SUBHARTHI RAY

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Personal Profile

Name	Subharthi Ray
Citizenship	Indian
Sex	Male

Professional Experience

Broad Research Area	**Theoretical Astrophysics, General Relativity and Cosmology.**
Present Position (2008 -)	Associate Professor, Astrophysics and Cosmology Research Unit, School of Mathematics, Statistics & Computer Sciences, University of KwaZulu-Natal, Durban, South Africa
Research Scientist/ Post Doctoral Fellow (2003-2008)	Inter University Centre for Astronomy & Astrophysics, Pune, India.
Research Scientist/ Post Doctoral Fellow (2002 - 2003)	Instituto de Fisica, Universidade Federal Fluminense, Niteroi, Rio de Janeiro, Brasil.
Research Scientist/ Post Doctoral Fellow (2001-2002)	Physical Research Laboratory, Ahmedabad, India
Senior Research Fellow 1999-2001	Dept. Of Physics, Presidency College, Calcutta, India (DST Fellowship SP/S2/K18/96)
Junior Research Fellow 1997-1999	Dept. Of Physics, Presidency College, Calcutta, India (DST Fellowship SP/S2/K18/96)

Education

Ph.D. (Thesis Submitted January 2001; Degree in December 2001)	Jadavpur University, Calcutta, India
Supervisor	Prof. Mira Dey
Thesis Title:	Description of compact objects as quark stars.
M.Sc. (Specialization in Nuclear Physics) 1996	Calcutta University, Calcutta West Bengal, India
B.Sc. (Honours in Physics) 1993	Vidyasagar College, Calcutta West Bengal, India (Affiliated to Calcutta University)
Higher Secondary (10+2) 1990	Vivekananda Institution, Howrah West Bengal, India (West Bengal Council of Higher Secondary Education)
Secondary (Class 10) 1988	RamaKrishna Mission Vidyapith, Purulia, West Bengal, India (West Bengal Board of Secondary Education)

Teaching

1. Two semesters MATH718 (General Relativity) for 4th year honours students (Feb-June, 2009 and 2012)(39 lectures + 26 tutorials for each semester)
   (Course outline: Review of tensor analysis, Particle motion in curved space, Curvature, Einstein's field equations, Schwarzschild spacetime, Gravitational Radiation)

2. Three semesters MATH344 (Tensors) for 3rd year students (July-November, 2009, 2010 & 2011)(39 lectures + 26 tutorials for each semester)
   (Course outline: Tensor concept and properties, Tensor algebra, Differentiation of tensors, Applications to fluid dynamics and geometry in curved spaces, Special relativity, Tensor calculus in Riemannian geometry, Introduction to general relativity.)

3. Two semesters MATH 343 (Advanced Mechanics) for 3rd year students (July-November, 2010, 2011 & 2012)(39 lectures + 26 tutorials for each semester)
   (Course outline: Generalised forces, Lagrangian and Hamiltonian mechanics, Hamilton-Jacobi formulations, Canonical Transformations, Liouville's theorem, Rigid body motion, Small oscillations)

4. One semester MATH334 (Advanced Differential Equations) for 3rd year students (Feb-June, 2010)(39 lectures + 26 tutorials for each semester)
   (Course outline: Power series solution, Special functions, Boundary value problem, Partial differential equations, Dirichlet problem)

5. Two semesters MATH235 (Mechanics) for 2nd year students (Feb-June, 2011 & 2012)(52 lectures + 26 tutorials)
   (Course outline: Newton's laws of motion and conservation laws. Kepler's laws, central forces

and planetary motion. Moving frames and Coriolis forces. Motion of a rigid body and Euler's Equations. Introduction to mechanics of continuous media.)

Research Supervision

1. Current Ph.D. students:
   (a) Mr Fidy Ramamonjisoa
   (b) Ms Annapurna Hazra
   (c) Mr Apratim Ganguly
   (d) Mr Sifiso Allan Ngubelanga
   (e) Mr Jefta Sunzu
2. Past students supervised:
   (a) Mr Sifiso Allan Ngubelanga (M.Sc)
   (b) Mr Darell Moodley (M.Sc)

Research Grants

- National Research Foundation (NRF) incentive grant of ZAR 200,000 (ZAR 40,000 p.a.) for a period 2011 - 2015 (5 years) against my NRF rating as a rated researcher in South Africa.
- National Research Foundation (NRF), South Africa aided South Africa-Russia unilateral research grant, worth ZAR 80,000 for the South African side for 2 years (2011-2013). Joint PI for this project with Prof Sunil Maharaj.
- University of KwaZulu-Natal Competitive research grant, worth ZAR 80,000 for 2 years (2009-2011).
- National Research Foundation (NRF), South Africa and Department of Science & Technology (DST), India, aided South Africa-India bilateral research grant, worth ZAR 300,000 for the South African side for 3 years (2009-2012). Joint PI for this project with Prof Sunil Maharaj.

