PANE NEWSLETTER
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feature


Cross sectional view of the ITER

We are continuing with our description about ITER in this two-part Feature Article by Prof Howard Wilson.

At the time of publishing this article, the progress made by the close cousin of ITER-type reactor, the Spherical Tokamak, is noteworthy.

MAST-Upgrade is the next-generation spherical tokamak with which Prof Wilson is directly associated.

CONTENTS

1-2
FEATURE
ITER

3 - 6
NEWS

7, 9 - 12
ARTICLES

8
RESEARCH HIGHLIGHTS
Neutrino Mixing

16
EDITORIAL
On the Brink

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Plasma Physics Research
iter and beyond - part II

Howard Wilson

One method for controlling the ELMs is to place current-carrying coils in the vicinity of the plasma surface. The magnetic field produced by these coils perturbs the confining magnetic fields of the tokamak, degrading the confinement in the pedestal region. This relaxes the pressure gradient there, below the level required for ELMs to be triggered. The technique was pioneered on the DIII-D tokamak in the US, but has since been demonstrated on many tokamaks around the world. However, it is not universally observed that the ELMs are suppressed, and in most parameter regimes they are merely mitigated (i.e. lower energy eruptions). The physics is complicated, but it is clear that the plasma attempts to screen the applied magnetic perturbations, preventing them from penetrating the plasma. We do not fully understand this screening process. Furthermore, when the magnetic field perturbations do successfully penetrate the plasma, we do not have a complete understanding of the transport processes that lead to the relaxation of the pedestal pressure gradient. This will be a key, early research area for ITER.

A second method to control the ELMs is to try to trigger them more frequently, releasing them before the stored thermal energy in the pedestal becomes too large. This is achieved on the ASDEX Upgrade and JET tokamaks by firing small frozen pellets of deuterium into the pedestal at the plasma edge. The resulting pressure perturbation triggers an ELM each time a pellet is fired, giving some optimism for the success of the scheme for ITER. The main research topics in this area include understanding the minimum pellet size required to trigger the ELM, and identifying the maximum ELM frequency that can be achieved. The latter is important, as the ELM energy is empirically observed to be inversely proportional to the ELM frequency. Therefore to understand the effectiveness of this ELM control technique for reducing the ELM size, we need to understand what is the achievable ELM frequency.

Prof Howard Wilson is the Director of York Plasma Institute at University of York, UK, also heads the EPSRC Fusion Doctoral Training Centre, UK. Among many awards, the most recent is the American Physical Society's James Dawson Award for Excellence in Plasma Physics, which he won in 2013. Prof Wilson is also the winner of Royal Society's Wolfson Research Merit Award. He is the EU Member of International Tokamak Physics Activity (ITPA) Pedestal Group.

In the last part this two-part Feature Article, Prof Wilson tells us about the international effort toward a cleaner energy source for the next generation.

Editor

Plasma Physics Research

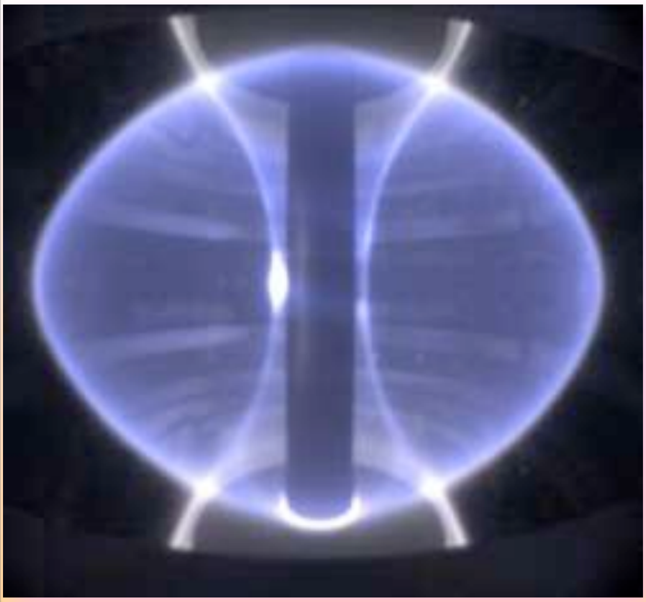
iter and beyond - part II

A number of macroscopic instabilities exist in tokamak plasmas that can limit the pressure for a given magnetic field and current in the plasma. One such instability is called the Neoclassical Tearing Mode. This instability causes a reorganisation of the confining magnetic field topology, due to filaments of depleted current density that flow along the magnetic field lines. This creates coherent magnetic structures in the plasma, called magnetic islands, which significantly degrade the confinement. These instabilities are likely to be present on ITER and, in the absence of a control scheme, would likely prevent it from achieving its fusion energy goals. A control scheme again exists, which involves locally driving current in the plasma using microwaves to fill in the missing filaments of current. This has been proven to work on several tokamaks, notably DIII-D and ASDEX Upgrade, and there is significant confidence that it will be effective on ITER. The tokamak plasma is actually metastable to the Neoclassical Tearing Mode, meaning that it requires some other event to create an initial seed magnetic island. If that magnetic island is smaller than a certain threshold size, then the plasma will heal it, but otherwise the Neoclassical Tearing Mode process amplifies the seed island, which then limits the plasma pressure. To control the Neoclassical Tearing Mode, the microwaves must fill in enough of the filamentary current holes to shrink the magnetic islands below this threshold – this defines the required level of microwave power. We do have theoretical models for this Neoclassical Tearing Mode threshold, but they are not yet sufficiently advanced to provide a quantitative predictive capability. This therefore remains a key area of research.

Large scale instabilities, like Neoclassical Tearing Modes, can lead to a so-called disruption. Control of the plasma is lost, and it typically flies into the top or bottom of the chamber. The thermal loads on surfaces are very high, but the main concern is perhaps the electromagnetic loads that such an event places on the tokamak structure. In a disruption, a substantial fraction of the current flows from the plasma into the components, creating forces on ITER in the millions of Newton range. Furthermore, strong electric fields are generated in a disruption that accelerate electrons to extremely high energies, and these high energy electron beams can also damage components. Disruption control schemes have been developed to mitigate the risk due to disruptions. One such mechanism is to inject large quantities of gas. This radiates the energy, cooling the plasma and quenching the current to terminate the plasma discharge in a benign, controlled way.

All heat injected into a tokamak plasma, or produced by the fusion reactions, must be exhausted. In the standard design, called a divertor geometry, a channel of plasma is created just outside the pedestal region called the scrape-off layer, or SOL. In the SOL, magnetic field lines direct the plasma exhaust away from the hot fusion core, into a remote region we call the divertor and onto material target plates, where it can be removed from the tokamak. The heat load that the divertor target plates must handle depends on the width of the SOL channel – a wide channel lowers this heat load. The width of the SOL is again probably influenced by plasma turbulence, and the nature of this turbulence is an active area of research. While this leads to some uncertainty about the level of heat load that the divertor target plates must handle, it is clear that next step fusion devices like ITER, and especially DEMO, must radiate a substantial fraction of the exhaust power from the SOL before it reaches the target plates. While we are confident this can be achieved on ITER, exhaust is a major challenge for demonstration power plants, leading to innovative new designs for the divertor. These include the so-called "snowflake divertor" which has shown initial promise on the TCV tokamak in Switzerland, and the "super-X divertor" that will be tested on the UK's MAST-Upgrade tokamak when it is being completed during 2015.

