Goa University

Discipline of Physics, School of Physical and Applied Sciences,

Report on Workshop on Gravitational waves and LIGO India

1. Title of the Event/Activity/program	**Workshop on Gravitational Waves and LIGO India**
2. Date and Time	27th November to 1st December 2023 9:00 am to 17:00 pm
3. Mode of conduct (Physical/Online)	Physical
4. School/ Directorate/ Section	School of Physical and Applied Sciences
5. Collaborating Agency/School/Directorate	Inter University Centre for Astronomy and Astrophysics Pune
6. Detail of the Resource Person (Brief biodata)	**1. Prof. Sanjeev Dhurandhar (IUCAA-Pune)** Prof. Sanjeev Dhurandkar is Emeritus Professor at IUCAA-Pune and a Fellow of the American Physical Society. Dr. Sanjeev Dhurandhar started the field of gravitational waves in India in 1989. He is one of the proposer's of LiGO-India project of constructing a detector on Indian soil. He received his Ph. D. in 1981 in Astrophysics at Tata Institute of Fundamental Research, Mumbai under the guidance of Prof. Jayant Narlikar. He received The Meghnad Saha Memorial Gold Medal for the year 2018 and The Milner's Special Breakthrough Prize for Fundamental Science shared with the Ligo Science Collaboration. He is the Fellow of the three academies of INDIA; Indian Academy of Sciences, Bangalore; National Academy of Sciences, Allahabad and Indian National Science Academy, Delhi.

2. Prof. Nigel T. Bishop (University of Rhodes South Africa)

Nigel Bishop studied at the University of Cambridge. He was tutored by someone who would become the most famous relativists of our time, Stephen Hawking. He obtained the BA (Honours) degree in mathematics, and moved to the University of Southampton obtaining the PhD degree in 1976. At the same time he was elected a Fellow of the Royal Astronomical Society. He was appointment as full Professor was at UNISA in 1992. In 2009 he moved to Rhodes University as Professor and Head of Department of Mathematics. He retired in 2016, and is currently Emeritus Professor. The subjects of this work range from mathematical analysis to computer programming, from quantum gravity to discoveries about the horizons of black holes, and from cosmology to the theory of travel faster than light. For about the last 30 years the focus of his work has been on gravitational waves, and in particular how they are calculated. He has held several visiting appointments in different countries including India. He has served as President of the South African Gravity Society. For many years he has been on the Council of the South African Mathematical Society, serving two terms as President. Internationally, he serves on the Council of the International Society on General Relativity and Gravitation.

3. Dr. Apratim Ganguly (IUCAA Pune)

Dr. Apratim Ganguly completed his undergraduate and postgraduate studies at the University of Calcutta and later ventured to South Africa as a Square Kilometre Array (SKA) research fellow, earning his Ph.D. in Applied Mathematics in 2016 from University of KwaZulu-Natal (UKZN), Durban. Dr. Ganguly gained diverse research experiences through postdoctoral positions at Rhodes University, PUCV Chile, and International Centre for Theoretical Sciences (ICTS) and in 2021, joined IUCAA as a LIGO-India staff scientist, contributing his expertise to the gravitational-wave data analysis. Since 2019, Apratim has been an active member of the LIGO-Virgo-KAGRA collaboration. His research pursuits span gravitational-wave

	astronomy, black hole perturbation theory, alternative theories of gravity, and pulsar astronomy. **4. Prof. Patrick Das Gupta (Delhi University)** Prof. Das Gupta is faculty at the Department of Physics & Astrophysics, Delhi University. He is experienced Professor with a demonstrated history of working in the research industry. Skilled in Mathematical Modeling, Physics, Computational Physics, Data Analysis, and Spectroscopy. Strong education professional with a Ph.D. focused in General Relativity, Astrophysics, Quantum theory, PhD in Observational Cosmology from TIFR, Mumbai. **5. Prof. Chandra Kant Mishra (IIT Madras)** Prof. Chandra Kant Mishra is faculty at department of Physics, Indian Institute of Technology Madras. His expertise and area of research is Gravitational waves. **6. Prof . Sanjit Mitra (IUCAA Pune)** Professor Sanjit Mitra is Scientist at IUCAA Pune. He is LIGO-India Science Spokesperson and LIGO-India Project Coordinator, IUCAA. Prof. Mitra works on observation of gravitational waves (GW) and cosmic microwave background (CMB). He has developed algorithms for accurate and efficient analysis of data coming from current GW and CMB experiments. For many years he is part of the LIGO-Virgo Scientific Collaboration, the IndIGO consortium and the Planck Collaboration. **7. Prof. Debarati Chatterjee (IUCAA Pune)** Prof. Debarati Chatterjee is a theoretical astrophysicist with an expertise in analytical and numerical description of compact stars (neutron stars and white dwarfs). Her main interests are in developing global models which take into account both microscopic (involving interdisciplinary physics such as nuclear and particle physics, superconductivity) and macroscopic aspects (magnetic fields, relativity) consistently in order to improve astrophysical simulations