NRF Rating

Received the **C2** rating from NRF for the period 01 January, 2011 to 31 December 2016 for the category of Established Researcher.

Refereeing in International Journals

Acted as referee multiple times for :

- The Astrophysical Journal (ApJ), American Astron. Soc., USA (presently IOP Publications, UK).
- Classical and Quantum Gravity (CQG), IOP Publications, UK.
- General Relativity and Gravitation (GRG), Kluwer Academic Sciences, The Netherlands.
- Nonlinear Analysis: Theory, Methods & Applications, Elsevier, The Netherlands.
- Astrophysics and Space Science, Kluwer Academic Sciences, The Netherlands.
- Publications of the Astronomical Society of Australia (PASA), Australia.

Other Reviewing and Refereeing

1. I have reviewed research applications for the NRF (National Research Foundation, Ministry of Higher Education, South Africa) rating of scientists in South Africa.

Member of Scientific communities

- Member of the South African Gravity Society (SAGS)
- Member of South African Mathematical Society (SAMS)
- Life member of the Indian Association for General Relativity and Gravitation (IAGRG)
- Life member of Astronomical Society of India (ASI)

Computational Skills

Platform familiarity	Unix/Linux, Dos, Windows, MAC OS
Workstation familiarity	DEC-ALPHA, Silicon Graphics, IBM RS6000-SP, Digital Unix, SGI, HP ES45 68/1250 cluster, IBM Blue Gene
Programming Languages	Fortran-77, F90, C, Mathematica, HTML, Perl, distributed computing with MPI and openMP.
Hardware	Some basic knowledge of computer hardware and have the knowledge of installing Linux Clusters, like the Rocks cluster.
High Performance Computing **(HPC)**	At present, in South Africa, I have used the facilities of the Centre for High Performance Computing (CHPC) at Cape Town, running codes in their 2048 processor IBM BLUE GENE cluster. During my Postdoctoral assignment, at IUCAA, I was actively involved in using the High Performance Computing (HPC) facility of IUCAA, which I mainly used to run our cosmology codes using parallel processing.

Recent conferences of importance:

1. Invited participant of the Thirteenth Marcel Grossmann Meeting on Recent Developments in Theoretical and Experimental General Relativity, Gravitation, and Relativistic Field Theory (MG13) at Stockholm University, Stockholm, Sweden, July 1 - 7, 2012.

2. Relativity and Gravitation – 100 Years after Einstein in Prague, Prague, Czech Republic, June 24 - 29, 2012. It has been a very fruitful conference where many renowned scientists in the field of General relativity and gravitation, were present, which enabled many scientific discussions of the contemporary issues in GR.

3. Gravitational Wave Astronomy in Africa (GWA) workshop, at Saint George Hotel and Conference Centre, Pretoria, May 31 - June 1, 2012. This workshop was targeted at exploring new avenues and scope for development of Gravitation Wave detectors in the country. There were international scientists on gravitational wave astronomy both from theoretical and observational side, discussing the subject.

4. 7^{th} International Conference on Gravitation and Cosmology, Hotel Holiday Inn, Goa, India, December 14-19, 2011. The ICGC is a mecca for international scientists working in Gravitation and Cosmology and held every 4th year in different parts of India. We had many interesting specialised parallel sessions besides the more general and broad plenary talks, and had many scientific interaction with other delegates. Our poster on estimation of the CMB polarisation power spectrum was presented there.

5. Testing General Relativity with Cosmology, Kavli Royal Society International Centre, Chicheley Hall, Chicheley, Buckinghamshire, MK, UK, February 28 - March 1, 2011. This was a very specialised meeting where participation was by invitation only. The Royal Society holds such specialised meetings to discuss on contemporary issues. In this meeting, the main theme was an introspection and a subsequent future direction of study of the modified theories of gravity, which can overcome the fiducial concept of dark energy and dark matter that are the building blocks of the standard models of cosmology. It was a very intense and stimulating meeting, which opened many new ideas for me, and is currently the main research topic that I am pursuing with one of my students.

Conferences organised

Had been in the organising committee of international and local conferences and workshops:

1. South Africa-India bilateral research meeting and mini workshop at UKZN, Westville Campus, during April 10-11, 2012.

2. “Tercentenary of the Laplace-Runge-Lenz vector", jointly hosted by Astrophysics and Cosmology Research Unit (ACRU), University of KwaZulu-Natal and Durban University of Technology, at the Salt Rock Hotel, Ballito, KwaZulu-Natal, South Africa, November 23-27, 2011.

