Nehal **Mittal**

ICFP Masters, ENS Paris

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Academic Credentials and Scholarships

2020-22	**Charpak:** Represented India as one of the 30 Charpak Masters excellence scholars for academic year 2020-21 and as one of the 10 renewed senior scholars for academic year 2021-22	*Campus France, Rép. Française*
2022	**M2:** Secured US equivalent of **A**+ in Advanced Quantum Mechanics, General Relativity, symmetries and quantum field theory, advanced (topological) topics in QFT and string theory	*ICFP Master, ENS Paris*
2021	**M1:** Scored 20/20 in group theory and general theory of relativity and **ranked 1st** in 2021 batch	*Paris-Saclay Uni.*
2016	**URA:** Received **Undergraduate Research Award** award for excellent aptitude towards research	*IIT Bombay*
2014	**JEE:** Among **top 1%** students in Joint Entrance Examination - Advance, out of **0.15 Million** students	
2013	**KVPY:** Awarded prestigious Kishore Vaigyanik Protsahan Yojana (KVPY) Scholarship to pursue higher education in science and invited for Vijyoshi national science camp	*Dept. of Science, Govt. of India*

Education

2021-22	**M2 Masters** ICFP, École Normale Supérieure	
2020-21	**M1 Masters** General Physics, Paris-Saclay University	
2014-19	**Integrated Bachelors and Masters** Engineering Physics, IIT Bombay	

Publications

Einstein Cartan Dirac Equations in Newman-Penrose Formalism | B.Tech. Thesis *TIFR, Mumbai*

GUIDE: PROF. T.P. SINGH, TATA INSTITUTE OF FUNDAMENTAL RESEARCH; PROF. URJIT A. YAJNIK, IIT BOMBAY *May'17 - Dec'18*

- Applied **Newman-Penrose formalism** to Dirac equation in Einstein-Cartan theory
- Discovered the exact symmetry between torsion and curvature in Dirac equation on U^4 manifold
- Discovered a 3+1 soliton-like solution that interpolates between black hole and Dirac fermion and motivated a new quantum gravity length scale that correctly reproduces quantum mechanics and general relativity in appropriate limits
- **Published** in Physical Review D (Phys. Rev. D 98, 064046), arXiv:1804.11334v2.

Shockwaves, QNEC and holographic entanglement entropy in Banados geometry *IIT Madras*

GUIDE: PROF. AYAN MUKHOPADHYAY, DEPARTMENT OF PHYSICS, IIT MADRAS *Sep'19 - June'20*

- Proposed a novel technique to calculate **Lyapunov exponent** using Shapiro time delay
- Studied **Banados geometries** and generated a **uniformization map** from Banados geometries to Poincare AdS$_3$
- Generated a Mathematica code to calculate **Holographic Entanglement Entropy** and **QNEC** for general Banados geometries
- Related solutions of Hill's equation with Banados geometries and worked on bounds on growth of entanglement entropy and deletion of information using shockwaves in Banados geometries
- Submitted to PRL for publication. Preprint at arXiv:2022.00022

Key projects

Interacting phases of matter on topological structures using dressed ultracold Dysprosium atoms | M2 thesis *College-de-France*

GUIDE: PROF. SYLVAIN NASCIMBENE, LKB, COLLEGE-DE-FRANCE *April'22 - July'21*

- Studied generation of artificial magnetic fields by dressing Dysprosium atoms using off-resonant laser light to measure quantum Hall effect and the associated topological structure of quantum states
- Following current work in the lab on extension of 2D quantum Hall analysis of arXiv:2110.12971 to 4D Hall response
- Planned to study interacting Bose-Einstein Condensates and their stability in presence of a light-induced artificial magnetic field

Flat space holography and Geroch transformations | M1 thesis *Ecole Polytechnique*

GUIDE: PROF. MARIOS PETROPOULOS, CPhT, ECOLE POLYTECHNIQUE *Jan'21 - July'21*

- Studied integrability properties of Einstein's equations in asymptotically AdS spacetime to understand fluid/gravity duality
- Generalizing **Geroch**'s solution generating procedure to all Einstein spaces to understand Schwarzschild Taub-NUT solution on AdS
- Studied holography as a dim. reduction technique to generate new solutions *á la* Geroch and used fluid/gravity correspondence to generate all algebraically special geometries from boundary fluid data to understand action of Geroch group on the boundary
- Preprint to appear soon

Determination of Cell–Cell and Cell–Substrate Forces in Tissues

IIT Bombay

GUIDE: PROF. RAGHUNATH CHELEKKOT, DEPARTMENT OF PHYSICS, IIT BOMBAY

Jun'16 - Oct'16

- Extensively studied particle-based simulation models by Zimmermann et. al and Basan et. al on **Contact Inhibition of Locomotion** (CIL) and **motility force alignment** as mechanism for spreading of colonies in wounded tissues
- Performed MATLAB simulations to study spreading dynamics and mechanical properties of cell segments in situations that closely corresponds to experimental configuration and received **Undergraduate Research Award** for exemplary interdisciplinary research

