Curriculum Vitae of

GUTTI JOGESH BABU

Director, Center for Astrostatistics

http://astrostatistics.psu.edu

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Citizenship: United States of America

Employment:

1985–present	Professor of Statistics, Pennsylvania State University.
2012–	Professor of Astronomy & Astrophysics, Penn State University.
January 1982–85	Professor, Indian Statistical Institute, India.
1976–December 1981	Associate Professor, Indian Statistical Institute, India.

Education:

1970	M. Stat., Indian Statistical Institute, Calcutta, India.
1974	Ph. D., Indian Statistical Institute, Calcutta, India.

Honors:

Elected Fellow - Institute of Mathematical Statistics.
Elected Fellow - American Statistical Association.
Elected Fellow - American Association for the Advancement of Science.
Elected Member - International Statistical Institute.
Elected Member - International Astronomical Union.
Fellow – International Astrostatistics Association (IAA).
First-ever Outstanding Contributions to Astrostatistics award - IAA.
The *American Statistical Association* (ASA) Astrostatistics Interest Group and the *American Astronomical Society* (AAS) Working Group on Astroinformatics and Astrostatistics have jointly established an award in G. Jogesh Babu's name. The G. Jogesh Babu Young Researcher Travel Award in Astrostatistics is an annual award that will fund students and postdocs to present, at national meetings, papers that develop & apply statistical methods to challenging problems in astronomy & cosmology.
National Research Council's Twinning Fellowship for 1997-1999.
Research Professor, Mathematical Sciences Research Institute, Berkeley (Jan.–Mar. 2005).
Mid-Atlantic Region University Continuing Education Association award for exemplary non-credit program development (Summer school in statistics for astronomers), 2007.
The book *Modern Statistical Methods for Astronomy with R applications*, won the 2012 Association of American Publishers' PROfessional and Scholarly Excellence Award in the Cosmology and Astronomy Category.

Visiting Appointments:

Sept.-Dec. 2016	Statistical and Applied Mathematical Sciences Institute (SAMSI), Research Triangle Park, NC
Sept.-Dec. 2012	SAMSI, Research Triangle Park, NC

Jan.-May. 2006	University Fellow, SAMSI & University of North Carolina, Chapel Hill
Jan. 2005	University of Hyderabad, India
Dec. 1998	Indian Statistical Institute, India
Oct.–Nov. 1998	Rutgers University
Sep.–Oct. 1998	Concordia University, Canada
June 1995	National Sun Yet-sen University, Kaohsiung, Taiwan
May 1995	Indian Statistical Institute
March 1992	Mathematical Sciences Research Institute, Berkeley
Nov. 1991	Monash University, Australia
Fall 1982	University of Ottawa
1981–1982	Rutgers University
Spring 1981	University of Arizona
Nov.–Dec. 1980	Math. Inst. of the Hungarian Academy of Sciences, Budapest
Summer 1980	University of Ottawa
1975–1976	University of Oregon
1974–1975	University of Illinois at Urbana-Champaign
1973–1974	Tata Institute of Fundamental Research, India

Editorial and Professional Service:

Editor-in-Chief, *Statistical Methodology* (2003 - 2016).

Series Editor, *Springer Series in Astrostatistics* (2011 -);
http://link.springer.com/bookseries/1432.

Coordinating Editor, *Journal of Statistical Planning and Inference* 1998 - 2004, and Associate Editor 1995 - 1997.

Associate Editor, *Journal of Nonparametric Statistics* 1989 - 2007.

Co-Editor, *Sankhyā*, Series A 1981 - 1993 and 1999 - 2007.

Advisory Committee for *Sankhyā* 1993 - 1999.

Search committee to select editors for the journal Sankhya 1998.

Babu and an astronomer colleague **coined** the term **Astrostatistics** in mid 1990s, while publishing a book by the same name.

Institute of Mathematical Statistics (**IMS**):
Chair, IMS Committee on **Fellows** 2002 - 2003.
Member, IMS Committee on Fellows 2001 - 2004.

American Statistical Association (**ASA**):
Member, ASA Committee on Scientific Freedom and Human Rights (Jan. 2010 - Dec. 2015).

International Statistical Institute (**ISI**):
Chair (2017-), Management Committee, Astrostatistics Special Interest Group.

International Astrostatistics Association (**IAA**):
Interim President (2017-) of IAA (http://iaa.mi.oa-brera.inaf.it)
Vice-President of IAA (2012-2017).

Statistical and Applied Mathematical Sciences Institute (**SAMSI**):
Chair, Program Leaders Committee, SAMSI 2016-17 Program on Statistical, Mathematical and Computational Methods for Astronomy (ASTRO), August 2016 - May 2017.
Chair, Program Leaders Committee, SAMSI Astrostatistics Program, January - May 2006.
Led the Astrostatistics group as part of 2012-2013 SAMSI program on *Statistical and Computational Methodology for Massive Datasets*.

Large Synoptic Survey Telescope (**LSST**), `http://lsst.org`:
Core Team Member, **LSST** *Informatics and Statistics Science Collaboration* (2009 -).
Member, **LSST** *Weak Lensing Science Collaboration team* (2006 -).

Kepler Mission: Member, review committee of Kepler Mission Occurrence Rate products and analysis plans. (October 9-10, 2014).

Summer Schools in Statistics for Astronomers:
Organized annual *Summer Schools in Statistics for Astronomers* since 2005 at Penn State. Also organized these summer schools in collaboration with the *Indian Institute of Astrophysics* in July 2007, July 2008, July 2010, and July 2013, at Vainu Bappu Observatory located near the village of Kavalur in India.

Astrostatistics School:
Organized an astrostatistics school for the Instruments Division at the Space Telescope Science Institute (STScI, http://www.stsci.edu/portal/) in September - November 2011.

International Indian Statistical Association (IISA): *Program Chair* 1998 - 2000.
Editorial Board, IISA Conference Proceedings Volume.

Served on NSF and NASA panels, including:
NSF Cyber-Enabled Discovery and Innovation Panel, NSF Software Infrastructure Panel, NASA Postdoc panel, NASA AISR Panel, NSF Mathematical Innovations in Astronomy Panel, NSF Mathematical Sciences Postdoctoral Research Fellowships panel, Member of Executive committee for NSF MSP Postdoc panel.

Reviewed research proposals for *NSF*, *NSA*, *Air Force Office of Scientific Research* and *Natural Sciences and Engineering Research Council of Canada*.

Written over 215 reviews for *Mathematical Reviews* and *Zentralblatt*.

Referee for the journals: Annals of Probability, Annals of Statistics, The Astrophysical Journal, The Astrophysical Journal Letters, Sankhyā, Probability Theory and Related Fields, Journal of the American Statistical Association, Journal of Multivariate Analysis, Journal of Environmental and Ecological Statistics, Annals of the Institute of Statistical Mathematics, Communications in Statistics, Canadian Journal of Statistics, Journal of Statistical Planning and Inference, Econometric Theory, Indian Journal of Statistics, Monthly Notices of the Royal Astronomical Society, Proceedings of the Royal Society, Statistics and Probability Letters, Sociological methodology, Technometrics.

Research Interests:

Bootstrap and other resampling methods. Statistical applications to Astronomy, Physics, and Climatology. Analysis of massive data. Nonparametric Methods. Inference for misspecified models. Goodness-of-fit tests when parameters are estimated. Edgeworth expansions. Statistical Group

Theory and its applications. Inference on finite populations. Density quantile estimation. Asymptotic theory of empirical processes, quantiles, functions of marginal quantiles, and L-statistics. Functional limits theorems. Large and Moderate deviations for dependent variables. Moderate deviations in general topological spaces. Probabilistic and Analytic number theory.

Research Grants:

2016–2019 Senior Personnel for 'Advanced Statistics in the Search for Planets'. (PI. Eric Feigelson). ≈ $0.3M. 9/1/2016 to 8/31/2019 .NSF No.AST-184636.

2016–2017 Principal Investigator for 'Research Fellow at the Statistical and Applied Mathematical Sciences Institute'. University of North Carolina at Chapel Hill (NSF Prime). $34,751. 8/1/2016 to 5/31/2017. Agency Award No. 5105085.

2016–18 Principal Investigator for '2016 Summer School in Statistics for Astronomers'. $5,000. 5/15/2016 to 4/30/2018. NSF No. AST-1613056.

2015–17 Principal Investigator for '2015 Summer School in Statistics for Astronomers'. $34,000. 6/1/2015 to 5/31/2017. NSF No. AST-1523283.

2014–16 Principal Investigator for '2014 Summer School in Statistics for Astronomers'. $48,013. 4/15/2014 to 3/31/2016. NSF No. AST-1418179.

2013–15 Principal Investigator for '2013 Summer School in Statistics for Astronomers'. $28,604. 2/15/2013 to 1/31/2015. NSF No. AST-1304920.

2012–14 Principal Investigator for '2012 Summer School in Statistics for Astronomers'. $24,269. 3/15/2012 to 2/28/2014. NSF No. AST-1212302.

2011–13 Principal Investigator for '2011 Summer School in Statistics for Astronomers, and The Fifth Statistical Challenges in Modern Astronomy Conference'. $34,799. 5/1/2011 to 4/30/2013. NSF No. AST-1113001.

2010–14 Principal Investigator for 'SI2-SSE: Statistical software for astronomical surveys'. $450,000. 9/15/2010 - 8/31/2014. NSF No. AST-1047586.

2010–12 Principal Investigator for '2010 Summer School in Statistics for Astronomers'. $32,172. 3/1/2010 to 2/29/2012. NSF No. AST-1019605.

2009–11 Principal Investigator for '2009 Summer School in Statistics for Astronomers; June 8-13, 2009'. $33,359. 3/15/2009 to 2/28/2011. NSF No. AST-0915069.

2008–10 Principal Investigator for '2008 Summer School in Statistics for Astronomers; June 9-14, 2008', Co-PI Eric Feigelson. $33,131. 3/1/2008 to 2/28/2010. NSF No. AST-0808877.

2007–10 Principal Investigator for 'MSPA-AST: Advancing statistical methodology in massive astronomical surveys', Co-PI Eric Feigelson. $100,000. 9/15/2007 to 8/31/2010. NSF No. AST-0707833.

2007–08 Scientific Computing Research Environments for the Mathematical Sciences (SCREMS), Co-P.I. - G. J. Babu. $50,000. 9/1/2007 to 8/31/2008. NSF No. DMS-0722351.

2005–2006 Principal Investigator for 'Statistical Challenges in Modern Astronomy IV'. $20,000. 9/15/2005 to 12/14/2006. NASA grant No: NNG05GQ16G.

2005–2007 Principal Investigator for 'Research Experience for Undergraduates' supplement (NSF Grant No. AST-0535454) to "Astrostatistics: Advancing statistical methodology for Astronomy" $12,000. 7/5/2004-9/30/2007. NSF No: AST-0434234.

2004–2008 Principal Investigator for "Astrostatistics: Advancing statistical methodology for Astronomy", Co-PI Eric Feigelson. $508,359. 10/1/2004 to 9/30/2008. NSF No: AST-0434234.

2004–2007 Principal Investigator for "Center for Astrostatistics", $35,000. Penn State's Outreach Program Innovation Fund.

2003–2008 ITR: Grid Service Workflow System as a Research Environment for Science with Massive Data Sets, Co-I G. J. Babu (PI. Roy D. Williams) NSF No. AST-0326524. $3,117,508. (Penn State's share $215,000). 10/1/2003 to 3/31/2008.