3. South Africa-India bilateral research meeting at IUCAA in “Compact Objects" during December 15-17, 2010.

4. South African Gravity Society meeting (SAGS 2010) jointly hosted by Astrophysics and Cosmology Research Unit (ACRU), University of KwaZulu-Natal and University of Zululand, at the Salt Rock Hotel, Ballito, KwaZulu-Natal, South Africa, September 23-26, 2010.

5. South Africa-India bilateral research meeting at IUCAA in “CMB and closely related fields" during December 8-10, 2009.

6. South African Gravity Society Meeting (SAGS) at University of KwaZulu-Natal, Howard College Campus, Durban, South Africa, April 6-7, 2009.

7. International Conference in Gravitation and Cosmology, (ICGC-07), IUCAA, Pune, India, December 17-21, 2007.

Talks/Presentations

1. "CMB TE polarization power spectrum estimation with non-circular beam and incomplete sky coverage", at the South African Gravity Society Meeting, Rhodes University, Grahamstown, South Africa, September 12, 2011.

2. "Estimate of stellar mass from their QPO frequencies": at the SAMS (South African Mathematical Society) congress in the special session dedicated for the birth centenary of S Chandrashekhar, at University of Pretoria, Pretoria, South Africa, November 4, 2010.

3. "A rapid estimation of CMB power spectrum with non-circular beams and incomplete sky": at the Astrophysics and Cosmology Research unit, UKZN, Durban, South Africa, April 2, 2009.

4. "Non-Circularity of experimental beams in the CMB power spectrum estimation": at Bose Institute, Kolkata, India, September 5, 2007.

5. "Strange Stars, from theory to their present standing" : at Raman Research Institute, Bangalore, India, April 9, 2007.

6. "Strange Stars, from theory to their present standing" : at Indian Institute of Astrophysics, Bangalore, India, April 5, 2007.

7. "Effects of the Non-Circular Beam in CMB Power Spectrum Estimation" : at XVII DAE-BRNS Symposium in High Energy & Astroparticle Physics, Department of Physics, Indian Institute of Technology, Kharagpur, India (December 11-15, 2006).

8. "Effects of the Non-Circular Beam in CMB Power Spectrum Estimation" : at Harish Chandra Research Institute (HRI), Allahabad, India, November 9, 2006.

9. "Estimation of the CMB Power spectrum" : at IUCAA, Pune, India, June 20, 2006.

10. "Strange stars at Finite Temperature" : at the Third 21COE Symposium : Astrophysics as Interdisciplinary Sciences, Waseda University, Tokyo, Japan (September 1-3, 2005)

11. "Surface vibration in Strange stars and their possible observational evidence" : at the XVI DAE-BRNS High Energy Physics Symposium, at Saha Institute of Nuclear Physics, Kolkata, India (November 29 - December 3, 2004).

12. *Surface Vibrations in strange stars* : at the QGP Meet 2004 held at Institute of Physics, Bhubaneshwar, India (2004).

13. *General relativistic effect of strong magnetic field on the gravitational force : Origin of Gamma Ray Bursts* : at the Conference on High Energy Astrophysics (HEAP04), Centre for Theoretical Studies, Indian Institute of Technology, Kharagpur, W. Bengal, India (2004).

14. *Electrically charged compact stars* : at the 10th Marcel Grosmann Meeting, Rio de Janeiro, RJ, Brasil (2003).

15. *Charged Compact Stars and Formation of Charged Black Holes* : at the Nuclear/Particle Astrophysics group of Instituto de Fisica, Universidade Federal Fluminense, Niteroi, RJ, Brasil (2003).

16. *Charged Polytropic Compact Stars* : Invited seminar at the XV Reunião de Trabalho sobre Interações Hadrônicas (XV th Workshop on Hadronic Interactions), Universidade Presbiteriana Mackenzie, Sao Paulo, SP, Brasil (2003).

17. *Are the Neutrons Stars really Neutral ?* : Invited seminar at the XI Jorge André Swieca Summer School in Nuclear Physics, Instituto de Física - University of Sao Paulo - Sao Paulo, SP, Brasil (2003).

18. *Radial Oscillations in Strange Stars and the Stellar Stability*: at the XXIII Encontro Nacional de Física de Partículas e Campos (XXIII th National Meeting of Particles and Fields), Águas de Lindóia, SP, Brasil (2002).

19. *Strange Quark stars : from theory to present day observations* : at the Theoretical Physics Division of the Physical Research Laboratory, Ahmedabad, India (2002).

20. *Compact Object: from the Strange Stars viewpoint* : at the National Conference on Young Astrophysicists of Today's India (YATI) held at the Birla Planetarium, Calcutta, India (2001).

21. *Quark Matter Equation of State and kHz QPOs in 4U 1728-34* : at the D. A. E. Symposium in Nuclear Physics at the Panjab University, Chandigarh, India (1999).

