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

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11.06.2010

Observed Stellar Spectra As Templates For Gaia

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

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Asiago Observatory

INAF ISTITUTO NAZIONALE DI ASTROFISICA

elsa

Gaia

Galaxy In Gaia Era ..

- 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.

Goal ...

- 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 :

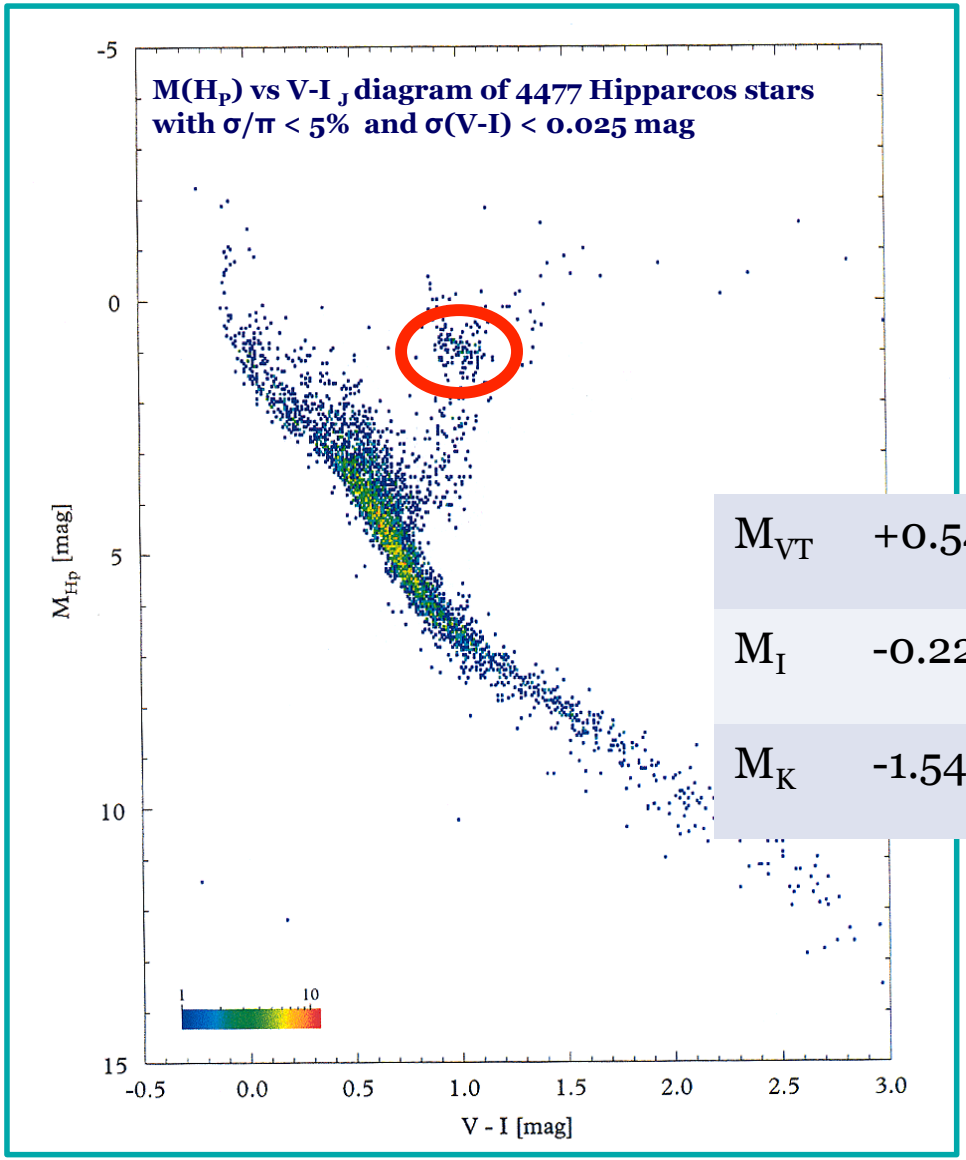
    - Disentangle the random motions in the galaxy with the motion shared by the disk rotation, streams and moving groups.
    - Kinematical structure of the Galaxy

✓ 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 wih low dispersion :

