Proposal for an ISSI International Team

The formation and evolution of the Galactic halo
Setting the scene for the large modern surveys

Abstract

The formation and evolution of galaxies is one of the great outstanding problems of astrophysics. In the currently favored ΛCDM galaxy formation paradigm smaller structures collapse first, while larger galaxies form later, with accretion events playing an important role, in particular for the build-up of stellar halos. The search for the surviving relics of such assembly processes is still open.

Because of their proximity, the Milky Way and its satellite system can be studied with exquisite detail and thus provide a unique benchmark for theories of galaxy formation and evolution. In particular, the Galactic halo is a much more lively environment than thought in the past: it seems to be formed by two distinct components (accreted and formed *in situ*); abundance gradients are present in the inner halo; substructures are present everywhere; its globular clusters (GCs) host multiple populations with peculiar chemical composition, indicative of a complex formation mechanism. The details of the assembly of the Milky Way from its progenitors are encoded in the **3D positions, motions and abundances** of stars seen today. While such data were once available only for rather small samples and/or nearby stars, we have now entered an era in which ground-based and space-based surveys are going to secure precise chemical and kinematic data for hundred thousands of stars spread over a significant volume of the local universe.

Indeed, the ESA's Gaia satellite, launched on 19 December 2013, is collecting data that will make possible accurate 3D mapping of more than a billion stars throughout the Galaxy and its closest satellites. Precise kinematics for such a huge number of stars will be coupled with detailed chemical information obtained from ground-based large surveys, either ongoing (APOGEE-2, Gaia-ESO Survey, GALAH, LAMOST/LEGUE) or around the corner (WEAVE and 4MOST will become fully operational in early 2018 and 2020, respectively). With all these data at hand, we will have the opportunity to study the fossil remnants of the early epochs of the Galaxy evolution with unprecedented detail and to reconstruct large pieces of its early history. We will unravel the nature of the fragments out of which the halo formed, and search for their analog survivors among the smallest, ultra-faint dwarf galaxies (UFDs) found lurking around the Milky Way, and the classical dwarf spheroidal galaxies.

We feel that time is ripe to build up the tools that will allow us to fully exploit the potential of the incoming huge flow of data. Our team is composed of twelve internationally recognized experts distributed across nine different countries. Members of the team have different, complementary expertise:

- **Stellar spectroscopy and derivation of chemical abundances**: G. Battaglia (ES); V. Hill (FR); P. Jablonka (CH); E. Pancino (IT); M. Shetrone (US); E. Starkenburg (DE); K. Venn (CA)
- **NLTE abundance calculations**: L. Mashonkina (RU)
- **Dynamics of stellar systems**: G. Battaglia (ES); V. Hill (FR); K. Venn (CA)
- **Numerical simulations, chemo-dynamical models, semi-analytical models**: F. Calura (IT); P. Jablonka (CH); D. Romano (IT); E. Starkenburg (DE)
- **Surveys, data mining**: V. Belokurov (UK); G. Clementini (IT); E. Pancino (IT)
- **Distance scale, pulsating variable stars**: G. Clementini (IT)

All these skills are necessary to achieve the **project objectives**: (i) to investigate and compare the level and significance of chemical inhomogeneities in low-metallicity systems (from the smallest UFDs to the Galactic inner and outer halo fields, through the classical dwarf spheroidals and Galactic GCs); (ii) to unravel the origin of low-metallicity stars with peculiar chemical composition (C-rich stars, low-[α/Fe] stars, second-generation stars in GCs...) found in the Local Group; (iii) to assess the role of galactic outflows in shaping the chemical properties of galaxies; (iv) to quantify and characterize the fractions of 'accreted' versus 'formed *in situ*' stars in the solar vicinity. Our efforts fit a more general, ambitious long-term goal: to provide a picture of the formation of the Milky Way halo and its satellites as consistent and comprehensive as possible. With the first data release from Gaia expected by mid-2016 and valuable abundance data from large spectroscopic surveys already in hand, our project is timely and has a high probability of leading to substantial scientific breakthroughs.

Scientific Rationale

The currently favored theory of hierarchical structure formation provides us with a crude picture of how galaxies were assembled from smaller building blocks. In practice, the process of linking individual stellar populations inside large galaxies to their original progenitors is still in its infancy. Eggen, Lynden-Bell and Sandage first recognized early in the Sixties (Eggen et al. 1962 [ApJ, 136, 748]) that the assembly histories of cosmic structures can be deciphered from the kinematics and chemical properties of their stars. In the last decade, important clues have begun to emerge from the nearest objects we have at our disposal –the Galaxy and its complex system of satellites and neighbors. It is now clear that the classical Local Group dwarf spheroidal galaxies seen today do not resemble the primordial building blocks of the Milky Way halo (e.g. Shetrone et al. 2001 [ApJ, 548, 592]). However, it is also found that extremely metal-poor stars ([Fe/H] ≤ –3 dex) display similar chemical abundance patterns, irrespective of the environment in which they are found (e.g. Tolstoy, Hill & Tosi 2009 [ARA&A, 47, 371]). This renews the interest in the connection between the ancient dwarf galaxies and the proto-galactic fragments from which the halo assembled. However, most of the halo samples analyzed up to now are *inner halo samples* (R < 15–20 kpc); it is important to extend the analysis to *outer halo samples* as well. Detailed studies of Local Group galaxies –both observational and theoretical– lie also at the heart of understanding the physical processes that regulate galaxy formation and evolution (e.g. Freeman & Bland-Hawthorn 2002 [ARA&A, 40, 487]; Tolstoy, Hill & Tosi 2009). Ignorance of these processes constitutes the most significant bottleneck to the achievement of a self-consistent theory of structures formation.

Future and ongoing large surveys from space and Earth

Significant advances in this field heavily rely on ongoing and future large surveys from space and Earth. Members of our team are actively involved in one or more of the missions and/or development of new observing facilities mentioned below, often with high level of responsibility.

The ESA cornerstone mission Gaia (launched December 2013) is measuring with unprecedented accuracy positions and magnitudes for about 1 billion stars in the Galaxy and its closest satellites (the nearest stars will have their distances measured to an accuracy of 0.001%; this will reduce to 20–30% for stars at a distance of ~10 kpc). The first release of data, expected by mid-2016, will provide positions, G-magnitudes and proper motions for more than 100000 stars in common with the HIPPARCOS catalogue (Hundred-Thousand Proper Motion Project; de Bruijne & Eilers 2012 [A&A, 546, A61]; see also Michalik et al. 2015 [A&A, 574, A115] for a possible extension to the 2.5 million stars in the *Tycho-2* Catalogue). These data will be limited to the solar neighbourhood and will constitute a first test bed for models of Galaxy formation. In order to obtain an equivalent accuracy in the measurements of velocities and chemical composition, synergy with ground-based observing facilities is necessary. This synergy is being provided, among others, by the Gaia-ESO Public Spectroscopic Survey in the optical (Gilmore et al. 2012 [The Messenger, 147, 25]) and APOGEE/APOGEE-2 in the infrared (e.g. Allende Prieto et al. 2008 [AN, 329, 1018]). In particular, APOGEE has operated in the context of the Sloan Digital Sky Survey (SDSS)-III and surveyed nearly 1500 red giant stars in part of the Galactic halo accessible to the northern hemisphere (released to the public in January 2015). From Fall 2014, APOGEE-2 has operated in the context of SDSS-IV and is expanding the northern hemisphere sample to include more faint, outer halo, stream stars. In 2016 APOGEE-2 will also be expanded with a second instrument and site which will allow a halo sample to be obtained in the southern hemisphere. In the near future, a survey is planned with WEAVE (first light in 2017), targeting ~50000 halo giants in ~500 streams over ~ 2500 deg^2 at V < 17–18, with the specific aim of characterizing the building blocks of the Milky Way halo. Looking even beyond that, the Maunakea Spectroscopic Explorer (MSE) project will transform the Canada-France-Hawaii Telescope (CFHT) into a 10m-class telescope dedicated multiobject spectroscopic facility. This will allow high-resolution spectroscopic studies of *several million stars* at magnitudes $g \approx 18$–19; a large fraction of these will be halo stars in the outer Galaxy. Having mentioned the SDSS, we remind that also relevant to our project is the discovery of new dim Milky Way companions in the context of that survey (e.g. Belokurov et al. 2006 [ApJ, 647, L111]). Imaging surveys such as ATLAS carried out on the VST, or DES done on the 4m CTIO are currently enlarging the sample of known UFDs (Belokurov et al. 2014 [MNRAS, 441, 2124]; Koposov et al. 2015 [arXiv:1503.02079]; Bechtol et al. 2015 [arXiv:1503.02584]) and discovering new stellar streams (Koposov et al. 2014 [MNRAS, 442, L85]) in the southern celestial hemisphere.

