CURRICULUM VITAE

JURI TOOMRE

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Current Appointments:

1975–present	Professor, Department of Astrophysical and Planetary Sciences (APS) (formerly Astro-Geophysics), University of Colorado at Boulder
1974–present	Fellow, Joint Institute for Laboratory Astrophysics (JILA), University of Colorado at Boulder

Education:

Ph.D.	Trinity College, University of Cambridge, 1967
M.Sc.	Massachusetts Institute of Technology, 1963
B.Sc.	Massachusetts Institute of Techonology, 1962

Biographical Sketch:

Toomre did his undergraduate studies at M.I.T. in aeronautics and astronautics, and then went to England as a Marshall Scholar to receive a Ph.D. in 1967 at Trinity College, University of Cambridge in applied mathematics. Toomre then spent four years in New York, first as a postdoc at NASA's Institute for Space Studies and then in 1969 as an assistant professor in mathematics at New York University and the Courant Institute, working on computationally-intensive theories of thermal convection and on the structure and interaction of galaxies. He came to Boulder in 1971 to join the Department of Astro-Geophysics of the University of Colorado as an associate professor, working in astrophysical fluid dynamics.

Areas of Technical Specialization:

Toomre's research centers on astrophysical fluid dynamics (AFD), with particular emphasis on nonlinear theories for compressible convection and magnetic dynamos in stars, and in studying nonlinear dynamical systems exhibiting multiple bifurcations and chaos. Extensive use is made in the 3–D turbulence simulations of vector and massively parallel supercomputers, and of substantial visualization systems to analyze the vast data sets that result. Toomre is active in helioseismology, using observations of the frequency-splitting of five-minute oscillations of the sun to search for subphotospheric flows, large-scale structures and differential rotation in the convection zone; inverse theory has been developed to interpret the data.

Recently the research has focused on the complementary topics of helioseismology used to probe the interior convective structure and dynamics of the sun, and on numerical simulations of turbulent solar convection influenced by rotation and magnetic fields as elements of the solar global dynamo. With helioseismology we have discovered and probed large-scale organized flows, which we now call solar subsurface weather (SSW), amidst the intense turbulence within the upper reaches of the convection zone. With our supercomputer simulations of compressible rotating convection in spherical shells, we have now attained angular velocity profiles with radius and latitude for the differential rotation in the convection zone that has a close resemblance to those being

deduced from helioseismic inversion. This provides a path for understanding how the strong differential rotation crucial to magnetic activity within the sun is established and maintained.

We have also studied the interaction of magnetic fields with vigorously turbulent convection, finding that strong downflows serve to pump magnetic flux downward into the stable zone below the solar convection zone, thereby providing seedfields to be stretched and greatly amplified by the shear of the tachocline there. The solar dynamo studies have revealed that wreaths of strong magnetic fields can be built in the bulk of the turbulent convection zone, contrary to prior beliefs, and that these wreaths play a significant role in the reversing cycles. We have also been studying core convection and dynamos in much more massive B star, finding that magnetic fields of mega-Gauss strengths can be achieved that are far stronger than previously thought possible. These may influence the later evolution stages that can lead to supernova explosions and compact remnants such as neutron stars.

Current Emphasis in Teaching:

Toomre is keenly interested in the craft of teaching, including using evolving technology where appropriate. In undergraduate teaching, Toomre has devised and utilized innovative web-based tools and modules to enhance the teaching of general astronomy and modern cosmology in large classroom settings, and has helped to evaluate the effectiveness of learning team approaches. These new computational tools help the students interact with the physical concepts being taught, while seeking to make palatable the math and physics that is essential in these topics. In graduate teaching, substantial emphasis in course refinement has been on devising computational and web-based tools that can bring an experimental immediacy to many of the topics, variously in the core graduate courses on fluid dynamics, mathematical methods, fluid instabilities and waves, or stellar structure. Major recent investments in new collaborative graduate education courses in solar and space physics, called COLLAGE, using web tools across multiple universities to broaden the regularly available graduate courses in support of the National Solar Observatory moving to the Boulder campus.