22. *Chargeless, Beta-Stable Strange Stars with realistic Interquark potential* : at the D. A. E. Symposium in Nuclear Physics held at the Bhabha Atomic Research Centre, Mumbai, India (1998).

List of Publications, Preprints & Proceedings
(In Reverse Chronological Order)

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1. Fidy A. Ramamonjisoa, **Subharthi Ray**, Sanjit Mitra & Tarun Souradeep; "Estimation of the TE polarization power spectrum of the CMB with non-circular beam, and their optimised numerical implementation" (in preparation) (2012).

2. Pedro M Takisa, **Subharthi Ray**, Sunil D Maharaj; "Study of charged compact objects in the linear regime"; Astrophysics and Space science (submitted) (2012).

3. Pedro M Takisa, **Subharthi Ray**, Sunil D Maharaj; "Study of charged compact objects in the quadratic regime"; Astrophysics and Space science (submitted) (2012).

4. Taparati Gangopadhyay, **Subharthi Ray**, Xiang-Dong Li, Jishnu Dey & Mira Dey, "Refined masses of 12 pulsars fit the strange star equation of state: a prediction of their radii " Monthly Notices of Royal Astronomical Society (submitted) (2012).

5. Taparati Gangopadhyay, **Subharthi Ray**, Jishnu Dey & Mira Dey, "4U 1820−30 and 4U 1608−52 as compact CFL strange stars" Monthly Notices of Royal Astronomical Society (submitted) (2012).

6. **Subharthi Ray**, Mira Dey & Jishnu Dey; "The viscosity-entropy bound, its relation to strange star and dense pion gas"; Phys. Lett. B (submitted) (2011)

7. Fidy A. Ramamonjisoa & **Subharthi Ray**; "Cosmic microwave background TE polarization power spectrum estimation with non-circular beam and incomplete sky coverage"; Special issue of African Skies/Cieux Africains, Vol 16 (2011).

8. **Subharthi Ray**, Taparati Gangopadhyay, Jishnu Dey & Mira Dey; "Estimate of stellar masses from their QPO frequencies", Pramana, **77**, 571-579, (2011).

9. Taparati Gangopadhyay, Xian-Dong Li, **Subharthi Ray**, Mira Dey & Jishnu Dey; "khz QPOs in LMXBs, relation between different frequencies and compactness of stars"; New Astronomy, **17**, 43 (2011).

10. Sanjit Mitra, Anand S. Sengupta, **Subharthi Ray**, Rajib Saha & Tarun Souradeep; "CMB power spectrum estimation with the non-circular beam for incomplete sky coverage", Monthly Notices of Royal Astronomical Society, **394**, 1419, astro-ph/0702100 (2009).

11. Manjari Bagchi, Jishnu Dey, Mira Dey, Taparati Gangopadhyay, Sibasish Laha, **Subharthi Ray** & Monika Sinha,"Bound for entropy and viscosity ratio for strange quark matter", Phys. Lett. **B 666**, 145; arXiv:0705.4645 [astro-ph] (2008).

12. Manjari Bagchi, Rachid Ouyed, Jan Staff, **Subharthi Ray**, Jishnu Dey & Mira Dey; "Chromo-thermal instabilities and collapse of quark stars to black holes: Astrophysical Implications.", Monthly Notices of Royal Astronomical Society **387**, 115; astro-ph/0607509, (2008).

13. Manjari Bagchi, **Subharthi Ray**, Jishnu Dey, Mira Dey, "Strange stars: An interesting member of the compact object family."; AIP Conf.Proc. **968**, 209 (2008).

14. Saibal Ray, Basanti Das, Farook Rahman & **Subharthi Ray**; " Physical properties of Tolman-Bayin solutions: some cases of static charged fluid spheres in general relativity" Int. Journal of Modern Physics, **D** Vol 16, No. 11, 1745, arXiv:0705.2444 [astro-ph] (2007).

15. Tarun Souradeep, Sanjit Mitra, Anand Sengupta, **Subharthi Ray** & Rajib Saha; "Non-Circular beam correction to the CMB power spectrum", Proceedings of the Fundamental Physics With CMB workshop, UC Irvine, March 23-25; New Astronomy Reviews, **50**, 1030; astro-ph/0608505 (2006).

16. Taparati Gangopadhyay, Manjari Bagchi, Mira Dey, Jishnu Dey & **Subharthi Ray**; "High Density Strange Star Matter and Observed Parity Doubling of Excited Hadrons", hep-ph/0610349, (2006).

