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## Academic Report (2020-21)

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# Ashoke Sen

## Research Summary:

My work during April 2020 - March 2021 has been mainly on the analysis of D-instanton contribution to string amplitudes. I developed a general procedure for dealing with the infrared divergences that appear in the computation of D-instanton amplitudes in string theory and showed how we can use string field theory to extract unambiguous results for these apparently divergent quantities. I used this to discuss unitarity of the D-instanton amplitudes and possible failure of unitarity when tachyonic modes are present on the D-instanton. I also used open string field theory to compute the overall normalization of the D-instanton amplitudes – a task not attempted earlier due to the infrared divergences that plague this computation.

In a separate work with Nabamita Banerjee, Ajit Bhand, Suvankar Dutta and Ranveer Singh, I showed how Bhargava's cube can be used to classify the duality orbits of the STU model.

## Publications:

1. A. P. Saha, B. Sahoo and A. Sen, *Proof of the classical soft graviton theorem in  $D = 4$* , JHEP **06** (2020), 153 doi:10.1007/JHEP06(2020)153 [arXiv:1912.06413 [hep-th]].
2. A. Sen, *D-instanton Perturbation Theory*, JHEP **08** (2020), 075, doi:10.1007/JHEP08(2020)075 [arXiv:2002.04043 [hep-th]].
3. A. Sen, *Divergent  $\implies$  complex amplitudes in two dimensional string theory*, JHEP **02** (2021), 086 doi:10.1007/JHEP02(2021)086 [arXiv:2003.12076 [hep-th]].

## Preprints:

1. N. Banerjee, A. Bhand, S. Dutta, A. Sen and R. K. Singh, *Bhargava's Cube and Black Hole Charges*, [arXiv:2006.02494 [hep-th]].
2. A. Sen, *Cutkosky Rules and Unitarity (Violation) in D-instanton Amplitudes*, [arXiv:2012.00041 [hep-th]].
3. A. Sen, *D-instantons, String Field Theory and Two Dimensional String Theory*, [arXiv:2012.11624 [hep-th]].
4. A. Sen, *Normalization of D-instanton Amplitudes*, [arXiv:2101.08566 [hep-th]].

## Invited zoom talks at Conferences / Workshops / Schools

1. *Divergent to Complex Amplitudes in Two Dimensional String Theory*, at 'String field theory and related topics', Sao Paulo, June 2020
2. *D-instanton Perturbation Theory*, Strings 2020, Cape Town, June 2020
3. *Soft Theorem and its Classical Limit*, at 'Recent Developments in S-matrix theory', ICTS, Bangalore, July 2020

4. *Classical radiation and soft graviton theorem, at the workshop on 'Rethinking the Relativistic Two-Body Problem', AEI Potsdam, August 2020*
5. *Cutting Rules and Unitarity (Violation) in D-instanton Amplitudes, at 'The dual mysteries of gauge theories and gravity', IIT Madras, October 2020*
6. *Soft theorem and classical radiation, Mini review at the DAE Symposium on High Energy Physics, NISER, Bhubaneswar, December 2020*
7. *Bhargava's cube and black hole charges, at 'Recent advances in Mathematics and Related areas 2020, Kerala school of Mathematics, Kozhikode, December 2020*
8. *How to compute string amplitudes, at the Kavli Asian Winter School (KAWS) on Strings, Particles and Cosmology, Beijing, January 2021*
9. *Unitarity and Analyticity in String Field Theory, 'Workshop Quantum Gravity, Higher Derivatives & Nonlocality', Tokyo Institute of Technology, March 2021*
10. *Classical gravitational radiation and soft theorem, CAmplitudes 2021, California, March 2021*

### **Invited zoom talks at other institutes**

1. *D-instanton Perturbation Theory, Italian String Webinars, May 2020*
2. *Gravitational Waves from Soft Theorem, University of Groningen, May 2020*
3. *D-instanton Perturbation Theory, Israel string theory seminar, June 2020*
4. *Four lectures on D-instanton Perturbation Theory, SAIFR, Sao Paolo, June 2020*
5. *Cutting Rules and Unitarity (Violation) in D-instanton Amplitudes, AEI Potsdam, November 2020.*
6. *Cutting Rules and Unitarity (Violation) in D-instanton Amplitudes, Queen Mary University, London, November 2020.*
7. *D-instanton Amplitudes, Harvard University, February 2021*
8. *D-instanton Amplitudes, ICTS, Bangalore, February 2021*
9. *D-instanton Amplitudes, University of Wurzburg, February 2021*
10. *D-instanton Amplitudes in String Theory, ETH Zurich, February 2021*
11. *D-instanton Amplitudes in String Theory, Paris area seminar, February 2021*
12. *D-instanton Amplitudes in String Theory, Oxford University, March 2021*
13. *D-instanton Amplitudes in String Theory, Nordic string seminar, Helsinki, March 2021*
14. *D-instanton Amplitudes in String Theory, London area seminar, March 2021*
15. *Three lectures on D-instanton Amplitudes in String Theory, KIAS, Seoul, March 2021*