2003–04 Scientific Computing Research Environments for the Mathematical Sciences (SCREMS), Co-P.I. - G. J. Babu. $65,347. 8/1/2003 to 7/31/2004. NSF No. DMS-0322673.

2003–04 Principal Investigator for 'Research Experience for Undergraduates' supplement (Grant No. DMS-0332264) to, "Multivariate Statistical Methodology for the Virtual Observatory". $10,000. 6/15/2001 to 5/31/2004. NSF No. DMS-0101360.

2001–04 Principal Investigator for the project, "Multivariate Statistical Methodology for the Virtual Observatory", Co-PI Eric Feigelson. $1,016,289. 6/15/2001 to 5/31/2004. NSF No. DMS-0101360.

2001–02 Principal Investigator for the project, "Conference on Statistical Challenges in Modern Astronomy III", Co-PI Eric Feigelson. $20,000. 3/1/2001 to 2/28/2002. NSF No. DMS-0096490.

2001–02 Principal Investigator for the project, "Conference on Statistical Challenges in Modern Astronomy III", funded by NASA. $20,000. 3/15/2001 to 3/14/2002. No. NAG5-10542.

2001 Principal Investigator for the project, "Conference on Statistical Challenges in Modern Astronomy III", funded by the Division of Continuing Education, Penn State University. (Program Innovation Fund) $4,000.

2000–01 Co-Principal Investigator for the project, "Conference on Statistical Challenges in Modern Astronomy III". $2,000. 10/1/2000 to 12/31/2001. The Pennsylvania Space Grant Consortium.

2000-01 Scientific Computing Research Environments for the Mathematical Sciences (SCREMS), Co-P.I. - G. J. Babu. $25,251. 9/1/2000 to 8/31/2001. NSF No. DMS-0079656.

1997–99 National Research Council's Twinning Fellowship, for travel to Lithuania and to host Professor E. Manstavičius for a month each year. $13,600. 9/1/1997 to 12/31/1999.

1997–99 Principal Investigator for the project, "Large Sample Methods". $45,503. 2/25/97 to 2/24/99. NSA No. MDA904-97-1-0023.

1996–99 Principal Investigator for the project, "Multivariate Estimation for Astronomy." $95,000. 8/1/96 to 7/31/99. NSF No. DMS-9626189.

1996–97 Co-principal Investigator for IAU Technical Workshop, "Conference on Statistical Challenges in Modern Astronomy II", funded by IAU. $1,831.95. From 4/1/96 till expended.

1995–97 Co-principal Investigator for the project, "Conference on Statistical Challenges in Modern Astronomy II", funded by NSF. $12,000. 6/15/95 to 5/31/97. No. DMS-9504783.

1995–96 Co-principal Investigator for the project, "Conference on Statistical Challenges in Modern Astronomy II", funded by Continuing and Distance Education, Penn State University. (Program Development Fund) $7,500.

1995–96 Principal Investigator for the project, "Conference on Statistical Challenges in Modern Astronomy II", funded by International Science Foundation, New York. Supported travel for two Russians.

1995–96 Principal Investigator for the project, "Conference on Statistical Challenges in Modern Astronomy II", funded by NASA. $15,000. 7/1/95 TO 12/31/96. No. NAGW-4793.

1994–95 Principal Investigator for the project "Planning Visit to India", funded by NSF. $2,200. January 1995 to December 1995. No. INT-9419424.

1992–95 Co-principal Investigator for the project, "Multivariate and Censored Data Analysis Methods for Astronomy", funded by NSF. 7-15-92 to 8-14-95. No. DMS-9208066.

1991 Principal Investigator for the project, "International Conference on – Statistical Challenges in Modern Astronomy", funded by NSF.$16,000. 1/1/91 to 12/31/91. No. DMS-9003083.

1990–1995 Co-Investigator for the project, "Multiwavelength and Statistical Research in Space Astrophysics", funded by NASA Long-term Space Astrophysics Research Program. 6/1/90 to 5/31/95. $120,000 per year. No. NAGW-2120.

1990–1992 Co-Principal Investigator for the project, "Advanced Statistical Methods for Analyzing Data from Astronomical Surveys", funded by NSF. 7/1/90 to 6/30/92. $68,450. No. DMS-9007717.

1990–1992 Principal Investigator for the project, "Edgeworth Expansions and Bootstrap", funded by National Security Agency. $30,000. 7/1/90 to 6/30/92. No. MDA904-90-H-1001.

1990–1992 Co-Principal Investigator for the project, "Advanced Statistical Methods for Improved Data Analysis of NASA Astrophysics Missions", funded by NASA's Astrophysics division. $83,000. 2/1/90 to 1/31/1992. No. NAGW-1917.

1989–1990 Co-Principal Investigator for the project, "Mathematical Sciences Research Equipment," funded by NSF. $41,683. July 1989 to June 1990. No. DMS–8905785.

1988–1990 Research Associate for the project, "Applications of advanced statistical methods to satellite survey," funded by Jet Propulsion Lab/NASA. $27,000. No. JPL-958013.

1988–1989 Co-Principal Investigator for the project, "Evaluate Statistical designs for travel surveys and formulate pilot sampling design", funded by Chesapeake Bay Stock Assessment Program of USDC. $75,000. 8/1/88 to 7/31/89.

1987–1988 Co-Principal Investigator for the project, "Mathematical Statistics and Statistics for Analysis and interpretation in Marine Fisheries Research and Management", funded by USDC. $73,333. 3/1/87 to 8/31/88.

1987–1988 Research Director and Principal Investigator for a project funded by Chesapeake Bay Stock Assessment Program. $50,000.

1986–1987 Co-Principal investigator, for two projects funded by NOAA. The total grant for these two projects is $195,000.

1985–1986 Worked with the Ecology group on a grant from National Oceanic and Atmospheric Administration (NOAA).

Ph.D. Students Supervised:

Kesar Singh, 1980, Indian Statistical Institute. Professor at Rutgers University, USA. (Passed away in 2011.)

Bhaskar Bagchi, 1983, Indian Statistical Institute. Professor at Indian Statistical Institute, Bangalore, India.

Arup Bose, 1987, Indian Statistical Institute. Professor at Indian Statistical Institute, Calcutta, India.

Regis Serinko, 1990. The Pennsylvania State University.

Kang, Hee-Jeong, 1995. Chonbuk National University, Chonju, Korea.

Mark Leeds, 2000.

James McDermott, 2003. State Street Associates, Cambridge, MA.

Hyun-sook Lee, 2006. Lam Research Korea.

Scott Roths, 2011. The Pennsylvania State University.

SaeNa Park, 2015. Samsung, S. Korea.

Doctoral Committees:

1986–87 Ernst Linder (Statistics) – Special Member.
1986–87 Ken Suman (Statistics) – Special Member.
1988–89 Ranga V. Ramasesh (Business Administration).
1988–89 Joe Scazzero (Business Administration).
1988–89 Gunnar Stefansson (Mathematics).
1988–90 Zhijun Liu (Statistics).
1988–90 Min Deng (Statistics).
1989–90 Regis Serinko (Statistics) – Advisor.
1989–91 Clint Coakley (Statistics).
1988–91 K. V. K. Prasad (Mining Engineering).
1989–92 Venkateshwar Reddy (Finance).
1989–92 Nandini Kannan (Statistics).
1991–95 Hee-Jeong, 1995 (Statistics) – Advisor.
1996–97 Rajiv Dama (Mechanical Engineering).
1996–99 Arthur Dryver (Statistics).
1995–00 Mary E. Stocken (Business Administration).
1998–00 Mark Leeds (Statistics) – Co-chair.
2000–03 James McDermott (Statistics) – Co-advisor.
2000–05 Srikant Vadali (Business Administration).
2003–06 Hyun-sook Lee (Statistics) – Advisor.
2005–07 Derek Young (Statistics).
2007–09 Kagan Kursungoz (Mathematics).
2007–11 Scott Roths (Statistics) – Advisor.
2007–11 Arseny Egorov (Mathematics).
2009–12 Day Prapanpong (Mathematics).
2011–14 Michael Kuhn (Astronomy & Astrophysics).
2012–15 Sae Na Park (Statistics) – Advisor.
2013–15 Benjamin Nelson (Astronomy & Astrophysics).
2013–16 Robert C. Morehead (Astronomy & Astrophysics).
2011–16 Jason Lee Curtis (Astronomy & Astrophysics).
2014–17 Nicholas Benjamin Senno (Physics).
2014– Gabriel Caceres (Astronomy & Astrophysics).
2016– Colin Turley (Physics).
2016– Danley Hsu (Astronomy & Astrophysics).

Masters Theses Supervised:

Regis Serinko (1988-1989)

Hyun-sook Lee (2001-2003)

Andrea De Maria (2012, Co-supervised with Professor Riccardo Borgoni of Università degli studi Milano Bicocca).

Master's Thesis Committees: Anamagdalen Nitica (1994), Derek Young (2005).

Undergraduate Students: (*Research Experience for Undergraduates*) Xiao-Yi Li (BS Honors) 2003, Stas Sheynkop (BS Honors) 2004, Tae W. Kang 2004, Michael L. Rogers, 2005, and Matthew A. Lohr (BS Honors) 2006.

Department of Statistics Committees:

Chair, Five year post tenure faculty performance evaluation committee 2000, 2006, 2010, & 2016.

Chair, Ph.D. qualifier exam committee 2010 (Member 2009, 2014-15).

Chair, Faculty hiring committee 1996–1997, & 2011–2012.

Chair, C.R. and Bhargavi Rao Prize selection committee 2003, 2005, 2007, 2009, & 2011 (Member 2014).

Professor-in-charge, Master of Applied Statistics Program 2001–2007.

Chair, Awards Committee 2004–2005.

Chair, Department's World Campus Program 1998–2002.

Chair, Promotion and Tenure Committee 1989.

Graduate Admissions Committee (2014, 2015)

Graduate program committee 2005–2012.

Fixed term faculty review committe 2010.

Interdisciplinary Activities Committee 2008-2009.

Faculty Recruiting Committee 2001–2004.

Eberly College of Science Committees:

Chair, Selection Committee for the John M. Chemerda Lectures in Science 2003–2004. (Member 1988–1989, & 1992–1993).

AD-14 Review Committee (2016-2017).

Interdisciplinary Science BS Advisory Group 2012–2013.

Academic Integrity Committee (2013-).

Outreach Council 2005–2013.

Sabbatical Leave Review Committee 2006.

Strategic Vision Committee 2004–2005.

Immediate Tenure committee 1998, & 2004.

Eberly College Promotion and Tenure Committee 1993–1995, & 2000–2002.

College of Science Promotion and Tenure Committees
Mathematical Sciences 1988, 1989, & 1991; *Biological Sciences* 1990.

University Committees:

Chair, Committee on Academic Standards, Graduate Council, Graduate Council, 1997–1998 & 2004–2005.

Chair, Subcommittee on World Campus (Faculty Senate committee on outreach activities) 1999–2000.

Graduate Council 1997-1999, 2003-2005, 2012–2014, & 2015-2017.

Executive Committee, Graduate Council 1998-1999, 2003-2005, 2012-2014, & 2015-2017.

Focus group to review Multimedia & Print Center (MPC), as part of Economic and Structural Review (ESR) initiative for the Penn States strategic plan for Finance and Business (F&B) 2017.

Alternate on Graduate Council 2011–2012.