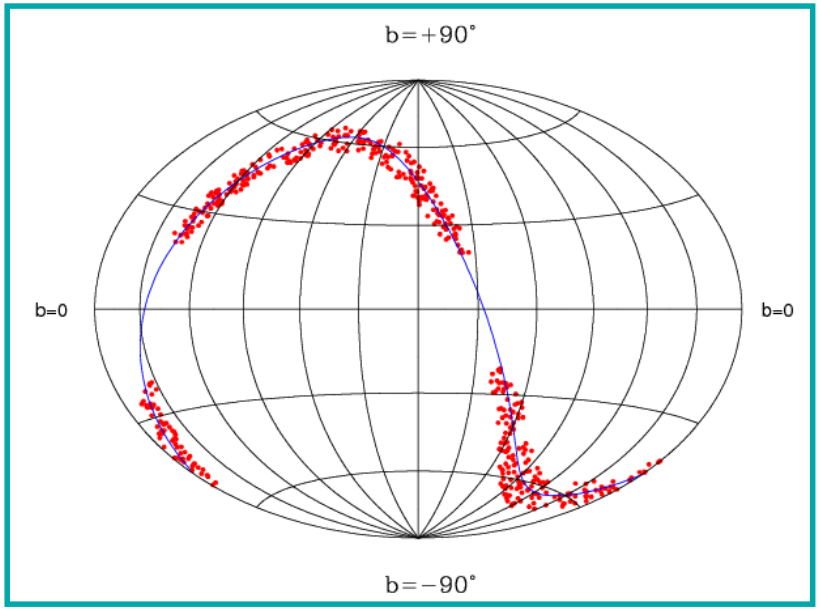
M_{VT}	+0.54	σ=0.05	This work
M_I	-0.22	σ=0.03	Groenewegen (2008)
M_K	-1.54	σ=0.04	Groenewegen (2008)

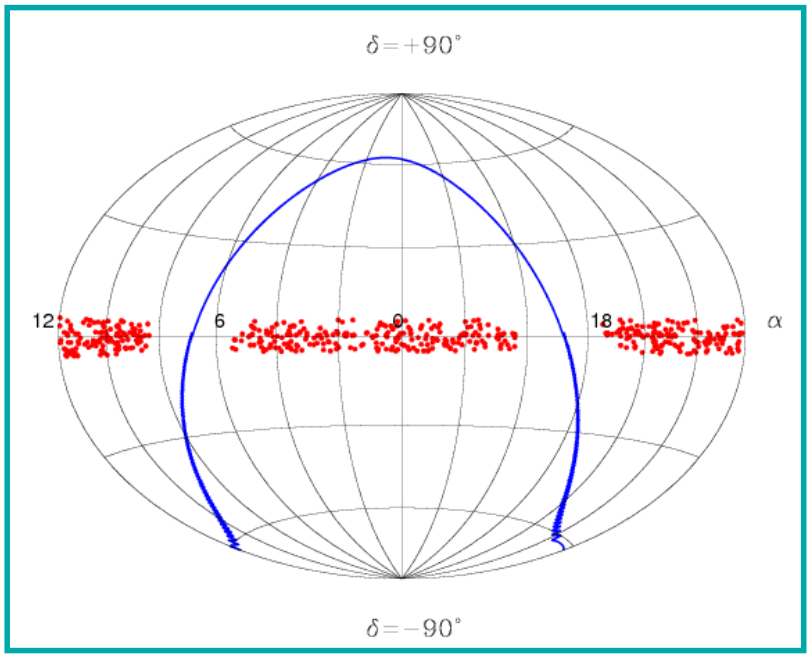
make Red Clump stars a prime tracer of Galactic structure and kinematics.

