



The Institute of Mathematical Sciences, Chennai

Quarterly Report

July - September 2023



Highlights: research and events

High Energy Physics Phenomenology

The Baryon Asymmetry of the Universe: The standard model (SM) of particle physics fails to adequately explain the observed baryon asymmetry of the Universe (BAU). It is commonly believed that physics beyond the standard model (BSM) is required to generate the BAU. Any such BSM model must satisfy the three Sakharov conditions, namely, violate C and CP symmetries, violate baryon number, and depart from thermal equilibrium. An effective theory with a Majorana fermion pair coupled to quark-like fermions was constructed, and the physical phases were identified. The theory was shown to have C and CP violation, and baryon number violation. The departure from thermal equilibrium is provided by the Hubble expansion of the Universe. Majorana fermion decays and scattering processes were included and the resulting BAU was estimated.

Reference: Effective theory for baryogenesis with a Majorana fermion pair coupled to quarks, By Shrihari Gopalakrishna and Rakesh Tibrewala, Phys. Rev. D 107, 115029, 26 June 2023.

Modular forms

The goal is to study Fourier coefficients of cusp forms, not necessarily Hecke eigenforms, of half-integer weight lying in the plus space. Our focal point are the Fourier coefficients of the form $c(|D|)$ supported at fundamental discriminants D . These coefficients encode deep arithmetic content and are much more intractable than those not arising from fundamental discriminants. In our work, we give a new proof that there are infinitely many fundamental discriminants D such that the Fourier coefficients evaluated at $|D|$ are non-zero. We also demonstrate that such Fourier coefficients must take quite large values. These lower bounds obtained in our work are best known, even in the situation of Hecke eigenforms. This article is now available as preprint in American Journal Math with link

Reference : Large fourier coefficients of half-integer weight modular forms S. Gun, W. Kohnen and K. Soundararajan, American Journal of Mathematics.
<https://preprint.press.jhu.edu/ajm/sites/default/files/AJM-gun-kohnen-soundara.pdf>

The authors investigate a non-Archimedean analogue of a question of Atkin and Serre. More precisely, they derive lower bounds for the largest prime factor of non-zero Fourier coefficients of non-CM normalized Hecke eigen cusp forms of weight k , level N

with integer Fourier coefficients. In particular, the authors show that for such a form f and for any real number $r > 0$, the largest prime factor of the p -th Fourier coefficient $a_f(p)$ of f , denoted by $P(a_f(p))$, satisfies

$$P(a_f(p)) > (\log p)^{1/8} (\log \log p)^{3/8-r}$$

for almost all primes p . This is the best known result in this direction. The authors also investigate a number field analogue of a recent result of Bennett, Gherga, Patel and Siksek about the largest prime factor of $a_f(p^m)$ for $m \geq 2$.

Reference : On a non-Archimedean analogue of a question of Atkin and Serre, Yuri F. Bilu, Sanoli Gun & Sunil L. Naik, Mathematische Annalen (July 2023).
<https://link.springer.com/article/10.1007/s00208-023-02686-8>

Let τ denote the Ramanujan tau function. In a recent work, Bennett, Gherga, Patel and Siksek proved that for any prime p and integer $m \geq 2$, the largest prime factor $P(\tau(p^m))$ of $\tau(p^m)$ satisfies

$$P(\tau(p^m)) > \alpha \cdot \frac{\log \log(p^m)}{\log \log \log(p^m)}$$

provided $\tau(p) \neq 0$. Here α is an absolute positive constant. The authors prove that for any $r > 0$ and integer $m \geq 1$,

$$P(\tau(p^m)) > (\log p)^{1/8} (\log \log p)^{3/8-r}$$

for almost all primes p . The above results are also valid for any non-CM normalized Hecke eigenforms with integer Fourier coefficients. This article is now accepted in Forum Math.

Reference : On the largest prime factor of non-zero Fourier coefficients of Hecke eigenforms, Sanoli Gun, Sunil L. Naik, Forum Mathematicum, August 2023.

