenesis and Primordial Gravitational Waves during PBH-induced Reheating", in the **New Horizons in Primordial Black Hole physics (NEHOP)'24** workshop, held at the National Galleries of Scotland during June 17-20, 2024.
- Presented a talk titled "Imprint of inflationary gravitational waves and WIMP dark matter in pulsar timing array data", in the **SUSY 2024, the 31st International Conference on Supersymmetry and Unification of Fundamental Interactions**, held at The Institute of Theoretical Physics (IFT), Madrid during June 10-14, 2024.
- Invited talk at **Chung-Ang University Seminar** titled "Gravitational wave imprints of physics beyond the Standard Model" on 16^{th} May, 2024.
- Presented a talk titled "Imprint of inflationary gravitational waves and WIMP dark matter in pulsar timing array data", in the **CAU BSM Workshop 2024**.
- Visited the Department of Astronomy and Astrophysics (DAA) of **Tata Institute of Fundamental Research**, Mumbai during 22 September-31 October, 2023, and also presented a talk titled "Gravitational wave imprints of physics beyond the Standard Model" in the DAA Seminar on 17^{th} October, 2023.
- Presented a talk titled "Cogenesis of Baryon asymmetry and gravitational dark matter from primordial black holes", in the **Phenomenology Symposium 2023**, organized by the University of Pittsburgh during 8-10 May, 2023.
- Presented a poster titled "Probing high scale seesaw and PBH generated dark matter via gravitational waves with multiple tilts", in the **XXV DAE-BRNS High Energy Physics (HEP) Symposium 2022**, organized by Indian Institute of Science Education and Research Mohali, Punjab.
- Visited **University of Warsaw** during 29 June-01 July 2022 and presented a talk titled "Impacts of an extra gauge symmetry and modified cosmologies in the Early Universe".
- Visited **LPTHE, Paris** during 27-28 June 2022 and presented a talk titled "Leptogenesis and Dark Matter in the presence of Primordial Black Holes" in the LPTHE Seminar.
- Presented a poster titled "Probing Miracle-less WIMP Dark Matter via Gravitational Waves Spectral Shapes" in **INVISIBLES 2022 Workshop** held in IJC Lab, Orsay, Paris during 20-24 June 2022.

- Invited talk titled "Leptogenesis and dark matter in the presence of primordial black holes" in the Weekly online meeting on cosmology (WOMC) at **IIT Madras** on December 18, 2021.
- Presented a talk titled "Low scale leptogenesis and dark matter in the presence of primordial black holes", in **PASCOS 2021, the 26th International Symposium on Particle Physics, String Theory, and Cosmology (Online)**.
- Presented a talk titled "Cosmic Inflation in Minimal $U(1)_{B-L}$ Model: Implications for (Non) Thermal Dark Matter and Leptogenesis", in the **XXIV DAE-BRNS High Energy Physics (HEP) Symposium 2020 (Online)**, organized by National Institute of Science Education and Research (NISER), Odisha.
- Presented a poster titled "Gravitational origin of dark matter and Majorana neutrino mass with non-minimal quartic inflation", in the **Kashiwa Dark Matter Symposium 2020 (Online)**.

Workshops/Schools/Symposiums Attended

2025

- 10th IBS-IFT Workshop, held in IFT, Madrid, during November 10-13, 2024.
- IBS Conference on Dark World, held at IBS, during October 27-30, 2025.
- Workshop on COSMOLattice, held at IBS, during September 22-26.
- 19th Dark Side of the Universe (DSU 2025) workshop, held at the new science campus of the Université de Montreal, Canada, from July 7-11 2025.
- 7th CUBES (Chirality in the Universe Beyond the Electroweak Scale) Workshop, held in Gurye, South Korea during April 25-28, 2025.

2024

- Dark World to Swampland 2024: 9th IBS-IFT Workshop, held in IBS, Daejeon, South Korea during November 5 -14, 2024.
- Kashiwa Dark Matter and Cosmology Symposium 2024, held in IPMU, Japan during 28 October - 01 November 2024.
- COSMO 2024, held at Kyoto University, Japan, during 28 October - 01 November 2024.
- Light Dark World 2024, 9^{th} meeting of the annual Light Dark World International Forum series, held at the Korea Advanced Institute of Science and Technology in Daejeon during 12 August-15 August,2024.
- New Horizons in Primordial Black Hole physics (NEHOP)'24 workshop, held at the National Galleries of Scotland during June 17-20, 2024.
- SUSY 2024, the 31st International Conference on Supersymmetry and Unification of Fundamental Interactions, held at The Institute of Theoretical Physics (IFT), Madrid during June 10-14, 2024.
- IBS CTPU-CGA 2024 Workshop on Cosmological Collider during June 3-7, 2024.
- IBS CTPU-CGA 2024 Workshop on (Primordial) Black Holes and Gravitational Waves during March 18-22, 2024.
- Chung-Ang University Beyond the Standard Model (CAU BSM) Workshop, during 19-23 February, 2024.