Precise astrometry, radial velocities and detailed chemical abundances for thousands of stars will soon provide unprecedented insights into the dynamical structure of the Milky Way halo and its satellites, while probing different nucleosynthesis processes in different environments. As a consequence, we will be allowed to distinguish between different cosmological formation scenarios put forward to explain the assembly and evolution of the Galactic halo and its satellite system.

The focus on chemistry

A valuable indicator of the formation history of a stellar system is the level of dispersion in abundance ratios at fixed metallicity, since it puts strong constraints on feedback and cooling processes (e.g. Marcolini et al. 2006 [MNRAS, 371, 643]; Revaz & Jablonka 2012 [A&A, 538, A82]), as well as on the stochasticity of star formation (e.g. Carigi & Hernandez 2008 [MNRAS, 390, 582]). Common wisdom that the smaller a stellar system, the higher the dispersion at a given [Fe/H], is challenged by recent work by Gilmore et al. (2013 [ApJ, 763, 61]) and Ishigaki et al. (2014 [A&A, 562, A146]), who find no evidence for dispersion in abundance ratios of giant stars in Boötes I, one of the UFDs recently found hiding around the Milky Way (but see also Vargas et al. 2013 [ApJ, 767, 134], for abundance measurements in other UFDs). The anomalously low [α/Fe] ratios observed in a minority fraction of low-metallicity stars, as well as the C-enhanced metal-poor stars found in the dwarf spheroidal galaxies and the halo field deserve particular attention, because they contain important information about the nature and properties of their stellar progenitors (see e.g. Kobayashi et al. 2014 [ApJ, 785, L5]; Skúladóttir et al. 2015 [A&A, 574, A129]).

While iron-peak and most alpha elements are homogeneous within the majority of GCs, characteristic anticorrelations are found for light elements (most notably, Na-O and Mg-Al) that are not present in field stars. Theoretical models which try to explain these anticorrelations differ in the nature of the proposed stellar polluters, and often require GC progenitors up to two order of magnitude more massive than the objects we see today in order for the chemical peculiarities to set up (references in Gratton & Carretta 2010 [A&A, 521, A54]; Gratton, Carretta & Bragaglia 2012 [A&ARev, 20, 50]). Martell et al. (2011 [A&A, 534, A136]) suggest that a minimum of 17% of the stars currently in the halo field must have formed in GCs; but this percentage might be as high as 90% (Decressin et al. 2007 [A&A, 464, 1029]; D'Ercole et al. 2008 [MNRAS, 391, 825]; Vesperini et al. 2010 [ApJ, 718, L112]). A number of questions remain unanswered: are GCs the relics of satellites that formed in isolation before being accreted by the Milky Way, or did they form in conjunction with the halo? Could their peculiar chemical properties be set only through the interaction with the environment provided by the early Galaxy? Addressing these questions is a high-priority issue if we want to get a comprehensive picture of the Milky Way halo formation.

Goals and timeliness of the project

Understanding the processes involved in galaxy formation

The huge amount of data that has started to become available in the last few years, complemented with the much more detailed information we expect in a couple of years from now, requires the development of new, more sophisticated models of galaxy formation and evolution. The simulations must allow to follow the evolution of structures in 3D, put them in the frame of the concordance ΛCDM cosmology, and consider the interactions with the environment. To fully exploit the body of incoming data, we need:

- **Detailed chemical evolution models** able to follow the evolution of several chemical species from H to Zn, as well as the neutron-capture elements, to take fully advantage of the information supplied by the large set of chemical elements that come with optical and near-infrared high-resolution observations. Such models are available to members of our team and have been applied to the study of Local Group dwarf spheroidals (Calura & Menci 2009 [MNRAS, 400, 1347]; Romano & Starkenburg 2013 [MNRAS, 434, 471]) and UFDs (Romano et al. 2015 [MNRAS, 446, 4220]) also in a cosmological context. However, pure chemical evolution models cannot deal with chemical inhomogeneities, nor explain the existence of chemically peculiar stars (see previous section), because they do not treat the gas dynamics properly.

- **A detailed treatment of the physical processes that affect the baryons.** A chemo-dynamical Tree/SPH code is in hand (GEAR; Revaz & Jablonka 2012; Nichols, Revaz & Jablonka 2014 [A&A, 564, A112]) and has been used to study the formation and evolution of the classical dwarf spheroidal galaxies of the Local Group, also including the effects of the local environment; however, this code currently deals with a limited number of chemical elements. A 3D hydrodynamical code with Adaptive Mesh Refinement (RAMSES; Teyssier 2002 [A&A, 385, 337]) is being implemented by members of our team (F. Calura and D. Romano), with the aim of studying the formation of multiple stellar populations in GCs and the development of outflows in small systems, such as the progenitors of GCs and UFDs (simulations currently running at CINECA, the Italian Supercomputing Center).

- **Coupling the different approaches and comparing the model outputs with the data.** The latter is a crucial step that requires a careful evaluation of the level and significance of inhomogeneities in different systems. This in turn implies: 1) accounting for NLTE corrections, that can become severe in low-

metallicity, low-gravity stars and 2) applying appropriate corrections for the effects of stellar mixing on the chemical composition of evolved stars (dredge-up episodes change the original abundances of C, N, O, Na in giant stars; hence, giant stars can be used as tracers of the enrichment history of these light elements in galaxies only if some corrections for evolutive effects are applied). Last but not least, the exploitation of large astronomical data sets requires a non-trivial work of data mining. Our team includes experts that can manage all these aspects.

As a long-term project, we will address the formation and evolution of the Galactic halo. This is a complex problem, to be faced in successive steps by considering the formation and evolution of all its substructures (the 'born *in situ*' component, the streams, the GC system) and related objects (the recently discovered UFDs, the classical dwarf spheroidals, the Magellanic Clouds). As intermediate steps in the framework of this project, taking into account a 18-20 months baseline for completion, we will:

- Study the origin of the low-metallicity stars with peculiar chemical composition (C-rich stars, low-[α /Fe] stars, Na-O, Mg-Al anticorrelations) in the Galactic halo, as well as in the Milky Way satellites.
- Quantify the amount of the dispersion in the [X/Fe] ratios at low metallicity for different systems and shed light on the physical mechanisms responsible for it (stochastic sampling of the IMF, different mixing time-scale for the stellar ejecta, different efficiencies of incorporation of chemical elements in dust grains, etc.).
- Study the interaction of the expanding shells of supernovae exploding in associations with the ambient medium under density/temperature conditions resembling those of proto-GCs and UFDs, in order to set limits on the poorly-known thermalization efficiencies from SNe and the development of galactic outflows and their role in shaping the chemical properties of the smallest stellar systems.
- Investigate the properties of outer halo stars, in comparison with those of inner halo stars.
- Make a complete census of 'accreted' versus 'formed *in situ*' stars in the solar neighbourhood, basing on both their kinematics and their detailed chemical abundances. This kind of studies is fundamental in order to constrain models of the formation of the Galaxy.

As for the first two points, we will take advantage of the large sets of homogeneous chemical abundances provided by ongoing large spectroscopic surveys. Regarding the fourth point, it is worth emphasizing that a statistically significant sample of outer halo stars has become available very recently (APOGEE data release, see previous section), which makes our project extremely timely. As for the fifth point, we will use the first data release from Gaia, expected by mid-2016 and limited to solar neighbourhood stars, as well as spectroscopic data (both archival and proprietary). In the future, we will extend this project to more and more distant Galactic regions, following the Gaia data release scenario. This part of our project is very important, since it lays the foundation to a full exploitation of the science from Gaia.

Expected output

Our meetings will reinforce extant collaborations and stimulate further interactions and new exciting projects. We expect to publish a number of high-level papers in peer-reviewed journals based on our efforts. Furthermore, the results of our investigations will be presented at international conferences. *The problem of the formation and evolution of the halo of our Galaxy is a complex one; however, by tackling the issues discussed above, we expect to make some significant breakthroughs towards its solution*.

Added value of ISSI

With twelve participants, our team is rather large. Its members come from nine countries, also overseas (Canada, France, Germany, Italy, Russia, Spain, Switzerland, UK, USA). ISSI, Bern offers unique opportunities to meet: it is in a logistically centralized location, and easy to reach; it provides meeting facilities, Internet access, and all the organizational support needed for the participants, allowing them to concentrate on the scientific aspects of the meetings only. Members of our team are not all collaborating with each other; rather, they are members of different collaborations who aim at sharing information in order to increase the understanding of specific scientific issues. My personal experience as a member of former ISSI International Teams is that brainstorm at ISSI really widens the research horizons, especially of young people: by gathering a relatively small number of scientists with different expertise in short-lasting –but intense!– meetings, the ideal conditions for active ideas exchange are met. Indeed, some of our collaborations were born at ISSI meetings.

