Curriculum Vitae of Barnali Chakrabarti

Personal Data

Name: Dr. *Barnali Chakrabarti*
Nationality: *Indian*
Date of Birth : *16 September 1971*
Civil status : *Married, one daughter and one son*

Present Position : Visiting Professor
University of Sao Paulo, Brazil

Permanent Position: Associate Professor
Work address : Department of Physics,
Presidency University, 86/1 College Street, Calcutta 700073, India.

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International Award : Nominated as Regular Associate for 6 years (2015-2020) in the International Centre for Theoretical Physics (ICTP), Italy.

Area of research work :

Quantum many-body formulation and its numerical implementation for ultracold atoms and Bose Einstein condensation.

Multi configuration time dependent Hartree for bosons (MCTDHB) for the study of ultracold atoms in optical lattice.

Quantum chaos and nonlinearity in the dynamics of BEC and its connection with quantum computation.

Few-body atomic, nuclear and molecular systems.

Computational Physics.

Supersymmetric quantum mechanics.

Education, degree and scientific career :

i) PhD awarded 2000. Work on "Use of Supersymmetry in quantum mechanical problems"
ii) Post Doctoral research work in Hong Kong Baptist University 2001-2002.
iii) Post Doctoral research work in University of Oklahoma 2002-2003.

Visiting Scientist / Visiting Professor position

1. Visiting Professor in International Center for theoretical Physics (ICTP), Italy 2 months, 2016 for collaborative research.

2. Visiting Professor University of South Africa, 2 months in 2014 for collaborative research.

3. Visiting Professor University of Heidelberg, University of Padova, 2 months 2013 for collaborative research.

4. Visiting Professor University of South Africa, 2 months 2012 for collaborative research.

5. Visiting Scientist in the University of Sao Paulo 2011 for 3 months for collaborative research.

6. Visiting Scientist, ICTP, Italy, 2009 for one month for collaborative research.

7. Visiting Scientist, University of Padova, 2009 for collaborative research.

Teaching Experience :

Assistant and Sr Assistant Professor : 2000 – 2012
Associate Professor : 2012 – till now

Details of Teaching Experience :

1) Associate Professor position in Presidency University, Calcutta, 26 December 2013 till now.
2) Associate Professor position in Kalyani University, Calcutta, 23 August 2012 till 25 December 2013.
3) Assitant Professor in Lady Brabourne College, Calcutta 1 August 2006 to 22 August 2012.
4) Senior Lecturer Post in Krishnath College 31 March 2000 to 31 July 2006.

Major subject taught

1) Subjects taught in undergraduate courses (since 2000 till now)

A) UG Sem 1 : Mathematical Physics.
B) UG Sem 2 : Electricity and magnetism.
C) UG Sem3 : Nuclear Physics and statistical Physics.

2) Subjects taught in Master courses (since 2009 till now)

A) Sem 1 : Mathematical Physics
B) Sem 2 : Atomic and Molecular Physics
C) Sem 3 : Nuclear Physics
D) Sem 4 : Condensed matter special.

Master Thesis Supervised (13 students supervised)

1. Shannon information entropy for interacting trapped bosons (1 student) 2017.

2. Finite-sized effect and beyond mean field calculation for trapped bosons (1 student) 2017.

3. Hyperspherical harmonics expnasion method for van der Waals cluster (1 student) 2016.

4. Supersymmetric quantum mechanics for polynomial potential (1 student) 2016.

5. Quasi exactly solvable potential in Supersymmetry quantum mechanics (2 student) 2014.

6. Field induced chaos (1student) 2013.

7. Finite number of trapped interacting bosons in 1D (1 student) 2013.

8. Supersymmetric WKB approximation and its application to real problems. (1 student) 2013.

9. Isospectral potential in supersymmetry and its application to nuclear problems (1 student) 2012.

10. Halo-nuclei and the study of 3-body problems in nuclear physics including computation (1 student) 2012

11. Calculation of quasi-degenerate problems and study of some realistic quantum many-body systems (1 student) 2011

12. Study of spectral statistics of interacting particles in trapped systems (1 student) 2010.

Undergraduate Thesis supervised (4)

