Synthetic & Observed Spectra Of Stars & Stellar Populations As Templates For Gaia

PhD. Student: Tenay Saguner
Supervisors: A. Vallenari & U. Munari
11.06.2010
Observed Stellar Spectra As Templates For Gaia

ARCS : The Asiago Red Clump Spectroscopic Survey @ 1.22m Telescope

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The primary objective of Gaia mission is the Galaxy:
- physical characteristics,
- kinematics,
- distribution of stars over a large fraction of its volume.

With the goal of achieving a full understanding of the Galaxy’s dynamics and structure.

Gaia will make this goal possible by providing, a catalogue which will sample a large and well defined fraction of stellar distribution in phase space from which significant conclusions can be drawn for the entire Galaxy.

Making such an observational effort seems necessary in order to make a physics laboratory out of our own galaxy, and ultimately ensure that the most relevant processes and properly understood.
The position of a star in phase space requires: distance, coordinates, apparent motions and the radial velocity.

A phase space characterization can be used for:

- Disentangle the random motions in the galaxy with the motion shared by the disk rotation, streams and moving groups.
- Kinematical structure of the Galaxy

What is needed: accurate radial velocity determination.

- Chemical evolution of the Galaxy.

What is needed: accurate stellar atmospheric parameters.
Red Clump Stars

The Red Clump is composed by intermediate mass stars that:
- burn He in the core and H in shell;
- high intrinsic luminosity with low dispersion:

\[
M_{VT} + 0.54 \quad \sigma = 0.05 \quad \text{This work}
\]
\[
M_I - 0.22 \quad \sigma = 0.03 \quad \text{Groenewegen (2008)}
\]
\[
M_K - 1.54 \quad \sigma = 0.04 \quad \text{Groenewegen (2008)}
\]

make Red Clump stars a prime tracer of Galactic structure and kinematics.
Selection Criteria Of Red Clump Samples

- Choosing a single stellar type, in particular one with well-defined luminosity, allows us to work with clean samples (Kaempf et al. 2004).

- 500 isolated red clump giant stars with spectral type G8 – K2
- No hint of binarity or variability according to Hipparcos Catalogue determination.
- High galactic latitude $|b| > 25^\circ$,
- Within 6 deg. around the celestial equator,
- Magnitude range $7.7 < V < 9.3$ (faint end)
Characteristics Of ARCS 1.22 meter Red Clump Samples
Observations

- Spectra obtained during the September 2009 - May 2010 with Asiago 1.22m telescope + B&C spectrograph + ANDOR iDUS 440A ccd.
- 1200 tr/mm grating used with a 200 micron slit width.
- 1228 Å/2036 pix that corresponds a dispersion of 0.603 Å/pix.
- Resolving Power 6000
- High S/N ~ 250
- 358 Red Clump Stars (+ 100 second epoch) + 100 Red Clump Stars from different catalogues

Longitude: E11° 31′ 43″  Latitude: +45° 51′ 44.7″  Altitude: 1045 m
Data Reduction

- Data reduction was carried out in a homogeneous way with IRAF (Image Reduction and Analysis Facility).

  - Particular care was put in the wavelength calibration procedure, a key step in the determination of the radial velocity at the required precision.

    - Producing an improved line-list for the comparison lamp for a better wavelength calibration.

  - The continuum normalization procedure have a strong impact on the final goodness of the derived data.

    - Our methods to derived astrophysical parameters suffers from different levels and asymmetries of continuum normalization.
Radial Velocity Determination

- For radial velocity determination, we used IRAF procedure *FxCOR*.
  - *FxCOR* performs a Fourier cross-correlation between an input spectrum and a template. The maximum of the cross-correlation function (CCF) gives the differential velocity of the input spectrum with respect to the template.

- This template can be a synthetic spectrum or another star spectrum of a similar type to the object of the study.

- We selected 15 IAU Radial Velocity Standard Stars used as templates with same spectral type and luminosity class as our red clump samples to avoid/minimize the errors introduced by template mismatches.
Tests On Radial Velocities

• G8-K3 III spectral type IAU radial velocity standard stars.

• We compare their radial velocities with radial velocities derived from IRAF’s FxCor procedure.

15 RV Standard Stars
2 Different Epoch
First Epoch
Second Epoch
Stellar Atmospheric Parameters

- In additional to radial velocities, we determined stellar parameters: Effective temperature ($T_{\text{eff}}$), Gravity ($\text{logg}$), Metallicity ($M/H$).

- To derive the stellar atmospheric parameters a chi2 technique (M. Fiorucci, 2009) is used against the Munari & Sordo 2005 synthetic stellar spectral library (fluxed version).

- The library based on Kurucz’s codes that covers the 2500-10500 Å, a good coverage of all HR diagram, no predicted lines, and well tested for the ability to reproduce the lines in detail.

- The library continuum normalized with the standard IRAF packages, in the same way with the same parameters for the observed spectra.

- 5 different chi2 solution applied to determine the stellar atmospheric parameters, each one focusing on a specific wavelength range.
First Wavelength Range 4700-6000 Ang.

