January 2023

Dedicated to my Parents ...

Declaration

I, **Anirban Chanda**, declare that the research in the thesis is my own *bona fide* work and carried out under the supervision of **Prof. (Dr.) Bikash Chandra Paul** from June 2017 to June 2022 at the **Department of Physics**, University of North Bengal, Darjeeling, Siliguri. The research contribution in the thesis has not been submitted for the award of any other degree/diploma. I declare that I have faithfully acknowledged and given credit to the research workers whenever and wherever their works have been cited in my work in the thesis. I further declare that I have not willfully copied any others' work, paragraphs, text, data, results, *etc.*, reported in journals, books, magazines, reports dissertations, thesis, *etc.*, or available at websites and have not included them in this thesis and have not cited as my own work.

Anirban Chanda

Date 13.01.2023

Place Siliguri

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CERTIFICATE OF SUPERVISOR

It is certified that the research work presented in the thesis entitled: "**Cosmological Models of the Universe in Different Gravitational Theories and Astronomical Observations"** by Mr. Anirban Chanda, Ph.D. Registration No.- ***Ph.D./Phy.(1305)/963/R-2019***, has been carried out under my supervision. The work is original and not submitted elsewhere for a degree.

January, 2023

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Document Information

Analyzed document	Anirban Chanda_Physics.pdf (D154790036)
Submitted	1/3/2023 9:07:00 AM
Submitted by	University of North Bengal
Submitter email	nbuplg@nbu.ac.in
Similarity	0%
Analysis address	nbuplg.nbu@analysis.urkund.com

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Cosmological Models of the Universe in Different Gravitational Theories and Astronomical Observations This thesis is submitted for the degree of Doctor of Philosophy by Anirban Chanda Under the supervision of Prof. Bikash Chandra Paul DEPARTMENT OF PHYSICS NORTH BENGAL UNIVERSITY SILIGURI, Dist: DARJEELING WEST BENGAL, Pin - 734013, INDIA REGISTRATION NO. YEAR OF SUBMISSION Ph.D/Phy.(1305)/963/R-2019 2023 Chapter 1 Introduction " There are more things in Heaven and Earth, Horatio, than are dreamt of in your philosophy. " —— William Shakespeare, Hamlet. I n 1915 Einstein proposed the general theory of relativity (GR) which revolutionized the theoretical understanding of the universe [2]. In 1917, Einstein applied his theory to obtain the model of the universe which initiated the study of relativistic cosmology [3]. As the astronomical observations during that time predicted a static universe, Einstein wanted to get a static model but failed to accommodate a static universe with his theory. In order to get a static universe, Einstein introduced a cosmological constant (Λ) which provides the repulsive force to obtain a stable static universe which is called Einstein's static universe (ESU). However, in 1922 Friedmann obtained relativistic solutions which describe an expanding universe without a cosmological constant [4]. But the cosmological solution was unattended and remained of academic interest for a long time. Later Lamaitre used the relativistic solution to formulate the Big Bang cosmological model [5]. However, in the year 1929 Hubble discovered that the spectral lines emitted from remote galaxies appear systematically shifted towards the red end of the spectrum indicating an expansion of the universe [6]. Hubble showed that galaxies recede in all directions and more distant ones recede more rapidly proportional to the distance between them. Hubble's discovery led Einstein to abandon the cosmological constant term (Λ), which he introduced to construct a static universe. Hubble's discovery indicates that the universe is expanding. If one extrapolates this cosmic expansion backward in time following the known laws of physics then the universe can be traced back to an extremely hot and dense state [7]. It led to a singularity, confirming initial explosion that occurred approximately 13.8 billion years ago called Big Bang. After the Big Bang, the universe began to expand and cooled sufficiently allowing nucleosynthesis, that led to the formation of stars and galaxies as we observe today. With the advent of modern science, cosmology is transforming from a

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Acknowledgements

The pursuit of scientific research requires immense patience and support from family, friends, and most importantly teachers and colleagues. The path to reach this stage of my research career was not smooth and the challenges made this experience all the more memorable. This Ph.D. thesis is not the end of my academic endeavors rather it is the beginning of a long journey. It is only appropriate to take this opportunity to express my gratitude to the amazing human beings who have supported me throughout my Ph. D. and will continue to do so in the future.

First and foremost, I would like to express my sincere gratitude to my supervisor, Dr. Bikash Chandra Paul, Professor, Department of Physics, University of North Bengal, for his continuous support and encouragement which motivated me to pursue my Ph.D. He was always there whenever I needed him and long discussions with him about different research avenues enriched my knowledge of the subject to a considerable degree. He handled his responsibilities as a mentor and supervisor despite being quite busy with other academic and administrative activities as the Head of the Department as well as the Dean of the PG Faculty of Science, University of North Bengal for some time. I owe him a great debt for teaching me Cosmology in my M.Sc. course and then throughout my Ph.D. program as well. He always encouraged me to pursue new research topics and always gave me the freedom to dive into topics other than my own research. The most admirable quality about him is that despite my mistakes he always took care of me and helped me as any parent would, never losing his temper. Growing up I always wondered why a teacher is called a friend, philosopher, and guide but knowing him I finally understood the true essence of that statement. He deserves all the credit in the world for shaping this thesis in its current form.

