

Curriculum Vitae of **DR. ANIL BHARDWAJ**

Space Physics Laboratory, Vikram Sarabhai Space Centre, Trivandrum 695022, Kerala, India
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EDUCATION:

M.Sc. in Physics, Lucknow University, 1987
Under Graduate Diploma in German language, Banaras Hindu University, Varanasi, 1989
Ph.D. in Physics (Space Physics), Institute of Technology, Banaras Hindu University, Varanasi, 1992

EMPLOYMENT:

1993–1997: Scientist-SD, Space Physics Laboratory, Vikram Sarabhai Space Centre, Trivandrum
1998–2002: Scientist-SE, Space Physics Laboratory, Vikram Sarabhai Space Centre, Trivandrum
2002–present: Scientist-SF, Space Physics Laboratory, Vikram Sarabhai Space Centre, Trivandrum
January 2004– October 2005 : National Research Council (NRC)-National Academy of Sciences (NAS)
Senior Research Associate at NASA Marshall Space Flight Center, Huntsville, AL, USA

RESEARCH INTERESTS:

Primary Research Area:

Theoretical and Observational Studies of Planetary Atmospheres
Ionospheres and Magnetospheres

Current research interests are:

Aurora and airglow processes in planetary atmospheres, chemistry of planetary and cometary atmospheres and ionospheres, charged particle acceleration and precipitation in gases, Monte Carlo simulations of processes in the atmospheres, interaction of energetic neutral atoms (ENAs) with atmospheres, ENA imaging of the magnetosphere-ionosphere system, space weather studies, ground-based and space-based multi-spectral studies of planetary bodies, multi-wavelength imaging and spectroscopy of planetary emissions, and comparative planetology.

The planetary bodies on which I have worked include, Jupiter, Saturn, Uranus, Neptune, Io, Europa, Ganymede, Triton, Titan, Mars, Earth, and Comets (particularly, comets 1P/Halley and 46P/Wirtanen).

RESEARCH SUPERVISION:

Ph.D.'s 1, Marykutty Michael in 2001, dissertation title “Model for electron degradation and production of emission in the atmosphere of Io”.

M.Tech Thesis - 2, K. Rajmohan in 1995, thesis title "Electron Excitation of Triton's Atmosphere"; K.B.Smart in 2003, thesis title "Sputtering of Europa by the Jovian Magnetospheric Plasma"; Cochin University of Science and Technology.

RESEARCH PROGRAMS and PROJECTS:

Experiments:

Indian PI of SARA experiment on the First Indian Lunar Mission Chandrayaan-1
Associate-I on soft x-ray telescope of ASTROSAT

Observation Programs:

PI on GMRT Jupiter observation program – 2003
Co-I on Chandra X-ray observation program for Jupiter, Saturn, Earth – 2000- 2005
Co-I on Joint Chandra-HST Jupiter observation program – 2002
Co-I on XMM Saturn observation program – 2005

Co-I on joint Chandra-XMM-Newton observation of Jupiter during New Horizon flyby (Feb. 2007)

TEACHING:

Developed curriculum and delivered introductory lectures to graduate students (research fellows) of SPL on topics: – The Sun, solar wind, and solar radiation; Planetary system: planets, satellites, comets, their atmospheres, ionospheres, and magnetospheres.

Lectures on "Atmospheres of Planets and Satellites" to post-graduate students of the *United Nations-CSSTEAP Post Graduate Course* in Space Physics and Atmospheric Sciences

Invited lectures on "Planetary Physics", to teachers from Universities and colleges as a part of *UGC-Refresher course in Physics*

Lectures on "Space Sciences and Planetary Sciences", to School Teachers and students in various Workshop and schools

EDITOR/Referee Responsibilities:

Editor-in-Chief, *Advances in Geosciences*, Volume 3- Planetary Science, World Scientific Publication, Singapore, 2006.