	and for better interpretation of multi-messenger astrophysical observations. **8. Prof. Anand Sengupta (IIT Gandhinagar)** Prof. Anand Sen Gupta is t Gravitational Wave Astronomer and at IIT Gandhinagar. His research interest are in Gravitational-wave physics and astrophysics. He is involved in developing efficient algorithms for extraction of gravitational waves embedded in the noisy data from a network of gravitational wave detectors, and solving the corresponding inverse problem to reconstruct the sources responsible for these signals. He also works on predictive modelling of ecological data using a variety of data-science techniques. **9. Dr. Suresh Doravari (IUCAA Pune Ligo Team)** Research faculty (STO-F R&D) at the Inter-University Centre for Astronomy and Astrophysics (IUCAA), Pune, India. Dr. Suresh has a keen interest in pursuing experiments in fundamental physics. That is usually combined with development of novel new sensors, actuators and design of control systems. He has chiefly worked on gravity related experiments, testing the equivalence principle, looking for new interactions, looking for violations of fundamental symmetry laws and such. He has a large amount of technical expertise in laboratory physics work ranging from UHV systems to precision control and data acquisition. Please see my CV for a details. **10. Dr. Manasadevi P. Thirugnanasambandam (IUCAA Pune Ligo Team)** R&D Scientific & Technical Officer-D at the Inter-University Centre for Astronomy and Astrophysics (IUCAA), Pune, India. She shares responsibility for the upcoming LIGO-India gravitational wave detector as a part of the gravitational wave research group at IUCAA. **11. Dr. Shivaraj Kandhasamy (IUCAA Pune Ligo Team)** Research faculty (STO-E R&D) at the Inter-University Centre for Astronomy and Astrophysics (IUCAA), Pune, India.

7. Number of Faculty attended/participated	10
8. Number of Student attended / participated	43
9. No. of external students/faculty/other participants	23
10. The objectives of the Program/activity/event	The Objective of the workshop is to instill a deep understanding of gravitational wave physics and data analysis techniques among participants, equipping them with the skills needed to understand and explore these groundbreaking discoveries. Practical sessions from data analysis to instrumentation participants will gain tangible skills to contribute meaningfully to ongoing and future research in Gravitational waves.
11. Description of the Program/activity/event	The era of gravitational wave astronomy has revolutionized our understanding of the universe. With the aim to have deep understanding of GW and data analysis the IUCAA-Pune and SPAS Goa University organized 5 days **workshop on Gravitational waves and LIGO India** from 27th November to 1st December 2023. The participants of the workshop were master students from Goa and from other states. The workshop comprised of theory of Gravitational wave Physics: general relativity, source modelling, basics of search and parameter estimation and detectors. It gave participants a profound understanding of the theoretical foundations and cutting-edge methodologies underpinning gravitational wave research. The data analysis and instrumentation sessions gave skills to contribute meaningfully to ongoing and future research. A public talk was organised on 28th November on the sources of Gravitational waves by Prof. Nigel T Bishop at Goa University.

12. Benefit/Key outcomes of the Program/activity/event	1. Understanding of gravitational wave physics and data analysis techniques among participants. 2. With LIGO-India set to become a critical player in the global gravitational wave network, this workshop gave unique opportunity for participants to connect with this ambitious project. 3. They will learn about the cutting-edge technologies and research opportunities it offers.
13. Enclosures with report	Brochure, Notice, Geo-tag photos, Attendance of students/faculty/external participants, Bio Data of resource person (if applicable), Any other information.