- **First Wavelength Range 4700-6000 Ang.**
- **Teff**: 5012-5312
- **[M/H]**: 4761: 5061
- **Test**: 5250 > λ < 5750
- **Logg**: 5700-6000

Diagram with spectral lines and regions:
- [M/H]: 4761: 5061
- Teff: 5012-5312
- Test: 5250 > λ < 5750
- Logg: 5700-6000
- NaID1,2
Obs. Spectra HD103967
Syn. Spectra Teff=4750 g=2.5 Z=0.008
Tests On Chi² Solutions For Atmospheric Parameters

- 40 selected red clump stars that are well separated in temperature, metallicity and gravity intervals with well determined astrophysical parameters by a line-by-line analysis from Takeda et al. 2008 and catalogue.

- 40 red clump stars from Hekker & Melendez 2007 catalogue.

- 20 red clump stars from Soubian & Girard 2005
External Accuracies From Literature Catalogue Data

Comparison Of Parameters From Hekker & Takeda
Red: Hekker

Black: Takeda

rms = 95.24

rms = 0.4

rms = 0.18
Internal Accuracies From Second Epoch Observations

\[ \langle \Delta [M/H] \rangle = 0.08171717172 \]

\[ \sigma_{\Delta [M/H]} = 0.09626748878 \]

\[ \langle \Delta [Vr] \rangle = 3.877070707 \]

\[ \sigma_{\Delta [Vr]} = 5.421242092 \]
Internal Accuracies From Second Epoch Observations

\[ \langle \Delta[T] \rangle = 35.67070707 \]

\[ \sigma_{\Delta[T]} = 26.68488165 \]

\[ \langle \Delta[\text{Logg}] \rangle = 0.208888889 \]

\[ \sigma_{\Delta[\text{Logg}]} = 0.1552475895 \]
The Scientific Applications

- Disk kinematics can be examined in detail with a typical analysis of the distribution of stars in the UVW space.

- ARCS 1.22 survey is a local survey on RC stars located:
  \[ 70 < d < 600 \text{ pc} \]
  \[ 40 < z < 1200 \text{ pc} \]
Spectrophotometric Distances

Keen & Barnbaum (2000)

V - M(V) vs. (m-M) Hipparcos - 2007

V Tycho
Space Velocity Components For RC Sample

\[ \langle U \rangle = -1.312719174 \quad \sigma_U = 30.320368646 \]

\[ \langle V \rangle = -14.52724703 \quad \sigma_V = 28.38071738 \]

\[ \langle W \rangle = 0.2883481073 \quad \sigma_W = 19.42156244 \]

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[Fe/H]<-1.0  -1.0<[Fe/H]<-0.5  -0.5<[Fe/H]<-0.2  -0.2<[Fe/H]<+0.2  +0.2<[Fe/H]<+0.5  +0.5<[Fe/H]
Space Velocity Components For RC Sample

$\langle U \rangle = -1.312719174$
$\sigma_U = 39.32936646$

$\langle V \rangle = -14.52724703$
$\sigma_V = 28.36071738$

$\langle W \rangle = 0.2863481073$
$\sigma_W = 19.42156244$

G6/8 III  G8 III  G8/K0 III  K0 III  K0/1 III  K1 III  K1/2 III  K2 III  K2/3 III
Comparison With Skuljan et.al. 1999

Velocity Distribution Of stars In The Solar Neighbourhood

4000 stars with parallaxes $> 10$ mas and Rv data existing in Hipparcos input catalog.
Moving Groups In ARCS RC Sample

(1) \( V_{\text{Sirius}} = 14.9 - (0.77 \times U) \)

(2) \( V_{\text{middle}} = -63.0 - (0.77 \times U) \)

(3) \( V_{\text{pleides}} = -24.2 - (0.77 \times U) \)

(4) \( V_{\text{herculus}} = -53.0 - (0.77 \times U) \)

\([Fe/H] < -1.0\)

\(-1.0 < [Fe/H] < -0.5\)

\(-0.5 < [Fe/H] < -0.2\)

\(-0.2 < [Fe/H] < +0.2\)

\(+0.2 < [Fe/H] < +0.5\)

\(+0.5 < [Fe/H] \)
The Catalogue ...

- Page containing literature data

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- Page containing ARCS results
  - **Temperature (T_{eff}), Logg, [M/H],**
  - **Radial Velocity, Galactic (X,Y,Z) coordinates,**
  - **Space (U,V,W) velocity, Age ...**
Summary & Future Work

• For now we derived from medium resolution (R~ 6000) optical spectra the radial velocities and atmospheric parameters for ~ 458 (first epoch) and + 100 (second epoch) stars.

• We aim to finish our observational campaign and achieve 500 observed red clump and among them at least for 200 multi-epoch observations.

• At the end we will provide a medium resolution observed stellar spectral library including all the catalogue data, if collected from literature or if calculated by us.

• We preliminary detected some overdensities possibly associated with moving groups, but to define the real membership as referred (Freeman ...) chemical tagging is needed.

• If we use our results coupled with astrometric and photometric external data, we will have a complete data set for ~ 800 objects which will use for investigation of the evolution, structure and dynamics of Galaxy.
Thanks For Your Attention ...