EMANUELE DALESSANDRO
Curriculum Vitae

Bologna, 19 December 2016

A - General Information

Full Name: Emanuele Dalessandro
Date of Birth: 01 September 1981
Place of Birth: Matera (Italy)
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Spoken Languages: Italian, English

B - Education

2005: Master degree in Astronomy cum Laude at the University of Bologna (UNIBO)
2009: PhD degree in Astrophysics at UNIBO – Thesis title *''A panchromatic study of stellar populations in Galactic globular clusters* "- Supervisor: Prof. F.R. Ferraro, Co-Supervisor: Prof. B. Lanzoni

C - Academic appointments

April-August 2009: Post-doctoral fellow at the Gemini Observatory North (HI-USA)
September 2009-September 2011: post-doctoral fellow at the Department of Physics and Astronomy (DIFA) at UNIBO
October 2011–July 2016: "Ricercatore Tempo Deteminato – tipo a)" (Assistant Professor) at DIFA-UNIBO
August 2016 – now: "Ricercatore a Tempo Indeterminato" (Researcher - Staff Scientist) at the National Institute for Astrophysics (INAF)

D - Awards

2007: Winner of the "Giovani Eccellenze" price at the Agenzia Spaziale Italiana (ASI)
2008: 3-months grant in the context of the MARCOPOLO project to work at the Department of Astronomy of the University of Virginia (USA) with Prof. R. Rood

E - Academic activity

(1) Teaching

- **Assistant Professor of the stellar courses** ("Astrofisica Stellare", "Evoluzione Stellare" and "Popolazioni Stellari Risolte") at DIFA – UNIBO since 2011
- **Assistant Professor of "Esperimentazioni di Fisica I"** at DIFA – UNIBO since 2011
- **Member of the examination boards of the quoted courses**

Detailed teaching activity timetable:

- A.A. 2007-2008: 30 hours of classes of Basic Math for the first year students, executed in the framework of the support activity planned by the "Presidente del Corso di Laurea in Astronomia"

- A.A. 2008-2009: 30 hours of classes of Basic Math for the first year students, executed in the framework of the support activity planned by the "Presidente del Corso di Laurea in Astronomia"

- A.A. 2011-2012: 12 hours of classes for the stellar course "Astrofisica Stellare"
  20 hours of classes and laboratories for the course "Esperimentazioni di Fisica I"

- A.A. 2012-2013: 12 hours of classes for the stellar course of "Astrofisica Stellare"
  45 hours of classes and laboratories for the course "Esperimentazioni di Fisica I"

- A.A. 2013-2014: 8 hours of laboratory for the course of "Laboratorio di Astrofisica"
  12 hours of classes for the stellar course of "Astrofisica Stellare"
  45 hours of classes and laboratories for the course "Esperimentazioni di Fisica I"

- A.A. 2014-2015: 12 hours of classes for the stellar course of "Astrofisica Stellare"
  45 hours of classes and laboratories for the course "Esperimentazioni di Fisica I"

- A.A. 2015-2016: 10 hours of classes for the stellar course of "Astrofisica Stellare"
  48 hours of classes and laboratories for the course "Esperimentazioni di Fisica I"

(2) Supervision of PhD students and post-doctoral fellows and working- group coordinator

- **Coordinator of the Work Package "Photometry" for the project "Comic-Lab** – star clusters as cosmic laboratories for Astrophysics, Dynamics and fundamental Physics", funded by ERC (under contract ERC-2010-AdG-267675)

- **Co-Supervisor of 4 PhD students**:

  Dr. Cristina Pallanca, 2011-2013, "Cosmic-Lab: Searching for optical companions to binary millisecond pulsars in globular clusters" – Current position: post-doctoral fellow at DIFA-UNIBO

  Dr. Davide Massari, 2012-2014, "Cosmic-Lab: Terzan 5 as a fossil remnant of the Galactic Bulge formation-epoch" Current position: post-doctoral fellow at the Leiden Observatory

Dr. Sara Saracino, 2014-present, "Cosmic-Lab: Looking for the building blocks of the Galactic Bulge"

Dr. Silvia Raso 2016-present, "An UV survey of Blue Straggler Stars and Multiple Stellar Populations in Galactic globular cluster"

- **Coordinator of the scientific activity of 5 Post-Doc fellows**:

  - Dr. Nicoletta Sanna (2010-2013)
  - Dr. Rodrigo Contreras (2010-2013)
  - Dr. Cristina Pallanca (2013-now)
  - Dr. Edoardo Prospero Lagioia (2013-2015)
  - Dr. Davide Massari (2014 – 2015)

- **Co-Supervisor of 11 Master Degree students at DIFA-UNIBO:**

  A.A. 2007-2008:
  "*La popolazione di Blue Stragglers nell' ammasso globulare Galattico post-core- collapse NGC7099*" - Simona Bovinelli

  A.A. 2008-2009:
  "Controparti ottiche di Millisecond Pulsar nell'ammasso globulare M28" – Cristina Pallanca

  A.A. 2009-2010:
  "L'ammasso globulare NGC4833" – Carmelo Barbaro

  A.A. 2010-2011:
  - *"Lo stato dinamico dell' ammasso globulare NGC6218 (M12)"* – Filippo Mancini
  - *"Analisi fotometrica delle popolazioni stellari in Terzan5"* – Davide Massari

  A.A. 2011-2012:
  - *"Osservazioni Hubble Space Telescope dell'ammasso globulare NGC6624"* – Claudia Castiglione

  A.A. 2012-2013:
  - *"Controparti ottiche di Millisecond Pulsar in M5"* – Caterina Tiburzi

  A.A. 2013-2014:
  - *"Le popolazioni stellari di Liller1 da osservazioni con ottiche adattive multi- coniugate"* – Sara Saracino
  - *"Ammassi stellari doppi nella Grande Nube di Magellano"* – Claudia Ferrari

  A.A. 2014-2015:
  - *"L'orologio dinamico negli ammassi della Grande Nube di Magellano"* – Davide Andruet

  A.A. 2015-2016:
  - "*Le Blue Stragglers e le popolazioni multiple in quattro ammassi globulari galattici*"

(3) Institutional responsibilities

2014: Member of the selection committee of students for the PhD program in Astrophysics at UNIBO (Cycle XXX)
2012-now: Member of the "Consiglio di Corso di Laurea in Astrofisica e Cosmologia" at UNIBO
2012-now: Member of the "Consiglio di Dipartimento di Fisica e Astronomia" at UNIBO
2007 and 2008: Tutor for the first year students at DIFA-UNIBO

2010-now: Member of selection committees for the assignment of several Post-Doctoral and pre-Doctoral positions at UNIBO:

1. 2014: Selection of a Post-Doc position at DIFA-UNIBO – Title: "Cosmic-Lab: optical companions to binary millisecond pulsars"
2. 2014: Selection of a Post-Doc position at DIFA-UNIBO – Title: "Searching for fossil remnants of the Galactic Bulge formation epoch"
3. 2013: Selection of Post-Doc position at DIFA-UNIBO – Title: "Cosmic-Lab: Stellar photometry in globular clusters"
4. 2012: Selection of a Post-Doc position at DIFA-UNIBO – Title: "Cosmic-Lab: photometry of hot stellar populations in Galactic globular clusters"
5. 2012: Selection of a Post-Doc position at DIFA-UNIBO – Title: "Cosmic-Lab: analysis of HST data in the near-UV"
6. 2010: Selection of a pre-Doctoral contract at DIFA-UNIBO – Title: "Studio fotometrico e spettroscopico delle due popolazioni stellari di Terzan5"
7. 2010: Selection of a Post-Doc position at DIFA-UNIBO – Title: "Le Blue Stragglers e la definizione dell'orologio dinamico per gli ammassi stellari"

F – Visiting programs at international institutes

- **2008 and 2011**: University of Virginia (VA- USA)
- **2008 and 2010**: European Space Agency (The Netherlands)
- **2008**: Kavli Institute for Theoretical Physics (CA – USA)
- **2009, 2010 and 2011:** GEMINI North Observatory (HI – USA)
- **2014:** Liverpool John Moores University (UK)
- **2015:** European Southern Observatory (ESO – Germany)
- **2016:** Liverpool John Moores University (UK)

G - Organization of meetings and courses

2017: Organizer and Chair of the Scientific Organizer Committee (SOC) for the Symposium "*Bridging the near and the far: from the Milky Way to nearby galaxies*" for the European Week of Astronomy and Space Science (EWASS) Conference 2017 – Prague (Czech Republic)

2016-now: Organizer of the official joint INAF-OABo/DIFA-UniBo Astrophysics seminars

2015: Organizer and Chair of the SOC for the Session "*Horizontal Branch Stars and UV radiation from old stellar systems: what we know and what we are still missing*" for the European Week of Astronomy and Space Science (EWASS) Conference 2015 – Tenerife (Canary Islands)

2014: Organizer of the PhD Course on "*Stellar Populations in the Local Group*" at DIFA-UNIBO (speakers: Dr. Monica Tosi, Dr. Livia Origlia, Prof. Ricardo P. Schiavon, Prof. Piercarlo Bonifacio)

H - International tasks

2015-2016:. **Co-Chair of the ESO Observing Programme Committee (OPC) panels** for period P99
member of the OPC panels for periods P97, P98

2015: member of the "Science Team" of MOONS - Multi Object Optical and Near-infrared spectrograph for the ESO-VLT (PI: Dr. M. Cirasuolo - ESO; web-page: http://www.roe.ac.uk/~ciras/MOONS/VLT-MOONS.html).
MOONS is an international project and Italy-INAF is a major partner of the Consortium. The first light is scheduled for the end of 2019.
The MOONS Consortium will have about 300 nights of guarantee time in which it will carry out two major surveys: a Galactic and an extra-Galactic one. I am actively contributing to the design and the implementation of the Galactic survey.

2015: external scientific collaborator of the "Science Team" of the Ultraviolet Imaging Telescope (UVIT) on the Canadian-Indian ISRO ASTROSAT space telescope (contact person: Dr. L. Bianchi – John Hopkins University; web-page: http://astrosat.iucaa.in/). ASTROSAT is a multi-wavelength astronomy mission on an IRS-class satellite in a 650-km, near-equatorial orbit. It is currently scheduled to be launched in October 2015. ASTROSAT will carry five astronomy payloads for simultaneous multi-band observations. UVIT is one of the five instruments and it consists of two twin 40cm telescopes covering far-UV to optical wavelengths.

2007-now: referee for the main Astrophysics international journals: The Astrophysical Journal (ApJ), Astronomy & Astrophysics (A&A) and Monthly Notice of the Royal Astronomical Society (MNRAS)

I - Funding information

Co-I of seven funding projects financed for a total of 585KEur:

2014: Co-I of the scientific project "The Kaleidoscope of stellar populations in Galactic Globular Clusters with the Hubble Space Telescope" (PI: Cassisi) financed with 128KEur in the context of the PRIN-INAF 2014.

2010: Co-I of the project "Probing the link between dynamics and stellar evolution" (PI: Ferraro) financed for 115KEur by the Agenzia Spaziale Italiana (ASI)

2010: Co-I of the project "Unveiling the true nature of the stellar system Terzan5: the relic a pristine fragment of the Galctic bulge?" (PI: Origlia) financed with 56KEur in the context of the PRIN-INAF 2010.

2010: Co-I of the project "Exploiting the adaptive power: a dedicated free software to optimize and maximize the scientific output of images from present and future adaptive optics facilities" (PI: Diolaiti) financed with 98KEur in the context of TECNO-INAF 2010

2008: Co-I of the project "Tracing stellar cluster dynamics with blue straggler stars, binary millisecond pulsars and intermediate-mass black holes" (PI: Fusi Pecci) financed for 67 KEur in the context of the PRIN-INAF 2008.

2006: Co-I of the project "Gli ammassi stellari: un laboratorio per l'astrofisica e la cosmologia" (PI: Ferraro) financed with 73KEur in the context of "Progetti Strategici di Ateneo"

2006: Co-I of the project "Probing the nature of binary BSS and MSP: two key stellar populations to trace internal cluster dynamics" (PI: Ferraro) financed with 48KEur in the context of the PRIN-INAF 2006.

J – Research activity

J1. General considerations and executive summary

The research activity of the candidate is mainly focused on the study of stellar populations in star clusters within the Milky Way and nearby galaxies.
Resolved stellar populations are efficient tracers of the formation and evolution of galaxies. In fact, the study of their evolutionary, chemical and dynamical properties and of the way they interact with the environment, provides the basis to obtain **"local calibrators and clocks"** necessary for the interpretation of distant and unresolved galaxies.
The research activity of the candidate is developed in collaboration with national and international scientists at many different international institutes (as for example the University of Liverpool, the University of Virginia, the University of California at Los Angeles). The main international collaborators of the candidate are:

- Prof. Maurizio Salaris (Liverpool John Moores University - UK)
- Prof. Robert R. O'Connel (University of Virginia - USA)
- Prof. Ricardo P. Schiavon (Liverpool John Moores University - UK)
- Dr. Mike R. Rich (University of California at Los Angeles - UCLA –USA)
- Dr. Rodrigo Ibata (Observatoire Astronomique Universite' de Strasbourg - France)
- Prof. Nate Bastian (Liverpool John Moores University - UK)
- Prof. Enrico Vesperini (Indiana University – USA)

