matter. None of the quarks or leptons can form dark matter. A new particle is required. Frameworks like supersymmetry or extra dimensions do contain additional fundamental particles, one of which could form dark matter. Neutrino masses can also be accommodated through various schemes in these frameworks. However, it turns out that most of the schemes which generate neutrino masses and their mixing will also introduce flavour-violating transitions in the charged leptonic sector, which puts severe constraints on these frameworks.

Computing accurate supersymmetric mass spectra in various models of supersymmetry breaking is the need of the hour, especially in the light of LHC data. Computation of the supersymmetric mass spectrum at high precision is a difficult task which involves several coupled nonlinear differential equations, matrix diagonalizations, loop functions, stability analysis, minimization and iterative techniques, etc. This is typically done by huge computer programs called spectrum generators. The presently available spectrum generators, however, are not suitable to handle flavour violation or non-zero neutrino masses through see-saw mechanisms. However, it is important to have such a code to deal with the current data either from LHC or from flavour physics or dark matter. For example, a small amount of flavour violation present in the squark sector can completely remove the 'strong' constraints on many supersymmetric models from branching ratio of ($b \rightarrow s^+$ photon). And, more importantly, realistic models of supersymmetry breaking do predict some flavour violation in the soft terms. To fill this gap, Vempathi and his group embarked upon constructing a spectrum generator with full flavour violation as well as including see-saw mechanism. Such a code is not a straightforward extension of the existing codes, as to put it in a loose manner, every coupling has to be replaced by a matrix and this complicates the code several folds. In this case, the code was developed using an original smaller code (1-loop RGE with flavour violation). The new code (written along with D. Chowdhury and R. Garani) (full two loops, one-loop thresholds, etc.) took about two years to complete and the first version was out in September 2011. The upgraded version 2 of the code was also accepted for publication. This is perhaps the first such publicly available code from India, which could be useful to both theoreticians as well as experimentalists worldwide. The code was useful in studying the implications of the Higgs and supersymmetric data from LHC on various supersymmetric models.

One of the popular extra-dimensional models is the so-called Randall–Sundrum (RS) models. The RS models are considered to be models of flavour. However, most RS models where the fermions are localized in the bulk do violate the current flavour-violating constraints. This is especially true in the leptonic sector where accommodation for non-zero neutrino masses invariably seems to be leading to large lepton flavour violation.

Furthermore, several contradictory statements exist in the literature regarding the fitting of neutrino masses. Together with Abhishek Iyer, Vempati and his group embarked on a detailed analysis which fitted the neutrinos as well as satisfied the flavour-violating constraints. Three possible models for neutrino mass generation were considered: higher dimensional operators, Dirac masses and Majorana masses. The O(1) Yukawa parameters were also varied in deriving the fits. The group found that higher-dimensional operators would require large negative bulk parameters, indicating that they are largely composite fermions if interpreted in terms of AdS/CFT correspondence. Dirac and Majorana cases give reasonably nice fits within 'acceptable' range for the bulk parameters. However, flavour-violating constraints in these cases are very strong ruling out most of the parameter space. Vempati and his group showed that if minimal flavour violation paradigm is assumed on the Yukawa couplings, flavour-violating constraints can be evaded in both these cases. Another important work in this direction has been 'hiding' the violation of the lepton number in the bulk, with neutrinos getting Dirac-type masses.

Infosys prize in physical sciences

Anil Bhardwaj, a distinguished planetary scientist who has made outstanding contributions through extensive studies of planetary systems/atmospheres, has been awarded the prestigious Infosys prize 2016 for his fundamental contributions, many of which are considered as 'benchmarks' in the field.

Bhardwaj was born in 1967 at Mursan, Aligarh district, Uttar Pradesh, India. He obtained his B Sc and M Sc degrees from Lucknow University in 1985 and 1987, and his Ph D degree from at the Institute of Technology, Banaras Hindu University, Varanasi, in 1992 working on airglow and auroral processes in the planetary atmospheres, mainly emphasizing on the outer planets and also comets.

After a brief stint as a Research Associate, Bhardwaj started his independent research career in 1993 at the Space Physics Laboratory, the autonomous research wing of ISRO's Vikram Sarabhai Space Centre (VSSC), Thiruvananthapuram.

In the initial years he concentrated on the development of coupled chemistry-transport models for cometary coma, with specific emphasis on the role of the so called 'auroral electrons' – a terminology introduced by him for comets 'for the first time' – in the inner coma of comets like Halley and Ikeya-Zhang.

Many of Bhardwaj's model predictions have turned out to be as anticipated and his model results have been treated as 'benchmark' values by ESA and NASA for their ROSETTA and Deep-Impact missions.