Selection Criteria Of Red Clump Samples

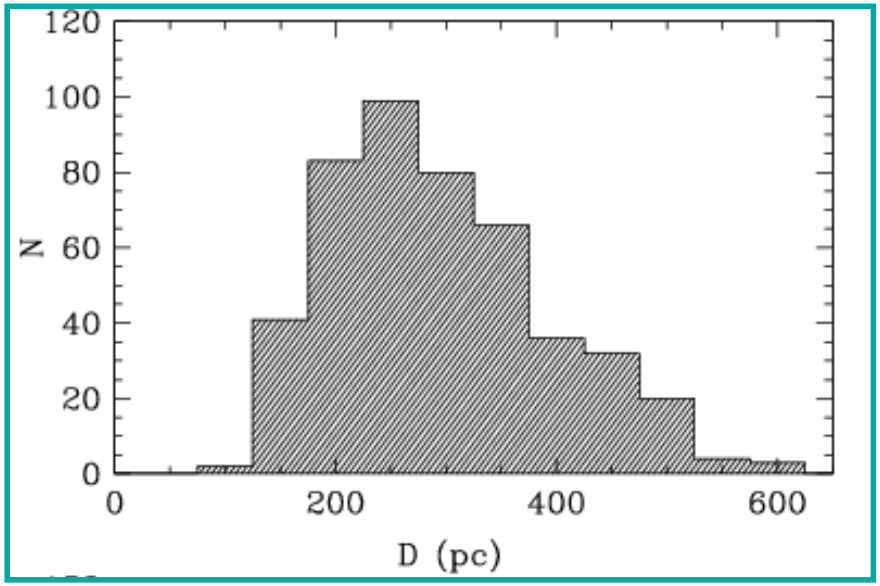
- Choosing a single stellar type, in particular one with well-defined luminosity, allows us to work with clean samples (Kaempf et al. 2004).

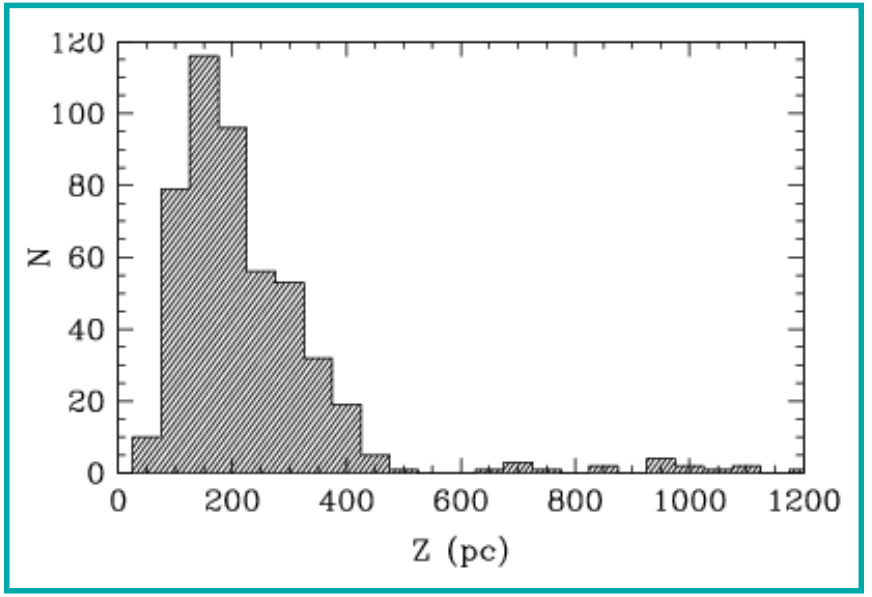
✓ 500 isolated red clump giant stars with spectral type G8 – K2
✓ No hint of binarity or variability according to Hipparcos Catalogue determination.
✓ High galactic latitude|b| > 25°,
✓ Within 6 deg. around the celestial equator,
✓ Magnitude range 7.7 < V < 9.3 (faint end)

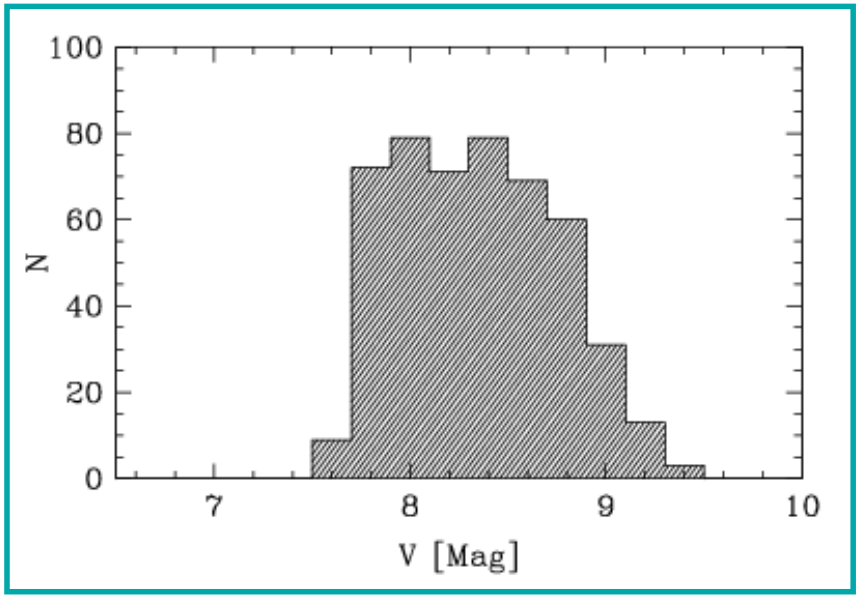




Characteristics Of ARCS 1.22 meter Red Clump Samples







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 .

