

# Arnab Chakraborty

Trottier Chair Fellow

## Contact Information

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## Employment

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### Trottier Chair Fellow

November 2021 – present

Department of Physics & Trottier Space Institute, McGill University, Montreal, Canada.

## Education

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Ph.D. in Astrophysics & Cosmology    July 2016 - September 2021  
Department of Astronomy, Astrophysics and Space Engineering  
Indian Institute of Technology, Indore  
Supervisors: Abhirup Datta

Master Degree in Physics    September 2013 - August 2015  
University of Burdwan, Burdwan, India  
Master Thesis: Secondary Anisotropies in Cosmic Microwave Background  
Supervisor: Sarbeswar Chaudhuri

Bachelor Degree in Physics    August 2010- July 2013  
Asutosh College, University of Calcutta, Kolkata, India

## Research Interests

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**Cosmology:** Cosmological data analysis, HI 21cm Intensity Mapping, Baryon Accoustic Oscillation, Epoch of Reionization and Cosmic Dawn, large scale structure

**Radio astronomy:** Developing pipeline to calibrate and imaging of radio interferometric low-frequency data, direction-dependent calibration, radio frequency interference (RFI) flagging.

**Foreground Characterization:** Modelling the emission of Galactic and extragalactic foregrounds, Compact sources and diffuse synchrotron radiation, foreground suppression and avoidance techniques.

**Strong Gravitational Lensing:** HI 21cm emission line from distant galaxies, strongly lensed by foreground galaxies, star formation history

**Interface of Astrophysics and Cosmology:** Radio continuum study of deep fields at low-frequency, studying clustering properties of sources, Active Galactic Nuclei, Star-Forming Galaxies, continuum study of Galactic plane at 1.4 GHz and 5 GHz.

## Honors & Awards

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- Trottier Chair Fellowship, McGill University, November 2021 to present
- Young Scientist Award at URSI-GASS 2021
- DST Inspire Fellowship for Ph.D, July 2016 to September 2021
- Scholarship for Higher Education (SHE) by DST-Inspire, October 2010 to October 2015

## Accepted observational proposals

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upgraded Giant Metrewave Radio Telescope (uGMRT):

- Characterizing Foregrounds in 21cm Cosmology Observations: Pilot Study with the uGMRT at 250-500 MHz, **ID:** 32\_120
- Characterizing Foregrounds in 21cm Cosmology Observations: Pilot Study with the uGMRT at 120-240 MHz, **ID:** 34\_141
- Characterizing Foregrounds in 21cm Cosmology Observations with the uGMRT at 120 - 240 MHz - Phase 1, **ID:** 41\_099
- Characterizing Foregrounds in 21cm Cosmology Observations with the uGMRT at 120 - 240 MHz - Phase 2, **ID:** 43\_077
- Characterizing Foregrounds in 21cm Cosmology Observations with the uGMRT at 120 - 240 MHz - Phase 3, **ID:** 46\_016
- The search for redshifted HI signal in redshift range 1.8 - 3.7 with the uGMRT, **ID:** 45\_124
- Towards 21-cm intensity mapping at  $1.8 < z < 3.7$  with uGMRT, **ID:** 46\_032

## Students Advised

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- Aishrila Mazumder, IIT Indore, Ph.D, December 2017 to November 2022.  
Project title: “Characterization of Foregrounds and Systematics for Sensitive Radio Observations”  
Now post-doc at the University of Manchester
- Akriti Sinha, IIT Indore, Ph.D, July 2018 to February 2024.  
Project title: “Star-formation in Radio Deep Fields: a Multi-wavelength Perspective”  
Now post-doc at Thuringer Landessternwarte Tautenburg, Germany
- Rashmi Sagar, IIT Indore, Ph.D, May 2021 to present.  
Project title: “Characterizing Foregrounds and constraint on HI 21cm signal from Epoch of Reionization with uGMRT.”
- Kyle Miller, McGill University, Master student, Fall 2023 to present.  
project title: “OH megamaser search with CHIME”