Bhardwaj gradually expanded the horizon of his activities to include multi-spectral (covering the whole range of the electromagnetic spectrum from X-rays to radio waves) observations of outer planets from space. Through these unique efforts, he accomplished several landmark discoveries like X-rays from the rings of Saturn (which were explained to be due to oxygen K-alpha emissions from water-ice in the rings), X-ray emissions from Jupiter's low latitude region and also from its satellites Io and Europa, and explained how the gas giants acted as diffuse mirrors for solar X-ray flares. His new observations of pulsating X-rays from Jupiter highlighted the complexities in the solar wind–magnetosphere–ionosphere interactions.

Bhardwaj's unique proposal to make the Chandra X-ray observatory satellite look at the Earth's polar regions, yielded 'unique' results on the soft X-rays from the Earth's auroral regions and more recently from Pluto. He also conducted the 'first ever' simultaneous observations of the UV and X-radiations of Jupiter by the Hubble Space Telescope and the Chandra X-ray observatory, revealing their close spatial and temporal association. Further, he conducted unique experiments using India's largest radio telescope to monitor the synchrotron radio emission from Jupiter and infer the dynamic nature of the Jovian inner radiation belts.

Not restricting himself to outer planets, Bhardwaj also studied the inner planets where-in he showed similarities between the X-ray emissions from Mars and those encountered from comets. Interestingly, many of his model forecasts were confirmed, e.g. bremstraulung auroral X-rays (>2 keV) detected by both Chandra X-ray observatory and the XMM Newton. Bhardwaj along with his students has carried out extensive model calculations pertaining to the dayglow emission processes from the inner planets and also from comets like Hale–Bopp and Hyakutake.

Motivated by the exciting discoveries and realizing the potential of data from the already operational space missions, Bhardwaj started dreaming about his own planned experimental studies. To begin with, he formulated proposals for the announced opportunities in the International Space Station and also for India's own planned space missions. Undeterred by the proposals (in spite of being unique in many ways) not getting fructified, he waited for an appropriate opportunity which came knocking at his door in the form of Chandryaan-1, India's first mission to moon. He came up with a unique INDO-SWEDISH proposal to monitor the flux of energetic neutral atoms (ENAs) in the lunar ambience with an aim to study the solar wind–moon interactions from a totally different angle. The available expertise, both in-house and with the collaborators, was optimally used in realizing the SARA experiment, which had two parts – the ENA detector and the solar wind monitor (SWIM). SARA, for which Bhardwaj was the Indian Principal Investigator (PI), paved the way for several new discoveries. The first ever ENA imaging of an atmosphere-less planetary body was obtained, in addition to the surface magnetic anomalies, including the first direct detection of the so called 'mini magnetospheres'. Many of the results like (i) the unusually large flux of neutral atoms in the night side, an outcome of complex interactive processes between the solar wind and the neutral atoms, (ii) significant amount of ENAs from the sunlit side that redefined the lunar albedo, and (iii) characterizing the proton velocity distribution in the lunar wake are considered path-breaking. The new discoveries and the overall scientific contribution from SARA stand out in the overall success of Chandrayaan-1. Bhardwaj had also been actively involved in understanding the lunar exospheric composition based on data from yet another successful experiment, viz. the CHACE (Chandra's Altitudinal Composition Explorer) from SPL His group brought out the first ever altitudinal/latitudinal distribution of several species like hydrogen, neon and also drew the upper limit of helium concentrations. The presence of several heavier species, in localized regions, was also inferred from this experiment.

Bhardwaj is the PI for the yet another successful experiment MENCA (Martians Exospheric Neutral Composition Analyser) on the Mars orbiter mission, Indian first venture to the red planet. While bringing out the altitudinal profiles of the neutral species he highlighted the dominance of carbon dioxide and atomic oxygen in the Martian exosphere. He is the PI for the CHACE-II experiment in the upcoming Chandrayaan-II mission, which will comprise of an orbiter and a rover. He is deeply involved in the ADITYA-1 mission being readied to be positioned at the first Lagrangian point, another major and first attempt by India.

Many of Bhardwaj's findings have figured in the press releases of ESA, NASA and ISRO under 'breaking news' category. He was the Editor-in-chief of Advances in Geophysics, elected as President of the Planetary Science Section; was an editorial board member of Planetary and Space Science, and member of the Science Panel of NASA for future X-ray Observatory Constellation as well as several national bodies like ADCOS (Advisory Committee for Space Research). He is also one of the recipients of the US National Academy of Sciences. He has a large number of scientific publications (125), and has written several review/invited articles and chapters in some of the most acclaimed journals and books.

Bhardwaj has been awarded the Shanti Swarup Bhatnagar Prize (2007) in the discipline of 'Earth Atmospheres, Ocean and Planetary Sciences', ISRO award for meritorious services and is also elected Fellow of all the three national academies. He is currently the Director of the Space Physics Laboratory, VSSC.

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