Curriculum Vitae & Scientific Rationale

Alfio M. Bonanno

Senior Researcher — Email: alfio.bonanno@inaf.it

INAF-Osservatorio Astrofisico di Catania — Web: http://webusers.oact.inaf.it/abo/

Via S.Sofia 78, 95128 Catania Italy — ORCID id: https://orcid.org/0000-0003-3175-9776

(a) Education & Training

Université Louis Pasteur	Strasbourg, Fr	Physics	Postdoc Fellow, 1996
Universitá di Catania	Catania, IT	Physics	Ph.D., 1995
Universitá di Catania	Catania, IT	Laurea in Fisica	*Magna cum Laude*, 1992

(b) Research & Professional Experience

2016 – present	Senior Researcher at Istituto Nazionale di Astrofisica
2015 – present	Italian national habilitation for Full Professor in Theoretical Physics
1999 – 2016	Ricercatore Astronomo, OACt
1993 – 1995	Research Assistant, University of Alberta, Canada

(c) Teaching

2006 – 2007	Fluid Dynamics and MHD, Universitá di Catania
2007 – 2008	General Relativity and Cosmology, Universitá di Catania
2009 – 2010	General Relativity and Cosmology, Universitá di Catania
2010 – 2011	General Relativity and Cosmology, Universitá di Catania
2014 – 2015	General Relativity and Cosmology, Universitá di Catania
2018 – 2019	General Relativity, Universitá di Catania
2019 – 2020	General Relativity, Universitá di Catania

(d) Awards and Funding

- Angelo Della Riccia Fellow, Accademia Gioenia awards for PhD Thesis, Consiglio Nazionale delle Ricerche (CNR) Fellow.
- Marie Curie Fellow, Astrophysikalisches Institut Potsdam, Potsdam, Germany (2006)
- PRIN INAF grant (Istituto Nazionale di Astrofisica) 2006 (local PI)
- AstroFit2 INAF program, Marie Sklodowska-Curie grant agreement No.664931 (Responsabile Scientifico).
- FLAG - INFN research grant (2020-present) scientific initiative (local PI).

(e) Publications

Most closely related

1. G. Guerrero, F. Del Sordo, A. Bonanno, and P. K. Smolarkiewicz, Global simulations of Tayler instability in stellar interiors: the stabilizing effect of gravity, MNRAS **490**, 4281–4291 (2019), arXiv:1909.02897 [astro-ph.SR] .
2. A. Bonanno, E. Corsaro, F. Del Sordo, P. L. Pallé, D. Stello, and M. Hon, Acoustic oscillations and dynamo action in the G8 sub-giant EK Eridani, A&A **628**, A106 (2019), arXiv:1907.01338 [astro-ph.SR] .
3. Alfio Bonanno, Stellar Dynamo Models with Prominent Surface Toroidal Fields, ApJ **833**, L22 (2016), arXiv:1612.00253 [astro-ph.SR] .

4. A. Bonanno, H. E. Fröhlich, C. Karoff, M. N. Lund, E. Corsaro, and A. Frasca, Magnetic activity, differential rotation, and dynamo action in the pulsating F9IV star KIC 5955122, A&A **569**, A113 (2014), arXiv:1408.3926 [astro-ph.SR] .
5. A. Bonanno, M. Baldo, G. F. Burgio, and V. Urpin, The neutron star in Cassiopeia A: equation of state, superfluidity, and Joule heating, A&A **561**, L5 (2014), arXiv:1311.2153 [astro-ph.HE] .
6. A. Bonanno, E. Corsaro, and C. Karoff, Asteroseismic stellar activity relations, A&A **571**, A35 (2014), arXiv:1409.5673 [astro-ph.SR] .
7. Alfio Bonanno, Solar Dynamo and Toroidal Field Instabilities, Sol. Phys. **287**, 185–196 (2013), arXiv:1211.5431 [astro-ph.SR] .
8. Alfio Bonanno and Vadim Urpin, Stability of the Toroidal Magnetic Field in Stellar Radiation Zones, ApJ **747**, 137 (2012), arXiv:1110.3340 [astro-ph.SR] .
9. Alfio Bonanno, Axel Brandenburg, Fabio Del Sordo, and Dhrubaditya Mitra, Breakdown of chiral symmetry during saturation of the Tayler instability, Phys. Rev. E **86**, 016313 (2012), arXiv:1204.0081 [physics.flu-dyn] .
10. A. Bonanno and V. Urpin, Non-axisymmetric instability of axisymmetric magnetic fields, A&A **488**, 1–7 (2008), arXiv:0806.4727 [astro-ph] .