1. Conditionally exactly solvable problems in quantum mechanics (1 student) 2017.

2. Calculation of WKB quantization condition for double and multiple barrier problem (1student) 2016.

3. Study of supersymmetric quantum mechanics (1 student) 2014.

4. Calculation of basis thermodynamic quantities for ideal Bose gas in harmonic trap (1 student) 2014.

Number of Publication & Journal Distribution (Details are in list of publication)

i) International Journal (peer reviewed) : **60**
ii) National (peer reviewed) : **6**
iii) Conference proceedings : **2**
iv) Chapter in a book **:** **1**

Physical Review A : **19**
Physical Review E : **5**
J. Chem. Physics : **4**
Phys. Lett. A : **5**
Eur. Phys. J. D : **2**
Eur. Phys. Lett. **: 1**
J. Phys. A/B/G : **8**
Others (JLTP, Int. J. Phys., FBS) : **12**

Foreign Country visited as visiting professor

Visiting Professor position for one year in University of Sao Paulo, Brazil 15 June 2017 to 14 June 2018.

1) ICTP and SISSA, Italy , visiting Professor, May-June, 2016
2) University of South Africa, visiting Professor, Oct-Nov, 2014.
3) University of Heidelberg, Germany as guest Professor, 2013.
4) ICTP and University of Padova, Italy as guest scientist, 2013.
5) University of South Africa, visiting Professor, May-June 2012.
6) University of Sao Paulo, visiting Professor, March-June 2011.
7) ICTP, Italy, Sep-Oct 2009, visiting research fellow.
8) University of Padova, Italy, 2009, for collaborative research work.

Invited Talk in *International* Conference/Seminar/ National conference/colloquium: **14**

1. Invited talk in SISSA, Italy, 11 May 2016, Spectral statistics and nonlinearity in the spectrum of trapped interacting bosons.

2. Invited talk in UNISA, South Africa, 9th October 2014, Quantum many-body physics.

3. Invited talk in University of Padova, Italy, 6th November 2013, Stability of attractive BEC.

4. Invited talk in UNISA, Souh Africa, 12th June, 2012, Correlated potential harmonics expansion method for interacting trapped bosons,.

5. Invited talk in a series of lecture in University of Sao Paulo, Brazil, 23rd May to 27th May 2011, Supersymmetry quantum mechanics and its many-body formalism.

6. Invited talk in the International conference on Cold and trapped atoms, jointly organized by ICTP, Italy and DAE, Govt. of India, held in Goa 10-14 January 2011.

7. Invited talk in Theoretical Physics Seminar circuit on 23 Sep 2010, Physical Research Laboratory India.

8. Invites talk in Physics Symposium held at BARC, Trombay on 14 September 2009.

9. Invited talk on Bose Einstein Condensation on 23 Sep 2009 in the Univ of Padova, Padova, Italy.

10. Invited talk in the International conference on Non-Hermitian Hamiltonians (PT symmetry) held at BARC (INDIA) 13-16 Jan, 2009.

11. Invited talk in the XIII th International Conference on Atomic and Molecular Physics, 16-20 January, 2001, held at IACS, Calcutta, India.

12. Presentation of paper in the International conference on Fundamental Science held in the National University of Singapore in 13-19 Feb 2000.

13. TPSC speaker, 2000 (IOP, Bhubaneswar and School of Physics, Hyderabad).

14. Thesis presentation in Physique en Herbe 2000,17 th European Physics Congress .

Research Collaborators :

1) Prof. Lorenz Cederbaum, University of Heidelberg, Germany.
2) Prof. M. L. Lekala, University of South Africa, South Africa.
3) Prof. Tapan Kumar Das, University of Calcutta, India.11
4) Prof. Sylvio Canuto, University de Sao Paulo, Brazil.
5) Prof. Luca Salasnich, University de Padova, Itlay.
6) Prof. V. K. B. Kota, Physical Research Laboratory, India.
7) Dr. Axel Lode, University of Basel, Switzerland.
8) Prof. Andrea Trombettoni, SISSA, Italy.

Details of Research Guidance: **(No. of PhD thesis supervised: 5)**

1. Anasuya Kundu, Ph. D. University of Calcutta, 2008.
Title : Study of some aspects of Bose-Einstein condensation using realistic interatomic interaction.