Graduate Council representative to the University Faculty Senate's Committee on Intra-University Relations 2012–2014, & 2015-2017.

Faculty Senate's Intra-University Relations' subcommittee on Assessment 2012–2013.

Faculty Senate's Intra-University Relations' subcommittee for the Student Transition Between Campuses 2013-2014.

Penn State Review Panel on Outreach Scholarship Conference (a partnership between Penn State, the University of Wisconsin-Extension, Ohio State, and the University of Georgia 2006.

Ad Hoc Committee on Professional Master's Programs, Graduate Council 2004–2005.

Penn State World Campus Steering Committee 1998–1999, & 2001–2005.

Implementation Committee on Electronic Theses and Dissertations 1998–2003.

Penn State Faculty Outreach Award Selection Committee 1998, & 2000-2002.

Faculty Senate Committee on Outreach Activities 1997–2002.

Graduate Council Subcommittee on Programs Review and Evaluation 2000–2001.

ETD sub-committee on Communication and Information 1999.

Committee on Committees and Procedures, Graduate Council 1997–1999.

Graduate Council's World Campus Working Group 1999.

Organization of Conferences and Schools:

Co-chair, Scientific Organizing Committee for the international conference on *Statistical Challenges in Modern Astronomy*. August 11–14, 1991. This inter–disciplinary conference is cosponsored by *IMS, NASA* and *NSF*.

Organized an invited paper session on *Statistics in Astronomy*, at 1993 Joint Statistical Meetings in San Francisco. Also chaired the session.

Co-chair, Scientific Organizing Committee for the international conference on *Statistical Challenges in Modern Astronomy II*. June 2–5, 1996. This inter–disciplinary conference is cosponsored by *IMS, ISI, IAU, ISF, NASA* and *NSF*.

Organized an invited paper session on 'Astrostatistics' for International Astronomical Union at 51st session of the International Statistical Institute, Istanbul, August 18-27, 1997.

Organized a session on 'Astrostatistics' (Track: Emerging Science: Transforming the Next Generation) at AAAS Annual meeting and science innovation exposition in Philadelphia, in February 1998.

Organized 'Subramanyan Chandrasekhar Memorial Session on Astrostatistics' on August 12, 1999, Joint Statistical Meetings in Baltimore.

Organized a session on 'Data Mining' in August 2000, at Joint Statistical Meetings in Indianapolis.

Member, Organizing Committee for the International Conference in Statistics in Calcutta, India during December 29-30, 2000.

Organized a session on 'Resampling methods' at the International Conference in Statistics in Calcutta, India during December 29-30, 2000.

Member, Advisory Committee for Joint Statistical Meeting in New Delhi, India during December 30, 2000 - January 2, 2001.

Organized a session on 'Astrostatistics' at the Joint Statistical Meeting in New Delhi, India during December 30, 2000 - January 2, 2001.

Co-chair, Scientific Organizing Committee for the international conference on *Statistical Challenges in Modern Astronomy III*. The Pennsylvania State University, July 18-21, 2001. This inter–disciplinary conference is cosponsored by *NASA, Penn State University* and *Pennsylvania Space Grant Consortium*.

Member, Program Committee for the conference 'Astronomical Data Analysis', part of *The International Society for Optical Engineering*'s (SPIE) Symposium on Optical Science and Technology, in San Diego, 29 July - 3 August 2001.

Member, Program Committee for the conference 'Astronomical Data Analysis II', part of *SPIE*'s Symposium on Astronomical Telescopes and Instrumentation, in Waikoloa, Hawaii, 22 - 28 August 2002.

Member, Scientific Organizing Committee at for the conference *Astronomical Data Analysis- III*, in Sant' Agata sui due Golfi (NA), Italy, 29 April to 1 May 2004.

Organized a session on 'Astrostatistics' at the International Conference on the *Future of statistical theory, practice and education*, at Hyderabad, India. December 29, 2004 - Jan 1, 2005.

Organized a *Summer School in Statistics for Astronomers and Physicists* at Penn State, during June 5-17, 2005.

Organized a *SAMSI Astrostatistics program planning meeting* at NASA Ames Center during July 14-15, 2005.

Chair of the Program Leaders Committee, and directed a semester long *Astrostatistics program* at SAMSI during January - May 2006.

Organized *Tutorials* for astronomers and statisticians at SAMSI (January 18-22, 2006).

Organized the *Opening Workshop* to focus on the scientific agenda of the Astrostatistics program at SAMSI (January 23-25, 2006).

Organized the second *Summer School in Statistics for Astronomers and Physicists* at Penn State, during June 6-10, 2006.

Co-Chair, Scientific Organizing Committee for 'Statistical Challenges in Modern Astronomy IV', held at Penn State University during June 12-15, 2006.

Member, Scientific Organizing Committee for *Astronomical Data Analysis IV*, held at Laboratoire d'Astrophysique deMarseille, Marseille, France, during September 18-20, 2006.

Organized the third *Summer School in Statistics for Astronomers* at Penn State, during June 4-9, 2007.

Organized a *Summer School in Statistics for Astronomers*, in collaboration with *The Indian Institute of Astrophysics, Bangalore*, at the Vainu Bappu Observatory near the village of Kavalur in India, during July 2-7, 2007.

Member, Scientific Organizing Committee for *Astronomical Data Analysis V*, Heraklion, Crete (Greece), during May 7-9, 2008.

Organized the fourth *Summer School in Statistics for Astronomers* at Penn State, during June 9-14, 2008.

Organized the second *Summer School in Statistics for Astronomers*, in collaboration with *The Indian Institute of Astrophysics, Bangalore*, at the Vainu Bappu Observatory near the village of Kavalur in India, during July 9-16, 2008.

Organized the fifth *Summer School in Statistics for Astronomers* at Penn State, during June 1-6, 2009.

Member, Scientific Organizing Committee for *III INPE Advanced Course on Astrophysics: Astrostatistics*, to be held at Sao Jose dos Campos-SP, Brazil, during September 14-18, 2009.

Member, Scientific Organizing Committee for *ADA VI – Astronomical Data Analysis*, conference in Honor of Albert Bijaoui, held at Monastir, Tunisia, during May 3-6, 2010.

Organized the sixth *Summer School in Statistics for Astronomers* at Penn State, during June 7-12, 2010. This was followed by a supplementary program on Statistics and Computation for Astronomical Surveys (June 12-14, 2010).

Organized the third *Summer School in Statistics for Astronomers*, in collaboration with *The Indian Institute of Astrophysics, Bangalore*, at the Vainu Bappu Observatory near the village of Kavalur in India, during July 19-27, 2010.

Organized the seventh *Summer School in Statistics for Astronomers* at Penn State, during June 6-10, 2011. This was followed by a two-day tutorials on three different topics (June 11-12, 2011).

Co-Chair, Scientific Organizing Committee for the cross-disciplinary conference, 'Statistical Challenges in Modern Astronomy V' to be held in June 13-17, 2011.

Organized an astrostatistics school for the Instruments Division at the Space Telescope Science Institute (STScI, http://www.stsci.edu/portal/) in September - November 2011.

Member, Scientific Organizing Committee, *ADA VII – Astronomical Data Analysis* conference, Cargese, Corsica, France, May 14-18, 2012.

Co-organized *Astrostatistics* workshop during September 19-21, 2012, at SAMSI, Research Triangle Park, NC.

Organized the eighth *Summer School in Statistics for Astronomers* at Penn State, during June 4-8, 2012.

Organized *Astrostatistics* sub-program along with four working groups as part of '2012-13 Program

on Statistical and Computational Methodology for Massive Datasets' at SAMSI, Research Triangle Park, NC during Fall 2012.

Working Group leader , at SAMSI during Fall 2012, for *MD Discovery & Classification in Synoptic Surveys* group

Organized the ninth *Summer School in Statistics for Astronomers* at Penn State, during June 3-7, 2013.

Organized the fourth *Summer School in Statistics for Astronomers*, in collaboration with *The Indian Institute of Astrophysics, Bangalore*, at the Vainu Bappu Observatory near the village of Kavalur in India, during July 22-29, 2013.

Organized the tenth *Summer School in Statistics for Astronomers* at Penn State, during June 2-13, 2014.

Organized the eleventh *Summer School in Statistics for Astronomers* at Penn State, during June 1-5, 2015.

Organized the twelfth *Summer School in Statistics for Astronomers* at Penn State, during May 31-June 4, 2016.

Honorary Co-Chair, Scientific Organizing Committee for 'Statistical Challenges in Modern Astronomy VI', Carnegie Mellon University, June 6-10, 2016, `www.scma6.org`.

Chaired the session 'Computational Astrostatistics' at Joint Statistical Meetings. July 30 - August 4, 2016 in Chicago, Illinois.

Chair of the Program Leaders Committee, and directed the year long program on *Statistical, Mathematical and Computational Methods for Astronomy* (ASTRO) at SAMSI during August 2016 - May 2017.

Organized the *Opening Workshop* to focus on the scientific agenda of the ASTRO program at SAMSI (August 22-26, 2016).

Co-Organized a Special session *409. Statistical, Mathematical, & Computational Methods for Astronomy (ASTRO): SAMSI 2016-17* at the 229 meeting of *American Astronomical Society* at Grapevine, TX held during 3-7 January 2017. Also chaired the session.

Co-Organized an Indo-US SAMSI-ICTS international joint workshop on *Time Series Analysis for Synoptic Surveys and Gravitational Wave Astronomy* at International Centre for Theoretical Sciences (ICTS) in Bangaluru held during 20-23 March 2017.

Member, organizing Committee for the *Transition Workshop* of the SAMSI year-long program on 'Statistical, Mathematical and Computational Methods for Astronomy May 8-10, 2017.

Organized the thirteenth *Summer School in Statistics for Astronomers* at Penn State, during June 5-9, 2017.

Member, Scientific Organizing Committee, *9th International Workshop on Applied Probability (IWAP 2018)*, 18-21 June 2018, Budapest, Hungary.

Invited Conferences:

On a grant from International Mathematical Union, attended the *International Congress of Mathematicians* at Helsinki, Finland in August 1978.

Oberwolfach Conference on *Analytic Number Theory* in November 1980 in West Germany.

Fourth Annual Conference of the *Indian Society for the Theory of Probability and its Applications* held at Indian Institute of Management, Calcutta in June 1983.

Fourth Mathscience Conference on *Number Theory*, held at Ooty, India. December, 1984.

Special Symposium on U. S. National *Monitoring Strategies.* Oceans 86. Washington D.C., during September 23–25, 1986.

ASA and EPA Conference on *Statistical Issues in Combining Environmental Studies*, at Washington D.C., during October 1-2, 1986.

AMS/SIAM/IMS Summer Research Conference on *Statistical Analysis of Measurement Error Models and Applications*, held at Humboldt State University during June 10–16, 1989.

International Conference on Recent Developments in *Statistical Data Analysis and Inference* held at the University of Neuchâtal, Switzerland, during August 21–24, 1989. *Chaired a Session.*

Statistics '91 Canada, Third Canadian Conference in Applied Statistics held at Concordia University, Montreal, Canada. May 23 - May 25, 1991.

International conference on *Analytic and Probabilistic Methods in Number Theory* at Palanga, Lithuania, USSR. September 24-28, 1991. (Presented an Invited paper, could not attend due to political unrest in USSR.)

Some Recent Contributions to Edgeworth Expansions. An invited talk presented at *Probability Day* at Penn State University. July 15, 1991.