The main tools used by the candidate to perform his research are accurate multi-band photometry and high-precision astrometry. The candidate has always explored and developed new and sometimes pioneering observational methodologies that are key also for the theoretical-interpretative point of view.
A detailed description of the scientific production along with the complete list of publications is reported in the following sub-sections. We can here schematically summarize the main general sectors of research where the candidate has a recognized primary role within the national and international community:

- *hot stellar populations in resolved and unresolved old stellar systems*
- *exotic objects in dense environments as tracers of dynamical evolution*
- *multi-band and multi-instrument high-precision photometry*

Understanding the origin and the frequency of hot stars in resolved stellar systems has important implications for the interpretation of integrated spectra of galaxies. Indeed hot stars have been suggested to be the responsible of the so-called "UV-upturn" observed in elliptical galaxies and in the bulge of spirals. The research activity of the candidate aims at using Galactic globular clusters as local templates to constrain the physical mechanisms characterizing hot and low mass stars and their link with the integrated UV properties of distant unresolved systems.
Based on two HST Large Programs (see point (3) below in this Section) of which the candidate is Co-I, and two surveys of Galactic globular clusters in UV with GALEX and, with Spitzer at Mid-IR wavelengths, his research follows two main lines: one is focused on the so called ***"Horizontal Branch second parameter problem"*** and the derivation of **an empirical mass loss law for population II giants** in resolved stellar systems, while the other is mainly focused on integrated UV indices for extra-Galactic systems.
The candidate has strongly contributed to recent advances in these fields, developing a new approach able to unveil the role of multiple stellar populations in shaping the horizontal branch morphology in globular clusters. The candidate has been invited to give a talk on the properties of the horizontal branch in globular clusters at the 40th COSPAR Scientific Assembly at Moscow (Russia) and he has been the organizer and Chair of the SOC of a dedicated session at the European Week for Astronomy (EWASS) 2015 "*Horizontal Branch Stars and UV radiation from old stellar systems: what we know and what we are still missing*".

Globular clusters are also known to be very efficient environments to form non-canonical stellar objects. In this context, the candidate plays an active role in the study of the properties of exotic populations (like Blue Straggler stars, millisecond pulsars, low mass X-ray binaries) as tracers of **the effects of internal dynamics on the evolution of stars in dense stellar systems.** This project aims at i) unveiling the formation processes of exotic objects and ii) defining innovative observational tools able to measure the degree of dynamical evolution of stellar systems, based on the properties of exotic systems. These are indeed crucial ingredients for understanding the past and future history of collisional systems and their properties in different environments. The observational material the candidate is exploiting primarily comes from two ESO and one HST Large Programs of which the candidate is Co-I (see point (3) below in this Section).
This research requires the development of optimal tools to compare observations with N-body simulations and stellar evolution models. Because of the expertise acquired in this field, the candidate is now a main collaborator of several groups developing dynamical models for stars clusters.

As in many fields of Astrophysics, also for the study of stellar populations, the use of a **multi-frequency, multi-instrument and multi-technique approach** is crucial to maximize the information and the accuracy of the results.
The candidate is well known in the community for his expertise in stellar photometry and accurate astrometry on data acquired with the last generation of ground based and space imagers at UV, optical and IR wavelengths. In particular, he has shown to make an efficient use (both in the acquisition and data-reduction phases) of 1) high-resolution UV-optical HST imaging cameras (WFPC2, WFC3 and ACS); 2) high-resolution near-IR imagers assisted by adaptive optics like (MAD@ESO-VLT and GeMS@GEMINI); and 3) low-resolution UV-GALEX and Mid-IR Spitzer data.
During his post-doctoral fellowship at the Gemini North Observatory, he has developed original routines for the reduction of data acquired with the space telescope GALEX and adaptive optics assisted camera GeMS@GEMINI for resolved photometry in dense stellar systems like globular clusters. He has also contributed to verify the scientific performances of these instruments in stellar fields of extreme conditions of crowding and faintness.
The candidate is also member of large collaboration led by the adaptive optics group at INAF-OABO that aims at developing new software and tools for the use of the last generation of adaptive optic systems for the study of resolved stellar populations and for testing the possible performances and science cases with the future MAORY-MICADO imager for the E-ELT.
Given his expertise in UV astronomy, the candidate is also a scientific collaborator of the "Science Team" of the Canadian-Indian UV-telescope UVIT aboard ASTROSAT. He is also collaborating with members of the Spanish-Russian WSO-UV telescope.

(1) Publication record

- **<u>94 publications on peer-reviewed international journals, 17 as first author</u>:**
  3 papers published on *Nature*, 62 on the *Astrophysical Journal (ApJ)*, 19 on the *Monthly Notice of the Royal Astronomical Society (MNRAS)*, 4 on the *Astronomical Journal (AJ)*, 2 on *Astronomy and Astrophysics (AA), 2 on the Astrophysics and Space Science (ApSS)* and 2 in press on the *ApJ* (the complete list of papers is reported in Section K)

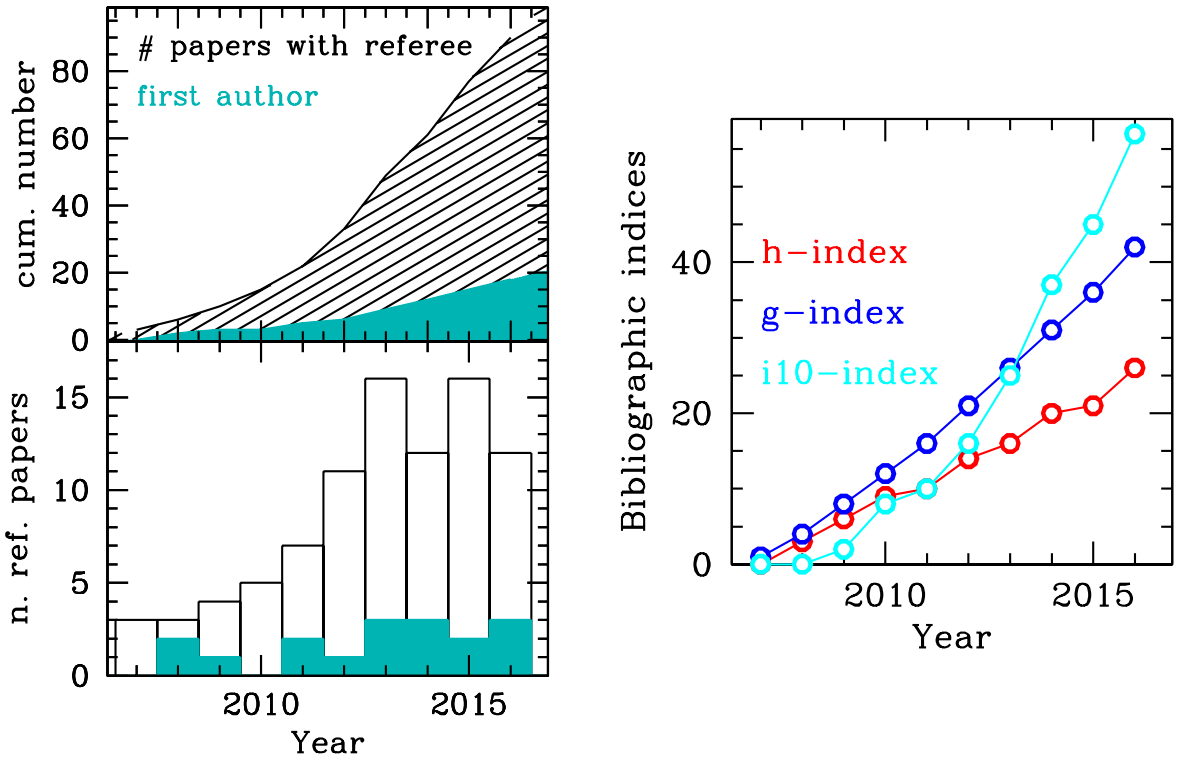
<u>Note that this publication record has been obtained in only 10 years (2007-2016) of research activity, including the 3 year-PhD thesis work.</u>