Team Members

Our team consists of twelve internationally recognized experts distributed across nine different countries, with different, complementary skills, all necessary to tackle the different aspects of the project:

Name	Institute	Skills
Giuseppina Battaglia	IAC, Tenerife, ES	Dynamics of stellar systems, stellar spectroscopy
Vasily Belokurov	IoA, Cambridge, UK	Surveys, data mining
Francesco Calura	INAF, Bologna, IT	Chemo-dynamical and semi-analytical models
Gisella Clementini	INAF, Bologna, IT	Distance scale, pulsating variable stars, surveys
Vanessa Hill	OCA, Nice, FR	Stellar spectroscopy, dynamics of stellar systems
Pascale Jablonka	EPFL, Lausanne, CH	Stellar spectroscopy, chemo-dynamical models
Lyudmila Mashonkina	IoA, Moscow, RU	NLTE abundance computations
Elena Pancino	INAF, Bologna, IT	Stellar spectroscopy, surveys, data mining
Donatella Romano	INAF, Bologna, IT	Chemo-dynamical models
Matthew Shetrone	Univ. of Texas, US	Stellar spectroscopy
Else Starkenburg	AIP, Potsdam, DE	Stellar spectroscopy, semi-analytical models
Kim Venn	Univ. of Victoria, CA	Stellar spectroscopy, dynamics of stellar systems

As already mentioned, team members are involved in large surveys and future instrumentation development, even with high level of responsibility; for instance, G. Battaglia is involved in WEAVE and is a member of the Science Team for the Maunakea Spectroscopic Explorer (MSE) project; V. Belokurov is deeply involved in the SDSS, ATLAS and DES surveys; F. Calura, V. Hill, E. Pancino, D. Romano are involved in the Gaia-ESO Survey; G. Clementini and E. Pancino are members of the Gaia Data Processing and Analysis Consortium (DPAC); M. Shetrone is the Pipeline Coordinator for APOGEE-2; E. Starkenburg is participating in 4MOST and, together with K. Venn, in the MSE project; V. Hill is deeply involved in WEAVE; G. Clementini in the VISTA near-infrared survey of the Magellanic Clouds System.

Schedule of the project

Based on our previous experience, we propose to have a first kick-off meeting of three days in December 2015, followed by a second 4-days meeting in Autumn 2016. Ideally, a last 3-days meeting would follow late in Spring 2017 or early in Summer 2017.

External experts participation

Depending on the specific schedule of each meeting, a few self-supported experts will be invited to join. In particular, A. Bragaglia (INAF, Bologna, IT), A. Helmi (Kapteyn Astronomical Institute, Groningen, NL), M. Irwin (IoA, Cambridge, UK), M. Nichols (EPFL, Sauverny, CH), Y. Revaz (EPFL, Sauverny, CH), E. Tolstoy (Kapteyn Astronomical Institute, Groningen, NL), and M. Tosi (INAF, Bologna, IT) have expressed their interest in our project.

Facilities required

We require standard meeting facilities: a large enough meeting room, projection facilities, access to Internet. We do not need computer equipment, since every participant is supposed to bring his/her own laptop. We are a large group and as such, although we would prefer to hold meetings with all participants, it is likely that not everybody would be available at a given time. We would thus need the usual facilities for videoconferences with Skype.

Financial support

We request the standard support provided by ISSI, i.e. a per diem for the living expenses of team members while residing in Bern, and travel cost refund to the team coordinator (D. Romano). We would also like to access the Young Scientists scheme for two young researchers +/– 2 years of the PhD, to be nominated in case of approval of the team.

Appendix A

Team members – contact information

★ **Giuseppina Battaglia**
Instituto de Astrofisica de Canarias
Calle Via Lactea s/n, 38205 San Cristobal de La Laguna, Tenerife
Spain
Tel: 34 922 605 200
Fax: 34 922 605 210
E-mail: gbattaglia@iac.es

★ **Vasily Belokurov**
Institute of Astronomy
Madingley Road, Cambridge, CB30HA
United Kingdom
Tel: 44 1223 337515
Fax: 44 1223 337523
E-mail: vasily@ast.cam.ac.uk

★ **Francesco Calura**
INAF, Osservatorio Astronomico di Bologna
Via Ranzani 1, 40127 Bologna
Italy
Tel: 39 051 2095720
Fax: 39 051 2095700
E-mail: fcalura@oabo.inaf.it

★ **Gisella Clementini**
INAF, Osservatorio Astronomico di Bologna
Via Ranzani 1, 40127 Bologna
Italy
Tel: 39 051 2095758
Fax: 39 051 2095700
E-mail: gisella.clementini@oabo.inaf.it

★ **Vanessa Hill**
Observatoire de la Côte d'Azur, Département Lagrange
Boulevard de l'Observatoire, F-06304 Nice Cedex 4
France
Tel: 33 (0)4 92 00 30 15
Fax: 33 (0)4 92 00 30 33
E-mail: Vanessa.Hill@oca.eu

★ **Pascale Jablonka**
Laboratoire d'Astrophysique, École Polytechnique Fédérale de Lausanne, Observatoire de Sauverny
51 Chemin des Maillettes, CH-1290 Sauverny
Switzerland
Tel: 41 22 379 24 69
Fax: 41 22 379 22 35
E-mail: pascale.jablonka@epfl.ch

★ **Lyudmila Mashonkina**
Institute of Astronomy of Russian Academy of Sciences
Pyatnitskaya str. 48, 119017 Moscow
Russia
Tel: 7 495 9513980
Fax: 7 495 9515557
E-mail: lima@inasan.ru

★ **Elena Pancino**
INAF, Osservatorio Astronomico di Bologna
Via Ranzani 1, 40127 Bologna
Italy
Tel: 39 051 2095775
Fax: 39 051 2095700
E-mail: elena.pancino@oabo.inaf.it

★ **Donatella Romano (coordinator)**
INAF, Osservatorio Astronomico di Bologna
Via Ranzani 1, 40127 Bologna
Italy
Tel: 39 051 2095776
Fax: 39 051 2095700
E-mail: donatella.romano@oabo.inaf.it

★ **Matthew Shetrone**
Hobby-Eberly Telescope
McDonald Observatory, 32 Fowlkes Road, Tx 79734-3005
USA
Tel: 432 426 4168
Fax: 432 426 3641
E-mail: shetrone@astro.as.utexas.edu

★ **Else Starkenburg**
Leibniz Institute for Astrophysics Potsdam
An der Sternwarte 16, 14482 Potsdam
Germany
Tel: 49 331 7499 213
Fax: 49 331 7499 209
E-mail: estarkenburg@aip.de

★ **Kim Venn**
Dept. of Physics and Astronomy, Univ. of Victoria
PO Box 1700 STN CSC, Victoria, BC, V8W 2Y2
Canada
Tel: 250 472 5182
Fax: 250 721 7715
E-mail: kvenn@uvic.ca

Curriculum Vitae of Giuseppina Battaglia

Instituto de Astrofisica de Canarias, calle Via Lactea s/n, 38205 San Cristobal de La Laguna, Tenerife, Spain. Email: gbattaglia@iac.es

EDUCATION AND EMPLOYMENT

- May 2014- now **Ramon y Cajal Fellow**, Istituto de Astrofisica de Canarias, Tenerife, Spain
- Dec 2013 – Feb 2104: Fellow at INAF – Astronomical Observatory of Bologna
- Oct 2011 – Sep 2013: **Marie Curie Intra-European Fellowship**, INAF – Astronomical Observatory of Bologna
- May 2011 – Jun 2011: European – Extremely Large Telescope Science Office, ESO, Garching bei Muenchen, Germany
- Nov 2007 – Apr 2011: **Postdoctoral Fellowship**, **ESO**, Garching bei Muenchen, Germany
- 2003-2007: PhD in Astronomy, University of Groningen, *"Chemistry and kinematics of stars in Local Group galaxies"* (Cum Laude)
- 1998-2003: Astronomy degree, University of Bologna. Dissertation "Dark matter halo and warp of the galaxy NGC5055". Final grade: 110/110 (Cum Laude)

SUPERVISION AND PHD COMMITTEES

Since 2014: Supervision of the PhD student L. Cicuendez Salazar, IAC, Spain. Co-supervision of PhD student G.Iorio, Universiy of Bologna, Italy.

2007 Daily supervision of the undergraduate student P.Parisi (Bologna) for his master project

Member of the PhD thesis committee of O.Gonzalez, ESO Garching; PhD defense committee of E.Starkenburg, University of Groningen (NL); PhD thesis reading committe of Annelies Cloet-Osselaer, University of Ghent, Belgium

PROFESSIONAL ACTIVITIES

- Referee for A&A, MNRAS, ApJ, New Astronomy, Science
- Member of the hiring committee of PhD students and postdoctoral fellows at ESO Garching (2 years)
- Member of the science team and working groups for:

E-ELT Design Reference mission; Phase A E-ELT instrument studies OPTIMOS-EVE and HARMONI; concept study of the E-ELT-MOS MOSAIC; Euclid mission "Milky Way and Nearby Galaxies" working group; WEAVE spectrograph at WHT; Maunea Kea Spectroscopic Explorer at CFHT.