2. Anindya Biswas, Ph. D. University of Calcutta, 2011.
Title : Study of many-body effect on the trapped interacting Bose gas.

3. Pankaj Kumar Debnath, Ph. D. University of Calcutta, 2014.
Title: Study of Bose-Einstein condensation in anharmonic and deformed trap.

4. Sudip Kumar Haldar, Ph. D. University of Calcutta, 2015.
Title: Stability of Bose Einstein condensation in finite optical trap.

5. Kamalika Roy, PhD University of Calcutta, 2017.
Title : Spectral statistics and nonlinearity in the energy spectra of interacting trapped bosons.

ii) Number of PhD students registered : **2**

Details of Project Grants Undertaken: Completed Major projects : 5)

1.Many body effects on the stability and anisotropic deformation of ultracold dipolar gases near Feshbach resonance.
Duration : 3 Years.
Fund and Funding Authority : Rs. 2.5 millions, Department of Science and Technology, Govt. of India.

2. Theoretical studies on Nonlinearity and Dynamical Instability of (driven) Bose-Einstein Condensate and Exploration of Suitable Control Mechanisms
Duration : 3 Years (February 2010 - January 2013).
Fund and Funding Authority : Rs. 1.2 millions, Department of Atomic Energy, Govt. of India.

3. Study of Bose Einstein condensation in finite optical trap.
Duration : 3 Years (September 2008 - August 2011).
Fund and Funding Authority : Rs. 1.595 millions, Dept. of Sc. & Technology(Govt. of India).

4. Study of Bose Einstein condensation using realistic interatomic interactions.
Duration : 3 + 1 Years
Own designation : Co-investigator.
Name of other Investigators : Prof. Tapan Kumar Das (PI)
Fund and Funding Authority : Rs. 0.9 million, Dept. of Sc. & Technology(Govt. of India).

5. Application of supersymmetric quantum mechanics to multidimensional realistic many body problems
Duration : 2 Years (Jun 2008 - May 2010).
Fund and Funding Authority : Rs. 0.06 million ,University Grants Commission (Govt. India)

Ongoing Major projects : 1

1. Quantum properties and energy level statistics of interacting trapped bosons and Bose Einstein condensation.
Duration : 3 Years.
Fund and Funding Authority : Rs. 1.595 millions, Dept. of Sc. & Technology(Govt. of West Bengal).

Publications in international refereed journals :

1. Characteristic features of the Shannon information entropy of dipolar Bose-Einstein condensates T.Sriraman, **B.Chakrabarti,** A. Trombettoni, and P. Muruganandam, **J. Chem. Phys. 147, 044304 (2017).**

2. Spectral analysis of molecular resonances in Erbium isotopes: Are they close to semi-Poisson? by K. Roy, **B. Chakrabarti**, N. D. Chavda, V. K. B. Kota, M. L. Lekala and G. J. Rampho, **Euro. Phys. Lett. 118, 46003 (2017).**

3. Structural and quantum properties of van der Waals cluster near the unitary regime. M. L. Lekala, **B. Chakrabarti**, S. K. Haldar, R Roy, G. J. Rampho, **Phys. Lett. A 381, 2256 (2017)**.

4. Statistical properties and condensate fluctuation of attractive Bose gas with finite number of particles. S. Bera, M. L. Lekala, **B. Chakrabarti**, S. Bhattacharyya and G. J. Rampho, **Physica A, 481, 79 (2017).**

5. Application of conditional shape invariance symmetry to obtain the eigen-
. S. Bera , Energy spectrum of the mixed potential V (r) = ar + br^ 2 + r c + l∗(l+1) r^ {2}, **B. Chakrabarti** and T.K. Das, **Phys. Lett. A 381, 1356 (2017).**

6. Use of two-body correlated basis functions with van der Waals interaction to study the shape-independent approximation for a large number of trapped interacting bosons. M. L. Lekala, **B. Chakrabarti,** T. K. Das, G. J. Rampho, S. A. Sofianos, R. M. Adam and S. K. Haldar **J.Low Temp Phys, 187, 232 (2017).**

7. Condensate fluctuation and thermodynamics of mesoscopic Bose-Einstein condensates: A correlated many-body approach, S. Bhattacharyya, **B. Chakrabarti, Phys. Rev. A 93, 023636 (2016)**.