Other significant publications

1. Alfio Bonanno and Hans-Erich Fröhlich, A New Helioseismic Constraint on a Cosmic-time Variation of G, ApJ **893**, L35 (2020).
2. A. Bonanno, R. Casadio, and A. Platania, Gravitational antiscreening in stellar interiors, J. Cosmology Astropart. Phys. **2020**, 022 (2020), arXiv:1910.11393 [gr-qc] .
3. Alfio Bonanno and Frank Saueressig, Asymptotically safe cosmology - A status report, Comptes Rendus Physique **18**, 254–264 (2017), arXiv:1702.04137 [hep-th] .
4. R. Silvotti, S. Schuh, R. Janulis, J. E. Solheim, S. Bernabei, R. Østensen, T. D. Oswalt, I. Bruni, R. Gualandi, A. Bonanno, G. Vauclair, M. Reed, C. W. Chen, E. Leibowitz, M. Paparo, A. Baran, S. Charpinet, N. Dolez, S. Kawaler, D. Kurtz, P. Moskalik, R. Riddle, and S. Zola, A giant planet orbiting the 'extreme horizontal branch' star V391 Pegasi, Nature **449**, 189–191 (2007).
5. A. Bonanno, D. Elstner, G. Rüdiger, and G. Belvedere, Parity properties of an advection-dominated solar $\alpha^2\Omega$-dynamo, A&A **390**, 673–680 (2002), arXiv:astro-ph/0204308 [astro-ph] .
6. Alfio Bonanno and Martin Reuter, Renormalization group improved black hole spacetimes, Phys. Rev. D **62**, 043008 (2000), arXiv:hep-th/0002196 [hep-th] .

(f) Recent academic activities

1. Regular referee for APS & AIP journals, MNRAS, A&A, CQG, JCAP
2. External referee for Research Council Leuven University, Research Foundation Flanders (FWO), National Romanian research grant application, Italian MIUR (Reprise experts lists).
3. Member of the *KASC*, Kepler Asteroseismic Science Consortium (KASC). WG1 (Solar-like oscillations), WG2 (Oscillating stars in open clusters): WG8 (RGB Oscillations), WG11 (Compact Pulsators).
4. Member of the *PLATO* (PLAnetary Transits and Oscillations of stars) consortium for the PLATO mission (scientific WG).