ITER will access fusion plasma regimes that have never been produced on Earth. It will open up new areas of scientific discovery that will point the way to the first demonstration fusion plants. On that journey, we will advance our knowledge about the nature of plasmas – knowledge that will have applications beyond fusion energy, influencing research fields as diverse as astrophysics and the many industrial applications of plasmas. These are exciting times for plasma physics. ***Concluded***



The Mega Ampere Spherical Tokamak (MAST) was an experimental thermonuclear reactor, which was operated by the Culham Centre for Fusion Energy (CCFE), Oxfordshire, United Kingdom. Its shape is spherical rather than the usual donut shaped tokamak. Its small aspect ratio (the ratio of the minor to the major radius) is the reason why it is called a spherical tokamak.

The spherical tokamak design has proved to be more efficient than its toroidal counterpart. On the left is the image of a MAST plasma discharge, showing its spherical nature.

MAST is undergoing MAST-Upgrade which is expected to be operational from 2016.

Editor

news

Event

workshop at tinsukia college

A DST, UGC, & OIL sponsored National level Workshop on "General Relativity and Astronomy – Its Foundation and Current Trends" was held in the Tinsukia College, Tinsukia, Assam, organized by Department of Physics, Tinsukia College from 28 to 30 January 2015.

The inaugural session was started with a Buddhist devotional prayer. Just after the lightening of lamp by the Chief Guest Prof A N Phukan, Retd Professor of Physics, Dibrugarh University, the Workshop Souvenir war released by the Guest of Honour, Professor D K Choudhury, Retd Prof of Physics from Gauhati University. Felicitation to the dignitaries included a special honour to Prof G D Baruah and Prof D K Choudhury for their lifelong contributions to science. The President of the Workshop and Principal of the college, Dr Bhuban Gogoi delivered a talk on the importance of workshops at colleges in general and on the theme in particular. Thereafter, Prof A N Phukan, delivered his talk stressing the need for theories, experiments and applications of science with the most relevant example on the workshop theme. Prof G D Baruah, Emeritus Professor, Dibrugarh University, in his Keynote Speech, talked on the Quantum Universe and Light. He explained the relevancy of spectroscopy in the quantum universe, vacuum fluctuation, squeezed states and gravitational wave detection. In connection with the session, the Working President of the workshop and Head of the Department Dr Rajib Konwar and the Convener of the Workshop Mr Satyajyoti Gogoi also presented their speeches. The session was closed with the vote of thanks offered by the organizing secretary of the workshop Dr Bulbul Gogoi.

Two informative lectures were delivered by Prof D K Choudhury. In his first talk, Prof Choudhury extensively explained and discussed the contributions of great geniuses like Einstein. In his second talk, Prof Choudhury, from his lifelong teaching and research experience, lucidly highlighted the fifty years of the discovery of the quark. Prof Ashoke K Sen, Professor of Physics from Assam University also delivered two lectures - one on the concept of space-time and structure of the Universe where he started from Newton's deterministic view to the modern probabilistic concept for the verification of Special Theory of Relativity and the predictions of General Theory of Relativity to the Big Bang. He added an exciting discussion as a public lecture on the topic "Why we cannot go back in time." Prof Subhenay Chakraborty, a renowned Mathematician from the Department of Mathematics, Jadavpur University, Kalkota delivered on a very interesting topic on universal thermodynamics. Dr Subhaditya Bhattacharjee, Department of Physics, IIT Guwahati also delivered a lecture on dark matter and related phenomenology. In his talk he discussed about the unexplored matter which is supposed to contribute toward the largest part of the Universe. Prof Patrik Das Gupta, a well known physicist from Delhi University, also delivered two talks. Prof Das Gupta explained the emergence of space-time, equivalence principle and gravitational wave. Prof Kalyanee Baruah, Professor of Physics, Gauhati University delivered two talks. In her first talk, she rigorously discussed on the discovery of cosmic ray and its measurement. In her second lecture, she talked about the *elementary zoo* of different particles and the recent researches on cosmic ray. Prof P N Deka from Department of Mathematics, Dibrugarh University also joined this workshop as a panel of speakers. His discussion was on the solar wind and its interaction with geomagnetic field. Dr Sidddhartha Kumar Lahiri, Department of Applied Geology, Dibrugarh University, delivered a talk about the inner earth from the geophysical perspective. Dr Bhuban Gogoi, the Principal of the College also acted as a resource person in the workshop. In his lecture, he explained the origin of earth. Prof G D Baruah, in addition to his Keynote Speech, in a technical session, delivered a lecture on the self-consistency of natural laws. In his thoughtful and investigative lecture, he cited how various natural laws viz. Archimedes principle to Einstein's closed Universe follow the self-consistency rule.

Another dimension of this workshop was the Sky Watching Programme where not only participants but the common publics were also invited. Dr Pranab Jyoti Chetia, Curator and In-Charge of Jorhat Science Centre and Planetarium, delivered a talk to the Sky-Gazers. A very highly skilled effort from Dr Chetia and his associate made it possible for all to see the Moon, Jupiter and it satellites.

News by Dr Satyajyoti Gogoi
Tinsukia College

recognition

Dr Syed Arshad Hussain from Department of Physics, Tripura University has joined as a member of the Editorial Board of the journal *Applied Clay Science* (Elsevier).

pane news

PANE News
what's new at pane

Theme based workshop

The first Theme Based Workshop of PANE will be held at Diphu Campus (at Diphu) of Assam University in the month of February 2016. One more Theme Based Workshop is expected to be hosted by Bodoland University at Kokrajhar.

A Themse Based Worshop is a short term (a day long) activity focussing on a very specific idea, which may be localised as per the need of the host institution. Some suggested themes for this kind of workshops are - Physics Teaching at Undergraduate Level, Improvising Basic Physics Experiments, Innovation Camps, Making Useful Experiments from Trash, Night-Sky Watching Programme among many other ideas. We welcome proposals for these kind of workshops from the educational institutions of the Northeast.

Xth PANE conference

The Xth PANE Conference, the biennial Conference of the Physics Academy of Northeast (PANE) to be held in 2016 will be organised by the Department of Physics, St Anthony's College, Shillong Meghalaya in the first week of November, 2016 (exact dates yet to be finalised).