2023

- Phenomenology Symposium 2023, organised by the University of Pittsburgh, during 8-10 May, 2023.

2022

- XXV DAE-BRNS High Energy Physics (HEP) Symposium, organised by Indian Institute of Science Education and Research Mohali, Punjab, during 12- 16 December 2022.
- INVISIBLES 2022 Workshop held in IJC Lab, Orsay, Paris during 20-24 June 2022.
- Physics of the Early Universe (Hybrid) Program organised by International Centre for Theoretical Sciences, Bengaluru during 3-12 January, 2022.

2021

- PASCOS 2021, the 26th International Symposium on Particle Physics, String Theory, and Cosmology (Online), during June 14-18, 2021.
- "ICTP Summer School on Particle Physics (Online)" from 31 May 2021 to 11 June 2021.

2020

- XXIV DAE-BRNS High Energy Physics (HEP) Symposium (Online), organised by National Institute of Science Education and Research (NISER), Odisha, during 14- 18 December 2020.
- Kashiwa Dark Matter Symposium 2020 (Online), held during 16- 19 November 2020.
- Less Travelled Path of Dark Matter: Axions and Primordial Black Holes (Online), organised by International Centre for Theoretical Sciences, Bengaluru during 09 -13 November, 2020.
- Physics of the Early Universe - An Online Precursor, organised by International Centre for Theoretical Sciences, Bengaluru during 31 August - 03 September 2020.

2019

- Workshop in High Energy Physics Phenomenology (WHEPP) at IIT Guwahati during 1-10 December, 2019.
- SERB Preparatory School in Theoretical High Energy Physics (THEP) at Tezpur University, Assam during October 14-November 9, 2019.

Administrative and Organisational Experiences

- Organiser of the biweekly informal arXiv Club in the IBS CTPU-PTC group in 2025 (July-December).
- Organiser of the weekly Journal Club in the IBS CTPU-PTC group in 2025 (January-June).
- Organiser of the weekly High Energy Physics (HEP) Journal Club in IIT Guwahati, during 2021-2022.
- Part of the local organising committee of *WHEPP (Workshop on High Energy Physics Phenomenology) XVI*, held in IIT Guwahati during December 1-10, 2019.

Dr. Suruj Jyoti Das,
Particle Theory and Cosmology Group,
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inspirehep.net/authors/1806323

Research Statement

Introduction & Motivation

My research areas have been broadly located at the interface of particle physics and cosmology. Owing to the incompleteness of the Standard Model of Particle Physics in addressing several key puzzles in our Universe, my research has focused on several **Beyond Standard Model** (BSM) theories in the early Universe. Primarily, I have been trying to understand the origin of **Dark Matter (DM)**, **Neutrino Mass**, **Baryon Asymmetry** and **Cosmic Inflation with Reheating**, and exploring methods to probe these new physics, with special emphasis on **Gravitational Waves** (GW), along with complementary searches in several particle physics and cosmology experiments. While the recent strong evidence of GW detection from various **Pulsar Timing Arrays** (PTAs) could also be possibly explained by cosmological sources, this requires significant further studies in terms of both theoretical and data analysis perspectives. As an associate member of the **Indian PTA (InPTA)** collaboration, I am gaining exposure to pulsar timing observations and preliminary data analysis techniques. I aim to substantially steepen this learning curve in advanced PTA data analysis methods, with a particular emphasis on exploring and constraining BSM physics scenarios.
Through this postdoctoral fellow position with **Dr. Axel Brandenburg** within the project **COSMOMAG**, I plan to explore a complementary direction with primordial magnetic fields, along with interconnections with gravitational waves. I am interested in exploring the origin of the cosmic magnetic fields and their subsequent evolution through cosmic history, including their connections with BSM physics. I believe this would provide me with a **multimessenger** new physics search direction along with my GW search route. Although my previous works are not directly on magnetogenesis, the early Universe physics scenarios I have studied and worked on, have close connections with possible magnetic fields. I am committed to building the necessary numerical expertise and requirements, greatly benefiting from the exposure in this project.

