# B V Rajarama Bhat

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## Short CV

Area of specialization: Operator Theory and Operator Algebras with special reference to Quantum Probability.

Education: PhD in Mathematics from the Indian Statistical Institute under the guidance of Prof. K. R. Parthasarathy in the year 1993.

Post-doctoral Research: At the University of Pisa, Italy from Jan. 1994 to Sept. 94, with fellowship from INDAM (Italy). At the Fields Institute, Canada, with fellowship from the Fields Institute during Sept. 94 to Aug. 96.

Employment: At the Indian Statistical Institute, Bangalore Centre since Oct. 96.

Academic administration: Head of Stat-Math Unit, Indian Statistical Institute, Bangalore Center from April 2010 to March 2017. Professor-in-Charge of the Statistics and Mathematics Division of the Indian Statistical Institute since November 2018. Chairman, Project Advisory Committee in Mathematics of SERB, Govt. of India since June 18,2019.

Recognitions: (i) The **INSA Medal for Young Scientists** from the **Indian National Science Academy, New Delhi,** (ii) The **Swarnajayanthi Fellowship** from the Department of Science and Technology, India, (iii) The **B. M. Birla Science Prize** in Mathematics from B.M. Birla Science Center, (iv) The **Shanti Swarup Bhatnagar Prize for Science and Technology (Mathematics)** from CSIR (v) The J C Bose Fellowship from SERB.

Fellowships: **Fellow of the Indian Academy of Sciences**, Bangalore and **Indian National Science Academy, Bangalore.**

Editorial: Past: (i) **Chief Editor** of the Proceedings of the Indian Academy of Sciences-Mathematical Sciences from January 1, 2013 to December 31, 2018. (ii) Member of the Council of Editors of the science education journal Resonance. Present: A member of the editorial board of following journals: (i) Proceedings of the Indian Academy of Sciences-Mathematical Sciences; (ii) Journal of Ramanujan Mathematical Society, (iii) The Annals of Functional Analysis (iv) Journal of Infinite Dimensional Analysis, Quantum Probability and Related Topics (v) Indian Journal of Pure and Applied Mathematics (vi) Ramanujan mathematical Society-Newsletter (vii) Indian Statistical Institute-Springer Series of books.

**As guide/mentor** (with different sources of funding):

Phds supervised: (i) Santanu Dey (ii) Mithun Mukherjee (iii) K. Sumesh (iv) Nirupama Mallick (v) Tiju Cherian John (vi) Vijaya Kumar U.

**Research projects:**

- INSA Young Scientist Research Project '$E_0$-Semigroups and dilation theory' started in July 1998, successfully completed in June 2001. One book, 3 research papers have come out of this project.
- A research paper was possible due to RIP (Research in pairs) program with M. Skeide at Oberwolfach in 1998.
- Principal investigator jointly with and W. Freudenberg of a DST-DAAD (Indo-German) joint project 'Tensor product systems of Hilbert modules'. S. Barreto, S. Dey from India and M. Skeide, V. Liebscher from Germany were other members.
- Participating member along with G. Misra, G. Pisier, P. Biane, and A. Pal in the Indo-French project 'Non-commutative Markov Processes and Operator spaces,' completed in March 2004 (K. B. Sinha and S. Attal were principal investigators for this project).
- A member of the Research in Pairs program of Oberwolfach with M. Skeide and V. Liebscher at Oberwolfach in 2007.
- Good progress in Swarnajayanthi Fellowship project entitled 'Quantum Dynamical Semigroups and Tensor Product Systems'. This project spanned from 2003 to 2008.
- A member of the UK-India Eduicational Research Initiative (UKIERI) Project on 'Quantum Probability, Noncommutative Geometry and Quantum Information', which ran from 2008 to 2011.
- Principal Investigator from the Indian side in Indo-Israeli joint project titled " $E_0$-semigroups: Classification and Invariants", with Prof. Daniel Markiewicz as the Principal Investigator from Israel, 2014-2018.
- JC Bose Fellowship Project initiated on March 1, 2017.

## Publications

*(a) Thesis*

[1]. Markov Dilations of Nonconservative Quantum Dynamical Semigroups and a Quantum Boundary Theory, submitted to Indian Statistical Institute on July 6, 1993.

*(b) Published Papers*

[2]. On a characterization of velocity maps in the space of observables,**Pacific Journal of Mathematics**, vol. **152**, No.1 : 1-14 (1992); MR **92K:46099**.