Established in 1934, St Anthonys College, Shillong is one of the oldest Colleges of North East India. Being run by the Salesians of Don Bosco, over the years, St Anthony's College has crossed many a milestones of achievement and success. As another step in the path of its continuous growth, the Department of Physics, St Anthony's College, Shillong is looking forward eagerly to host the biennial PANE Conference for the first time in the state of Meghalaya. The process has already begun with the formation of the various committees for the conference in the last Executive meeting of PANE held on 30 November, 2015.

Internet facility for PANE members

PANE has introduced an Internet Facility for its members which will be primarily used to access scientific journals. For this purpose a facility with computers and Internet connectivity has been opened in PANE Headquarter at the premise of the Physics Department, Gauhati University. This facility is being provided with the logistic support from the Physics Department, Gauhati University. The journal access will be provided through Gauhati University's INFLIBNET Centre.

This facility is being created with an aim to provide access to different scientific journals to the PANE members from different colleges where Internet access facility to scientific journals might be limited. Following is a list of some of the journals which can be accessed through this facility. For details, please contact the General Secretary, PANE or send an email to `pane@gauhati.ac.in`

1. ACS Applied Materials and Interfaces
2. Acta Physica Polonica B
3. Advances in Physics
4. Advances in Physics Theories and Applications
5. Algebra
6. American Journal of Physics
7. Angewandte Chemie Intenational Edition
8. Annalen der Physik
9. Annals of Physics
10. Annual Review of Condensed Matter Physics
11. Applied Optics
12. Applied Physics Letter
13. Astrophysics and Space Science
14. Bulletin of Material Science
15. Chinese Physics Review Letter
16. Classical and Quantum Gravity
17. Communications in Nonlinear Science and Numerical Simulation
18. Current Science
19. Defense science journal
20. Econophysics of Wealth Distributions
21. European Physics Journal C
22. Europhysics Letter
23. Foundation of Physics
24. Foundation of Physics Letters
25. Frontiers in Physics
26. General Relativity and Gravitation
27. Gravitation and Cosmology
28. Indian Journal of Physics
29. Indian Journal of Pure and Applied Physics
30. International Journal of Modern Physics A
31. Journal of Biological Physics
32. Journal of Biosciences
33. Journal of Cosmology and Astroparticle Physics
34. Journal of Experimental Nanoscience
35. Journal of Geometry and Physics
36. Journal of High Energy Physics
37. Journal of Instrumentation
38. Journal of Mathematical Physics
39. Journal of Modern Physics
40. Journal of Molecular Liquids
41. Journal of Physics A: Mathematical and Theoretical
42. Journal of Physics B
43. Journal of Physics C
44. Journal of Physics D: Applied Physics
45. Journal of Physics G
46. Journal of Physics and Chemistry of solids

47. Journal of Physics: Condensed Matter
48. Journal of Raman Spectroscopy
49. Journal of Statistical Physics
50. Journal of colloid and Interface Science
51. Langmuir
52. MNRAS
53. Modern Physics Letter A
54. Molecular simulation
55. Nano Letters
56. Nature Letters
57. Nature Nanotechnology
58. New Journal of Physics
59. Nonlinear Progress in Geophysics
60. Nuclear Instruments and Methods in Physics
61. Nuclear Physics A
62. Nuclear Physics B
63. Optics Communications
64. PLoS One
65. PRAMANA Journal of Physics
66. Pattern Recognition Letters
67. Physica A
68. Physica D: Nonlinear Phenomena
69. Physica Scripta
70. Physica status solidi B
71. Physical Review C
72. Physical Review D
73. Physical Review E
74. Physical Review Letters
75. Physics Letters A
76. Physics Letters B
77. Physics of Atomic Nuclei
78. Physics of Fluids
79. Physics of Plasma
80. Proceedings of the Royal Society A
81. Publication of Astronomical Society of Japan
82. Quantum Information Process
83. Research in Astronomy and Astrophysics
84. Scientific Reports
85. Solar Physics
86. Solid State Communications
87. Spectroscopy Letters
88. Superconductor Science and Technology
89. The Astrophysical Journal Letters
90. The Central European Journal of Physics
91. The European Physical Journal C
92. The European Physics Journal B
93. The Journal of Physical Chemistry
94. The Journal of chemical Physics
95. The Open Food Science Journal
96. Theoretical and Mathematical Physics

The above list not a complete list and subject availability and terms and condition laid down by Gauhati University. For a complete list of journals available through Gauhati University, please visit the university website at `http://gauhati.ac.in`

Editor

news

Events

CICAHEP 2015

Prof J V Narlikar, delivering the Keynote Address at the CICAHEP 2015 Conference in Dibrugarh University.

In his talk, Prof Narlikar talked at length about the unresolved issues that plague present-day astrophysics and cosmology.

The Department of Physics, Dibrugarh University had organized a national conference on *Current Issues in Cosmology, Astrophysics, and High Energy Physics* (CICAHEP) during November 2-5, 2015 with financial assistance from the Science and Engineering Research Board (SERB) of Department of Science and Technology (DST), Government of India; Tata Institute of Fundamental Research (TIFR), Mumbai, and Inter-University Centre for Astronomy and Astrophysics (IUCAA), Pune to promote the research activities in the fascinating fields of Cosmology, Astrophysics and High Energy Physics among the new generation of researchers in the Northeast India. There were 24 invited delegates and 70 other participants in this conference from all over in India.

The keynote address of the conference was delivered by Professor Jayant Vishnu Narlikar, Emeritus Professor, IUCAA, Pune on "Some Conceptual Problems in Cosmology". In his address, Professor Narlikar highlighted many prospective areas for future research in cosmology and related fields. It should be noted that Professor Narlikar is a recipient of Padma Bhushan in 1965 and Padma Vibhushan in 2004. 14 eminent scientists of national and international repute had delivered plenary talks on various emerging issues in this conference. These include, Professor Naba K Mondal, Project Director, India-based Neutrino Observatory (INO) and Senior Professor, TIFR, Mumbai, Professor Narayan Banerjee, Indian Institute of Science Education and Research (IISER), Kolkata, Professor Pankaj S Joshi, TIFR, Mum-