8. Energy fluctuation of a finite number of interacting bosons: A correlated many-body approach. S. Bhattacharyya, M. L. Lekala, **B. Chakrabarti,** and G. J. Rampho, **Phys. Rev. A 93**, **033624 (2016)**

9. Many-body entropies, correlations and the emergence of statistical relaxation in interaction quench dynamics of ultracold bosons, Axel U. J. Lode, **B. Chakrabarti**, Venkata K. B. Kota, **Phys. Rev. A 92 033622 (2015).**

10. Statistical properties of spectral fluctuations of N interacting bosons in an harmonic trap, K. Roy, **B. Chakrabarti**, V. K. B. Kota, **Phys. Rev. E 90, 052137 (2014)**.

11. Condensate fraction and critical temperature of interacting Bose gas in anharmonic trap, S. K. Haldar, **B. Chakrabarti**, S. Bhattacharya, T. K. Das, **Eur. Phys. J. D 68, 262 (2014).**

12.Level-spacing statistics and spectral correlations in diffuse van der Waals clusters, S. K. Haldar, **B. Chakrabarti**, N. D. Chavda, T. K. Das, S. Canuto, and V. K. B. Kota, **Phys. Rev. A 89, 043607 (2014).**

13. Behavior of trapped ultracold dilute Bose gases at large scattering length near a Feshbach resonance. M. L. Lekala, **B. Chakrabarti,** G. J. Rampho, T. K. Das, S. A. Sofianos, and R. M. Adam, **Phys. Rev. A 89, 023624 (2014)**.

14. A Few-Body Approach to Bose-Einstein Condensation, S.A. Sofianos, T.K. Das, **B. Chakrabarti** , M.L. Lekala, R.M. Adam, G.J. Rampho, **Few-Body Systems 54, 1529 (2013).**

15. Effects of interaction on thermodynamics of a repulsive Bose-Einstein condensate, S. Bhattacharya, T. K. Das and **B. Chakrabarti**, **Phys. Rev. A 88, 053614 (2013)**.

16. Macroscopic quantum many-body tunneling of attractive Bose-Einstein condensate in anharmonic trap, S. K. Haldar, P. K. Debnath and **B. Chakrabarti**, **Eur. Phys. J. D 67, 188 (2013).**

17. Correlated many-body calculation to study characteristics of Shannon information entropy for ultracold trapped interacting bosons, S. K. Haldar, **B. Chakrabarti**, T. K. Das and A. Biswas **Phys. Rev. A 88, 033602 (2013)**.

18. Spectral fluctuation and correlation structure of δ_n statistics in the spectra of interacting trapped bosons, K. Roy, **B. Chakrabarti**, V. K. B. Kota, **Phys. Rev. E 87, 062101 (2013).**

19. Dynamical features of Shannon information entropy of bosonic cloud in a tight trap, S. K. Haldar and **B. Chakrabarti**, **Int. J. Mod. Phys. B 27, 1350048 (2013)**.

20. Beyond mean-field ground state energies and correlation properties of trapped Bose Einstein condensate, S. A. Sofianos, T. K. Das, **B. Chakrabarti**, M. L. Lekala, R. M. Adam, and G. J. Rampho, **Phys. Rev. A 87, 013608 (2013)**.

21. Energy level statistics of interacting trapped bosons, **B. Chakrabarti**, A. Biswas, V. K. B. Kota, K. Roy, and S. K. Haldar, **Phys. Rev. A 86, 013637 (2012)**.

22. Structural Properties and energetic of diffuse 87-Rb clusters in three dimension , P. K. Debnath, **B. Chakrabarti**, T. K. Das and S. canuto, **J. Chem. Phys 137, 014301 (2012).**

23. Spectral fluctuation and $1/f^{\alpha}$ noise in the energy level statistics of interacting trapped bosons, K. Roy, **B. Chakrabarti**, A. Biswas, V. K. B. Kota, and S. K. Haldar, **Phys. Rev. E 85, 061119 (2012).**

24. Supersymmetric isospectral formalism for the calculation of near-zero energy states: Application to the very weakly bound ^{4}He trimer excited state, S. K. Haldar, **B. Chakrabarti**, and T. K. Das, **Few-Body Systems 53, 283-292 (2012)**.