Guest Editor, *Planetary and Space Sciences*, Special Issue on AOGS 2005 "HIGHLIGHTS IN PLANETARY SCIENCE", 2006

Editor-in-Chief, *Advances in Geosciences*, Planetary Science Volume 9, World Scientific Publication, Singapore, 2007

Referee, several International (e.g., JGR, GRL, Icarus, ApJ, Planetary & Space Sci.) and National Journals

MEMBERSHIPS:

- 1) American Geophysical Union
- 3) Astronomical Society of India

- 2) Kerala Academy of Sciences
- 4) Indian Space Scientist Association

PROFESSIONAL ACTIVITIES AND RESPONSIBILITIES:

Recognized Research Guide, Mahatma Gandhi University and Kerala University

Member, SGTG WG "Space Sciences and Interplanetary Missions" of ISRO - Vision 2000-2025

Member PLANEX "National Research Program on Planetary Sciences and Planetary Exploration in India", a National Program of ISRO

President, Planetary Sciences, Asia Oceanic Geosciences Society (2006-2008)

Member, ADCOS Science Panel –3 for Vision document on Planetary Exploration Programme of ISRO

Member, Indian CAWSES Program

Member, Academic Committee of Space Physics Laboratory (SPL)

DISTINCT ACHIEVEMENTS:

Best paper award for the article "Non-Stationary Plasma Processes on Comets and its Implications", presented at the PLASMA-95 Symposium held at Banaras Hindu University, October 1995

GRL 2005 paper by Bhardwaj et al. "Solar Control on Jupiter's Equatorial X-ray Emissions: 26-29 November 2003 XMM-Newton Observation", selected as "AGU Journal Highlight"

ESA did a Press Release on March 7, 2005, titled "Jupiter: A Cloudy Mirror for the Sun?" on the GRL paper "Solar Control on Jupiter's Equatorial X-ray Emissions: 26-29 November 2003 XMM-Newton Observation"

NASA did a Press Release on May 25, 2005, titled "**NASA's Chandra Finds Saturn Reflects X-Rays from Sun**" on the ApJL paper "Chandra Observation of an X-ray Flare at Saturn: Evidence for Direct Solar Control on Saturn's Disk X-ray Emissions"

NASA did the press release on June 27, 2005, titled “**Saturn's Rings Sparkle with X-rays**” on the ApJL paper “The Discovery of Oxygen K α X-ray Emission from the Rings of Saturn”

NASA did a press release on December 28, 2005, titled “**Chandra Looks Back At The Earth**” on the JASTP paper “First Terrestrial Soft X-ray Auroral Observation by The Chandra X-ray Observatory”

INVITED TALKS:

More than 40 invited talks at several Institutes in India and abroad

CONFERENCE PARTICIPATION:

Presented over 50 research papers at conferences in India and abroad

CONFERENCES/SYMPOSIA ORGANIZATION:

Convener or Co-convener of several sessions at National and International meetings

Organizer of Workshops and conferences

PUBLICATIONS:

1. **A. Bhardwaj**, S.A. Haider, and R.P. Singhal
Auroral and Photoelectron Fluxes in Cometary Ionospheres.
Icarus, 85, 216-228 (1990).
2. **A. Bhardwaj** and R.P. Singhal
Auroral and Dayglow Processes on Neptune.
Indian Journal of Radio and Space Physics, 19, 171-176 (1990).
3. R.P. Singhal and **A. Bhardwaj**
Monte Carlo Simulation of Photoelectron Energization in Parallel Electric Fields: Electroglow on Uranus.
Journal of Geophysical Research, 96, 15963-15972 (1991).
4. R.P. Singhal, S.C. Chakravarty, **A. Bhardwaj**, and B. Prasad
Energetic Electron Precipitation in Jupiter's Upper Atmosphere.
Journal of Geophysical Research, 97, 18245-18256 (1992).
5. S.A. Haider, **A. Bhardwaj**, and R.P. Singhal
Role of Auroral and Photoelectrons on the Abundances of Methane and Ammonia in the Coma of Comet Halley.
Icarus, 101, 234-243 (1993).
6. **A. Bhardwaj** and R.P. Singhal
Optically Thin H Lyman Alpha Production on Outer Planets: Low-Energy Proton Acceleration in Parallel Electric Fields and Neutral H Atom Precipitation from Ring Current.
Journal of Geophysical Research, 98, 9473-9481 (1993).
7. **A. Bhardwaj**, S. A. Haider, and R. P. Singhal
Consequences of Cometary Aurora on the Carbon Chemistry at Comet P/Halley.
Advances in Space Research, 16(2), 31-36 (1995).