## Teaching Experience

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- Teaching Assistant, Radio Astronomy, IIT Indore, 2017-2019  
Taught basics of Radio Astronomy and Radiative Transfer to the Master Students and first-year Ph.D students in their course-work.
- Computer lab assistant, Radio data analysis and astrostatistics, IIT Indore, 2018-2019  
Take computational lab course and taught radio data analysis: Calibration, RFI flagging and imaging using CASA.
- Tutorial on data analysis in school “Frontiers in 21 cm Cosmology” held at Kodaikanal Solar Observatory, December 2018  
Take a tutorial on calibration and imaging of radio data and power spectrum estimation from it.
- Take tutorial on radio astronomy data analysis in school “First billion years” held at Indian Institute of Technology, Indore, January 2020.

## Collaboration Member

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**The Canadian Hydrogen Intensity Mapping Experiment (CHIME):** HI intensity mapping group

**The Canadian Hydrogen Observatory and Radio-transient Detector (CHORD):** Intensity mapping and HI galaxy survey group

## Service

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### To the Astrophysics Community:

- Referee, Monthly Notices of the Royal Astronomical Society
- Referee, Astronomy and Astrophysics (A&A)
- Referee, GMRT time allocation committee

## Publications

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### Led or Co-led

1. **Chakraborty A.**, Datta A., Choudhuri S., Roy N., Intema H., Choudhury M., Datta K.K., Pal S., Bharadwaj S., Dutta P., Choudhury T.R. (2019), *Detailed study of the ELAIS N1 field with the uGMRT - I. Characterizing the 325 MHz foreground for redshifted 21 cm observations*, MNRAS, 487(3), 4102–4113, doi:10.1093/mnras/stz1580, [[arXiv:1906.01655](#)]
2. **Chakraborty A.**, Roy N., Datta A., Choudhuri S., Datta K.K., Dutta P., Bharadwaj S., Intema H., Choudhury M., Pal S., Choudhury T.R. (2019), *Detailed study of ELAIS N1 field with the uGMRT - II. Source properties and spectral variation of foreground power spectrum from 300-500 MHz observations*, MNRAS, 490(1), 243–259, doi:10.1093/mnras/stz2533, [[arXiv:1908.10380](#)]

3. **Chakraborty A.**, Dutta P., Datta A., Roy N. (2020), *The study of the angular and spatial distribution of radio-selected AGNs and star-forming galaxies in the ELAIS N1 field*, MNRAS, 494(3), 3392–3404, doi:10.1093/mnras/staa945, [arXiv:2001.02358]
4. **Chakraborty A.**, Datta A., Roy N., Bharadwaj S., Choudhury T.R., Datta K.K., Pal S., Choudhury M., Choudhuri S., Dutta P., Sarkar D. (2021), *First Multi-redshift Limits on Post-Epoch of Reionization 21 cm Signal from  $z=1.96-3.58$  Using uGMRT*, APJL, 907(1), L7, doi:10.3847/2041-8213/abd17a, [arXiv:2012.04674]
5. **Chakraborty A.**, Roy N., Wang Y., Datta A., Beuther H., Medina S.N.X., Menten K.M., Urquhart J.S., Brunthaler A., Dzib S.A. (2020), *Characterization of unresolved and unclassified sources detected in radio continuum surveys of the Galactic plane*, MNRAS, 492(2), 2236–2240, doi:10.1093/mnras/stz3621, [arXiv:2001.02358]
6. **Chakraborty A.**, Datta A., Mazumder A, 2021, *A Comparative Analysis To Deal With Missing Spectral Information Caused By RFI In Cosmological HI 21CM Observations*, The Astrophysical Journal, Volume 929, Issue 1, id.104, 13 pp., doi:10.3847/1538-4357/ac5cc5, [arXiv:2203.04994]
7. Shaw A, **Chakraborty A** and other, *Probing early universe through redshifted 21-cm signal: Modelling and observational challenges*, 2022, Review article, Accepted for publication in the Special Issue of Journal of Astrophysics and Astronomy on "Indian Participation in the SKA", [arxiv:2211.05512]
8. **Chakraborty A** and Roy N, *Detection of HI 21cm emission from a strongly lensed galaxy at  $z=1.3$* , MNRAS, Volume 519, Issue 3, pp.4074-4081, doi: 10.1093/mnras/stac3696, [arxiv:2301.05987]
9. Shaw A, Jagannath M, Mazumder A, **Chakraborty A**, Patra N, Mondal R, Choudhuri S, *Detecting galaxies in a large HI spectral cube*, Journal of Astrophysics and Astronomy, Volume 43, Issue 2, article id.99, [arxiv:2211.02041]

