

**Dr. Rahul Kumar Kushwaha**  
Postdoctoral Researcher  
Experimental Astrophysics/Planetary Science

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## Positions/Employment

03/2023 – **Postdoctoral Researcher**  
Jet Propulsion Laboratory, California Institute of Technology,  
Pasadena, CA, USA

10/2021 – 03/2023 **Postdoctoral Researcher**  
Institute for Nuclear Research (ATOMKI), Debrecen, Hungary

09/2020 – 10/2021 **Postdoctoral Researcher**  
Physical Research Laboratory (PRL), Ahmedabad, India

## Education

07/2015 – 12/2021 **PhD (Experimental Astrochemistry)**  
(submitted – 08/2020) Physical Research Laboratory (PRL), Ahmedabad, India *affiliated with* Mohanlal Sukhadia University (MLSU), Udaipur, Rajasthan, India

07/2013 – 07/2015 **Master of Science (Physics, University 1<sup>st</sup> Rank)**  
University of Allahabad, Prayagraj, India

07/2010 – 07/2013 **Batchelor of Science (Physics, Chemistry & Mathematics)**  
University of Allahabad, Prayagraj, India

## Recognition and awards

- **Department of Science and Technology (DST), India – Deutsche Forschungsgemeinschaft (DFG), Germany** award to attend **69<sup>th</sup> Lindau Nobel Laureates Meeting (Physics)**, (June 30<sup>th</sup>, 2019 – July 5<sup>th</sup>, 2019), Lindau, Germany and **visit various premier research institutes in Germany** from July 6<sup>th</sup>, 2019 – July 12<sup>th</sup>, 2019.
- Junior/Senior Research Fellowship 2015 – 2020, Department of Space, India.
- Junior Research Fellowship 2016, University Grant Commission, India.
- **Interview on my research journey featured in the 111<sup>th</sup> issue of the AstroPAH Newsletter**, Leiden University, Netherlands, September 2024.

## Current Research Projects

**Jet Propulsion Laboratory, California Institute of Technology, Pasadena, USA**

- Involved in design, development and installation of an FT-InfraRed spectroscopy setup, a part of **Planetary Cloud/Aerosol Research Facility (PCARF)** at JPL.
- Performed calorimetry experiments on cometary ice analogs to understand the exothermicity of water ice and comet outgassing at Ice Spectroscopy Lab, JPL, Pasadena.
- Conducted experiments on high energy (MeV) electron irradiation of microbes, both with and without ices, **to understand the survivability of microbes under radiation environments of icy bodies at Medical Industrial Radiation Facility, National Institute of Standard and Technology (NIST)**, Gaithersburg, MD, USA.

## Previous Research Projects/Experience

### ATOMKI, Debrecen, Hungary

- Played a key role in design, development, and installation of **AQUILA - a low temperature set-up for astrochemistry experiments at the Electron Cyclotron Resonance Ion Source (ECRIS) at ATOMKI, Debrecen, established as part of the EUROPLANET 2024 Research Infrastructure** facility.
- Test and installation of evaporator with the astrochemistry set up depositing molecules with low vapour pressure such as PAHs, sulphur powder etc.
- Performed experiments on high energy (keV - MeV) ion irradiation and thermal processing of molecular ices relevant to astrobiological/astrochemical interest and probing using infrared spectroscopy and mass spectrometry at Ice Chamber for Astrophysics & Astrochemistry (ICA) at Tandatron ion facility, ATOMKI, Debrecen.
- A systematic study of electron irradiation of Titan's ice analogues (*in progress*).

