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asteroseismology and Galactic populations

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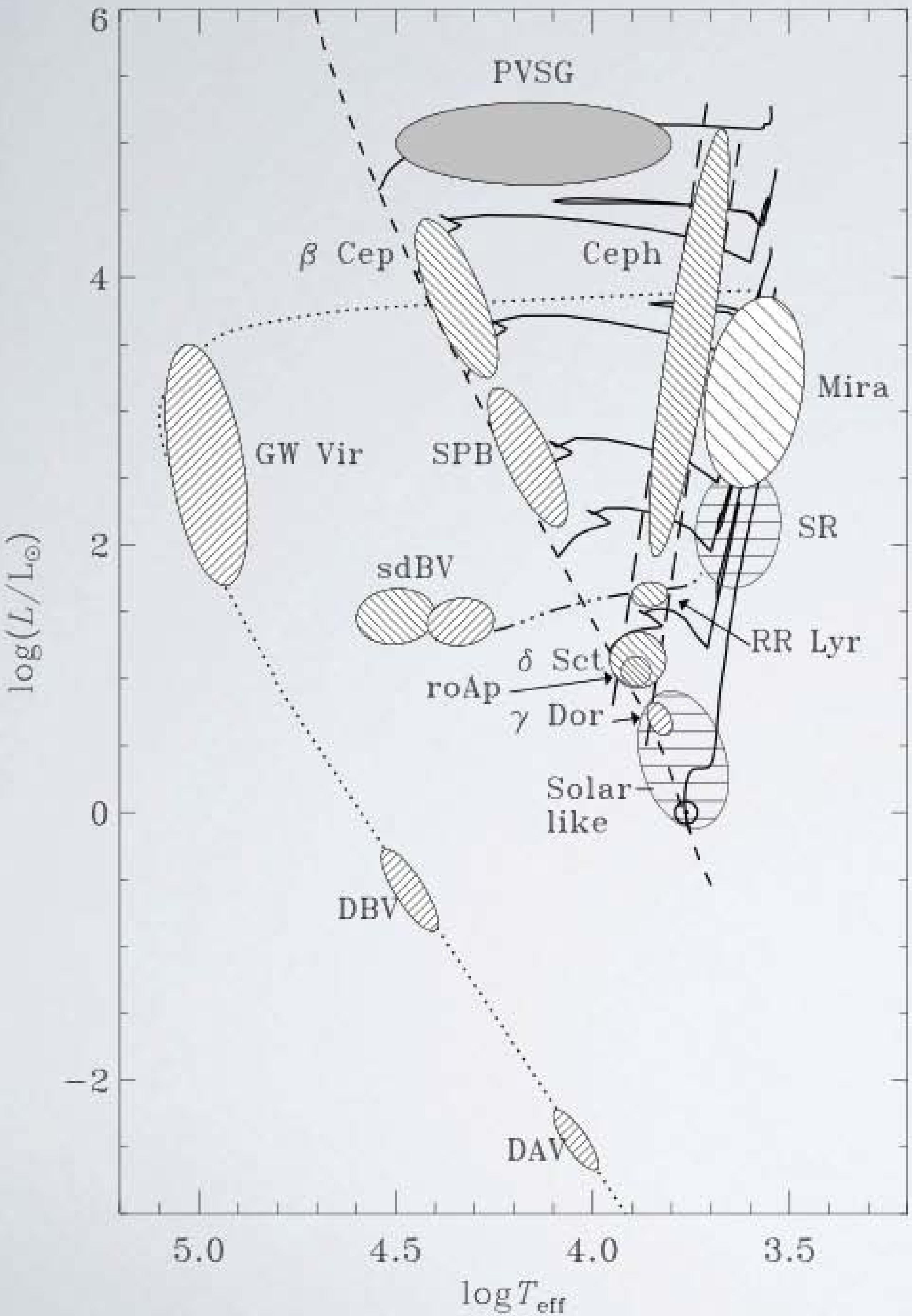
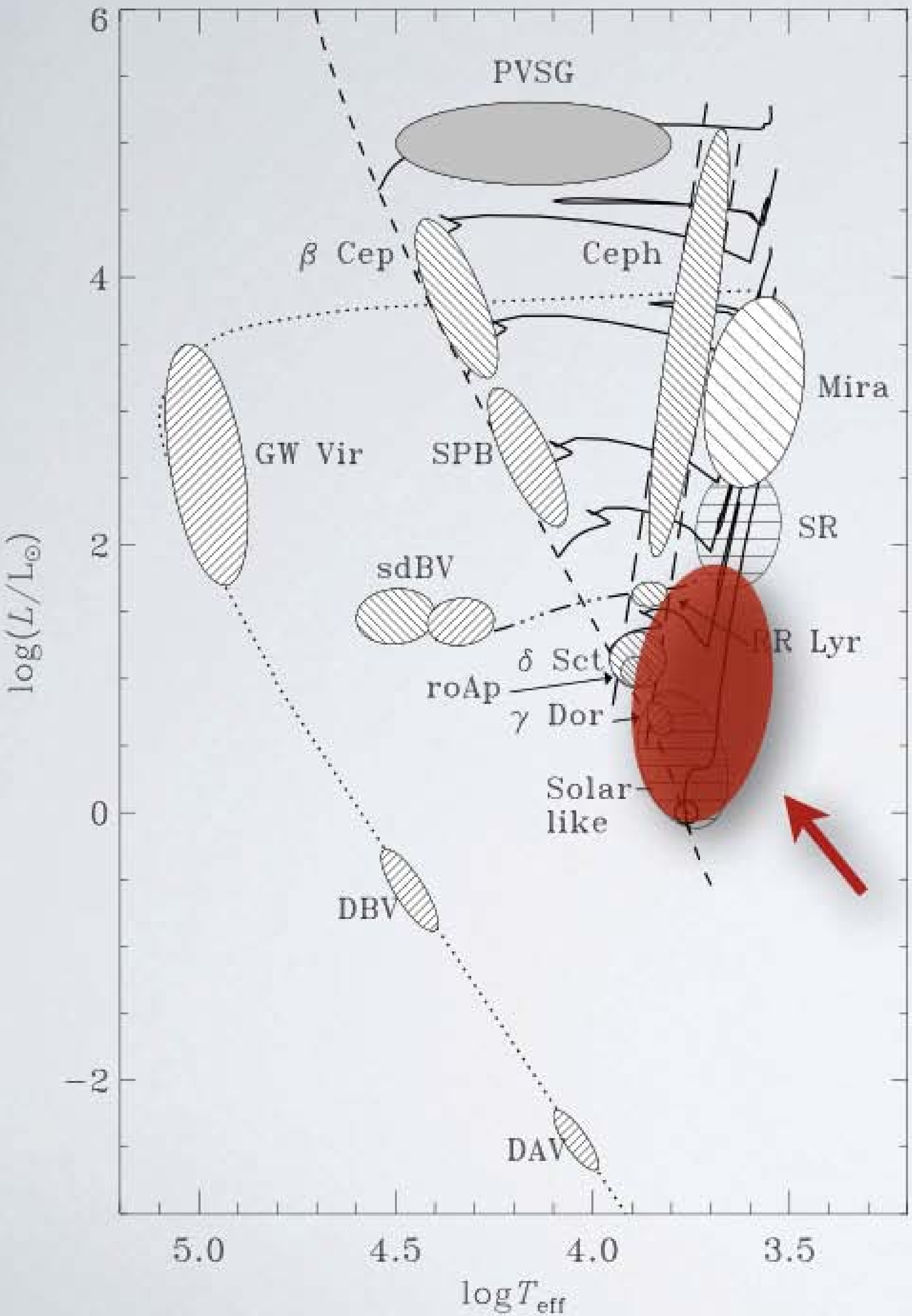
University of Birmingham, UK
and
STELLAR ASTROPHYSICS CENTRE
University of Aarhus, Denmark

Aerts, Christensen-Dalsgaard & Kurtz 2009



PULSATING STARS AND STELLAR POPULATIONS STUDIES

Aerts, Christensen-Dalsgaard & Kurtz 2009



PULSATING STARS AND STELLAR POPULATIONS STUDIES

Solar-Like Oscillating Stars:

Standard Clocks and Rulers for Galactic Studies

Desirable properties:

- intrinsically luminous
- numerous
- photospheric composition proxy of the ISM at time of birth
- pulsation spectrum rich yet simple
- precise distance and age indicators
- span a wide age interval sampling look-back times as long as the age of the Galaxy.

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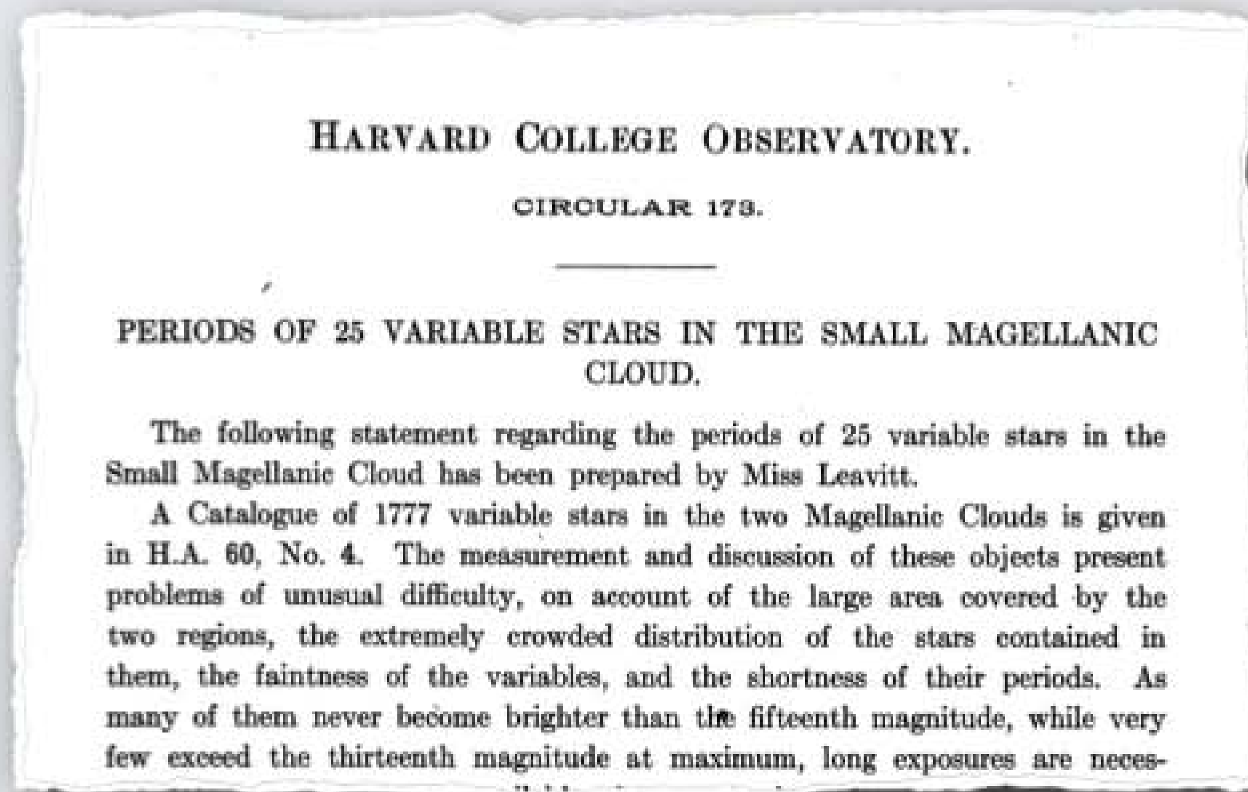
ENSEMBLE SEISMOLOGY OF G-K GIANTS

- Radius → distance

Pulsating stars as distance indicators:

RR Lyrae, Cepheids: $P \propto (M/R^3)^{-1/2}$

$\log(P) = a \log(L) + b \log(M) + c \log(T_{eff}) + d$



HARVARD COLLEGE OBSERVATORY.

CIRCULAR 173.

PERIODS OF 25 VARIABLE STARS IN THE SMALL MAGELLANIC CLOUD.

The following statement regarding the periods of 25 variable stars in the Small Magellanic Cloud has been prepared by Miss Leavitt.

A Catalogue of 1777 variable stars in the two Magellanic Clouds is given in H.A. 60, No. 4. The measurement and discussion of these objects present problems of unusual difficulty, on account of the large area covered by the two regions, the extremely crowded distribution of the stars contained in them, the faintness of the variables, and the shortness of their periods. As many of them never become brighter than the fifteenth magnitude, while very few exceed the thirteenth magnitude at maximum, long exposures are neces-

Leavitt 1912

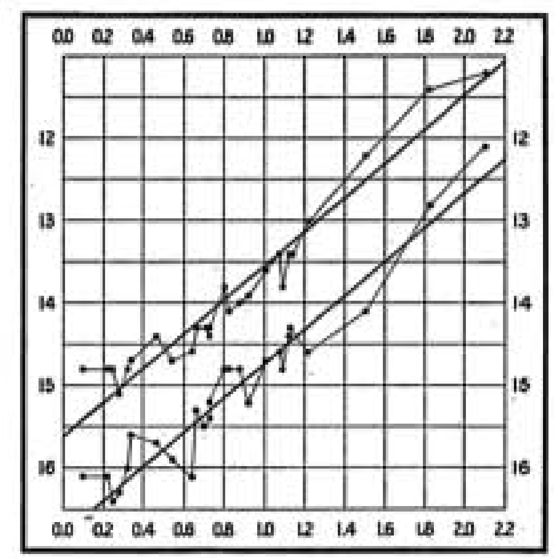


FIG. 2.

ENSEMBLE SEISMOLOGY OF G-K GIANTS

- Mass → age

GIANTS:

Age(RGB)~ τ_H

τ_H~M/L

L~M^{η} η~3.5

↓

Age(RGB)~ $M^{-2.5}$

ENSEMBLE SEISMOLOGY OF G-K GIANTS

- Mass ➡ age

GIANTS:

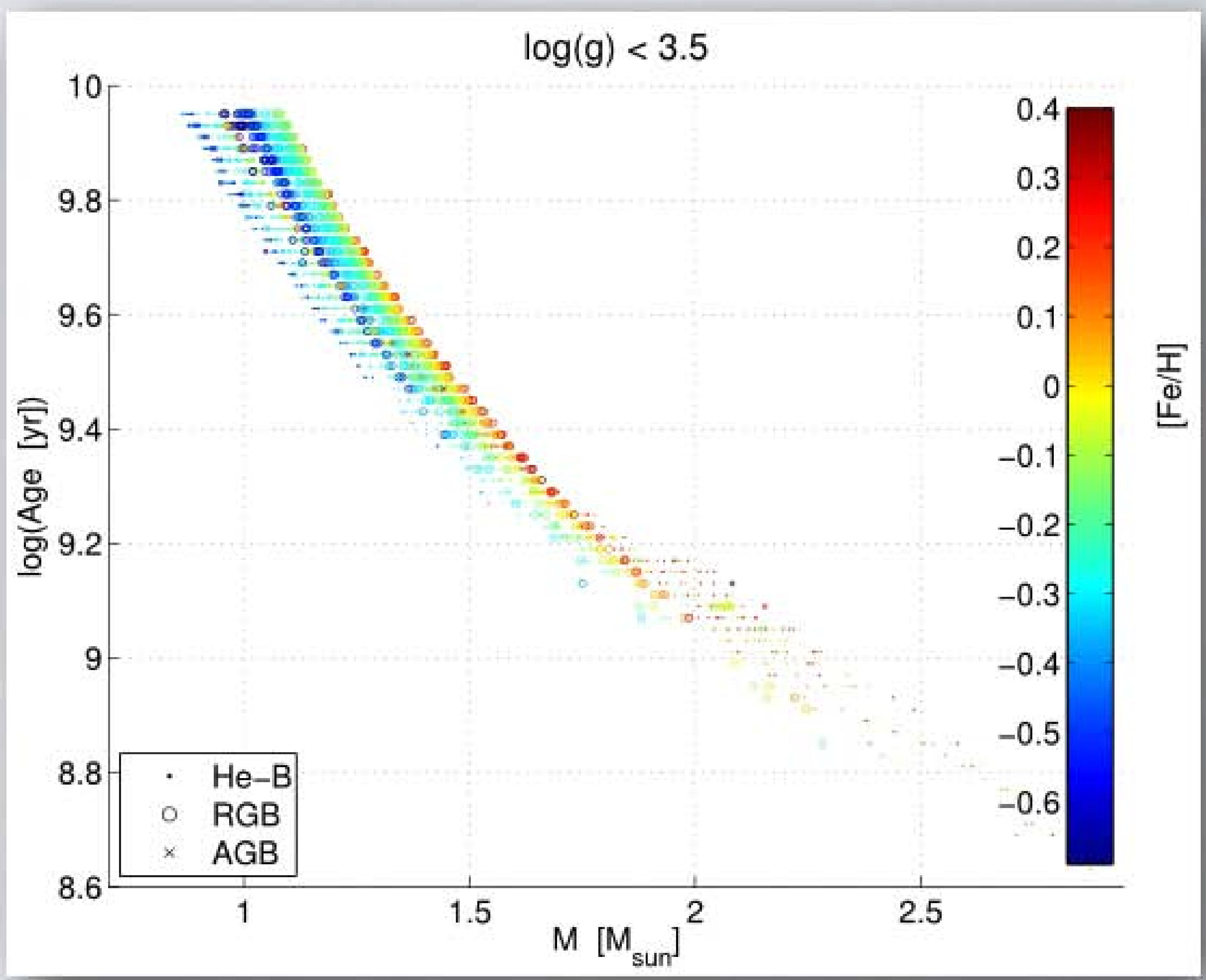
Age(RGB)~ τ_H

τ_H~M/L

L~M$^\eta$ η~3.5

⬇

Age(RGB)~ M$^{-2.5}$



M+[Fe/H]: "chronometer" for evolved stars

1 first steps

2 coordinated activities

3 next steps

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ENSEMBLE SEISMOLOGY OF G-K GIANTS