First International Triennial Calcutta Symposium on *Probability and Statistics* at Calcutta University, India. December 27, 1991 to January 1, 1992.

Statistics in Astronomy. (With Eric Feigelson). Invited talk presented at 1993 Joint Statistical Meetings in San Francisco on August 11, 1993.

Bootstrap and other Resampling Methods. An invited talk presented at *Bootstrap Day* at Penn State University. November, 12, 1994.

Bootstrap and other resampling schemes. A 90 minute invited talk on given at *NSF Summer Symposium on the Bootstrap 1996* at Econometrics Laboratory, University of California at Berkeley. July 30 - August 6, 1996.

Conjecture by Erdős and additive functions on the set of pairs of integers. Invited talk given on September 24, 1996 at *II International Conference on Analytic and Probabilistic Number Theory* organized by Vilnius University during September 23-27, 1996 at Palanga, Lithuania, to honor Professor Jonas Kubilius on his 75th birthday.

The resurgence of astrostatistics. Invited talk at *51st session of the International Statistical Institute* at Istanbul, 18-26 August 1997. The session on Astrostatistics is sponsored by International Astronomical Union.

Conditional Edgeworth Expansions and Resampling Schemes. Invited talk at *85th Session of the Indian Science Congress*, Osmania University, Hyderabad, India, January 3-7, 1998.

Asymptotic theory for random permutations with applications to genetics. Invited talk at 1998 Lukacs Symposium, *Statistics for the 21st Century*, Bowling Green University, April 24-26, 1998.

Comparison of Resampling Procedures. Invited talk at *Rutgers Bootstrap Conference*, May 14-16, 1998.

Breakdown theory for estimators based on bootstrap and other resampling schemes. Invited talk at *IISA International conference 1998*, McMaster University, Hamilton, Canada, October 10-11, 1998.

Random Permutations and the Ewens sampling formula in genetics, at the International conference on *Combinatorics, Statistics, Pattern Recognition and Related Areas*, Mysore, India, on December 29, 1998.

Limit Theorems for Random Permutations, at the conference, *Paul Erdős and his Mathematics*, Budapest, Hungary July 4-11, 1999.

Functional Limit Theory for processes generated by random permutations. Invited talk at *Workshop on the Interface of Probability and Number Theory*, University of Illinois at Urbana-Champaign, May 19-20, 2000.

Statistical methodology for NVO. Invited talk at the *Conference on Virtual Observatories of the Future*, Caltech, June 13 - 16, 2000.

Statistical Methodology for NVO. ESO/ESA/NASA/NSF Astronomy Conference, *Toward an International Virtual Observatory*, June 10 - 14, 2002, Garching, Germany.

Goodness-of-fit tests when parameters are estimated. Special invited lecture at the *Fourth Biennial International Conference on Statistics, Probability and Related Areas*, June 14-16, 2002, Northern Illinois University in DeKalb, Illinois.

Statistical methodology for massive datasets and model selection. Invited speaker at *Astronomical Data Analysis II (ADA)*, part of SPIE Symposium on Astronomical Telescopes and Instrumentation, in Waikoloa, Hawaii, 22-28 August 2002.

Invited participant at the 'Workshop on Statistical methods for the analysis of massive streams of data', organized by the National Academies' Committee on Applied & Theoretical Statistics. National Academies Building, Washington, D.C. December 13-15, 2002.

Statistical and computational challenges, and opportunities in Astronomy. Invited talk at *International Conference on Ranking and Selection, Multiple Comparisons and Reliability, and Their Applications*, December 28-30, 2002, Chennai, India

Goodness of fit tests with estimated parameters. Invited talk at *XXIII International Seminar on Stability Problems for Stochastic Models*, May 12-17, 2003, Pamplona, Spain.

Statistical challenges in Modern Astronomy (with E. Feigelson). Invited presentation at *International Conference on Advanced Statistical Methods in Particle and Astro-Particle Physics*, September 8-12, 2003, SLAC, Stanford, CA.

Probabilistic Number Theory and Random Permutations: Functional Limit Theory. Invited presentation at *Conference on Zeta Function*, December 13-15, 2003, National Institute of Advanced Studies (NIAS), Bangalore, India.

Model fitting in the presence of nuisance parameters. Invited presentation at the conference *Astronomical Data Analysis-III*, Sant' Agata sui due Golfi (NA), Italy, 29 April to 1 May 2004.

Invited participant at the *Statistical Issues in Data Acquisition*, organized by the National Academies' Committee on Applied & Theoretical Statistics. Lawrence Berkeley National Laboratory, Berkeley, July 16, 2004. http://sites.nationalacademies.org/DEPS/BMSA/DEPS_047678.

Statistical Challenges in Modern Astronomy. Invited presentation at International Conference on *Recent developments in statistics and their applications*, Tirupati, India. January 3-4, 2005.

Invited participant at *Statistics for Gravitational Wave Data analysis* workshop, Penn State. May 19-21, 2005.

Weak convergence for additive functions on random partitions of an integer. Invited speaker at the international conference on *Probability and Number partitions Theory*, Kanazawa, Japan. June 20-24, 2005.

Goodness-of-fit and all that! Invited speaker at *ADASS IV - Astronomical Data Analysis Software & Systems XV*, San Lorenzo de El Escorial, Spain. October 2-5, 2005.
Tutorial. R: A powerful public software environment for statistical analysis of astronomical data. (with David Hunter, Eric Feigelson). 170 participants

Statistical Problems in Astronomy (December 21, 2005).
Resampling Techniques (December 22, 2005). Invited speaker at the *Workshop on Astrostatistics*, Calcutta University, Kolkata, India, December 2Theoretical Institute for Advanced Research in Astrophysics, Academia Sinica, Taipei, Taiwan1-23, 2005.

Invited Discussant at *Statistical Challenges in Modern Astronomy IV*, Penn State University, June 12-15, 2006

Object detection in multi-epoch data. Invited speaker at *Astronomical Data Analysis IV*, Laboratoire d'Astrophysique deMarseille, Marseille, France. September 18-20 2006.

Invited participant at the *Phystat-LHC Workshop on Statistical issues for LHC Physics*, CERN, Geneva, June 27-29, 2007.

Marginal quantiles: Asymptotics for functions of order statistics. Invited speaker at the conference on *Recent Advances in Probability* held at the Indian Statistical Institute, Calcutta. December 11-15, 2007. Part of Platinum Jubilee celebration of the Indian Statistical Institute.

Invited participant at *The LSST All-Hands Meeting*, the National Center for Supercomputing Applications, University of Illinois, Urbana-Champain, May 19-23, 2008.

Edgeworth expansions and their applications. Invited speaker at the conference on *Advances in Statistics*, held in honor of the 65th birthday of Zhidong Bai at National University of Singapore, July 20, 2008.

Understanding 21st Century Astronomical Data Cubes. Invited speaker at the IJCAI-09 Workshop on *Machine Learning and AI Applications in Astrophysics and Cosmology*, Pasadena, California, July 16-17, 2009.

Participant at the 'Prague Stochastics 2010' conference held at Charles University in Prague, Czech Republic during August 30 to September 3, 2010.

Feature identification in datacubes. Invited speaker at *ALMA Software Development Workshop*, National Radio Astronomy Observatory, Charlottesville, VA, October 12-14, 2011.

Analysis of Astronomical data cubes. Invited speaker at *Digging Deeper: Algorithms for Computationally-Limited Searches in Astronomy - Part II* at Caltech in Pasadena, California, sponsored by the Keck Institute for Space Studies, December 12-15, 2011.

Invited panelist at US/India NSF Workshop on *Virtual Institutes for Computational and Data-Enabled Science & Engineering*, Bangalore, India on December 21-22, 2011. Panelist for Data-Intensive Computing & Astrophysics.

Bayesian and frequentist approaches. Invited speaker at *Astronomical Data Analysis Conference (ADA VII)*, Cargèse, Corsica, France, May 14-18, 2012.

Invited core participant at *The LSST All-Hands Meeting*, Tucson, Arizona, August 13-17, 2012. Presented a talk on 'Statistical Resources'.

Big Data in Observational Astronomy. Invited speaker at the SAMSI undergraduate workshop on *Computational Methodology for Massive Datasets*, RTP, NC, October 26-27, 2012.

Fitting astrophysical models: Chi-square, KS tests, bootstrap, and MLE. Invited speaker at the *First International Meeting of Astrostatistics in Valparaiso (IMAV 2013)*, Chile, May 6-10, 2013.

Also gave four lectures on Probability, Statistical Inference and Bootstrap.

Exploratory Analysis of Light Curves. Invited speaker at the SAMSI *Massive Datasets Transition Workshop*, RTP, NC, May 20-22, 2013.

Highlights on Kesar Singh's contributions. Invited speaker at *Kesar Singh Memorial Session: JSM 2013*, Montréal, Canada, August 6, 2013.

Big data in observational astronomy. Invited speaker (in session IPS057 on August 28, 2013) at 59th ISI World Statistics Congress held in Hong Kong, China during 25-30 August 2013.

Invited talk entitled, 'Astrostatistics: Past, Present and future' given at La Estadistica y la Astronomia: Una relation explosiva, held at Instituto Technologico Autonomo de Mexico (ITAM), Mexico City, Mexico, November 29, 2013.

Invited opening speaker at the Interdisciplinary Workshop on 'Statistical and Analysis Methods in Nuclear, Particle and Astrophysics' organized by the Excellence Cluster Universe at the Max Planck Institute for Extraterrestrial Physics, Garching, Germany. Feb 17-18, 2014. Title of the talk: Statistical Modeling for Astronomy.

Invited second presentation at the Interdisciplinary Workshop on 'Statistical and Analysis Methods in Nuclear, Particle and Astrophysics' organized by the Excellence Cluster Universe at the Max Planck Institute for Extraterrestrial Physics, Garching, Germany. Feb 17-18, 2014. Title of the second talk: Statistical analysis of astronomical datacubes.

Invited talk entitled, 'Primer to Kepler Transits', given at JSM 2014 in Boston during August 3-7, 2014, in the session on *Statistical Analysis of Kepler Data at SAMSI*.

Invited talk entitled, A Primer for Exoplanets: statistical and computational challenges in detecting/confirming exoplanets' in Special Topic Session STS039, July 27, 2015: New advances in astrostatistical research; 60th ISI World Statistics Congress - Rio de Janeiro, Brazll, druing 26-31 July 2015.

Invited 'Conference Summary' given at *Statistical Challenges in Modern Astronomy VI*, Carnegie Mellon University June 6-10, 2016.

Invited 'Opening remarks', 'Panel Discussion', 'working group organization for the year-long SAMSI program', at the Statistics and Applied Mathematical Sciences Institute's ASTRO: Opening Workshop, August 22 - 26, 2016, held at Hamner Conference Center, North Carolina Biotechnology Center in RTP, NC.

Invited talk 'Overview of SAMSI Astrostat program' given at 'AISC 2016 International Conference on Advances in Interdisciplinary Statistics and Combinatorics'. September 30 - October 2, 2016 University of North Carolina at Greensboro, Greensboro, NC.

Invited talk 'Overview of the SAMSI year-long program on Statistical, Mathematical and Computational Methods for Astronomy' given at the Special session *409. Statistical, Mathematical,*

& Computational Methods for Astronomy (ASTRO): SAMSI 2016-17 of the 229 meeting of *American Astronomical Society* at Grapevine, TX held during 3-7 January 2017.

