red giants and the galactic structure

Andrea Miglio

School of Physics and Astronomy, University of Birmingham, UK

and

STELLAR ASTROPHYSICS CENTRE
University of Aarhus, Denmark
why are ageing stars relevant for the PLATO mission
ageing stars: their planets
1 ageing stars: their planets

2 ageing stars: constraints on earlier phases
1. ageing stars: their planets
2. ageing stars: constraints on earlier phases
3. ageing stars: Galactic probes
ageing stars: their planets
Kepler-56: a red giant hosting planets

Stellar Spin-Orbit Misalignment in a Multiplanet System


| Host Star | | Planet b | | Planet c |
|-----------|-----------|-----------|-----------|
| Radius ($R_\odot$) | 4.23 ± 0.15 | | |
| Mass ($M_\odot$) | 1.32 ± 0.13 | | |
| Mean Density (g cm$^{-3}$) | 0.0246 ± 0.0006 | | |
| log [Surface gravity] (cgs) | 3.31 ± 0.01 | | |
| Effective Temperature (K) | 4840 ± 97 | | |
| Metallicity [M/H] (dex) | 0.20 ± 0.16 | | |
| Age (Gyr) | 3.5 ± 1.3 | | |
| Stellar Inclination (degrees) | 47 ± 6 | | |

| Time of Transit (BJD) | 2454978.255642 ± 0.000571 | | |
| Orbital Period (days) | 10.50166 ± 0.00149 | | |
| Semi-major axis (AU) | 0.10284 ± 0.00370 | | |
| Radius ($R_\oplus$) | 6.51 ± 0.28 | | |
| Mass ($M_\oplus$) | 22.1 ± 3.6 | | |
| Mean Density (g cm$^{-3}$) | 0.442 ± 0.080 | | |

Huber et al., 2013, Science
Figure 1: Power spectrum analysis to measure the inclination of the stellar rotation axis.

Top panel: Power spectrum centered on the frequency range with excited oscillations. The spherical degree $l$ of each identified mode is indicated. Red and blue areas highlight gravity-dominated and pressure-dominated mixed dipole modes, respectively.

Bottom panels: Zoom on the mixed dipole modes highlighted in the top panel. Each mode is split into triple frequencies. The azimuthal order $m$ of each component is indicated. Red and blue lines show the modeled Lorentzian profiles. The scatter in the data about the model is due to the finite mode lifetimes ($\approx 6$).

Huber et al., 2013, Science
other examples:  
Kepler-91  Lillo-Box et al. A&A 2013

+  $V_{rad}$ : papers by Hatzes, Livio, Niedzielski, Villaver
ageing stars: constraints on earlier phases
non-radial modes in ageing stars

gravity mode

acoustic mode

He core

H-burning shell

H-rich radiative core

convective envelope
non-radial modes in ageing stars

laboratories to test stellar physics:

- e.g. mixing of chemicals during MS
  - e.g. Montalban et al 2013

- angular momentum transport
  - papers by Beck, Cantiello, Deheuvels, Eggenberger, Marques, Mosser

improve predictions of stellar evolution, also in earlier evolutionary stages
ageing stars: Galactic probes
Report by the ESA-ESO Working Group on Galactic populations, chemistry and dynamics

Abstract

Between the early 40s, when Baade showed the first evidence for the existence of two distinct stellar populations, and today, with our Galaxy surprising us with new substructures discovered almost on a monthly basis, it is clear that a remarkable progress has been achieved in our understanding of the Galaxy, of its structure and stellar populations, and of its chemical and dynamical signatures. Yet, some questions have remained open and have proven to be very challenging.

The main task of this Working Group has been to review the state-of-the-art knowledge of the Milky Way galaxy, to identify the future challenges, and to propose which tools (in terms of facilities, infrastructures, instruments, science policies) would be needed to successfully tackle and solve the remaining open questions. Considering the leadership position that Europe has reached in the field of Galactic astronomy (thanks to the Hipparcos mission and the Very Large Telescope) and looking at the (near-)future major initiatives it has undertaken (VISTA and VST survey telescopes, Gaia mission), this work clearly has been very timely.