25. Destruction of attractive bosonic cloud due to high spatial coherence in tight trap, A. Biswas, **B. Chakrabarti**, T. K. Das and L. Salasnich, **Phys. Rev. A 84, 043631 (2011).**

26. Use of correlated potential harmonic basis functions for the description of the ${4}$He trimer and small clusters, T. K. Das, **B. Chakrabarti** and S. Canuto, **J. Chem Phys. 134, 164106 (2011).**

27. Beyond mean-field effects in attractive Bose Einstein condensate, P. K. Debnath, **B. Chakrabarti**, T. K. Das, **Int. Jour. of Quantum Chemistry 111, 1333 (2011) .**

28. Resonance states and Quantum tunneling of Bose-Einstein condensates in a 3D shallow trap.
S. K. Haldar, **B. Chakrabarti**, T. K. Das, **Phys. Rev. A 82, 043616 (2010)**.

29. Instability of collective excitations and Power laws of attractive Bose-Einstein condensate in an anharmonic trap.P. K. Debanth, **B. Chakrabarti, Phys. Rev. A 82 , 043614 (2010).**

30. Stability of attractive bosonic cloud with van der Waals interaction, A. Biswas, T. K. Das, L. Salasnich, and **B. Chakrabarti**, **Phys. Rev. A 82, 043607 (2010)**.

31. Pair-correlation properties and momentum distribution of finite number of interacting trapped bosons in three dimension, A. Biswas, **B. Chakrabarti**, T. K. Das, **J. Chem. Phys. 133, 104502 (2010)** .

32. Finite number of trapped bosons interacting through the harmonic Calogero interaction in one dimension, **B. Chakrabarti**, T. K. Das, **Phys. Rev. A 81 , 015601 (2010) .**

33. Stability of a Bose Einstein condensate in an anharmonic trap, **B. Chakrabarti**, T. K. Das, P. K. Debnath, **Phys. Rev. A 79 , 053629 (2009).**

34. ^{85}Rb Bose Einstein condensate with tunable interaction : a quantum many body approach, T.K.Das, A. Kundu, S. Canuto, **B. Chakrabarti**, **Phys. Letts A 373 (2009) 258.**

35. An essentially exact many body calculation for muonic molecular ions and exotic coulombic systems, **B. Chakrabarti ,** T. K. Das , **Molecular Physics 107 (2009) 1817.**

36. Zero-temperature Properties of Attractive Bose Einstein Condensate by Correlated Many-body Approach. **B.Chakrabarti**, T.K.Das, P.K.Debnath, **J. Low Temp. Phys. 157 (2009) 527 .**

37. Shape independent approximation for Bose Einstein condensate interacting through van der Waals potential, **B. Chakrabarti**, T. K. Das, **Phys. Rev. A 78 (2008) 063608.**

38. Energy eigenvalues of quantum anharmonic oscillator from supersymmetry : concept of conditional shape invariance symmetry, **B. Chakrabarti , J. Phys. A : Math. Theor. 41 (2008) 405301.**

39. Behaviour of a Bose-Einstein condensate containing a large number of atoms interacting through a finite-range interatomic interaction , T.K.Das, S. Canuto, A. Kundu and **B. Chakrabarti, Phys. Rev A 75 (2007) 042705**.

40. An approximate many body calculation for trapped bosons with attractive interaction - A. kundu, **B. Chakrabarti**, T. K. Das and S. Canuto, **J. Phys. B 40 (2007) 2225.**

41. A finite number of trapped interacting bosons: an approximate many-body calculation, **B. Chakrabarti**, A. Kundu, T. K. Das, **J. Phys. B 38 (2005) 2457**.