### Physical Research laboratory, Ahmedabad, India

- **Developed a Low-Temperature Astrochemistry set-up at Physical Research Laboratory (PRL), Ahmedabad, India**, to synthesize molecular ices under astrochemical conditions and probe them using infrared (IR) spectroscopy.
- Designed and conducted a series of experiments using the IR setup (*at PRL, Ahmedabad*) on astrochemical ices to understand their morphology and chemical evolution.
- **Vacuum Ultraviolet Spectroscopy of astrochemical ices (pure ice and energetic photon irradiated ice matrix) at National Synchrotron Radiation Research Center (NSRRC), Taiwan.**
- Photo-irradiation and thermal processing of pure/mixed/layered astrochemical ices to study synthesis of new molecules, change of ice morphology, and the formation of residue.
- Imaging and elemental analysis of residue from irradiated ice for its physical structure using HR-TEM and FE-SEM.
- Commissioning of a set-up for Quadrupole Mass Spectrometry (1 - 5000 Da) (*at PRL, Ahmedabad, India*) to analyse the processing of molecules/ices via intense shock, electron irradiation, or from other energetic sources.

### University of Allahabad, Allahabad, India

- Polarization of electric field vector due to the applied magnetic field
- Theoretical and experimental analysis of Second-harmonic generation (SHG) in an asymmetric crystal (Lithium niobate)
- Experimental use of an Nd-Yag laser and its application to produce SHG

## Programming Language

- MATLAB and PYTHON
- LabVIEW
- Data plotting and analysis in Origin

## Other Interests

1. Educating and motivating young students in villages and remote area through a Science Fair
2. Volunteer for National Science Days and Open House in our research institute to motivate younger students towards science.
3. Reaching out to schools in the villages and remote areas to popularise science (Science Express) with models and hands-on experiments

## Conferences & Workshops

1. Earth and Planetary Clouds Workshop (EPCW) 2024, California Institute of Technology, Pasadena, USA.
2. UV Science and Instrumentation Workshop 2024, NASA-Jet Propulsion Laboratory, Pasadena, USA.
3. (Poster) Jet Propulsion Laboratory Research Poster Day 2023, NASA-Jet Propulsion Laboratory, USA.
4. (Talk) Europlanet Science Congress (EPSC), 2022, Granada, Spain.
5. (Talk) Chemistry and Physics at Low Temperature (CPLT), 2022, Visegrád, Hungary.
6. (Talk) Europlanet Science Congress (EPSC), 2021, Virtual Meeting.
7. (Talk) Europlanet Science Congress (EPSC), 2020, Virtual Meeting.
8. (Poster) Spectroscopy and Dynamics of Molecules and Clusters (SDMC), 2020, Rajasthan, India.
9. (Poster) Indian Planetary Science Conference (IPSC), 2020, PRL, Ahmedabad
10. International Conference on Infrared Astronomy and Astrophysical Dust (IRAAD), 2019, IUCAA, Pune.
11. (Poster) National Conference on Atomic and Molecular Physics 2019, IIT – Kanpur, India
12. (Talk) Young Physicists Meet (YPM) 2019, PRL, Ahmedabad, India
13. (Poster) National Symposium on Space Science 2019, Pune University, IUCAA, NCRA, Pune, India
14. (Poster) International Workshop on Atomic and Molecular Collision 2018, Udaipur, India
15. (Poster) Asian International Symposium on Atomic and Molecular Physics (AISAMP) 2018, TIFR & IIT- B, Mumbai, India
16. (Talk) Exploring the Universe: Near-Earth Space Science to Extra-Galactic Astronomy (EXPUNIV) 2018, SBNCBS, Kolkata, India
17. (Talk) **National Conferences on Advances in Spectroscopy: Molecules to Materials (NCASMM) 2018 (*Best oral presentation award*), IITRAM, Ahmedabad India**
18. **Young Astronomers' Meet 2018 (Organizer and a Session Chair) PRL, Ahmedabad, India**
19. (Talk) Young Astronomers' Meet 2017 (Participant) IUCAA-Pune, India
20. Optical astronomy using large telescopes (School – 2017), IUCAA-Pune, India
21. ASTROSAT Users' Proposal Workshop 2016, IUCAA-Pune, India