bai, Dr K K Yadav, Bhabha Atomic Research Centre (BARC), Mumbai, Dr Varsha R Chitnis, TIFR, Mumbai, Dr Bipul Bhuyan, IIT Guwahati, Professor Kajari Mazumdar, TIFR, Mumbai, Professor Raj Gandhi, Harish-Chandra Research Institute (HRI), Allahabad, Professor A K Ray, TIFR, Mumbai, Professor K P Singh, TIFR, Mumbai, Professor Tarun Souradeep, IUCAA, Pune, Dr Anil K Pandey, Aryabhatta Research Institute of Observational Sciences (ARIES), Nainital, Professor Shrihari Gopalakrishna, Institute of Mathematical Sciences (IMSC), Chennai and Dr Koushik Dutta, Saha Institute of Nuclear Physics (SINP), Kolkata. A special lecture on Nobel Prize in Physics, 2015 was delivered by Professor N N Singh, Manipur University, Imphal in the evening session on November 4. The number of contributory papers in the conference were 64. Among these, 41 were presented as contributory talks and the rest were presented as the posters. Various sessions of this conference were chaired by most of plenary speakers and some other eminent scientists of national and international repute or well-know personality in the fields. These other personalities include Professor B S Acharya, TIFR, Mumbai (Who is also Chairperson, CICAHEP, 2015), Professor Sayan Kar, IIT, Kharagpur, Prof K Boruah, Gauhati University, Guwahati and Dr P S Joarder, Bose Institute, Kolkata. Rapporteuring on various contributory papers in the conference were done by Professor Madhurjya P Bora, Gauhati University, Guwahati (on Astronomy and Astrophysics Section), Professor N N Singh, Manipur University, Imphal (on High Energy Physics Section), Dr H Nandan, Gurukula Kangri Vishwavidyalaya, Haridwar (on Cosmology Section), Dr U Alam, Indian Statistical Institute (ISI), Kolkata (on Cosmology Section) and Dr S Somorendro Singh, Delhi University, Delhi (on High Energy Physics Section).

News and photographs by Dr Umananda Dev Goswami
Physics Department, Gauhati University

2015 Nobel Prize in physics

Takaaki Kajita of University of Tokyo (Japan) and Arthur B McDonald of Queens University (Canada) have been jointly awarded the Nobel Prize in Physics for the year 2015 for their work on neutrino oscillation.

Neutrinos are nearly massless particles traveling almost at the speed of light and are produced in copious amount in the stars and extragalactic sources. They are also among the most inert particles, which can travel through the space billion billion miles, through solid bodies like earth, without any interactions. They come in three types - $e, \mu,$ and τ neutrino. One of the greatest puzzle which eluded physicists was the discrepancy in detecting the these three types of neutrinos in their right proportions on earth. The neutrino detectors can be huge underground reservoirs of heavy water tanks where, despite the very low tendency of the neutrinos to interact with matter, scientists have been able to catch the tale tale signatures of neutrino interactions. The accepted answer to this detection discrepancy is the neutrino oscillation theory according to which neutrinos change from one to another type while traveling.

Kajita and his team worked in the Super-Kamiokande neutrino detector in Japan and discovered the atmospheric neutrino oscillation, while McDonald worked in the Sudburry Neutrino Observatory (SNO) in Canada, where he and his team discovered the solar neutrino oscillation. "*This years prize highlights a seriously important step in our understanding of the fundamental particles of the universe, and one that has improved our understanding of both particle physics and cosmology*", said Robert G W Brown of the American Institute of Physics

Report by
Neelakshi Sarma and Gayatri Ghosh
Physics Department, Gauhati University

article

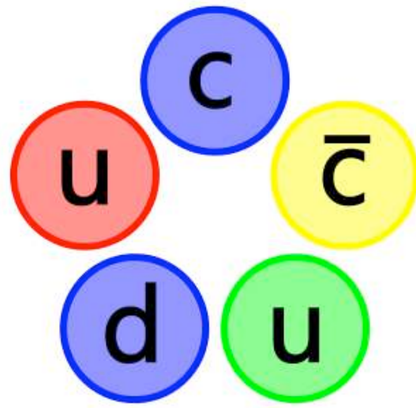
Newly discovered exotica
pentaquarks

D K Choudhury, Tapashi Das, and Baishali Saikia

Pentaquarks, the evidence for a novel family of particles which contains four quarks and one anti quark, reported in 2003 has generated a huge amount of interest among the physics community. In the year of 2003, T Nakano et al reported the evidence for an exotic multi-quarks state called $\theta^{+}(1540)$, which was interpreted as $u\,u\,d\,d\,\bar{s}$. The existence of pentaquark was originally hypothesized by Dmitri Diakonov, Victor Petrov and Maxim Polyakov in 1997. They used a specific model called Chiral Soliton model and predicted an anti-decup let pentaquark. Later experiments have indicated the existence of two more such pentaquark states $\Xi^{--}(d\,d\,s\,s\,\bar{u})$ and $\Xi^{0}(d\,u\,s\,s\,\bar{d})$. After the discovery of 'Higgs Particle' in the year of 2013 by CERN, LHCb collaboration identified two new pentaquark states in July 2015 named $P_c^{+}(4380)$ and $P_c^{+}(4450)$, which had individual statistical significances of 9σ and 12σ, respectively and a combined significance of 15σ. These two states consist of two up quarks, a down quark, a charm quark and an anti-charm quark i.e. $u\,u\,f\,c\,\bar{c}$, making them Charmonium-pentaquarks where Charmonium belongs to the particles composed $c\bar{c}$ pair.

"*The pentaquark is not just any new particle*", said LHCb spokesperson Guy Wilkinson. "*It represents a way to aggregate quarks, namely the fundamental constituents of ordinary protons and neutrons, in a pattern that has never been observed before in over fifty years of experimental searches. Studying its properties may allow us to understand better how ordinary matter, the protons and neutrons from which we're all made, is constituted.*"

Physicists attribute cosmological significance to the discovery of pentaquarks. According to them, pentaquarks may be existing in the core of the stars as they collapse. It will be interesting to see, how it will affect the existing theory of the universe. Whatever may be the cosmological or astrophysical significance of the pentaquarks, the search for those exotica is now going on in different laboratories of the world. Undoubtedly the area of pentaquarks is emerging as one of the new frontiers of Quantum Chromo Dynamics



Structure of P_c^+ pentaquark

The existence of an exotic state of quarks nwo known as *pentaquark* has been speculated way back in 2003, when their discovery was claimed in Japan. However, other experiments could not replicate the Japan result, which is why their rightful existence was not acertained. In July 2015, the LHCb Collaboration has detected this exotic state which can be calimed to be definitive.

Prof Dilip Kumar Choudhury and his collaborators are telling us exactly what is a pentaquark.

Editor

Further Reading

T Nakano et al, Phys Rev Lett **91**, 012002 (2003).

D Diakonov et al, Z Phys A **359**, 305 (1997).

V V Barmin et al (DIANA collaboration), hep-ex/0304040.

B Aubert et al (BABAR collaboration), hep-ex/0304021

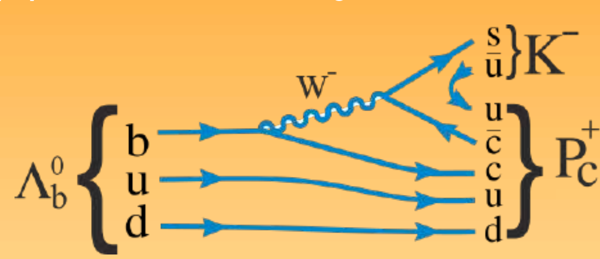
D Besson et al (CLEO collaboration], hep-ex/0305017

R Aaij et al (LHCb collaboration), hep-ex/1507.034142

The detection of $P_c^{+}(4380)$ and $P_c^{+}(4450)$ pentaquark states by LHCb collaboration in July 2015 was not the primary objective of the study. They were actually studying matter-antimatter asymmetry and accidentally "stumbled upon" these pentaquark states.

