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ALESSANDRO BRESSAN

Curriculum vitae

Present Position

Full Professor
SISSA, Scuola Internazionale Superiore di Studi Avanzati,
via Bonomea, 265, 34136 Trieste, IT
From 2011 to 2016 Head of the Astrophysics Sector
From 2011 to 2016 Elected member of the SISSA Senate

Previous Appointments/Affiliations

1995-2010 Associate Astronomer INAF, Astronomical Observatory of Padova (Italy).
1989-1995 Associate Researcher at the Astronomical Observatory of Padova

Honours/Awards

2006 June	Commendatore dell'Ordine al Merito della Repubblica Italiana

Memberships

1993	International Astronomical Union (IAU)
2004	ISI Highly Cited Researcher 2001
2005	Associazione Gruppo 2003, Charter Member

Scientific Impact

The scientific activity of the writer is documented by more than **360** papers published.
From ADS: citation number ~ **18,600 (4000 normalized)**.
h-index: **60**; g-index: **134;** i10-index: **147**
3 papers with more than **1000** citations; **5** with **500-1000** citations; **30** with **100-500** citations

Academic and Professional Activities

1990-1995	Lecturer of "Theoretical Astrophysics" Astronomy Department, Padova, Italy.
1996-2010	Lecturer of "Stellar Structure and Evolution" SISSA, TS, Italy
2000-2005	Lecturer of "Stellar Evolution and Population Synthesis" Ph.D. Course INAOE Puebla, Mexico
1990	Lecturer of "Stellar Evolution and Population Synthesis" SISSA, TS, Italy
1991	Lecturer of "Evolution of Massive Stars" Italian National School for Astrophysics.
1993	Lecturer of "Physics of Stellar Interiors", Italian National School for Astrophysics.
1994	Lecturer of "Stellar Evolution" Ph.D. Course Universidad Autonoma de Madrid, Spain
1995	Lecturer of "Numerical Methods for Astrophysics" Astronomy Department, Pd, Italy
1998	Lecturer of "Population synthesis and applications to galaxy formation" Ph.D.Course Hefei University, China
1996-2001	Local coordinator of the Padova node of the European TMR programme "The Formation and Evolution of Galaxies".

Visiting Astronomer at several institutions: Universidad Autonoma de Madrid, Spain; Beijing

Astronomical Observatory, China, Hofei University, China; INAOE Puebla Mex.
Several Degree, MSc and Ph.D. theses supervised.
Several national and international meetings and workshops attended.
Several papers refereed for international astrophysics journals.

Research Interests

- Stellar Structure and Evolution
  - Physics of stars.
  - Calculation of databases of stellar evolutionary tracks for stellar population studies of resolved and unresolved stellar systems. All masses from very low (0.1 Msun) to very massive (>200 Msun) are evolved until advanced phases. Very broad range of initial chemical composition and partition of heavy elements are considered.
  - Stellar BH formation

- Population synthesis
  - Isochrones in several photometric systems for the analysis of resolved stellar populations, such as star clusters in the Galaxy and in other nearby galaxies.
  - Spectral Evolution of Galaxies
  - Study of the panchromatic integrated properties of star clusters and galaxies, from the far ultraviolet to the mid and far Infrared.
  - Chemo-spectro-photometric models of galaxies, in a comprehensive range of magnitudes and colours, integrated spectra and narrow band indices.

- Interstellar medium
  - Analysis of effect of dust in the integrated light of galaxies.
  - Prediction of dust yields from stellar environments.

- Specific observational projects for testing the predictions of stellar evolution theory and for the analysis of the properties of stellar populations in nearby and distant galaxies.

HIGHLIGHTS OF THE SCIENTIFIC ACTIVITY

The current activity of the writer is mainly addressed to the theory of stellar evolution (advanced phases of intermediate and low mass stars, evolution of massive stars) and chemo-spectro-photometric evolution of galaxies (Stellar Populations, Early type galaxies in the MID infrared; analysis of spectroscopic galaxy surveys; properties of Ultra Luminous Infrared Galaxies).
A synthesis of the past activity is provided below.