Graduate Research Students Obtaining PhD Degrees:

Toomre has supported and supervised the training of 26 graduate students in their journeymanship into research, all of whom have received PhD degrees, working dominantly in astrophysical fluid dynamics. They are, with year of degree: 1. David Hathaway (with P. Gilman) (1979), 2. Laurence November (1979), 3. Barbara Mihalas (1979), 4. Frank Hill (1982), 5. Brian Fiedler (1982), 6. Jason Porter (with K. Gebbie) (1984), 7. Neal Hurlburt (1983), 8. Deborah Haber (1987), 9. Anil Deane (1987), 10. William Merryfield (1988), 11. Xin Xie (1991), 12. Philip Jones (1991), 13. Mark Rast (1995), 14. Alejandro Spina (1996), 15. Mark Miesch (with E. Zweibel) (1998), 16. Andrew Siegel (1999), 17. Marc DeRosa (2001), 18. Kelly Cline (with N. Brummell) (2003), 19. Jason Lisle (2004), 20. Matthew Browning (2005), 21. Geoffrey Vasil (with N. Brummell) (2007), 22. Benjamin Brown (2009), 23. Nicholar Featherstone (2011), 24. Nicholas Nelson (2013), 25. Kyle Augustson (2013), 26. Benjamin Greer (with B. Hindman) (2016). In addition, currently 2 graduate students are working with Toomre in their doctoral research

Supervision and Support of Postdoctoral Researchers:

Toomre has supported and supervised 21 postdoctoral researchers while at CU, who in alphabetical order (with current associations indicated) are: Allan Sacha Brun (CEA Saclay), Nicholas Brummell (UC Santa Cruz), Fausto Cattaneo (U. Chicago), Thomas Clune (NASA Goddard), Noel Dolez (CNRS), Julian Elliott (Eurobios), Nicholas Featherstone (U. Colorado), Deborah Haber (U. Colorado), Neal Hurlburt

(Lockheed-Martin), Bradley Hindman (U. Colorado), David Hughes (U. Leeds), Keith Julien (U. Colorado), Rasmus Munk Larsen (Software), Sonya Legg (Imperial Coll.), Mark Rast (U. Colorado), Steven Tobias (U. Leeds), Regner Trampedach (Space Sciences), Geoffrey Vasil (U. Sydney), Joseph Werne (CoRA).

Research Grant Support and Directions:

Toomre has consistent external research funding support, both from NSF and NASA, typically averaging three or four grants in parallel, with an overall yearly funding level ranging from about $400K to $1400K, with the current yearly level close to $400K. He has headed two NSF and NASA-funded 'grand challenge' teams dealing with high-performance computation issues in modeling turbulent convection and dynamos; been actively involved in getting the ground-based GONG project in helioseismology underway and the space-based MDI helioseismology experiment on SOHO initiated, launched and now succcessfully operated for nearly fifteen years; he has similarly been active with the HMI helioseismology instrument on the recently launched Solar Dynamics Observatory (SDO); and he has headed the NASA Solar-Terrestrial Theory Program grant through multiple cycles, with the program funded as the major Heliophysics Theory grant to study solar turbulent convection and magnetic dynamo elements. Toomre joined with Hart in building and operating two space flights of the Geophysical Fluid Flow Cell (GFFC) on micro-gravity missions with the Space Shuttle. Toomre has hosted yearly workshops to devise and refine theory needed for the inversion techniques being applied to various helioseismology data. Toomre and colleagues continue to be very intensive users of supercomputing facilities made available competitively by NSF and NASA, with the current allocations totalling about 30M processor hours per year, thus permitting some of the highest resolution 3–D simulations of turbulent convection and dynamo processes within stars like the sun. In all stages, our graduate students and postdocs are central players in these research efforts.

Department and Institute Service:

Toomre has chaired the APS Graduate Admissions Committee for several years (with substantial revamping of procedures to successfully attract highly qualified students within the intensely competitive national scene), is chair of the APS Course Fees and Programs Committee, has several times run the APS Chair Nominating Committee, and has been on the APS Executive Committee for a number of terms. Toomre serves on the JILA Executive Committee, and headed the JILA Beautification Committee to accomplish a major refreshing of all JILA facilities. Toomre has served on many faculty search committee, especially recently with welcoming the National Solar Observatory to the Boulder campus.