Quantum Information Paradox

IIT Bombay

GUIDE: PROF. URJIT A. YAJNIK, DEPARTMENT OF PHYSICS, IIT BOMBAY; BLACK HOLE PHYSICS GROUP

Nov'16 - May'17

- Studied QFT and Quantum Information/Entanglement Theory to understand the Quantum Information Paradox
- Reviewed **Hawking's Radiation**, **Page time**, **Black Hole Complementarity**, and **Firewall** proposal
- Used Gidding's model to determine complementarity and first-order Firewall effects at Black hole horizon in 1+1 Dimensions

Field Theory Approaches to Condensed Matter Systems

IIT Bombay

GUIDE: PROF. PICHAI RAMADEVI, DEPARTMENT OF PHYSICS, IIT BOMBAY

May'18 - Aug'19

- Reviewed AdS/CFT correspondence, Black Hole thermodynamics, Superconductivity and Monte Carlo method
- Applied Quantum Critical Transition knowledge to black holes and d-branes to understand **Holographic Superconductors**
- Calculated Green's function using AdS/CFT with bulk in Gaussian potential to match dilute, weak impurities in strongly coupled CFT
- Studied **OTOC** and its calculation in **SYK model** and other CFTs (free bosonic CFT at the critical point in 1-D spin-1/2 **XXZ** chain model) using Conformal Ward identities for twist field operators in n-copy surfaces
- Verified these OTOC results through Numerical DMRG calculations in collaboration with Prof. Soumya Bera and Rof. Sumiran Pujari

Gravitationally lensed Ordinary Type IA Supernova PS1-10afx

IPMU, Tokyo

GUIDE: PROF. ANUPREETA MORE, IPMU, TOKYO, PROF. VIKRAM RENTALA, DEPARTMENT OF PHYSICS, IIT BOMBAY

Aug'15 - Nov'15

- In a group of 2, reviewed the **Gravitational Lensing hypothesis** for anomalous case of PS1-10afx by observing spectral features from detailed .fits files and related research publications
- Downgraded the HST image to match the spatial resolution and PSF smearing to reproduce **Keck specifications**
- Used Anaconda to separate 2 Gaussian components from HST image of [O II] spectrum to fit Keck's spectrum

Test scores

2018	**General GRE:**	Scored 323/340. (Quantitative: 168/170, Verbal: 155/170, Writing: 4.00/6.00)
2018	**Physics GRE:**	Scored 920/990 in Physics GRE (86th percentile)
2018	**TOEFL:**	Secured 110/120 in English proficiency test TOEFL iBT

Course Projects

CMB Anisotropies: Analysis of the Planck Data

Paris-Saclay University

GUIDE: PROF. MARIAN DOUSPIS, INSTITUT D'ASTROPHYSIQUE SPATIALE

Dec'20

- Observed spectral energy density as a function of frequency for different astrophysical components observed along with CMB using the available parametric signal models. Concluded that high frequency maps can be used to mask astrophysical background
- Studied component separation using Internal Linear Combination (ILC) to create masked CMB anisotropy map
- Used **healpy** package to measure the power spectrum of CMB and calculated Hubble constant, spatial curvature and Baryon density

Turbulence and an effective gravitational temperature for sedimentation

Paris-Saclay University

GUIDE: PROF. ANNIINA SALONEN & PROF. GIUSEPPE FOFFI, LPS ORSAY

Dec'20

- Wrote an article on Navier-Stokes existence and smoothness and insights from soft matter physics
- Presented "An effective gravitational temperature for sedimentation" (https://doi.org/10.1038/35054518) in Journal club meeting

Topological Defects and Curvature in Graphene

IIT Bombay

GUIDE: PROF. ANSHUMAN KUMAR, DEPARTMENT OF PHYSICS, IIT BOMBAY

Feb'18 - Apr'18

- Studied high energy phenomenon such as Klein tunneling and Dirac equation in flat spacetime on graphene
- Modeled curvature and studied the effects of defects on local density of states through numerical methods and matlab simulations

Synthesis and Analysis of Graphene Oxide

IIT Bombay

GUIDE: PROF. M. ASLAM, DEPARTMENT OF PHYSICS, IIT BOMBAY; GROUP MEMBERS: 2

Feb'18 - Apr'18

- **Synthesized** Graphene oxide nanoparticles using modified Hummers method with reduced toxic emission
- Characterized the nanoparticles using FTIR, Raman, UV-Vis, and XRD spectroscopy and observed **17%** increase in efficiency

Hives, A Smart Living Solution

IIT Bombay

GUIDE: PROF. RAJ JASWA, CHAIRMAN, CEO AND PRESIDENT, DYYNO, INC.; GROUP MEMBERS: 6

Jul'18 - Dec'18

- Conducted market research and generated a potential model for **'capsule homes'**, a cheap living solution for **underprivilaged**
- Developed and presented a complete business model canvas to **100+** different hotels, hospitals and NGOs