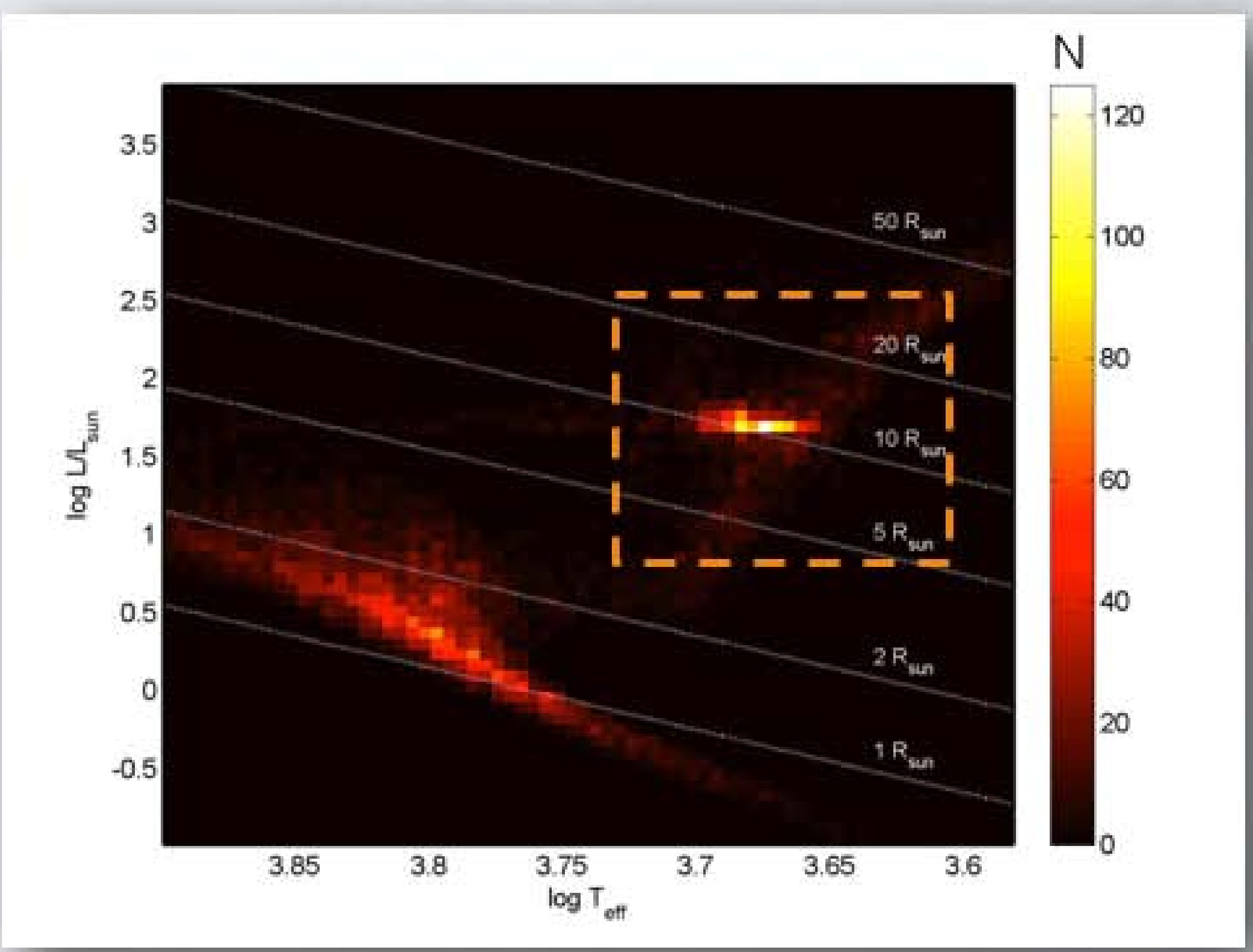
CoRoT: the pioneer

≈1000 red giants in CoRoT's LRc01 exofield 11<R<16

Hekker et al. 2009

seismology of populations of stars!

population expected

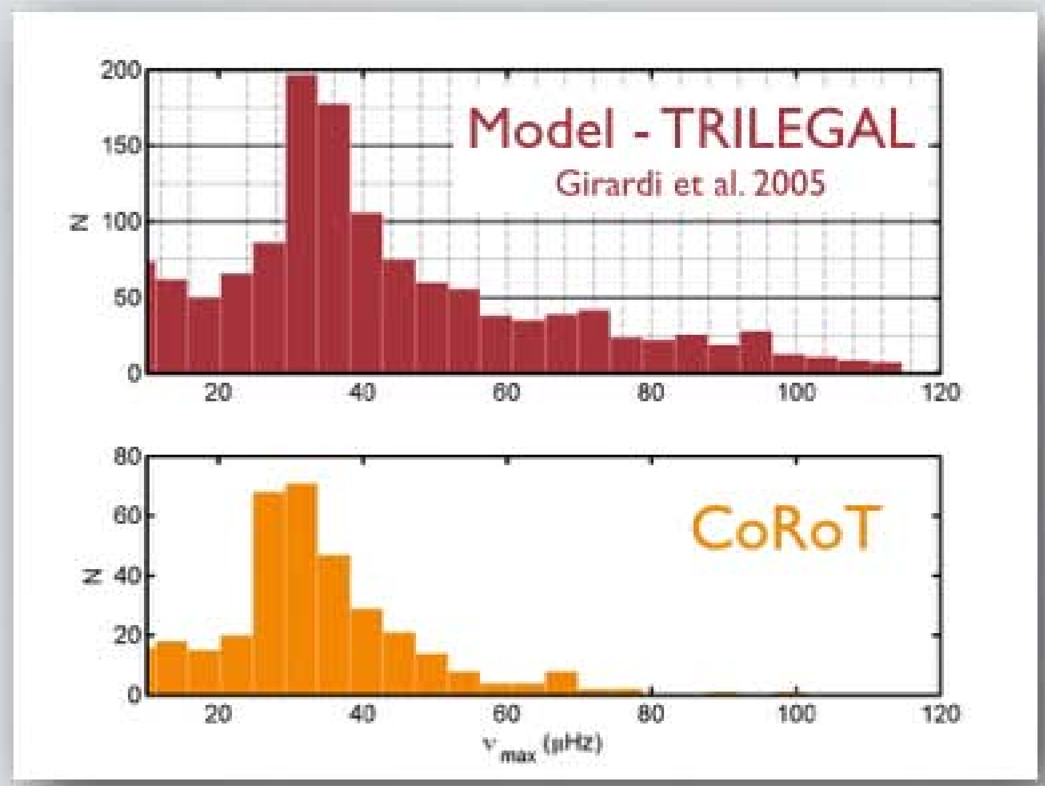


Miglio et al. 2009

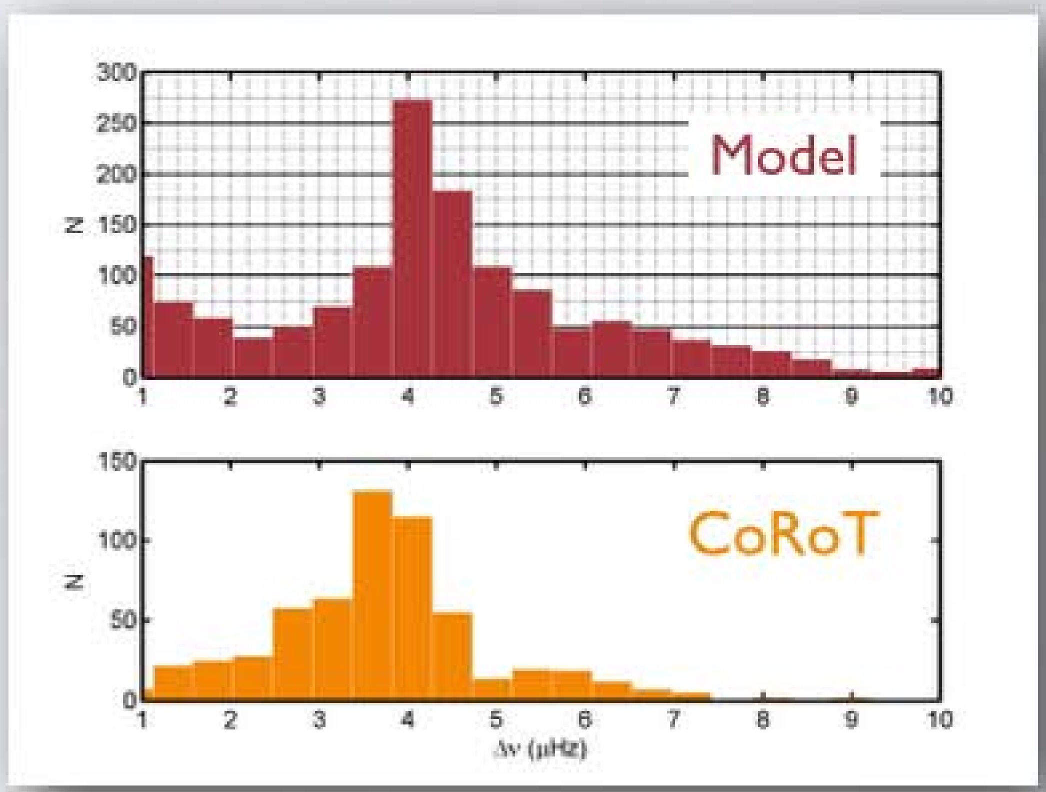
ENSEMBLE SEISMOLOGY OF G-K GIANTS

observed vs synthetic populations

ν_{max}



$\Delta\nu$

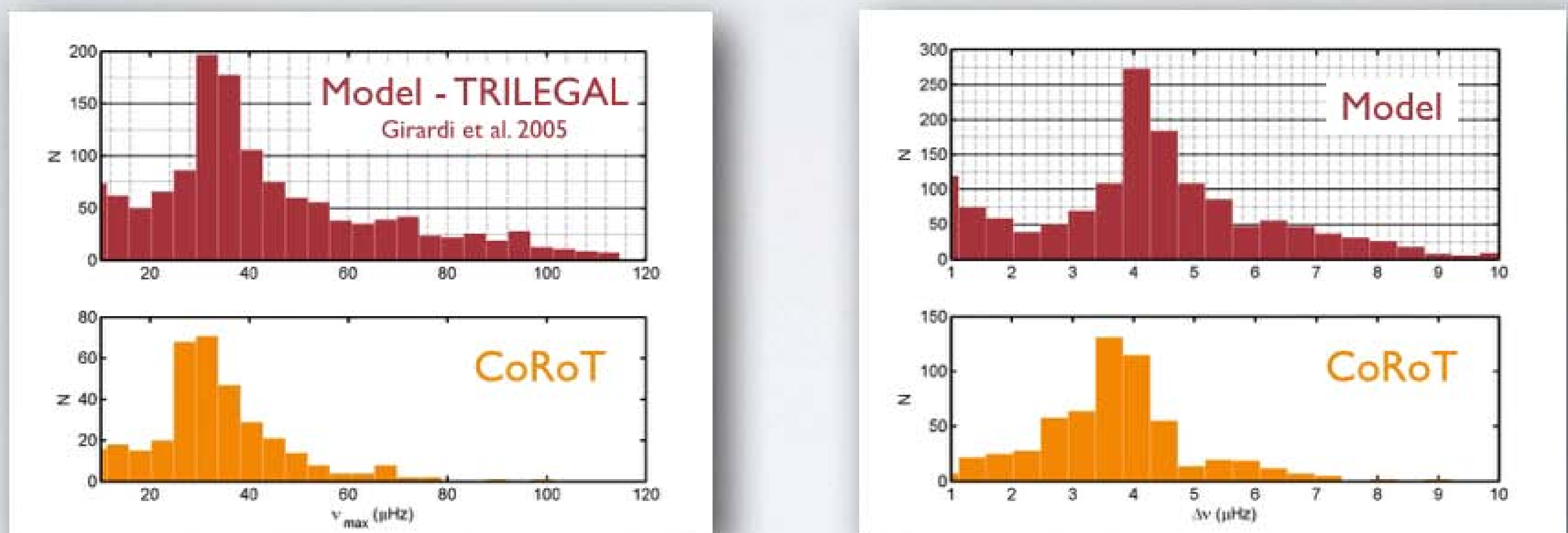


Miglio et al. 2009

ENSEMBLE SEISMOLOGY OF G-K GIANTS

observed vs synthetic populations

ν_{max} $\Delta\nu$



Miglio et al. 2009

bear the signature of the population's mass and radius distributions

ENSEMBLE SEISMOLOGY OF G-K GIANTS

empirical tests of scaling relations

e.g.

- a few nearby/CoRoT dwarfs and giants
  Bruntt et al. 2011, Miglio 2011, Bedding 2011, Lagarde et al. 2015
- interferometry
  Huber et al. 2012
- *Kepler* dwarfs+ Hipp parallaxes
  Silva Aguirre et al. 2012
- NGC6791, NGC6819, NGC6811, NGC6633:
  Miglio et al. 2012, Brogaard et al. 2012, Sandquist et al. 2013, Lagarde et al. 2015