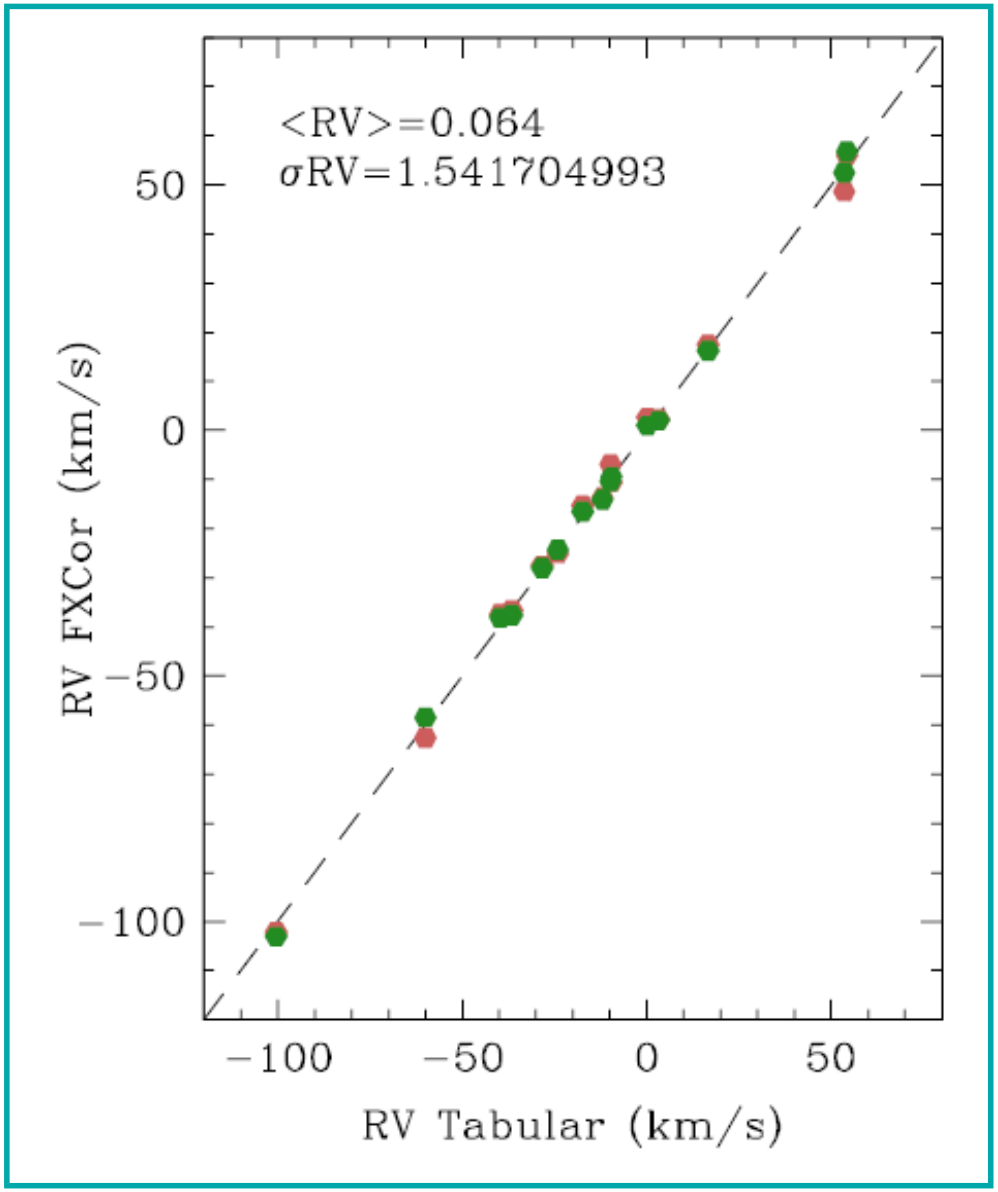
➢ The continuum normalization procedure have a strong impact on the final goodness of the derived data.