The discovery of pentaquarks is crucial in studying the nature of the strong force which is basically the foundation of quantum chromodynamics. The study on pentaquarks is also expected help physicists in understanding some of the issues which involve neutron stars.

The decay of Λ_b^0 into a kaon K^- and a pentaquark state P_c^+.



Editor

research highlight

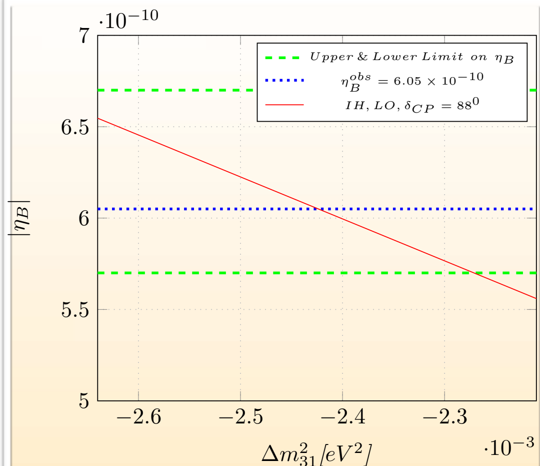
Neutrino Experiments
baryogenesis and octant of θ_{23}

Kalpana Bora

Neutrinos are weakly interacting neutral particles, and they have very tiny mass (sum of the three flavours of neutrinos is expected to be few eV only). They are known to mix with each other - hence they oscillate to other flavours as they travel. This phenomenon is called neutrino mixing (and oscillation), and is characterized by three mixing angles and two mass squared differences in the neutrino mass matrix, and one CP Violation (CPV) phase. These mixing angles are called - solar angle, atmospheric angle, and reactor angle. The mass squared differences are called the solar and atmospheric mass differences. Neutrino experiments have already measured the two mass squared differences and the three mixing angles. But still, the mass hierarchy is not fixed, nor is the leptonic CPV phase. Long Baseline Neutrino Experiments (LBNE) seem to be very promising as they have the potential to measure these unknown quantities along with other physics studies. But they are inflicted by the presence of parameter degeneracies [1-3] i.e. more than one solution is found to be present in the data. For example, two values of octant of atmospheric angle, two values of CPV phase etc., are found to be present in the analysis of their data.

In our earlier work [4], we have shown how the octant degeneracy can be removed by combining LBNE/DUNE (Deep underground Neutrino Experiment) data with that from the reactor experiments. This is because the reactor experiments have the capability to measure the reactor angle very precisely. Then, in a later work, we found, that CPV discovery potential at LBNE can be improved, if its data is combined with that from its ND (Near Detector) and reactors. The near detectors reduce the systematic uncertainties. In our more recent work [5], we have shown, how the CPV-Octant (of atmospheric angle, θ_{23}) entanglement can be resolved, if we use data from BAU (Baryon Asymmetry of the Universe), using leptogenesis. We know that in our Universe, there is more matter than antimatter - this is called BAU. This could be explained, if there is lepton-antilepton asymmetry (leptogenesis) in the Universe. This in turn, arises due to CP violation. CP transformation changes a particle to its antiparticle. Hence to explain the BAU, CP must must be violated.

Since the BAU (η_B) depends on the CP phase of the neutrino mass matrix, we propose that CPV phase-Octant entanglement can be broken, using the data for the BAU. We have considered the variation of η_B within its 3 sigma range and variation of $\Delta_{m^2_{31}}$ within its 2 sigma range (see the accompanying figure [5]). We find that our calculated values of η_B lie within the 3 sigma range of experimental limits [6]. We conclude that lower octant and inverted hierarchy is favoured by this analysis.



Plot of η_B vs Δm^2_{31} eV^2 with CP phases $\delta_{CP} = 88°$ (red solid line) for the case when R matrix consists of both V_{CKM} and U_{PMNS}. The red solid line corresponds to $\theta_{23}, \delta_{CP} = 88°$, and inverted hierarchy. The values of Δm^2_{31} eV^2 are within 2 sigma error of its best fit values. The blue dotted horizontal line corresponds to $\eta_B^{\rm obs} = 6.05 \times 10^{-10}$, the upper and lower limit on η_B, $5.7 \times 10^{-10} < \eta_B < 6.7 \times 10^{-10}$ are characterised by green dashed horizontal lines. The plots lie within the present experimental limits on η_B.

These results could be important, as the quadrant of leptonic CPV phase and octant of atmospheric mixing angle θ_{23} are yet not fixed experimentally. Also, they are significant in context of precision measurements of neutrino oscillation parameters, specially the octant of atmospheric angle θ_{23}, and the reactor angle θ_{13}.

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Dr Kalpana Bora of Physics Department, Gauhati University writes about their group's recent work on neutrino oscillation. This year neutrino Physics Nobel Prize also is given in recognition of detection of neutrino oscillation. *Editor* article

Breath Figures
breath figures and soft lithography

V Madhurima and K Nilavarasi

Breath Figure is a term usually used to describe spatial ordering of 'water' which is obtained by '*breathing*' on a cold surface like the condensation we obtain by breathing out on the surface of a glass of cold water. However, little do we think about these everyday phenomena until we realise the tremendous amount of science which is hidden within.

Dr V Madhurima and her collaborator K Nilavarasi from Central University of Tamilnadu writes about these Breath Figures and also highlight their work.