RDessai

Dr. Reshma Raut Dessai

Assistant Professor, SPAS

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Seal of the School

School of Physical and Applied Sciences
Goa University

Workshop on GRAVITATIONAL WAVES & LIGO INDIA

27th November to 1st December 2023

Organised by Inter University Centre for Astronomy and Astrophysics Pune and Goa University

About the workshop:

The era of gravitational wave astronomy has revolutionized our understanding of the universe. This workshop endeavours to instill a deep understanding of gravitational wave physics and data analysis techniques among participants, equipping them with the skills needed to understand and explore these groundbreaking discoveries. Featuring a series of lecture sessions covering the fundamentals of gravitational wave physics: general relativity, source modelling, basics of search and parameter estimation and detectors, will furnish participants with a profound understanding of the theoretical foundations and cutting-edge methodologies underpinning gravitational wave research. The heart of this workshop lies in its practical sessions. From data analysis to instrumentation, they will gain tangible skills to contribute meaningfully to ongoing and future research. With LIGO-India set to become a critical player in the global gravitational wave network, this workshop is a unique opportunity for participants to connect with this ambitious project. They will learn about the cutting-edge technologies and research opportunities it offers.

About the Organizing Institutions

Goa University

Goa University was established under the Goa University Act of 1984 and commenced operations on 1 June 1985. The university provides higher education in the Indian state of Goa. It is located on Taleigao Plateau overlooking Zuari estuary on a picturesque campus spread over 402 acres with state-of-the-art infrastructure. The University, on its campus, has 10 schools. The formation of schools has been done at the start of the academic year 2019-20 with amalgamation of traditional departments to allow organic evolution of new courses. They offer programmes leading to Undergraduate degree (3), Masters degree (35) and Ph.D. degree (25) in various disciplines.

IUCAA-Pune

The Inter-University Centre for Astronomy and Astrophysics (IUCAA) is an autonomous institution under the University Grants Commission (UGC) of India to promote the nucleation and growth of active groups in astronomy and astrophysics at Indian universities. IUCAA's activities fall under two broad programmes: core academic programmes, which include basic research, the Ph.D. programme, advanced research workshops and schools, the giant metre-wave radio telescope, and guest observer programmes; and the visitor academic programmes, which include the visitor and associates programme, refresher courses for teachers.

Who can participate:

The workshop is meant for postgraduate/Engineering students interested in GW astronomy. A small number of highly motivated final-year undergraduate students will be considered. Background in gravitational wave astronomy is preferred.

How to apply

Upcoming workshop details can be found at : http://astrosat-ssc.iucaa.in/workshops

Apply here : http://surl.li/lmtgu

Important Deadlines

Participation Limit : 40 who will be provided travel sleeper class funds, boarding and lodging

Duration of workshop: 27thNov-1st Dec 2023

Last date to submit application: 15 October 2023

Selected applicants will be informed by : 20 October 2023

Coordinators: IUCAA: Dr. Apratim Ganguly, email id: apratim@iucaa.in

Goa University: Dr. Reshma Raut Dessai, email id: reshma@unigoa.ac.in

Venue : School of Physical and Applied sciences, Goa University, Goa

LIGO INDIA

IUCAA

INVITATION

Gravitational waves and their sources

Tuesday, 28th November 2023 from 5:30 to 6:30 pm

Guest Speaker

Prof. Nigel T. Bishop

Emeritus Professor, University of Rhodes South Africa

Abstract:
Gravitational waves (GWs) were predicted in 1916, just after the formulation of general relativity. It took another 50 years, for the theory to be fully developed and for the first attempts at observation; and then another 50 years until 2015 when the first direct observation of GWs was made. After reviewing the history of GWs, the talk will discuss their generation and the astronomical systems that produce strong signals; and the effects of GWs on matter that they pass through and thus strategies for their detection. It will also discuss what the GW observations made to date tell us about physics and astronomy, and what we expect to learn in the future.

Venue:

Conference Hall, Goa University (Admin Block)

All are cordially Invited

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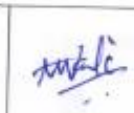
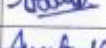
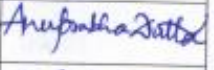
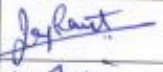
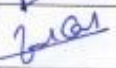
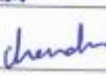
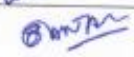
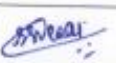
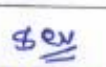
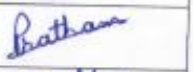
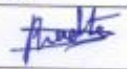
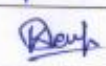
SCHOOL OF PHYSICAL AND APPLIED SCIENCES (SPAS) GOA UNIVERSITY
ATTENDANCE
Workshop on Gravitational waves and LIGO India