model-based tests of $\Delta\nu$ scaling relation

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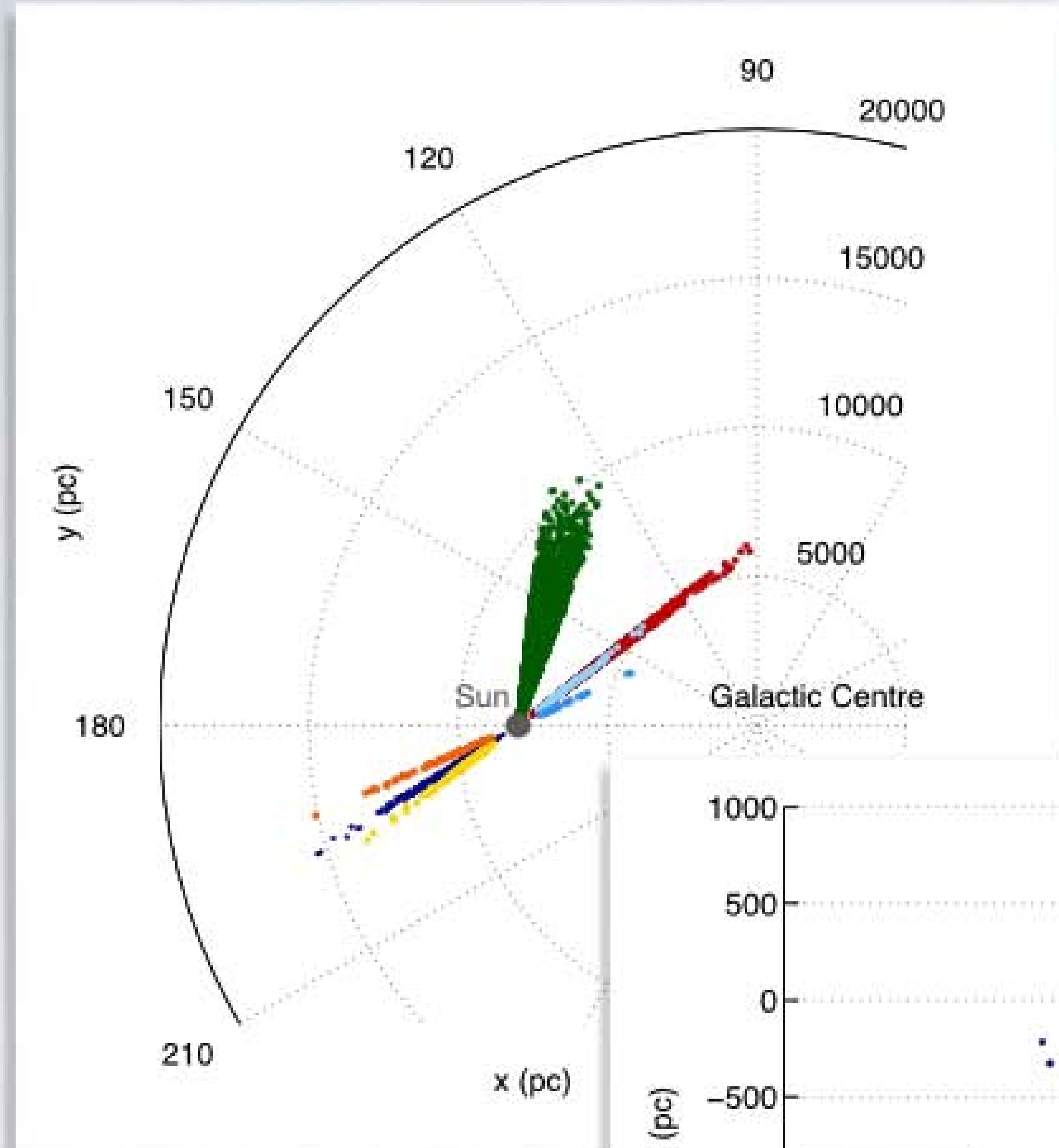
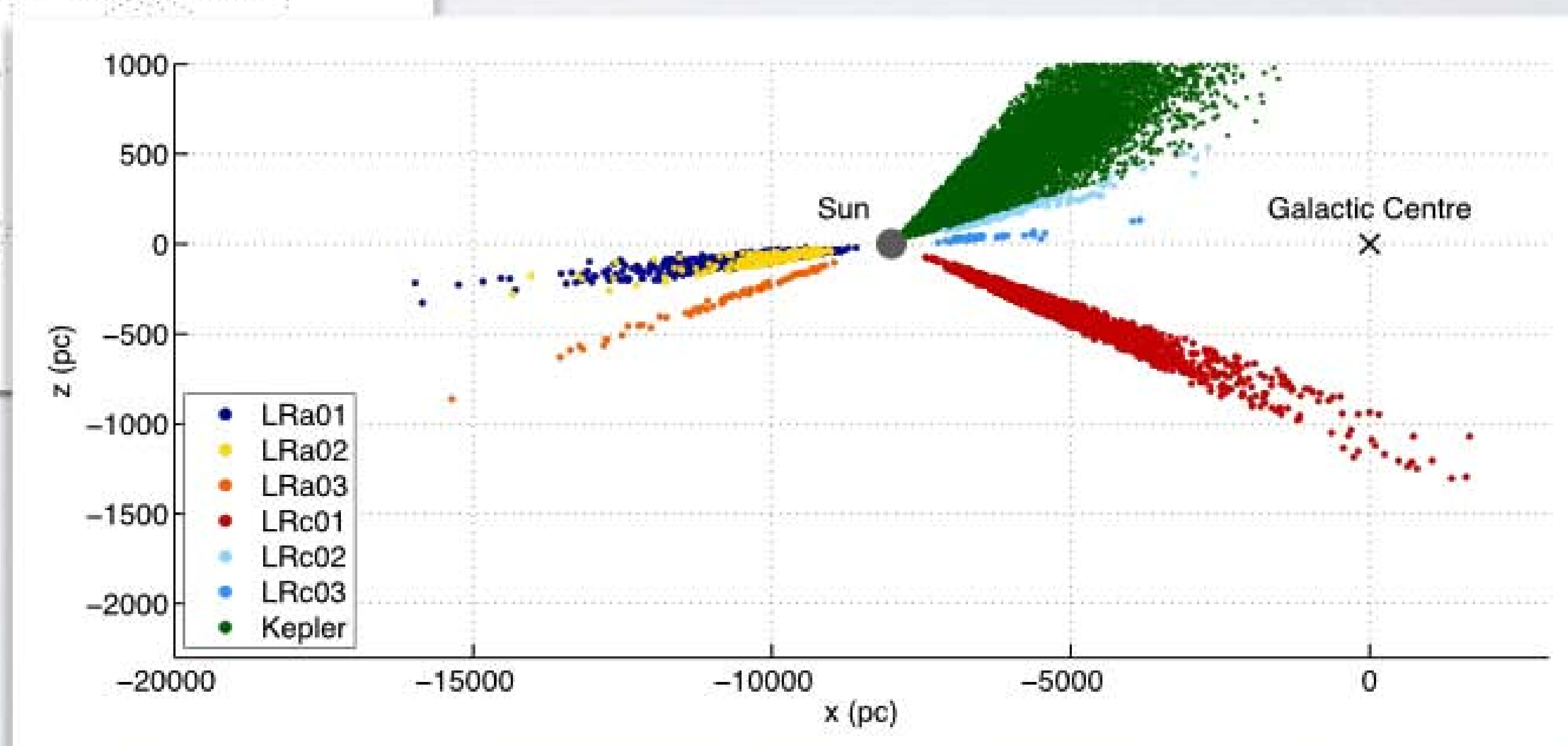
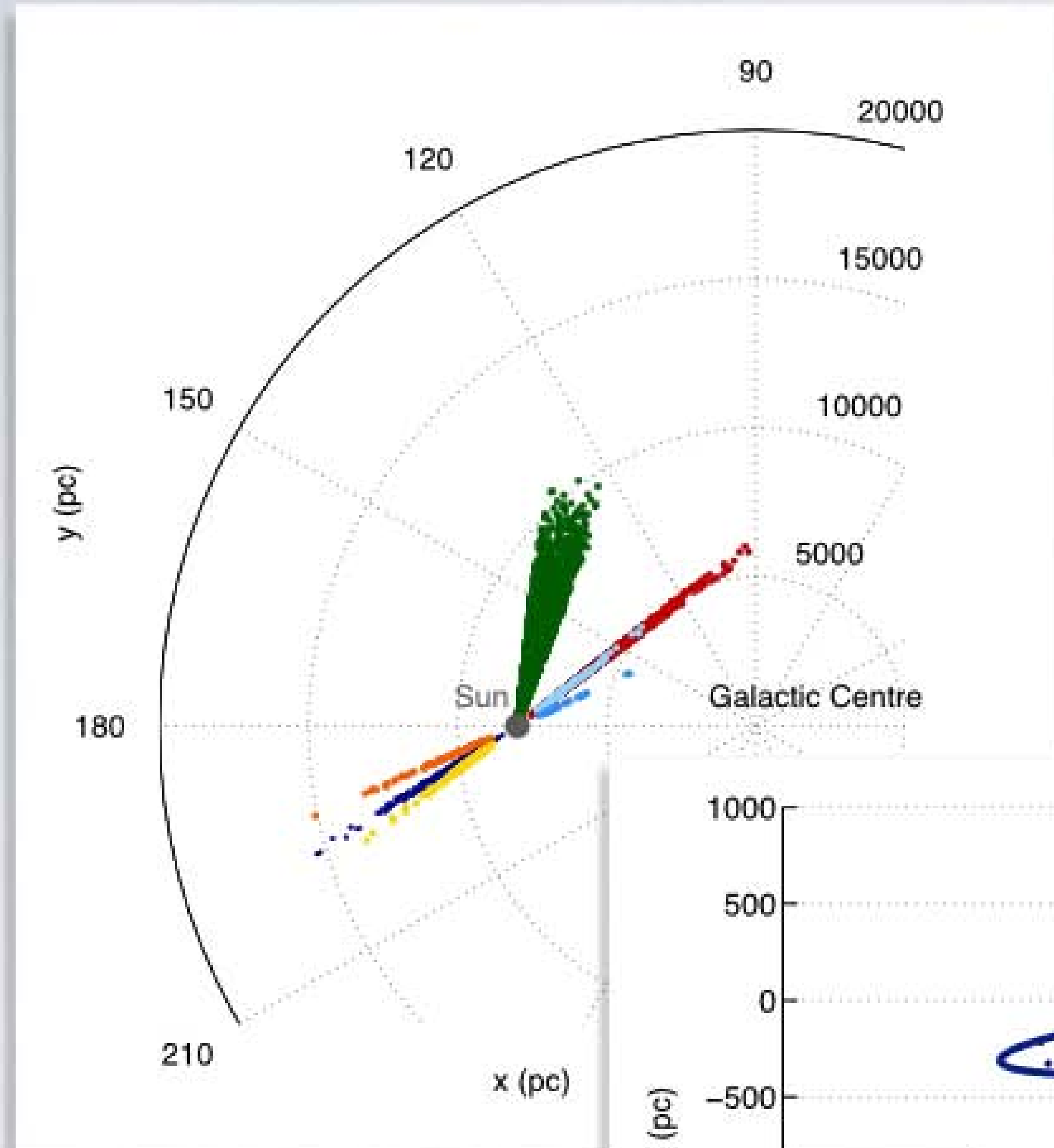
EARLY RESULTS: DISTANCES