MISCELLANEOUS

- Invitations for talks: 3 reviews and 7 talks at international conferences, 3 departmental colloquia and 6 seminars. 2 invitations for lectures at PhD schools.
- 38 refereed publications (1864 citations); h-index = 22
- PI of Marie Curie fellowship (funding = 187k€)
- ~200h of VLT observing time awarded as PI

MOST RELEVANT RECENT PUBLICATIONS FOR ISSI APPLICATION

- *Bellazzini, Beccari,* ***Battaglia*** *et al. A&A, accepted, arXiv:1412.5857 "The StEllar Counterparts of Compact high velocity clouds (SECCO) survey. I. Photos of ghosts"*
- ***G.Battaglia****, A.Helmi, M.Breddels,* ***New Astronomy Reviews****, 2013, 57, 52, issue on Galactic Archaeology, "Internal kinematics and dynamical models of dwarf spheroidal galaxies around the Milky Way"*
- **G.Battaglia,** M.Irwin, E.Tolstoy, T.de Boer, M.Mateo 2012, ApJL, 761, 31 "The extensive age gradient of the Carina dwarf spheroidal galaxy"
- ***G.Battaglia &*** *E.Starkenburg 2012, A&A, 539, 123 "Cleaning spectroscopic samples of stars in nearby dwarf galaxies. The use of the nIR Mg I line to weed out Milky Way contaminants"*

Vasily Belokurov

Personal details

Name	Vasily Belokurov
Date of birth	1 June 1976
Nationality	British, Russian

Education

Graduate	Oxford University, DPhil in Theoretical Physics, 2000 - 2003."Variability in Astrophysical Surveys"
Undergraduate	Moscow State University, BSc+MSc in Astronomy with distinction, 1993 - 1999. "Image Reconstruction for the Einstein Cross (QSO2237+0305) Gravitational Lens"

Professional history

2011-...	University Lecturer, Institute of Astronomy, University of Cambridge
2008-present	Royal Society University Research Fellow, IoA, Cambridge
2006-2008	STFC Postdoctoral Fellow, IoA, Cambridge
2003-2006	Research Associate, PPARC Observational Rolling Grant, IoA, Cambridge

Professional services

Referee for	Nature, ApJ, ApJL, MNRAS, A&A
Referee for TACs	WHT, CFHT, INT telescopes
PhD Examiner	Oxford, Cambridge, Durham, Edinburgh, Sydney
Event Organizer	IoA Colloquium series (2007-present)
	"Darkness Visible" international conference (Cambridge, Aug 2010)
	"LSST@Europe" international conference (Cambridge, 2014)

List of publications

The total number of publications I have co-authored in refereed journals is > 100. Below are some on the topics relevant to the ISSI proposal.

1. Fellhauer, M., **Belokurov, V.**, et al., *"The Origin of the Bifurcation in the Sagittarius Stream"*, 2006, ApJ, 651, 167-173 (
2. **Belokurov, V.**, et al., *"A Faint New Milky Way Satellite in Bootes"*, 2006a, ApJ, 647, L111-L114
3. **Belokurov, V.**, et al., *"The Field of Streams: Sagittarius and Its Siblings"*, 2006b, ApJ, 642, L137-L140
4. **Belokurov, V.**; Evans, N.W.; Irwin, M.; Hewett, P.; Wilkinson, M., *"The discovery of tidal tails around the Globular Cluster NGC 5466"*, 2006c, ApJ, 637, L29-L32
5. **Belokurov, V**., et al., *"An Orphan in the "Field of Streams"*, 2007b, ApJ, 658, 337-344
6. **Belokurov, V.**, et al., *"The Hercules-Aquila Cloud"*, 2007c, ApJ, 657, L89-L92
7. Irwin, M.; **Belokurov, V.**, et al., *"Discovery of an Unusual Dwarf Galaxy in the Outskirts of the Milky Way"*, 2007, ApJ, 656, L13-L16
8. **Belokurov, V.**, et al., *"Cats and Dogs, Hair and a Hero: A Quintet of New Milky Way Companions"*, 2007d, ApJ, 654, 897-906
9. Bell, E.; Zucker, D.; **Belokurov, V.**, et al., *"The Accretion Origin of the Milky Way's Stellar Halo"*, 2008, ApJ, 680, 295-311
10. Koposov, S.; **Belokurov, V.**; Evans, N. W.; Hewett, P.; Irwin, M.; Gilmore, G.; Zucker, D.; Rix, H.-W.; Fellhauer, M.; Bell, E.; Glushkova, E., *"The Luminosity Function of the Milky Way Satellites"*, 2008, ApJ, 686, 279-291
11. Watkins, L.; Evans, N.W.; **Belokurov, V.**; Smith, M.; Hewett, P.; Bramich, D.; Gilmore, G.; Irwin, M.; Vidrih, S.; Wyrzykowski, Ł.; Zucker, D., *"Substructure revealed by RR Lyraes in SDSS Stripe 82"*, 2009, MNRAS, 398, 1757-1770
12. Niederste-Ostholt, M.; **Belokurov, V.**; Evans, N. W.; Peñarrubia, *"Re-Assembling the Sagittarius Dwarf Galaxy"*, J., 2010, ApJ, 712, 516-526
13. Deason, A.; **Belokurov, V.**; Evans, N., *"Rotation of halo populations in the Milky Way and M31"*, 2010, MNRAS, 411, 1480
14. Deason, A. J.; McCarthy, I. G.; Font, A. S.; Evans, N. W.; Frenk, C. S.; **Belokurov, V**.; et al., *"Mismatch and misalignment: dark haloes and satellites of disc galaxies"*, 2011, MNRAS, 415, 2607
15. Deason, A. J.; **Belokurov, V.**; Evans, N. W., *"The Milky Way stellar halo out to 40 kpc: squashed, broken but smooth"*, 2011, MNRAS, 416, 2903
16. Deason, A. J.; **Belokurov, V.**; Evans, N. W., An, J *"Broken degeneracies: the rotation curve and velocity anisotropy of the Milky Way halo"*, 2012MNRAS.424L..44D
17. **Belokurov, V.**; *"Galactic Archaeology: The dwarfs that survived and perished"*, 2013NewAR..57..100B

Curriculum Vitae - Francesco Calura

Born 10 October 1974 in Ferrara, Italy (Italian citizenship)

- **Studies**

– 1999: Degree in Physics at the Ferrara University
– 2004: PhD in Physics at the Trieste University

- **Employment History**

2004: Research contract at the Department of Astronomy of the Trieste University
2004-2006: Contract for young researchers at the Department of Astronomy of the Trieste University
2006-2008: I.N.A.F. (National Institute for Astrophysics) Post Doc fellowship, at the Trieste Observatory
2008-2009: Contract for young researchers at the Department of Astronomy of the Trieste University
2009-2010: Contract for young researchers at the Trieste Observatory
2010-2011: Jeremiah Horrocks Fellow at the University of Central Lancashire (UCLAN), United Kingdom
2011-now: researcher at the Bologna Observatory.

- **Didactic activity**

2005-2008: lectures given as teaching assistant of the Courses "Fisica Stellare" and "Evoluzione Chimica delle Galassie", Trieste University.
2004-2006: teaching assistant at the exams of the course "Introduzione all'Astrofisica, Trieste University.
2004-2008: co-supervised the degree thesis of two students of the "Laurea Specialistica in Astrofisica e Fisica Spaziale" at the Trieste University.
2010-2011: Module tutor of the course: "Galaxies Beyond the Milky Way" at UCLAN
2010-2011: Moderator of the course:" Instruments and methods for Astronomy" at UCLAN
2010-2011: Member of the Faculty Pool of Research Referees at UCLAN
2010-2012: Director of Studies of Kate Pilkington, PhD student at UCLAN
2012: Teacher of the PhD Course on "Baryonic structure formation and cosmic chemistry" at the Bologna University.

- **Research interests**

My research interests are mainly focused on theoretical studies of the chemical abundances and of the properties of the stellar populations in galaxies of different morphological types. Such aspects are investigated in a cosmological framework by means of semi-analytical galaxy formation models. In the past, I have also performed an analysis of the results of cosmological smoothed-particle hydrodynamics simulations in order to assess the stellar metallicity distributions in Milky-Way like galaxies. I am co-author of other studies of chemical evolution in MW-like galaxies carried on by means of grid-based hydrodynamic codes. Recently, I have also embarked in a hydro-dynamical study of the physical conditions in proto-globular clusters.

- **Participation** as invited speaker to 8 scientific international workshops, and referee of 3 international astronomical journals (ApJ, A&A, MNRAS.)

