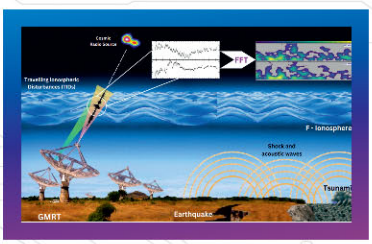
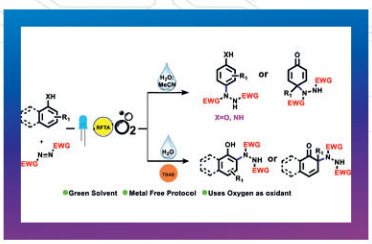
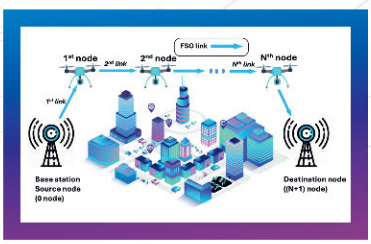
Research Spectrum

A Compendium of Graphical Abstracts
Illustrating Research at IIT Indore

Volume 2 Issue 3







Editors

Prof. Biswarup Pathak • Prof. Debayan Sarkar • Prof. Puneet Gupta
Prof. Raghunath Sahoo • Prof. Sandeep Chaudhary

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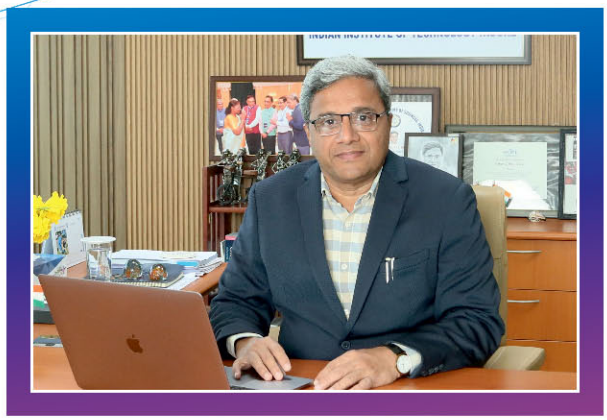

Director's Message

With great pride and honour, I write this foreword to the Third Issue of the Second Volume of 'Research Spectrum'. My heartiest congratulations to the team of Editors, and the executive team from R&D office, Prof. Abhirup Datta, Dean R&D, Dr. Bodhisatwa Mazumdar, Associate Dean R&D for their consistent efforts in publishing it regularly.

The endeavor of 'Research Spectrum' aims to disseminate wonderful research carried out by the professors and students of IIT Indore, in the form of pictorial abstracts.

We sincerely wish that the readers will find Research Spectrum containing graphical abstracts, easy to understand we hope that it will further help disseminate the novel research ideas depicted therein amongst the avid researchers and lovers of technology.

With best wishes,

Prof. Suhas S Joshi
Director

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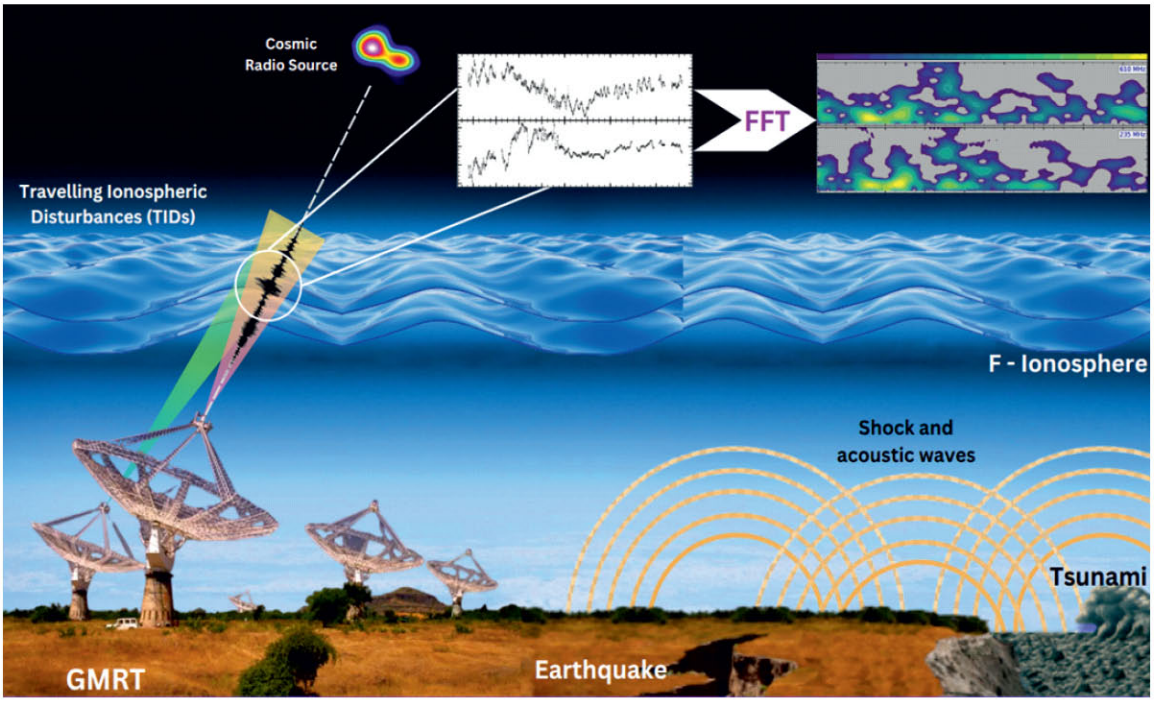
Spectral Analysis of Ionospheric Density Variations Measured with the Large Radio Telescope in the Low-Latitude Region

Sarvesh Mangla[1], Abhirup Datta[1*]

[1]Department of Astronomy, Astrophysics and Space Engineering, IIT Indore, India



The Earth's ionosphere limits sub-GHz sky observations, introducing a challenging to calibrate phase term. Calibration data from radio interferometry can also study the ionosphere more precisely than conventional methods. In this study the GMRT was used to observe the Equatorial Ionization Anomaly region through dual-band observations of a bright radio source. It detected variations in total electron content (TEC) and measured TEC gradients with high accuracy. Spectral analysis of TEC gradients revealed medium-scale traveling ionospheric disturbances and smaller waves down to ~10 km wavelengths. Results showed unexpected ionospheric changes during sunrise, including large plasma irregularities and smaller structures moving in the same direction.