Sr. No	Name	Affiliation	Sign
1	Naresh Kumar Patra	BITS Pilani K K Birla Goa Campus	
2	Lokesh Kumar	BITS Pilani K K Birla Goa Campus	
3	N Nazeef	BITS Pilani Hyderabad Campus	
4	Saurabh Singh	Maharashtra Institute of Techonology (MIT-WPU)	
5	Bhavik Girnara	Department of Physics Sardar Patel University	
6	Amrita Baruah	Cardiff University	A. Baruah
7	Toshan Kumar Dhaker	IIT Bombay	
8	Sanskriti Sarkar	Rajiv Gandhi Institute Of Petroleum Technology	
9	Kaushal Joshi	Visvesvaraya National Institute of Technology, Nagpur	
10	Shreyan Goswami	Sardar Vallabhbhai National Institute of Technology, Surat	
11	Sina Milan VK	University of Calicut	
12	Satya Srikar M	National Institute of Technology, Karnataka	
13	Gaurav Gawade	St. Xavier's College (Autonomous), Mumbai	

14	Malvika Naik	St. Xavier's College, CSMT, Mumbai, Maharashtra	
15	Ajinkya Naik	Savitribai Phule Pune University	
16	Anirudh Nemmani	Indian Institute of Science Education and Research Tirupati	
17	Aboli Bhandari	Fergusson College,Pune	
18	ANUPRABHA Dutta	National institute of technology Warangal	
19	Jayesh Raut	COEP	
20	Psuhparaj Chakravarti	IISER Pune (Master's at IUCAA)	
21	Sreelakshmi Mundakkal	IISER Tirupati	
22	Nidhi Biswas	Indian Institute of Technology, Madras	
23	Ladeeda C	School of Pure and Applied Physics, MG University, Kottayam	
24	Anirudh Parsekar	Goa University	
25	Chandra Mishra	Goa University	
26	Manthan Sawant	Goa University	
27	Sakshi Desai	Goa University	
28	Krutika Shivolkar	Goa University	
29	Adnyey naik	Goa university	
30	Sukhdev Yadav	Goa University	
31	Pratham Bhat	Goa University	
32	Apeksha Phadte	Goa University	
33	Karina Velip	Goa University	
34	Mahima Patekar	Goa University	

35	Kusumita Ramnathkar	Goa University	
36	Pujal Govekar	Goa University	
37	Shubham Gawas	Goa University	
38	Ravina Patil	Goa University	
39	Harish Gad	Goa University	
40	Govinda Phadte	Goa University	
41	Menchie Fernandes	Goa University	
42	~~Kusumita Ramnathkar~~	~~Goa University~~	
43	Snehal Hasolker	Goa University	
44	Suharsh Padlosar	Goa University	

SCHOOL OF PHYSICAL AND APPLIED SCIENCES (SPAS) GOA UNIVERSITY
ATTENDANCE
Workshop on Gravitational waves and LIGO India

Sr. No	Name	Affiliation	Sign
1	Shivaraj Kandhasamy	IUCAA, Pune	
2	Apratim Ganguly	IUCAA, Pune	
3	Namita C. Rane	SPAS, Goa University	Namita
4	Pranav Naik	SPAS. Goa University	
5	Bhargav Narayani	SPAS Goa University	
6	S V Dhurandhar	IUCAA	
7	Chandrakanth	IIT Madras	
8	ANAND SENGUPTA	IIT GANDHINAGAR	
9			
10			

SCHOOL OF PHYSICAL AND APPLIED SCIENCES (SPAS) GOA UNIVERSITY

ATTENDANCE

Workshop on Gravitational waves and LIGO India

Sr. No	Name	28/11/23	29/11/23	30/11/23	1/12/23
1	Naresh Kumar Patra				
2	Lokesh Kumar				
3	N Nazeef				
4	Saurabh Singh	Ab			
5	Bhavik Girnara				
6	Amrita Baruah				
7	Toshan Kumar Dhaker				
8	Sanskriti Sarkar	Ab	Ab	Ab	
9	Kaushal Joshi				
10	Shreyan Goswami				
11	Sina Milan VK				
12	Satya Srikar M				
13	Gaurav Gawade				
14	Malvika Naik				
15	Ajinkya Naik				
16	Anirudh Nemmani				
17	Aboli Bhandari				
18	ANUPRABHA Dutta				
19	Jayesh Raut				
20	Psuhparaj Chakravarti				
21	Sreelakshmi Mundakkal				