8. **A. Bhardwaj**
Non-Stationary Plasma Process on Comets and its Implications.
In *Recent Advances in Plasma Science and Technology*, Eds. R.P. Singh, et al., Allied Publishers Ltd., New Delhi, pp131-134 (1996).
9. **A. Bhardwaj**, S. A. Haider, and R. P. Singhal
Production and Emissions of Atomic Carbon and Oxygen in the Inner Coma of Comet Halley: Role of Electron Impact.
Icarus, 120, 412-430 (1996).
10. **A. Bhardwaj** and M. Michael
Photoelectron Excitation of Io's Atmosphere.
Advances in Space Research, 20(2), 301-304 (1997).
11. S.A. Haider and **A. Bhardwaj**
Chemistry of the Ions ≤ 40 AMU in the Inner Coma of Comet Halley.
Advances in Space Research, 20(2), 291-294 (1997).
12. M. Michael and **A. Bhardwaj**
On the Dissociative ionization of SO₂ in the Io's Atmosphere.
Geophysical Research Letters, 24, 1971-1974 (1997).
13. **A. Bhardwaj**
Ring current H Atom Precipitation on the Outer Planets.
Advances in Space Research, 20(2), 233-237 (1997).
14. **A. Bhardwaj**
On the Role of Solar EUV, Photoelectrons, and Auroral Electrons in the Chemistry of C(¹D) and the Production of CI 1931 Å in the Inner Cometary Coma: A Case for Comet P/Halley.
Journal of Geophysical Research, 104, 1929-1942 (1999).
15. **A. Bhardwaj** and M. Michael
On the Excitation of Io's Atmosphere by the Photoelectrons: Application of the Analytical Yield Spectrum of SO₂.
Geophysical Research Letters, 26, 393-396 (1999).
16. **A. Bhardwaj** and S.A. Haider
Modeling of Metastable Carbon Atoms in Comets: Implications for ROSETTA.
Advances in Space Research, 23(7), 1325-1328 (1999).
17. **A. Bhardwaj** and M. Michael
Monte Carlo Model for Electron Degradation in SO₂ Gas: Cross Sections, Yield Spectra and Efficiencies.
Journal of Geophysical Research, 104, 24713-24728 (1999).
18. **A. Bhardwaj** and G.R. Gladstone
Auroras on Saturn, Uranus, and Neptune.
Advances in Space Research, 26(10), 1551-1558 (2000).
19. M. Michael and **A. Bhardwaj**
Precipitation of Energetic Electrons in the Atmosphere of Io: Production of UV Emissions.
Advances in Space Research, 26(10), 1519-1524 (2000).
20.

A. Bhardwaj and G.R. Gladstone
Auroral Emissions of the Giant Planets.
Reviews of Geophysics, 38, 295-353 (2000).
20.

This article made the cover page of *Reviews of Geophysics*, vol.38, No.3, August 2000.