Past Research

Here, I briefly discuss few of my past research works which has *close connections with my proposed Research Plans*:

- **Testing WIMP DM with GW from Cosmic Strings and Inflation:**
  In [1], we proposed a way of probing a class of *Weakly Interacting Massive Particle (WIMP) DM*, which has interaction strength large enough to be produced in equilibrium in early Universe, but less (motivated by null results in DM experiments) than the typical WIMP leading to overproduction. This can be realized through DM annihilations mediated by a gauge boson like $Z_{\text{B-L}}$, with a high scale symmetry breaking, which can also form *cosmic strings*. The thermally overproduced DM relic can be brought down by the late-time decay of a diluter field (present within the same framework of $U(1)_{\text{B-L}}$ itself). This leads to **unique spectral breaks in the GW spectra from *cosmic strings*, with a one-to-one correspondence between the spectral break frequency and the DM mass (MeV-TeV)**, which are within reach of **LISA, BBO, ET**. This scenario also has unique predictions for **light neutrino mass** and for generating baryon asymmetry through *leptogenesis*.
  The same above scenario can also have implications for the recent PTA data, which was further studied in [2]. While *blue-tilted inflationary GW* can be a possible source of the PTA observations, this requires a very low reheating temperature. In our scenario, this can be circumvented due to the *early matter domination* from the diluter field, leading to a unique *doubly peaked* GW spectrum carrying information about DM. While the **spectrum can fit *PTA* data at lower frequencies, the peak at higher frequencies can be tested at upcoming *LIGO* run**, thus offering a *PTA-LIGO* complementarity for testing *WIMP DM*.

- **Axion Physics:**
  I have worked on axion dynamics in the early Universe, which can play role in **cogenesis of the baryon asymmetry and dark matter** abundance of the Universe. In [3], we explored such a cogenesis framework using the popular (Conventional) **Misalignment mechanism**. The baryon asymmetry is produced through the **Spontaneous Baryogenesis** mechanism, when the axion-like particle (ALP) slides across the decreasing potential barries, while after the potential saturates, the ALP gets trapped producing the DM abundance. The dynamics of axion fluctuations leading to **fragmentation** was also investigated. A similar dynamics connected with the **inflationary** epoch was explored in [4], with a **non-minimal coupling to gravity**, which also has strong **predictions in GW experiments**, because of the **kination** era.
- **Imprint of Primordial Black Hole domination on Cosmic Strings:**
  In [5], we performed a general study of how *primordial black hole* (PBH) domination can uniquely effect the *Cosmic String* GW spectrum. The *scalar-induced* **GW from PBH density fluctuations leads to a unique spectral feature with a plateau, a red tilt followed or preceded by a sharp blue tilt, which is a distinct feature compared to other sources of matter domination**. PBH may thus act as a portal between gravitational waves and particle physics models. Such connections were explored for *Type I seesaw* explaining neutrino mass in [6], and for PBH-generated *purely gravitational DM* in [7], where the latter leads to a unique spectrum with *multiple tilts*.

Scientific Objectives

Following are the primary scientific objectives (SO) that I plan to (but not limited to) explore. Some of these are ongoing projects. Also, not all of them may be directly connected to the project **COSMOMAG**, but I am interested in exploring them in the coming years, with possible connections with magnetogenesis.

- **SO 1 (PTA/BSM):** Investigate well-motivated **BSM** models connected with **magnetogenesis**, with the help of **PTA**; along with **complementary searches** in particle physics, CMB, astrophysics and other high frequency GW experiments.
- **SO 2 (GW anisotropies):** Look for potential BSM and magnetic field signatures in the **anisotropies of the GW background**.
- **SO 3 (Inflation/Non-gaussianity):** Investigate the **very early Universe: Cosmic Inflation** with **magnetic field** generation.

Research Methodology and Work Plan

- **SO 1:** Having gained significant experience in theoretical studies of various cosmological GW sources, including *(a) Cosmic Strings, (b) Primordial Black Holes, (c) Inflation, (d) Domain Walls, (e) First-Order Phase Transitions*, I plan to expand and further develop these topics in multiple new directions. My specific plans are outlined below:

  (I) Exploring new theoretical ideas:

  I will continue exploring well-motivated early Universe particle physics models on the theoretical side, particularly scenarios involving **dark matter, baryogenesis, axion physics, inflation, reheating, and Primordial Black Holes (PBH)**, with interesting GW signatures across several frequencies. I plan to explore several new ideas and perspectives, especially related to **magnetogenesis and unique GW signatures**. Through this project, I am particularly interested in exploring the **interconnections between chiral anomaly, helical magnetic fields and baryon/lepton asymmetry**.
  In the context of **astrophysics**, I am currently exploring **dipole radiation from binary objects, such as Black Holes or Neutron Stars**. While energy loss from binaries is typically dominated by quadrupole emission of GWs, alternative energy loss channels such as monopole or dipole radiation can also arise, particularly if the black hole is endowed with some charge evading the no-hair theorem in many **modified gravity/BSM** theories. Currently, I am actively involved in calculations of these dipole contributions and investigating their implications for the detection of **individual Super Massive Black Hole Binaries**, particularly in the upcoming **Square Kilometre Array (SKA)** era. This has the exciting potential to constrain the properties of BSM scalar fields (*axions* for instance) or **modified gravity theories beyond GR**. Morever, although I am currently focusing on PTA, such studies can be extended to other frequency ranges, for higher PN effects, considering, for eg. modified gravity theories. Effects of BSM physics on rotating neutron stars would also be interesting to me from a PTA perspective. Moreover, I plan

to explore well-motivated models of **regular** primordial/astrophysical BH, with associated signatures in **quasi-normal modes and Hawking radiation**.
With **my building experience on GW data analysis with exposure to PTA activities**, I will be able to search for these BSM signatures in GW using improved Bayesian and other statistical techniques, utilising tools such as PTArcade [8]. As GW spectra depend sensitively on fundamental particle physics parameters (e.g., mass scales, coupling strengths), PTA observations can powerfully constrain these parameters.

(II) Complementary searches in other experiments and GW multiband analysis:

In complementarity, these new predictions of the BSM theories can also be tested at other experiments. For instance, PBH in the appropriate mass ranges can have potential signatures or be constrained from accretion events and electromagnetic radiation through Hawking evaporation, or even through neutrino emission. Various theories of generating the baryon asymmetry through baryogenesis or leptogenesis, requires **CP violation** and also predicts particles such as **Heavy Neutral Leptons (HNLs)**. The predictions for CP violation can be tested through meson or baryon decay channels in colliders. On the other hand, HNLs can be searched through their production and prompt decays in colliders. In addition, the CP phase can affect neutrino oscillations, while HNLs can mix with active neutrinos of the Standard Model; leaving signatures in neutrino experiments. Several BSM physics scenarios typically predicts GW not only in the nano-Hz frequency range, but also at higher frequencies in the reach of upcoming experiments such as BBO, LISA, LIGO O4, CE etc., which would be interesting to pursue. This would provide a **GW complementary signature**. I plan to investigate such a multiband analysis across several frequencies, which is a promising key aspect in the search for new physics.

- **SO 2:** While the cosmological GW background is expected to be largely isotropic (unlike the astrophysical), it can still contain small amounts of anisotropies as that in CMB. This can be exploited to extract very useful information and phenomenology about BSM physics in the early Universe, especially in the future with better sensitivities of GW detectors. In particular, regardless of the GW source, the cosmological anisotropies are affected by physics such as the initial conditions during inflation (adiabatic or non-adiabatic) and the early Integrated Sachs-Wolfe (ISW) effect. Thus, the **anisotropy spectrum would carry information about physics that otherwise doesn't have a direct signature on the monopole GW background, and may also help in breaking the degeneracy among some particle physics parameters, which produce the same monopole background, but can lead to different signatures in anisotropies**. In addition, the anisotropies might get enhanced because of some new physics such as large *non-Gaussianities* (**more in SO 3**), characterised by the parameter f_{NL}, which might be used to constrain such new physics scenarios. I plan to explore such anisotropy studies and searches, and explore scenarios which can also generate magnetic fields along with GW anisotropies.
  Given any monopole GW spectrum, I can implement it in GWCLASS [9] to find the corresponding angular power spectrum, which could possibly be used to look for signatures of new physics. The spectral shapes of C_l's are sensitive to the change in slope of the monopole spectral background, hence features such as peaks can also lead to unique corresponding features in the anisotropy signature. The **cross-correlation** between C_l 's at different frequency bands (including ones accessible to, for eg. **LISA**) might be important in this regard. Finally, the cross-correlation of GW anisotropy with the CMB anisotropy, which can have a higher signal-to-noise ratio, is an interesting direction I plan to explore.