22	Nidhi Biswas				
23	Ladeeda C				
24	Anirudh Parsekar				
25	Chandra Mishra				
26	Manthan Sawant				
27	Sakshi Desai				
28	Krutika Shivolkar				
29	Adnyey naik				
30	Sukhdev Yadav				
31	Pratham Bhat				
32	Apeksha Phadte				
33	Karina Velip				
34	Mahima Patekar				
35	Kusumita Ramnathkar				
36	Pujal Govekar				
37	Shubham Gawas				
38	Ravina Patil				
~~39~~	~~Harish Gad~~				
40	Govinda Phadte				
41	Menchie Fernandes				
~~42~~	~~Kusumita Ramnathkar~~				
42	Snehal Hasolker				
43	Suhasish Padlostar				
44	Pranjali Gad				

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In the realm of gravitational waves

Govind S Poteker

Prof Nigel T Bishop, emeritus professor, University of Rhodes, South Africa delivering a public talk on the subject 'Gravitational Waves and its Sources,' The workshop was jointly organized by Goa University and Inter-University Centre for Astronomy and Astrophysics, Pune.

Gravitation Waves (GW) radiation is observed in massive neutron stars and black holes. GW is basically 'ripples' in the fabric of space-time caused by some of the most violent activity and energetic processes that are observed in the Universe. Prof Bishop said, "GW was not understood till recently although it was postulated by Albert Einstein in his General Theory of Relativity in 1915 and a year later, GWs were predicted. He thought that it would be very difficult to study GW as they are very small to measure. It was difficult to understand then. Initially, bar detectors were used to find GWs."

Prof Bishop who has more than 70 publications and three books to his credit in astrophysics and cosmology is known for his discoveries about the apparent horizons of black holes, their mergers, numerical simulations, and understanding of Einstein's Equation. Now, the Laser Interferometer Gravitational-wave Observatory (LIGO) is conducting observations to find evidence of GW.

Prof Nigel T Bishop

According to Special Theory, nothing travels faster than the speed of light. In the last 50 years, the theory of GWs has been developed. Observational evidence of a pulsar was recorded while studying PSR1913+16 in 1970, and the first direct evidence of GW was observed in 2015, Prof Bishop mentioned about the great discovery. While electromagnetic radiation is the interaction between two sources, GW can be generated by a single source that can pass through any matter.

By using LIGO, accurate detection is possible provided one conduct study for 5-10 years. The ground-based observatory uses three detectors for detecting GW, but still, the detection is only 80 percent accurate. LIGO (US), Virgo (Italy) and KAGRA (Japan) observatories are presently looking out for any signs of GWs emitted by neutron stars and black holes. Playing a video simulation of the merger of equal mass binary black holes and neutron stars mergers, Prof Bishop informed that GW observation so far has shown consistency with Einstein's General Theory of Relativity. GW was detected while observing GW170817, a neutron star merger in an elliptical galaxy.

Concluding his talk on cosmology's newest challenge, he felt there are better prospects as GW provides clues in understanding mergers of neutron stars and black holes as mergers are standard sirens that help in estimating distance leading to the Hubble Constant, which help find how fast the universe is expanding.

A similar facility is being set up in the Hingoli district of Maharashtra, India. LIGO India is a mega project in astronomy that is expected to start operation in 2030. It is for a breakthrough research outcome, development of cutting-edge technology, and opportunity for students and researchers.

During the workshop, galaxy of researchers besides Prof Bishop (University of Rhodes South Africa) presented lectures that included Prof Sanjeev Dhurandhar (IUCAA-Pune), Prof Patrick Das Gupta (Delhi University), Prof Chandra Kant Mishra (IIT Madras), Dr Debarati Chatterjee (IUCAA Pune), Dr Apratim Ganguly (IUCAA Pune), Prof Sanjit Mitra (IUCAA Pune), Prof Anand Sengupta (IIT Gandhinagar), Dr Suresh Doravari, Dr Manasadevi P Thirugnanasambandam and Dr Shivaraj Kandhasamy (All IUCAA, Pune LIGO Team) gave presentations on the latest happenings in different fields of astronomy and astrophysics.

Dr Apratim Ganguly and Dr Reshma Raut Dessai coordinated the workshop. It focused on the theory of Gravitational waves, Relativity, LIGO Detectors, the sources of gravitational waves, the data analysis, and instrumentation sessions. Participants included masters' students from Goa University and students from other states.