University and Other Honors:

CRCW Distinguished Research Lecturer, 1995, giving the eighty-seventh lecture on research and creative work, "High Performance Computing: Window on Turbulent Convection in Stars", on 20 Apr 95, Fiske Planetarium. Accompanying Faculty Fellowship in 1995–96.

SOAR Teaching Recognition Award, 1999, class size 200 to 500 students, for teaching of general astronomy; this is a student-chosen teaching honor given by the Student Organization for Alumni Relations (SOAR).

Honorary Doctorate, Tartu University, Estonia, Dec 1999, among the first seven such degrees awarded by this ancient university in anticipation of Estonian re-independence, degree documents physically collected in special ceremony on Aug 2007. [Impending launch of Hubble Space Telescope prevented Toomre's participation in original ceremony.]

Fellow, Institute of Physics (UK), Aug 2004 onward.

Overseas Fellow, Sept 2004 – Dec 2004, Churchill College, University of Cambridge, England.

Professor of Distinction, College of Arts and Sciences, University of Colorado, Boulder, July 2009.

Hazel Barnes Prize winner, Chancellor, University of Colorado, Boulder, Mar 2010. As part of this award, Toomre gave the commencement address at the Dec 2010 graduation ceremonies.

International Astronomical Union Symposium 271, "Astrophysical Dynamics: From Stars to Galaxies", Nice, France, 21–25 June 2010, dedicated to Juri Toomre's career.

National Professional Activities:

Toomre has been vice-chair of the Solar Observatories Council (SOC) of AURA (Association of Universities for Research in Astronomy) with oversight for the National Solar Observatory, completed several terms on the Observatories Council (OC) dealing with NOAO, and has been member and chair of the Space Telescope Institute Council (STIC) which has oversight for the Space Telescope Science Institute (STScI) operating the Hubble Space Telescope (HST). Toomre took over from Lyman Spitzer directly after HST was launched. Toomre was chair of the scientific advisory committee to GONG (Global Oscillation Network Group), the major ground-based project in helioseismology. Toomre was a Co-I on the SOI–MDI helioseismology experiment on SOHO, and is a Co-I on the Helioseismic and Magnetic Imager (HMI) on the recently launched Solar Dynamics Observatory (SDO). Toomre has served on the Panel on the Sun and Heliospheric Physics, Solar and Space Physics Survey Committee, NAS Space Studies Board; on the Alliance Users Advisory Committee (UAC), National Center for Supercomputing Applications (NCSA); and has chaired the HST TAC Review Committee, examining observing time allocations and procedures for Hubble Space Telescope carried out by STScI. He has chaired the national AURA Decadal Steering Committee dealing with UVOIR astronomy. He served on the central committee of the NAS Decadal Survey of Astronomy and Astrophysics, Astro 2010, also called "New Worlds, New Horizons in Astronomy and Astrophysics". He served on the major NSF Astronomy Portfolio Review subsequent to Astro 2010.

Professional Societies:

International Astronomical Union, American Astronomical Society, Association of Marshall Scholars, American Physical Society, American Geophysical Union, Institute of Physics.

Publications:

"Magnetohydrodynamic Jets," Ph.D. Thesis, University of Cambridge (1967), 294 pp.

"The Annihilation of a Two-Dimensional Jet by a Transverse Magnetic Field," *J. Fluid Mech.* **30**, 65–82 (1967), with H.K. Moffatt.

"Time-Dependent Cellular Convection," *GFD WHOI Notes* **69-41**, 126–128 (1969).

"On Intergalactic Bridges," *Bull. Am. Astron. Soc* **2**, 350 (1970), with A. Toomre.

"Theoretical Model of NGC 4038/39," *Bull. Am. Astron. Soc.* **3**, 390 (1971), with A. Toomre.

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"Galactic Tails and Bridges," *Astrophys. J.*, **178**, 623–666 (1972), with A. Toomre.

"Radial Velocities in the Tail of NGC 4676A," *Publ. Astron. Soc. Pacific*, **84**, 851–853 (1972), with

J. Theys, E.A. Spiegel.

"Thermohaline Convection by Finite-Difference and Modal Techniques," *Trans. Amer. Geophys. U.* **53**, 425 (1972), with S.A. Piacsek.

"Violent Tides Between Galaxies," *Scientific American* **229**, 38–48 (1973), with A. Toomre.