## Publications

1. Cryogenic Differential Calorimetry: Exothermicity of Amorphous-to-Crystalline Phase Transitions (ACPT) in Astrophysical and Cometary Ice Analogs, **K K Rahul**, Murthy S. Gudipati, Bryana L. Henderson (*Under review The Astrophysical Journal, 2024*)
2. Survival of Spacecraft Microbial Spores under Europa-like MeV Electron Radiation Environment, Jared Brodrick, Bryana L. Henderson, Murthy S. Gudipati, **K K Rahul**, Fred B. Bateman (*Under preparation*)
3. Radiolytic Cyanide and Cyanate Formation in Astrophysical Ice Analogues, **K K Rahul**, P. Herczku, D. V. Mifsud, S. T. S. Kovács, B. Sulik, R. Rácz, G. Lakatos, P. A. Hailey, Z. Kaňuchová, S. Biri, S. Ioppolo, N. J. Mason and Z. Juhász (*Under preparation*)
4. An Arctic Analogue for the Future Exploration of Possible Biosignatures on Enceladus F. Franchi, M. Túri, G. Lakatos, **K K Rahul**, D.V. Mifsud, G. Panieri, R. Rácz, S.T.S. Kovács, E. Furu, R. Huszánk, R.W. McCullough, (*Accepted in Planetary and Space Science, 2025*)
5. AQUILA: A Laboratory Facility for the Irradiation of Astrochemical Ice Analogues by keV Ions, R. Rácz, S.T.S. Kovács, G. Lakatos, **K. K. Rahul**, D.V. Mifsud, P. Herczku, B. Sulik, Z. Juhász, Z. Perduk, S. Ioppolo, N.J. Mason, T.A. Field, S. Biri, and R.W. McCullough, *Review of Scientific Instruments*, **95**, 095105, 2024.
6. Residue from vacuum ultraviolet irradiation of benzene ices: Insights into the physical structure of astrophysical dust. **K K Rahul**, E Shivakarhik, J K Meka, A Das, V Chandrasekaran, B N Rajasekhar, J -I Lo, B -M Cheng, P Janardhan, A Bhardwaj, N J Mason, B Sivaraman, *Spectrochimica Acta Part A: Molecular and Biomolecular Spectroscopy*, **231**, 117797, 2020a.  
(*Appeared on the cover page of 65<sup>th</sup> issue of the AstroPAHs Newsletter, Leiden University, Netherlands*).
7. Infrared attenuation due to phase changes from amorphous to crystalline observed in astrochemical propargyl ether ices, **K K Rahul**, J K Meka, S Pavithraa, P Gorai, A Das, J -I Lo, B N Rajasekhar, B -M Cheng, P Janardhan, A Bhardwaj, B Sivaraman, *Spectrochimica Acta Part A: Molecular and Biomolecular Spectroscopy*, **224**, 117393, 2020b.
8. Ultraviolet spectrum reveals the presence of ozone on Jupiter's moon Callisto, R Ramachandran, J K Meka, **K K Rahul**, W Khan, J-I Lo, B-M Cheng, DV Mifsud, BN Rajasekhar, A Das, H Hill, P Janardhan, Anil Bhardwaj, NJ Mason, B Sivaraman, *Icarus*, **410**, 115896, 2024
9. N-graphene synthesized in astrochemical ices, B Sivaraman, **K K Rahul**, M Ambresh, D Sahu, JK Meka, S-L Chou, Y-J Wu, Divita Gupta, A Das, J-I Lo, B-M Cheng, BN Rajasekhar, Anil Bhardwaj, H Hill, P Janardhan, NJ Mason, *The European Physical Journal D*, **77**, 2, 2023
10. A systematic IR and VUV spectroscopic investigation of ion, electron, and thermally processed ethanolamine ice, Jin Zhang, Alejandra Traspas Muiña, Duncan V Mifsud, Zuzana Kaňuchová, Klaudia Cielinska, Péter Herczku, **K K Rahul**, Sándor T S Kovács, Richárd Rácz, Julia C Santos, Alfred T Hopkinson, Luca Craciunescu, Nykola C Jones, Søren V Hoffmann, Sándor Biri, István Vajda, István Rajta, Anita Dawes, Bhalamurugan Sivaraman,