It is of uttermost importance for European astronomy to keep and further consolidate its leading position. This Working Group has made recommendations that would allow dissecting our backyard laboratory, the Galaxy, even further. ESO survey telescopes about to become operational and the upcoming ESA Gaia mission are a guarantee for opening new horizons and making new discoveries. We, the astronomers, with the support of our funding agencies, are ready to fully commit to the best exploitation of the treasure that is ahead of us. The main recommendations this Working Group has made to ESA and ESO are to guarantee the expected tremendous capabilities of these new facilities, to vigorously organise their synergies and to jointly give ways to European astronomers to be leaders in the exploitation of their output data.
7 Recommendations

Europe has led the way in Galactic research as regards astrometry and spectroscopy and is on the brink of taking the lead in photometry: ESA’s Hipparcos mission pioneered space astrometry and paved the way for the ambitious Gaia mission, which will perform the first parallax survey down to magnitude $V = 20$; ESO’s innovative telescopes (NTT and VLT) coupled to leading capabilities in the construction of multi-object spectrographs have yielded detailed stellar abundances of faint stars; ESO is about to start massive programs of optical/near-IR photometry with two dedicated survey telescopes (VISTA and VST). This observational work is backed by unique European expertise in modelling stars and galaxies (stellar atmospheres, stellar and galactic evolution, population synthesis, dynamics, etc.).

The opportunities for European science are tremendous if we make strenuous efforts fully to capitalise on these assets. This involves both taking full advantage of the instrumentation that we have and planning new facilities. Particular attention has to be paid to the optimisation of synergies between Gaia and ground-based observations, especially with present or potential ESO instruments.

A number of suggestions in this direction are given below.

(1) **ESA initiatives**

(a) **Gaia**: make maximum effort to achieve the science requirements (accuracies and limiting magnitudes for the astrometric, photometric and spectroscopic aspects of the mission). Only if these requirements are fulfilled can the satellite provide the promised revolution in our knowledge of the Galaxy by unveiling populations through the study of chemistry and dynamics. [All subsections of Section 5].

(b) **Infrared astrometry**: this would be the ideal complement to Gaia, which is not able to observe deeply in the Galactic centre, the bulge and parts of the disc because of heavy extinction and crowding. ESA should encourage the community to submit proposals for an IR instrument that has an astrometric accuracy of $10 \mu$as down to magnitude 17 in the 0.9 $\mu$m $z$ band. A first step in this direction might be a collaboration with the Japanese project JASMINE (10 $\mu$as astrometric accuracy for stars brighter than $z = 14$). [Sections 5.1.5, 5.2, 5.3, 5.4].

(c) **Higher astrometric accuracy in the optical** (better than 4 $\mu$as): this is the requirement for resolving the internal motions of the outer
globular clusters and dwarf galaxies of the Local Group, for which Gaia will provide only mean motions. This capability would also enable us to obtain direct distances to extragalactic stellar candles. ESA should encourage the community to prepare for the next generation of astrometric missions. 
[Sections 5.7, 5.8].

(d) **Asteroseismology**: this is a major tool to complement Gaia with respect to age determination. ESA should encourage the community to prepare for a next-generation mission, which would sample the different populations of the Galaxy much more widely than CNES-ESA’s Corot (50 targets, mainly main-sequence stars with a metallicity close to solar) and NASA’s Kepler (mainly main-sequence stars, some giants and pulsating stars). 
[Sections 5.1.6, 5.4, 5.5, 5.6, 5.7].

(e) **UV spectroscopy**: Ground-based adaptive optics (AO) has reduced Hubble’s advantage at optical wavelengths. But now that NASA’s satellite FUSE has died, UV wavelengths are only accessible through Hubble. ESA should support the longevity of Hubble, with a substantial share of its observing time being devoted to UV instruments, and support the use of COS, the new UV spectrograph to be installed on Hubble during the Servicing Mission 4. 
[Sections 5.1.8, 5.1.4, 5.8].
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CoRoT, Kepler, K2:

pilot studies

Miglio et al. 2009  Casagrande et al. 2014
Chaplin et al. 2011  Rodrigues et al. 2014
Miglio et al. 2013  Pinsonneault et al. 2014

but limitations:

● number of stars
● selection biases
● duration of the observations
• 2 long pointings of 2-3 years
• step-and-stare phase (2-5 months per pointing)

Æ covers ~50% of the sky
PLATO 2.0: a complement to GAIA

Gaia

stellar distances and proper motions

Spectroscopic surveys
Gaia-ESO, APOGEE, GALAH, LAMOST, 4MOST, …

chemical tagging, logg, $T_{\text{eff}}$, $v_{\text{rad}}$

seismology
pilot studies: CoRoT, Kepler, K2
PLATO

age
ageing stars in PLATO

WP127000 Seismic constraints from ageing stars
   Benoit Mosser

WP127100 Seismic diagnostics and stellar evolution
   Andrea Miglio

WP127200 Stellar models of evolved stars
   Paolo Ventura

WP127300 Constraints from main sequence stars
   Josefina Montalban
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interaction with “Galactic science” community
asteroseismology of STEllar Populations