Invited talk 'Statistics in Astronomy & the SAMSI ASTRO Program' given at the Indo-US SAMSI-ICTS international joint workshop on *Time Series Analysis for Synoptic Surveys and Gravitational Wave Astronomy* at International Centre for Theoretical Sciences (ICTS) in Bangaluru held during 20-23 March 2017.

Two invited presentations at the Transition Workshop for the SAMSI year-long program on 'Statistical, Mathematical and Computational Methods for Astronomy May 8-10, 2017. Talk 1 - Recap of the ASTRO Program; Talk 2 - Pulsar Timing for GWB: Statistical Methods.

Two invited lectures at the Summer School on Astrostatistics and Big Data (September 4-8, 2017), Theoretical Institute for Advanced Research in Astrophysics, Academia Sinica, Taipei, Taiwan. Lecture 1 - Probability; Lecture 2 - Model Fitting, Bootstrap, and Model Selection.

Invited Talks:

International institutions, where invited talks are given include: University of Oslo (Norway), University of Lund (Sweden), University of Copenhagen (Denmark), Mathematical Institute of Paderborn (West Germany), University of Szeged (Hungary), Andhra University (India), Monash University (Australia), Melbourne University (Australia), Latrobe University (Australia), Australian National University (Australia), Indian Statistical Institute, (Kolkata, India), Keio University (Japan), Institute of Statistical Mathematics (Japan), Hiroshima University (Japan), Osaka city University (Japan), National Sun Yet-sen University (Taiwan), Concordia University (Canada), University of Hyderabad (India), University of Poona (India), Inter-University Centre for Astronomy and Astrophysics (India), Nanyang Technical University (Singapore), National University of Singapore (Singapore), National Tsing Hua University (Taiwan), Institute of Statistical Science, Academia Sinica (Taiwan), Theoretical Institute for Advanced Research in Astrophysics, Academia Sinica (Taiwan), LAMOST project of National Astronomical Observatory of the Chinese Academy of Sciences (Beijing, China), Northeast Normal University (Changchun, China), Jilin University (Changchun, China), Indian Institute of Astrophysics (Bangalore, India), Raman Research Institute (Bangalore, India), Instituto Technologico Autonomo de Mexico (ITAM, Mexico), and other universities and institutes.

Institutions in the USA, where invited colloquia talks are given include: Rutgers University, University of Pennsylvania, University of Maryland at Baltimore County, Michigan State University, Case Western Reserve University, Mathematical Sciences Research Institute (Berkeley), University of Georgia, Florida State University, Purdue University, Iowa State University, Ohio State University, Wright State University, Texas A&M university, Statistical and Applied Mathematical Sciences Institute (Research Triangle Park, North Carolina), North Carolina State University, University of South Carolina, University of Minnesota, University of California at Irvine, The Pennsylvania State University (Department of Industrial and Manufacturing Engineering), University of Texas at Dallas, Columbia University (New York), Temple University, University of California at San Diego, Univesity of California at Berkeley, and other institutes and universities.

Media accounts of research or outreach:

- Interviewed by SynTalk (Mumbai, India) for the episode *The Future Of Prediction* on March 18, 2017. The audio (and the description) is available online at https://syntalk.wordpress.com/episodes/turn-three/tfop/ and https://goo.gl/1UJyDq (SoundCloud).

- Babu's work on astrostatistics in the context of Big data is quoted in the article titled, 'Astronomy & Big, Big data' by Peter Tyson (editor in chief), *Sky & Telescope*, September 2016, pp 14-21.

- 2014 November 4. Interviewed for an article, *'The rise of Astrostatistics'* for Symmetry (http://www.symmetrymagazine.org/), a joint Fermilab/SLAC online magazine about particle physics and its connections to other aspects of life and science, from interdisciplinary collaborations to policy to culture. [http://www.symmetrymagazine.org/article/november-2014/the-rise-of-astrostatistics]

- Penn State Outreach Magazine, Spring 2007: Rock Stars, Real Stars & Astronomical Success.

- 2005. Featured in the DVD produced by Penn State Public Broadcasting entitled, *'Penn State Outreach. Shared Stories: Faculty talk about Outreach'*.

- 2005. Interviewed for *Celestial Collaborators*, Span, pp. 56-60 http://issuu.com/spanmagazine/docs/200501-02-r. Span magazine, published by the US embassy in India, provides content that bridges U.S.-India relations ranging from education, culture, lifestyle and business, to science and technology.

List of Research Publications of G. J. Babu

The numbers following **MR** denote the *Mathematical Reviews* numbers.

Books Published:

1. Feigelson, E. D., and Babu, G. J. (Editors) (2012). *Statistical Challenges in Modern Astronomy V*. Springer, New York.

2. Feigelson, E. D. and Babu, G. J. (2012). *Modern Statistical Methods for Astronomy with R applications*. Cambridge University Press, Cambridge. Won the 2012 Association of American Publishers PROSE Award in the Cosmology and Astronomy section. http://www.proseawards.com/index.html

3. Babu, G. J., and Feigelson, E. D. (Editors) (2007). *Statistical Challenges in Modern Astronomy IV*. ASP Conference Series, Vol. 371, Astronomical Society of the Pacific, San Francisco.

4. Feigelson, E. D., and Babu, G. J. (Editors) (2003). *Statistical Challenges in Astronomy*. Springer-Verlag, New York.

5. Babu, G. J., and Feigelson, E. D. (Editors) (1997). *Statistical Challenges in Modern Astronomy II*. Springer-Verlag, New York.

6. Babu, G. J., and Feigelson, E. D. (1996). *Astrostatistics*. Chapman and Hall, London. Reprinted (1997).

7. Feigelson, E. D., and Babu, G. J. (Editors) (1992). *Statistical Challenges in Modern Astronomy*. Springer-Verlag, New York.

8. Babu, G. J. (1978). *Probabilistic Methods in the Theory of Arithmetic Functions.* Macmillan Lecture Series, Series 2, New Delhi. (**MR** #80g: 10057).

Research Publications:

1. G. Jogesh Babu and Andrea Toreti. (2016). A goodness-of-fit test for heavy tailed distributions with unknown parameters and its application to simulated precipitation extremes in the Euro-Mediterranean region. *Journal of Statistical Planning and Inference*, **174**, 11-19. DOI:10.1016/j.jspi.2016.02.002

2. G. Jogesh Babu and Ashish Mahabal. (2016). Skysurveys, light-curves, and statistical challenges. *International Statistical Review*, **84**, 506-527. DOI: 10.1111/insr.12118

3. G. Jogesh Babu. (2014). Kesar Singh's contributions to statistical methodology. *Statistical Methodology*, **20**, 2-10.

4. G. Jogesh Babu and Eric Feigelson (2014). Planet Hunting to Sky Surveys, Astronomy and Statistics Realign. Space.com (A perspective article on Astrostatistics, written at the invitation of American Statistical Association), October 31, 2014. http://www.space.com/27611-astrostatistics-drives-modern-astronomy.html. Also on Yahoo News (the most visited news website in the world). http://news.yahoo.com/planet-hunting-sky-surveys-astronomy-statistics-realign-op-210741753.html;_ylt=AwrBEiHxjXNULG8A8jvQtDMD

5. Arnab Chakraborty, Eric D. Feigelson, and G. Jogesh Babu. (2013). VOStat: A Statistical Web Service for Astronomers. *Publications of the Astronomical Society of the Pacific*, **125**, No. 925, pp. 295-305.

6. Smith, M. W. E., Fox, D. B., Cowen, D. F., Meszaros, P., Tesic, G., Fixelle, J., Bartos, I., Sommers, P., Ashtekar, A., Babu, G. J., Barthelmy, S. D., Coutu, S., DeYoung, T., Falcone, A. D., Gao, S., Hashemi, B., Homeier, A., Marka, S., Owen, B. J., Taboada, I. (2013). The Astrophysical Multimessenger Observatory Network (AMON). *Astroparticle Physics*, **45**, 56-70.

7. Feigelson, E. D., and Babu, G. J. (2013). Statistical Methods for Astronomy. In *Planets, Stars and Stellar Systems. Volume 2: Astronomical Techniques, Software, and Data*, Terry Oswalt and Howard E. Bond (eds.). Springer, New York, NY, 445-480.

8. Lee, H., Babu, G. J., and Rao, C. R. (2012). A jackknife type approach to statistical model selection. *Journal of Statistical Planning and Inference*, **142**, issue 1, 301-311.

9. Feigelson, E. D., and Babu, G. J. (2012). Big Data in Astronomy. *Significance*, **9**, issue 4, August, 22-25.

10. Babu, G. J. Resampling methods for model fitting and model selection. (2011). *Journal of Biopharmaceutical Statistics*, **21**, issue 6, 1177-1186.

11. Babu, G. J., Bai, Z. D., Choi, K.-P., and Mangalam, V. (2011). Limit Theorems for functions of marginal quantiles. *Bernoulli*, **17**, Number 2, 671-686.

12. Babu, G. J., Chattopadhyay, T., Chattopadhyay, A., and Mondal. S. (2009). Horizontal branch morphology of globular clusters: A multivariate statistical analysis. *The Astrophysical Journal*, **700**, 1768-1778.

13. Babu, G. J. (2009). Marginal quantiles: Asymptotics for functions of order statistics. In *Perspectives in Mathematical Sciences I: Probability and Statistics*. Statistical Science and Interdisciplinary Research, **Vol. 7**. World Scientific Publishing Co., 31-39.

14. Babu, G. J., Mahabal, A., Williams, R., and Djorgovski, S. G. (2008). Object detection in multi-epoch data. *Statistical Methodology*, **5**, issue 4, 299-306. [Slides]

15. Babu, G. J. (2008). Edgeworth Expansions: A brief review of Zhidong Bai's contributions. In *ADVANCES IN STATISTICS*, Zehua Chen, Jin-Ting Zhang & Feifang Hu (Eds.). World Scientific Publishing Co, 16-18.

16. Babu, G. J., and Padmanabhan, A. R. (2007). Re-sampling methods for testing for location against unrestricted and ordered alternatives. *Journal of Statistical Planning and Inference*, **137**, issue 11, 3261-3267.

17. Babu, G. J., Manstavičius, E., and Zacharovas, V. (2007). Limiting processes with dependent increments for measures on symmetric group of permutations. *Advanced Studies in Pure Mathematics*, **49**, 41-67. (**MR** #2009h: 60022).

18. McDermott, J. P., Babu, G. J., Liechty, J. C., and Lin, Dennis K. J. (2007). Data skeletons: simultaneous estimation of multiple quantiles for massive streaming datasets with applications to density estimation. *Statistics and Computing*, **17**, issue 4, 311-321.

19. Babu, G. J., and Mahabal, A. (2007). Using R-based VOStat as a low-resolution spectrum analysis tool. *Journal of Statistical Software*, **18**, issue 11, 1-12.

20. Babu, G. J. (2006). Probabilistic Number Theory and Random Permutations: Functional Limit Theory. In *The Riemann Zeta function and related themes*, R. Balasubramanian and K. Srinivas (eds.). Ramanujam Mathematical Society – Lecture Notes Series, No. 2, 19-27. (**MR** #2008g: 60019).

21. Babu, G. J., and Chaubey, Y. P. (2006). Smooth estimation of a distribution and density function on hypercube using Bernstein polynomials for dependent random vectors. *Statistics and Probability Letters*, **76**, no. 9, 959-969. (**MR** #2008h: 62078).