"Nonlinear Cellular Motions in Poiseuille Channel Flow," *J. Fluid Mech.* **64**, 319–345 (1974), with J.-P. Zahn, E.A. Spiegel, D.O. Gough.

"Modal Equations for Cellular Convection," *J. Fluid Mech.* **68**, 695–719 (1975), with D.O. Gough, E.A. Spiegel.

"Highly Stretched Meshes as Functionals of Solutions," in *Lecture Notes in Physics*, Proc. Fourth Intern. Conf. Numer. Methods Fluid Dynam. (ed. R.D. Richtmyer, Springer-Verlag), 191–196 (1975), with D.O. Gough, E.A. Spiegel.

"Stellar Convection Theory. I. The Anelastic Modal Equations," *Astrophys. J.* **207**, 233–243 (1976), with J. Latour, E.A. Spiegel and J.-P. Zahn.

"Stellar Convection Theory. II. Single-Mode Study of the Second Convection Zone in an A-Type Star," *Astrophys. J.* **207**, 545–563 (1976), with J.-P. Zahn, J. Latour, E.A. Spiegel.

"Geophysical Fluid Dynamics Background for Ocean Thermal Power Plants," ERDA Publication NRL-GFD/OTEC 11/75, 67 pp. (1976), with S.A. Piacsek and G.O. Roberts.

"Numerical Solutions of Single-Mode Convection Equations," *J. Fluid Mech.* **79**, 1–31 (1977), with D.O. Gough, E.A. Spiegel.

"Recirculation and Thermocline Perturbations from Ocean Thermal Power Plants," ERDA Publication NRL-GF/OTEC 2/76, 26 pp. (1977), with S.A. Piacsek, P.J. Martin, G.O. Roberts.

"The Height Variation of Supergranular Velocity Fields Determined from Simultaneous OSO-8 Satellite and Ground-Based Observations," *Astrophys. J.* **227**, 600–613 (1979), with L. November, K.B. Gebbie, G.W. Simon.

"Convective Instability when the Temperature Gradient and Rotation Vector are Oblique to Gravity. I. Fluids without Diffusion," *Geophys. Astrophys. Fluid Dynam.* **13**, 289–316 (1979), with D.H. Hathaway, P.A. Gilman.

"Convective Instability when the Temperature Gradient and Rotation Vector are Oblique to Gravity. II. Real Fluids with the Effects of Diffusion," *Geophys. Astrophys. Fluid Dynam.* **15**, 7–37 (1980), with D.H. Hathaway, P.A. Gilman.

"Overshooting Motions from the Convective Zone and Their Role in Atmospheric Heating," *Highlights Astron.* **5**, 571–580 (1980).

"Nonlinear Evolution and Structure of Salt Fingers," in *Marine Turbulence*, (ed. J.C.J. Nihoul, Amsterdam), 193–219 (1980), with S.A. Piacsek.

"Internal Gravity Waves in the Solar Atmosphere. I. Adiabatic Waves in the Chromosphere," *Astrophys. J.* **249**, 349–371 (1981), with B.W. Mihalas.

"The Detection of Mesogranulation on the Sun," *Astrophys. J.* **245**, L123–L126 (1981), with L.J. November, K.B. Gebbie, G.W. Simon.

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"Steady Flows in the Solar Transition Region Observed with SMM," *Astrophys. J.* **251**, L115–L118 (1981), with K.B. Gebbie, F. Hill, L.J. November, G.W. Simon, R.G. Athay, E.C. Bruner, R.A. Rehse, J.B. Gurman, R.A. Shine, B.E. Woodgate, E.A. Tandberg-Hanssen.

"Internal Gravity Waves in the Solar Atmosphere. II. Effects of Radiative Damping," *Astrophys. J.* **263**, 386–408 (1982), with B.W. Mihalas.

"Time-Dependent Solutions of Multi-Mode Convection Equations," *J. Fluid Mech.* **125**, 99–122

(1982), with D.O. Gough, E.A. Spiegel.

"Nonlinear Modal Analysis of Penetrative Convection," *Geophys. Astrophys. Fluid Dynam.* **22**, 159–193 (1982), with J.-P. Zahn and J. Latour.

"Single-Mode Theory of Diffusive Layers in Thermohaline Convection," *J. Fluid Mech.* **125**, 75–97 (1982), with D.O. Gough.