42. Potential Harmonics expansion method for trapped interacting Bosons : inclusion of two body correlation, T. K. Das and **B. Chakrabarti, Phys. Rev. A 70 (2004) 063601.**

43. Quality of hyperspherical adiabatic approximation for excited states of atomic system, T. K. Das and **B. Chakrabarti**, **Int. Jour. Mod. Phys.A 19 (2004) 4973.**

44. Calculation of resonaces in weakly bound system, S. K. Dutta, T. K. Das, M. A. Khan and **B. Chakrabarti, Int. Jour. Mod. Phys. E 13 (2004) 811.**

45. Resonances in A=6 nuclei: Use of supersymmetric quantum mechanics, S.K. Dutta, T. K. Das, M.A. Khan and **B. Chakrabarti, Few-Body Systems 35 (2004)33.**

46. Level correlation in coupled harmonic oscillator systems, **B. Chakrabarti** and B. Hu, **Phys. Lett. A 315 (2003) 93**.

47. Computation of 2^{+} resonance in $^6{He}$: bound state in the continuum, S. K. Dutta, T. K. Das, M. A. Khan and **B. Chakrabarti, J. Phys. G 29 (2003) 2411**.

48. Shnirelman peak in level spacing distribution of Calogero like three body problem, **B. Chakrabarti** and B. Hu, **Phys. Rev. E 65 (2002) 067103**.

49. Connection between classical and supersymmetric turning points for quasi-degenerate problems of one dimension, **B. Chakrabarti** and T. K. Das, **J. Phys. A 35 (2002) 2441**.

50. Existence of quasi-exact shape invariance symmetry for singular power potential $V(r) = a r^{2} + b r^{-4} + c r^{-6}$, **B. Chakrabarti** and T. K. Das, **J. Phys. A 35 (2002) 4701**.

51. Conditionally exactly solvable singular even power potential in supersymmetric quantum mechanics, **B. Chakrabarti** and T. K. Das, **Mod. Phys. Lett. A 17 (2002) 1367.**

52. Analytic superpotential of Yukawa potential by perturbation of the Riccati equation, **B.Chakrabarti** and T.K.Das, **Phys. Lett. A 285 (2001) 11**.

53. Calculation of resonances using isospectral potential, T. K. Das and **B. Chakrabarti, Phys. Letts. A 288 (2001) 4**.

54. Study of the excited state of double - Λ hypernuclei by hyperspherical supersymmetric approach, Md. A. Khan, T. K. Das and **B. Chakrabarti, Int. Jour. Mod. Phys. E 10 (2001) 107.**

55. Calculation of the first excited $^{1}S^{e}$ state of the He atom using supersymmetric quantum mechanics and extension to the n-th excitation, T. K. Das and **B. Chakrabarti, Phys. Rev. E 62 (2000) 4347.**

56. Reformulation of SWKB quantization condition for quasi-degeneracy in one dimension involving oscillating superpotential, **B. Chakrabarti** and T.K.Das, **J. Phys. A 33, (2000) 805**.

57. A simple variational calculation for a three-body model of ^{11}Li, **B. Chakrabarti**, T. K. Das and S. N. Mukherjee, **Fizika B 9 (2000) 11.**

58. Quality of the supersymmetric WKB quantization condition for non shape invariant potentials, **B. Chakrabarti** and T.K.Das, **Phys. Rev. A 60 (1999) 104.**

59. Comparison of the SWKB and WKB approximations for the finite square well. **B.Chakrabarti**, **Fizika B7, 73 (1998)**.

60. Application of supersymmetry to coupled system of equations : concept of superpotential matrix. T.K.Das and **B. Chakrabarti, J. Phys. A 32,2387 (1999)**.

Publictaions in national refereed journals:

1. Use of isospectral formalism in realistic quantum mechanical problems, **B. Chakrabarti, Pramana - Journal of physics 73 (2009) 405** .

2. Spectral statistics of supersymmetric shape invariant potentials. **B. Chakrabarti, Pramana Journal of Physics, 70 (2008) 41.**

3. Quality of potential harmonics expansion method for dilute Bose-Einstein condensate - A. Kundu and **B.Chakrabarti, Pramana, Journal of Physics, 69 (2007) 329.**

4. Application of potential harmonic expansion method to BEC: Thermodynamic properties of trapped ^{23}Na atoms, A. Kundu, **B. Chakrabarti** and T. K. Das, **Pramana, Journal of Physics, 65 (2005) 61.**

5. Application of multidimensional SSQM formalism to He atom. **B. Chakrabarti Ind. Jour. Phys. B 76 (2002) 415.**

6. Application of the WKB method to the double oscillator well. **B.Chakrabarti, Indian Journal of theoretical physics, 46, 149 (1998).**

Books:

Non-Hermitian hamiltoninas in Qunatum Physics, Page 405 - 416.