17. **Subharthi Ray**, Manuel Malheiro, José P S Lemos & Vilson T Zanchin, "Electrically Charged Compact Stars", Published in *Rio de Janeiro 2003, Recent developments in theoretical and experimental general relativity, gravitation, and relativistic field theories*, pt. **B** 1361-1363, nucl-th/0604039 (2006)

18. Manjari Bagchi, **Subharthi Ray**, Mira Dey, Jishnu Dey; "Evidence for strange stars from joint observation of harmonic absorption bands and of redshift", Monthly Notices of Royal Astronomical Society, **368**, 971, astro-ph/0602348 (2006).

19. **Subharthi Ray**, Manjari Bagchi, Jishnu Dey, Mira Dey; "Strange stars at finite temperature", (Proceedings of 3rd 21st Century COE Symposium: Astrophysics as Interdisciplinary Science, Tokyo, Japan, 1-3 Sep 2005) J.Phys.Conf.Ser. **31**, 107, astro-ph/0602095 (2006).

20. Manjari Bagchi, **Subharthi Ray**, Mira Dey, Jishnu Dey; "Compact strange stars with a medium dependence in gluons at finite temperature", Astronomy and Astrophysics, **450**, 431, astro-ph/0601282, (2006).

21. Manjari Bagchi, **Subharthi Ray**, Mira Dey & Jishnu Dey, "Strange star equation of state with modified Richardson potential", Proceedings of COSPAR Colloquium on Spectra and Timing of Compact X-ray Binaries, Mumbai, India, 17-21 Jan 2005; Adv.Space Res. **38**, 2912; astro-ph/0509703, (2006). astro-ph/0509703.

22. Monika Sinha, Mira Dey, **Subharthi Ray** & Jishnu Dey, "Superbursts and long bursts as surface phenomenon of compact objects", Proceedings of COSPAR Colloquium on Spectra and Timing of Compact X-ray Binaries, Mumbai, India, 17-21 Jan 2005; Adv.Space Res. **38**, 2915; astro-ph/0509661, (2006).

23. Monika Sinha, **Subharthi Ray**, Mira Dey, Jishnu Dey; "Strange stars and superbursts at near-Eddington mass accretion rates", astro-ph/0504292, (2006).

24. Rodrigo Picanço, Manuel Malheiro & **Subharthi Ray** "The effect of a radial electric field in the structure of a polytropic star" AIP Conference Proceedings, Vol 739, Issue 1, 711 (2004).

25. Manuel Malheiro, **Subharthi Ray**, Jishnu Dey & Herman J. M. Cuesta, "General Relativistic effects of strong magnetic fields on the gravitational force : a driving engine for gamma-ray bursts in SGRs ?", International J. of Modern Physics D, **16**, 489; astro-ph/0411675, (2007).

26. A. R. Prasanna & **Subharthi Ray**, "Self lensing effects for compact stars and their mass-radius relation", Modern Physics Letters A Vol. 19, No. 32, 2431 (2004).

27. Rodrigo Picanço, Manuel Malheiro and **Subharthi Ray**, "Charged polytropic stars and a generalization of Lane-Emden equation", International J. of Modern Physics D, **13**, 1441; astro-ph/0402253, (2004).

28. Luis Paulo Linares, Manuel Malheiro and **Subharthi Ray**, "The importance of the relativistic corrections in hyperons stars", International J. of Modern Physics D, **13**, 1355 (2004).

29. **Subharthi Ray**, Manuel Malheiro, José P. S. Lemos & Vilson T. Zanchin, "Charged polytropic compact stars", Brazilian Journal of Physics **34**, 310 (2004).

30. Manuel Malheiro, Rodrigo Picanço, **Subharthi Ray**, José P. S. Lemos & Vilson T. Zanchin, "Of charged stars and charged black holes", International J. of Modern Physics D, **13**, 1375 (2004).

31. **Subharthi Ray**, Jishnu Dey, Mira Dey & Siddhartha Bhowmick, "Possible evidence of surface vibration of realistic strange stars from stellar observations", Monthly Notices of Royal Astronomical Society, **353**, 825, (2004).

32. **Subharthi Ray**, Aquino L. Espindola, Manuel Malheiro, José P. S. Lemos & Vilson T. Zanchin, "Electrically charged compact stars and formation of charged black holes", Phys. Rev. **D68**, 084004, astro-ph/0307262 (2003).

33. Banibrata Mukhopadhyay, **Subharthi Ray**, Jishnu Dey & Mira Dey, "Origin and interpretation of kilohertz QPOs from strange stars in X-ray binary system: theoretical hydrodynamical description", Astrophysical Journal Letters, **584** L83; astro-ph/0211611, (2003).

34. Monika Sinha, Jishnu Dey, Mira Dey, **Subharthi Ray** & Siddhartha Bhowmick, "Have we observed the skin vibration of realistic strange stars (ReSS) ?", Mod. Phys. Lett. **A Vol. 18** No. 9, 661; astro-ph/0211612, (2003).

