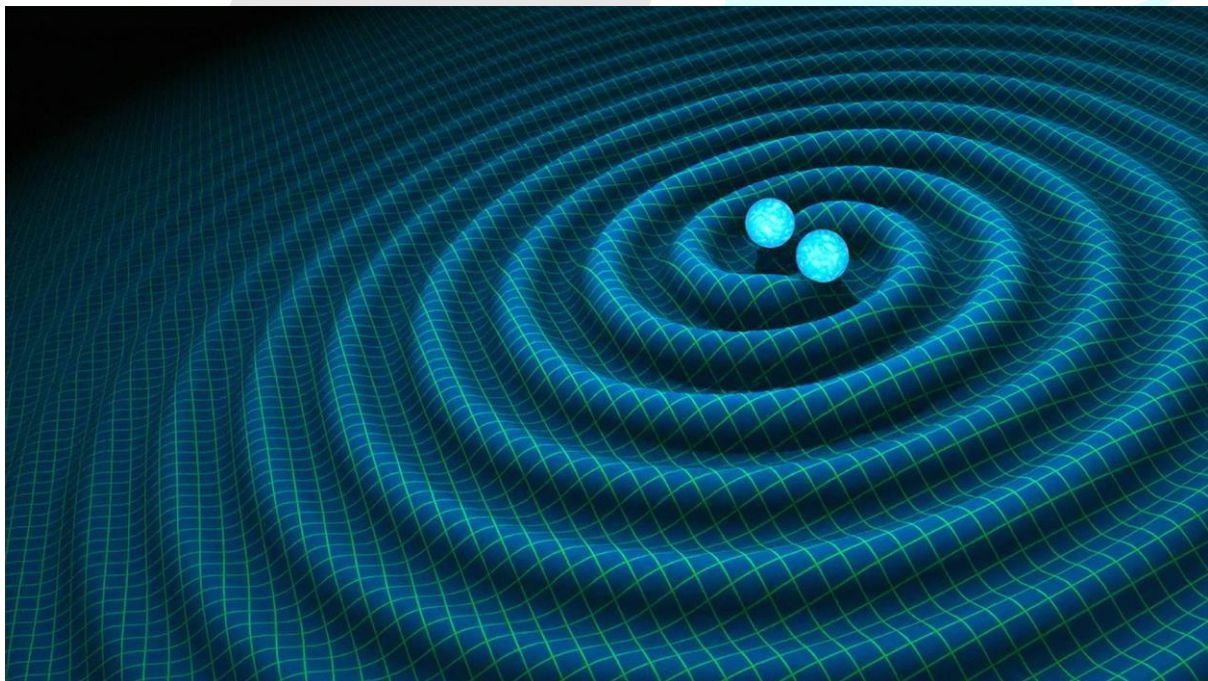


A Paper Presentation on Gravitational Waves

“The curvature of spacetime is influenced by the presence of Gravity” - this statement shows the major breakthrough in the way we perceive the Universe; that came when the genius Albert Einstein published his work on General Relativity. But when this work is related to the outcomes of special relativity - saying that no information can travel faster than light, it was hypothesized that acceleration of masses would cause disturbances in space-time, similar to how accelerating charges produce electromagnetic waves.

Through some interesting events like neutron star merging and supernova, it is observed that such disturbances in masses cause ripples in the spacetime continuum; and which are now called Gravitational Waves. Einstein's mathematics showed that massive accelerating objects (such as neutron stars or black holes orbiting each other) would disrupt space-time in such a way that 'waves' of distorted space would radiate from the source.

Through recent times efforts have been made to observe and study these waves and their properties. Studying them reveals about the structure and history of our universe.