Contribution to conference proceedings

1. Approximate shape invariance symmetry in few body system, connection with hyperspherical adiabatic approximation (HAA)- **B. Chakrabarti**, presented at International Conference on Fundamental Sciences 2000 **(ICFS 2000)** at National University of Singapore, Singapore.

2. Use of supersymmetric quantum mechanics for improving convergence of excited state calculation **- B. Chakrabarti** and T. K. Das, presented at the Conference on Computational Physics 2000 **(CCP2000)** at the University of Queensland, Australia.

Research Statement

I am working in the diverse area of theoretical physics which includes broadly complex many-body systems like ultracold trapped bosons, Bose Einstein condensation, few-body atomic and molecular physics, nonlineraity and quantum chaos, quantum information, statistical relaxation and thermalization.

<u>Present scientific research and future proposal</u>

A) Statistical Relaxation, eigenstate thermalization hypothesis and many-body localization and information entropy.

Transition from localization to delocalized phases in many-body quantum systems due to interparticle interaction has received a great interest in recent days. Nonintegrable quantum systems thermalize and the eigenstate thermalization hypothesis is considered as the underlying mechanism. The standard measure of thermalization in the quench dynamics in many-body system is the study of dynamics of von Neumann entropy. This is the most challenging research area in many-body physics.

We have solved the exact quench dynamics of interacting bosons by utilizing the multiconfiguration time dependent Hartree for bosons (MCTDHB). Apart from Shannon information entropy we also define other measures of many-body information entropies. Our numerical calculation nicely show that for weak interaction the system is in prethermalized state. Whereas very strong interaction pushes the system to thermalization. ETH is also established as the expectation values of typical obsevables saturate to microcanonical value. **Our numerical works are able to manifest the recent experimental observation on the transition from prethermalization to thermalization state and the coexistence of prethermalization and thermalization for long range interaction**. This work is almost finished and it would be the fi**rst theoretical calculation which proves the experimental observation**. MCTDHB allows the exact quench dynamics and offers the many-body physics. We also calculate both first-order, second-order and higher-order correlation function which can be obtained in the interference experiment of Bose Einstein condensation. **Our numerical results also demonstrate that the statistical relaxation, thermalization and saturation in the dynamics of many-body information entropy are synchronized.**

Future Work:

1) We are working for interacting bosons in 1D optical lattice. Utilizing the different filling factor both for commensurate and incommensurate we nicely demonstrate the superfluid to Mott insulator phase transition. We also correlate the delocalization to localization transition in terms of the definition of statistical entropy. The ETH can be verified by the quench dynamics in entropy for larger interaction. MCTDHB also allows us

to study the pathway from condensation to fragmentation to fermionization in term of several measures of entropy. The effect of realistic long range interaction and dynamics of correlation are the important issue in this direction. **The full dynamics will facilitate to show how the correlation is gradually build up and then lost when the system makes transition to thermalization for larger interaction.**

2) We are trying to establish that ETH can be verified by the observation that all definition of thermodynamics will be universal. **The study of interacting bosons in optical lattice and harmonic oscillator trap and the establishment of ETH will be the first theoretical many-body calculation for realistic and experimentally achievable system.**

B) Quantum many body formulation and its numerical implementation for ultracold trapped bosons and Bose Einstein condensation (BEC).

Since the experimental achievement of BEC, it is the most challenging research area both for experimental and theoretical physicist as it is highly complex many-body systems. BEC is interesting by itself where the concepts from different branches of physics, condensed matter, statistical physics, quantum mechanics are indeed required for its correct description. It is the system which facilitates the study of quantum effect on macroscopic scale. The presence of external trap makes the system inhomogeneous and exhibits several special features. D**ue to its uniqueness it puts a challenge to theoretical physicist to provide the theory which can incorporate all essential features.** BEC is truly macroscopic but it never reaches thermodynamic limit. So it exhibits **finite sized effect and the possibility of phase transition is a long term question** since its first discovery. Although the system is dilute, the interatomic interaction plays an important role in the measurement of several properties of the system. The interatomic correlation is also crucial for the attractive BEC. Thus it definitely requires **quantum many-body calculation, keeping interatomic correlation and using realistic interatomic interaction.**