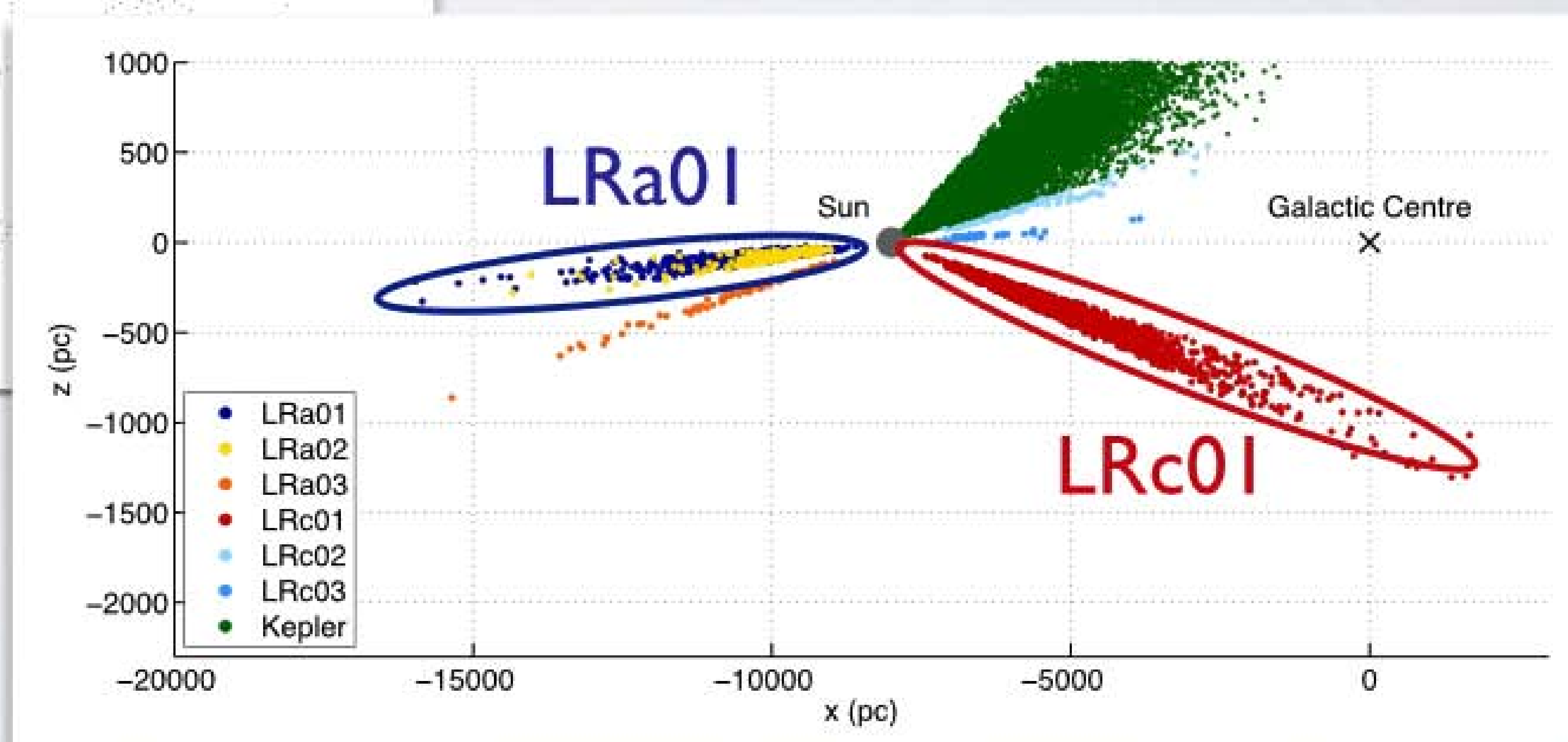
Miglio, Chiappini, Morel et al. 2013



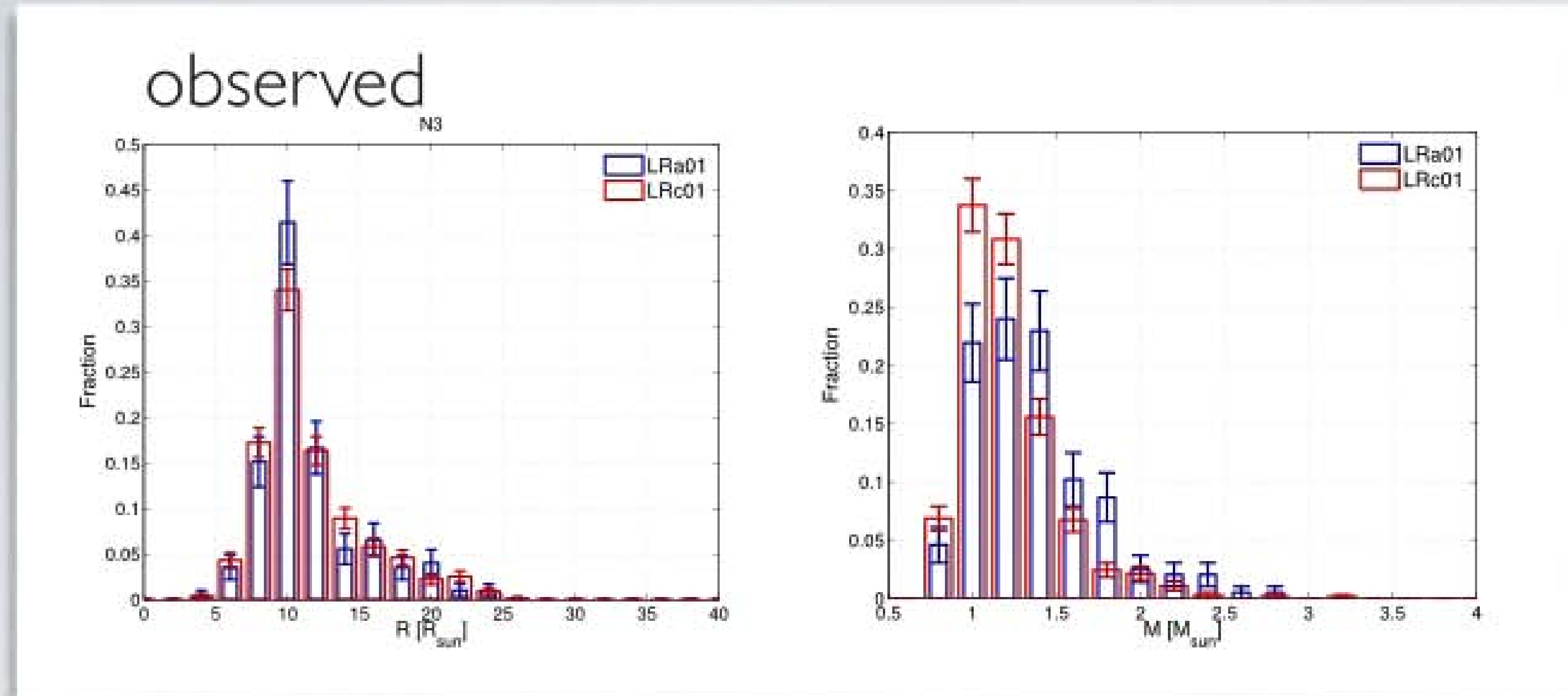
EARLY RESULTS: DISTANCES



Miglio, Chiappini, Morel et al. 2013



EARLY RESULTS: DIFFERENTIAL POPULATION STUDIES

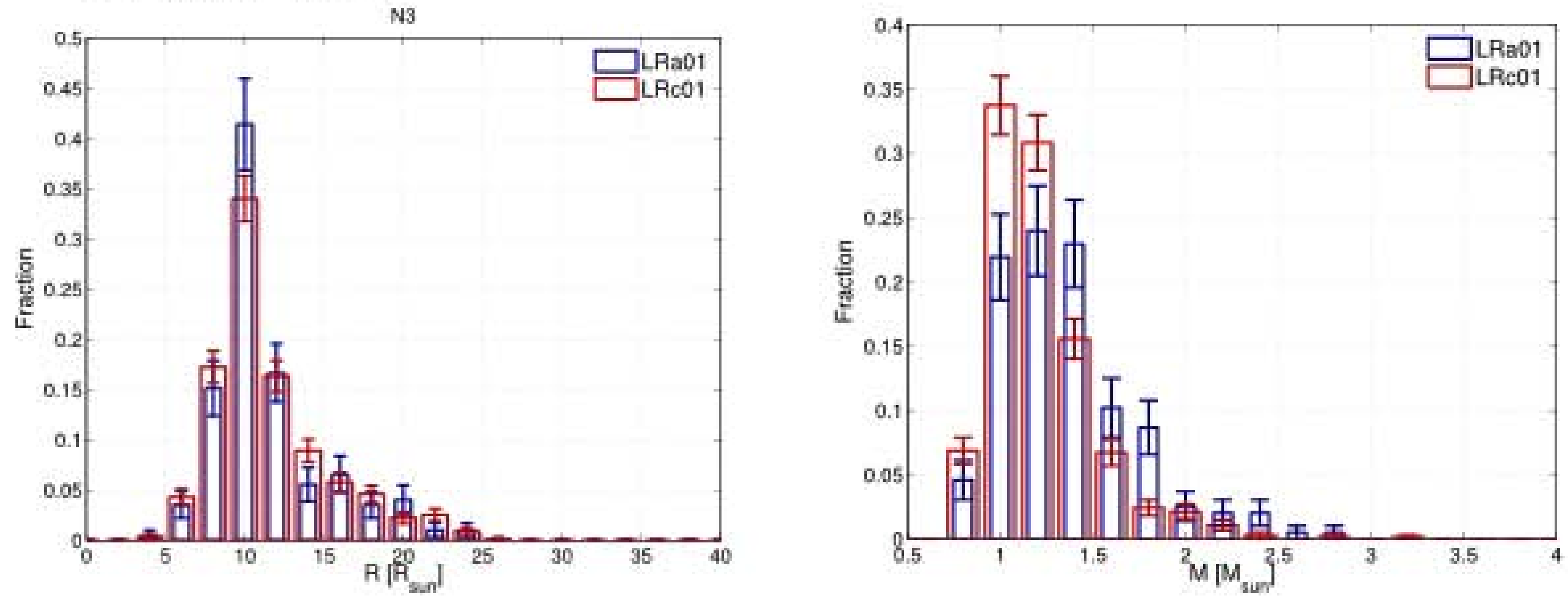


$\bar{Z}_{LRa01} < \bar{Z}_{LRc01}$

Miglio, Chiappini, Morel et al. 2013

EARLY RESULTS: DIFFERENTIAL POPULATION STUDIES

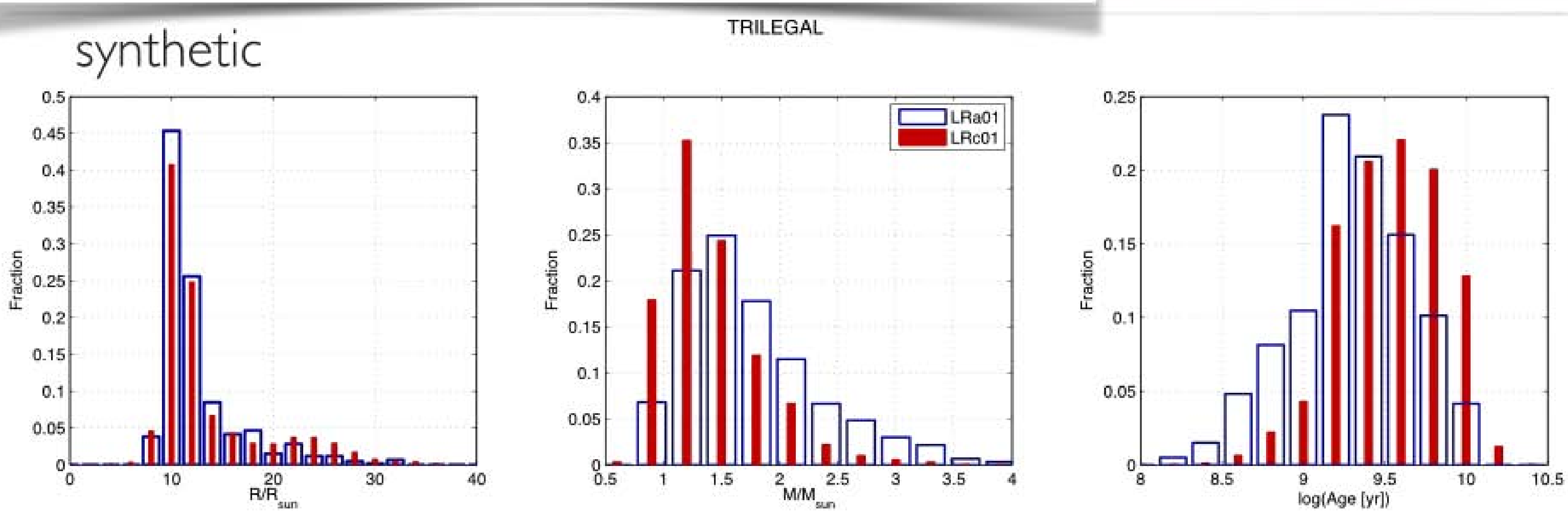
observed



$\bar{Z}_{LRa01} < \bar{Z}_{LRc01}$

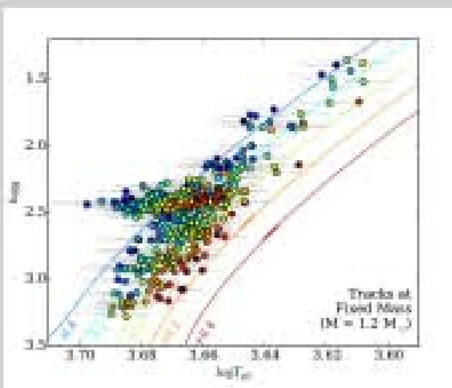
Miglio, Chiappini, Morel et al. 2013

synthetic

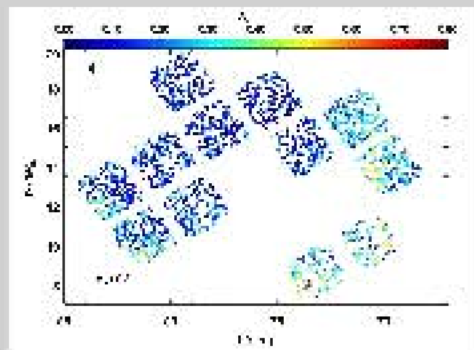


+ photospheric constraints from SAGA, APOKASC, COROGEE, GESS

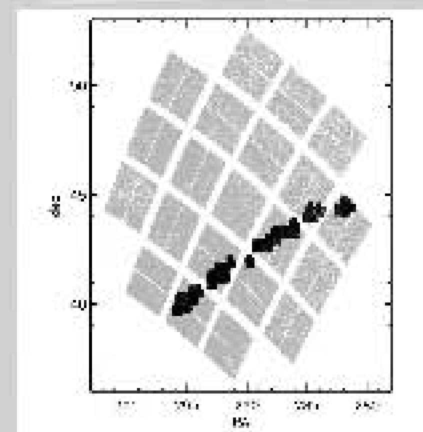
e.g.



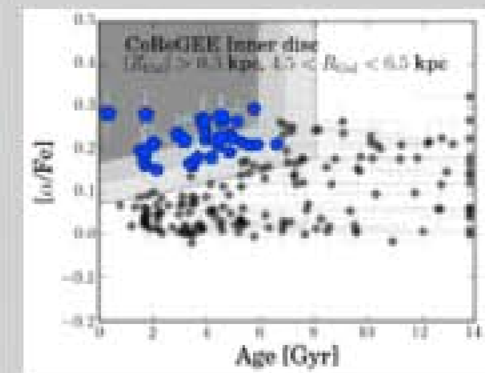
Pinsonneault et al.



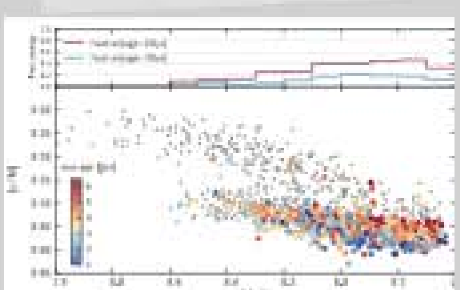
Rodrigues et al.



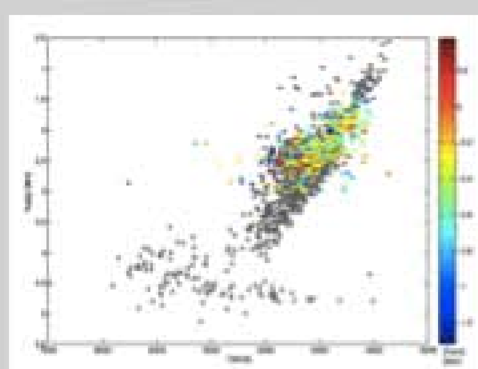
Casagrande et al.



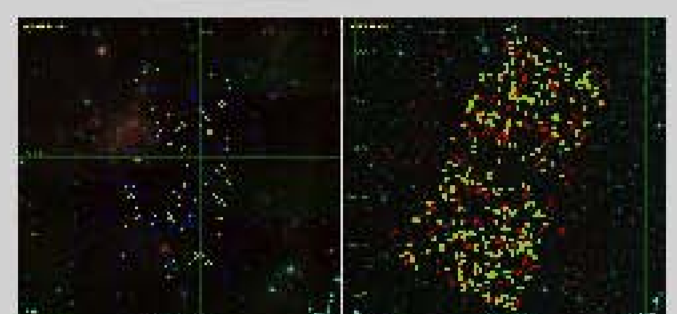
Chiappini et al.



Martig et al.



Valentini et al.



Anders et al.

what have we learnt

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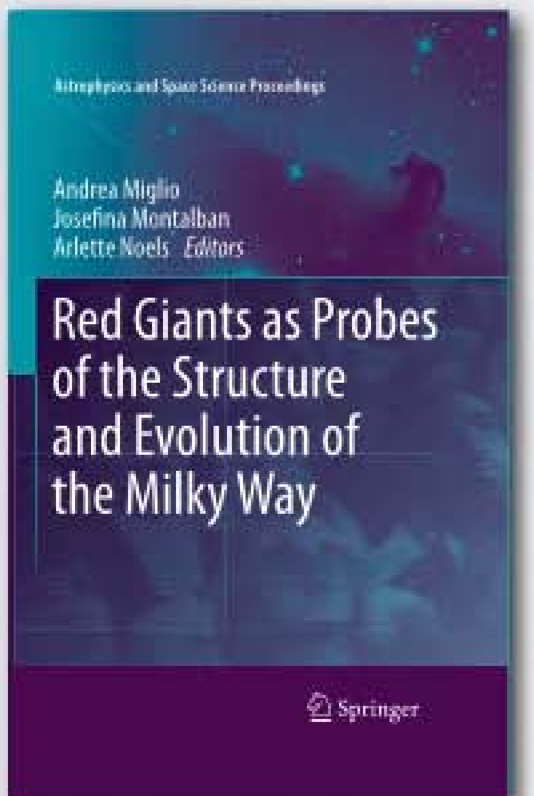
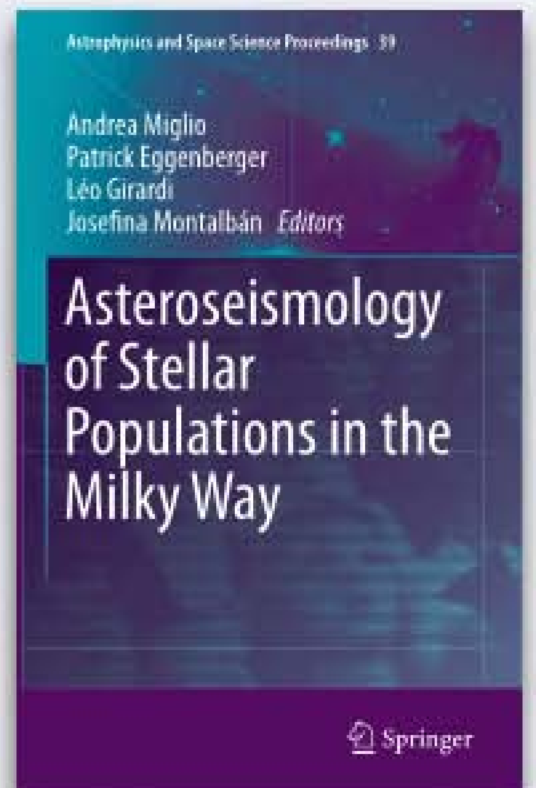
Need to combine expertise:

- stellar evolution
- asteroseismology
- spectroscopy
- galactic stellar populations studies
- chemodynamical models of the MW

2010 Roma



2013 Sesto



e.g.

Uncertainties in Models of Stellar Structure and Evolution ..
Arlette Noels and Angela Bragaglia

Photospheric Constraints, Current Uncertainties in Models of Stellar Atmospheres, and Spectroscopic Surveys............
Bertrand Plez and Nicolas Grevesse

asteroseismology of STEllar Populations

Open collaboration, 3 areas of expertise:

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

~100 scientists from ~20 countries

example 1

Analysis and interpretation of K2 data for Galactic studies: a collaborative effort

- K2 data analysis
- spectroscopy
- modelling

Enrico	Corsaro	X			
Eric	Depagne		X	X	
Eric	Michel	X		X	
Frederic	Thevenin		X		
Gail	Zasowski		X		APOGEE spectroscopy, photometry / reddening
Guy	Davies	X			
Gyula	Szabo		X		spectroscopy of bright objects
Holger	Lehman		X		brighter objects Thueringer
Ian	Roxburgh			X	
Isa	Brandao			X	Gaia-ESO survey
Jason	Drury	X			
Jennifer	Johnson		X		APOGEE
Jerome	Ballot	X			
Joao Pedro	Marques			X	
Jose Dias	do Nascimento Jr.		X		
Josefina	Montalban			X	
Joss	Hawthorn		X		
Juan Carlos	Suarez	X			
Leo	Girardi			X	
Luca	Casagrande		X		
Marc	Pinsonneault		X	X	APOGEE / photometry / modelling
Marcio	Catelan				
Maria	Bergemann		X		
Maria Pia	Di Mauro			X	
Marian	Suran			X	
Marica	Valentini		X		RAVE, Gaia-ESO
Martin	Asplund		X		Hermes, AAOmega
Mathieu	Vrard	X			
Maurizio	Salaris			X	
Nadege	Lagarde			X	
Orlagh	Creevey			X	
Othman	Benomar	X			
Paola	Marigo			X	

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Jason	Drury	X			
Jennifer	Johnson		X		APOGEE
Jerome	Ballot	X			
Joao Pedro	Marques			X	
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Josefina	Montalban			X	
Joss	Hawthorn		X		
Juan Carlos	Suarez	X			
Leo	Girardi			X	
Luca	Casagrande		X		
Marc	Pinsonneault		X	X	APOGEE / photometry / modelling
Marcio	Catelan				
Maria	Bergemann		X		
Maria Pia	Di Mauro			X	
Marian	Suran			X	
Marica	Valentini		X		RAVE, Gaia-ESO
Martin	Asplund		X		Hermes, AAOmega
Mathieu	Vrard	X			
Maurizio	Salaris			X	
Nadege	Lagarde			X	
Orlagh	Creevey			X	
Othman	Benomar	X			
Paola	Marigo			X	
Patrick	Gaulme	X			
Patrick	Eggenberger			X	

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Jerome	Ballot	X			
Joao Pedro	Marques			X	
Jose Dias	do Nascimento Jr.		X		
Josefina	Montalban			X	
Joss	Hawthorn		X		
Juan Carlos	Suarez	X			
Leo	Girardi			X	
Luca	Casagrande		X		
Marc	Pinsonneault		X	X	APOGEE / photometry / modelling
Marcio	Catelan				
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Maria Pia	Di Mauro			X	
Marian	Suran			X	
Marica	Valentini		X		RAVE, Gaia-ESO
Martin	Asplund		X		Hermes, AAOmega
Mathieu	Vrard	X			
Maurizio	Salaris			X	
Nadege	Lagarde			X	
Orlagh	Creevey			X	
Othman	Benomar	X			
Paola	Marigo			X	
Patrick	Gaulme	X			
Patrick	Eggenberger			X	
Paul	Beck	X			
Rafa	Garcia	X			
Rafael	Peralta	X		X	

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Jennifer	Johnson		X		APOGEE
Jerome	Ballot	X			
Joao Pedro	Marques			X	
Jose Dias	do Nascimento Jr.		X		
Josefina	Montalban			X	
Joss	Hawthorn		X		
Juan Carlos	Suarez	X			
Leo	Girardi			X	
Luca	Casagrande		X		
Marc	Pinsonneault		X	X	APOGEE / photometry / modelling
Marcio	Catelan				
Maria	Bergemann		X		
Maria Pia	Di Mauro			X	
Marian	Suran			X	
Marica	Valentini		X		RAVE, Gaia-ESO
Martin	Asplund		X		Hermes, AAOmega
Mathieu	Vrard	X			
Maurizio	Salaris			X	
Nadege	Lagarde			X	
Orlagh	Creevey			X	
Othman	Benomar	X			
Paola	Marigo			X	
Patrick	Gaulme	X			
Patrick	Eggenberger			X	
Paul	Beck	X			
Rafa	Garcia	X			
Rafael	Peralta	X		X	
Rasmus	Handberg	X			
Reza	Samadi			X	
Rhita Maria	Ouazzani			X	