"Vertical Flows of Supergranular and Mesogranular Scale Observed on the Sun with OSO-8," *Astrophys. J.* **258**, 846–859 (1982), with L.J. November, K.B. Gebbie, G.W. Simon.

"Solar Five-minute Oscillations as Probes of Structure in the Subphotosphere," in *Proc. Pulsations in Classical and Cataclysmic Variable Stars*, ed. J.P. Cox and C.J. Hansen (JILA), 139–146 (1982), with F. Hill, L.J. November.

"Review of Time-Dependent Convection and Attempts to Couple it to Pulsation in Stars," in *Proc. Pulsations in Classical and Cataclysmic Variable Stars*, ed. J.P. Cox and C.J. Hansen: (JILA), 170–181 (1982).

"Nonlinear Anelastic Modal Theory for Solar Convection," *Solar Phys.* **82**, 387–400 (1983), with J. Latour, J.-P. Zahn.

"Variability in the Power Spectrum of Solar Five-Minute Oscillations," *Solar Phys.* **82**, 411–425 (1983), with F. Hill, L.J. November.

"On the Detection of Subphotospheric Convective Velocities and Temperature Fluctuations," *Solar Phys.* **82**, 401–410 (1983), with D.O. Gough.

"Period Doubling and Chaos in Partial Differential Equations for Thermosolutal Convection," *Nature* **303**, 663–667 (1983), with D.R. Moore, E. Knobloch, N.O. Weiss.

"Penetrative Cellular Convection in a Stratified Atmosphere," *Astron. Astrophys.* **140**, 1–16 (1984), with J.M. Massaguer, J. Latour, J.-P. Zahn.

"Two-Dimensional Compressible Convection Extending Over Multiple Scale Heights," *Astrophys. J.* **282**, 557–573 (1984), with N.E. Hurlburt, J.M. Massaguer.

"Frequent UV Brightenings Observed in a Solar Active Region with Solar Maximum Mission," *Astrophys. J.* **283**, 879–886 (1984), with J.G. Porter, K.B. Gebbie.

"Attempt to Measure the Solar Subsurface Velocity," *Mem. Soc. Astron. Italiana* **55**, 153–161 (1984), with F. Hill, D.O. Gough.

"On the Determination of the Lifetime of Vertical Velocity Patterns in Mesogranulation and Supergranulation," in *Proc. Small-Scale Dynamical Processes in Quiet Stellar Atmospheres*, ed. S. Keil, (National Solar Observatory), 160–172 (1984), with F. Hill, L.J. November, K.B. Gebbie.

"Strong Downward Plumes Resulting from Compressibility in Nonlinear Convection and Their Coupling to Gravity Waves," in *Proc. Small-Scale Dynamical Processes in Quiet Stellar Atmospheres*, (ed. S. Keil, National Solar Observatory), 222–234 (1984), with N.E. Hurlburt, J.M. Massaguer.

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"Seismology of the Sun," *Science*, **229**, 923–931 and color cover, (1985), with J. Christensen-Dalsgaard, D.O. Gough.

"Transitions to Chaos in Two-Dimensional Double-Diffusive Convection," *J. Fluid Mech.* **166**, 409–448 (1986), with E. Knobloch, D.R. Moore, N.O. Weiss.

"Properties of Solar Oscillations," in *Seismology of the Sun and the Distant Stars*, (ed. D.O. Gough, Reidel), 1–22 (1986).

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"Travelling Waves and Chaos in Thermosolutal Convection," *Phys. Rev. A* **36**, 2862–2869 (1987), with A.E. Deane, E. Knobloch.

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"Oscillatory Doubly Diffusive Convection: Theory and Experiment," in *Physics of Structure Formation: Theory and Simulation* (ed. W. Güttinger, Springer-Verlag), 117–129 (1987), with E. Knobloch, A.E. Deane.

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Cattaneo, F., Hurlburt, N.E., Toomre, J. "Supersonic convection," *Astrophys. J. Lett.* **349**, L63–L66 (1990).

Merryfield, W.J., Toomre, J., Gough, D.O. "Nonlinear behavior of solar gravity modes driven by ^{3}He in the core. I. Bifurcation analysis," *Astrophys. J.* **353**, 678–697 (1990).

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