- **Publications relevant to the project**

55 refereed papers and 30 non-refereed papers with total of 1840 citations (h-index=24), including:
Calura, F.; Menci, N., "Chemical evolution of local galaxies in a hierarchical model", MNRAS, 2009, 400, 1347
Calura, F.; Recchi, S.; Matteucci, F.; Kroupa, P., "Effects of the integrated galactic IMF on the chemical evolution of the solar neighbourhood", 2010, MNRAS, 406, 1985
Pilkington, K.; Few, C. G.; Gibson, B. K.; Calura, et al., "Metallicity gradients in disks. Do galaxies form inside-out?", 2012, A&&, 540, 56
Few, C. G.; Courty, S.; Gibson, B. K.; Kawata, D.; Calura, F.; Teyssier, R., "RAMSES-CH: a new chemodynamical code for cosmological simulations", 2012, MNRAS, 424, L11
Pilkington, K.; Gibson, B. K.; Brook, C. B.; Calura, F., et al., "The distribution of metals in cosmological hydrodynamical simulations of dwarf disc galaxies", 2012, MNRAS, 425, 969
Calura, F., et al., "The stellar metallicity distribution of disc galaxies and bulges in cosmological simulations", 2012, MNRAS, 427, 1401
Calura, F.; Ciotti, L.; Nipoti, C., "A fast and accurate method to compute the mass return from multiple stellar populations", 2014, MNRAS, 440, 3341

Short Curriculum Vitae of Gisella Clementini

Laurea degree in Astronomy at the Astronomy Department of the Bologna University in 1980. INAF - Bologna Astronomical Observatory (OABo) permanent staff member since 1983. ESA fellow at the Space Telescope Science Institute (Baltimore, MD, USA) from May 1986 through May 1988. Member of panels for the allocation of observing time at the ESO telescopes. ESA member of TACs for HST time allocation. Large observational expertise with Italian and international telescopes (Loiano, TNG, ESO, Palomar, INT, WHT, McDonald, CTIO, Magellan, LBT, GTC, HST, SPITZER).

Gisella Clementini has worldwide acknowledged expertise in the field of pulsating variable stars (specially, RR Lyrae stars) and their use as standard candles for the definition of the astronomical distance scale (e.g. Clementini et al. 2003, AJ 125, 1309; Aloisi, Clementini et al. 2007, ApJ 667, L151; Cioni, Clementini et al. 2011, A&A 527, 116), and as stellar population tracers (e.g. Clementini et al. 2003, ApJ 588, L85; Clementini et al. 2009, ApJ 704, L103), with applications to variables in the field and globular clusters of the MW, Andromeda (M31), and other Local Group galaxies. She leads the study of pulsating variable stars at OABo.

She has supervised several undergraduate and PhD students and has been PI of research programs funded by the Italian Ministry of University and Research and by the Italian Space Agency (ASI). In particular, she has been Scientific Coordinator of the ASI project 2010: "Ultra-faint" dwarf galaxies: when size does matter, and National Coordinator of PRIN-INAF 2006 "From Local to Cosmological Distances", of PRIN-INAF 2010 "Looking for the elusive building blocks of the Milky Way and Andromeda halos", of PRIN-INAF 2014 "EXCALIBURS: EXtragalactic distance scale CALIBration Using first - Rank Standard candles", and Local Coordinator of PRIN-INAF 2008 "The ESO Magellanic Cloud Surveys: Tracing the stellar populations and beyond".

She is widely involved in the Gaia project. As a member of the Gaia Data Processing and Analysis Consortium (DPAC) she leads the Supplementary Observations, and the Cepheids/RR Lyrae Specific Object Study work packages, within the Variability Processing Coordination Unit (CU7), and is CU7 representative in the Ground Based Observations for Gaia (GBOG) working group. She is also largely involved in the preparation for the scientific exploitation of the Gaia data through the FP7-funded project Gaia Research for European Astronomy Training - Initial Training Network (GREAT - ITN, G.A. no.: 264895)) of which she is PI for the INAF node and leader of Work Package 6: Grand Challenges: Distance Scale and Transient Sky. She is Co-I of the *VISTA near-infrared Y, J, Ks survey of the Magellanic System* (VMC; PI M.-R. L. Cioni: see Cioni et al. 2011, A&A, 527, 116) an ESO public survey that has been awarded more than 200 nights over a five years time-span; of the *The Carnegie RR Lyrae Program (CRRP)*, 779 hours in Cycle 9 with IRAC on board the Spitzer telescope; of *SMASH - Spitzer Merger History and Shape of the Galactic Halo*, 646 hours in Cycle 10 with IRAC on board the Spitzer telescope; and of the HST proposals *Calibrating the RR Lyrae PL relation at H-Band using HST and Gaia Parallax Stars*, 45 targets in Cycle 21 with WFC3 on board the HST, and *CHP-II - Carnegie H_0 Program-II*, 132 primary and 52 parallel orbits in Cycle 22 with ACS and WFC3 on board the HST. In the last years she mainly devoted her activities to: i) the Gaia project, both within the DPAC (see e.g., Eyer et al. 2012, Ap&SS 341, 207) and in the preparation for Gaia scientific exploitation; ii) the VMC project (see e.g., Ripepi et al. 2015, MNRAS, 446, 303; Muraveva et al. 2014, MNRAS, 443, 432; Moretti, Clementini et al. 2014, MNRAS 437, 2702); and iii) the study of variable stars and stellar populations in the ultra-faint satellites recently discovered around the MW and M31 spirals (see e.g. Dall'Ora, Clementini et al. 2006, ApJ653, L109; Greco, Dall'Ora, Clementini et al. 2008, ApJ 675, L73; Clementini 2010, Sternberg Astronomical Institute Publications, p.111; Clementini et al. 2012, ApJ 756, 108; Garofalo et al. 2013, ApJ 767, 62; Cusano, Clementini et al. 2013, ApJ 779, 7). She is PI of proposals at the GTC and LBT, for the study of the variable stars and stellar populations in a large number of MW ultra-faint dwarfs and new M31 satellites. In the last 5 years she has authored/co-authored 35 among peer reviewed papers and invited reviews (see list below).

Refereed papers: Rubele et al. 2015, MNRAS, in press (arXiv: 1501.05347); Pancino et al. 2015, MNRAS, 447, 2404; Ripepi et al. 2015, MNRAS, 446, 3034; Piatti et al. 2014, A&A, 570, 74; Fabrizio et al. 2014, A&A, 570, 61; Muraveva et al. 2014, MNRAS, 443, 432; Ripepi et al. 2014, MNRAS, 442, 1897; Li et al. 2014, ApJ, 790, 35; Cioni et al. 2014, A&A 562, A32; Moretti et al. 2014, MNRAS 437, 2702; Ripepi et al. 2014, MNRAS 437, 2307; Cusano et al. 2013, ApJ 779,7; Annibali et al. 2013, AJ 146, 144; Tatton et al. 2013, A&A 554, A33; Garofalo et al. 2013, ApJ 767, 62; Contreras Ramos et al. 2013, ApJ 765, 71; Musella et al. 2012, ApJ 756, 121; Clementini et al. 2012, ApJ 756, 108; Eyer et al. 2012, Ap&SS 341, 207; Fiorentino et al. 2012, Ap&SS 341, 143; Ripepi et al. 2012, Ap&SS 341, 51; Dopita et al. 2012, Ap&SS 341, 1; Ripepi et al. 2012, MNRAS 424, 1807; Dall'Ora et al. 2012, ApJ 752, 42; Fiorentino et al. 2012, A&A 539, A138; Clementini et al. 2011, ApJ 743, 19; Contreras Ramos et al. 2011, ApJ 739, 74; Glatt et al. 2011, AJ 142, 36; Di Criscienzo et al. 2011, AJ 141, 81; Cioni et al 2011, A&A 527, A116; Marconi et al. 2010, ApJ 713, 615; Fiorentino et al. 2011, ApJ 711, 808. Invited reviews: Clementini 2014, IAUS 301, 129; Clementini 2011, EAS 45, 267; Clementini 2010, vsgh.conf, 107.

Vanessa HILL
Born 2 September 1970
French citizen
e-mail: Vanessa.Hill@oca.eu

Département Lagrange,
Observatoire de la Côte d'Azur,
F-06304 Nice Cedex 4 (France)
Tel. +33 4 92 00 30 15

Education:

1992: Degree in Physics, Nice Sophia Antipolis University
1993: Masters degree "Astrophysique et Techniques Spatiales", Paris 7 University
1997: PhD Thesis "Astrophysique et Techniques Spatiales", Paris 7 University*: "Evolution Chimique des Nuages de Magellan"*

Work experience:

- 1993-1996: PhD studentship at Observatoire de Paris
- 1994-1997: Teaching assistant at Paris13 University
- 1998: Postdoctoral position at IAG, São Paulo (Bresil),
- 1998-2001: ESO Postdoctoral Fellow (Garching, Germany).
- 2001- 2005: CNRS Chargée de recherche at the GEPI, Observatoire de Paris
- 2008-present: CNRS Chargée de recherche at Lagrange, Observatoire de la Côte d'Azur.