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Jason	Drury	X			
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Josefina	Montalban			X	
Joss	Hawthorn		X		
Juan Carlos	Suarez	X			
Leo	Girardi			X	
Luca	Casagrande		X		
Marc	Pinsonneault		X	X	APOGEE / photometry / modelling
Marcio	Catelan				
Maria	Bergemann		X		
Maria Pia	Di Mauro			X	
Marian	Suran			X	
Marica	Valentini		X		RAVE, Gaia-ESO
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Mathieu	Vrard	X			
Maurizio	Salaris			X	
Nadege	Lagarde			X	
Orlagh	Creevey			X	
Othman	Benomar	X			
Paola	Marigo			X	
Patrick	Gaulme	X			
Patrick	Eggenberger			X	
Paul	Beck	X			
Rafa	Garcia	X			
Rafael	Peralta	X		X	
Rasmus	Handberg	X			
Reza	Samadi			X	
Rhita Maria	Ouazzani			X	
Sanjib	Sharma				
Santi	Cassisi			X	
Sarbani	Basu			X	
Saskia	Hekker	X			
Savita	Mathur	X			
Sebastien	Deheuvels	X			

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Analysis and interpretation of K2 data for Galactic studies: a collaborative effort

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	Jr.				
Josefina	Montalban			X	
Joss	Hawthorn		X		
Juan Carlos	Suarez	X			
Leo	Girardi			X	
Luca	Casagrande		X		
Marc	Pinsonneault		X	X	APOGEE / photometry / modelling
Marcio	Catelan				
Maria	Bergemann		X		
Maria Pia	Di Mauro			X	
Marian	Suran			X	
Marica	Valentini		X		RAVE, Gaia-ESO
Martin	Asplund		X		Hermes, AAOmega
Mathieu	Vrard	X			
Maurizio	Salaris			X	
Nadege	Lagarde			X	
Orlagh	Creevey			X	
Othman	Benomar	X			
Paola	Marigo			X	
Patrick	Gaulme	X			
Patrick	Eggenberger			X	
Paul	Beck	X			
Rafa	Garcia	X			
Rafael	Peralta	X		X	
Rasmus	Handberg	X			
Reza	Samadi			X	
Rhita Maria	Ouazzani			X	
Sanjib	Sharma				
Santi	Cassisi			X	
Sarbani	Basu			X	
Saskia	Hekker	X			
Savita	Mathur	X			
Sebastien	Deheuvels	X			
Steve	Kawaler	X		X	already experience with K2 SC
Steven	Bloemen	X			
Thaise	Rodrigues			X	
Thierry	Morel		X		Gaia-ESO, not only
Thomas	Kallinger	X			

example 1

Analysis and interpretation of K2 data for Galactic studies: a collaborative effort

- K2 data analysis
- spectroscopy
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Luca	Casagrande		X		
Marc	Pinsonneault		X	X	APOGEE / photometry / modelling
Marcio	Catelan				
Maria	Bergemann		X		
Maria Pia	Di Mauro			X	
Marian	Suran			X	
Marica	Valentini		X		RAVE, Gaia-ESO
Martin	Asplund		X		Hermes, AAOmega
Mathieu	Vrard	X			
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Nadege	Lagarde			X	
Orlagh	Creevey			X	
Othman	Benomar	X			
Paola	Marigo			X	
Patrick	Gaulme	X			
Patrick	Eggenberger			X	
Paul	Beck	X			
Rafa	Garcia	X			
Rafael	Peralta	X		X	
Rasmus	Handberg	X			
Reza	Samadi			X	
Rhita Maria	Ouazzani			X	
Sanjib	Sharma				
Santi	Cassisi			X	
Sarbani	Basu			X	
Saskia	Hekker	X			
Savita	Mathur	X			
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Thaise	Rodrigues			X	
Thierry	Morel		X		Gaia-ESO, not only
Thomas	Kallinger	X			
Tim	White	X			and interferomertric data, when possible
Tim	Bedding	X			
Ulrike	Heiter		X		Gaia-ESO
Victor	Silva Aguirre		X	X	

example 1

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Maurizio	Salaris			X	
Nadege	Lagarde			X	
Orlagh	Creevey			X	
Othman	Benomar	X			
Paola	Marigo			X	
Patrick	Gaulme	X			
Patrick	Eggenberger			X	
Paul	Beck	X			
Rafa	Garcia	X			
Rafael	Peralta	X		X	
Rasmus	Handberg	X			
Reza	Samadi			X	
Rhita Maria	Ouazzani			X	
Sanjib	Sharma				
Santi	Cassisi			X	
Sarbani	Basu			X	
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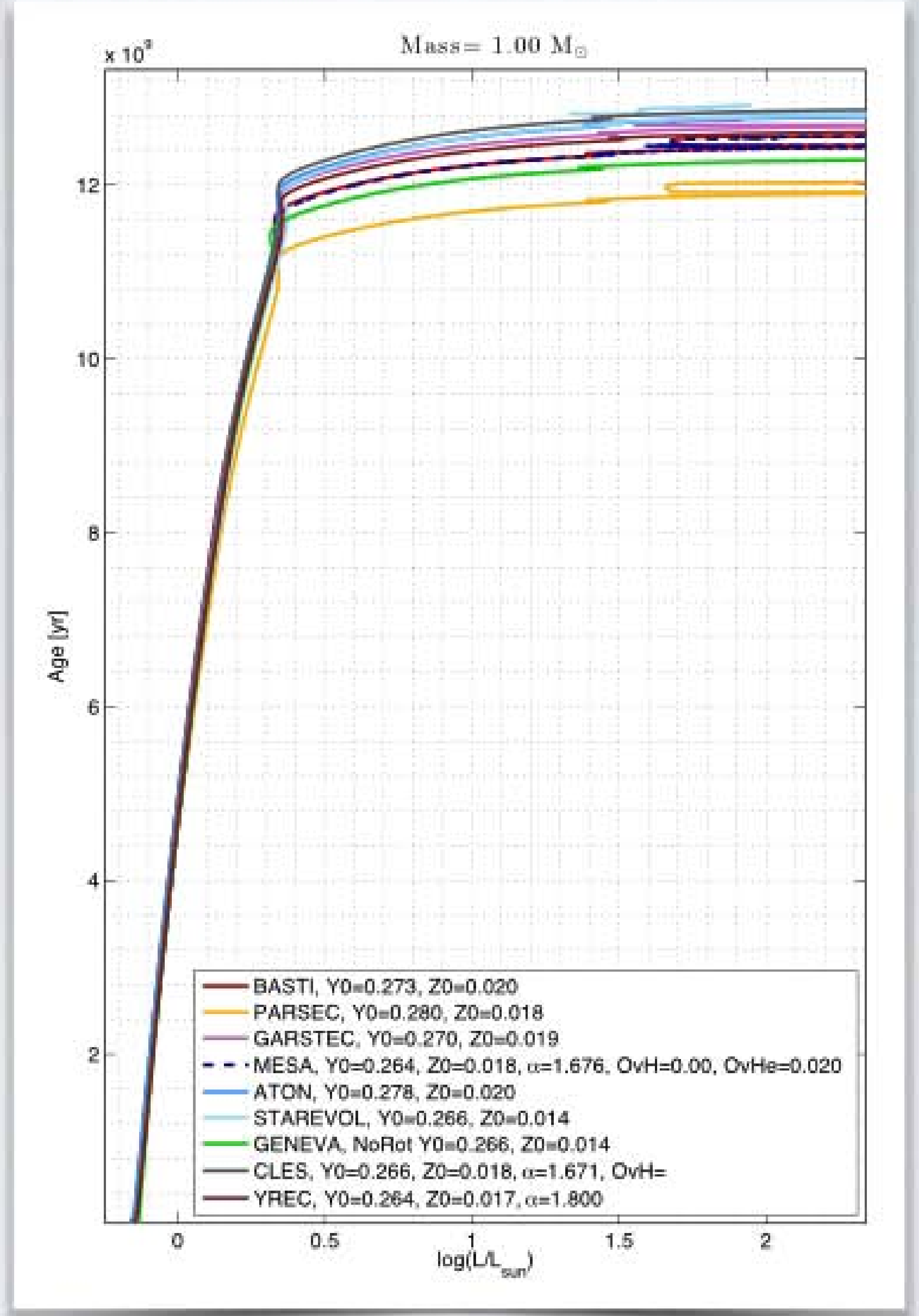
Thomas	Kallinger	X			
Tim	White	X			and interferomertric data, when possible
Tim	Bedding	X			
Ulrike	Heiter		X		Gaia-ESO
Victor	Silva Aguirre		X	X	
Warrick	Ball			X	
Yveline	Lebreton			X	
Yvonne	Elsworth	X			
Zhao	Guo		X		

example 2

isochrone fitting (old problem), has to be revisited in the light of new constraints

systematic uncertainties: collaborative project involving several codes



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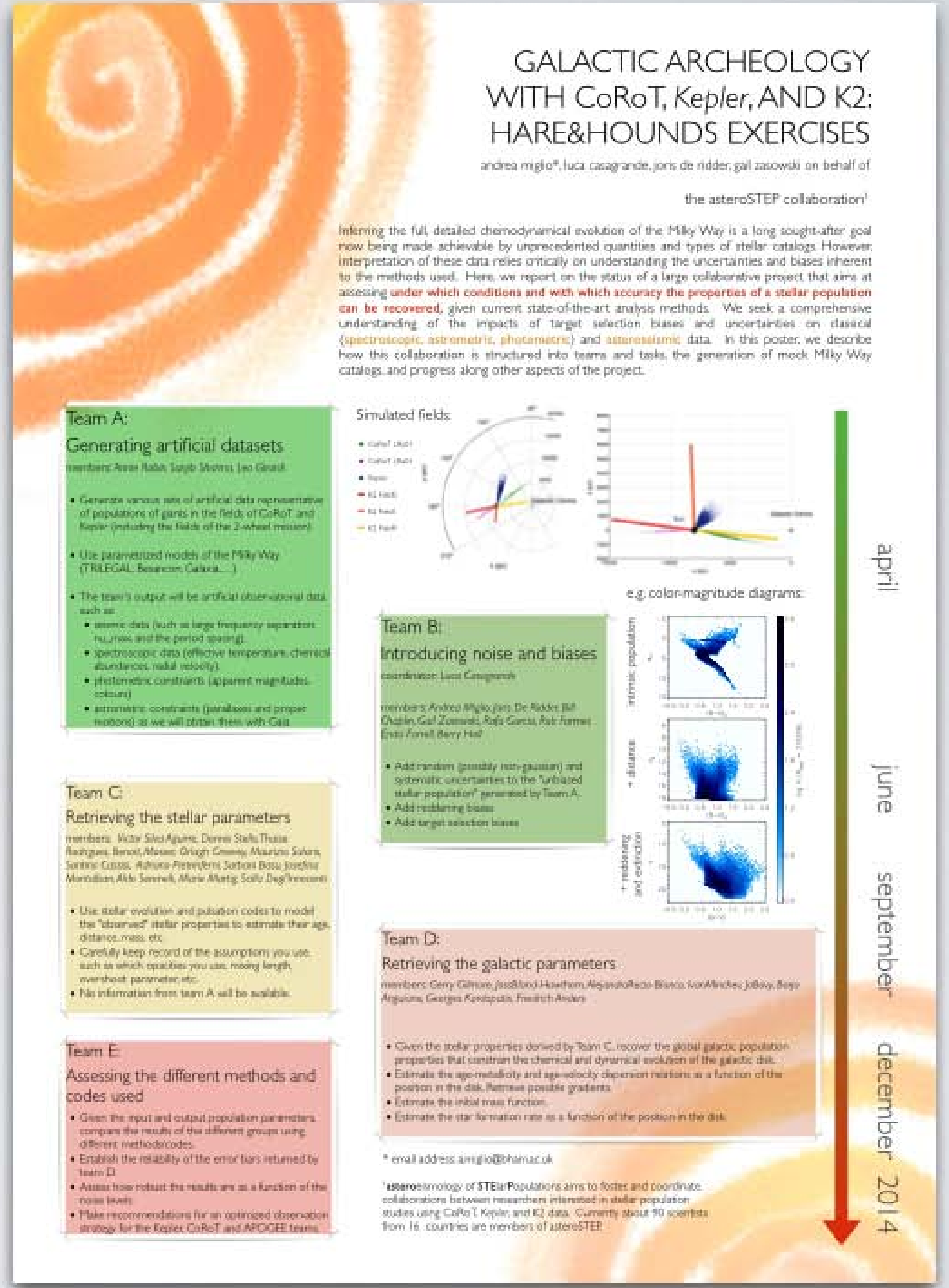
example 3

asteroSTEP:

Hare&hounds exercises



GALACTIC ARCHEOLOGY WITH CoRoT, *Kepler*, AND K2: HARE&HOUNDS EXERCISES

andrea miglio*, luca casagrande, joris de ridder, gail zasowski on behalf of

the asteroSTEP collaboration[1]

Inferring the full, detailed chemodynamical evolution of the Milky Way is a long sought-after goal now being made achievable by unprecedented quantities and types of stellar catalogs. However, interpretation of these data relies critically on understanding the uncertainties and biases inherent to the methods used. Here, we report on the status of a large collaborative project that aims at assessing **under which conditions and with which accuracy the properties of a stellar population can be recovered**, given current state-of-the-art analysis methods. We seek a comprehensive understanding of the impacts of target selection biases and uncertainties on classical (spectroscopic, astrometric, photometric) and asteroseismic data. In this poster, we describe how this collaboration is structured into teams and tasks, the generation of mock Milky Way catalogs, and progress along other aspects of the project.

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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,…)
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  - seismic data (such as large frequency separation, nu_max, and the period spacing),
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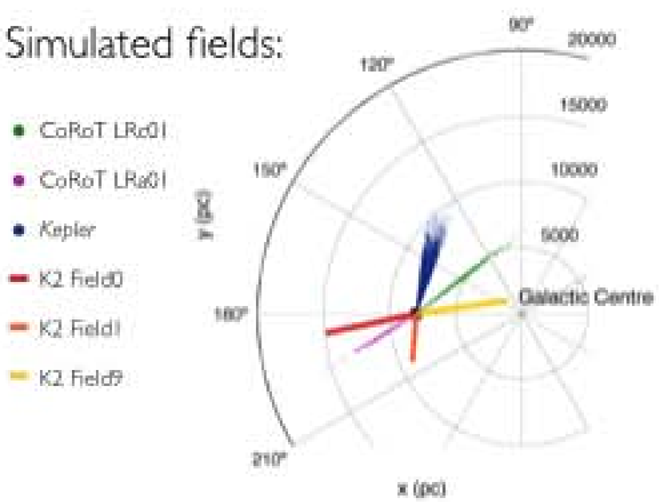
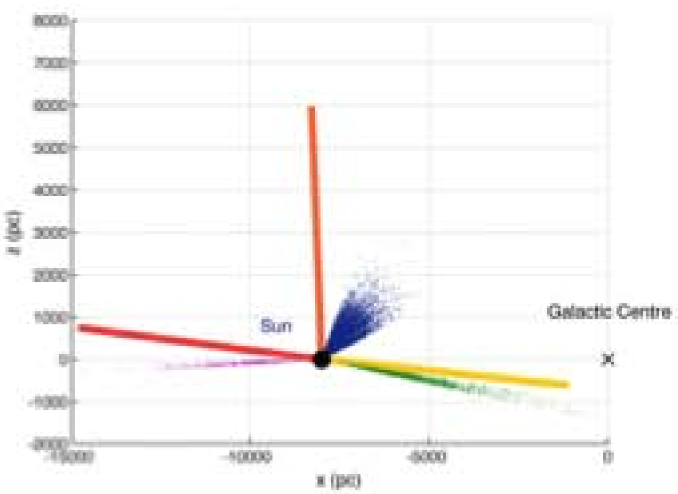
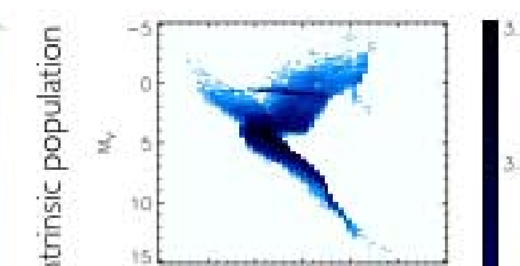
Simulated fields:





e.g. color-magnitude diagrams:



Team B:
Introducing noise and biases

coordinator: *Luca Casagrande*

april

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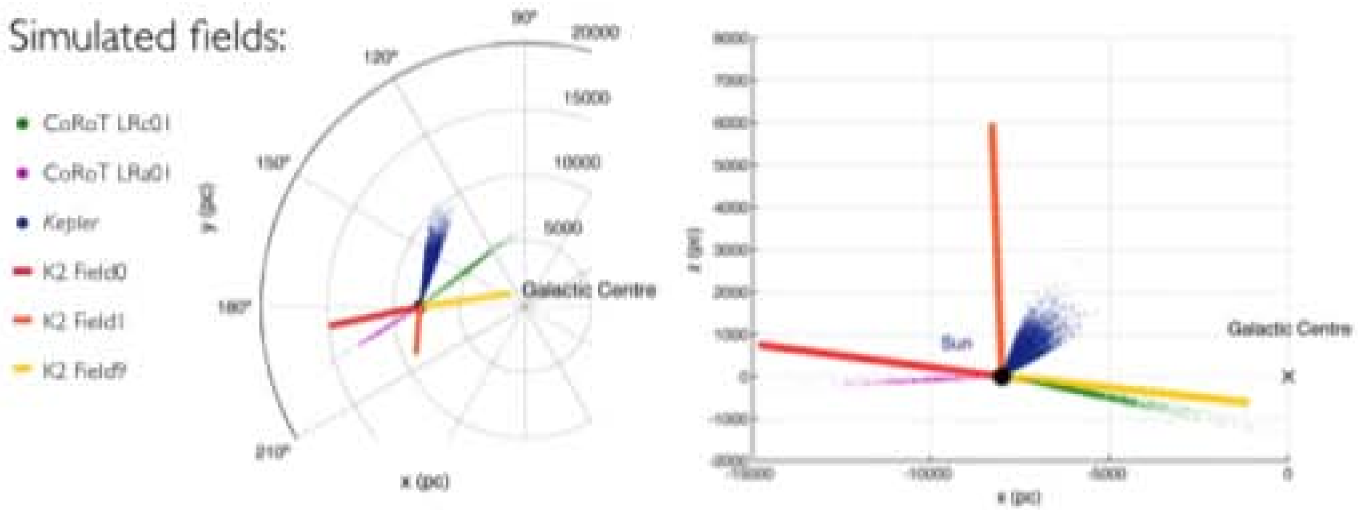

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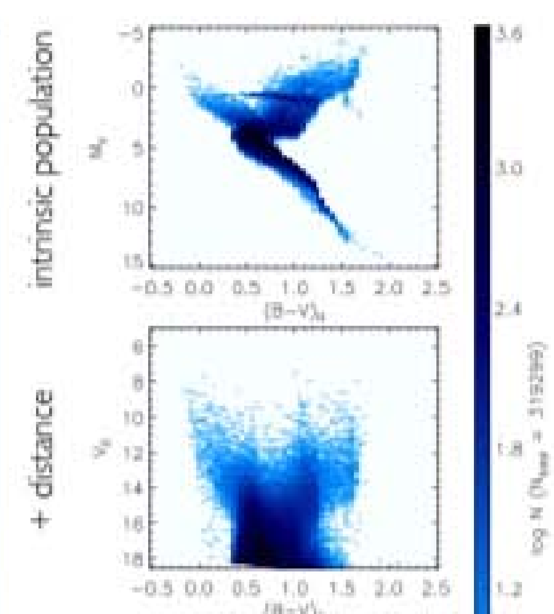

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Team C:

april

june

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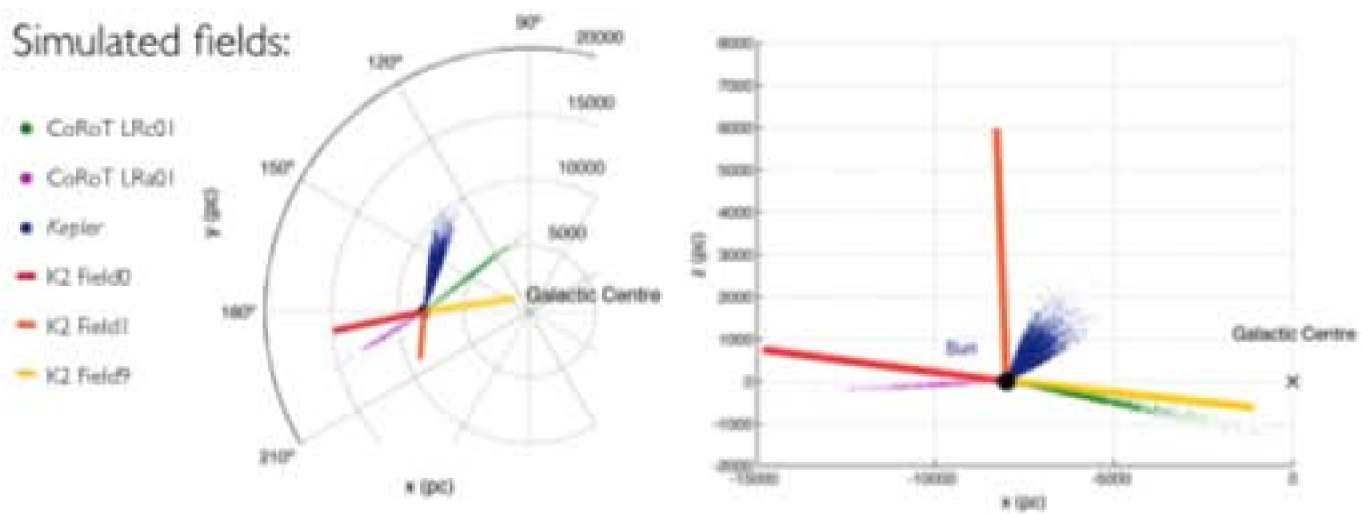

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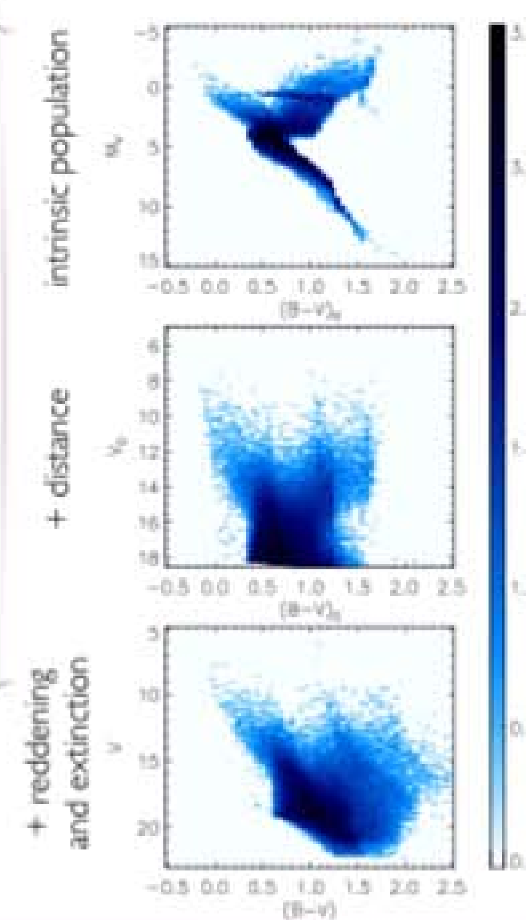

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april

june

septe

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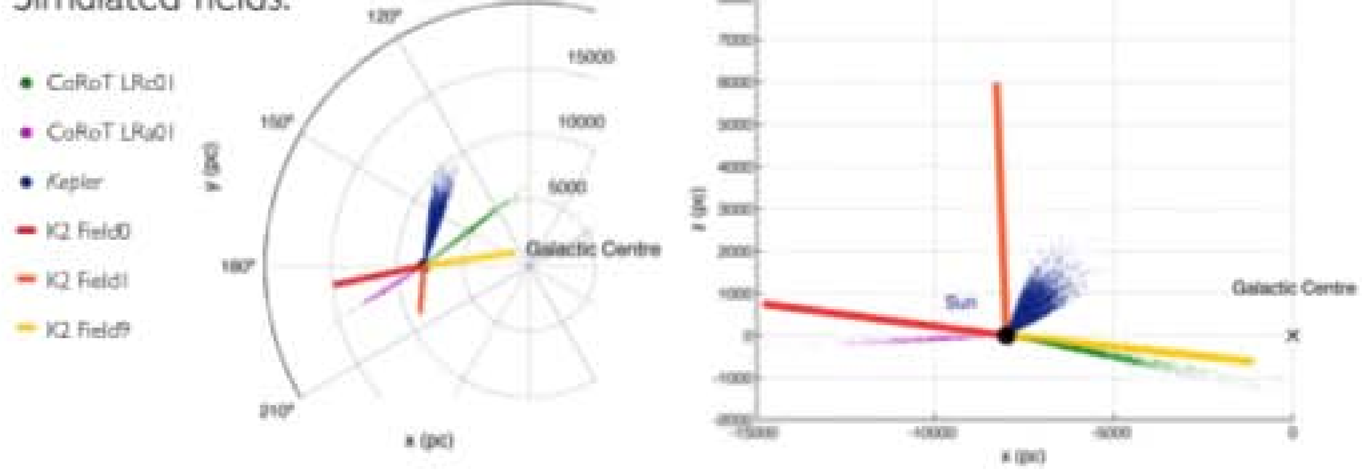

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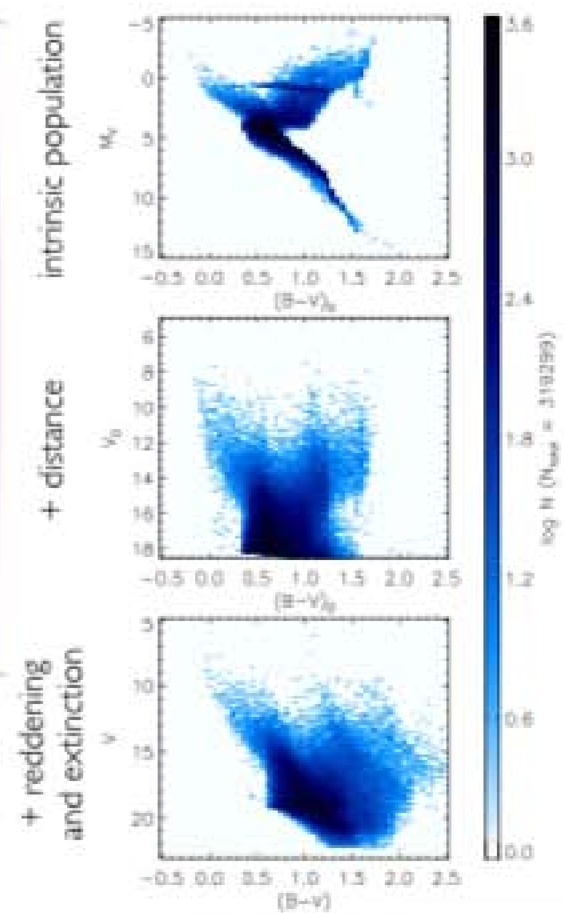

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members: *Gerry Gilmore, JossBland-Hawthorn, AlejandraRecio-Blanco, IvanMinchev, JoBovy, Borja Anguiano, Georges Kordopatis, Friedrich Anders*

- 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.

Team E:

Assessing the different methods and codes used

april

june

september

decem

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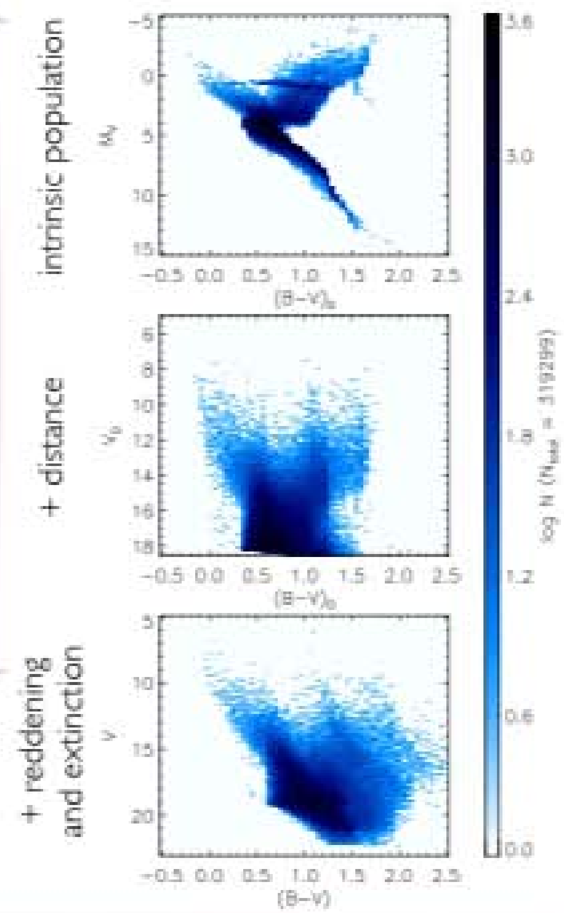

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- Estimate the star formation rate as a function of the position in the disk.

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] **astero**eismology of **STE**lar**P**opulations 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.

june
september
december 2014

1 first steps

2 coordinated activities

3 next steps

Ensemble seismology

- impose that a solution $(\nu_{\rm max},\ \Delta\nu,\ [{\rm Fe/H}], T_{\rm eff})$ belongs to an evolutionary track

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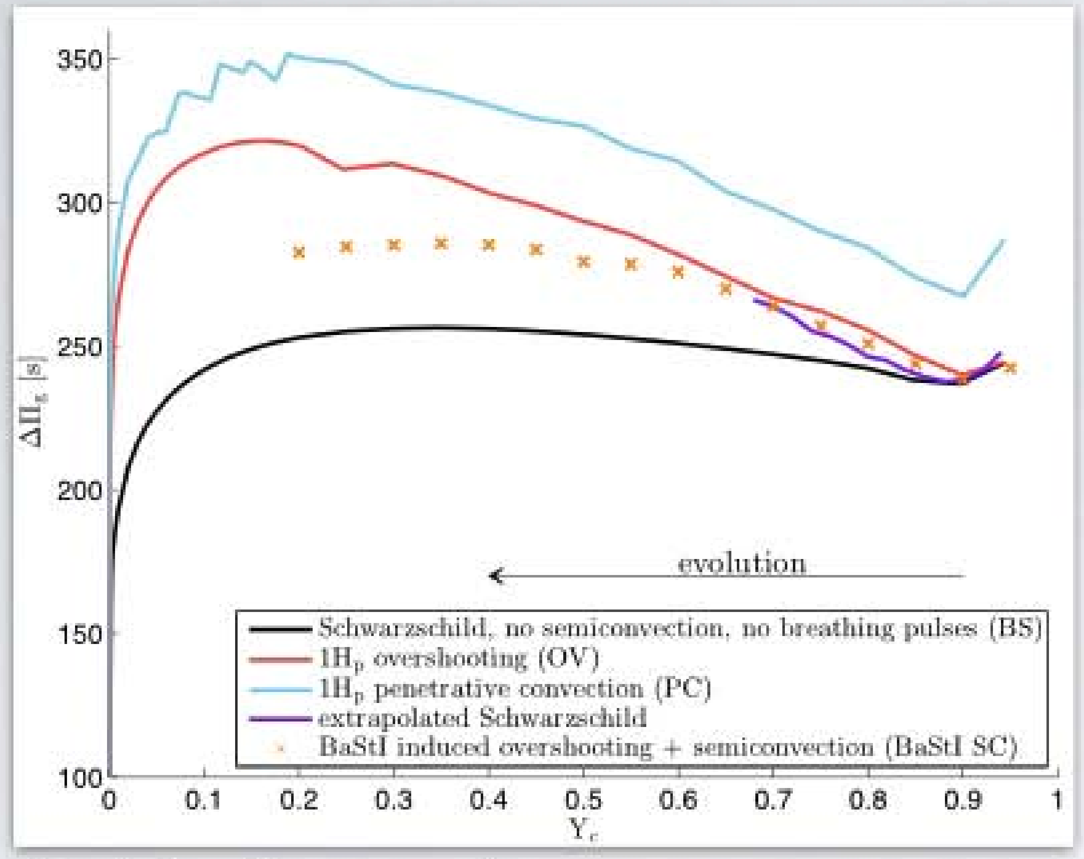
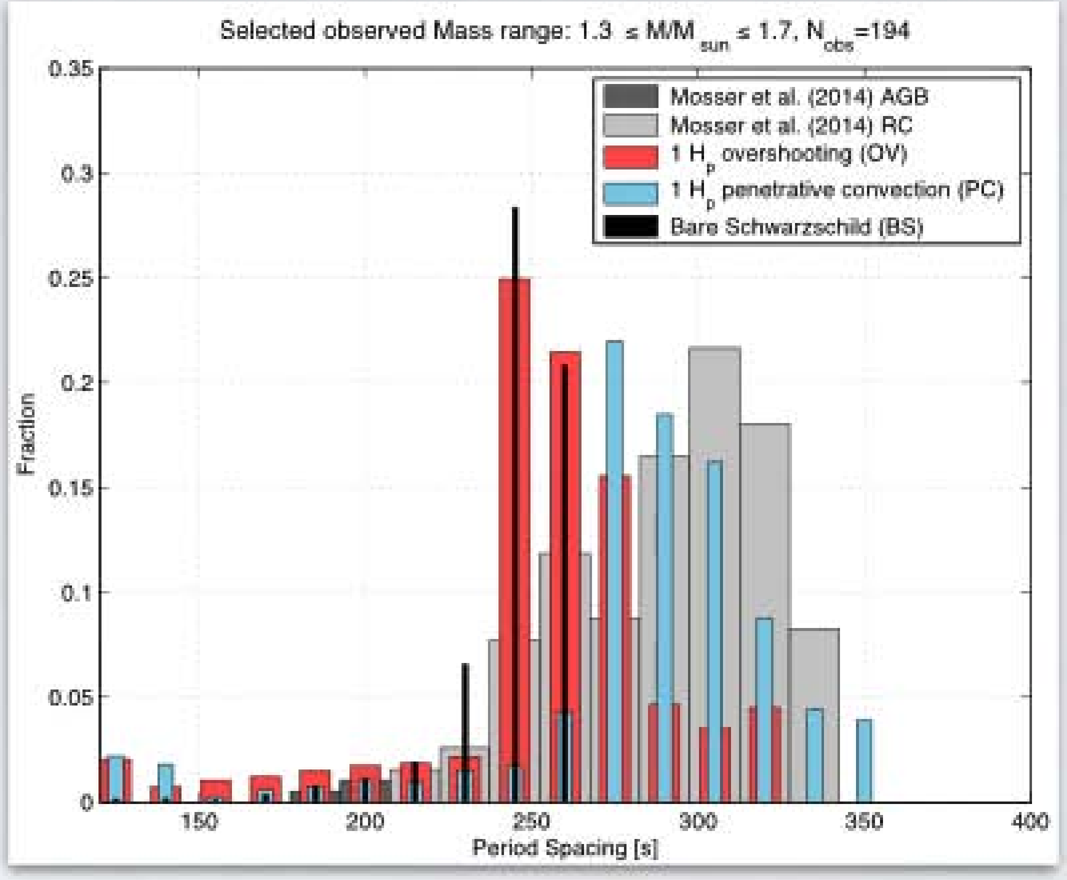
examples of current efforts in Birmingham