- **SO 3:** The period of exponential expansion of the very early Universe: **Cosmic Inflation**, is one of the most promising frontiers of modern cosmology. Through this project, I plan to investigate several directions connected to the inflationary dynamics, with **emphasis on inflation and reheating models with gauge fields that can lead to magnetogenesis.** My plans can be grouped broadly as:
  (I) Inflation Model Building:
  I will develop well-motivated particle-physics frameworks that realize an inflationary phase consistent with current CMB constraints, and that naturally connect to **baryogenesis, magnetogenesis, dark matter, axion physics and formation of PBH**. A particularly promising direction is **axion(like) inflation**, which has close connections to baryogenesis and dark matter. I will study these models analytically and also simulate their **non-linear dynamics** (preheating, particle production) with lattice methods, using my growing skills on **CosmoLattice** [10] (after participating in the recent CosmoLattice Workshop.) Regarding

PBH, I plan to investigate their formation in modified theories of gravity which could also possibly lead to some signatures in dipole radiation relevant for PTA (**related to SO1**).

(II) Non-Gaussianities and particle content:

Interactions of the inflaton, either self-interactions or couplings to other field, can imprint **non-Gaussianity (NG)** in the primordial fluctuations. The leading NG is the **bispectrum (three-point correlation function)**; higher order appears in the **trispectrum (four-point correlation function)**. These observables act as a probe of **new particles present during inflation**. In the so-called **squeezed limit**, the correlation "shape" can show **oscillatory features** whose frequency tracks the **mass** of the extra particle, while angular dependence encodes its **spin**. This is the basis of the **Cosmological Collider (CC)** [11] idea: inflation behaves like a particle accelerator with access to energies far beyond terrestrial machines. I will use these NG and CC signals to test **well-motivated BSM frameworks**: for example **extended Higgs sectors (e.g., two Higgs-doublet models)**, axion-like fields with gauge couplings, or heavy neutrino/hidden-sector states that can leave characteristic NG patterns. I plan to learn and build simple, data-ready templates for the bispectrum and trispectrum, and provide forecasts and estimators that CMB and large-scale-structure teams can apply directly. The NG features can then be mapped with the model parameters. Interestingly, the NG features can also lead to possible strong **anisotropies** in the stochastic GW map (**related to SO2**). These efforts naturally **complement collider and flavor searches pursued by the particle physics group**: CC-inferred masses/spins/couplings can be cross-checked against **collider limits** and low-energy probes, sharpening both sides.

(III) Primordial GW (PGW):

I will compute PGWs produced during and after inflation (e.g., from axion-gauge field amplification, PBH formation etc.). A key target is (a) **chiral** or **parity-violating** signals (with possible connections to **baryogenesis**) and their (b) **anisotropy** signatures (related to SO2). These features can also help to distinguish cosmological GWs from astrophysical backgrounds. I plan to investigate well-motivated theoretical models, that can leave such imprints on the GW data.

I will connect predictions across **multiple frequency bands**: from CMB scales to **PTAs, LISA, and ground-based detectors such as ET**, and study their imprints in **CMB polarization** (TB/EB) and in **PTA spherical-harmonic maps**. These GW templates and forecasts will also link naturally with my GW anisotropy plans listed in **SO 2**, enabling joint analyses that use both the average spectrum and its angular structure for model testing. My developing **PTA** experience, together with possible exposure to other high frequency GW experiments will facilitate multi-band collaboration with experimental teams, strengthening the robustness of the resulting tests of new physics.

Tentative Timeline

Here is a brief tentative timeline of my planned research project:

- Year 1: Downselect well-motivated BSM physics (related to dark matter, ALP, baryogenesis, magnetogenesis, neutrinos); compute stochastic GW background + anisotropies and search for signatures in PTA; extend predictions to LIGO/LISA/ET; compute non-gaussian signals and CMB imprints.
- Year 2: Probe BSM and MG scenarios that can produce GW or magnetic field signatures in low redshift compact binaries/black holes; assess impact for PTA and links to collider/low-energy constraints; build PTA templates/forecasts.

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भारतीय प्रौद्योगिकी संस्थान गुवाहाटी

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विद्या वाचस्पति की उपाधि

सूरुज ज्योति दास

को इस उपाधि के प्रदान हेतु विनियम विहित अपेक्षाएँ जुलाई 2023 में सफलतापूर्वक पूर्ण करने पर प्रदान करता है।

भारतीय गणराज्य के अंतर्गत गुवाहाटी में आज 27 नवंबर 2023 को संस्थान की यह मुद्रा अंकित उपाधि दी गई।

INDIAN INSTITUTE OF TECHNOLOGY GUWAHATI

upon the recommendation of the Senate hereby confers the degree of

Doctor of Philosophy

on

Suruj Jyoti Das

who has successfully completed in July 2023, the requirements prescribed under the regulations for the award of this degree.

Given this day, under the seal of the Institute at Guwahati in the Republic of India, the 27th day of November, 2023.

Thesis Title : Production of Dark Matter and Baryon Asymmetry in Non-standard Cosmologies

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