The work has been published in the Geophysical Research Letters (GRL): S.Mangla, A. Datta (2023), 50,14. doi: https://doi.org/10.1029/2023GL103305

Redefining Lobe-Wise Ground-Glass Opacity in COVID-19 Through Deep Learning and its Correlation With Biochemical Parameters

Budhadev Baral[1], Shweta Jakhmola[1], Omkar Indari[1], Jatin Jangir[2], Ashraf Haroon Rashid[2], Suchita Jain[3], Ajay Kumar Jain[3], M. Tanveer[2*], Nirmal Kumar Mohakud[4*], and Hem Chandra Jha[1*]

[1]Infection Bioengineering group, Department of Biosciences and Biomedical Engineering, IIT Indore, India
[2]Department of Mathematics, IIT Indore, India
[3]Choithram Hospital and Research Center, Indore, India
[4]Department of Pediatrics, Kalinga Institute of Medical Sciences, Deemed to be University, Bhubaneswar, India

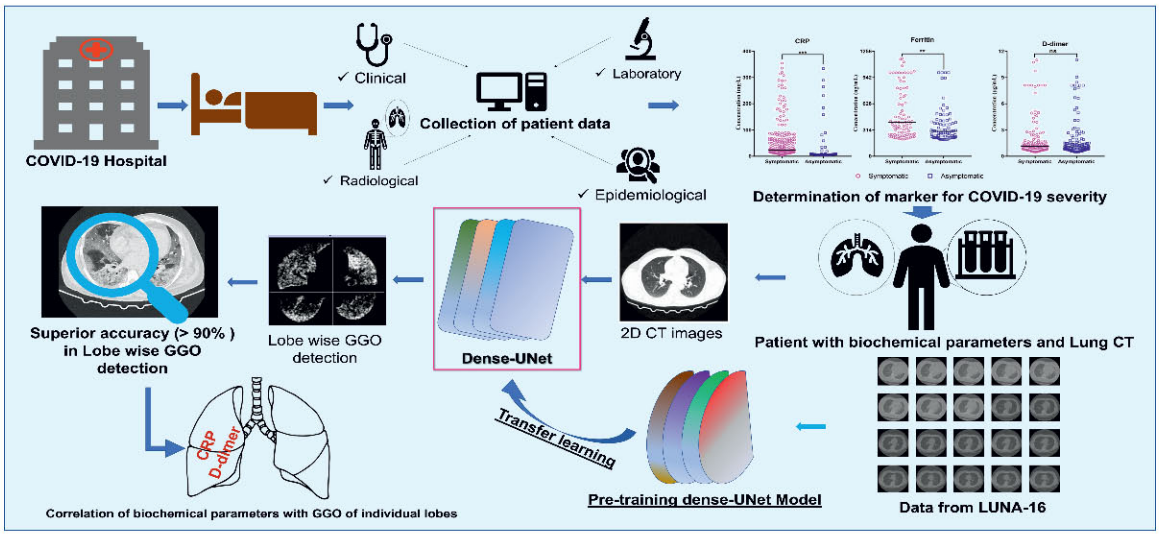


Figure: Development of deep learning-based algorithm for detection of ground-glass opacity in COVID-19 patients and its correlation with biochemical markers

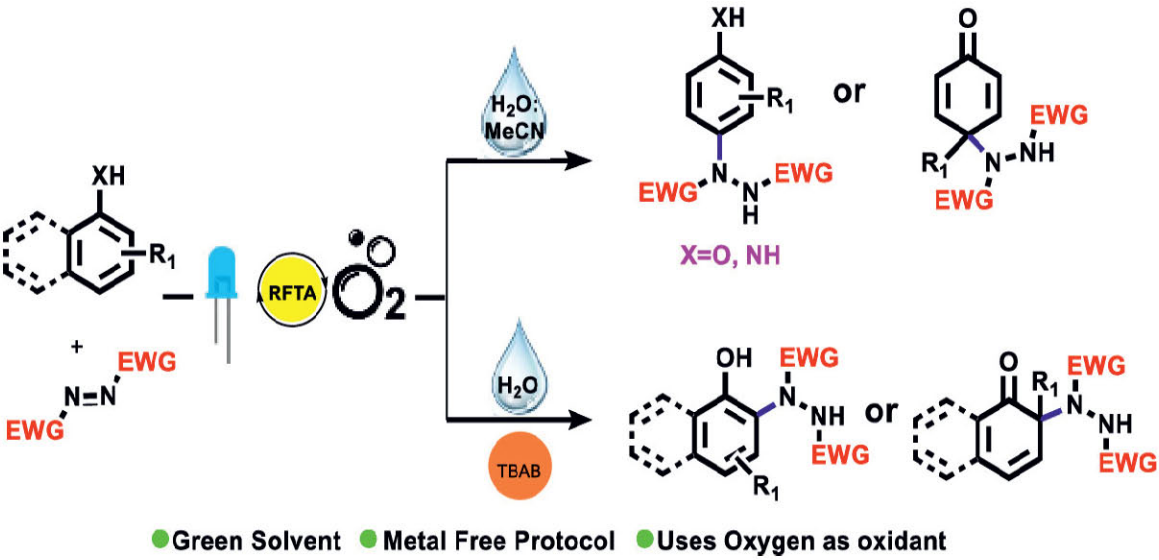
CT scan has been used widely for detection of COVID-19 severity. However, there is a lack of clear understanding of the correlation of lung inflammation with biochemical parameters. This study involving 136 patients found C-reactiveprotein (CRP) the most critical parameter for classifying symptomatic and asymptomatic. To overcome the limitations of manual chest CT scoring system, we used 2D U-Net-based deep learning approach to detect ground glass-opacity (GGO) in specific lobes with > 90% accuracy, compared to the manual method (~80%). The final Dice Coefficient (or the F1 score) and Intersection-Over-Union for testing accuracy are 95.44% and 91.95%, respectively. This study may reduce the burden and manual bias besides increasing the accuracy of GGO scoring.