TESTING NEAR-CORE MIXING IN RC STARS



Bossini et al, in preparation

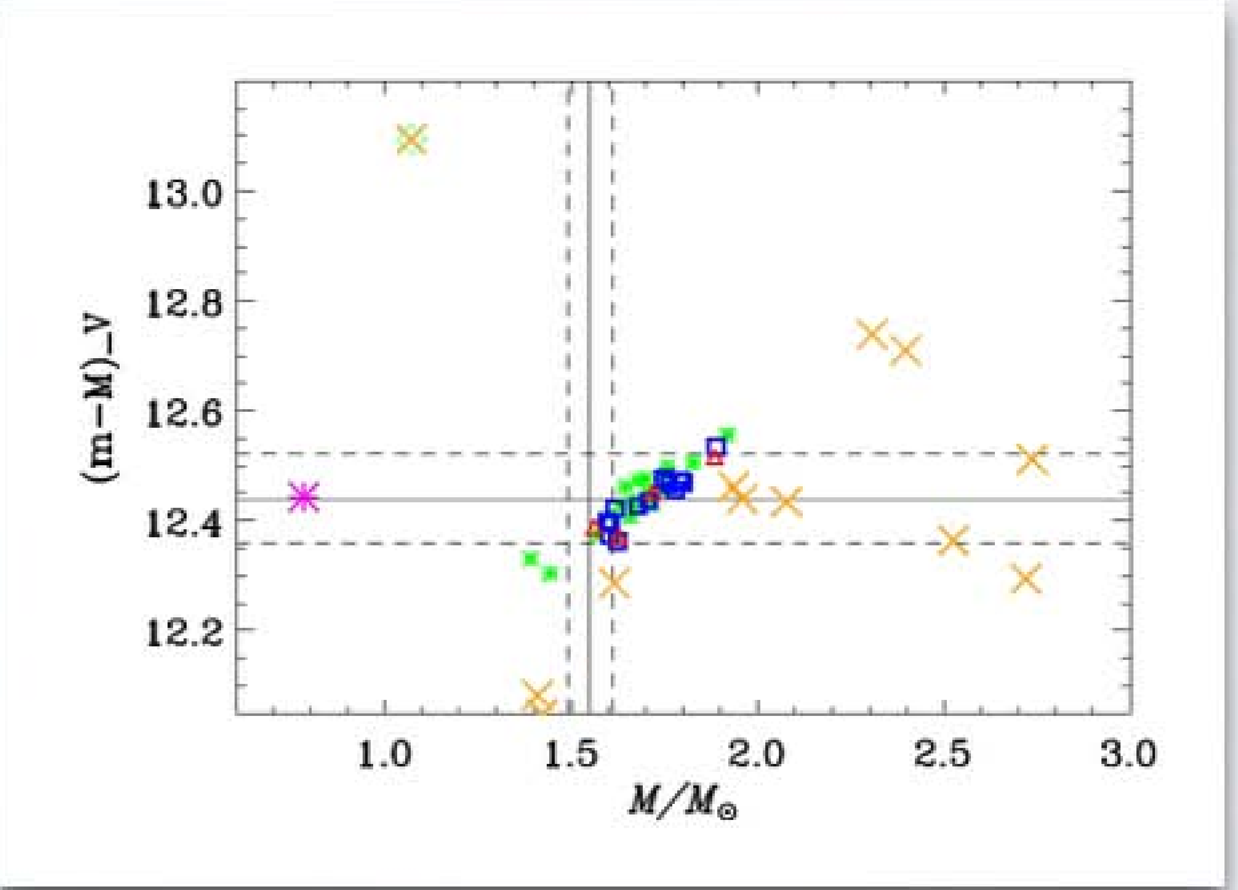


testing stellar structure

improve accuracy of model predictions

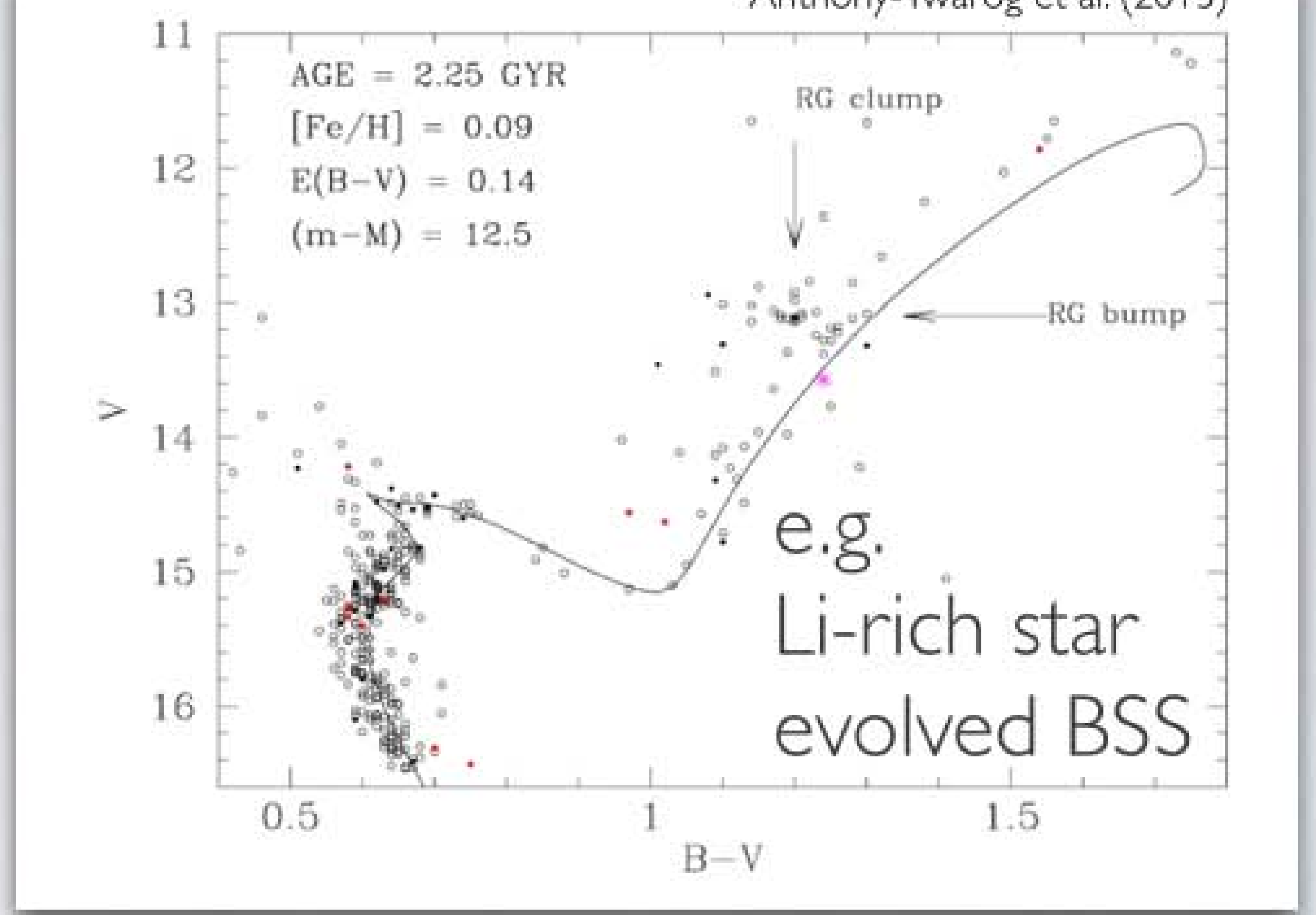
SEISMOLOGY OF GIANTS IN CLUSTERS

- mean density from individual radial-modes frequencies
- more stringent tests of scaling relations



Handberg, Miglio, Brogaard, in preparation

Anthony-Twarog et al. (2013)



- stars that evolved through 'non-standard' evolution are being identified.

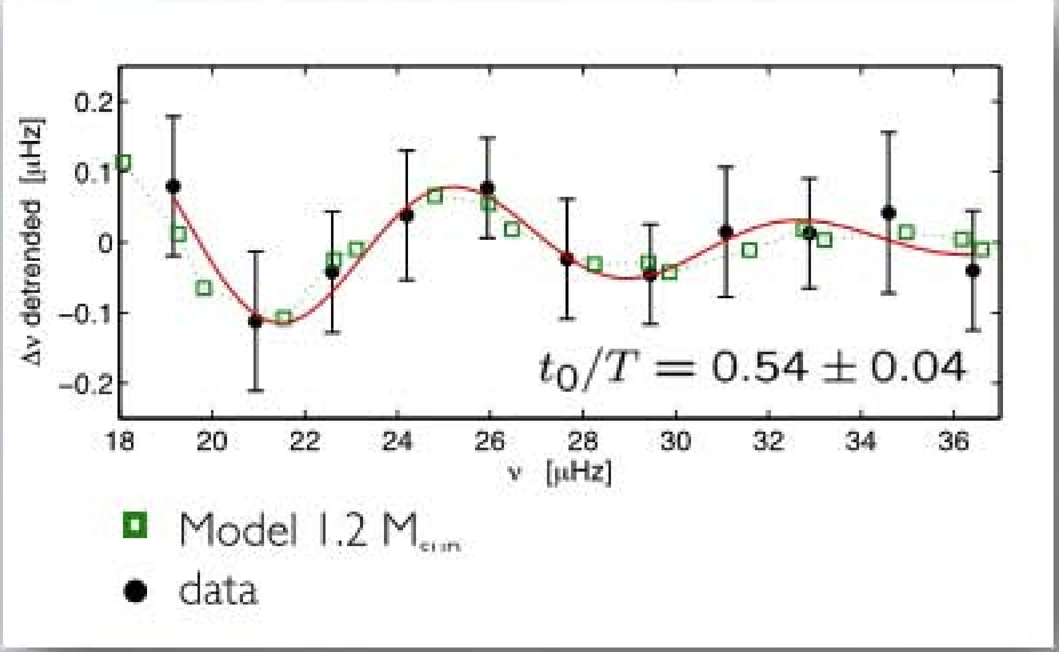
Brogaard et al. 2015

Handberg, Miglio, Brogaard, in preparation

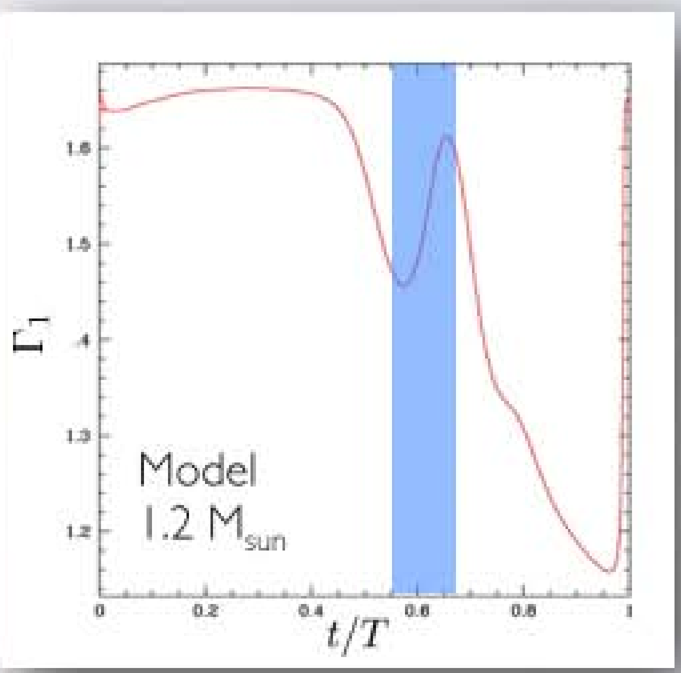
ACOUSTIC GLITCHES IN GIANTS

CoRoT

Hell ionisation zone in a red giant



Miglio et al. 2010



where

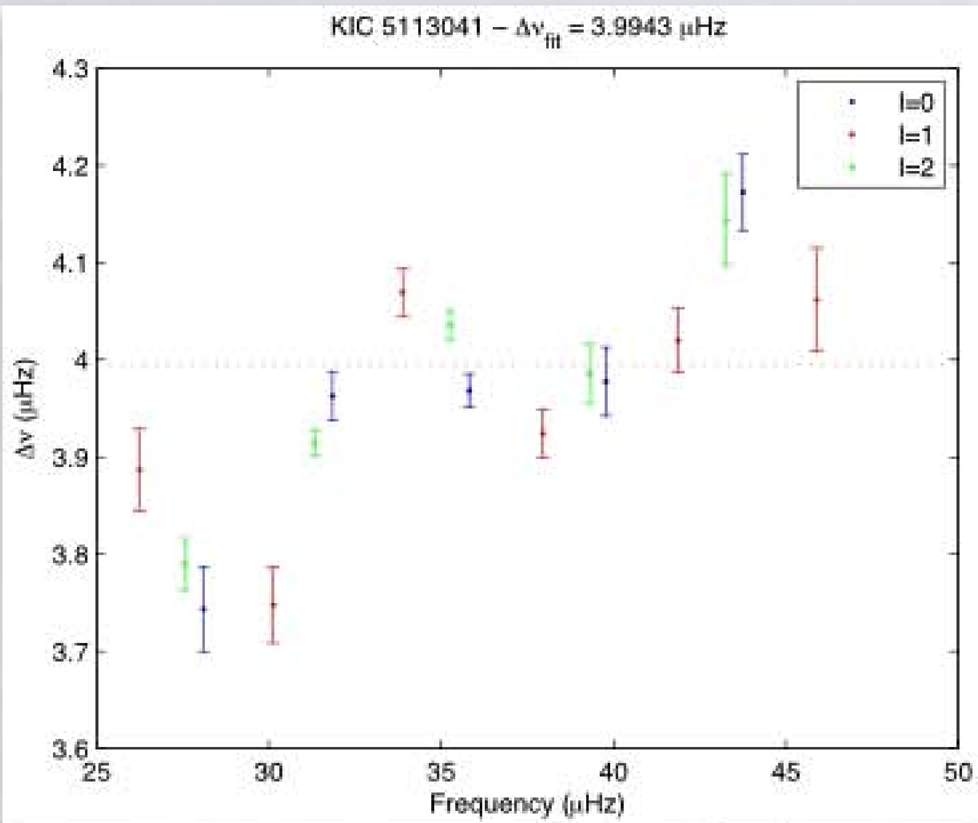
$$t(r) = \int_0^r \frac{\mathrm{d}r'}{c}$$