- Zoltán Juhász, Béla Sulik, Harold Linnartz, Liv Hornekær, Felipe Fantuzzi, Nigel J Mason, Sergio Ioppolo, *Monthly Notices of the Royal Astronomical Society*, stae1860, 2024.
11. A systematic mid-infrared spectroscopic study of thermally processed H<sub>2</sub>S ices, Duncan V. Mifsud, Péter Herczku, Ragav Ramachandran, Pavithraa Sundararajan, **K.K. Rahul**, Sándor T.S. Kovács, Béla Sulik, Zoltán Juhász, Richárd Rácz, Sándor Biri, Zuzana Kaňuchová, Sergio Ioppolo, Bhalamurugan Sivaraman, Robert W. McCullough, Nigel J. Mason, *Spectrochimica Acta Part A: Molecular and Biomolecular Spectroscopy*, **319**, 124567, 2024.
  12. Sulphur ion implantation into O<sub>2</sub>, CO, and CO<sub>2</sub> ices: Implications for the formation of sulphur-bearing molecules in the Kuiper Belt, Duncan V. Mifsud, Zuzana Kaňuchová, Péter Herczku, Zoltán Juhász, Sándor T.S. Kovács, Gergő Lakatos, **K.K. Rahul**, Richárd Rácz, Béla Sulik, Sándor Biri, István Rajta, István Vajda, Sergio Ioppolo, Robert W. McCullough, Nigel J. Mason, *Icarus*, 115926, 2024.
  13. Bombardment of CO Ice by Cosmic Rays. I. Experimental Insights into the Microphysics of Molecule Destruction and Sputtering, Alexei V. Ivlev, Barbara M. Giuliano, Zoltán Juhász, Péter Herczku, Béla Sulik, Duncan V. Mifsud, Sándor T. S. Kovács, **K. K. Rahul**, Richárd Rácz, Sándor Biri, István Rajta, István Vajda, Nigel J. Mason, Sergio Ioppolo, and Paola Caselli, *The Astrophysical Journal*, **944**, 181, 2023.
  14. A systematic mid-infrared spectroscopic study of thermally processed SO<sub>2</sub> ices, Duncan V. Mifsud, Péter Herczku, **K. K. Rahul**, Ragav Ramachandran, Pavithraa Sundararajan, Sándor T. S. Kovács, Béla Sulik, Zoltán Juhász, Richárd Rácz, Sándor Biri, Zuzana Kaňuchová, Robert W. McCullough, Bhalamurugan Sivaraman, Sergio Ioppolo, Nigel J. Mason, *Phys. Chem. Chem. Phys.*, **25**, 26278, 2023.
  15. Sulfur Ion Implantations into Condensed CO<sub>2</sub>: Implications for Europa, D. V. Mifsud, Z. Kaňuchová, P. Herczku, Z. Juhász, S. T. S. Kovács, G. Lakatos, K. K. Rahul, R. Rácz, B. Sulik, S. Biri, I. Rajta, I. Vajda, S. Ioppolo, R. W. McCullough, N. J. Mason, *Geophysical Research Letters*, **49**, e2022GL100698, 2022.
  16. Energetic electron irradiations of amorphous and crystalline sulphur-bearing astrochemical ices, Duncan V. Mifsud, Péter Herczku, Richárd Rácz, **K. K. Rahul**, Sándor T. S. Kovács, Zoltán Juhász, Béla Sulik, Sándor Biri, Robert W. McCullough, Zuzana Kaňuchová, Sergio Ioppolo, Perry A. Hailey and Nigel J. Mason, *Frontiers in Chemistry*, 10:1003163, 2022.
  17. Ozone production in electron irradiated CO<sub>2</sub>:O<sub>2</sub> ices. D V Mifsud, Z Kaňuchová, S Ioppolo, P Herczku, A Traspas Muiña, B Sulik, **K K Rahul**, P A Hailey, N J Mason, Z Juhász, *Physical Chemistry Chemical Physics*, **22**, 24, 2022.
  18. Vacuum ultraviolet photo-absorption spectra of an in-situ synthesized peptide precursor: hydroxylamine on a cold astrochemical dust analogue. R Thombre, D Gupta, S Pavithraa, J -I Lo, S -L Chou, Y -J Wu, **K K Rahul**, B -M Cheng, H Hill, A Bhardwaj, B N Raja Sekhar, N J Mason, B Sivaraman, *The European Journal D*, **76**, 2022.
  19. Vacuum ultraviolet photoabsorption spectra of icy isoprene and its oligomers. R Ramachandran, S Pavithraa, J K Meka, **K K Rahul**, J -I Lo, S -L Chou, B -M Cheng, B N Rajasekhar, A Bhardwaj, N J Mason, B Sivaraman, *Spectrochimica Acta Part A: Molecular and Biomolecular Spectroscopy*, **268**, 120586, 2022.