Other Academic activities:

- Deputy director of the Lagrange department (2012-present)
- Director of the "Programme National Cosmology and Galaxies" (2013-present); Scientific secretary of the Section 17 (Astrophysics) of the CNRS (2008-2012)
- Telescope time allocation comities for various telescopes: ESO (2006); TAC CFHT (2006-2009); French national 2m class telescopes (2006-2009).
- ESO Extremely Large Telescope Science Working Group (2007-2008); French representative at the ESO Users Committee (2008-2011); Member of the Astronet Working group on Wide Field Spectroscopy (2010-2011)

Research Interests

Galactic Archaeology; Galaxy evolution; chemical evolution; dwarf galaxies; the Milky-Way; Gaia; stellar spectroscopy

Publications:

- **132 papers in refereed publications cited 9 000 fois**
- **16 invited talks** (mostly review) **et 6 contributed talks** at international conferences

Selection of 5 significant publications:

1. Cayrel R., **Hill V.,** Beers T., et al., *"A new galactic chronometer from the first stellar Uranium Measurement"* **2001** Nature 409, 691
2. **Hill V.,** Cayrel R., Plez B., et al. *"First stars. I. The extreme r- element rich, iron-poor halo giant CS 31082-001. Implications for the r-process site(s) and radioactive cosmochronology"* **2002**, A&A 387, 560
3. Tolstoy E., **Hill V.,** Tosi M., *Star Formation Histories, Abundances and Kinematics of Dwarf Galaxies in the Local Group,* **2009** ARAA 47, 371
4. **Hill V.,** Lecureur A., Gómez A., et al., *The metallicity distribution of bulge clump giants in Baade's window*, **2011,** A&A 534, 80
5. Starkenburg E., **Hill V.,** Tolstoy E. et al., *The extremely low-metallicity tail of the Sculptor dwarf spheroidal galaxy* **2013**, A&A 549, 88.
6. Van der Swaelmen M., **Hill V.,** Primas, F., Cole A.A., *Chemical abundances in LMC stellar populations. II. The bar sample*, **2013,** A&A 560, 44.
7. Mikolaitis, S., **Hill V.** et al. *The Gaia-ESO Survey: the chemical structure of the Galactic discs from the first internal data release* **2014,** A&A 572, 33

PASCALE JABLONKA

Contact Information	Laboratoire d'Astrophysique Ecole Polytechnique de Lausanne (EPFL) Observatoire 51 Chemin des Maillettes CH-1290 Versoix	*Phone:* +41 (0)22 379 24 69 *Fax:* +41 (0)22 379 22 35 *Email:*pascale.jablonka@epfl.ch
Nationality	French and Swiss	

Title and current appointment:

• 2012: Directrice de recherche at CNRS (France); current of leave as research associate at EPFL (Ecole Polytechnique Fédérale de Lausanne, Switzerland).

Scientific Interests

• Formation and evolution of galaxies • Large scale structures, the impact of environment • Galaxy chemical evolution and star formation history • First stars

Appointments

• 2012-2016: CoNRS member [Comité national du CNRS, Section 17], appointed by the French Ministery of Research. Member of the office, appointed by the Institut National des Sciences de l'Univers [INSU] • 2012: FP7 European Commission Expert, serving in the FP7-PEOPLE-2012-IEF-IIF-IOF Physics panel • 2011: Reviewer for the Netherlands Organisation for Scientific Research (NWO) • 2011: Reviewer for the European Research Council (ERC) • 2009-2013: Member of the CFHT Telescope Time Allocation Committee, appointed by the Institut National des Sciences de l'Univers [INSU] • 2010: ECOS-Sud referee (France/Argentine) • 2009 & 2010: Referee for the ANR [French National Agency for Research] • 2009: Co-chair of the French (INSU) prospective in Astrophysics, panel "Galaxies and Cosmology" • 2007-2011: Appointed member of the CSAA [Commission Spécialisée Astronomie et Astrophysique de l'Institut National des Sciences de l'Univers] • 2005-2006: European expert for the FP6 Research Programme in Physics • 2003-2007: French representative at the ESO User's Committee (Chair from 2005 to 2007)• 2003-2005: Appointed member of the CSE [Commission des Spécialistes en Enseignement] of Paris VII University• 2003-2005: Member of the ESO Observing Program Committee

Choice of relevant recent publications

• Lemasle, B.; de Boer, T. J. L.; Hill, V.; Tolstoy, E.; Irwin, M. J.; Jablonka, P.; Venn, K.; Battaglia, G.; Starkenburg, E.; Shetrone, M.; and 6 coauthors, 2014, A&A, 572, 88: *VLT/FLAMES spectroscopy of red giant branch stars in the Fornax dwarf spheroidal galaxy*

• Nichols, M.; Revaz, Y; Jablonka, P., 2014, A&A, 564, 112, *Gravitational tides and dwarf spheroidal galaxies*

• Starkenburg, E.; Hill, V.; Tolstoy, E.; François, P.; Irwin, M. J.; Boschman, L.; Venn, K. A.; de Boer, T. J. L.; Lemasle, B.; Jablonka, P. et al., 2013, A&A, 549, 88, *The extremely low-metallicity tail of the Sculptor dwarf spheroidal galaxy*

• P. North, P. Jablonka, V. Hill, G. Cescutti, M. Shetrone, B. Letarte, B. Lemasle, K.A. Venn, G. Battaglia,E. Tolstoy , M.J. Irwin, F. Primas , and P. François, *Manganese in dwarf spheroidal galaxies*, 2012, A&A, 541, 45

• Revaz, Y., Jablonka P., *The Dynamical and Chemical Evolution of Dwarf Spheroidal Galaxies with GEAR*, 2012, A&A, 538, 45

CURRICULUM VITAE

Name Mashonkina Given name Lyudmila
Date of birth April 3, 1952 Place of birth Primorskii area, Russia
Citizenship Russia
Work Address: Institute of Astronomy of Russian Academy of Sciences,
Pyatnitskaya str., 48, 119017 Moscow, Russia
Position: Leading Researcher
Telephone: +7 495 9513980 Fax: +7 495 9515557
Email: lima@inasan.ru

EDUCATION:

June 1974 - graduated from Kazan State University (KSU), Department of Astronomy,
Sept. 1981 - Aug. 1984, post-graduate course at KSU,
Sept. 1985 - PhD (Candidate of Physics and Mathematics) defence,
March 2003 - Doctor of Physics and Mathematics defence.

SELECTED ACADEMIC DISTINCTIONS

President, the International Astronomical Union Commission 14,
Invited Professor, Chinese Academy of Sciences.

RESEARCH INTERESTS:

Stellar atmospheres – non-equilibrium line formation – fundamental stellar parameters – chemical abundances – origin of the elements – chemical evolution of the Galaxy

PUBLICATIONS: The complete list includes about 90 refereed journal articles.

Recent Publications most relevant to this project:

1. Mashonkina L., Christlieb N. The Hamburg/ESO R-process Enhanced Star survey (HERES) IX. Constraining pure r-process Ba/Eu abundance ratio from observations of r-II stars. - A&A, v. 565, A123 (2014)

2. Shi J.R., Gehren T., Zeng J.L., **Mashonkina L.**, Zhao G. Statistical Equilibrium of Copper in the Solar Atmosphere. - ApJ, v. 782, id. 80 (2014)

3. Alexeeva S., Pakhomov Yu., **Mashonkina L.** Sodium non-LTE Abundances of Red Giants in the Thick and Thin Galactic Disk. - Astron. Letters, v. 40, p. 406 (2014)

4. Ryabchikova T., **Mashonkina L.** The role of atomic and molecular data in stellar atmosphere studies: atmospheric structure and chemistry. - Physica Scripta. v. 89, 114007 (2014)

5. **Mashonkina L.** Astrophysical tests of atomic data important for the stellar Mg abundance determinations. - A&A, v. 550, A28 (2013)

6. **Mashonkina L.,** Ryabtsev A., Frebel A. Non-LTE effects on the lead and thorium abundance determinations for cool stars, A&A, v. 540, A98 (2012)

7. **Mashonkina L.**, Gehren T., Shi, J.R., Korn A.J., Grupp, F. A non-LTE study of neutral and singly-ionized iron line spectra in 1D models of the Sun and selected late-type stars. - A&A, v. 528, A87 (2011)

8. **Mashonkina L.**, Christlieb N., Barklem P., Hill V., Beers T.C., Velichko A. The Hamburg/ESO R-process Enhanced Star survey (HERES). V. Detailed abundance analysis of the r-process enhanced star HE 2327-5642. - A&A, v. 516, A46 (2010)