- ***<u>18 published contributions to</u>* <u>international conferences and workshops</u>** (workshop papers are listed in Section L)

- **<u>22 press releases:</u>**
  3 from ESO, 3 from NASA/ESA, 2 from the Keck Observatory, 1 from European Research Council, 6 from UNIBO, 6 from INAF and 1 from the GEMINI Observatory (Press releases and links to the relative web-pages are in point (2) below in this Section)

- **<u>Co-author of one chapter of the book "Ecology of Blue Straggler Stars",</u>** *Astrophysics and Space Science Library, Volume 413*, ISBN 978-3-662-44433-7. Springer-Verlag Berlin Heidelberg, 2015

Total citations: 2188 -- **Average citations per product:** 24.3 -- **Hirsch (H) index:** 26



<u>Left upper panel</u>: cumulative distribution of papers published on peer-reviewed international Journals;
<u>Left bottom panel:</u> histogram of the number of publications on peer-reviewed international Journals per year;
<u>Right panel:</u> variation of the main bibliographic indices as a function of time. The h-index is defined as the largest number h such that h papers have at least h citations. Given a set of article ranked in decreasing order of the number of citations, the g-index is the (unique) largest number such that the top g article received (together) at least g^2 citations. The i10-index represents the number of paper with at least ten citations.

(2) Press Releases

- **07-09-2016: "Astro-archeology: a rare fossil of the early Universe"**
  An international team of astronomers has discovered that a fossil remnant of the early Milky Way harbors stars of hugely different ages. This stellar system, named as Terzan 5, is located in the heart of our galaxy (the Bulge) and has the appearance of a globular cluster, but it is like no other star cluster known. It contains stars remarkably similar to the most ancient ones in the Milky Way, but it also hosts a significant population of much younger objects. Hence Terzan 5 could be a site in the Galactic Bulge where recent star formation occurred.

  NASA/ESA/HUBBLE https://www.spacetelescope.org/news/heic1617/
  ESO https://www.eso.org/public/news/eso1630/
  Keck http://www.keckobservatory.org/recent/entry/rare_fossil_relic_of_early_milky_way_discovered
  UNIBO http://www.magazine.unibo.it/archivio/2016/09/07/le-due-facce-di-terzan5-il-fossile-della-via-lattea
  INAF http://www.media.inaf.it/2016/09/07/la-doppia-vita-di-terzan5/

- **13-01-2016: "A cosmic scale unmasks thin-looking fat stars"**
  A few heavy stars generated by stellar interactions are hidden in the core of ancient stellar systems made of millions lighter stars (with masses lower than that of our Sun). A team of researchers of the Bologna University (Italy), in collaboration with INAF, has proposed a "cosmic scale" able to unmask these elusive thin-looking fat stars.

  INAF http://www.media.inaf.it/2016/01/11/come-ti-smaschero-le-stelle-false-magre/
  UNIBO http://www.unibo.it/en/notice-board/a-201ccosmic-scale201d-unmasks-thin-looking-fat-stars

- **16-06-2015: "Seeing where the stars collide"**
  Using the advanced adaptive optics system GeMS at the Gemini South telescope, astronomers have imaged a beautiful stellar jewel-box – a tightly packed cluster of stars that is one of the few places in our galaxy where astronomers think stars can actually collide. The discovery has been reported by tens of journal and websites worldwide.

  GEMINI Observatory http://www.gemini.edu/node/12379
  UNIBO http://www.magazine.unibo.it/archivio/2015/07/02/ecco-liller-1-lammasso-globulare-dove-le-stelle-collidono
  INAF http://www.media.inaf.it/2015/06/17/la-dove-le-stelle-collidono/

- **19-12-2012: "Dynamical age differences among coeval star clusters as revealed by blue stragglers"**
  The discovery of a clear correlation between the position of the minimum in the radial distribution of Blue Straggler stars and the relaxation time of the host systems represents the first definition and calibration of a totally empirical clock able to precisely measure the dynamical age of star clusters. The discovery has been reported by tens of journal and websites worldwide.

  ESO http://www.eso.org/public/news/eso1252/
  NASA/ESA http://www.spacetelescope.org/news/heic1221/
  ERC http://erc.europa.eu/succes-stories/how-look-young-when-you're-not-––stars-reveal-secret-aging-well
  UNIBO http://www.magazine.unibo.it/archivio/2013/un_orologio_cosmico
  INAF http://www.media.inaf.it/2012/12/19/vagabonde-blu/

- **<u>26-11-2009</u>: "The cluster Terzan 5 as a remnant of a primordial building block of the Galactic bulge"**
  The discovery of two stellar populations with different iron content and (possibly) age in the globular cluster-like system Terzan 5 suggests that it could be the remnant of one of the Bulge primordial building blocks. This discovery sheds new light on the Bulge formation and on the origin of the exceptional millisecond pulsar population of Terzan5. The discovery has been reported by tens of journals and web sites worldwide.