Stellar Evolution

Convection in stellar interiors: the problem of internal mixing
The author begun his scientific career in the field of convective energy transport in stellar interiors under the supervision of Prof. C. Chiosi. After a critical analysis of some existing formulations of the problem (Maeder 1975, Roxburgh1978), the author derived a new formulation for non-local convection and applied it to the evolution of massive stars (Bressan, Bertelli & Chiosi 1981). The efficiency of the overshoot in the core has been since then always a matter of strong debate with very different opinions among the community (Bressan et al. 1984; Bertelli, Bressan et al.1985; Bertelli, Bressan et al. 1986). Only recently it has been regarded as an important phenomenon, necessary to explain observable features in the colour magnitude diagrams of star clusters, by the stellar evolution community. New asteroseismological observational data provided by KEPLER space telescope (e.g. Miglio et al. 2012, Bossini et al. 2015) and accurate HST data on star clusters (Girardi et al. 2013) indicate that its efficiency is similar to that predicted by the author in his first formulation. A larger efficiency seem to be suggested for the mixing below the bottom of convective envelopes both in low mass stars (Fu et al. 2015) and in massive stars (Tang et al. 2015, 2016).

The Padova Database of Stellar Evolution Tracks and Isochrones
In collaboration with Dr. G. Bertelli and Prof. C. Chiosi, the author embarked in the large effort of renovating the complex stellar physics needed to follow the wide range of stellar evolutionary phases: low mass stars up to the helium flash, horizontal branch stars and intermediate mass stars up to the development of the double shell phase (the so called Asymptotic Giant Branch phase) and, finally, cooling along the White Dwarf sequence. As a result, a very large homogeneous and complete set of evolutionary tracks was for the first time computed and shared to the astrophysic community (Bressan et al. 1993; Alongi, Bertelli, Bressan et al 1993, Fagotto, Bressan et al. 1994a; Fagotto, Bressan et al. 1994b; Fagotto, Bressan et al. 1994c; Girardi, Bressan et al. 1996; Girardi, L., Bressan, et al., 2000). A number of accompanying investigations have been devoted to the calibration of several input physical parameters, whose theoretical determination was highly uncertain due to the complexity of the associated physical scales, e.g. convective overshoot because of unknown convective scale length, mass loss in the red giant phase because of the (still) poorly known driving mechanism, etc.. (Chiosi, Bertelli, & Bressan, 1988; Chiosi, Bertelli, & Bressan, 1992; Bertelli, Mateo, Chiosi, & Bressan, 1992; Girardi, Chiosi, Bertelli & Bressan, 1995)
These early evolutionary tracks and the more recent updates are at the base the largest existing databases of stellar isochrones widely used in almost all the interpretative studies of the spectro-photometric properties of stellar systems "The Padova Isochrones" (Bertelli, Bressan et al. 1994; Girardi, Bertelli, Bressan et al. 2002)
The author has recently performed a thorough revision of the stellar evolution code which is now named "PARSEC", the PAdova TRieste Stellar Evolution Code (Bressan et al. 2012). **According to a 2016 analysis, this paper is among the top 1% most highly cited papers in Astrophysics.**

Stellar Mass BH formation
The author recently performed the most exhaustive calculation of massive single star evolution, sixteen values of chemical composition and stellar masses from

12 M_Sun to 500 M_Sun (Chen et al. 2014, 2015, Tang et al. 2015,2016). These calculations led to the redefinition of the initial–final mass relation of massive stars and corresponding chemical yields (Spera, Mapelli & Bressan 2015, Slemer et al 2016). **Figure 6 in the paper by Spera et al. has been inserted as the first figure in the paper "Astrophysical Implications of the Binary Black Hole Merger GW150914" by Abbott et al. 2016, accompanying the announcement of the discovery of the gravitational-wave (GW) source GW150914 with the Advanced LIGO detectors.**