35. Monika Sinha, Manjari Bagchi, Jishnu Dey, Mira Dey, **Subharthi Ray** & Siddhartha Bhowmick, "Incompressibility of strange matter", Phys. Lett. **B 590**, 120; hep-ph/0272027, (2004).

36. Monika Sinha, Jishnu Dey, Mira Dey, **Subharthi Ray** and Siddhartha Bhowmick, "Stability of strange stars derived from realistic equation of state", Mod. Phys. Lett. **A vol.17** No. 27, 1783 (2002), astro-ph/0208366.

37. A. R. Prasanna and **Subharthi Ray**, " 'Strange stars' – Have they been discovered?", New Research on Astrophysics, Neutron Stars and Galaxy Clusters, ISBN: 1-60021-110-0; astro-ph/0205343, (2002).

38. Monika Sinha, Mira Dey, **Subharthi Ray** and Jishnu Dey, "Superbursts and long bursts as surface phenomenon of compact objects", Monthly Notices of Royal Astronomical Society, **337**, 1368; astro-ph/0208082, IUCAA preprint – 37/2001 (2002).

39. **Subharthi Ray**, Jishnu Dey, Mira Dey, Kanad Ray and B. C. Samanta, "Entropy & equation of state (EOS) for hot bare strange stars", Astronomy & Astrophysics **364**, L89 (2000), astro-ph/0003472.

40. Dorota Gondek-Rosińska, Tomasz Bulik, Leszek Zdunik, Eric Gourgoulhon, **Subharthi Ray**, Jishnu Dey and Mira Dey, "Rotating Compact Strange Stars", Astronomy & Astrophysics **363**, 1005; astro-ph/0007004 (2000).

41. **Subharthi Ray**, Jishnu Dey and Mira Dey, "Density dependent strong coupling constant of QCD derived from Compact Star data", Mod. Phys. Lett. **A 15**, 1301; astro-ph/0004327, IUCAA preprint - 15/2000 (2000).

42. Mira Dey, Ignazio Bombaci, Jishnu Dey, **Subharthi Ray**, E. P. J. van den Heuvel and Xiang-Dong Li, "QCD-Motivated Quark Stars in the Light of Recent Astrophysical Observations", Int. Journal of Modern Phys. **B 14**, 1939, (2000).

43. Jishnu Dey, **Subharthi Ray**, Xiang-Dong Li, Mira Dey and Ignazio Bombaci, "Glimpses of a Strange Star", astro-ph/0001305 (2000).

44. Xiang-Dong Li, **Subharthi Ray**, Jishnu Dey, Mira Dey and Ignazio Bombaci, "On the nature of the Compact Star in 4U 1728−34", Astrophysical Journal Letters, **527**, L51 (1999).

45. Jishnu Dey, Siddhartha Bhowmik, Kanad Ray and **Subharthi Ray**, "Limiting Temperature of Hadrons using states predicted from κ−deformed Poinceré Algebra", Indian J. Phys. **73B**, 409 (1999).

46. Mira Dey, Ignazio Bombaci, Jishnu Dey, **Subharthi Ray** and B. C. Samanta, Indian J. Phys. **73B**, 377 (1999).

47. Mira Dey, Ignazio Bombaci, Jishnu Dey, **Subharthi Ray** and B. C. Samanta, "Strange stars with realistic quark vector interaction and phenomenological density dependent scalar potential", Phys. Lett. **B 438**, 123 (1998), Addendum **B 447**, 352 (1999), Erratum **B 467**, 303 (1999).

48. Jishnu Dey, Siddhartha Bhowmick, Rajat Mahapatra and **Subharthi Ray**, "Thermodynamics of a Gas of Mesons using states predicted from κ–deformed Poinceré Algebra", IFT PRINT-97-189, (1997).

Research Interests

My research interest is divided into two broad categories: The primary one is in Astroparticle physics, with strange quark matter, quark gluon plasma and quark stars and the physics and astrophysics involved with matter at extreme high density. With a more recent interest in investigation of the modified gravity theories in the realm of strong gravity. The second interest that has arisen in the last few years is in Cosmology. More specifically, my interest in cosmology is with the CMB and closely related fields. With space based experiments like the WMAP and the recently launched PLANCK and HERSCHEL and data pouring from the ground based experiments like the South Pole Telescope (SPT) and the Atacama Cosmology Telescope (ACT), the scope of cosmology with the CMB is enormous. My current trend of research in Cosmology involves both theoretical and a lot of numerical investigations. In the process we have to use heavyweight computing in the form of large computer clusters incorporating distributed engines like MPI and openMP and running over days to weeks. Currently we are using the IBM Blue Gene/P supercomputer hosted by the Centre for High Performance Computing (CHPC), CSIR, Cape Town, to fulfil our computing requirements.