22. Babu, G. J., and Djorgovski, S. G. (2004). Some statistical and computational challenges, and opportunities in astronomy. *Statistical Science*, **19**, no. 2, 322-332.

23. Babu, G. J., and Rao, C. R. (2004). Goodness-of-fit tests when parameters are estimated. *Sankhyā*, **66**, no. 1, 63-74. (**MR** #2005c: 62053).

24. Babu, G. J. (2004). A note on the bootstrapped empirical process. *J. of Statistical Planning and Inference*, **126**, no. 2, 587-589. (**MR** #2006a: 62053).

25. Babu, G. J., Boyarsky, A., Chaubey, Y. P. and Gora, P. (2004) New statistical method for filtering and entropy estimation of a chaotic map from noisy data. *International Journal of Bifurcation and Chaos*, **14**, no. 11, 3989-3994. (**MR** #2005j: 37136).

26. Babu, Gutti Jogesh, and Rao, M. Bhaskara. (2004). Occurrence/exposure rate. In *Encyclopedia of Actuarial Science*, Bjoern Sundt and Jef Teugels (Eds.), Wiley, Chichester, Vol **3**, 1199-1201.

27. Babu, G. J., and Rao, C. R. (2003). Confidence limits to the distance of the true distribution from a misspecified family by bootstrap. *J. Statistical Planning and Inference*, **115**, no. 2, 471-478. (**MR** #2004c: 62072).

28. Scargle, J. D., and Babu, G. J. (2003). Point processes in astronomy: Exciting events in the universe. *Handbook of Statistics,* **Vol. 21** "Stochastic Processes: Modeling and Simulation." C. R. Rao and D. N. Shanbhag (Eds.), Elsevier Science Publishers B. V., Amsterdam, 795-825.

29. Babu, G. J., Singh, K., and Yang, Y. (2003). Edgeworth expansions for compound poisson processes and the bootstrap. *The Annals of the Institute of Statistical Mathematics*, **55**, no. 1, 83-94. (**MR** #2004b: 62084).

30. Babu, G. J., and Padmanabhan, A. R. (2002). Re-sampling methods for the nonparametric Behrens-Fisher problem. *Sankhyā*, Series A, **64**, 678-692.

31. Babu, G. J., and Manstavičius, E. (2002). Infinitely divisible limit processes for the Ewens sampling formula (Russian). *Lietuvos Matematikos Rinkinys*, **42**, no. 3, 294-307. English translation in *Lithuanian Math. J.*, **42**, no. 3, (2002), 232-242. (**MR** #2003k: 60044).

32. Babu, G. J., and Manstavičius, E. (2002). Limit processes with independent increments for the Ewens sampling formula. *The Annals of the Institute of Statistical Mathematics*, **54**, no. 3, 607-620. (**MR** #2003j: 60041).

33. Babu, G. J., Canty, A., and Chaubey, Y. (2002). Application of Bernstein Polynomials for Smooth Estimation of a Distribution and Density Function. *J. Statistical Planning and Inference*, **105**, no. 2, 377-392. (**MR** #2003d: 62088).

34. Babu, G. J., Pathak, P. K., and Rao, C. R. (2000). Consistency and accuracy of the sequential bootstrap. In "Statistics for the 21st century: Methodologies for application of the Future." C. R. Rao and G. Szekély (Eds.), Marcel Dekker, Inc, New York, 21-31.

35. Babu, G. J., Pathak, P. K., and Rao, C. R. (1999). Second order correctness of the Poisson bootstrap. *Annals of Statistics*, **27**, no. 5, 1666-1683. (**MR** #2001c: 62059).

36. Babu, G. J., and Manstavičius, E. (1999). Brownian motion for random permutations. *Sankhyā*, Series A, **61**, 312-327. (**MR** #2001j: 60016).

37. Babu, G. J. (1999). Breakdown theory for estimators based on bootstrap and other resampling schemes. In *Asymptotics, Nonparametrics, and Time Series*. Subir Ghosh (Ed.). Marcel Dekker, New York, 669-681.

38. Babu, G. J., Padmanabhan, A. R., and Puri, M. L. (1999). Robust one-way ANOVA under possibly non-regular conditions. *Biometrical Journal*, **41**, 321-339. (**MR** #2000d: 62108).

39. Babu, G. J., and Manstavičius, E. (1999). Random permutations and the Ewens sampling formula in genetics. *Probability and Mathematical Statistics*. B. Grigelionis *et al.* (Eds.), TEV, Vilnius and VSP, Utrecht, Netherlands, pp 33-42.

40. Mukherjee, S., Feigelson, E. D., Babu, G. J., Murtagh, F., Fraley, C., and Raftery, A. (1998). Three types of Gamma ray bursts. *The Astrophysical Journal*, **508**, November 20, 314-327.

41. Padmanabhan, A. R., Chinchilli, V. M., and Babu, G. J. (1997). Robust analysis of within-unit variances in repeated measurement experiments. *Biometrics*, **53**, 1520-1526.

42. Babu, G. J. (1997). On a conjecture by Erdős and its extension to additive functions on the set of pairs of integers. *New Trends in Probability and Statistics*, Vol 4. Analytic and Probabilistic Methods in Number Theory. A. Laurincikas, E. Manstavičius and V. Stakenas (Eds.); TEV, Vilnius and VSP, Utrecht, Netherlands, 261-270. (**MR** #2000a: 11136).

43. Babu, G. J. (1997). Bootstrap – A review. In *Probability and its applications*. M.C. Bhattacharjee and Sujit Basu (Eds.), The Oxford University Press, Delhi, 167-178.

44. Babu, G. J., and Bai, Z. D. (1996). Mixtures of global and local Edgeworth expansions and their applications. *J. Multivariate Analysis*, **59**, No. 2, 282-307. (**MR** #98d: 62023).

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Selected recent research & future plans, highlights of earlier research, interdisciplinary work, and honors.

Gutti Jogesh Babu

My research interests are in statistics and probability including their applications to massive data, problems in biomedical research, astronomy and astrophysics. I have contributed extensively to probabilistic number theory (my **Erdős** Number is **1**; http://www.oakland.edu/enp/; https://files.oakland.edu/users/grossman/enp/Erdos1.html), resampling methods including bootstrap, nonparametric methods and asymptotic theory. I have published eight books and over 140 research articles in leading journals. A ninth book on Statistical Inference is under preparation. I along with an astronomer colleague coined the term **Astrostatistics** in mid 1990s, when we published a book by the same name. This interdisciplinary field of Astrostatistics is thriving due to our efforts in advancing it worldwide, bringing together statisticians, astronomers and computer scientists. I was appointed as professor of Astronomy & Astrophysics at Penn State in 2012.

In addition to theoretical research in statistics and probability, I currently work on astrostatistical issues for Large Synoptic Survey Telescope (LSST), collaborate with Caltech on classification of light curves from Catalina Real-time Transient Survey (CRTS), Kepler Exoplanet data analysis with SAMSI working group, and Penn State's Astrophysical Multimessenger Observatory Network (AMON). I initiated collaboration with Chilean astronomers and statisticians from Pontifica Universidad Catolica de Valparaiso and Universidad de Valparaiso in 2013. I worked on statistical methods for faint source detection/transient detection in multilayer astronomical datacubes. Atacama Large Millimeter/Submillimeter Array (ALMA) group at the National Radio Astronomy Observatory (NRAO) is expected to produces massive data cubes that require parallel computing. This work on astronomical data cubes lends itself for parallelization for computational purposes. The method will also apply to the very important problem of detection of transients in multi-epoch survey data. The Keck Institute for Space Studies at Caltech has drafted me as a core team member to develop strategies (statistical methods and computationally efficient algorithms) that enhance the sensitivity for some types of computationally limited signals, where either faster computers or better algorithms would lead to more discoveries in the same massive data sets or data streams. This is especially important in view of the current push for analysis of 'BIG DATA' by the White House.

I am also a member of AMON at Pennsylvania State University. AMON seeks to perform a real-time correlation analysis of the high-energy signals across all known astronomical messengers - photons, neutrinos, cosmic rays, and gravitational waves - in an effort to:
Enhance the combined sensitivity of collaborating observatories to astrophysical transients by searching for coincidences in their sub-threshold data; and Enable rapid follow-up imaging or archival analysis of the putative astrophysical sources.

I organized and led several long-term research programs on Astrostatistics at *Statistical and Applied Mathematical Sciences Institute* (SAMSI) since Spring 2006. SAMSI is one of the Mathematical Sciences Institutes supported by the **National Science Foundation**. The principal purpose of the SAMSI long-term research program on Astrostatistics is to identify promising research paths for statistical sciences and applied mathematics in problems of observational astronomy, astrophysics and particle physics, and to initiate research on these problems. More details on SAMSI

programs that I led are given below.

I have organized very popular annual summer schools in statistics for astronomers at Penn State since 2005 and four in collaboration with the Indian Institute of Astrophysics in Bangalore, India. The Penn State Summer Schools have trained over 600 participants since its inauguration in 2005. A substantial new textbook *Modern Statistical Methods for Astronomy with R Applications* by Feigelson & Babu, and based on the Summer Schools has been published by the Cambridge University Press in 2012. In 2013 it was announced that the textbook won the 2012 PROSE Award in Cosmology and Astronomy given by the Association of American Publishers. I led the development of Web computing environment VOStat specifically for very-large datasets encountered in astronomy research in general, and Virtual Astronomical Observatory (VAO) in particular. VOStat is fully integrated seamlessly with VO services for the use by the international VAO community.

I am the Vice-Chair and an Executive Board Member of the International Astrostatistics Association (IAA). IAA is derived from the Astrostatistics Committee and Network of the International Statistical Institute (ISI) in 2012. The main goal of IAA with over 500 members is to foster collaboration between members of the statistical and astronomical communities. I am one of the *five core team members* of the **LSST** *Informatics and Statistics Science Collaboration*. At the invitation of the Office of NSF Director (OD), I served on the working group on US/India Virtual Institutes for Computational and Data-Enabled science and engineering in Bangalore in Dec 21-22, 2011. I also served on the Panel on Data-Intensive Computing and Astrophysics.

Research

Interdisciplinary research

My current interdisciplinary research efforts focus on statistical methodology on faint source detection, classification of light curves, Kepler exoplanet data analysis, gravitational wave detection, and on astrostatistical issues for LSST. I am also collaborating with Andrea Toreti of Justus-Liebig University of Giessen, Germany on applications of bootstrap methods to Climate change.

Gravitational Wave Detection: I spent December 2012 at the National University of Singapore collaborating with Choi Kwok Pui and Bai Zhidong on statistical problems with potential applications to data-intensive radio astronomy. The project is on gravitational wave detection via pulsar timing using bootstrap methods. The effort was initiated by a Skype meeting with Pui, and Joseph Lazio (Jet Propulsion Laboratory, acting Director for the Square Kilometer Array project). The planned methods include partial autocorrelations and multiple correlations to extract the effect of Gravitational Wave Background. Our group is also working on Gaussian Process modeling.

LSST: The 8.4-meter LSST will survey the entire visible sky deeply in multiple colors every three days with its three-billion pixel digital camera, probing the mysteries of Dark Matter and Dark Energy, and opening a movie-like window on objects that change or move. This color 'movie' of the Universe will open an entirely new window: the time domain. Data Data everywhere! LSST will generate more than 30 Terabytes per night leading to a 50 Petabyte archive over 5 years; approximately 10^9 static and time-variable sources will be observed repeatedly every 3 nights. My future research plans include, scaling the recently developed faint object detection techniques

and analysis of datacubes for the LSST mission, in addition to developing other astrostatistical methodology for LSST both at the design stage and at the analysis stage.