Dust Formation in AGB and Massive stars
The author is performing a thorough revision of the Asymptotic Giant Branch (AGB) phase. This phase of low and intermediate mass stars dominates the near infrared (NIR) rest frame spectral region and is one of the main sources of dust production.
But, in spite of its importance for our knowledge of the evolution of the galaxies in the early Universe, the evolution of stars in the AGB phase is not yet computed in a self-consistent way. There are several physical phenomena that still require a certain degree of tuning, like mass-loss and mixing. Together with other collaborators the author will compute new sets of stellar evolutionary tracks with composition matching that of the observed systems, and corresponding input physics such as EOS and Opacities. The latter point is particularly relevant because, for example, the variation of opacity due to carbon synthesis or destruction may drive the star towards regions of higher or lower mass loss rates (Marigo, Girardi, Bressan, et al. 2008). We have developed a numerical model to follow the detailed chemistry of dust along the AGB (Nanni, et al. 2013, 2014, 2016, Marigo et al. 2016, Aringer et al. 2016). This will be a key ingredient because we plan a) to obtain direct estimates of the mass-loss rates of AGB stars using MIR Color Magnitude Diagrams (CMD) of nearby stellar systems; b) to reassess the luminosity, lifetimes and chemistry of AGB stars, using optical-NIR CMDs, as well as chemical abundances in planetary nebulae; c) derive new chemical and dust yields at varying chemical composition. This analysis will be extended also to supergiant stars with circumstellar environments similar to those of AGB stars (red supergiants and Luminous Blue Variables). We will finally provide reliable SSP models over a large range of age and metallicity, that will be used also for the study of high redshift systems. **These activities are being performed in the framework of the ERC project STARKEY (2014-19: PI P. Marigo, UNIPD**).

Dark Matter annihilation effects on the first stars
The author analysed the effects of weakly interacting massive particles (WIMPs) dark matter (DM) on the collapse and evolution of the first stars in the Universe. DM particles of the parent halo are accreted in the protostellar interior by adiabatic contraction and scattering/capture processes. We find that energy release from annihilation reactions might effectively counteract the gravitational collapse, in agreement with suggestions from other groups about the presence of a long lasting stalling phase. However, contrary to what suggested, this phase is only transient and the stars may contract toward the Zero Age Main Sequence. Later in the evolution, DM scattering/capture rate becomes high enough that energy deposition from annihilations may significantly alter the pre-MS evolution of the star in a way that depends on DM velocity dispersion, density and elastic scattering cross-section with baryons. **This is the first consistent analysis of DM annihilation effects on the evolution of first stars (Iocco et al 2008, Ripamonti et al 2010).**

Early Type Galaxies

Chemo-spectro-photometric evolution of early type galaxies.
The author constructed the first consistent chemo-spectro-photometric population synthesis model to predict the spectral evolution of galaxies at varying chemical composition (Bressan, Chiosi & Fagotto, 1994). Previous models were based on the solar chemical composition and were restricted to a limited range of evolutionary phases. The inclusion of stellar models of both low and high

metallicity allowed for the first time to follow in a great detail the evolution of spectral properties as function of the chemical enrichment and age. Important results were obtained in the domain of early type galaxies (ETG): i) the prediction of the existence of very luminous (and highly attenuated) proto-ellipticals at redshifts z > 2; ii) the explanation of the ultraviolet (UV) excess in ETGs in term of old metal rich stellar population, still accepted today as the most likely scenario (see also Bertola, Bressan et al. 1995); iii) the need of abandoning simple pictures of galactic chemical evolution, like the close box approximation. The latter point was further investigated in Tantalo, Chiosi, Bressan & Fagotto (1996) and in Portinari, Chiosi, & Bressan (1998) and Chiosi, Bressan et al. (1998), where more complete chemical and spectral evolution models were derived. Recently the writer participated to the construction of the first consistent model of joint evolution of spheroidal galaxies and central massive objects (Granato, De Zotti, Silva, Bressan & Danese 2004).

Narrow Band Indices

Since broad band colors of ETGs are affected by a strong age-metallicity degeneracy that prevents any firm age ranking of their stellar population content (see e.g. Charlot, Worthey & Bressan 1996), the author expanded the techniques developed by researchers at the Lick Observatory for the investigation of the optical narrow band indices of ETGs. The first consistent galaxy evolution model in the narrow band indices were obtained by Bressan, Chiosi & Tantalo (1996). This article contains one of the first discussions of the nowadays called "downsizing effect" i.e. that lower velocity dispersion galaxies appear to have a more prolonged star formation activity than higher velocity dispersion galaxies. This was confirmed by a later investigation where, for the first time the effects of the so called α–enhancement effect (i.e. the larger proportion of α–elements -O, Ne, Mg, etc.- with respect to Fe, likely due to a predominance of supernovae from massive stars in the chemical enrichment process) were investigated (Tantalo, Chiosi, & Bressan 1998).
Current developments of this technique are focussed on the effects of arbitrary partitions of heavy elements (Annibali, Bressan et al. 2007) and on the analysis of large galaxy surveys such as the Sloan Digital Sky Survey (Clemens, Bressan et al 2006, 2009). **The latter investigations provide a very clean picture of the imprinting left by the interplay between clustering of dark matter halos and feedback effects, in the formation and evolution of ETGs.**