SELECTED INVITED TALKS

1. Mashonkina L. Strongly r-process enhanced stars: constraining the pure r-process Ba/Eu abundance ratio from observations, invited lecture at the Russbach Workshop on nuclear astrophysics, Russbach, Austria, 10-14 March, 2014

2. Mashonkina L. Review: progress in NLTE calculations and their application to large data-sets, IAU Symposium No. 298, "Setting the scene for Gaia and LAMOST", Lijiang, China, May 20-24, 2013

3. Mashonkina L. The Galaxy chemical evolution from studies of metal-poor stars, invited lecture at the 39th All-Russia Student Winter School, Kourovka, Russia, February 1-4, 2010

Elena Pancino – Short Curriculum Vitae

Born 10 June 1968 in Venice, Italy (Italian citizen)

Qualifications

Astronomy degree (Laurea in Astronomia) – 1998, Padova University, Italy
Astronomy Ph.D. (Dottorato in Astronomia) – 2003, Bologna University, Italy

Appointments

Gaia DPAC: *WP leader* (auxiliary data publication), 2012-present,
ASI Science Data center, Rome, Italy: *senior scientist*, 2012-present
Gaia-ESO spectroscopic Survey: *WP leader* (calibrations), 2012-present,
Gaia-ESO spectroscopic Survey: *Abundance node leader*, 2010-present,
Gaia DPAC: *WP leader* (flux calibration), 2006-present,
Gaia DPAC: *WG deputy* (ground-based observations for Gaia), 2006-2014,
INAF - Bologna Observatory, Italy: *staff astronomer*, 2004-present,
INAF - Bologna Observatory, Italy: *research grant*, 2003-2004,
ESO Garching, Germany: *ESO studentship*, 2001-2002,
Bologna University, Italy: Italian Ministry *Ph.D. grant*, 2000-2002,
ESO Garching, Germany: ESO Imaging Survey *team member*, 1999-2000.

Students and fellows

Co-advisor of 5 master students, 5 Ph.D. students, 6 post-docs. Notable students and fellows:
C. Lardo, Ph.D in 2013, Bologna University, Italy, now Moore's University (UK) post-doc,
S. Marinoni, Ph.D in 2011, Bologna University, Italy, now ASI/INAF post-doc,
G. Altavilla, Post-doc, 2006-2009, Bologna Observatory, Italy, now INAF astronomer,
R. Carrera, Ph.D in 2006, La Laguna University, Spain, now IAC (E) post-doc,
A. Sollima, Ph.D. in 2005, Bologna University, Italy, now INAF post-doc,
L. Monaco, Ph.D. in 2004, Bologna University, now staff at ESO chile.

Research interests

My main scientific interest, and the source of most of my refereed publications, lies in the study of resolved stellar populations, with special emphasis on the chemical abundances and kinematics of small stellar system, like dwarf galaxies, globular clusters, and open clusters. I worked with developers of automatic tools for the abundance analysis of stellar spectra. I became involved into the Gaia mission preparation activities and later into the Gaia-ESO survey, two large projects for the study of the Milky Way and of stellar astrophysics.

Publications

I managed have an above-average publication record (h-index=30, INAF average=25; almost 3,000 citations and 45,000 reads[1]), with 76 refereed papers; 33 non-refereed papers; and 32 technical notes and planning documents within the Gaia DPAC. Here below 10 representative refereed publications:

``*Chemical abundances of solar neighbourhood RR Lyrae stars"*, **Pancino**, Britavsky, Romano, Cacciari, Mucciarelli, Clementini, 2013, ApJ, 766, 78

``*The Gaia spectrophotometric standard stars survey - I. Preliminary results"*, **Pancino** et al., 2012, MNRAS, 426, 1767

``*The subgiant branch of ω Centauri seen through high-resolution spectroscopy. II. The most metal-rich population"*, **Pancino** et al., 2011, A&A, 534, 53

`` *The subgiant branch of ω Centauri seen through high-resolution spectroscopy. I. The first stellar generation in ω Cen?"*, **Pancino** et al., 2011, A&A, 527, 18

``*Low-resolution spectroscopy of main sequence stars belonging to 12 Galactic globular clusters. I. CH and CN band strength variations"*, **Pancino** et al., 2010, A&A, 524, 44

``*Chemical abundance analysis of the open clusters Cr 110, NGC 2099 (M 37), NGC 2420, NGC 7789, and M 67 (NGC 2682)"*, **Pancino** et al. 2010, A&A, 511, 56

``*Na-O anticorrelation and HB. VII. The chemical composition of first and second-generation stars in 15 globular clusters from GIRAFFE spectra"*, Carretta, …, **Pancino**, … et al., 2009, A&A, 505, 117

``*DAOSPEC: An Automatic Code for Measuring Equivalent Widths in High-Resolution Spectra"*, Stetson & **Pancino**, 2008, PASP, 120, 1332

``*High-Resolution Spectroscopy of Metal-rich Giants in ω Centauri: First Indication of Type Ia Supernova Enrichment"*, **Pancino** et al., 2002, ApJ, 568, 101

``*New Evidence for the Complex Structure of the Red Giant Branch in ω Centauri"*, **Pancino** et al., 2000, ApJ, 534, 83

---

[1] **Source:** NASA ADS system (http://adsabs.harvard.edu/index.html) please note that the ADS citations are not complete.

Donatella Romano-Curriculum vitae

Born October 29, 1972 in Trieste, Italy (Italian citizen)
Married, two children

Education

- PhD in Astrophysics, October 11, 2002. International Schools for Advanced Studies (SISSA/ISAS), Trieste, Italy
- Laurea Degree in Physics, May 14, 1998. University of Trieste, Italy (final grade: 110/110)

Positions and Professional Services

- June 2011—present: Staff astronomer, INAF—Osservatorio Astronomico di Bologna, Italy
- November 2008—September 2010: Senior post-doc, Dipartimento di Astronomia, Università di Bologna, Italy
- January 2003—May 2008: Post-doc, INAF—Osservatorio Astronomico di Bologna, Italy
- November 1998—October 2002: PhD grant, International School for Advanced Studies (SISSA/ISAS), Trieste, Italy
- August 1998—October 1998: Research grant, Osservatorio Astronomico di Trieste, Italy

- Peer reviewer for ApJ, MNRAS, A&A, NewA
- Local organization of workshop: "From Dwarfs to Giants", July 29-August 2, 2013, Sexten Center for Astrophysics, Sesto, Italy
- Scientific and local organization of conference: "Chemical evolution in the Universe: the next 30 years", September 16-20, 2013, Hotel Riva del Sole, Castiglione della Pescaia, Italy
- Editor of the Proceedings of IAUS 317, "The General Assembly of Galaxy Halos", August 3-7, 2015, Honolulu, Hawaii, USA
- Member of International Teams selected by the International Space Science Institute (ISSI, Bern, CH):

2004—2005: "LoLa-GE: Local Late Galactic Evolution" (team leaders: J. Geiss, M. Tosi)

2009—2010: "Defining the full life-cycle of dwarf galaxy evolution: the Local Universe as a template" (team leader: E. Tolstoy)

2009—2010: "MODULO: MOlecules and DUst at LOw metallicity" (team leader: L. K. Hunt)

2012—2013: "The Evolution of the First Stars in Dwarf Galaxies" (team leader: P. Jablonka)

Major Scientific Interests
Galaxy formation and evolution - chemical evolution of galaxies - globular clusters formation - primordial nucleosynthesis - stellar evolution and nucleosynthesis

Scientific Output
Author or co-author of 38 publications in refereed journals (16 as first author) totaling 1400+ citations; 4 invited talks and 3 invited reviews at international conferences/workshops.