[3]. A stochastic differential equation with time dependent and unbounded operator coefficients, (with Kalyan B. Sinha). **Journal of Functional Analysis**, Vol. **114**, 12-31 (1993); MR **95a:60080**.

[4]. Generalized harmonic oscillators in quantum probability, (with K.R. Parthasarathy), **Seminaire de Probabilites** XXV , Springer LNM-**1485** : 39-51 (1991); MR **93k:81117**.

[5]. On greatest common divisor matrices and their applications, **Linear Algebra and Its Applications**,Vol. 158 : 77-99(1991) ; MR **92K:15038**.

[6]. On some convex sets and their extreme points, (with V.Pati and V. S. Sunder), **Mathematische Annalen**, **296**, 637-648 (1993); MR **94f:46076**.

[7]. Kolmogorov's existence theorem for Markov processes in $C^*$ algebras (with K. R. Parthasarathy), **Proceedings of Indian Academy of Sciences ( Math. Sci.)**, Vol.**103**, 253-262 (1994), MR **95g:46118**.

[8]. Markov dilations of nonconservative dynamical semigroups and a quantum boundary theory, (with K. R. Parthasarathy) **Annales de l'Institut Henri Poincare**, Vol. **31**, 601-651 (1995). MR **96i:46079**.

[9]. Examples of unbounded generators leading to nonconservative minimal semigroups, (with Kalyan B. Sinha), **Quantum Probability and Applications**, Vol. **IX**, 89-103 (1994).

[10] An index theory for quantum dynamical semigroups, **Transactions of American Mathematical Society**, Vol. **348** 561-583 (1996); MR **96g:46059**.

[11]. On quantum extensions of semigroups of Brownian motions on an half-line (with F. Fagnola and K.B. Sinha), **Russian Journal of Mathematical Physics, (John Wiley) 4 (1)**, 13-28 (1996), MR **97j:81177**.

[12]. On minimality of Evans-Hudson flows (with F. Fagnola), **Bull. dell' Unione Mat. Ital., Serie VII**, Vol. **IX-A-3p.** (1997) 671-683, MR **98i:81124**.

[13]. Product systems of one dimensional Evans-Hudson flows, **Quantum Probability Communications**, Vol. **X** (1998)187-194. MR **2001h:81127**.

[14]. A generalised intertwining lifting theorem, **the Fields Institute Communications Volume: 20** *Operator Algebras and their Applications, Vol. II*, Ed. P. Fillmore, J. Mingo, (1998) 1-10, MR **99j:47010**.

[15]. Minimal dilations of quantum dynamical semigroups to semigroups of endomorphisms of $C^*$-algebras, **J. Ramanujan Math. Soc. 14**, No. 2 (1999) 109-124. MR **2000m:46132**.

[16]. Cocycles of CCR flows, **Mem. Amer. Math. Soc., 149**, no. 709 (2001). MR **2002e:46083**.

[17]. Tensor product systems of Hilbert modules and dilations of completely positive semigroups (with M. Skeide), **Infin. Dimens. Anal. Quantum Probab. Relat. Top.**, Vol. **3**, Number 4, 519-575(2000). MR **2001m:46149**.

[18]. Minimal isometric dilations of operator cocycles, **Integral Equations and Operator Theory, 42**(2002)125-141. MR **1870435 (2002m:47051)**.

[19]. A model theory for $q$-commuting contractive tuples, (with T. Bhattacharyya), **J. Operator Theory** Vol. **47**(2002), no. 1, 97-116. MR **1905815 (2003c:47018)**.

[20]. Atomic dilations, Advances in quantum dynamics (South Hadley, MA, 2002), 99-107, **Contemp. Math.,** Vol. **335**, Amer. Math. Soc., Providence, RI, 2003. MR **2026012 (2005b:46150)**.

[21]. Standard noncommuting and commuting dilations of commuting tuples. (with Tirthankar Bhattacharyya and Santanu Dey), **Trans. Amer. Math. Soc.** Vol. **356**(2004), no. 4, 1551-1568. MR **2034318 (2005b:47011)**.

[22]. Type I product systems of Hilbert modules, (with S. Barreto, V. Liebscher and M. Skeide), **J. Funct. Anal.** Vol. **212** (2004), no. 1, 121-181. MR **2065240 (2005d:46147)**.