The work has been published in the IEEE Journal of Biomedical Health Informatics (IEEE-JBHI): Baral et al. IEEE-JBHI (2024), 27, 6, 2782-2793. doi: https://doi.org/10.1029/2023GL103305

Sustainable Organic Photocatalysis for Site-Selective Hydrazocoupling of Electron-Rich Arenes

Biswajit Das[1], Sushree Ranjan Sahoo[1], Amitabha Das[2], Biswarup Pathak[*2] and Debayan Sarkar[2*]

[1]Department of Chemistry, National Institute of Technology Rourkela, Odisha 769008, India
[2]Department of Chemistry, IIT Indore, 453552, India



An efficient photocatalytic para- and ortho-selective amination and aminative dearomatization of phenols, naphthols, and anilines with azodicarboxylates was developed using riboflavin tetraacetate (RFTA) as an organic photocatalyst. The site selectivity was controlled using tetrabutylammonium bromide (TBAB), which also acts as a phase transfer catalyst. The reaction conditions are simple and mild, giving high regioselectivity with good to excellent yields. A broad substrate scope and nice functional group tolerance with scalability and post-functionalization make this protocol both useful and regioselective.

The work has been published in the Organic Letters of the American Chemical Society (ACS) Publications: B. Das, et al. Org. Lett. (2023), 25, 7733-7738. doi: https://doi.org/10.1021/acs.orglett.3c03137

Gobair - A Novel Cow Dung Based Foaming Agent for Developing Low-cost Sustainable Light Weight Construction Materials

Sanchit Gupta[1] and Sandeep Chaudhary[1*]

[1]Department of Civil Engineering, IIT Indore, India

Figure 1. Light weight block developed using GOBAiR

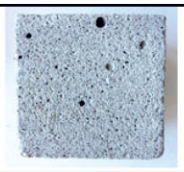
			
AAC blocks	**Foam concrete**	**Lightweight aggregate concrete**	**GOBAiR foam concrete**
3.5 MPa INR 4000 to 6000/m^3 <1000 kg/m^3	10.0 MPa INR 4500 to 5500/m^3 1200 – 1600 kg/m^3	15.0 MPa INR 5000/m^3 2000 kg/m^3	12.0 MPa INR 3550/m^3 1400 – 1600 kg/m^3
IS 2185 (part 3)	IS 2185 (part 4)	IS 2185 (part 2)	Relevant as per IS 2185 (part 4)

Figure. 2. Comparison of light weight block prepared using GOBAiR with commercially available lightweight blocks

GOBAiR is a first-of-its-kind cow dung based sustainable foaming agent. GOBAiR offers an eco-friendly, cost-effective alternative to chemical foaming agents for thermal insulation and lightweight concrete blocks and bricks. GOBAiR is easy to use, does not require autoclaving, reduces production costs and enables on-site manufacturing. Block prepared with GOBAiR are more economical than commercially available alternatives. GOBAiR supports sustainable construction, improves energy efficiency and enhances GRIHA/LEED scores. GOBAiR also supports the high value commercialization of cow dung, which can help managing the stray cattle and associated challenges in India.

The work has been filed for patent with the Indian Patent Office: Application No. 202421010279

UNFOLD: 3-D U-Net, 3-D CNN, and 3-D Transformer-Based Hyperspectral Image Denoising

Aditya Dixit[1], Anup Kumar Gupta[1], Puneet Gupta[1*], Saurabh Srivastava[2], and Ankur Garg[3]

[1]Department of Computer Science and Engineering, IIT Indore, India
[2]Department of Computer Science and Engineering, IIT Dhanbad, India
[3]Space Applications Centre, Ahmedabad, India

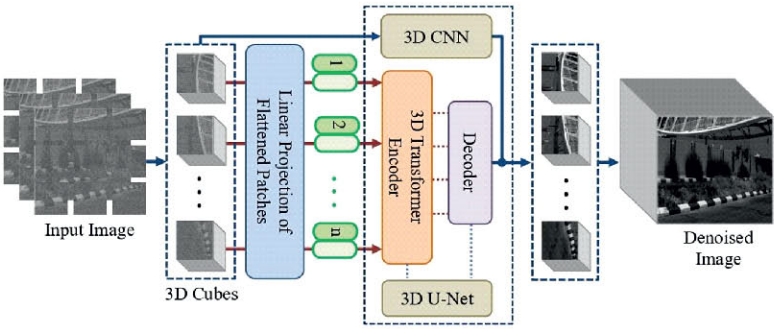
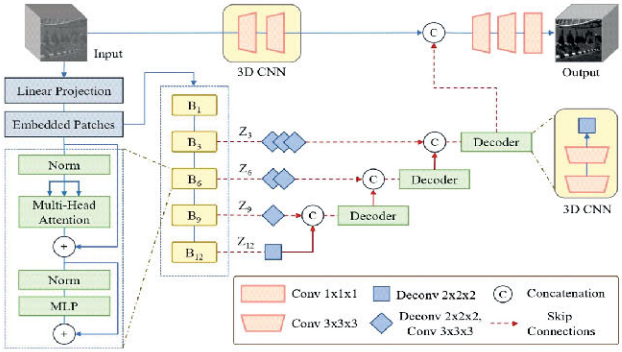


Figure 1. Overview of UNFOLD. It utilizes a 3-D Transformer for capturing long-range dependencies, a 3-D U-Net for preserving structural integrity, and 3-D CNN for preserving local details for effective HSIs denoising.

Figure 2. Detailed architecture of the proposed method UNFOLD. The input is divided into cubes and passed through a 3-D Transformer that acts as an encoder of the 3-D U-Net. Encoder outputs from different Transformer blocks are combined with the decoder through skip connections. To preserve local spatial information, the input is also passed through a 3-D CNN, the output of which is merged with the decoder output to obtain the denoised HSI.