I would like to start my long list of acknowledgments with my *late* grandmother Sabita Chanda. *"Katu"* where ever you are thank you for making my childhood so special with your constant support and motivation. My *late* grandfather Sisir Ranjan Chanda also deserves an honourable mention although I wasn't fortunate enough to meet him, he was always there in my family's thoughts and prayers. It is difficult to express in words how much I owe my parents. Whatever I have achieved in my life it is due to my father Mr. Asim Kumar Chanda and my mother Mrs. Sagarika Chanda who stood tall beside me sheltering me from all the storms. They never dissuaded me from choosing my own career options and always supported my dreams and ambitions. Thanking them will never be enough. I am grateful to my three pishies (aunties) Mrs. Shyamasree Chanda, Mrs. Babli Chanda, and Mrs. Jayasree Chanda for their unconditional love and support since childhood. My mejho pishi always considered me as her elder son and I have spent countless nights in her house since my college days. I would like to take this opportunity to thank my mejho masi, Mrs. Dora Adhikary also who also played a major role in my life. My cousins Dr. Pratyay Ghosh, Mrs. Karubaki Adhikary, Mr. Soumya Ghosh, and Ms. Nilanjana Majumdar deserve special mention as they always acted as my happy place whenever I was under stress. Late-night Dota 2 sessions with my brother Soumya always brought a smile to my face no matter how stressful my day was. My elder sister Karubaki always provided me with mental peace and support whenever I needed that. Lastly, all my family members whose names are not mentioned here also deserve my gratitude for making this journey worthwhile.

Most of us heard the phrase “a brother from another mother”, Mr. Sagar Dey played that role for me in my life. Since my school days, we formed a very close bond that carried through my Ph.D. life and I am hopeful it will stay like that in the coming days. He was always there whenever I needed him and academic discussions with him made this journey much easier. My seniors, Dr. Arindam Saha and Dr. Souvik Ghose deserve special credit. They provided me with immense help and deep knowledge whenever I encountered any difficulties regarding my research. I would like to thank Dr. Binay Rai who was my colleague in the lab for his invaluable assistance. My gratitude extends to all the research scholars of my department Bibhash, Bikash, Prabir, Joy, Pratik, Avijit, Rajat da, Smriti, Priyanta, Apsari, Manoj to name a few. We formed a secondary family in the department and I will miss our road trips and gossip sessions over a cup of coffee. I am grateful to all my co-authors and collaborators for their constant assistance and constructive suggestions especially, Prof. Aroonkumar Beesham, Prof. Sunil D. Mahraj, Dr. Shounak Ghosh, Dr. Amit Das, Dr. Souvik Ghose, and Dr. Arindam Saha. This thesis wouldn’t have been possible without their infinite contribution. I also want to acknowledge the IUCAA Centre for Astronomy Research and Development (ICARD), NBU for providing me necessary research facilities to carry out my work. I am thankful to IUCAA, Pune for giving me the opportunity to access the library facilities during my visits. My gratitude and warm wishes extend to all the seniors and juniors of my department whom I came in contact with over the years and whose names cannot be mentioned due to lack of space.

I am deeply thankful to all the teachers of the Physics Department, NBU for their valuable advice and guidance. I am also thankful to all the non-teaching employees of my department especially Rajesh da, Sudip da, Lubai da, Ayub da, Sarita di to name a few. We shared

a friendly bond and had long chats in the departmental office as well as in the computer lab. My deepest gratitude extends to my teachers Mr. Dipesh Chanda and Mrs. Basabdatta Bose, Physics Department, Siliguri college. They successfully ignited the passion to pursue advanced studies in the mind of a small-town boy and always acted as a family. My physics teacher from my hometown, Mr. Utpal Pal played a crucial role in my life and he made me fall in love with this subject for which I will always be grateful. I would like to thank all the employees of the University who helped me with my fellowship-related issues. My buddies Biswadip Roy Choudhury, Palash Basak, Arup Das, Gourab Ghosh, Koushik Roy among others deserve special credit and I am eternally thankful for their unconditional love and support. They believed in me and always encouraged me to believe in myself as well. Lastly, this has been a long journey and I have lost many loved ones along the way but I would like to take this opportunity to thank them for their contribution to making this journey possible.
I am thankful to IUCAA, Pune for granting me the opportunity to visit the institution on multiple occasions as a part of their visitor student program. Some of my research work was done in that premier institution. The hospitality and warm welcome that they provided is unmatched. The calm ambiance and clean environment along with its state of the art facilities provided the perfect setting to pursue high-quality research. I am thankful to the University of North Bengal for awarding me the State fellowship.
The University of North Bengal has been my second home for the last seven years. I enjoyed each and every moment I spent on this beautiful campus and can vouch for its scenic beauty as well as its academic excellence. The memories which I have with my classmates, seniors, and juniors are unforgettable and I will treasure them for the rest of my life.
Finally, I am thankful to the Almighty for providing me with the strength and courage to carry on with my dream even when I faced severe obstacles throughout my life. The infinite cosmos and its countless wonders motivated me to take a small sip from this vast ocean. This accomplishment would not have been possible without the contribution of each and every one mentioned above. Words are not enough to express the amount of gratitude that I harbour in my mind but this is the easiest way to let them know how much thankful I am.

List of figures

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