Editor

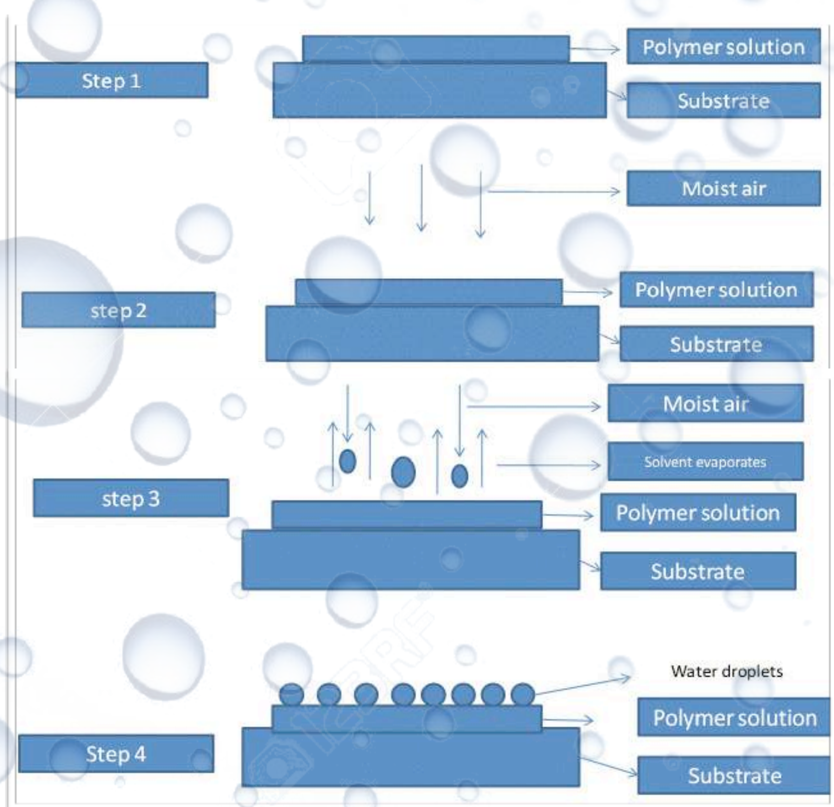
Introduction

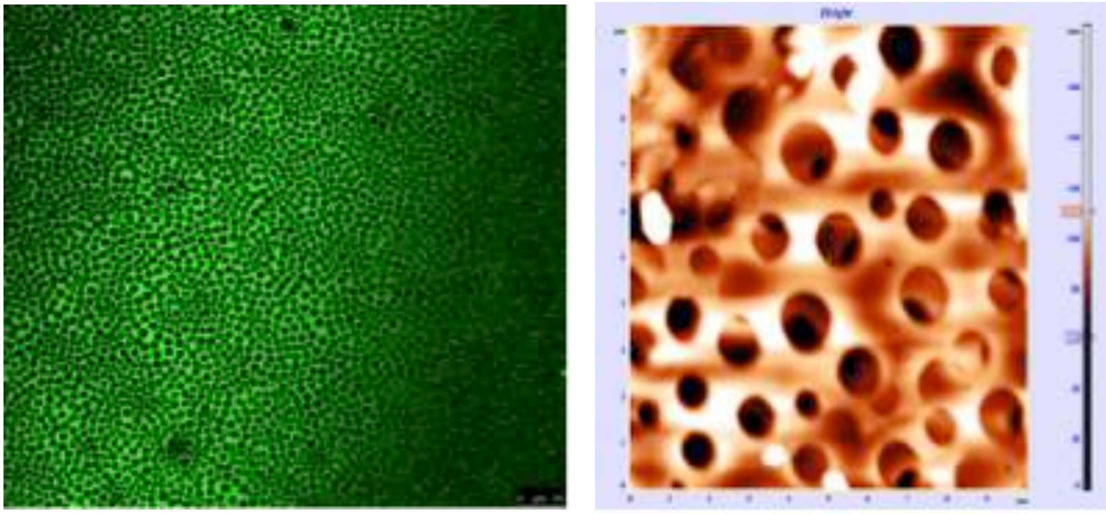
The droplets formed on closed vicinity on a cold surface due to condensation was first termed as "*Breath Figures*" and studied by Lord Rayleigh in 1911. These breath figures are a combination of condensation and linked wetting and de-wetting phenomenon. When water vapour comes in contact with a cold surface, droplets of water are formed through condensation. These nanometer to micron sized droplets are stabilized by a Coloumb repulsion dominated by a dipolar term, giving it a long range order, only if the area is constrained. However, there have been many reports of the formation of breath figures, even in the absence of area constraint, which can hence be explained only by including an attractive term to the interaction potential. One explanation of this attraction between similarly charged surfaces is that it is due to electrostatic stresses caused by dipolar fields which leads to a capillary attraction between the two surfaces. The pattern formation by the droplets can be broadly classified into three time regimes, as discussed below.

The pattern formation by the droplets can be broadly classified into three time regimes (see figure below)

Stage 1 : *Nucleation of water droplets*
In the first regime, the droplets nucleate and grow. An evaporative cooling of the solvent due to the flow of moist air over the surface occurs and droplets are formed all over the surface which are of approximately same size. There are spaces between the droplets at this stage. The sizes of the droplets grow as a power law in time. This can be expressed as $D \sim t^{1/3}$, where D is the diameter of the droplets. This power law behaviour is explained either as due to the convection currents formed in the solvent due to evaporation and the airflow across the substrate driving the ordering of the droplets or alternatively, as the process of evaporation maintaining a non-perishing layer of vapor over the substrate that keeps the drops from coalescing.

Stage 2 : *Evaporation of water droplets*
After nucleation, the droplets tend to arrange themselves in to a hexagonally ordered array. Early in this stage there is no coalescence of droplets. Rather, the drops sink into the polymer solution. When a suitable temperature is attained by the system, the water from the droplets evaporates, leaving behind the characteristic pits. After complete evaporation of water, there will be an imprint of water droplets on the surface of the polymer film. Thus the surface now will be patterned with hexagonally ordered array of spheres. At the end of the second stage, coalescence begins to start i.e. in the later part of the second regime, the spacing between the droplets decreases until the spacing is of the same order as the diameter of the droplet. At this stage, coalescence of smaller droplets into bigger ones begins. In the second regime, the droplets are found to be self-similar.





Confocal image of patterned surface (left) and AFM image of patterned surface indicating multimodel pattern

At this stage the droplet number density increases with increase in time and until it reaches a plateau.

Stage 3 : *Coalescence of droplets*
At a very late stage, the rapid coalescence of droplets may occur. Two or more droplets combine together to form a bigger droplet. When there is coalescence of droplets, there won't be hexagonally ordered array but the resulting pattern comprises of smaller and bigger droplets. In the third regime, the random small spaces between the merged droplets provide a new nucleation spots for further condensation of water droplets. In this stage, the droplet size varies as t, i.e. $D \sim t$. As a result of all three regimes there will be a bimodal distribution of droplets comprising of Gaussian distribution of larger droplets and a highly poly dispersed distribution of smaller droplets.

Experimental Parameter Dependence

The size of the breath figure drops ranges from a few hundreds of nm to several μm depending on the experimental conditions under which the breath figures are prepared. The most influential parameters are relative humidity, the rate of moist airflow, surface temperature, polymer concentration, polymer conformation, interfacial tension between solvent and water.

Patterning Polymers

This phenomenon of breath figures is made use of to pattern soft surfaces of polymers. The polymers are solvated in volatile solvents, coated over the substrates (usually glass) as a thin film and allowed to evaporate in the presence of water vapor. The process of evaporation of solvent causes the temperature of the polymeric surface to fall and this aids the condensation of water droplets on the surface, typically in the form of a honeycomb structure. However, there are fundamental differences between condensation droplet formation and pattern formation by polymers. While dew formation is due to lowering of temperature of substrate below the dew point, in polymers, the process of breath figure formation is due to evaporation driven cooling. This in turn implies that while the coalescence of drops is inevitable in the case of dew drops, it is not so with the polymers. The polymers can self assemble into regular patterns without coalescence, for dilute solutions of polymers. In other words, the size dispersion of the condensation droplets can vary from mono dispersion (one size) to poly dispersion (many sizes) depending on the concentration of polymer used. The mono dispersion of sizes has been modeled using a Fick's diffusion law limited exchange of polymer and solvent in the presence of water vapor.