  UNIBO-INAF:http://www.magazine.unibo.it/archivio/2009/11/26/il_primo_fossile_cosmico
  ESO: http://www.eso.org/public/news/eso0945/
  Keck: http://www.keckobservatory.org/recent/entry/a_galactic_fossil_in_the_core_of_the_milky_way

- **<u>23-12-2009</u>: "Two distinct sequences of blue straggler stars in the globular cluster M 30"**
  The discovery of two distinct sequences of Blue Stragglers in the Post Core Collapsed globular cluster M30 could represent the first clear-cut detection of the signature of the two BSS formation processes (binary evolution and collisions), both boosted by the cluster core collapse (CC) event. The discovery has been reported by tens of journals and web sites worldwide.

  UNIBO http://www.magazine.unibo.it/archivio/2010/cosi_le_stelle_si_mantengono_giovani/
  NASA/ESA http://www.spacetelescope.org/news/heic0918/,
  INAF http://www.media.inaf.it/2009/12/23/cosi-le-stelle-si-mantengono-giovani/

(3) Telescope Time allocated at international facilities

- **<u>PI of 1 HST program</u>** for observations with WFC3 for a total of 8 orbits
  - *"Multiple populations in the low-mass globular clusters Ruprect106 and IC4499" (*Prop ID: 14075)

- **<u>PI of 6 ESO-VLT programs</u>** for observations with FORS2 and FLAMES for a total of 10 nights allocated
  - ***"****What sets the location of the Grundahl jump in the massive globular cluster NGC~6388?"* (FLAMES; Prop:099.D-0263)
  - *"Cosmic-Lab: the binary fraction radial distribution in dynamically evolved Galactic globular clusters"* (FORS2; Prop:097.D-0145)
  - *"The Kinematics of multiple populations in NGC6362: a glance to the epoch of cluster formation"* (FLAMES; Prop:097.D-0325)
  - *"Cosmic-Lab: the binary fraction in the outer regions of Galactic globular clusters"* (FORS2; Prop:093.D-0228)
  - "*Multiple populations in low-mass globular clusters: the case of NGC6362*" (FLAMES; Prop: 093.D-0618)
  - *"Cosmic-Lab: the binary fraction in the outer regions of Galactic globular clusters"* (FORS2; Prop:091.D-0562)

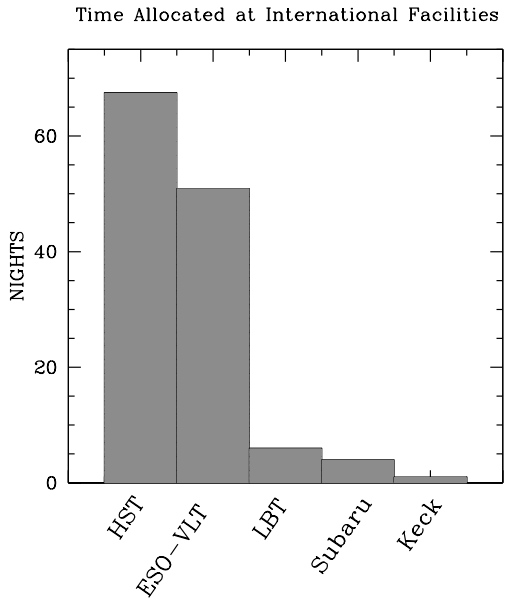
- **<u>PI of 3 LBT programs</u>** for observations with LBC for a total of 4 nights allocated
  - "*Search for extra-tidal features around old Galactic open clusters*"
  - "*Multiple populations in the low-mass globular clusters"*
  - *"The radial variation of globular cluster MF"*

- **Co-I of 22 ESO-VLT programs** for a total allocated time of 48 nights
- **Co-I of 8 programs with the Hubble Space Telescope** for a total of 405 orbits allocated
- **Co-I of several successful proposals with Keck, LBT and Subaru** for a total of 11 nights
- **Visiting astronomer at several observatories** (ESO-VLT, GEMINI North, Green Bank Radio Telescope …)

Large Programs and surveys

Co-I of 2 HST Large Programs:
- "*The HST Legacy Survey of Galactic Globular Clusters: Shedding UV Light on Their Populations and Formation"* (131 orbits; Cycle 21 – ID 13297 – PI: Piotto)
- "UV light from old stellar populations: a census of UV sources in Galactic Globular Clusters" (177 orbits; Cycle 16 – ID 11975 – PI: F.R. Ferraro)

Co-I of 2 ESO Large Programs with FLAMES, KMOS and SINFONI:
- *"Cosmic-Lab. Probing globular cluster internal dynamics: radial velocity dispersion and rotation profiles of 30 Galactic globular clusters"* (194 hr; PI: F.R. Ferraro - Prop 193.D-232)
- *"Unveiling the kinematics in the core of high-density globular clusters with SINFONI"* (101 hr; PI: F.R. Ferraro – Prop 195.D-0750)



Number of nights allocated at the major international telescopes trough open competition. HST orbits have been converted in nights assuming 1.5 hr per orbits and 9 hr per night.

(4) Invited and contributing talks, seminars

- **Invited review talk on "***Globular clusters through the HST and JWST eyes"* at the conference Science with Hubble and James Webb Space Telescopes V – Venice March 2017

- **Invited review talk on "***Photometric evidence of multiple stellar populations in globular clusters"* at the conference Multiple Populations in globular clusters: where do we stand? – Sexten July 2016

- **Invited talk** on "*UV properties of globular clusters: stellar populations through the HST and GALEX eyes"* at the 40th COSPAR Scientific Assembly Moscow (Russia) 2014

- **Contributing talks** at international conferences:

  - "Blue Straggler Stars in GCs: observational results"; COSMIC-LAB/MODEST conference 18-22 April 2016 – Bologna
  - *"What's the standard afterall? Clues for new HST observations"* – Workshop on multiple stellar populations in GCs – 26-28 April 2016 - Liverpool (UK)
  - *"Tracing mass segregation in globular clusters with three different indicators";* Modelling and Observing Dense Stellar systems – MODEST 2-6 March 2015 – Concepcion (Chile)
  - *"Constraining the true nature of an exotic binary in the core of NGC6624"* COSPAR Scientific Assembly – Moscow (Russia) 2014
  - *"Globular clusters in UV: from the Horizontal Branch to the integrated colors"* ; Resolved and unresolved stellar populations – RASPUTIN 13-17 October 2014 ESO Garching (Germany)
  - *"First evidence of fully spatially mixed first and second generations in GCs"*; A Critical Look at Globular Cluster Formation Theories: Constraints from young Massive Clusters – 14-18 July Sexten (Italy)
  - *"Old stellar systems in UV: resolved and integrated properties"* ESO/NUVA/IAG Workshop on Challenges in UV astronomy 7-11 October 2013 ESO Garching (Germany)
  - *"An empirical clock to measure the dynamical age of stellar systems"* 10th Pacific Rim Conference on Stellar Astrophysics 27-31 May 2013 – Seoul (South Korea)
  - *"UV properties of Galactic globular clusters with GALEX"* Reading the Book of globular clusters with the lens of stellar evolution 26-28 November 2012 Rome (Italy)
  - *"Probing the dynamical state of stellar aggregates with BSS double sequences"* Ecology of Blue Straggler stars 5-9 November 2012 – Santiago (Chile)
  - *"Another non-segregated Blue Straggler population in a globular cluster: the case of NGC2419"* Italian Astronomical Society Meeting 2009 Teramo (Italy)
  - *"Testing the Lens-Thirring effect with the current generation of orbiting satellites"* Cospar General Assembly Montreal (Canada)

- **8 invited seminars at national and international Institutes** at ESO, ESA-Estec, Gemini North Observatory, University of Virginia, ASI, INAF-OAR, INAF-OABO

- **2 invited outreach seminars** at "Gruppo Astrofili Bolognesi" and "Planetario di Reggio Calabria".