[23]. Regular quantum stochastic cocycles have exponential product systems (with J. Martin Lindsay), in *Quantum Probability and Infinite Dimensional Analysis,* Ed. M. Schurmann and U. Franz, QP-PQ, Vol. XVIII, World Scientific (2004) 126-140. MR **2211885 (2007h:81128)**.

[24]. On product systems arising from sum systems (with R. Srinivasan), **Infinite Dimensional Analysis, Quantum Probability and Related Topics,** Vol. **8**, no. 1 (2005) 1-31. MR **2126876 (2006e:46075)**.

[25]. A completely entangled subspace of maximal dimension, **International Journal of Quantum Information,** Vol. **4**, No. 2 (2006) 325-330.

[26]. Minimal Cuntz-Krieger dilations and representations of Cuntz-Krieger algebras, (with Santanu Dey and J. Zacharias), **Proceedings of the Indian Academy of Sciences, Mathematical Sciences,** Vol. **116** (2006), No. 2, 193-220. MR **2226131 (2007h:46066)**.

[27]. Integrators of matrices, (with Mithun Mukherjee), Integrators of matrices. **Journal of Linear Algebra and its Applications,** Vol. **426** (2007), no. 1, 71–82. MR **2344560**.

[28]. A Problem of Powers and the Product of Spatial Product Systems, (with Volkmar Liebscher and Michael Skeide), Proceedings of the 28th Quantum Probability Conference, Sep 2-8, 2007, held in Guanajuato, Quantum probability and related topics, 93-106, QP-PQ: Quantum Probab. White Noise Anal., 23, World Sci. Publ., Hackensack, NJ, (2008). MR2590656 (2011c:46142).

[29]. Maximal Commutative Subalgebras Invariant for CP-Maps: (Counter-)Examples, (with Franco Fagnola and Michael Skeide ) **Infinite Dimensional Analysis, Quantum Probability and Related Topics (IDAQP)** Vol. 11, No. 4 pp. 523-539. (2008). **arXiv:0804.1864** , MR **2483795** (2009m:46100).

[30]. Inclusion systems and amalgamated products of product systems (with Mithun Mukherjee), **Infinite Dimensional Analysis Quantum Probability and Related Topics (IDAQP)** Vol. 13, No. 1, 1-26, (2010) MR**2646788 (2011f:46087)**.

[31]. Subsystems of Fock Need Not Be Fock: Spatial CP-Semigroups, (with Volkmar Liebscher and Michael Skeide ), **Proceedings of the American Mathematical Society** 138 no. 7, 2443–2456, (2010). **arXiv:0804.2169** MR **2607874**.

[32]. Stinespring's theorem for maps on Hilbert C*-modules (with G. Ramesh and K. Sumesh), **J. Operator Theory** 68:1(2012), 173-178. MR2966040

[33]. The spatial product of Arveson systems is intrinsic. (with Volkmar Liebscher, Mithun Mukherjee, Michael Skeide) **J. Funct. Anal.** 260, no. 2, 566-573 (2011),MR **2737413** (2011k:46090).

[34]. Linear maps respecting unitary conjugation, **Banach J. of Math. Anal.** Vol. 5, No. 2, 1-5 (2011). MR2780863 (2012d:47111)

[35]. Roots of states, **Communications on Stochastic Analysis** Vol. 6, No. 1 (2012) 85-93. MR2890852.

[36] Bures distance for completely positive maps (with Sumesh K.), **Infinite Dimensional Analysis Quantum Probability and Related Topics** 16 (2013), no. 4, 135001, 22pp MR3192708.

[37] The Schur-Horn theorem for operators with finite spectrum, with Mohan Ravichandran, **Proceedings of the American Mathematical Society** 142 (2014), no. 10, 3441-3453. MR3238420.

[38] Nilpotent completely positive maps (with Nirupama Mallick). **Positivity** 18 (2014), no. 3, 567-577. MR3249920.

[39] On submajorization and eigenvalue inequalities, (with Arup Chattopadhyay, G. Sankara Raju Kosuru), **Linear Multilinear Algebra** 63 (2015), no. 11, 2245-2253. MR3401940

[40] Stability of Quantum Dynamical Semigroups (with Sachi Srivastava), Operator semigroups meet complex analysis, harmonic analysis and mathematical physics, (Ed. W. Arendt, R. Chill and Y. Tomilov), Operator Theory: Advances and Applications, Vol. 250, 67-85 (2015).