Hyperspectral Images (HSIs) encompass data across numerous spectral bands, offering utility in fields like remote sensing and agriculture. Noise introduced during sensing limits their effectiveness, necessitating denoising for optimal utilization. Existing approaches face challenges: CNNs struggle with long-range dependencies, while Vision Transformer struggles to capture local details. UNFOLD is a novel 3D architecture that synergizes 3D U-Net, 3D CNN, and 3D Transformers to address these limitations. By leveraging self-attention for global dependencies and CNNs for local features, UNFOLD preserves spatial and spectral information. Further, it utilizes a 3D Transformer-based U-Net encoder to preserve structural details, achieving state-of-the-art performance.

This work has been published in the IEEE Transactions on Geoscience and Remote Sensing (IEEE TGRS): Dixit et al. IEEE TGRS (2023), 61, 1–10. doi: 10.1109/TGRS.2023.3328922

Multi-Hop UAV-Based FSO System over Doubly Inverted Gamma-Gamma Turbulence Channel

Prashant Sharma[1], Swaminathan R[1*]., and Deepshika Singh[1]

[1]Department of Electrical Engineering, IIT Indore, India

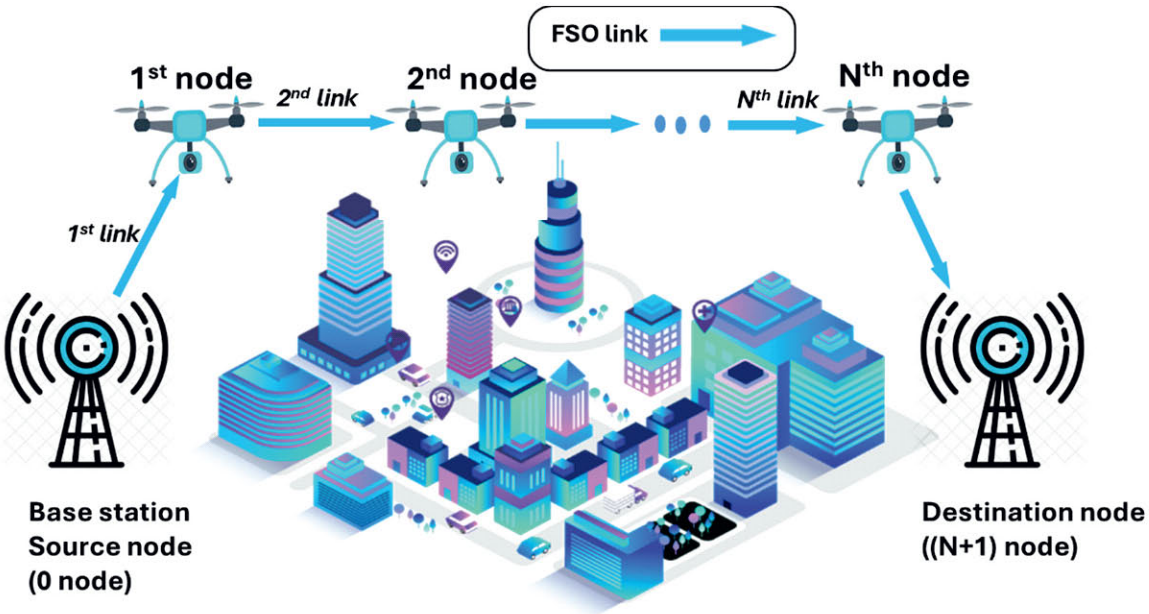


Figure: System model of a multi-hop UAV-based FSO communication

This paper analyses the performance of a multi-hop unmanned-aerial-vehicle (UAV)-based free space optics (FSO) communication system over a doubly inverted Gamma-Gamma (IGGG) turbulence channel using a decode-and-forward (DF) relaying strategy. UAV-based FSO communication improves wireless connectivity, allowing flexible deployment to establish a line-of-sight (LoS) communication with ground-based nodes. The model accounts for atmospheric turbulence, non-zero boresight pointing errors, path loss, and angle of arrival (AoA) fluctuations. Closed-form expressions for outage probability (OP), average bit error rate (ABER), and ergodic capacity are derived, alongside diversity gain and outage/BER floor through asymptotic analysis. Monte-Carlo simulations validate the analytical results.

The work has been published in IEEE Communications Letter: Sharma et al., 28, 10, 2313-2317, 2024. doi: 10.1109/LCOMM.2024.3450177

Relation between Sleep Spindles and Semantically Induced False Memory

Kedarmal Verma[1*], Kalpana Pandey[2] and Naveen Kashyap[2,3]

[1]Cognitive Experimental Laboratory, School of Humanities and Social Sciences, IIT Indore, India
[2]Sleep and Cognition Laboratory, IIT Guwahati, India
[3]Department of Humanities and Social Sciences, IIT Guwahati, India