Early type galaxies in the Mid Infrared: discovery of the 10 μm excess.
A distinct peculiarity of the isochrones computed by the author is that they have been pushed up to the latest phases of the evolution of low and intermediate mass stars, the so called Asymptotic Giant Branch (AGB) phase, and beyond (Marigo, Bressan & Chiosi 1996; Marigo, Bressan, & Chiosi 1998; Marigo, Girardi & Bressan 1999). In this field a very relevant contribution is constituted by the calculations of the effects of dust in the circum-stellar envelopes of mass loosing AGB stars (Bressan, Granato & Silva 1998). This work has provided the first consistent picture of stellar evolution in the mid infrared spectral range (MIR) and **has led the author to discover the MIR excess in ETGs, based on a series of approved Spitzer Space Telescope observational programs (Bressan et al. 2006).** Currently, the MIR spectral region of ETGs is used to detect the presence of intermediate age stellar populations as well as tiny amount of recent star formation and or nuclear activity (Buson et al 2009, Vega et al 2010, Annibali et al 2010, Clemens et al 2011, Panuzzo et al 2011, Rampazzo et al. 2013, Rampazzo et al.2014).

Spectrophotometric Properties of Late Type and Starburst Galaxies

The author has also given a significant contribution to the study of the properties of the interstellar medium (ISM) in late type and starburst galaxies.

Nebular emission lines
The writer computed **the first extended grid of HII emission line regions that take into account the variation of metallicity in both the line emission properties and ionizing star cluster (Garcia-Vargas, Bressan, Diaz 1995a; 1995b)**. This grid has been later included in the Database for Galaxy Evolution Modeling (Leitherer et al , 1996). It has been recently updated (Molla et al 2009). Other relevant applications of these models were made in the study of obscured star formation in Luminous Infrared Galaxies. By means of an original technique that combines the intensity of the emission and absorption spectral lines and the continuum properties (first devised by the writer), it was possible to clarify the complex pattern between star formation and age selective extinction in these luminous galaxies (Poggianti, Bressan, & Franceschini 2001, Panuzzo et al 2003, Fan et al 2014) and to explore the early dust-obscured phase of galaxy formation with blind mid-/far-infrared spectroscopic surveys (Bonato et al 2014, 2015).

Spectro-photometric evolution of galaxies with dust
The writer has actively participated to the huge effort of constructing **the first consistent spectrophotometric galaxy evolution model in presence of dust (Silva, Granato, Bressan, & Danese 1998)**. This model is widely recognized as the most advanced diagnostic tool for the panchromatic study of the spectral energy distribution (SED) of late type and starburst galaxies.
It has been adopted as the standard spectral evolution code by several world leading groups in the field of Semi-analytic Galaxy Formation (e.g. among others, a collaboration that begun in the context of the TMR EU program "Galaxy Formation and Evolution (1996-2001)", of which the author was the Italian Scientist in Charge, - Granato et al. 2000, Baugh et al. 2005, Lacey et al 2010, Almeida et al. 2010).

Radio emission and the panchromatic spectral evolution of galaxies
The author is currently involved in a large project for the panchromatic analysis of galaxy evolution. To this purpose the original dust spectral evolution model has been extended to include thermal and non-thermal radio emission related to star formation (Bressan, Silva & Granato 2002), and nebular line emission (Panuzzo, Bressan et al. 2003, Obi et al. 2017). In the former investigation the author provided an elegant explanation for the existence of the Far Infrared/Radio correlation over a very wide range in star formation rates (hence strengths of radiation and magnetic fields). Basing on the success of this explanation, **the author devised a new dating method that exploits the expected deviations from the above correlation at early and late starburst phases (Prouton, Bressan et al. 2004; Vega, Silva, Panuzzo, Bressan, 2005)**. This technique is applied to the study of star formation, AGN activity and the properties of the dense ISM in local Ultra Luminous Infrared Galaxies (Clemens, Vega, Bressan et al. 2008; Vega, Clemens, Bressan et al. 2008, Clemens et al 2010) as well as in high redshift star forming spheroidals (Lapi et al. 2011, Cai et al. 2014, Fan et al. 2014, Mancuso et al. 2015, Obi et al. 2017).