A Study of Sloshing Modes

IIT Bombay

GUIDE: PROF. KUNDU TAPANENDU, DEPARTMENT OF PHYSICS, IIT BOMBAY; GROUP MEMBERS: 5

Mar'16 - Apr'16

- Observed and studied dynamics behind **sloshing modes** of a rectangular tank using Euler and Laplace equations
- Plotted the amplitude of the liquid inside the rectangular container using MATLAB and Image Processing

Synchronization of Chaotic Systems

IIT Bombay

GUIDE: PROF. AMITABHA NANDI AND PROF. RAGHUNATH CHELAKKOT, DEPARTMENT OF PHYSICS IIT BOMBAY

Oct'15 - Nov'15

- Studied dynamics of **Chaotic systems** (**Rossler**) and how synchronization of such an oscillator can be achieved by applying an external force or by coupling 2 such systems
- Experimentally observed real world examples of Phase synchronization, Lag synchronization and Complete synchronization, worked out its dynamics and computationally anaysed the system

Remotely Controlled Ping-Pong game using FPGA module

IIT Bombay

GUIDE: PROF. PRADEEP SARIN, DEPARTMENT OF PHYSICS, IIT BOMBAY; GROUP MEMBERS: 2

Mar'16 - Apr'16

- Designed a 2-player/single-player ping-pong game in **VHDL** and implemented it using FPGA (DE0-nano board)
- Created a **VGA** circuit to convert the FPGA input/output and display it on a screen

Teaching Experience

Mentor | Summer School of Science

Department of Physics, IIT Bombay

- Mentored 4 students on special relativity, quantum mechanics, group theory and quantum field theory respectively.

May'21 - July'21

- Devised course plans, assignments and provided essential guidance to learn the topics

Teaching Assistant | Electronics Lab I

Department of Physics, IIT Bombay

- Responsible for creating and testing dynamic lab assignments for 40+ students with **'bonus'** problems challenging TAs

Jul'18 - May'19

- Reviewed Instrumentation and application of LCR circuits, semiconductors, diodes, transistors, and logic gates thoroughly

Teaching Assistant | Quantum Mechanic I

Department of Physics, IIT Bombay

- Entrusted with responsibility of tutoring 40 undergraduate students to the introductory course in Quantum Mechanics

Jan'18 - May'18

- Helped students get better insight of the course, clarified doubts and assisted the instructor in creating interesting problems

Voluntary Teaching

National Service Scheme

- Worked in a team of 20 to teach basic mathematics and science to underprivileged students in slum areas of Mumbai

Aug'16 - May'17

- Coordinated with NGOs **Abhyasika** and **Teach for India** to design and demonstrate basic science experiments

Workshops and Conferences

Virtual/Covid Workshops 2020

Aug' 20	Hamilton School on Mathematical Physics	*Trinity College*
Aug' 20	Anual Integrability in Gauge and String Theory (IGST)	*ICTP-SAIFR*
July 20	Joint ICTP-Trieste/ICTP-SAIFR School on Particle Physics	*ICTP-SAIFR*
June 20	Complexity from Quantum Information to Black Holes	*UvA-AEI*

An introduction to Topological Insulators

IIT Bombay

RIBHU KAUL, UNIVERSITY OF KENTUCKY

May'19

- Physical examples of topological insulators in various dimensions and the 'Tenfold way' classification were discussed

QCD Matter

IMSC Chennai

RAJEEV BHALERAO, RAJIV GAVAI, PUSHAN MAJUMDAR, AJIT SRIVASTAVA

Sep'19

- Various aspects of Lattice Gauge theory and heavy quark diffusion coefficient from lattice were introduced
- CMB physics, magnetohydrodynamics and collectivity in large and small systems in relativistic heavy-ion collisions were discussed

Applied Holography: A Practical Mini course

IIT Madras

MATTEO BAGGIOLI, UNIVERSIDAD AUTÓNOMA DE MADRID, MADRID

Sep'19

- Bottom-up holography was motivated with examples from near-horizon geometries, membrane paradigm and DC conductivity
- Numerical and analytical methods (Matching method, Determinant method, gauge invariant variables etc) were used to describe holographic Green's functions, Quasinormal modes and hydrodynamic excitations

A modern take on the Information Paradox and progress towards its Resolution

ICTS, Bangalore

AHMED ALMHEIRI, INSTITUTE FOR ADVANCED STUDY, PRINCETON

Oct'19

- Various attempts at resolving Hawking's information paradox along with ideas which lead to firewall paradox were described
- A new toy model was proposed to describe how these paradox can be resolved using holographic methods

Extra-Curricular Activities

- Excelled in **boxing** course conducted by Summer School of Sports, IIT Bombay
- Completed introductory courses in **French** and **German** languages under Summer School of Cult, IIT Bombay
- Steered Hostel 9 to **1st** position in Performing Arts Festival'16; Handled productions department
- Part of Techfest, IIT Bombay 2016 team responsible for organising **CURED**, 'Can U Really Escape Diabetes?' a pan-India event screening 1 lakh+ people for diabetes and **IAmPower** to empower girls to become leaders through exposure to science and technology