5. Member of *TASOC* Asteroseismic Science Consortium (TASC), WG-1: Asteroseismology of TESS exoplanet hosts, WG-2: Oscillations in solar-type stars, WG-3: Oscillating stars in clusters, WG-7: Red Giant oscillations
6. PI of the Project 2.2 Asteroseismology of active stars in *TASOC*. and PI of eight spectroscopic asteroseismic multisite observing campagin with SARG@TNG on solar like-stars. PI of photometric observing campaign on sub-dwarfs.
7. Member of the Scientific Board of *International PhD school on Nuclear Physics and Astrophysics* of Catania University. Co-Chair of SOC e LOC dello International Astronomical Union Symposia and Colloquia: Advances in Plasma Astrophysics, IAU S274 (2010). SOC Member of IAU SYMPOSIUM 354, SOLAR and STELLAR Magnetic Fields, Copiapo', Atacama, Chile (2019). SOC Member workshop on "“Stellar Magnetism: Challenges, Connections, and Prospects”, Potsdam, 2017.
8. Selected invited talks and seminars: "Magnetohydrodynamic instabilities of current-carrying jets", Lorentz Center, Leiden, 2011, (solicited contribution) and Co-chair of the final panel discussion. "Stellar dynamo and Kepler mission", Nordita program on "Dynamo, dynamical systems and Topology", Stockholm, July-Aug, 2011. "Stellar Dynamo Theory: new insights from the Kepler Mission", Magnetic Fields in the Universe, MFUIII, Zakopane, Poland. “Asterosesismology and stellar activity in the Kepler era: a new view on the solar-stellar connection”, American Museum of Natural History, NY, USA. ”Models of solar cycle and predictions”, LWS/SDO-3/SOHO-26/GONG-2011 meeting, Stanford, CA, USA. "Current-driven Instabilities in Stellar Radiation Zones: linear analysis and nonlinear evolution from DNS", Nordita program on "Differential Rotation and Magnetism across the HR Diagram", Stockholm, 2013. "The generation of magnetic fields in neutron stars", EWASS 2013, special symposium on “Stellar Magnetic Activity Across the HR Diagram”, Turku, Finlandia. "The Stability of magnetic fields in massive stars" Keynote Talk in "Stars with a Stable magnetic field: from pre-main sequence to compact remnant", University of Brno, 2078. "The Sun as a laboratory for fundamental physics", UFMG (Belo Horizonte) Brasil (2018), and Pontificia Universidad Catholica de Chile (Santiago), 2020.

RESEARCH INTERESTS

(a) The stability of magnetic fields in massive stars

Magnetic fields are ubiquitous along the HR diagram where, depending on the stellar mass, they play an important role in several astrophysical transport phenomena such as mixing and angular momentum transport. From the observational point of view the magnetic fields of hot stars are topologically much simpler and generally much stronger than the fields of cool stars. Moreover, unlike cool stars, their characteristics show no clear correlations with fundamental stellar parameters and for this reason the origin of these fields has been long debated.

Under the action of differential rotation even a weak fossil field with non-vanishing poloidal component will quickly wrap up into a predominantly toroidal configuration. Such configuration can be generated if Re_m of differential rotation is greater than 1, or $|\nabla\Omega| > \eta_m/r^3$ where Ω and η_m are the angular velocity and magnetic diffusivity, respectively. Estimating $|\nabla\Omega| \sim \Delta\Omega/r$ where $\Delta\Omega$ is a departure from the rigid rotation and assuming that the conductivity of plasma is $\sim 10^{16}$ s^{-1}, one obtains that this condition is satisfied if $\Delta\Omega/\Omega > 10^{-18}\Omega_{sec}^{-1}$ where Ω_{sec} is the angular velocity in inverse seconds. Therefore, even very weak departures from the rigid rotation lead to a generation of a strong toroidal field in stellar radiative interiors. On the other hand, during its evolution a massive star develops multiple convective regions, as a consequence a dynamo-generated field produced in these regions can in general penetrate the neighboring radiative zones and alter the transport properties of the local plasma.

It is difficult to imagine that a dynamo action can operate in stellar radiation zones as plasma flows with $\mathrm{Re}_m \gg 1$ (Re_m is the magnetic Reynolds number) are not available in internal radiation zones. The viability of the mechanism proposed in[1], and further investigated in[2] has never been proved[3]. For these reasons the prevalent opinion is that these fields have fossil origin, although recent analysis of the available observational data have seriously questioned this possibility[4]. It is therefore essential to progress in both analytical and numerical studies of magnetic field instabilities, in spite of the mathematical complexity of the problem. In fact, numerical simulations alone can fail to detect for instance resonant instabilities with very short azimuthal wavenumber[5].

The stability of toroidal field in stellar radiation zone has been discussed by Tayler in his seminal work[6]. The important conclusions of his investigations can be summarized in the following necessary and sufficient conditions for instability

$$\frac{d\ln B_\phi}{d\ln s} < 1, \quad m = 0, \qquad \frac{d\ln B_\phi}{d\ln s} < -\frac{1}{2}, \quad m \pm 1 \tag{1}$$

where s is the cylindrical radius and m is the azimuthal wavenumber. On the other hand, in spherical geometry the situation is much more involved and there are no clearly established sufficient conditions for instability in this case.