## Publications Led by a Supervised Student

1. Mazumder A, **Chakraborty A**, Datta A, *Characterizing EoR foregrounds: A study of the Lockman Hole Region at 325 MHz*, MNRAS, Volume 495, Issue 4, pp.4071-4084, doi:10.1093/mnras/staa1317, [arxiv:2005.05205]
2. Mazumder A, **Chakraborty A**, Datta A, *A study on the clustering properties of radio-selected sources in the Lockman Hole region at 325 MHz*, MNRAS, Volume 517, Issue 3, pp.3407-3422, doi:10.1093/mnras/stac2801, [arxiv:2208.00992]
3. Mazumder A, Datta A, **Chakraborty A**, Majumder S, *Observing the reionization: effect of calibration and position errors on realistic observation conditions*, MNRAS, Volume 515, Issue 3, pp.4020-4037, doi: 10.1093/mnras/stac1994, [arxiv:2207.06169]
4. Sinha, A, Basu A; Datta A, **Chakraborty A**, *Deep uGMRT observations of the ELAIS-North 1 field: statistical properties of radio-infrared relations up to  $z \sim 2$* , 2022, MNRAS, Volume 514, Issue 3, pp.4343-4362, doi: 10.1093/mnras/stac1504, [arxiv:2111.08336]