However till now the Gross Pitaveskii (GP) mean-field theory is the most efficient tool in this field as the number of atoms in the external trap varies from just few to several millions. Although the GP equation qualitatively gives the essential features of BEC, however discripancy remains for quantitative estimate. It **uses contact interaction which is not a realistic interatomic interaction and also interatomic correlation is not taken into account**. However in present days experiments, utilizing the Feshbach resonance **one can truly make strongly interacting BEC.** So one indeed needs the many-body calculation. Diffusion Monte Carlo (DMC) is an exact method and can take care of realistic shape-dependent potential. However due to **severe computational restriction DMC can treat maximum 100 bosons in the trap**. It is admitted that there is no other ab initio exact method even for few-body (N=4) problems. One has to take a proper approximation for the correct description.

Here we propose to decompose the many-body wave function into two-body Faddeev component and keep all possible two-body correlations. Since 2004, we are gradually improving our technique. The basic scenario of our methodology : when two particles interact, the remaining are inert spectators. Thus we deliberately ignore the contribution coming from three-body correlation. This choice is perfectly suitable for the description of experimental BEC. We choose van der Waals interaction and can keep quite large number of bosons. We have extensively applied our methodology (called Correlated Potential Harmonic Expansion Method (CPHEM)) for several experimentally achieved BEC and have reproduced the experimental results nicely. **Our methodology is applicable for correlated BEC, exhibits finite sized effect, uses realistic interatomic interaction and can tackle the whole range of atom number which are considered experimentally. All static, dynamic and thermodynamic results have been reproduced well. This is the first many-body calculation which accurately reproduce the controlled collapse experiment of JILA.**

Future Plan

i) We are trying to extend our methodology to probe the BEC-BCS crossover.

ii) We are working on the strongly correlated dipolar Bose gas which is very special d**ue to its anisotropic**

nature of interaction. Mean field GP theory can never produce the real experimental features. The utilization of CPHEM will be a good step in this direction.
Iii) The possibility of incorporation of three-body correlation is going on.

C) Theoretical studies of nonlinearity and quantum chaos in BEC: Energy level statistics and spectral fluctuation

It is an well established fact that integrable systems exhibit Poisson statistics and chaotic systems exhibit Wigner statistics in the energy level distribution. From the earlier study of spectral statistics in atomic and nuclear systems, Bohigas conjectured that lowlying levels are uncorrelated and high lying levels are correlated and exhibit a smooth transition from Poisson to GOE (Gaussian Orthoginal Ensemble) .

We analyse the spectral statistics, spectral correlation for the energy spectra of interacting trapped bosons. **Trapped bosons are not only complex but very interesting for the existence of two energy scale.; the interatomic interaction and the trapping potential.** Our observations are as follows :

1) Low-lying levels are of collective nature and highly correlated and the spectral statistics is close to Wigner.

2) This is the first realistic extensive calculation where **we observe the breakdown of BGS conjecture.**

3) We also observe the existence of **Shnirelmn peak in spectral statistics.**

4) We have also done all possible spectral analysis of Rb spectra.

5) We analyse the recent experimental results of Er-isotopes and conclude that **interacting trapped bosons is a realistic system which shows smooth transition from Wigner to Poisson statistics. The possibuility of chaos has been discussed.**

6) For the first time we show that BEC is the experimentally achivable system where we demonstrate that **$1/f^{\alpha}$ noise is the ubiquitous in nature.**

Future Work :

1) We are extending our calculation for the anharmonic trap which gives additional inhomogenity to the system.

2) Work for truly dipolar BEC is going on.

D) Dynamical instability of (driven) Bose-Einstein condensate and exploration of suitable control mechanisms.

This is another rich area of study by MCTDHB, where we can consider the driven Bose-Einstein condensation and we can explore suitable mechanism for its dynamical instability. The work in this direction is under process.

Apart from this I also work in different few-body system like van der Waals cluters which exhibit Efimov physics.