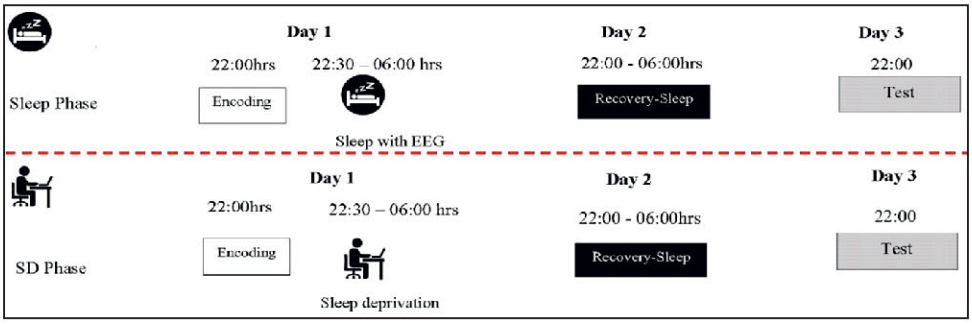


Figure 1: Study protocol for sleep/sleep deprivation nights

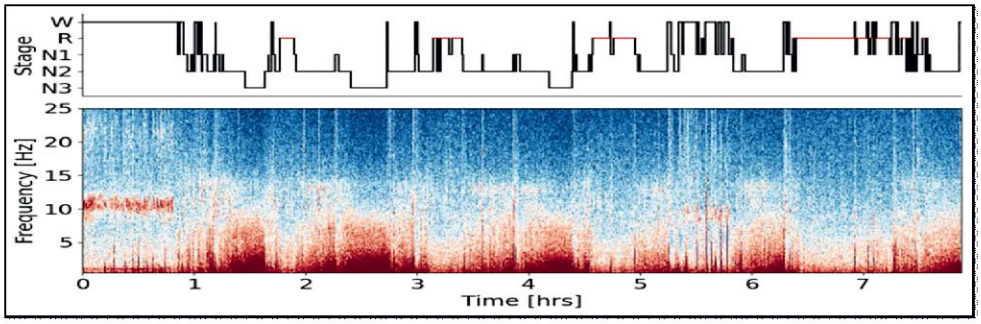


Figure 2: Average Hypnogram and Spectral Representation of 8 hrs. of Sleep

This study investigates the effects of sleep on false memories, emphasizing the role of sleep spindle density. Fifteen male volunteers were assessed using a false memory paradigm with semantic associates across sleep and sleep deprivation nights. Participants completed old/new recognition tests following recovery sleep. Results revealed no significant difference in sleep effects on true and false memories. However, correlations between spindle density and false memories were slightly higher compared to true memories, with a stronger association observed in the right hemisphere. These findings suggest that sleep-dependent false memory consolidation is linked to spindle density, particularly in the brain's right hemisphere.

The work has been published in the journal Sleep and Breathing. It was published online in volume 29 in the year 2024 and is scheduled for offline publication in 2025. doi:: https://doi.org/10.1007/s11325-024-03186-y

Fundamental Solutions of an Extended Hydrodynamic Model in Two Dimensions: Derivation, Theory, and Applications

Himanshi[1], Anirudh Singh Rana[2] and Vinay Kumar Gupta[1*]

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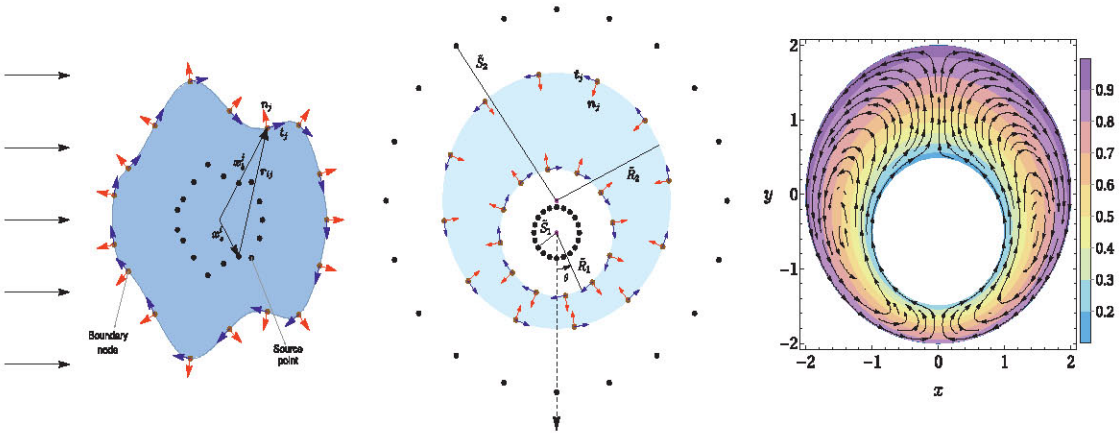
[2]Department of Mathematics, Birla Institute of Technology and Science Pilani, India



Schematic representation of flow past an object of arbitrary shape depicting boundary discretization and the placement of source points outside the flow domain (left panel); schematic of rarefied gas confined between two noncoaxial cylinders with different wall temperatures (middle panel); and velocity streamlines overlaid on temperature contours (right panel).

The inability of the Navier-Stokes-Fourier equations in capturing rarefaction effects motivates us to adopt an extended hydrodynamic model, the so-called CCR model. This work couples the CCR model with a meshless method, the method of fundamental solutions (MFS), to simulate quasi-two-dimensional flows of rarefied gases. The fundamental solutions for the linearized CCR model are determined and applied to the problems of gas flows between two coaxial and two non-coaxial cylinders. The demonstrated results validate the efficiency and accuracy of the MFS in capturing rarefaction effects at a significantly low computational cost.

The work has been published in the Physical Review E: Himanshi et al. Phys. Rev. E (2023), 108, 015306. doi: https://doi.org/10.1103/PhysRevE.108.015306

Gradient Microstructure and Properties of Surface Mechanical Attrition–Treated AZ91D Alloy: An Effect of Colliding Balls Velocity

Nilesh K. Kumbhar[1], Vikesh Kumar[1], Digvijay Singh[2], and Santosh S. Hosmani[1*]

[1]Department of Metallurgical Engineering and Materials Science, IIT Indore, India
[2]Research Center for Structural Materials, National Institute for Materials Science, Tsukuba, Ibaraki 305-0044, Japan