My research interest focus on stability analysis and direct numerical simulations of realistic stably stratified stellar interiors in order to estimate the combined effect of gravity, rotation and finite thermal diffusivity in order to understand the complex observational zoo of Ap/Bp stars.

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2. J. Braithwaite, A&A **449**, 451 (2006), astro-ph/0509693 .

3. J.-P. Zahn, A. S. Brun, and S. Mathis, A&A **474**, 145 (2007), arXiv:0707.3287 .
4. L. Ferrario, A. Melatos, and J. Zrake, Space Sci. Rev. **191**, 77 (2015), arXiv:1504.08074 [astro-ph.SR] .
5. A. Bonanno and V. Urpin, Phys. Rev. E **84**, 056310 (2011), arXiv:1111.4040 [astro-ph.SR] .
6. R. J. Tayler, MNRAS **161**, 365 (1973).

(b) Coupling the internal dynamo with the corona in cool dwarfs

One of the most compelling problems in modern dynamo theory is the formulation of a realistic coupling between the internal magnetic field and the external field in the atmosphere. In particular, the fundamental issue of the definition of the habitability zone in cool-dwarf is hampered by our poor understanding of the coupling between the internal dynamo and the outer corona.

In fact the boundary conditions for the electric and the magnetic field at the stellar surface put severe constraints on the allowed coronal field configurations, and it is often necessary to resort to very crude approximations for the latter.

The standard textbook boundary condition employed in mean-field dynamo theory amounts to consider a current-free field in the region $r \geq R$ where R is the stellar radius, so that $\nabla \times \mathbf{B} = 0$ in this domain. Although in the solar case this assumption is motivated by the possibility of describing the almost rigid rotation of the coronal holes in the lower corona[1], it be might incorrect to extend its validity in more active stars. In fact, as current-free fields represents the states of minimum energy under the constraint that the normal component of the field at the photosphere is fixed, they cannot provide the additional energy required to sustain a significant activity level. Recent measurements of Faraday rotation in the solar corona support the evidence for large scale coronal currents[2], an essential ingredient to explain coronal heating in terms of Joule dissipation. Clearly on much smaller scales the presence of currents is unavoidable in order to explain the twisted field structure of filaments and prominences.

Force-free magnetic fields, defined by $\nabla \times \mathbf{B} = \alpha_{ff}(\mathbf{x})\mathbf{B}$ where $\alpha_{ff}(\mathbf{x})$ is a scalar function, can be more appealing from the physical point of view, at least for very low plasma-β values. However, recent investigations based on direct numerical simulations have shown that the free magnetic energy and the efficiency of coronal heating via currents dissipation are still very limited in these models[3]. On the other hand, current numerical simulations by construction fail to consider the back-reaction of a realistic corona in the dynamo action in the interior, which assumes a vacuum field configuration for the outer boundary[4].

A consistent dynamo model can however be constructed following the approach outlined by the writer in his recent works[5,6]. My research interest to extend this approach in order to include a more realistic model of the corona also by taking into account of the data from the Solar Orbiter Mission The ultimate goal of this direction of research is to improve our still very limited understanding of the solar magnetic cycle, considering a consistent coupling between the interior field and the outer corona.

1. A. G. Nash, N. R. Sheeley, Jr., and Y.-M. Wang, Sol. Phys. **117**, 359 (1988).
2. S. R. Spangler, ApJ **670**, 841 (2007), astro-ph/0702438 .
3. H. Peter, J. Warnecke, L. P. Chitta, and R. H. Cameron, A&A **584**, A68 (2015), arXiv:1510.04642 [astro-ph.SR] .

4. R. F. Pinto, A. S. Brun, L. Jouve, and R. Grappin, ApJ **737**, 72 (2011), arXiv:1106.0882 [astro-ph.SR] .
5. A. Bonanno, ApJ **833**, L22 (2016), arXiv:1612.00253 [astro-ph.SR] .
6. A. Bonanno and F. Del Sordo, A&A **605**, A33 (2017), arXiv:1706.02223 [astro-ph.SR] .