J2. Research topics

<u>i) Interplay between dynamics and stellar evolution in star clusters</u>

Globular clusters are the ideal laboratory to study how the environment and internal dynamics can affect the evolution of single and passively evolving stars. In fact, their ultra-dense cores are very efficient "furnaces" for generating exotic objects as low-mass X-ray binaries, cataclysmic variables, millisecond pulsars (MSPs) and blue straggler stars (BSS).
In this contest the "stellar evolution" group at UNIBO, in collaboration with other national and international institutes is conducting a wide study aiming at:

1- **probing the nature of BSS**: toward the definition of a "dynamical clock" for stellar systems

2- **hunting for the most massive neutron stars**: probing the equation of state of matter at the nuclear equilibrium density.
3- **unveiling the existence of IMBHs**: the missing link in the formation of cosmic structures

This project has been the subject of the PhD Thesis of the candidate and of a significant fraction (more than 20 papers) of his production. The candidate has been also the supervisor of the PhD thesis of Dr. Cristina Pallanca that was focused mainly on the search for optical companions to exotic objects with transient properties, like MSPs.
At least two main recent results that have strongly contributed to move a step forward in the field can be highlighted from this project. Two of the related papers have been published by Nature and have been the object of several press releases (see point (2) of Section J1).

- *Detection of two distinct sequences of BSS in the post core-collapse globular clusters* – These works have shown that BSS can form both via collisions and mass-transfer and BSS double sequences can be used as unique tools to precisely date the catastrophic event of the core-collapse.

- *Dynamical age differences among coeval star clusters as revealed by blue* – This work has introduced the definition of the so called "dynamical clock", a fully empirical tool based on the BSS radial distribution able to rank globular clusters according to their dynamical age.

The project requires the use of high-resolution photometric (HST in particular) and spectroscopic data (like FLAMES or XSHOOTER) and a detailed comparison with dynamical models and N-body simulations.
Three Large Programs have been assigned to the project in the last years, one with HST and 2 with ESO instruments.
The candidate has strongly contributed to the advance in this field in the last few years by developing new techniques for the analysis of HST data, UV in particular, and the search for transient objects in stellar clusters. He has also developed new diagnostics able to shed new light on the formation channels of exotic objects and on the interpretation of the dynamical properties of their host systems.
The candidate has strongly contributed to the definition of the observational data-base the project is based on and he has played a crucial role in training students, PhD and post-doctoral fellows directly involved in the project.
The candidate is currently leading a pilot program that has been awarded 4 nights of observations with FORS2 at ESO-VLT to characterize the binary population in low-density Galactic globular clusters both in their cores and in the outer regions.

ii) Old stellar populations in the Ultraviolet

The UV properties of old stellar populations have been the subject of intense scrutiny since the late sixties when the so-called UV-upturn was first discovered. In spite of major recent progress, there are still important gaps in our understanding of the nature of stars that dominate the UV light of old systems.

The candidate, in collaboration with the Bologna "stellar evolution" group, M. Salaris and R. Schiavon from the Liverpool University and R. O'Connel from the University of Virginia, is conducting an intense study aimed at 1) characterizing the ***UV properties of Galactic and extra-Galactic systems*** and 2) ***constrain the physical mechanisms driving the formation of hot stars in old systems.***

By means of two combined Large programs with the UV space telescopes GALEX and HST in UV filters (see point (3) of Section J1), the candidate has built up the largest and homogeneous collection of integrated and resolved UV photometric data of Galactic GCs.
This collection offers the unique opportunity to understand the driving mechanisms of the UV properties of old stellar populations and of the so-called "*Horizontal Branch (HB) second parameter problem".*

Indeed, by using these data, the candidate has unveiled, from the unresolved point of view, interesting correlations between UV colors and integrated properties (like metallicity, age ...) of GCs. In particular, for the first time he has found that UV colors are correlated with the mass of the host galaxy, being red in dwarf (like the Sagittarius dwarf galaxy) and extremely blue in giant elliptical galaxies (like M87).
Such a result is likely connected with the different chemical enrichment efficiency experienced by GCs and it represents new ingredient to account for in any theoretical model of the formation mechanisms of GCs and their multiple populations.

On the resolved side, tracing the UV properties of old stellar populations basically means studying the evolution and frequencies of hot and low-mass stars like Horizontal Branch and their progeny. In this context, the candidate has developed a new approach and optimized tools that make use of high-quality HST UV data, state of the art theoretical models and synthetic populations (as typically used for star formation history analyses) to constrain the physical mechanisms driving the effective temperature distribution of HB stars and the relative fraction of post-HB stars. The role of not well constrained physical effects (like radiative levitation and gravitational settling) in horizontal branch stars has been properly tested and implemented in the models. This study has been able to unambiguously highlight the role of He abundance spreads on HB stars by avoiding any assumption about poorly constrained physical mechanisms like mass loss along the red giant branch.
The success and the novelty of the approach have made the candidate a reference to the scientific community in the field. He has been invited to give a review talk on the UV properties of Galactic globular clusters (see point (4) of Section J1), he has been selected for contributing talks on the subject and as referee of papers related to this topic. Also, he has organized and he is the SOC Chair of the Session entitled "Horizontal Branch Stars and UV radiation from old stellar systems: what we know and what we are still missing" for the EWASS conference 2015. The candidate is now playing an active role in the "Horizontal Branch" group of the HST UV legacy Survey (point (3) in Section J1).