As an example, we present here, the confocal microscope and AFM images of the breath figures patterned by us with PDMS with chloroform as polymer solution and CD as substrate.

Control Parameters for Breath Figures

The experimental procedures involved in the preparation of breath figures can be classified as (a) Static or Dynamic, based on how the water vapor is introduced into the system and (b) Sessile or Pendent drop, depending on whether placement of the substrate. In the static method, the substrate is left with water in a closed enclosure such that the relative humidity is at least 45-50\%. Breath figures are not formed at lesser relative humidity. Higher relative humidity ensures regular pore distribution. In order to obtain closely packed pores, moist air is allowed to flow through the apparatus, thus leading to faster evaporation rates and faster condensation. Slower evaporation rate will also ensure that the pores are deeper.

Conclusions

The stages of formation of breath figures were briefly discussed. It is clear that with proper choice of solvent and polymer, it is a one step process of creating honeycomb patterns. The use of water droplets as templates makes it as a simpler and cost effective method of patterning surfaces.

Further Reading

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ASTROSAT
a multi-messenger spacecraft

Kalyanee Boruah

Not long ago, India has successfully launched its space born astronomical observatory called ASTROSAT. It is multi-wavelength observatory and went up to the space on a textbook-like precision launch and has since been functioning optimally.

Prof Kalyanee Boruah of Physics Department, Gauhati University is telling us more about it.

Editor

ASTROSAT is India's first dedicated multi-wavelength space born observatory which was launched into a 650 km orbit, by ISRO (Indian Space Research Organisation) on 28 September 2015. Motivated by the growing importance of the "Cosmic dimension" in the contemporary research in a more detailed understanding of the nature of our complex universe and a need for indigenous development of technology, ISRO approved the implementation of the full-fledged astronomy satellite, ASTROSAT in 2004.

The first Indian satellite, Aryabhata, built by ISRO, was launched by the Soviet Union in 1975. ISRO subsequently developed Polar Satellite Launch Vehicle (PSLV) for launching satellites into polar orbits and the Geosynchronous Satellite Launch Vehicle (GSLV) for placing satellites into geostationary orbits. Astrostat was launched in the near-earth equatorial orbit using PSLV-C30 launch vehicle from Sriharikota. In this mission, PSLV-C30 also launched 6 smaller satellites, four from the United States, one from Canada, and one from Indonesia. This flight of the Polar Satellite Launch Vehicle (PSLV) is historic in many respectes. For the first time, American satellites were launched by India with this mission India became the first country in the developing world to have its own telescope in space capable of monitoring intensity variations in a broad range of cosmic sources. Indian astronomers who used to rely on international resources for X-ray and UV data are now empowered with the indigenous ASTROSAT.

The ASTROSAT observatory is capable of handling simultaneous multi-wavelength observations of various astronomical objects. ASTROSAT can observe in the optical, ultraviolet, low and high energy X-ray regions, whereas most other scientific satellites are capable of observing only in a narrow range of wavelength band. Multi-wavelength observations of ASTROSAT can be further extended with co-ordinated observations using other spacecrafts and ground based observations. All major astronomy Institutions and some universities in India will participate in these observations. The scientific data gathered by five payloads of ASTROSAT are telemetered to the ground station at the spacecraft control centre at Mission Operations Complex (MOX). The data is then processed, archived, and distributed by Indian Space Science Data Centre (ISSDC) located at Byalalu, near Bangalore. The five instruments on board, cover the visible (320–530 nm), near UV (180–300 nm), far UV (130–180 nm), soft X-ray (0.3–8 keV and 2–10 keV) and hard X-ray (3–80 keV and 10–150 keV) regions of the electromagnetic spectrum.

The mission life of Astrostat is 5 years and it aims at studying celestial objects such as, black holes, neutron stars pulsars, white dwarfs, quasars, and active galactic nuclei. The total cost of ASTROSAT is about Rs 170 crore and has been made ready in ten years though it was conceived more than 20 years ago. The 1,515-kilogram satellite has been assembled at the ISRO Satellite Centre in Bengaluru. For the first time, several scientific institutions got together to contribute the scientific instruments. Top Indian institutions like Tata Institute of Fundamental Research (TIFR), Mumbai; Indian Institute of Astrophysics (IIA), Bengaluru; Inter-University Centre for Astronomy and Astrophysics (IUCAA), Pune, and the Raman Research Institute (RRI), Bengaluru, are involved in payload development. Two of the payloads are in collaboration with Canadian Space Agency (CSA) and University of Leicester, UK.

The objectives

1. To understand high energy processes in binary star systems containing neutron stars and black holes.
2. Estimate magnetic fields of neutron stars.
3. Study star birth regions and high energy processes in star systems lying beyond our galaxy.
4. Detect new briefly bright X-ray sources in the sky.
5. Perform a limited deep field survey of the Universe in the Ultraviolet region.

Payloads

1. **UVIT**: The Ultraviolet Imaging Telescope can observe the sky in the visible, near UV and far UV regions.
2. **LAXPC**: Large Area X-ray Proportional Counter isdesigned to study the variations in the X-ray emissions from different sources.
3. **SXT**: Soft X-ray Telescope is designed to study how the X-ray spectrum of 0.3-8 keV range coming from distant celestial bodies varies with time.
4. **CZTI**: Cadmium Zinc Telluride Hard X-ray Imager, extends the capability of the satellite to

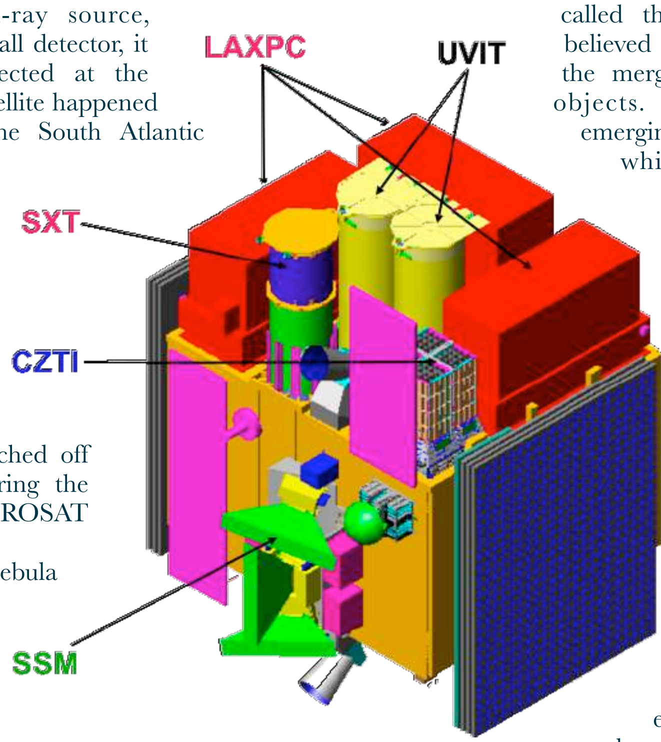
sense X-rays of high energy in 10-100 keV range.

