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 renewed 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 100 000 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 ~50 000 halo giants in ~500 streams over ~2500 deg² 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 = 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&ARv, 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 spheriodals (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 timescale 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:

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

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 committee of Annelies Cloet-Osselaer, University of Ghent, Belgium

PROFESSIONAL ACTIVITIES

- 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

- 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”
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 TACs WHT, CFHT, INT telescopes
PhD Examiner Oxford, Cambridge, Durham, Edinburgh, Sydney
Event Organizer IoA Colloquium series (2007-present)
“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.

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
  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.


- **Publications relevant to the project**
  55 refereed papers and 30 non-refereed papers with total of 1840 citations (h-index=24), including:
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 H0 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, 332; 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).

Vanessa HILL  
Département Lagrange, 
Born 2 September 1970  
Observatoire de la Côte d’Azur, 
French citizen  
F-06304 Nice Cedex 4 (France)  
e-mail: Vanessa.Hill@oca.eu  
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  

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:  
PASCALE JABLONKA

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 Ministry 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 Netherlands Organisation for Scientific Research (NWO)
- 2009: Referee 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]
- 2005-2006: European expert for the FP6 Research Programme in Physics
- 2003: Appointed member of the CSAA [Commission Spécialisée Astronomie et Astrophysique de l’Institut National des Sciences de l’Univers]
- 2002-2005: Member of the ESO Observing Program Committee

Choice of relevant recent publications
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 - Aug. 1984, 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:

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)

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
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,

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, Italy, 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 reads1), 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:

"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 Cent?", 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

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

- 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: “MODULO: MOlecules and DUst at LOw metallicity” (team leader: L. K. Hunt)

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

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
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 coauthors, 2015 AJ


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


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


**Talks:** 10 invited and 8 contributed talks at international meetings and conferences
Kimberley Ann (Kim) Venn  
28 March 2015

CONTACT INFORMATION
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University of Victoria  
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Victoria, BC, V8W 2Y2, CANADA  
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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/  
Multi Object Adaptive Optics  
PI K.A. Venn  
2005-2009  
$341,200

BCKDF  
(Instrumentation Development Lab)  
US gov’t  
PECASE/CAREER award  
K.A. Venn  
2000  
$500,000  
(Presidential Early Career Award in Science and Engineering in Observational Astrophysics)

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 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