## Collaboration Equivalent as a contributor to the work

1. **CHIME collaboration including Chakraborty A**, *A Detection of Cosmological 21 cm Emission from CHIME in Cross-correlation with eBOSS Measurements of the Ly-alpha Forest*, The Astrophysical Journal, Volume 963, Issue 1, id.23, 11 pp., [arxiv:2309.04404]
2. **CHIME Collaboration, including Chakraborty, A**, *Holographic Beam Measurements of the Canadian Hydrogen Intensity Mapping Experiment (CHIME)*, The Astrophysical Journal, [arxiv:2408.00172]
3. **Haochen Wang, Kiyoshi Masui, Kevin Bandura, Arnab Chakraborty, et. al**, *Demonstration of hybrid foreground removal on CHIME data*, PRD, [arxiv:2408.08949]
4. **CHIME Collaboration, including Chakraborty A**, *Characterization of the John A. Galt Telescope for radio holography with CHIME*, Proceedings of the SPIE, Volume 12190, id. 121902V 16 pp. (2022), [arxiv:2207.13876]
5. **CHIME collaboration, including Chakraborty, A**, *Beam Maps of the Canadian Hydrogen Intensity Mapping Experiment (CHIME) Measured with a Drone*, [arxiv:2407.04848]
6. Pal S, Elahi A, Bharadwaj A, Ali S, Choudhuri S, Ghosh A, **Chakraborty A**, Datta A, Roy N, Choudhury M, Dutta P, *Towards 21-cm Intensity Mapping at  $z=2.28$  with uGMRT using the Tapered Gridded Estimator I: Foreground Avoidance*, MNRAS Volume 516, Issue 2, pp.2851-2863, [arxiv:2208.11063]
7. Elahi A, Bharadwaj A, Ghosh A, Pal S, Ali S, Choudhuri S, **Chakraborty A**, Datta A, Roy N, Choudhury M, Dutta P, *Towards 21-cm intensity mapping at  $z=2.28$  with uGMRT using the tapered gridded estimator II: Cross-polarization power spectrum*, MNRAS Volume 520, Issue 2, pp.2094-2108, [arxiv:2301.06677]
8. Elahi A, Bharadwaj A, Ghosh A, Pal S, Ali S, Choudhuri S, **Chakraborty A**, Datta A, Roy N, Choudhury M, Dutta P, *Towards 21-cm intensity mapping at  $z=2.28$  with uGMRT using the tapered gridded estimator III: Foreground removal*, MNRAS Volume 525, Issue 3, pp.3439-3454, [arxiv:2308.08284]
9. Elahi A, Bharadwaj A, Ghosh A, Pal S, Ali S, Choudhuri S, **Chakraborty A**, Datta A, Roy N, Choudhury M, Dutta P, *Towards 21-cm intensity mapping at  $z=2.28$  with uGMRT using the tapered gridded estimator – IV. Wideband analysis*, MNRAS Volume 529, Issue 4, pp.3372-3386, [arxiv:2403.06736]
10. Gayen S, Sagar R, Mangla S, Dutta P, Roy N, **Chakraborty A**, Kumar J, Datta A, Choudhuri S, *Calibration requirement for Epoch of Reionization 21-cm signal observation. Part III. Bias and variance in uGMRT ELAIS-N1 field power spectrum*, JCAP, Volume 2024, Issue 05, id.068, 24 pp. [arxiv:2402.18306]
11. Choudhury, M, Datta, A, **Chakraborty, A** *Extracting the 21 cm Global signal using artificial neural networks*, MNRAS, Volume 491, Issue 3, p.4031-4044. [arxiv: 1911.02580]
12. Dzib S.A, .... **Chakraborty A**, 2022, *A global view on star formation: The GLOSTAR Galactic plane survey. VI. Radio Source Catalog II:  $28^\circ < l < 36^\circ$  and  $|b| < 1^\circ$ , VLA B-configuration*, [arxiv:2210.00560]

13. Mazumder A, Datta A, Sathyanarayana Rao M, **Chakraborty A** and others, 2022, *Synthetic Observations with the Square Kilometre Array (SKA) – development towards an end-to-end pipeline*, Journal of Astrophysics and Astronomy on "Indian Participation in the SKA", [\[arxiv:2211.04302\]](https://arxiv.org/abs/2211.04302)

## Contributed Talks

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| DECEMBER 2017 | "Characterizing Foregrounds in 21 cm Cosmology Observation with the uGMRT at 300-500 MHz",<br>"Universe after the first 200 million years Cosmic Dawn, Reionization and Post reionization with 21cm"<br>held at Presidency University from 11-13 December, 2017 |
| DECEMBER 2018 | "Detailed study of ELAIS N1 field using uGMRT observation at 300-500 MHz",<br>Frontiers in 21 cm Cosmology" held at Kodaikanal Solar Observatory from 10-18th December, 2018  |
| JANUARY 2020  | "Detail study of foregrounds in ELAIS N1 field",<br>"First Billion Years" at Indian Institute of Technology, Indore, 2020   |
| MARCH 2021    | "Characterizing Low-frequency Foregrounds for Cosmological HI studies with the uGMRT<br>- Indian SKA pathfinder" in AAS 236 virtual meeting held at USA   |
| JANUARY 2021  | "First multi-redshift limits on HI 21 cm signal from $z = 1.96 - 3.58$ using uGMRT"<br>in SAZERAC SIP (on 29th Jan 2021) on the 21-cm Signal from Cosmic Dawn and the Epoch of Reionisation   |
| JUNE 2023     | "Progress towards measuring HI auto power spectrum using CHIME data"<br>in TomFest: Frontiers in Radio Science and Engineering with Tom Landecker, at DRAO.   |
| MARCH 2024    | "Progress towards measuring HI auto power spectrum using CHIME data"<br>in Cosmology in the Alps conference, Switzerland  |