iii) Mass loss from Population II giants

The final stages of stellar evolution are characterized by non-negligible events of mass-loss.
The mass lost from stars has a crucial impact on their following evolution and its exact knowledge is crucial to properly build theoretical models. Despite its importance, very few empirical estimates of mass loss have been obtained so far on population II stars and basically all theoretical models are still based on the Reimers law.
Mass loss along the Red Giant Branch phase has a direct impact on the temperature distribution of stars in the Horizontal Branch phase and therefore on our capability to predict the UV colors of unresolved populations and the physical mechanisms involved in that.
In order to move a step forward in this field, our group (with the main collaboration of L. Origlia from INAF-OABO and M. Rich from UCLA) has performed a mid-IR survey with the space telescope Spitzer. This program has produced extremely accurate and deep images of the central regions of 17 GCs with photometric bands around 10 microns, thus opening a new window on the mass loss mechanisms in giants. The project has succeeded in producing **the first empirical mass loss law for population II giants**. These results have shown important differences with respect to the literature thus allowing a significant step forward in our understanding and interpretation of the late stages of the evolution of low-mass stars. We have in fact provided clear evidence that mass loss is an episodic mechanism involving red giant branch stars only for a relatively small fraction (~15%-20%) of their evolution during their brightest phases. Moreover, we have found that mass loss increases only mildly with increasing metallicity, in contrast with previous expectations.
The candidate has contributed to the definition of optimized diagnostics able to highlight the presence of stars with clear evidence of mass loss, i.e. able to trace the **presence of cool gas or dust excess** due to the photospheric activity of the stars. He has also trained young students involved in the project on the data reduction and interpretation.

In collaboration with Prof. M. Salaris (University of Liverpool), the candidate is currently working on the implementation of such a new empirical law in the available stellar evolution models. He is also testing the impact of these new results on the second parameter problem and the UV-upturn in the elliptical galaxies.

iv) Multiple Stellar Populations in GCs

An increasing number of spectroscopic observations have provided strong evidence for a widespread presence of multiple stellar populations in globular clusters. The observed star-to-star variations of light elements, such as Na, O, Al and Mg, indicate that a significant fraction of globular clusters must have formed out of gas processed through a high-temperature CNO cycle. Moreover, photometric studies have revealed the presence of multiple main sequences, sub-giant and red giant branches, thus providing additional and crucial elements to the observational framework of multiple stellar populations.

The candidate is part of a project that involves researchers at DIFA-UNIBO, INAF-OABO and the University of Liverpool that aims at tracing the **dynamical and kinematical differences among multiple populations** to **disentangle among different formation scenarios and constraining the primordial events of gas and dust production** in globular clusters.
Within this wide and ambitious project and given his expertise, the candidate is currently leading a full characterization of multiple stellar populations in GCs by means of photometric data. This is indeed the first crucial step to provide basic information to perform N-body simulations, develop multiple stellar evolution dynamical evolution models and to design spectroscopic follow-ups.
By using a combination of HST, ground-based wide field and Sloan Digital Sky Survey data and making use of state of the art built-in-house software and routines, the candidate has recently obtained the following main results on this topic:

- In the majority of GCs, second-generation stars are more centrally concentrated than the first generation ones. This observational evidence provides indirect support to the scenario where Intermediate-mass Asymptotic Giant Branch and/or Fast Rotating Massive stars are the main polluters of the primordial gas in GCs.
- The low mass GC NGC6362 represents a unique (so far) exception to this general behavior; in fact in this system multiple stellar populations share the same radial distribution. This case provides a crucial benchmark to test predictions from other formation scenarios. In fact, such a configuration can be the result of an extremely advanced dynamical state of the cluster or it can indicate that multiple populations formed through a different formation channel in this cluster.
- An ongoing kinematical campaign with FLAMES that includes a program of which the candidate is PI and a dedicate ESO Large Program (see point (3) of Section J1), has revealed significant evidence of the kinematical differences among different sub-populations. Such a result may open a new window on our comprehension of the nature of different sub-populations and on the very early stages of the stellar cluster formation.

The candidate is currently investigating possible imprints of the formation of multiple populations on the stellar mass function. By means of the most advanced instruments, like MUSE@VLT, we are complementing the preliminary results obtained with FLAMES
In addition, young clusters in the Large and Small Magellanic Clouds are under analysis with both HST and high-resolution spectrographs as templates of the early phases of life of old stellar systems.

v) The Galactic bulge formation process

By using the last generation of Infrared ground-based (GeMS@GEMINI, XShooter@ESO-VLT, Nirspec@KeckII) and space instruments (WFC3-IR@HST), the candidate with the "stellar evolution group" in Bologna, is conducting a large survey of the Galactic bulge. This research is part of a general project that aims at **understanding the Galactic structure and the formation of its components**.

The Galactic bulge has been proposed to have formed from massive sub-structures that suffered strong dynamical interactions with other similar systems at the early epoch of the Galaxy's formation or with the central disk/bar later on. Most of these early fragments dissolved/merged together to form the bulge, but a few of them could have survived the total disruption and could still be present somewhere in the Galaxy.
By using the multi-conjugate adaptive optics demonstrator MAD@VLT and NIRSPEC@Keck, our group has opened a new window on the comprehension of the **formation of the Bulge**. Indeed we have found that the Bulge stellar system Terzan5 has at least three clearly distinct stellar populations with very different iron content ([Fe/H]=-0.70, [Fe/H]-0.2 and [Fe/H]=+0.3) and it does not show evidence of Al-O anti-correlation commonly found in GCs. In addition, Terzan5 shows metal content and α-enhancement very closely resembling those of the bulge stars.
These striking similarities with the bulge population strongly suggest that, at odds with ωCentauri, that was probably accreted from outside the Galaxy, Terzan5 formed and evolved within its current environment, being therefore a **candidate fossil fragments** that contributed to form the galactic Bulge.
To test this possibility, our group, in collaboration with the one of the Universidad de Concepcion (Chile) and UCLA (USA) is currently surveying Terzan5 and its peripheries to trace possible evidence of interactions with the environment and constrain its orbit.
We are currently searching for other similar systems in the Bulge (like Liller1 or Terzan6 for example) to shed new light on our understanding of spheroids formation and evolution.
The candidate is strongly contributing to the project leading the acquisition and analysis of the adaptive optics and HST data. This work requires the development of the ad-hoc data-analysis technique that the candidate is optimizing in collaboration with the adaptive-optic group at INAF-OABO.
The candidate has been supervisor of the Master Degree and PhD thesis of Dr. Davide Massari that are both strictly related to this project. Also, he is supervisor of the Master Degree thesis and of the ongoing PhD project of Sara Saracino who is working on GeMS@GEMINI data to unveil the presence of stellar systems similar to Terzan5 (see Section F).
The project has led to the publication of several papers, one of them on Nature and has been the object of press releases from the most important international institutes.