List of recent publications relevant to the ISSI project

1. Cescutti G., **Romano D.,** Matteucci F., Chiappini C., Hirschi R., *The role of neutron star mergers in the chemical evolution of the Galactic halo,* 2015, A&A in press (arXiv:1503.02954)
2. Lind K., …, **Romano D.,** et al., *The Gaia-ESO Survey: A globular cluster escapee in the Galactic halo,* 2015, A&A, 575, L12
3. **Romano D.,** Bellazzini M., Starkenburg E., Leaman R., *Chemical enrichment in very low metallicity environments: Boötes I,* 2015, MNRAS, 446, 4220
4. Ripepi V., … **Romano D.,** et al., *STEP: the VST survey of the SMC and the Magellanic Bridge – I. Overview and first results,* 2014, MNRAS, 442, 1897
5. **Romano D.,** Starkenburg E., *Chemical evolution of Local Group dwarf galaxies in a cosmological context,* 2013, MNRAS, 434, 471

Matthew David Shetrone

CURRICULUM VITAE

32 Fowlkes Rd McDonald Observatory, Tx 79734
Phone: (432) 426 3613 Fax: (432) 426 3694 Email: shetrone@astro.as.utexas.edu

Education

Ph.D. Astronomy and Astrophysics, UC Santa Cruz, June 1996
Thesis Title: Observational Tests of Deep Mixing in Population II Red Giants
Advisor: Dr. Bob Kraft

M.S. Astronomy and Astrophysics, UC Santa Cruz, June 1996
Thesis Title: Observational Tests of Deep Mixing in Population II Red Giants
Advisor: Dr. Bob Kraft

B.A. Astronomy and Astrophysics, University of Texas at Austin, 1991
High Honors; Special Honors in Astronomy

Experience

University of Texas, McDonald Observatory:

2007-present	Senior Research Scientist; Head of Night Operations for HET Research Scientist;
2012-2014	Senior Research Scientist; Interim Facility Manager for HET
2004-2007	Research Scientist; Head of Night Operations for HET
2002-2004	Research Scientist; Lead Resident Astronomer for HET
2000-2002	RESA IV; Lead Resident Astronomer for HET
Summer 2001	Lecturer for UT Observing Techniques Class
1998-2000	RESA III; Resident Astronomer for Hobby-Eberly Telescope

Sul Ross University, Alpine TX:

1999-2000	Guest Instructor for Intro. Physics

European Southern Observatory, Chile:

1996-1997	Research Fellow

Research Groups, Service and Professional Societies

2014-present	SDSSIV External Participant & APOGEE Software and Commissioning Lead
2008-2014	SDSSIII APOGEE Architect
2002-present	Dwarf Abundance and Radial Velocity Team (DART)
2000-present	International Astronomical Union Member
1994-present	American Astronomical Society Member

Relevant Publications

"Exploring Anticorrelations and Light Element Variations in Northern Clusters Observed by the APOGEE Survey" Meszaros, Martell, Shetrone and 20 coathors, 2015 AJ

"Carbon in Red Giants in Globular Clusters and Dwarf Spheroidal Galaxies", Kirby, Guo, Zhang, Deng, Cohen, Guhathakurta, Shetrone, Lee, Rizzi, 2015, ApJ 801, 125.

"The first carbon-enhanced metal-poor star found in the Sculptor dwarf spheroidal", Skuladottir, Tolstoy, Salvadori, Hill, Pettini, Shetrone, Starkenburg, 2015, AA 574, 129.

"Testing the Asteroseismic Mass Scale Using Metal-poor Stars Characterized with APOGEE and Kepler", Epstein, Elsworth, Johnson, Shetrone, and 28 coauthors, 2014, ApJL 785, 28.

"Calibrations of Atmospheric Parameters Obtained from the First Year of SDSS-III APOGEE Observations", Meszaros, and 27 coauthors, 2013, AJ 146, 133.

"Carbon Abundances for Red Giants in the Draco Dwarf Spheroidal Galaxy", Shetrone, Smith, Stanford, Siegel, Bond, 2013 AJ 145, 123.

Dr. Else Starkenburg

Office address Leibniz-Institut für Astrophysik Potsdam (AIP)
An der Sternwarte 16, 14882 Potsdam, Germany

Employment

Oct '14 – present	Post-Doctoral Fellow at the Leibniz-Institute for Astrophysics, Potsdam, Germany, 100% independent research
Jan '12 – Sep '14	Post-Doctoral Fellow with the Department of Physics and Astronomy at the University of Victoria, Canada, 100% independent research

Education

Nov '07 – Dec '11	Ph.D. student under supervision of Prof. E. Tolstoy & Prof. A. Helmi, University of Groningen, Kapteyn Astronomical Institute
Sep '01 – Aug '07	Doctoral degree ("Masters") in Astronomy at the Rijks Universiteit Groningen, Kapteyn Astronomical Institute

Research interests: Milky Way formation, Chemical Evolution in the Local Group, Low- and high-resolution spectroscopy, First Stars

Awards

2015 – 2020: Emmy Noether Prize from the Deutsche Forschungsgemeinschaft for a Junior Research Group
2014 – 2017: Leibniz-Institute for Astrophysics Schwarzschild Fellow
2012 – 2014: Canadian Institute for Advanced Research (CIFAR) Global Scholar
2012 – 2013: Canadian Institute for Theoretical Astrophysics (CITA) National Fellow
2012: Van Swinderenprijs, prize for the best summary and presentation of a cum laude PhD thesis in the medical or physical sciences at the University of Groningen

(Selected) Publications

In total 28 (co-)authored refereed publications, 690+ citations.
On average 44+ citations to first author publications

- Starkenburg, E.; Shetrone, M. D.; McConnachie, A. W.; Venn, K. A. *"Binarity in carbon-enhanced metal-poor stars"*, 2014, MNRAS, 441, 1217
- Starkenburg, E.; Helmi, A.; De Lucia, G.; Li, Y.-S.; Navarro, J. F.; Font, A. S.; Frenk, C. S.; Springel, V.; Vera-Ciro, C. A.; White, S. D. M., *"The satellites of the Milky Way - insights from semi-analytic modelling in a ΛCDM cosmology",* 2013, MNRAS, 429, 725
- Starkenburg, E.; Hill, V.; Tolstoy, E.; François, P.; Irwin, M. J.; Boschman, L.; Venn, K. A.; de Boer, T. J. L.; Lemasle, B.; Jablonka, P.; Battaglia, G.; Groot, P.; Kaper.; L., "*The extremely low-metallicity tail of the Sculptor dwarf spheroidal galaxy"*, 2013 A&A, 549, 88

Talks: 10 invited and 8 contributed talks at international meetings and conferences

Kimberley Ann (Kim) Venn
28 March 2015

CONTACT INFORMATION

Department of Physics & Astronomy
PO Box 1700 STN CSC
University of Victoria
Victoria, BC, V8W 2Y2, CANADA

PH: 250 472 5182
FAX: 250 721 7715
email: kvenn@uvic.ca
http://www.astro.uvic.ca/~venn

EDUCATION and TRAINING

PDF	Max Planck Institute for Astrophysics, Munich, Germany	1994-1996
PhD	University of Texas at Austin	1994
BSc	University of Toronto	1987

FACULTY POSITIONS HELD

2014-present	Professor, University of Victoria, BC	Physics & Astronomy
2005-2014	Associate Professor, University of Victoria, BC	Physics & Astronomy
2001-2005	Associate Professor, Macalester College, MN	Physics
2002-2003	Visiting Astronomer, University of Cambridge, UK	Institute of Astronomy
1996-2001	Assistant Professor, Macalester College, MN	Physics

FIELDS of INTEREST

Galactic Archaeology, stellar spectroscopy, nucleosynthesis and chemical analyses, Galaxy formation and chemical evolution, dwarf galaxies, metal poor stars, chemically peculiar stars, stellar debris disks and exoplanets. With 79 refereed and 106 non-refereed publications, I have gathered over 5000 citations for an h-index of 38: 20 papers are written as first or single author, and 23 with student coauthors.

MAJOR RESEARCH FELLOWSHIPS & AWARDS

CRC	Canada Research Chair (Tier II)	K.A. Venn	2005-present	$100,000/yr
CFI/ BCKDF	Multi Object Adaptive Optics *(Instrumentation Development Lab)*	PI K.A. Venn	2005-2009	$341,200
US gov't	PECASE/CAREER award *(Presidential Early Career Award in Science and Engineering in Observational Astrophysics)*	K.A. Venn	2000	$500,000
Clare Boothe Luce	Professorship & Award	K.A. Venn	1996-2001	$78,800/yr
NSF	Macalester College Observatory	PI K.A. Venn	1997-1999	$115,700

MAJOR COMMITTEES & CHAIRS

ARC	Astronomy Research Centre (UVic)	Director (new position)	2014-present
MTR	Mid Term Review: CASCA LRP2010	Panel member	2013-present
HST	Science Panel & PDF Selections	Panel member, Chair(2014)	2013-present
SDSS	Review of the SDSS-III APOGEE Survey	Panel member	2013
Gemini Obs.	Science and Technology Advisory	Canadian representative	2011- 2014
C-GSC	Canadian Gemini Science Committee	Chair (2011-2013)	2010-2013
NSERC	National Science & Engineering Research Council, *Physics Evaluation Comm., Astronomy & Space Physics Sub-Comm.*	Chair (2012)	2010-2012
CASCA	Canadian Astronomical Society Awards	Chair (2009-2011)	2007-2011
ESO	Observing Programs Committee	Panel Chair	2008-2010
NOAO	Time Allocation Committee	Panel Chair	2005-2008

SHORT LIST OF PUBLICATIONS RELEVANT TO ISSI APPLICATION

1. Venn K. A., et al., 2012, ApJ, 751, 102; 2. Starkenburg E., et al., 2010, A&A, 513, 34; 3. McConnachie A.W., et al., 2009, Nature, 461, 66; 4. Pritzl B.J., Venn K.A., Irwin M.J., 2005, AJ, 130, 2140; 5. Venn, K. A., et al., 2004, AJ, 128, 1177