5. **SSM**: Scanning Sky Monitor, having large field of view is intended to scan the sky for long term monitoring of bright X-ray sources in binary stars, and for the detection and location of sources that become bright in X-rays for a short duration of time.

Performance appraisal

The Crab Nebula, which also includes the Crab Pulsar, is the brightest hard X-ray source in the sky, and is very often used to calibrate hard X-ray detectors. Although, Crab is the brightest hard X-ray source, visible even to a small detector, it could not be detected at the beginning as the satellite happened to pass through the South Atlantic Anomaly (SAA) region when Crab was in the field of view. SAA avoidance zone was deliberately kept wide to protect the instruments, and detectors were switched off in this interval during the initial days of ASTROSAT operation.

Finally Crab Nebula was detected on Oct 9, 2015, by CZT Imager. During the first week of CZTI operation, the supernova remnant Crab Nebula and the black hole source Cyg X-1 were monitored. Later, Crab was also visible in the image recorded by the SSM. The Crab Nebula can be treated as a standard candle and it was used as a calibrator for timing and imaging, and also to measure the response of the instrument at large off-axis angles. Subsequently, SSM recorded a sudden upsurge in counts – with a rise time of ~ 2 minutes and a decay time of ~ 18 minutes, which was understood to be X-rays due to a M-class Solar flare, as confirmed from the US satellite "GOES" data.



GRB event and ASTROSAT

A more exciting event called GRB (Gamma Ray Burst, GRB 151006A) is also recorded by the CZT imager, coinciding with the one reported by the Swift satellite. Cosmic GRBs were discovered by accident in the late 1960's by satellites designed to detect gamma rays produced by atomic bomb tests on Earth. The GRBs appear first as a brilliant flash of gamma rays, that rises and falls in a matter of minutes. These bursts are often followed by afterglows at X-ray, optical and radio wavelengths. Currently, there are two dedicated satellites measuring their properties: the Swift and the Fermi satellites. Thousands of GRBs have been detected and some of them are identified to be associated with farthest galaxies. However, GRBs still remain a mystery. One class of GRBs called the long GRBs are associated with newly formed black holes while another class, called the short GRBs, are believed to be signatures of the merger of two compact objects. There is also an emerging school of thought which postulates that GRBs originate from neutron stars with extremely high magnetic field, called the magnetars. The characteristics of the burst of gamma-rays and the radiation mechanisms responsible for the emission are not well understood and different models are proposed to explain this phenomenon.

A collaborative research in this line has been initiated by the Gauhati University Cosmic Ray Group with BARC, Mumbai and IUCAA, Pune, to study the GRB prompt emission using spectral and temporal data from Swift and Fermi satellites. Now, with ASTROSAT coming into operation, and with capability to record GRB spectrum very accurately, it will be possible to analyse more data to solve the puzzle.

Further Reading

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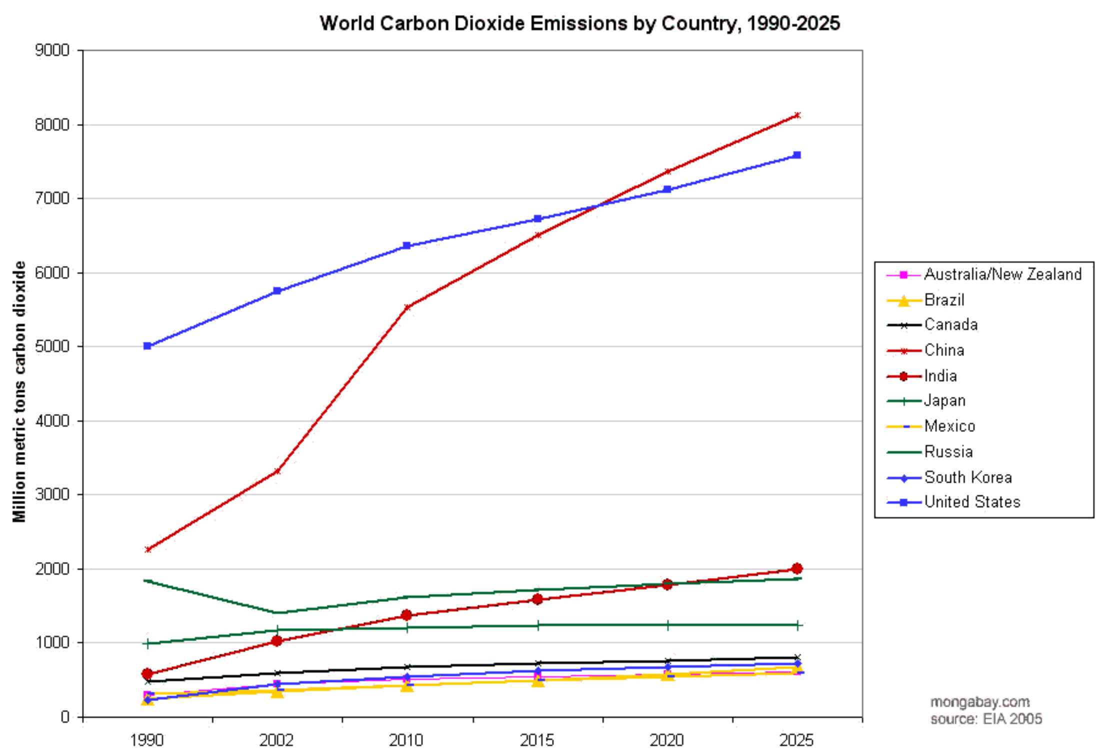
editorial

On the Brink
saving the environment

Madhurjya P Bora

The recent spurt of activities by Delhi Government to save the capital from being abandoned by its residents as environmental pollution is threatening the very lifeline, shows the desperate situation we are in. Little has been done to cut down the pollution - be it in the form of vehicular emission or emission from the factories. Our rivers are chocked with effluence from the factories, coastal lines are littered with tons of plastic waste, atmosphere is un-breathable. Still, we burn crackers worth crores of rupees in one night, only to find out in the next morning that we are suffocating our own children to death! Is this our culture?

Clean energy is now not a requirement, it has become a necessity. The fusion plasma research is a long step toward fulfilling this goal. With this issue of this newsletter, we have concluded a two-part essay on ITER - the experimental thermonuclear reactor, which is coming up in France and of which India is a part. Encouraging our students to take up fusion research as a career will serve in long way toward arriving at a cleaner technology. Needless to say, we need lots and lots of young minds to succeed in this race against time.



pane newsletter vol 3 no 2