Open collaboration, 3 areas of expertise:

- Galactic astrophysics
- Spectroscopy
- Stellar structure, evolution, seismology

~100 scientists from ~20 countries
asteroSTEP:
Hare&hounds exercises

Team A:
Generating artificial datasets
members: Annie Robin, Sanjib Sharma, Leo Girardi
- Generate various sets of artificial data representative of populations of giants in the fields of CoRoT and Kepler (including the fields of the 2-wheel mission)
- Use parametrized models of the Milky Way (TRILEGAL, Besancon, Galaxia, …)
- The team’s output will be artificial observational data such as:
  - seismic data (such as large frequency separation, nu_max, and the period spacing),
  - spectroscopic data (effective temperature, chemical abundances, radial velocity),
  - photometric constraints (apparent magnitudes, colours)
  - astrometric constraints (parallaxes and proper motions) as we will obtain them with Gaia

Team B:
Introducing noise and biases
coordinator: Luca Casagrande
members: Andrea Miglio, Joris De Ridder, Bill Chaplin, Gail Zasowski, Rafa Garcia, Rob Farmer, Enda Farrell, Berry Holl
- Add random (possibly non-gaussian) and systematic uncertainties to the "unbiased stellar population" generated by Team A.
- Add reddening biases
- Add target selection biases

Team C:
Retrieving the stellar parameters
members: Victor Silva Aguirre, Dennis Stello, Thoise Rodrigues, Benoit, Messer, Orlofh Cleevey, Maurizio Solaris, Santino Cassisi, Adriano Pietrinferni, Sabani Basu, Josephina Montalan, Aldo Serenelli, Marie Martig
- Use stellar evolution and pulsation codes to model the "observed" stellar properties to estimate their age, distance, mass, etc.
- Carefully keep record of the assumptions you use, such as which opacities you use, mixing length, overshoot parameter, etc.
- No information from team A will be available.

Team D:
Retrieving the galactic parameters
members: Joss Bland-Hawthorn, Alejandra Recio-Blanco, Ivan Minchev, Jo Bovy, Borja Anguiano, Georges Kordopatis, Friedrich Anders
- Given the stellar properties derived by Team C, recover the global galactic population properties that constrain the chemical and dynamical evolution of the galactic disk.
- Estimate the age-metallicity and age-velocity dispersion relations as a function of the position in the disk. Retrieve possible gradients.
- Estimate the initial mass function.
- Estimate the star formation rate as a function of the position in the disk.

Team E:
Assessing the different methods and codes used
- Given the input and output population parameters, compare the results of the different groups using different methods/codes.
- Establish the reliability of the error bars returned by team D.
- Assess how robust the results are as a function of the noise levels.
- Make recommendations for an optimized observation strategy for the Kepler, CoRoT, and APOGEE teams.

* email address: a.miglio@bham.ac.uk

1 asteroseismology of STEProPopulations aims to foster, and coordinate, collaborations between researchers interested in stellar population studies using CoRoT, Kepler, and K2 data. Currently about 90 scientists from 16 countries are members of asteroSTEP.
1. ageing stars: their planets
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592. WE-Heraeus-Seminar – 1st to 5th June 2015

Reconstructing the Milky Way’s History: Spectroscopic Surveys, Asteroseismology and Chemodynamical Models

Venue:
Physics Center Bad Honnef
Hauptstrasse 5
53604
Bad Honnef (near Bonn, Germany)
The Physics Center is run by the Deutsche Physikalische Gesellschaft e. V. (DPG) and is supported by the University of Bonn and the state North Rhine – Westphalia.
The stately mansion housing the Physikzentrum is surrounded by a park at the foot of the Siebengebirge (“The Seven Hills”) on the right bank of the Rhine River.
The Physics Center Bad honnef is located near Bonn (15 km) and Cologne (40 km).

Accommodation and Meals:
All participants will be hosted in the beautiful Bad Honnef mansion. Meals and accommodation will be covered by the organizers.
Some support is available for travel expenses of invited speakers.
We are allowed a maximum of 70 participants.

Important Dates:
Registration opens: 1st November 2014
Registration closes: 15th March 2015
Abstracts Deadline: 15th March 2015
Conference dates: 1-5 June 2015

https://escience.aip.de/592-WE-Heraeus-Seminar/cms/