21. M. Michael and **A. Bhardwaj**
FUV Emissions on Io: Role of Galileo-Observed Field-Aligned Energetic Electrons.
Geophysical Research Letters, 27, 3137-3140 (2000).
22. **A. Bhardwaj**, G.R. Gladstone, and P. Zarka
An Overview of Io Flux Tube Footprints in Jupiter's Auroral Ionosphere.
Advances in Space Research, 27, No.11, 1915-1922 (2001).
23. G.R. Gladstone, J.H. Waite, Jr., D. Grodent, W.S. Lewis, F.J. Crary, R.F. Elsner, M.C. Weisskopf, T. Majeed, J.-M. Jahn, **A. Bhardwaj**, J.T. Clarke, D.T. Young, M.K. Dougherty, S.A. Espinosa, T.E. Cravens
A Pulsating Auroral X-Ray Hot Spot on Jupiter.
Nature, 415, 1000-1003 (2002).
24. **A. Bhardwaj** and S.A. Haider
Chemistry of O(¹D) Atoms in the Inner Coma: Implications for Cometary Missions.
Advances in Space Research, 29, No.5, 745-750 (2002).
25. **A. Bhardwaj**, G. R. Gladstone, R. F. Elsner, J. H. Waite, Jr., D. Grodent, T. E. Cravens, R. R. Howell, A. E. Metzger, N. Ostgaard, A. N. Maurellis, R. E. Johnson, M. C. Weisskopf, T. Majeed, P. G. Ford, A. F. Tennant, J. T. Clarke, W. S. Lewis, K. C. Hurley, F. J. Crary, E. D. Feigelson, G. P. Garmire, D. T. Young, M. K. Dougherty, S. A. Espinosa, J.-M. Jahn
Soft X-Ray Emissions from Planets, Moons, and Comets.
ESA Special Publication 514, 215-226 (2002).
26. R.F. Elsner, G.R. Gladstone, J.H. Waite, Jr., F.J. Crary, R.R. Howell, R.E. Johnson, P.G. Ford, A.E. Metzger, K.C. Hurley, E.D. Feigelson, G.P. Garmire, **A. Bhardwaj**, D. Grodent, T. Majeed, A.F. Tennant, M.C. Weisskopf
Discovery of Soft X-Ray Emission from Io, Europa and the Io Plasma Torus.
Astrophysical Journal, 572, 1077-1082 (2002).
27. **A. Bhardwaj** and M. Michael
Io-Jupiter System: A Unique Case of Moon-Planet Interaction.
ESA Special Publication 514, 115-121 (2002).
28. **A. Bhardwaj**
On the Solar EUV Deposition in the Inner Comae of Comets with Large Gas Production Rates.
Geophysical Research Letters, 30(24), 2244, doi:10.1029/2003GL018495, PLA 2/1-5 (2003).
29. **A. Bhardwaj**
X-ray Emissions from the Jovian System.
Bulletin of Astronomical Society of India, 31, 159-166 (2003).
30. T. Majeed, J. H. Waite, Jr., S. W. Bougher, R. V. Yelle, G. R. Gladstone, J. C. McConnell, and **A. Bhardwaj**
The Ionospheres-Thermospheres of the Giant Planets.
Advances in Space Research, 33, No.2, 197-211 (2004).
31. P. Vatti Palle, J. M. Ajello, and **A. Bhardwaj**
The High Resolution Far Ultraviolet Spectrum of Electron-Excited SO₂.
Journal of Geophysical Research, 109, A02310, doi:10.1029/2003JA009828, pp.1-17 (2004).
32. O. P. Makarov, J. M. Ajello, P. Vatti Palle, I. Kanik, M. C. Festou, and **A. Bhardwaj**
Kinetic Energy Distributions and Line Profile Measurements of Dissociation Products of Water Upon Electron Impact.
Journal of Geophysical Research, 109, A09303, doi:10.1029/2002JA009353, pp.1-15 (2004).