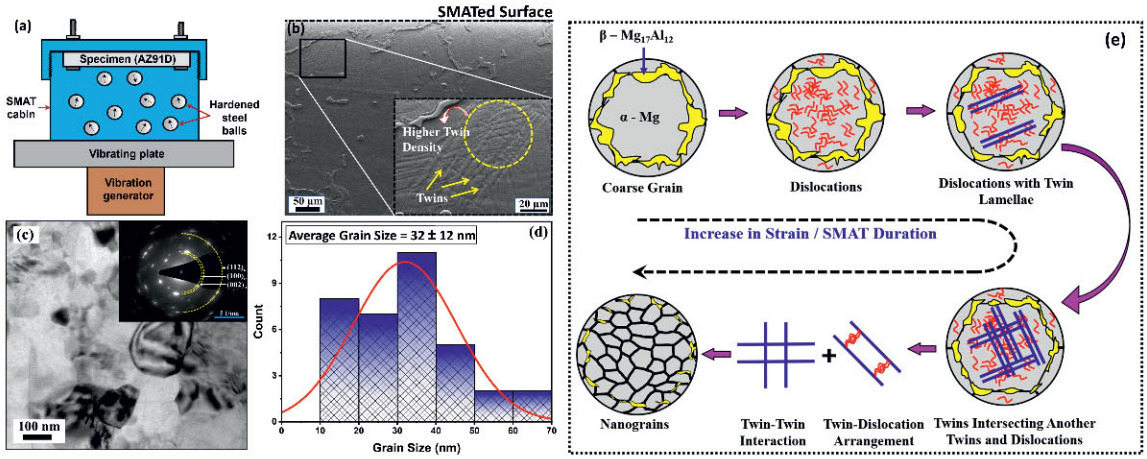


Figure: (a) Schematic representation of SMAT setup, (b) SEM micrographs of the near-surface cross-section, (c) BF TEM image illustrating nanograins with the corresponding SAED pattern, (d) nanograin distribution and (e) Schematic representation of the grain refinement mechanism in the near-surface region, for the SMATed AZ91D alloy.

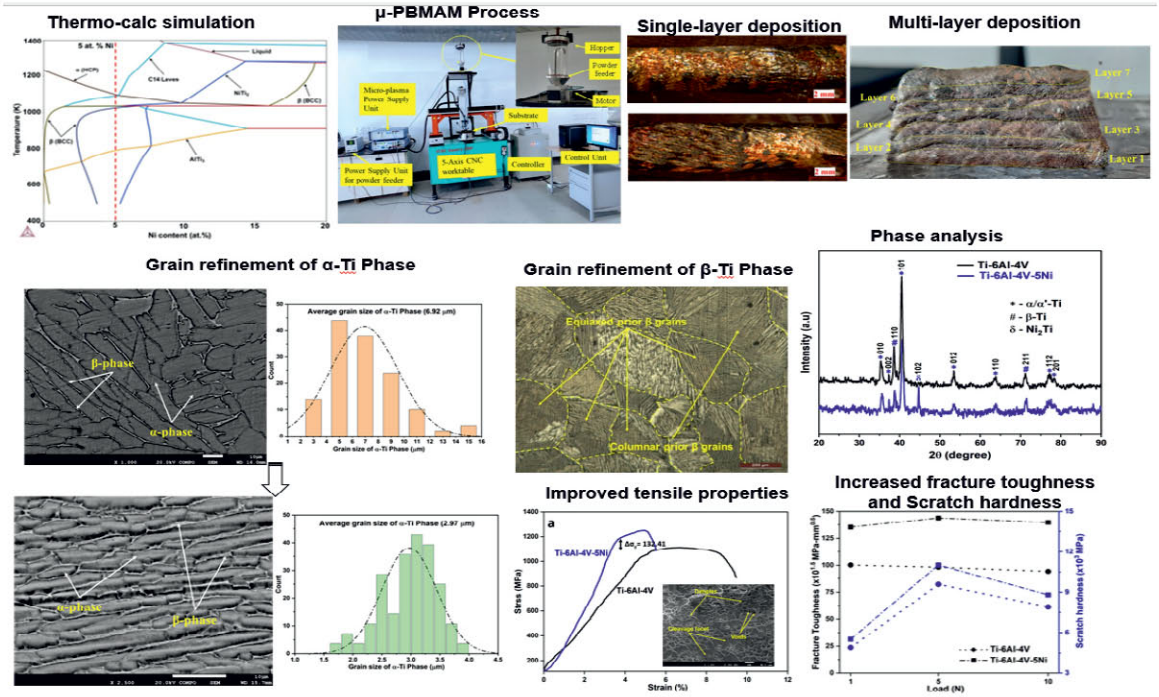
The surface properties of AZ91D alloy were enhanced using Surface Mechanical Attrition Treatment (SMAT) at ball velocities of ~3 m/s and ~10 m/s. Higher ball velocity resulted in finer grain size (~32 nm) at the surface, a thicker gradient layer (~3500 μm), and improved hardness (~1.98 GPa) and compressive residual stress (~281 MPa) within 10 minutes. Nanomechanical properties, including nanohardness, creep resistance, and strain rate sensitivity (SRS), were significantly influenced by SMAT. The SRS near the SMATed surface decreased to 0.018–0.027 due to grain refinement and exhibited depth-dependent variations due to microstructural gradients.

The work has been published in the Journal of Advanced Engineering Materials (AEM): Kumbhar et al. AEM (2023), 2300549, 1-23. doi: https://doi.org/10.1002/adem.202300549

Microstructure Evolution and Mechanical Properties of Multi-layer Deposition of Ti-6Al-4V-5Ni alloy developed by µ-plasma based Metal Additive Manufacturing Process

Pradyumn Kumar Arya[2], Neelesh Kumar Jain[1], Dan Sathiaraj[1*]

[1]Department of Mechanical Engineering, IIT Indore, India
[2]Department of Mechanical Engineering, IIT Kanpur, India



It describes development of Ti6Al4V5Ni alloy by adding thermo-calc simulated Ni amount to aerospace grade Ti6Al4V alloy via µ-plasma metal additive manufacturing process. Ni addition increased volume fraction of β-Ti phase and refined grains of α-Ti and β-Ti phases. It increased microhardness, fracture toughness, abrasion resistance, porosity, yield and ultimate tensile strength but reduced % elongation. It changed fracture mechanism to combined ductile and brittle with cleavage facets and voids. The developed alloy will be useful for high temperature, high strength, and lightweight applications in aerospace, space, automobile, and dies and mould industries.