- 1) Four fundamental forces are known to exist in the Universe. Weak and Strong Nuclear Forces are strong, but very short-ranged. On the other hand, Electromagnetic and Gravitational Forces are long-ranged. We know about these forces because they interact with matter in different ways. Gravity is somewhat distinct, as it exists because of matter itself. It is shown that this Force propagate in the form of waves.
 - What are Gravitational Waves and how are they modelled using General Relativity and causality speed limit? How is the wavefront generated in the linearised field? Explain why these waves propagate at the speed of light either intuitively or mathematically.
 - The waves will disorient the spacetime its travelling through by polarising it in the direction perpendicular to it is travelling. Show how the field equations account for this polarisation of spacetime.
- 2) Binary systems are very well known sources of Gravitational Waves. In theory, any accelerating mass should radiate energy in the form of such waves. But the effect is almost negligible. That's why massive object binaries - like spiralling Neutron Star pairs or Black Hole binaries are now targeted to know more about the nature of gravitation.
 - What is the energy carried by the gravitational waves? Explain how this energy radiated is responsible for the loss of Angular Momentum of the binary system, and causes inward spiralling of the two objects till the objects merge.
 - What is the frequency and wavefront of the waves that are generated in these systems?
 - The Hulse-Taylor Binary system, which was first perceived as a pulsar, provided the first evidence of gravitational waves. Describe in detail how the evidence was experimentally established by observing the strong orbital decay of the system?
 - It is known that a Supernova event shreds almost all of the star's mass into space, leaving the compact dense core. Despite being well-known sources of Gamma Ray Bursts, show that such events would radiate massive energy in the form of Gravitational waves as well. How will be the waveform, frequency and energy be different in this case?
- 3) Blackhole binaries are objects of interest, as the in-spiral movements and merging releases enormous energy. Such a black hole merger was detected on Earth in September 2015 by the LIGO Instrument. It has been recorded as a signal lasting about a second, called as a "chirp".
 - Where is the location of the binary black hole system which was observed then? What is the approximate energy released during this merger process? How is the location and orientation of the instrument would affect the observed signals?
 - The LIGO instrument is based on optical interferometry. Briefly describe what is interferometry and how was it applied in the detection of gravitational waves, showing the construction of the detector. How has the instrument been able to measure at such high accuracy levels?
 - Weber Bars are an alternate proposed method of detection, which implies on the resonance of heavy metal cylindrical bars with the waves. Show in detail

how this idea can be implemented to obtain positive results, and up to which accuracy level it can get. What can be the limitations to this approach?

- 4) The European Space Agency is currently developing the Laser Interferometry Space Antenna (LISA) project - a prototype of a space-based instrument which will be used to detect gravitational waves. It is also based on the interferometry principle, similar to how it is applied on LIGO.
- As LISA will be a space-based instrument, point out the advantages that it will have over ground-based detectors like LIGO.
 - The mission comprises of three spacecrafts put in a heliocentric orbit. Briefly describe the trajectory and the model working process of the spacecrafts to detect ripples in spacetime caused by Gravitational Waves.
 - What is the frequency range of the waves that LISA is designed to detect? How is this frequency band related to the spacecraft trajectory and the instruments involved in it?
 - What can be the potential targets that can be chosen for this instrument? Describe them with proper justification.

Q4 reference (LISA) - https://en.wikipedia.org/wiki/Laser_Interferometer_Space_Antenna
<https://www.ligo.org/science/Publication-O1StochNonGR/index.php>
<http://www.ams.org/journals/notices/201707/rnoti-p684.pdf>

ABOUT REPORT

- Format: The online report must be submitted in PDF formats only. Report must be submitted in English language. All other formats will automatically be rejected.
- Page Limit: The report must not exceed 16 pages which include front page, index, appendix and bibliography. The font size used for writing the content should be 12-14.

ABOUT PRESENTATION

- The final round, that is, the Presentation and Questionnaire, will be held during NSSC 2019 at IIT Kharagpur
- The time limit for the presentation is 14 minutes.
- The teams have to wrap up the presentation within the given time limit. A warning bell shall be issued one minute before the time limit.
- However, the presentation for the final round will be in **PowerPoint (PPT, PPTX) format (Please note carefully)**.
- The diagrams should be neat and clearly labelled and images must be given credit.
- You may draw your own labelled illustrations wherever required and embed paper work as images wherever necessary.

RULES AND REGULATIONS

- Team Size: The maximum permissible number of members in a participating team is 2. However, they need not belong to the same institute/ college/ university.
- The best teams will be selected and they will be presenting their reports in NSSC'19 at IIT Kharagpur.
- All teams must submit the digital version of their documents latest by **30th September, 2019** along with the **names, contact and institute details** of the participants. Entries without the above details will not be accepted.
- All entries have to be submitted to **paperpresentation@nssc.in**
- Top 3 teams will be awarded a Certificate of Excellence for the event.
- Prize money worth 20,000 INR will be distributed to the winning teams.
- Plagiarism in content shall not be accepted and will result in cancellation of the entry.

JUDGING PARAMETERS

The event consists of 100 points. They are distributed as follows:

- 45 points for the Report submitted as part of the Preliminary round
- 40 points for the Final Presentation (if selected for the final round) which will be conducted during NSSC 2019.
- 15 points for the Questionnaire session after the presentation.
- Extra points will be awarded for posing well-reasoned questions.