33. R. F. Elsner, N. Lugaz, J. H. Waite, Jr., T. E. Cravens, G. R. Gladstone, P. Ford, D. Grodent, **A. Bhardwaj**, R. J. MacDowall, M. D. Desch, and T. Majeed
Simultaneous Chandra X-ray, HST Ultraviolet, and Ulysses Radio Observations of Jupiter's Aurora.
Journal of Geophysical Research, 110, A01207, doi:10.1029/2004JA010717, pp.1-16 (2005).
34. **Anil Bhardwaj**, G. Branduardi-Raymont, R. F. Elsner, G. R. Gladstone, G. Ramsay, P. Rodriguez, R. Soria, J. H. Waite, Jr., and T. E. Cravens
Solar Control on Jupiter's Equatorial X-ray Emissions: 26-29 November 2003 XMM-Newton Observation.
Geophysical Research Letters, 32, L03S08, doi:10.1029/2004GL021497, pp1-5 (2005).
35. **Anil Bhardwaj**
Discussion on Forum Article "What is the Aurora".
EOS Transactions, American Geophysical Union, vol. 86, No.11, p.110 (2005).
36. Joseph Ajello, Prahlad Vatti Pale, Hervé Abgrall, Evelyne Roueff, **Anil Bhardwaj**, and Jacques Gustin
The Electron Excited UV Spectrum of HD: Cross Sections and Transition Probabilities.
Astrophysical Journal Supplement Series, 159, 314-330 (2005).
37. **Anil Bhardwaj**, R. F. Elsner, J. H. Waite, Jr., G. R. Gladstone, T. E. Cravens, and P.G. Ford
Chandra Observation of an X-ray Flare at Saturn: Evidence for Direct Solar Control on Saturn's Disk X-ray Emissions
Astrophysical Journal Letters, 624, L121-L124 (2005).
38. **Anil Bhardwaj**, R. F. Elsner, J. H. Waite, Jr., G. R. Gladstone, T. E. Cravens, and P.G. Ford
The Discovery of Oxygen K α X-ray Emission from the Rings of Saturn.
Astrophysical Journal Letters, 627, L73-L76 (2005).
39. S.A. Haider and **Anil Bhardwaj**
Radial Distribution of Production Rates, Loss Rates and Densities Corresponding to Ion Masses ≤ 40 amu in the Inner Coma of Comet Halley: Composition and Chemistry.
Icarus, 177, 196-216 (2005). DOI:10.1016/j.icarus.2005.02.019
40. **Anil Bhardwaj**, Stas Barabash, Yoshifumi Futaana, Yoichi Kazama, Kazushi Asamura, R. Sridharan, Mats Holmström, Peter Wurz, and Rickard Lundin
Low Energy Neutral Atom Imaging on the Moon with the SARA Instrument aboard Chandrayaan-1 Mission
Journal of Earth System Sciences, 114 (no.6), 749-760 (2005).
41. G. Branduardi-Raymont, **A. Bhardwaj**, R. Elsner, G. Gladstone G. Ramsay, P. Rodriguez, R. Soria, J. H. Waite, T.E. Cravens
X-ray Exploration of the Giant Planets, their Magnetospheres and the Solar Connection: From XMM-Newton to XEUS.
ESA Special Publication ESA SP-588, Proceedings of 39th ESLAB Symposium "Trends in Space Science and Cosmic Vision 2020", pp.393-396 (2005).
42. M.T. Capria, G. Cremonese, **A. Bhardwaj**, and M.C. De Sanctis
O(1 S) and O(1 D) emission lines in the spectrum of 153P/2002 C1 (Ikeya-Zhang).
Astronomy and Astrophysics, 442, 1121-1126 (2005) DOI: 10.1051/0004-6361:20053047
43. Yoshifumi Futaana, Stas Barabash, Mats Holmström, and **Anil Bhardwaj**
Low Energy Neutral Atoms Imaging of the Moon.
Planetary and Space Science, 54 (no.2), 132-143 (2006).