This work has been published in The International Journal of Advanced Manufacturing Technology, 126 (11-12), 5391-5408, doi: https://doi.org/10.1007/s00170-023-11491-1

Energy flow in Ultra-high Energy Cosmic Ray Interactions as a probe of Thermalization: A Potential Solution to the Muon Puzzle

Ronald Scaria[1], Suman Deb[2], Captain R. Singh[1], and Raghunath Sahoo[1*]

[1]Department of Physics, IIT Indore, India
[2]Laboratoire de Physique des 2 infinis Irène Joliot-Curie, Université Paris-Saclay, CNRS-IN2P3, France

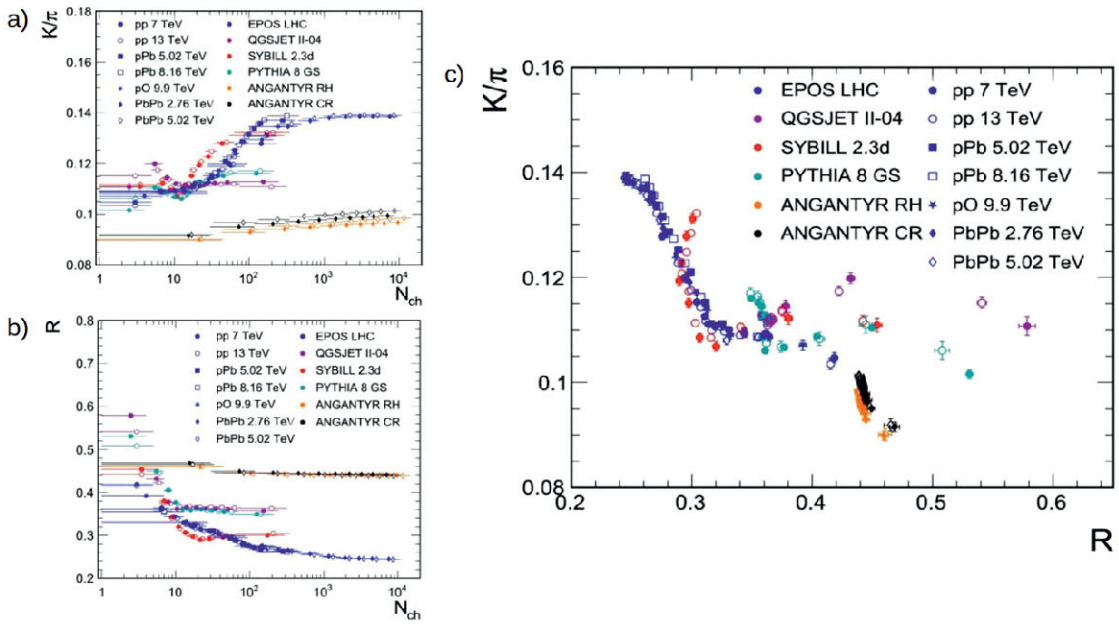
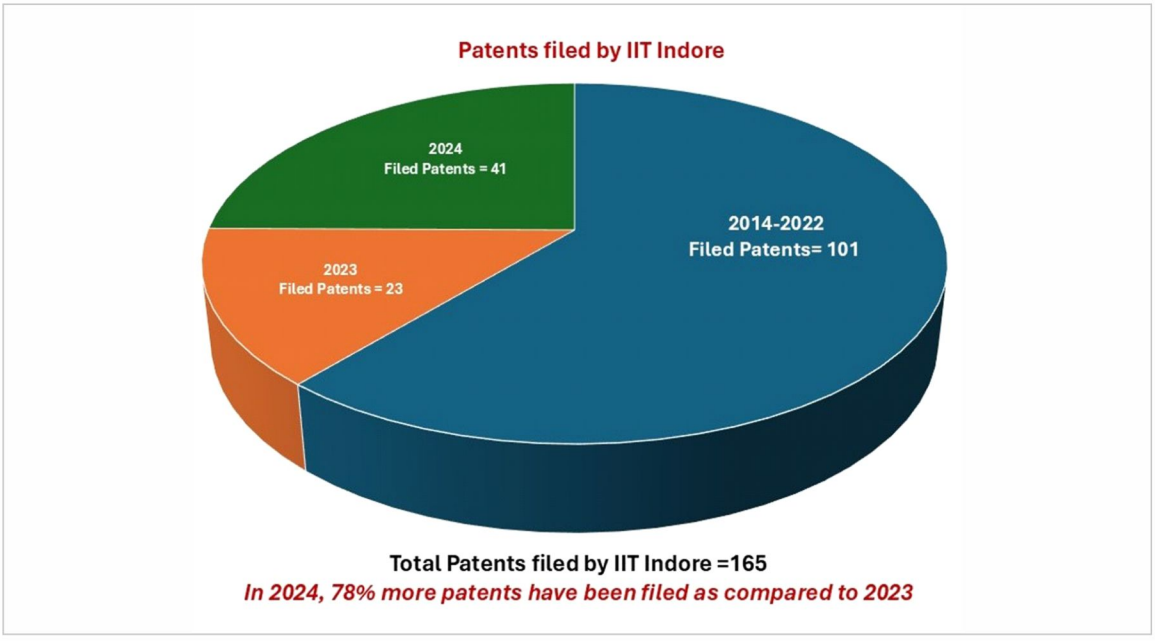


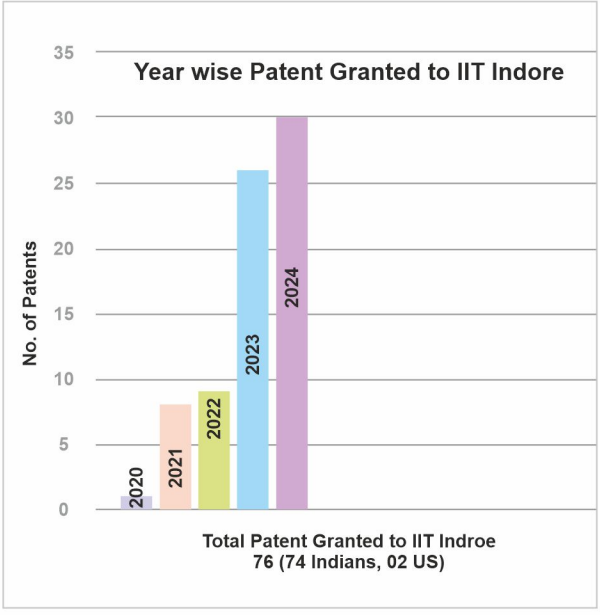
Figure: (a) The increase of strangeness as a function of charged particle multiplicity obtained across various colliding species and center of mass energies using different models. (b) The corresponding electromagnetic-to-hadronic energy fractions (R) and (c) Correlation between strangeness production and R in each of the different models