ALMA: The fields of radio and microwave astronomy are experiencing huge advances in instrumentation. Innovations in broadband receiver, fast correlator and other technologies are leading to order-of-magnitude improvements in sensitivities and throughput from meter through submillimeter wavelengths. According to one cosmological model, the universe is dominated at its largest scales by 'dark energy' that makes it expand faster, and on the scale of galaxies and clusters of galaxies, gravitational effects from 'dark matter'. One of the predictions of this model, which has not been verified by observation, is that there should be many sub-galactic clumps of dark matter, which should be visible as 'dwarf' galaxies due to the influence of gravity. Dwarf galaxies are numerous but not in the numbers predicted by the theory. Observations of the 21 cm emission line of atomic hydrogen in nearby galaxies are a powerful diagnostic tool for studying the dynamics and gas distribution in these galaxies. The data comes in the form of 3-dimensional 'datacube' (or 'hyperspectral image') giving brightness as a function of location in the two-dimensional sky at many channels of frequency. The new ALMA correlators will typically produce $\sim 1-100$ GBy datacubes with images of $\sim 1-10$ million pixels at $\sim 1-10$ thousand frequency channels. Over a decade, ALMA will produce petabytes of datacubes. These image cubes will be the inputs to the statistical source finding techniques that I have been developing.

Statistics and Probability Research

Goodness of fit: Many nonparametric goodness-of-fit tests, such as Kolmogorov-Smirnov, and Cramer-von Mises, are based on the empirical distribution function. In the presence of nuisance parameters, the tests are generally constructed by first estimating the nuisance parameters. However, even when the parametric model is specified, the asymptotic null distribution of the test statistic depends in a complex way on the unknown parameters. Bootstrap methods are used to estimate the null distribution. I have demonstrated that, under very general conditions, the difference between the empirical process and the population distribution with estimated parameters converges weakly to the same Gaussian process as the corresponding bootstrap version. This result is used to show that the bootstrap method consistently estimates the null distributions of various goodness-of-fit tests. These results hold not only in the univariate case but also in the multivariate setting. For the case when the hypothesis is rejected, using Kullback-Leibler measure of separation, I have developed a resampling method to set confidence bands to the difference of the true and the closest distribution in the specified family. The ideas generated here would also help in model selection. I have developed a model selection procedure based on jackknife type arguments, as an alternative to *Akaike Information Criterion* (AIC) and *Bayesian Information Criterion* (BIC), These results are very useful to problems in astronomy. I am currently extending these results to Anderson-Darling type statistics for data from heavy tailed distributions. These modified statistics will have potential applications to Climatology.

Multivariate density estimation: A multivariate version of Bernstein polynomials for approximating a bounded and continuous function is adapted for smooth estimation of a distribution function concentrated on the unit hypercube. The smoothness of the resulting estimator, naturally lends itself in a smooth estimator of the corresponding density. The functions with other compact or non-compact support are also dealt with through suitable transformations. The asymptotic

properties, namely, strong consistency and asymptotic normality of the resulting estimators are investigated under strong mixing. The problem was motivated by estimation of conditional densities in non-linear dynamical systems. Metric entropy is an important measure of chaos in a dynamical system. A new statistical method is developed for *(Chaotic processes)* filtering and entropy estimation of a chaotic map from noisy data.

Applied Probability: The Ewens sampling formula gives the distribution of the allelic partition of a sample of genes from the so-called infinitely many neutral alleles model of population genetics. Though for the past several years the focus has moved away from allozyme data and more towards DNA sequence data, the combinatorial content of the Ewens sampling formula has been recognized as central to the study of a broad class of combinatorial structures in applied probability, and it is closely associated with partitions of an integer. Continuing my work on functional limit theory for 'certain' processes defined through partial sums of dependent variables with respect to the Ewens sampling formula, I have shown that the process converges weakly in a function space if and only if a related process defined through sums of independent random elements converges. Using techniques from probabilistic number theory, I have developed a functional limit theory where the limiting processes need not be processes with independent increments. For these processes, the limiting process of the partial sums of dependent variables differs from that of the associated process defined through the partial sums of independent random variables. There are many interesting problems in this area, and my collaboration on this with E. Manstavičius, a Lithuanian mathematician, will continue. Although the results are motivated by Ewens sampling formula, they have wide range of applications including partitions of an integer in number theory and other combinatorial structures such as, 'assemblies'. These objects are related to physics (representations and Young diagrams), theoretical computer science (tree-based searching and symbolic processing algorithms based upon forests), cryptology (factorization of polynomials), and chemistry (random trees as models for cyclic polymerization).

Bootstrapping empirical measures: Contrary to the intuition, properly normalized empirical distribution is not approximated uniformly by its bootstrapped counterpart. The bootstrap does not work for variables given by rare events or very small quantiles with Poisson limit laws. The main problem is at the values near the tails of the population distribution. My results specify the central regions where the uniform distance vanishes if the sample size tends to infinity.

Asymptotics for functions of marginal quantiles: I along with Bai and Choi of National University of Singapore, investigated the large-sample properties of means of functions of marginal quantiles. The investigation is motivated by the problem of parameter estimation in regression models when the linkage between the dependent and independent variables is partially lost. The study includes asymptotic normality, the strong law of large numbers, and functional limit theory.

Other research includes: a) Robust tests for unrestricted and ordered alternatives in the multisample problem without assuming homogeneity of scales and/or symmetry of the underlying distributions. The methodology consists of bootstrapping appropriately centered Mann-Whitney statistics. Data sets from Physics and Psychology illustrate the methodology. b) Simultaneous estimation of multiple quantiles for massive streaming datasets with applications to density estimation. c) Estimation of occurrence/exposure rates under competing risks.

Interdisciplinary Promulgation

Center for Astrostatistics: Astronomy at the beginning of the 21st century, and particularly research arising from wide-field survey observatories at various wavebands, finds itself with serious challenges in statistical treatments of data to achieve its astrophysical goals. A vast range of statistical problems arise in the scientific interpretation of astronomical studies. It is this diversity of statistical issues confronting astronomy today that led to the creation of the Center for Astrostatistics in 2003 at Penn State to facilitate development and promulgation of statistical expertise and toolkits for astronomy and related observational sciences. I am the founding director of the Center for Astrostatistics. The Center serves as a crossroads where researchers at the interfaces between statistics, data analysis, astronomy, space and observational physics collaborate, develop and share methodologies, and together prepare the next generation of researchers. I also maintain the resource rich Center Web site that includes: bibliographies, summer school lectures, tutorials, data sets, StatCodes, and VOStat. Due to the multifaceted activities, the Penn State is now known as THE place for astrostatistics world wide. Due mainly of the efforts of the Center for Astrostatistics, several national as well as international collaborating groups in the field have been established. Astronomers and astrophysicists around the globe tap on the resources of the Center for Astrostatistics for guidance on Statistical methodology. Over the years, the Center attracted large number of visitors, students and post-docs from both national and international institutions.

SAMSI: At the invitation of the NSF institute *Statistical and Applied Mathematical Sciences Institute* (SAMSI), I directed a semester-long Astrostatistics program in Spring 2006. The principal purpose of the SAMSI program on Astrostatistics is to identify promising research paths for statistical sciences and applied mathematics in problems of observational astronomy, astrophysics and particle physics, and to initiate research on these problems. A vital ingredient of the program was to provide a single geographical location, where researchers at the interface between statistics, applied mathematics, astronomy, and particle physics can congregate and initiate lasting collaborations. The participation by graduate students and postdocs gave them a rare opportunity to develop skills needed for cross-disciplinary work. I led a second Astrostatistics program at SAMSI in Fall 2012 as part of '*2012-13 Program on Statistical and Computational Methodology for Massive Datasets*'. After the opening Astrostatistics workshop (September 2012), the participants joined working groups focusing on Astronomical Discovery & Classification, Imaging, and Stochastic Processes & Astrophysical Inference. The working groups met on regular weekly/bi-weekly basis face-to-face and also via WebEx through May 2013. These meetings led to new collaborations and strengthened existing collaborations between astronomers and statisticians. My invited presentation on October 26, 2012 entitled, 'Big Data in Observational Astronomy' at SAMSI undergraduate workshop, on Computational Methodology for Massive Datasets, was well received. I am again leading a year-long 2016-17 Program on Statistical, Mathematical and Computational Methods for Astronomy (ASTRO) at SAMSI.

Astrostatistics Schools: Under my direction, the Center for Astrostatistics, organized very popular annual summer schools since 2005 at Penn State and trained over 650 astronomers and physicists in advanced statistical methods for handling a diversity of statistical issues confronting astronomy, space sciences, and high energy particle physics. The decennial offering was supplemented by an additional week of instruction on 'Statistical modeling of cosmic populations and 'Bayesian Computing for Astronomical Data Analysis. In addition, I have also organized four schools in as-

trostatistics in India in collaboration with the Indian Institute of Astrophysics (IIA). The 2013 school in India held during July 22-29, had 30 participants. The Indian school in 2013 attracted 8 international participants, one each from Max Planck Institute in Germany, Brno University of Technology in Czech Republic, Instituto Nacional de Pesquisas Espacias in Brazil, Jageillonian University in Poland, Notre Dame University in Lebanon, and Instituto de Fisica de Cantabria in Spain, and two from University of Zanjan in Iran, in addition to the participants from Indian Institutions. At the invitation of the Instruments Division of the Space Telescope Science Institute (STScI), I gave a series of lectures on probability and statistics in Fall 2011 at STScI. I presented series of lectures on statistics for astronomers at Pontificia Universidad Catolica de Valparaiso, Valparaiso, Chile, May 6-10, 2013. I also gave few lectures on astrostatistics at Instituto Technologico Autonomo de Mexico (ITAM), Mexico City, Mexico, during November 28-29, 2013.

Statistical Challenges in Modern Astronomy (SCMA): The SCMA conferences, held every five years since 1991, are the premiere forum for research statisticians and astronomers to discuss methodological issues of mutual interest. President of the American Statistical Association, Bradley Efron, in the 'President's Corner' of the Jan 2004 issue of Amstat News refers to the success and the impact of the Penn State's 'Astrostatistics' conference series:

> "The statistical tide continues to roll in, now lapping at the previously unreachable shores of the hard sciences. This September I attended 'Phystat2003' at the Stanford Linear Accelerator Center, a joint conference for physicists and statisticians. Phystat2003 was at least partially inspired by the success of Penn State's 'Astrostat' conference series. Yes, confidence intervals apply as well to neutrino masses as to disease rates, and raise the same interpretative questions, too."

Continuing this tradition, the fifth in a series of interdisciplinary international research conferences, SCMA V was organized in June 2011. It attracted leading statisticians and astronomers to Penn State.

VOStat – Statistical Analysis for the Virtual Observatory: VOStat is a Web service designed to assist non-expert astronomers in statistical analysis of data, particularly datasets acquired through the international Virtual Observatory software system. The service provides 50 statistical analyses in a user-friendly format, so the astronomer need not digest statistical textbooks and be proficient in statistical software. VOStat encourages astronomers to learn further by leading them to educational resources and providing scripts in the R statistical software system. The present VOStat infrastructure was developed over a period of three summers under my direction, and it is now fully integrated into VO software environments through the SAMP communication protocol. The stable version of VOStat was released in summer 2013 at http://vostat.org hosted by Penn State. A refereed paper was published describing the service: Arnab Chakraborty, Eric D. Feigelson, and G. Jogesh Babu, "VOStat: A Statistical Web Service for Astronomers", Pub. Astro. Soc. Pacific, 125, 295 (2013).