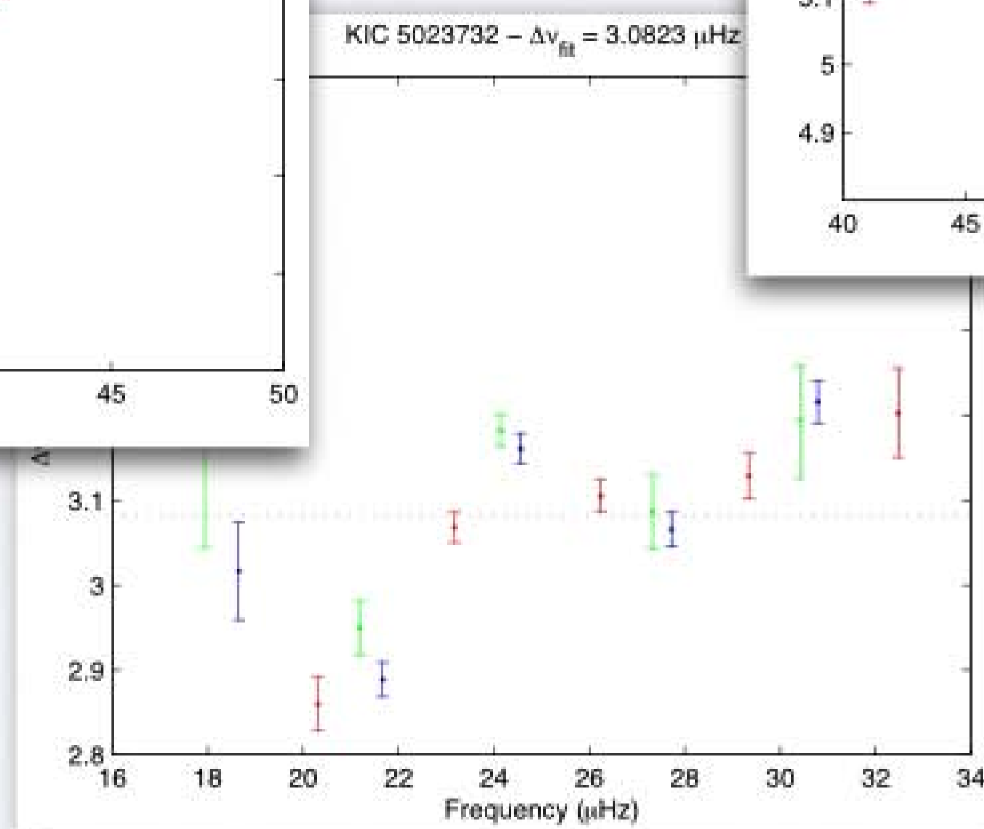
$$c^2 = \Gamma_1 \frac{P}{\rho}$$

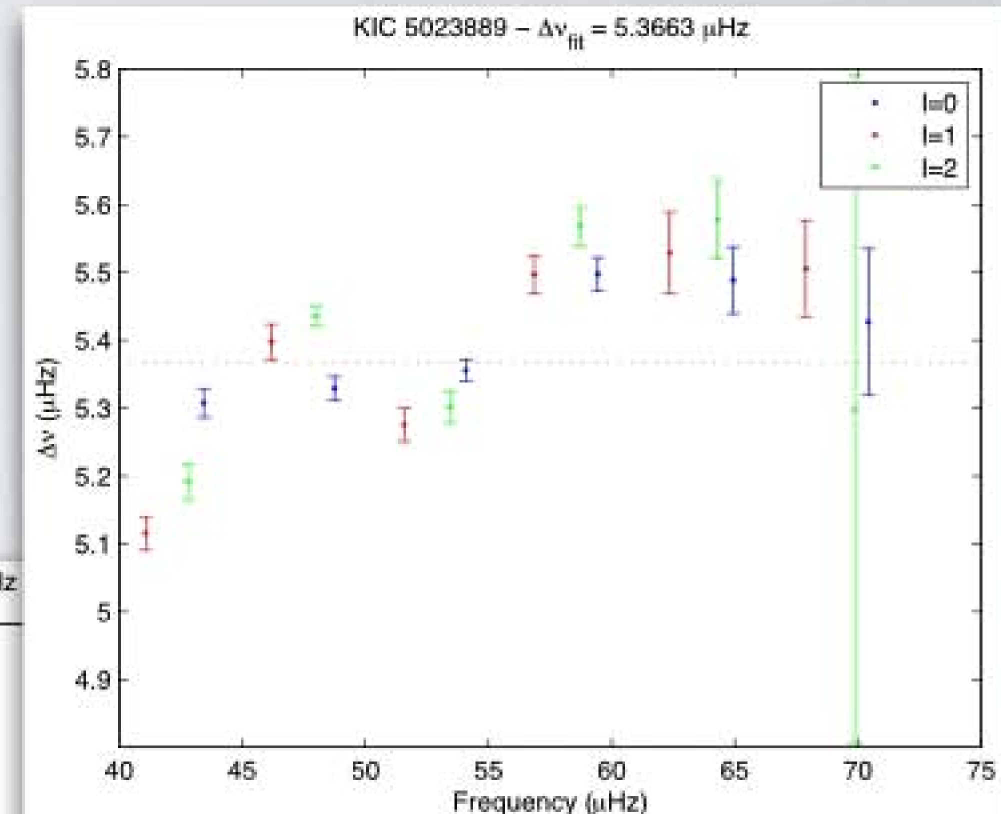
$$\Gamma_1 = \left(\frac{\partial \ln P}{\partial \ln \rho}\right)_{\mathrm{ad}}$$

ACOUSTIC GLITCHES IN GIANTS

Kepler giants in NGC6819







Handberg, et al, in preparation

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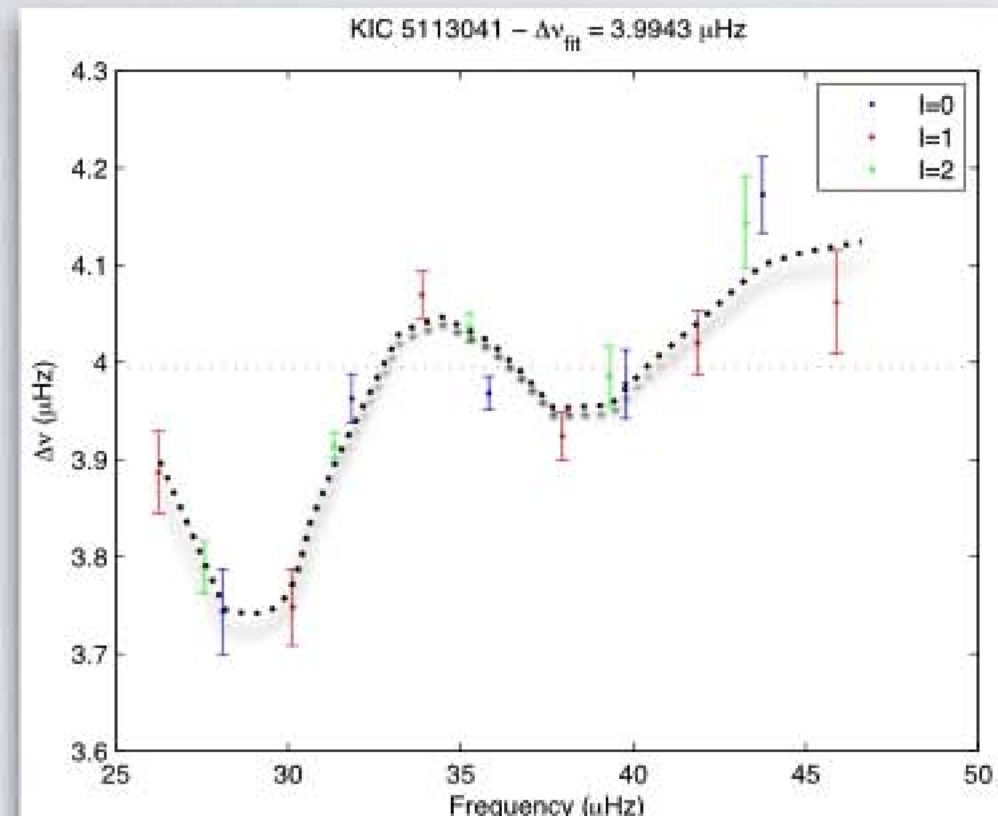

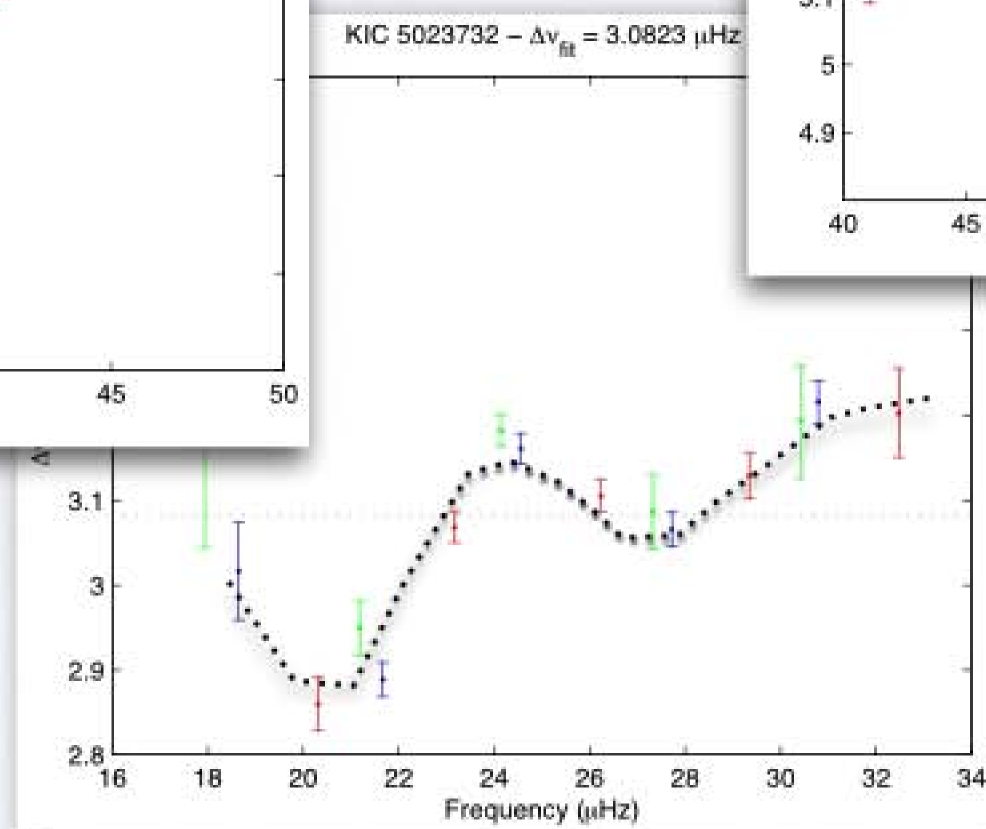

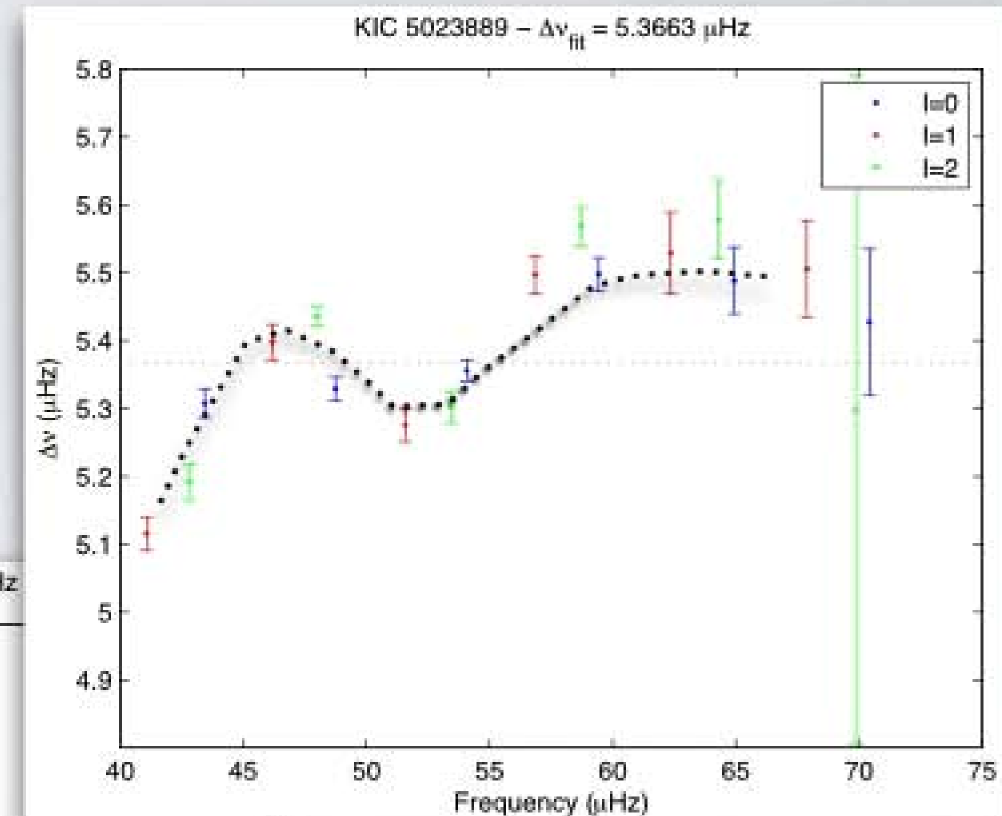

Handberg, et al, in preparation

aiming for the Milky Way but ... need for accurate stellar models!

- average seismic parameters depend to some extent on stellar structure (and physics within)
- internal mixing: interpretation of photospheric abundances
- age estimates: model dependent

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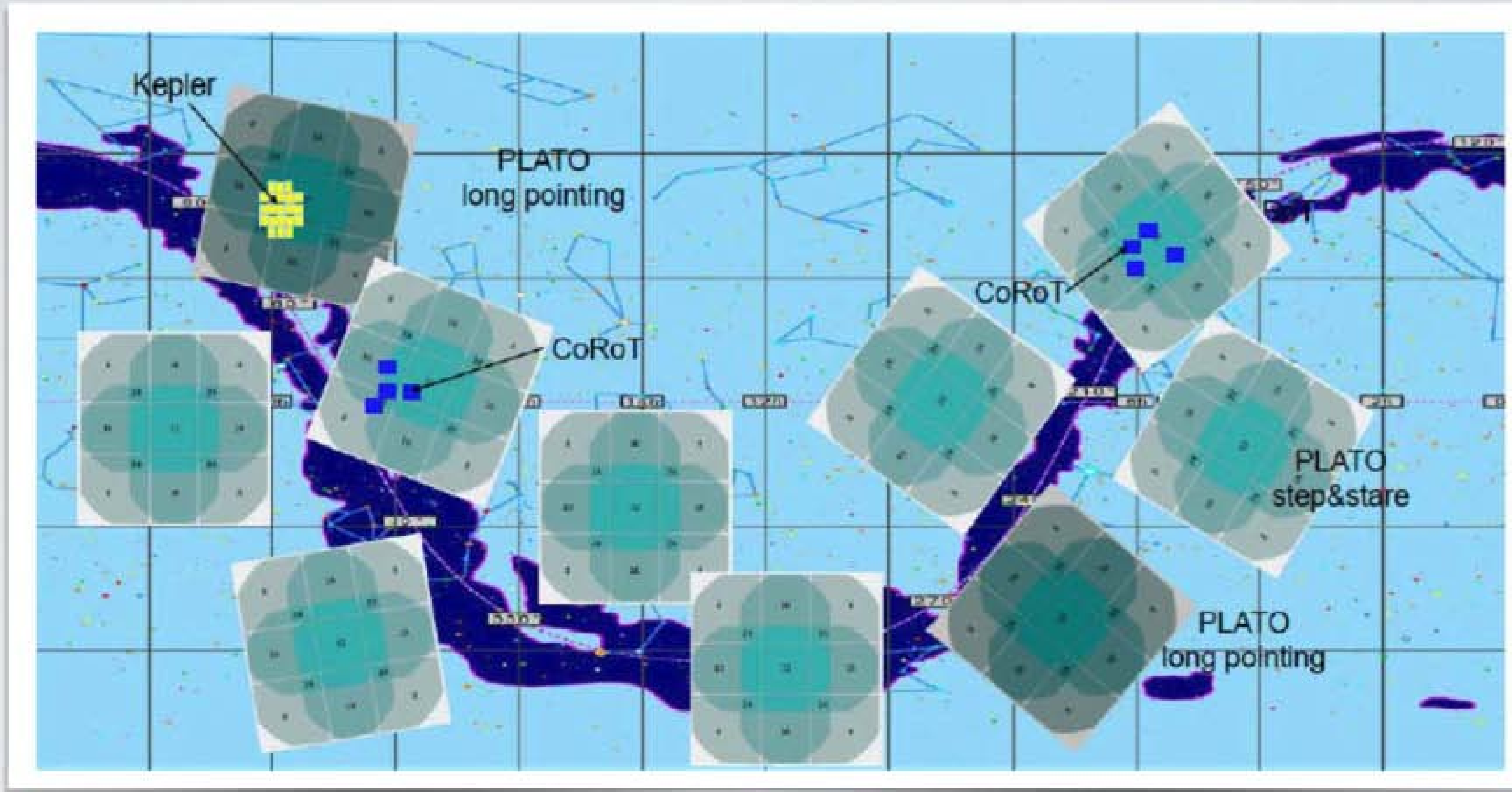
CoRoT, *Kepler*, K2: calibration fields for GAIA and gold standards for Galactic astronomy

PLATO: FIELD OF VIEW



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DISCUSSION

collaborations

- would an open platform to exchange expertise / foster collaborations be worth keeping / expanding?
- K2: no proprietary light curves, but proprietary spectroscopic data: "run away and publish" or wide collaborations?
- Hare&Hounds exercises are the way to go?

seismic inferences

- asteroseismology of red giants: just scratching the surface
- asteroseismology of sun-like stars: few and nearby targets, but relevant as age calibrators
- age determination: precision vs. accuracy. differential ages as a first step?

DISCUSSION

future

- PLATO: come up with criteria for target/field selection, lobby for targets
-

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 Physikzemtrum 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).

Accomodation and Meals:

All participants will be hosted in the beautiful Bad Honnef mansion.

Meals and accomodation 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

This seminar is generously funded by the Wilhelm und Else Heraeus-Stiftung.

Click here to learn more about the foundation.

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