44. K. Dennerl, C. M. Lisse, **A. Bhardwaj**, V. Burwitz, J. Englhauser, H. Gunell, M. Holmstrom, F. Jansen, V. Kharchenko, and P. Rodriguez
First observation of Mars with XMM-Newton: High resolution X-ray spectroscopy with RGS.
Astronomy and Astrophysics, 451, 709-722 (2006). DOI: 10.1051/0004-6361:20054253
45. Yoichi Kazama, Stas Barabash, **Anil Bhardwaj**, Kazushi Asamura, Yoshifumi Futaana, Mats Holmström, Rickard Lundin, R. Sridharan, and Peter Wurz
Energetic Neutral Atom Imaging Mass Spectroscopy of the Moon and Mercury Surfaces.
Advances in Space Research, 37, No. 1, 38-44 (2006).
46. G. Branduardi-Raymont, **A. Bhardwaj**, R. Elsner, G. Gladstone G. Ramsay, P. Rodriguez, R. Soria, J. H. Waite, and T.E. Cravens
XMM-Newton Observations of X-ray Emission from Jupiter.
ESA Special Publication ESA SP-604, Vol. 1, Proceedings of the Symposium “*The X-ray Universe 2005*”, Escorial, Spain, pp. 15-20 (2006).
47. **Anil Bhardwaj**, G. Randall Gladstone, Ronald F. Elsner, Nikolai Østgaard, J. Hunter Waite, Jr., Thomas E. Cravens, Shen-Wu Chang, Tariq Majeed, and Albert E. Metzger
First Terrestrial Soft X-ray Auroral Observation by the Chandra X-ray Observatory.
Journal of Atmospheric and Solar-Terrestrial Physics, in press (2006).
48. **Anil Bhardwaj** and R. Sridharan
Planetary Sciences in India – Recent Developments.
Proceedings of IAA Asia-Pacific Regional conference on “Advances in Planetary Exploration” submitted (2005).
49. T. E. Cravens, J. Clark, **A. Bhardwaj**, R. F. Elsner, J. H. Waite, Jr., A. N. Maurellis, and G. R. Gladstone, and G. Branduardi-Raymont
X-Ray Emission from the Outer Planets: Albedo for Scattering and Fluorescence of Solar X-Rays.
Journal of Geophysical Research, 111, No. A7, A07308 (2006).
<http://dx.doi.org/10.1029/2005JA011413>
50. G. Branduardi-Raymont, **A. Bhardwaj**, R. Elsner, G. Gladstone G. Ramsay, P. Rodriguez, R. Soria, J. H. Waite, and T.E. Cravens
XMM-Newton Observations of X-ray Emission from Jupiter.
Advances in Geosciences, Vol. 3, 203-214 (2006).
51. Marina Galand, **Anil Bhardwaj**, and Supriya Chakrabarti
On the Importance of the Cross-body Approach in Planetary Aeronomy.
Advances in Geosciences, Vol. 2, 239-248 (2006).
52. **Anil Bhardwaj**
X-ray emission from Jupiter, Saturn, and Earth: A Short Review
Advances in Geosciences, vol.3, 215-230 (2006).
53. W. -H. Ip, I. -G. Jiang, D. Kinoshita, L.N. Hau, A. Fujiwara, Y. Saito, F. Yoshida, K.W. Min, **A. Bhardwaj**, H. Boehnhardt, P. Hartogh, T. M. Capria, G. Cremonese, A. Milillo, S. Orisini, D. Gautier, D. Jewitt, and T. Owen
A Mission Called SAPPORO.
Advances in Geosciences, vol.3, 241-253 (2006).
54. Andrew W. Yau, **Anil Bhardwaj**, Iver H. Cairns, C. Z. Cheng, Wing H. Ip, Yasumasa Kasaba, Kyoung W. Min, Masato Nakamura, Yoshifumi Saito
Solar Terrestrial and Planetary Science Missions in Asia-Oceania: Opportunities for Collaborative Research.
Advances in Geosciences, vol. 2, 249-264 (2006).

55. **Anil Bhardwaj**, Ronald F. Elsner, G. Randall Gladstone, Thomas E. Cravens, Carey M. Lisse, Konrad Dennerl, Graziella Branduardi-Raymont, Bradford J. Wargelin, J. Hunter Waite, Jr., Ina Robertson, Nikolai Ostgaard, Peter Beiersdorfer, Steven L. Snowden, and Vasili Kharchenko
X-rays from Solar System Bodies.
Planetary and Space Science, in press, (2006).
56. G. Branduardi-Raymont, **A. Bhardwaj**, R. F. Elsner, G. R. Gladstone G. Ramsay, P. Rodriguez, R. Soria, J. H. Waite, Jr., and T.E. Cravens
Latest results on Jovian disk X-rays from XMM-Newton.
Planetary and Space Science, in press, (2006).
57. **Anil Bhardwaj** and Carey M. Lisse
X-rays in the Solar System.
Chapter in *Encyclopedia of the Solar System*, in press (2006).
58. **Anil Bhardwaj**
Planetary X-rays: Relationship with solar X-rays and solar wind.
Proceedings of ILWS Workshop 2006, Goa, India, Feb. 19-24 (2006).
59. **Anil Bhardwaj**, Ronald F. Elsner, G. Randall Gladstone, J. Hunter Waite, Jr., Graziella Branduardi-Raymont, Thomas E. Cravens, and Peter Ford
Low- to Mid-Latitude X-Ray Emission from Jupiter.
Journal of Geophysical Research, in press (2006).
60. D. McCann, S. Barabash, H. Nilsson, and **A. Bhardwaj**
Miniature Ion Mass Analyser
Planetary and Space Science, in press (2006).
61. G. Branduardi-Raymont, **A. Bhardwaj**, R. F. Elsner, G. R. Gladstone, G. Ramsay, P. Rodriguez, R. Soria, J. H. Waite, Jr., and T. E. Cravens
A study of Jupiter's aurorae with XMM-Newton
Astronomy and Astrophysics, submitted (2006).