Honors and Awards:

I was elected Fellow of the Institute of Mathematical Statistics in 1987 for my work on the asymptotic theory of bootstrap methods, and was elected Member of the International Statistical Institute

in 1989. I was elected Fellow of American Statistical Association in 1997, for outstanding and wide-ranging contributions to probability and statistics; for leadership in promoting interdisciplinary activities to bring astronomers and statisticians together; and for service to the statistical profession. I was elected Fellow of American Association for the Advancement of Science in 1997, for research on asymptotic theory, resampling methods, probabilistic number theory, and statistical methods for astronomy and for promoting interdisciplinary activities. I have also received National Research Council's Twinning fellowship for 1997-1999 to initiate collaboration, on Statistical Group Theory and Probabilistic Number Theory, with colleagues from Vilnius University, Lithuania. I was appointed as Research Professor (Spring 2005), Mathematical Sciences Research Institute, Berkeley; and SAMSI University Fellow (Spring 2006). I received a 2007 University Continuing Education Association (Mid-Atlantic Region) award for exemplary non-credit program development for the 2007 summer school.

I have received the first-ever Outstanding Contributions to Astrostatistics award - IAA in 2016, for my efforts in advancing the field of **astrostatistics** worldwide. I was elected Fellow of International Astrostatistics Association (IAA) in 2016. The ASA (American Statistical Association) Astrostatistics Interest Group and the AAS (American Astronomical Society) Working Group on Astroinformatics and Astrostatistics have jointly established an award in my name (G. Jogesh Babu) to fund students and postdocs to present at national meetings papers that develop and apply statistical methods to challenging problems in astronomy and cosmology.

Press and electronic media recognition

1. Interviewed by SynTalk (Mumbai, India) and recorded as SynTalkr for #TFOP (The Future Of Prediction) on March 18, 2017. The audio episode (and the description) is available online at https://syntalk.wordpress.com/episodes/turn-three/tfop/ ? (website link), and https://goo.gl/1UJyDq (short link, SoundCloud).

2. Babu's work on astrostatistics in the context of Big data is quoted in the article titled, 'Astronomy & Big, Big data' by Peter Tyson (editor in chief), *Sky & Telescope*, September 2016, pp 14-21.

3. Interviewed for an article, *'The rise of Astrostatistics'* for Symmetry, a joint Fermilab/SLAC online magazine about particle physics and its connections to other aspects of life and science, from interdisciplinary collaborations to policy to culture. November 4, 2014.

4. Penn State Outreach Magazine, Spring 2007: Rock Stars, Real Stars & Astronomical Success.

5. The interdisciplinary work received wide recognition in the press. Span (Celestial Collaborators, p. 56), New Delhi 2005 on U.S.-India cooperation in astronomy and astrophysics. SPAN is a publication brought out by the American Embassy in India.

6. Media accounts of research and outreach: Featured in the DVD produced in 2005 by Penn State Public Broadcasting entitled, 'Penn State Outreach. Shared Stories: Faculty talk about Outreach'

Earlier research

Probabilistic number theory

I contributed extensively to *Probabilistic number theory* in early 1970's, and published a monograph, **Probabilistic Methods in the Theory of Arithmetic Functions**, in 1978. My main contributions in this area include a partial solution to a long standing conjecture of Erdős, and the result that every bounded additive arithmetic function has a singular distribution. I introduced a concept of density of natural numbers, capable of detecting large gaps in a set of natural numbers, and investigated the existence of distribution of values of an arithmetic function under this density. An important consequence of this is that if $\omega(m)$ denotes the number of distinct prime factors of m, then

$$\#\{n < m < n + b(n) : \omega(m) - \log\log m < x\sqrt{\log\log n}\}/b(n) \to \Phi(x), \qquad (*)$$

where $(\log\ b(n))\sqrt{\log\log n}/\log n \to \infty$, and Φ denotes the standard normal distribution function. This is a generalization of the well known Erdös-Kac Theorem and it leads to a better understanding of integers with large number of prime factors. It is shown that (*) fails to hold if $b(n) < (\log n)/(\log\log n)^2$. Given an additive function f, the problem of determining the slowest growing function b so that f has a distribution was also studied. Part of this was joint work with late Professor Paul Erdős.

Bootstrap methods

My research in early 1980's provided theoretical support to Efron's resampling method called 'bootstrap'. This work on the asymptotic theory for the bootstrap method resulted in establishing the superiority of the bootstrap approximation for a wide class of statistics. I have shown that the bootstrap works best for asymptotically pivotal quantities (studentized versions). This is achieved using Edgeworth expansions. This laid the foundation for subsequent work on second order approximations of the bootstrap method. I was the **first** to show that bootstrap fails if the second moment is not finite.

I along with C. R. Rao and Pathak have proposed a sequential approach called Poisson bootstrap, in which resampling is carried out until a certain proportion of distinct observations are sampled from the original data. Using conditional Edgeworth expansions, we have established the second order correctness (skewness correction) for a wide class of statistics as in the case of classical bootstrap. One of the main advantages of the sequential approach over the fixed sample size bootstrap is, to prevent too many repeated observations in a bootstrap sample that may lead to a degenerate value for the statistic under consideration. Thus Poisson bootstrap avoids zero value for variance estimator.

Practically there is no literature on statistics which are asymptotically distributed as linear combinations of Chi-squares exists. To study such statistics I proposed a modification of bootstrap statistic and have shown that their distributions are very close to each other. This gave a much needed practical method to obtain confidence intervals for such statistics. This method was applied by various authors to study the so called U-statistics.

Bootstrap estimation of variance of sample quantiles were studied and exploited the proof to obtain a method of estimation of density quantile function. Simulation studies showed that the bootstrap method gives better results for studentized statistics. These observations are explained by the theoretical studies. A method to obtain confidence intervals is suggested using the bootstrap method. It is shown to perform better than the percentile method of Efron in the one sided case. The method is extended to autoregressive models.

Subsample and half sample methods are closely related to bootstrap and jackknife method. I investigated the large sample performance of this method. It is shown that the half-sample method is robust in estimating the parameters of a linear regression model when the errors are heterogeneous.

To assess the accuracy of the estimators thus obtained, one needs to estimate the variance of the estimators. There are several options, including bootstrap and halfsample methods. Bootstrap and jackknife are two widely used methods to estimate variance of a statistic. For non-smooth statistics such as sample median, it is well known that jackknife method fails. In this connection, I examined the bootstrap method using the notion of breakdown point in robustness, in the context of estimation of the variance of an estimator and of confidence intervals. Even when the estimators are robust, bootstrap estimator of the variance is strongly influenced by a single outlier, as the bootstrap utilizes all the data points. On the other hand halfsample method has high breakdown point, sometimes as high as 1/4, in the case of estimator of the variance of sample median.

Edgeworth expansions

Edgeworth expansions play an important role in resampling methods such as bootstrap. In 1991, I obtained an s-term Edgeworth expansions for a wide class of statistics which are smooth functions of lattice and nonlattice marginals, where $s > 2$. The result is then applied to a statistic similar to the student's t-statistic, where the scaling factor, the sample standard deviation is replaced by the more robust mean absolute deviation. Edgeworth expansions for the product limit estimator and estimators based on product limit estimator were also obtained in the same year.

I and Z. D. Bai have established Edgeworth expansions for sums of independent but not identically distributed multivariate random vectors. We have also established expansions for functions of multivariate means under partial Cramér's condition and under minimal moment conditions. These results are applied to obtain valid Edgeworth expansions for estimates of regression parameters in linear errors-in-variable models. Using these expansions, the bootstrap distribution is shown to approximate the sampling distribution of the studentized estimators, better than the classical normal approximation. This justifies the use of bootstrap in applying the errors-in-variables regression to the cosmic distance scale, one of the important problems in Astronomy. Expansions that are local in one coordinate and global in rest of the coordinates were also obtained for sums of independent but not identically distributed random vectors. The results were then applied to derive Edgeworth expansions for bootstrap distribution, Bayesian bootstrap distribution, and for the distributions of statistics based on samples from finite populations. I explored expansions for sums of non-identically distributed random vectors and of random vectors with lattice and non-lattice coordinates, along with their applications to errors-in-variables models, least absolute deviation estimators etc.

Edgeworth expansions for samples from finite populations: Edgeworth expansions were obtained for the mean of a simple random sample drawn, from a finite multivariate population, without replacement. These are obtained under very general assumptions, which are easy to verify in practice. Consider the two sample non-parametric statistics of the type $T = (1/n)\sum f(R_i/N)$, where f is a smooth function and $R_1, \ldots, R_n$ are the ranks of one of the samples. In our results we need only to assume that f is continuous and monotone in a small interval. It appears that not much is known about the expansions of T, when $\{f(i/N)\}$ takes only two values. This and other related problems in sample surveys can be handled by using the results on the lattice case. As one of the applications we obtain expansions for the univariate statistics which can be expressed in a certain linear plus a quadratic form. A fairly large class of statistics used in sample surveys fall in this category. These results can be used to get bootstrap approximation to various statistics in the finite population case.

Other research

Density quantile estimation: Density quantile estimators based on the smoothness properties of the density were constructed and were shown to be asymptotically efficient in the mean square error sense. Unlike density estimators these do not require knowledge of the actual values of the derivatives of the density. Uniformly almost sure bounds for these estimators in an interval were obtained in the dependent case too.

Competing risk models: In a series of papers, a standard competing risk situation with possibility of censoring due to withdrawal or end of study were investigated. Large sample theory is derived and bootstrapping is discussed as a way to estimate the variance. Some of this is joint work with C. R. Rao.

Moderate deviations in Banach spaces: Probabilities of moderate deviations for i.i.d. sequences taking values in a separable Banach Space under precise necessary and sufficient conditions were obtained jointly with C. M. Deo. These results are not known earlier even for real valued random variables.

Occupation measure of empirical processes: The limit behavior of the occupation distribution

$$L_t(E) = \int_0^1 I_E(\sqrt{(\log\log t)/t}\;\; K(s,t))ds,$$

where K denotes a Kiefer process, was studied. Strong approximation results are then used to derive the law of iterated logarithms in Chung's form for various functions of empirical processes.

Robust estimation: The large sample properties of statistics based on the robust mean absolute deviation from the sample mean as well as sample median are obtained. These are applied to regression context, the procedures are more robust against outliers compared to the usual procedures base on the classical least squares method.

Mixing sequences: The so called **r**-quick limit points of empirical distribution functions of mixing processes were characterized. Also obtained an **r**-quick version of Bahadur-Kiefer type representation for sample quantiles. These results are applied to linear functions of order statistics.

Environmental statistics: Trawl surveys are carried out regularly by the Northeast Fisheries Center (NEFC) to assess the fish stocks of various species. The external factors influencing the assessment

include the ship used, doors, nets, etc. Occasionally some of these have to be replaced. So there is a need for a conversion factor to neutralize this influence. Major difficulty encountered in this problem is due to the large proportion of zero catches. A method of estimation for the conversion factor is suggested and various asymptotic properties of the estimator studied. The results are illustrated by a data set provided by NEFC.