20. Phenol in High-mass Star-forming Regions. R Ghosh, M, S K Mondal, P Gorai, D Sahu, **R K Kushwaha**, B Sivaraman and A Das, *Research in Astronomy and Astrophysics*, **22**, 065021, 2022
21. Mid-IR and VUV spectroscopic characterisation of thermally processed and electron irradiated CO<sub>2</sub> astrophysical ice analogues. D V Mifsud, Z Kaňuchová, S Ioppolo, P Herczku, A Traspas Muiña, T A Field, P A Hailey, Z Juhász, S T S Kovács, N J Mason, R W McCullough, S Pavithraa, **K K Rahul**, B Paripás, B Sulik, S -L, Chou, J -I Lo, A Das, B -M Cheng, B N Rajasekhar, A Bhardwaj, B Sivaraman, *Journal of Molecular Spectroscopy*, **385**, 111599, 2022
22. Sticking of dust/ micrometeorite particles on to ices at high impact velocities - Implications for astrochemical ice enrichment. E Shivakarhik, J K Meka, Harish, V S Surendra, **K K Rahul**, R Thombre, H Hill, S Vijayan, B Sivaramana, *Planetary and Space Science*, **104972**, 2020.
23. Vacuum Ultraviolet Photoabsorption of Prime Ice Analogues of Pluto and Charon. S Pavithraa, J -I Lo, **K Rahul**, B -M Cheng, N J Mason, B Sivaraman, *Spectrochimica Acta Part A: Molecular and Biomolecular Spectroscopy*, **190**, 2018.

#### Presented at Europlanet Science Congress (EPSC)

1. Astrochemistry Experimental Setup at Atomki-ECRIS: A Europlanet Facility, **Kushwaha, R. K.**, Rác, R., Kovács, S. T. S., Herczku, P., Sulik, B., Juhász, Z., Biri, S., Mifsud, D. V., Ioppolo, S., Kanuchová, Z., Field, T. A., Hailey, P., McCullough, R., and Mason, N. J., EPSC 2022, Granada, Spain, 18–23 Sep 2022, *EPSC2022-1019*, 2022.
2. Graphene in Titan. **Kushwaha, R. K.**, A Mallya, D Sahu, J K Meka, S -L Chou, Y -J Wu, D Gupta, A Das, J -I Lo, B -M Cheng, B N Rajasekhar, A Bhardwaj, H Hill, J Padmanabhan, N J Mason, B Sivaraman. *EPSC2021-480*, 2021.
3. Biomarker on Callisto **Kushwaha, R. K.**, J-I Lo, B M Cheng, B N Rajasekhar, N J Mason, B Sivaraman. *EPSC2020-1005*, 2020.