Muon puzzle refers to a higher muon yield than expected in high-energy cosmic ray-air showers. An increase in strange particle yields, observed in relativistic nuclear collisions as a consequence of quark-gluon plasma (QGP) formation, has been suggested as a solution. Another suggestion is to decrease the electromagnetic-to-hadronic energy fraction (R) in air showers at high energies. This work explores the relationship between these two factors using different hadronic interaction models. The EPOS-LHC model with QGP-like phenomena better explains the strangeness data and shows an anti-correlation between strangeness and R, suggesting the possibility of QGP formation in high-energy air showers.

The work has been published in the Physics Letters B Journal: R. Scaria et al., 844, 138118 (2023). doi: https://doi.org/10.1016/j.physletb.2023.138118

IIT Indore's Remarkable Achievements in Research and Innovation in 2024





2024 has been a landmark year for IIT Indore, showcasing remarkable achievements in Research and Development. The institute saw a 78% increase in patent filings, totaling 76 patents, including 74 Indian and 2 U.S. patents. IIT Indore secured 30 patents in 2024, accounting for 41% of the total Indian patents granted to the institute. The institute also registered 2 new designs, blending creativity with functionality. Additionally, 4 technologies were licensed to industries, and 11 were adopted by start-ups, promoting entrepreneurship and sustainable development. These milestones reflect IIT Indore's commitment to innovation, societal impact, and global contributions.

Foundation Day of IIT Indore

Indian Institute of Technology Indore marked its 16th Foundation Day on February 17, 2025, with a grand ceremony celebrating technological advancements, ground-breaking research, and outstanding employees. The event witnessed the presence of distinguished guest Dr. Rajesh Gokhale, Secretary, Department of Biotechnology, Government of India (GoI), faculty, students, and staff reflecting on the institute's achievements and future aspirations.

A key highlight of the celebration was the release of the second edition of "A Handbook of Ideas, Innovations, and Technologies of IIT Indore." This comprehensive compilation showcases ground-breaking research, technological advancements, and innovative projects developed by the institute's faculty and students. The handbook aims to foster collaboration and inspire further advancements in science and technology.

With a strong commitment to academic and research excellence, IIT Indore continues to make significant contributions to India's innovation ecosystem, reinforcing its position as a leading institution in the country.

Women in Space and Allied Sciences Leadership Program (WiSLP)

IIT Indore hosted the Women in Space and Allied Sciences Leadership Program (WiSLP) - Cohort 4 from February 18-21, 2025, under the joint initiative of the British Council and WISE-KIRAN program (DST).

Prof. Kiran Bala was the coordinator for the event. The event was inaugurated by Prof. Suhas S. Joshi, Prof. Avinash Sonawane, and other esteemed dignitaries. The program featured expert-led workshops by Dr. Alison Halford and Dr. Mike Hardy from Coventry University, alongside Indian experts Dr. Sanjay Mishra, Dr. Annapurni Subramaniam, Mr. Siba Prasad Hota, and Prof. Ruchi Sharma.

Through interactive sessions, leadership training, and networking opportunities, participants gained essential skills for career advancement. The event concluded with presentations, a closing ceremony, and certificate distribution, marking a significant step in empowering women scientists in Space and Allied Sciences.

One-Day Workshop on Standards in Measuring Water Quality

One-Day Workshop on Standards in Measuring Water Quality was held on 4th January 2025 at IIT Indore, organized by the Bureau of Indian Standards (BIS) and the Centre for Narmada River Basin Management Studies (cNARMADA). The workshop brought together experts, researchers, and policymakers to discuss water quality standardization for accurate assessments, effective policymaking, and sustainable management.

The inaugural session, moderated by Prof. Manish Kumar Goyal, featured distinguished speakers, including Prof. Ajay Kalamdhad (IIT Guwahati), Prof. Deepak Khare (IIT Roorkee), Prof. P. Ganesh (BITS Hyderabad), and Dr. Mayur Shirish Jain (IIT Indore), who emphasized collaborative efforts in maintaining standards. Technical sessions covered groundwater management, emerging contaminants, landfill leachate treatment, and alternative water supply strategies. Discussions focused on updating BIS standards to address pollutants like arsenic, microplastics, and pharmaceuticals.

The workshop underscored the need for interdisciplinary collaboration, aligning with SDGs, and strengthening crisis management strategies for water security in India.

Workshop on Narmada River Basin Management Studies

The Narmada River Basin Management Studies (NRBMS) Workshop, held on 16th-17th January 2025 at IIT Indore, brought together experts, policymakers, and researchers to discuss sustainable management of the Narmada River Basin. Organized under cNARMADA, the workshop focused on Unpolluted River Flow (Nirmal Dhara) and Continuous River Flow (Aviral Dhara) through integrated, multidisciplinary approaches.

Key discussions covered climate change, hydrology, groundwater management, and environmental conservation, featuring experts like Prof. Vinod Tare (IIT Kanpur), Prof. C.S.P. Ojha (IIT Roorkee), and Mr. Mukesh Chauhan (Narmada Control Authority). Narmada Samagra Nyas showcased community projects, including riverbank afforestation and eco-friendly idol immersion. A panel on Integrated River Basin Management, led by Prof. Manish Kumar Goyal (IIT Indore), emphasized technology-driven solutions and community participation. The workshop fostered collaboration, bridging scientific research, policy, and local initiatives to ensure the long-term resilience of the Narmada River Basin.

Learning Resource Centre

Academic Building

Sports Complex

Central Workshop

Health Centre

Computer & Information Technology Centre

Vindhyachal Guest House

Hostel Accommodation

Nalanda Auditorium

Kendriya Vidyalaya

Seminar Hall

Faculty and Staff Residence

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ISBN: 978-93-5967-954-9