1. **Relativistic stars**
   (Collaborators: Prof Jishnu Dey, Prof Mira Dey, Prof Sunil Maharaj, Prof Sanjay Jhingan, Prof Sushant Ghosh, Prof Ignazio Bombaci, Prof Xiang-Dong Li, Prof Rachid Ouyed, Prof Dipanjan Mitra, Dr Manjari Bagchi, Dr Gabriel Govender, Ms Taparati Gangopadhyay, Mr Pedro Mafa Takisa, Mr Sifiso A Ngubelanga, Mr Apratim Ganguly, Mr Jefta Sunzu)

   (a) **Earlier works**:
   We developed a strange matter equation of state which is a relativistic Hartree-Fock type mean field model with interacting quarks and density dependent quark and gluon masses. The strange quark stars from our model successfully explained many of the observed astrophysical candidates as strange quark stars, which were earlier difficult to be explained as neutron stars with the existing neutron star models.

   We carried out the finite temperature calculation of our strange matter and found the behaviour of stars upto 80 MeV temperature, the temperature that is critical to form a star with our equation of state. In a later paper we argued the formation of Chromo-thermal instability of strange stars and possibility of collapse to black holes.

   We worked on many properties of strange matter and tried to link them with many astrophysical observations, like kilohertz-QPOs, accretion phenomena, superbursts, etc., and had been fairly successful in this effort.

   We have also worked on the effect of charge and magnetic fields inside a compact star and found important results that they bring to the morphology of the compact stars.

   (b) **Future works**:

   Some of the interesting problems with compact stars are:

   i. Recent observations revealed that some of the compact stars have large mass, much larger than the standard known neutron star models. So, a very immediate problem is to find out equation of state for nuclear matter that can fit in such large mass.
   ii. The possibility of using density dependence of the Neutron - Neutron interaction obtained from field theory seems very interesting.
   iii. The possibility of hyperon stars (HS) is interesting - but work by Bombaci and Vidana have shown that the mass of maximum mass of HS star is small. So small mass stars can either be HS or SS. It is important to find which is the correct explanation.
   iv. Observations decide all the above theoretical issues.

v. Another interesting problem which I am trying to address with Prof D. Mitra of National Centre for Radio Astronomy (NCRA), Pune, India, is as follows:
(a) In a pulsar, when several pulses are added together, an average profile is formed, which is supposed to be stable over decades
(b) However it has been observed that the pulsar is able to go into another stable mode (or profile shape), and stays there for hours, and once again returns back to its original shape.
This is called the mode change, and we are trying to understand what causes this.

vi. A very new research idea which I have been thinking of recently, and is borne out of the present issues with the standard model of cosmology, being not so 'standard'. This idea is boosted by a recent meeting – Theo Murphy International Scientific meeting on Testing General Relativity with Cosmology, that I attended on 28th February - 1st March, 2011 at the Kavli Royal Society, UK.
Latest datasets coming from different sources, such as the Cosmic Microwave Background Radiation and supernovae surveys, seem to indicate that the energy budget of the universe is approximately 4% ordinary baryonic matter, 23% dark matter and 73% dark energy. Dark energy is an unknown form of energy which not only has not been detected directly, but also does not cluster as ordinary matter does and seems to resemble in high detail a cosmological constant. Due to its dominance over matter (ordinary and dark) at present times, the expansion of the universe seems to be an accelerated one, contrary to past expectations.
There has been effort in explaining the late time accelerated nature of the universe as a modification to the Einstein's general theory of relativity. Many models of modified gravity has been proposed of which the most widely talked about is the f(R) theory of gravity where the standard Einstein-Hilbert gravitational Lagrangian, proportional to the scalar curvature R, is replaced by a function of R while the matter part of the Lagrangian is left unchanged.
In my proposed future plan, I would like to test the effect that modified gravity models can bring in the strong gravity regime of the relativistic compact stars, like neutron stars and strange stars. Present day observations of the compact stars in the optical, X-ray and radio, give us more realistic values of the stellar parameters. This can conversely bring in some tight constraints on the parameters of the f(R) gravity models present in the literature. Also such study of the modified gravity can justify the necessity of understanding the Universe without the help of any fiducial Dark Energy.
One of my students (Mr A Ganguly) has already started working with me on the effect of Chamelion Gravity, on the strong gravity regime.

vii. We are following a comprehensive programme of understanding the role of equation of state with ultra-dense matter with Prof Sunil Maharaj and doctoral students Mr P Mafa Takisa, Mr S Ngubelanga and Mr J Sunzu.