<https://doi.org/10.1515/forum-2023-0050>

Non-perturbative QCD, Lattice Gauge Theory, QGP

A plasma far from equilibrium, containing a gauge field coupled to fermionic matter fields with an initial handedness or chirality is known to be an unstable system. From a first principles study, using classical-statistical lattice techniques, we systematically track the dynamics of the chirality in a system of fermions coupled to non-Abelian $SU(2)$ gauge fields. We reconfirm that the initial transfer of chirality from the fermions to gauge fields occurs through the onset of instabilities i.e. exponential growth of certain momentum modes of the gauge fields. More interestingly the chirality in the fermion sector gets absorbed by gauge fields via non-trivial topological transitions. This has interesting consequences, like the saturation of momentum distribution of the low energy modes of gauge fields unlike the onset of turbulence observed in an Abelian electromagnetic plasma by us in an earlier work. Our findings have consequences for the ongoing experimental searches at Brookhaven National Laboratory and at CERN on the signatures of Chiral Magnetic effect.

Reference : Chiral Instabilities and the Fate of Chirality Imbalance in Non-Abelian Plasmas, Sören Schlichting and Sayantan Sharma, Physical Review Letters, 131, 102303, 2023.

Exotic hadrons are of significant topical interest to physicists. In a recent work, we present the first lattice calculation that unambiguously predicts the existence of a bound exotic tetraquark (Tbc) with a bottom and a charm quark. Our finding is particularly important given the recent discovery of its lighter cousin, Tcc. Recent experimental progress in doubly heavy quark production promises the discovery of Tbc in near future. Previous phenomenological and lattice predictions for Tbc are scattered or inconclusive, whereas our conclusive findings proliferate the interest in Tbc and similar hadrons that await discovery.

Reference: Bound isoscalar axial-vector bcud tetraquark Tbc in QCD, M. Padmanath, Archana Radhakrishnan, Nilmani Mathur, arXiv:2307.14128

AIS - Advanced Topics in Finite Fields - 2023 (10 July 2023 to 29 July 2023)

The theory of finite fields lies at the crossroads of algebra, combinatorics, and number theory. Finite fields play an important role in many application areas, such as coding theory and cryptography. The topics covered in this workshop include the following: the structure of finite fields, matrices and linear operators over finite fields, polynomials over finite fields, sequences over finite fields, exponential sums over finite fields, and equations and varieties over finite fields. This workshop was intended for graduate students with a potential interest in finite fields and their applications.

Organisers : Prof. Amritanshu Prasad, IMSc, Chennai and Dr. Sartaj Ul Hasan, IIT, Jammu

Awards and Honours

- Prof. C.M. Chandrashekar was elected as a member of The National Academy of Sciences, India.

Participation in conferences

Coimbatore Balram, Ajit

Visited Harish-Chandra Research Institute, Prayagraj during Jul 24 – Jul 28, 2023. invited seminar

Participated in Discussion Meeting on Non-Equilibrium Correlated Systems held at Harish Chandra Research Institute, Prayagraj during Jul 24 – Jul 26, 2023. invited talk

Gun, S.

Participated in Automorphic forms and L-functions of higher rank held at QMUL, London, UK during Sep 11 – Sep 15, 2023. Invited Speaker

Madanagopalan, Padmanath

Participated in 40th International Symposium on Lattice Field Theory held at Fermilab, Batavia, Illinois, USA during Jul 31 – Aug 4, 2023. Presented (Online) our recent work on Tbc tetraquark, arXiv:2307.14128.

Mahajan, Meena B.

Participated in The 26th International Conference on Theory and Applications of Satisfiability Testing SAT. held at Alghero, Italy during July 4 – July 8, 2023. co-Chair, Program Committee.

Participated in Highlights of Logic, Games and Automata held at Kassel, Germany during Jul 24 – Jul 28, 2023. Keynote speaker. Gave a talk titled "Quantified Boolean Formulas and Proof Complexity"

Participated in Workshop on Algebra and Computation held at Chalmers University of Technology, Gothenburg, Sweden during Aug 14 – Aug 16, 2023.

Sharma, Sayantan

Participated in INT workshop on Chirality and Criticality in Heavy-Ion Collisions held at Online, organized by the Institute of Nuclear Theory, University of Washington, Seattle, US during Aug 21 – Aug 25, 2023. Delivered a seminar titled "Chiral Plasma Instabilities in non-Abelian Gauge Theories"