[41] Pure semigroups of isometries on Hilbert C*-modules, ( with Michael Skeide),**Journal of Functional Analysis** 269 (2015), no. 5, 1539-1562. MR3369946.

[42]. On the equivalence of separability and extendability of quantum states, (with K. R. Parthasarathy and Ritabrata Sengupta), **Reviews in Mathematical Physics**, Vol. 29, No. 4 (2017) 1750012.

[43] Regular representations of completely bounded maps (with Nirupama Mallick and K. Sumesh), **Pacific Journal of Mathematics** Vol. 289 (2017), No. 2, 257-286. DOI: 10.2140/pjm.2017.289.257.

[44] Additive units of product systems (with J. Martin Lindsay and Mithun Mukherjee), **Transactions of the American Mathematical Society**, 370 (2018), no. 4, 2605-2637. MR3748579.

[45] Real Normal Operators and Williamson's Normal Form (with Tiju Cherian John), Acta Sci Math (Szeged), Volume 85, Numbers 3-4, ( 2019), 507-518.

[46] Infinite mode quantum Gaussian states (with Tiju Cherian John and R. Srinivasan), Rev. Math. Phys. 31 (2019), no. 9, 1950030, 33 pp. 8. MR4014466.

[47] Roots of completely positive maps (with Robin Hillier, Nirupama Mallick, and Vijaya Kumar U ). Linear Algebra Appl. 587 (2020), 143-165. MR4030295.

[48] Structure of block quantum dynamical semigroups and their product systems (with Vijaya Kumar U), Infin. Dimens. Anal. Quantum Probab. Relat. Top., Vol. 23, No. 01, 2050001 (2020). arXiv:1908.04098.

*(c) Preprints*

1. Two states (with Mithun Mukherjee), to appear in the Houston Journal of Mathematics. arXiv:1710.00180.

2. A factorization property of positive maps on $C^*$-algebras, (with H. Osaka), to appear in the International Journal of Quantum Information. arXiv:1912.02381.

3. A caricature of dilation theory (with Sandipan De and N. Rakshit), arXiv:2004.09255

4. Stinespring's Theorem for Unbounded Operator valued Local completely positive maps and Its Applications, (with Anindya Ghatak and P. Santhosh Kumar), arXiv:2004.12717

5. $C^*$-extreme points of positive operator valued measures and unital completely positive maps, (with Tathagata Banerjee and Manish Kumar), arXiv:2006.07076.

*(d) Books*

1. Lectures on Operator Theory, (Editor jointly with G. Elliott and P. Fillmore), Fields Institute for Research in Mathematical Sciences Monograph Series, Vol. **13**, Amer. Math. Soc. 323pp. (1999). MR **2001j:46077**.

2. Quantum Independent Increment Processes I: From classical probability to quantum stochastic calculus. (with David Applebaum, Johan Kustermans, J. Martin Lindsay ), Springer Lecture Notes in Mathematics, 1865 (Ed. M. Schurmann and U. Franz), Springer-Verlag, Berlin, (2005). MR**2132092 (2005j:81087)**.

*(e) Reports*

1. Mini-Workshop: Product Systems and Independence in Quantum Dynamics. Abstracts from the mini-workshop held February 15-21, 2009. Organized by B. V. Rajarama Bhat, Uwe Franz and Michael Skeide. Oberwolfach Reports. Vol. 6, no. 1. Oberwolfach Rep. 6 (2009), no. 1, 493-547, MR **2604064.** [Report of a Workshop on recent developments in the field].

*(f) Expository articles*

1. Continuous tensor product systems of Arveson and Powers' Index Theory for $E_0$-semigroups, Centro Vito Volterra (Preprint series No. 177), Universita Degli Studi di Roma "Tor Vergata", June 1994.

2. Dilations of quantum Markov semigroups, in *Symposium on Recent developments in E-semigroups and related topics,* Ritsumeikan University, Japan (2005).

3. Operators as Random Variables, in Proceedings of the UGC sponsored national seminar on spectral theory of operators and wavelet analysis, NSS College, Ottapalam, 45-51 (2006).

4. Wigner's Semicircle Law and Free Independence, **Resonance, J. of Science Education**, Vol. 14, No 10, 970-977 (Oct. 2009).

5. Invariants, **Resonance, J. of Science Education**, Vol. 15, No. 7 595-603 (July 2010).

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