K - List of publications on peer-reviewed international journals

1. **Multiple Populations in the Old and Massive Small Magellanic Cloud Globular Cluster NGC 121**
   Dalessandro, E.; Lapenna, E; Mucciarelli, A.; Origlia, L.; Ferraro, F.R.; Lanzoni, B.; 2016, ApJ 829, 77

2. **GeMS/GSAOI performances from a user perspective**
   Dalessandro, E.; Saracino, S.; Origlia, L.; Marchetti, E.; Ferraro, F. R.; Lanzoni, B.; Geisler, D.; Mauro, F.; 2016, SPIE 9909, 5V

3. **GeMS/GSAOI photometric and astrometric performance in dense stellar fields**
   Dalessandro, E.; Saracino, S.; Origlia, L.; Marchetti, E.; Ferraro, F.R.; Lanzoni, B.; Geisler, D.; Cohen, R.E.; Mauro, F.; Villanova, S.; 2016, ApJ 833, 111

4. **No mass segregation in the low mass globular cluster NGC6101**
   Dalessandro, E.; Ferraro R.F., Massari D., Lanzoni B., Miocchi P., Beccari G.; 2015, ApJ 810, 40

5. **Evidence of tidal distortions and mass loss from the old open cluster NGC 6791**
   Dalessandro, E.; Miocchi, P.; Carraro, G.; Jilkova, L.; Moitinho, A; 2015 MNRAS 449, 1811

6. **Old stellar systems in UV: resolved and integrated properties**
   Dalessandro E.; 2014 Ap&SS 354, 47

7. **First Evidence of Fully Spatially Mixed First and Second Generations in Globular Clusters: The Case of NGC 6362**
   Dalessandro, E.; Massari, D.; Bellazzini, M.; Miocchi, P.; Mucciarelli, A.; Salaris, M.; Cassisi, S.; Ferraro, F. R.; Lanzoni, B.; 2014, ApJ 791L, 4

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   Dalessandro E., Pallanca C., Ferraro F. R., Lanzoni B., Castiglione C., Vignali C., Fiorentino G.; 2014, ApJ 784L, 29

9. **Double Blue Straggler Sequences in Globular Clusters: The Case of NGC 362**
   Dalessandro E., Ferraro F.R., Massari D., Lanzoni B., Miocchi P., Beccari G., Bellini A., Sills A., Sigurdsson S., Mucciarelli A., Lovisi L.; 2013, ApJ, 778, 135

10. **Ultraviolet Observations of the Globular Cluster M10 from HST and GALEX: The BSS Population**
    Dalessandro E., Ferraro F. R., Lanzoni B., Schiavon R. P., O'Connell R. W., Beccari, G.; 2013, ApJ, 770, 45

11. **The horizontal branch in the UV colour-magnitude diagrams - II. The case of M3, M13 and M79**
    Dalessandro E., Salaris M., Ferraro F.R., Mucciarelli A., Cassisi S.; 2013, MNRAS, 430, 459

12. **Ultraviolet Properties of Galactic Globular Clusters with Galex. II. Integrated Colors**
    Dalessandro E.; Schiavon R.P., Rood R. T., Ferraro F.R., Sohn S.T., Lanzoni B., O'Connell R. W.; 2012, AJ, 144, 126

13. **The Binary Fraction in the Globular Cluster M10 (NGC 6254): Comparing Core and Outer Regions**
    Dalessandro E., Lanzoni B., Beccari G., Sollima A., Ferraro F. R., Pasquato M.; 2011, ApJ, 743, 11

14. **The peculiar Horizontal Branch of NGC2808**
Dalessandro E., Salaris M., Ferraro F.R., Cassisi S., Lanzoni B., Rood R.T., Fusi Pecci F., Sabbi E.; 2011, MNRAS, 410, 694

15. **Multiwavelenght Photometry in the Globular Cluster M2**
Dalessandro, E., Beccari G., Lanzoni B., Ferraro F.R., Schiavon R.P., Rood R.T.; 2009, ApJS, 182, 509

16. **Another non-segregated Blue Straggler population in a globular cluster: the case of NGC2419**
Dalessandro E., Lanzoni B., Ferraro F.R., Vespe F., Bellazzini M., Rood R.T.; 2008, ApJ, 681, 311

17. **Blue Straggler Stars in the Unusual Globular Cluster NGC6388**
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18. **Two distinct sequences of blue stragglers stars in the globular cluster M30**
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19. **The cluster Terzan 5 as a remnant of a primordial building block of the Galactic Bulge**
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20. **Dynamical age differences among coeval star clusters as revealed by blue stragglers**
Ferraro F.R., Lanzoni B., **Dalessandro E.,** Beccari G., Pasquato M., Miocchi P., Rood R. T., Sigurdsson S., Sills A., Vesperini E., Mapelli M., Contreras Ramos R., Sanna N. and Mucciarelli A.; 2012, Nature, 492, 393

21. **Testing multimass dynamical models of star clusters with real data: mass segregation in three Galactic globular clusters**
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27. **The Age of the Young Bulge-like Population in the Stellar System Terzan 5: Linking the Galactic Bulge to the High-z Universe**
Ferraro, F. R.; Massari, D.; **Dalessandro, E.;** Lanzoni, B.; Origlia, L.; Rich, R. M.; Mucciarelli, A.; 2016, ApJ 828, 75

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31. **Weighing Stars: The Identification of an Evolved Blue Straggler Star in the Globular Cluster 47 Tucanae**
Ferraro, F.R.; Lapenna, E.; Mucciarelli, A.; Lanzoni, B.; **Dalessandro, E.;** Pallanca, C.; Massari, D.; 2016, ApJ 816, 70

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37. **Probing the MSP Prenatal Stage: The Optical Identification of the X-Ray Burster EXO 1745-248 in Terzan 5**
Ferraro, F. R.; Pallanca, C.; Lanzoni, B.; Cadelano, M.; Massari, D.; **Dalessandro, E.;** Mucciarelli, A.; 2015, ApJL 807, 1

38. **Radio Timing and Optical Photometry of the Black Widow System PSR J1953+1846A in the Globular Cluster M71**
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39. **Proper motions in Terzan 5: membership of the multi-iron sub-populations and first constrain to the orbit**
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41. **The Binary Mass Transfer Origin of the Red Blue Straggler Sequence in M30**
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43. **The Temperature Distribution of Horizontal Branch Stars: Methods and First Results**
Lagioia, E. P.; **Dalessandro, E.;** Ferraro, F. R.; Salaris, M.; Lanzoni, B.; Pietrinferni, A.; Cassisi, S.; 2015, ApJ 800, 52

44. **Kinematics of a globular cluster with an extended profile: NGC 5694**
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50. **Spinning Like a Blue Straggler: The Population of Fast Rotating Blue Straggler Stars in ω Centauri**
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