2. **Cosmology:**
(Collaborators: Prof Tarun Souradeep, Prof Anand S Sengupta, Prof Sanjit Mitra, Prof Kavilan Moodley, Prof Rajib Saha, Mr Fidy A Ramamonjisoa)

Cosmology today is more a precision science, with the basic picture being in place, but many of the fundamental questions remain unanswered. With the tremendous growth in computational and observational power, cosmology is a rapidly moving and fairly young field and can also be quite competitive.

(a) **CMB power spectrum estimation and the systematic effects:**
Over the past decade, the data from the WMAP satellite program has kept scientists busy analysing them, tuning the standard model of cosmology to the finer details and testing various models of cosmology - a true decade of precision cosmology. With the launch of the PLANCK by the ESA in 2009, and with data currently starting to pour in, it becomes

more challenging for the analysis of the data, as PLANCK will probe for a much smaller angular width (larger multipoles). PLANCK will scan the CMB sky to multipoles of ~ 3000 as compared to 1000 by the WMAP. To make full use of the potential of the data that we will receive, it is necessary to accurately determine the observed data, eliminating the systematic effects.

One of the primary objectives to probe the CMB sky to such high multipoles is to determine the polarized CMB signals. It was shown in our earlier work (MNRAS, 2009) that the non-circular beams do show a lot more deviation in the power spectrum estimation than just approximating to circular ones, as the FWHM of the beam width becomes comparable to the angular width of the two point co-relation function, and smaller. We are in working towards a semi-analytical approach to estimate the cross power spectrum of the temperature anisotropy T and the E-mode polarization using the pseudo-C_l method. The common assumption of circular instrumental beam response in CMB data analysis introduces systematic errors in the power spectrum estimation at angular scales comparable to the beam width which is further enhanced in high sensitive experiments and needs a careful attention to minimize these systematic effects. For an unbiased estimation of C_l we need to correct for the beam asymmetry by assuming an elliptical beam with a Gaussian profile. It is also necessary to remove the foreground contamination from extragalactic radio and infra-red sources in the galactic equatorial plane by applying masks to obtain an unbiased estimation of the power spectrum.

At present I and one of my PhD student (Fidy Ramamonjisoa) are working in this direction, exploring the polarization effects i.e., the TE, EE and BB modes in the CMB signal with the non-circularity of the experimental beams, which will be a major issue with the data received from the PLANCK surveyor, and other high resolution ground based CMB experiments. The accurately measured BB mode of the polarized CMB signals will reveal the inner details of the primordial gravity wave, which is otherwise very hard to estimate from the gravity wave interferometry experiments like the LIGO and VIRGO.

Future projects involve:

i. So far we have been dealing with the TE polarisation signal only. Our immediate future project is to find the complete analytical expression for the bias matrix of the CMB for EE and the BB polarised signals taking into account the effect of the non-circular beams and the incomplete sky coverage.

ii. Parametrization of the cosmological models by running a Markov Chain Monte Carlo (MCMC) engine for the CMB power spectrum estimation of the latest WMAP dataset and also the datasets of the ground based experiments like ACBAR, DASI, QUaD, etc., with their temperature and polarization signals. The motivation for this work is to determine the contribution of the adiabatic mode. The adiabatic mode is defined as a perturbation affecting all the cosmological species such that the relative ratios in the number densities remain unperturbed. It is associated with the curvature perturbation via Einstein's equation, since there is a global perturbation of matter content.

iii. The work can also be extended to find an optimization window for the future ground based CMB experiments particularly for the polarization signals.

3. **Science with The Square Kilometer Array (SKA):**

(Collaborators: Prof Sanjay Jhingan, Prof Sushant Ghosh, Prof Sunil Maharaj, Mr Annapurna Hazra, Mr Apratim Ganguly)

Astronomy with the Square Kilometer array (SKA) is the next big thing that is happening on the South African soil. The scope for science is enormous with the SKA, from observation of the distant compact objects like the pulsars, to the cosmological study of the reionization epoch of the Universe. Pulsars are Neutron stars emit signals in the form of pulses from certain hotspots on the stellar surface. With the size of the pulsars being so small, the accurate determination of

their morphology always had been a challenge and hence has been a great hindrance for the study of the same. With the precise observation of the pulsars by the SKA, the theories behind their behaviour will be tested and thus will give an inner sight to the fundamental laws of the nature.

The other areas of astronomy where SKA will be extremely useful for my research is in the field of Astro statistics. This research area I have started with one of my students, Ms Annapurna Hazra, who is also a staff member in the Statistics Department. We are in discussion with postgraduate students in Statistics and Computer Science who are interested in pursuing research in this direction. The main objective here is to use advanced statistical techniques to classify galaxy clusters according to their different morphologies. A dearth of too many data points cripples the convergence of the statistical models. With the SKA, the floodgates for information on more galaxy clusters will open up, and will directly help in this study.