✓ 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



15 RV Standard Stars
2 Different Epoch
First Epoch
Second Epoch

- G8-K3 III spectral type IAU radial velocity stand stars.
- We compare their radial velocities with radial velocities derived from *IRAF*'s FxCor procedure.

Stellar Atmospheric Parameters

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

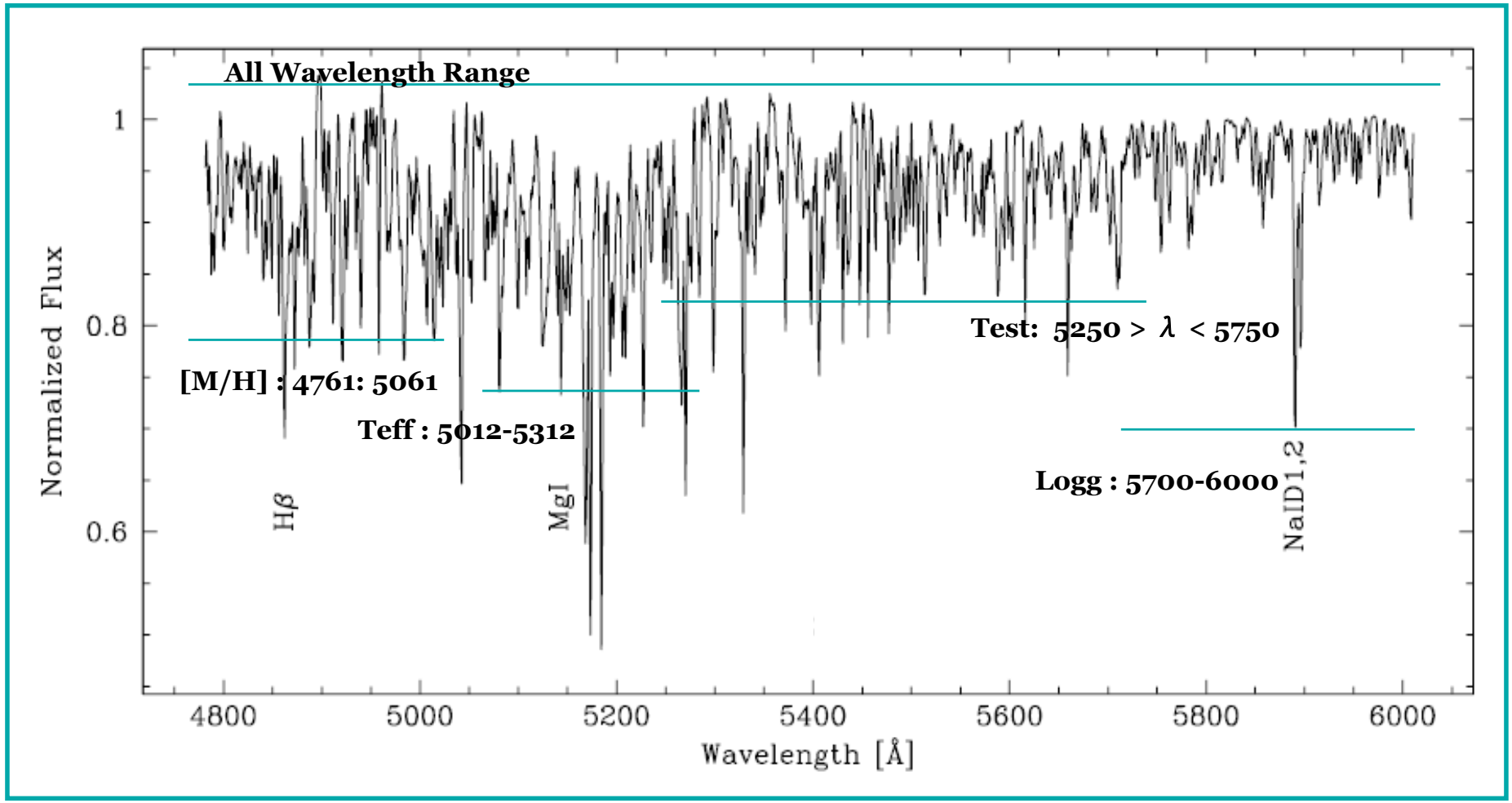
- To derive the stellar atmospheric parameters a chi2 technique (M. Fiorucci, 2009) is used against the Munari & Sordo 2005 synthetic stellar spectral library (fluxed version).

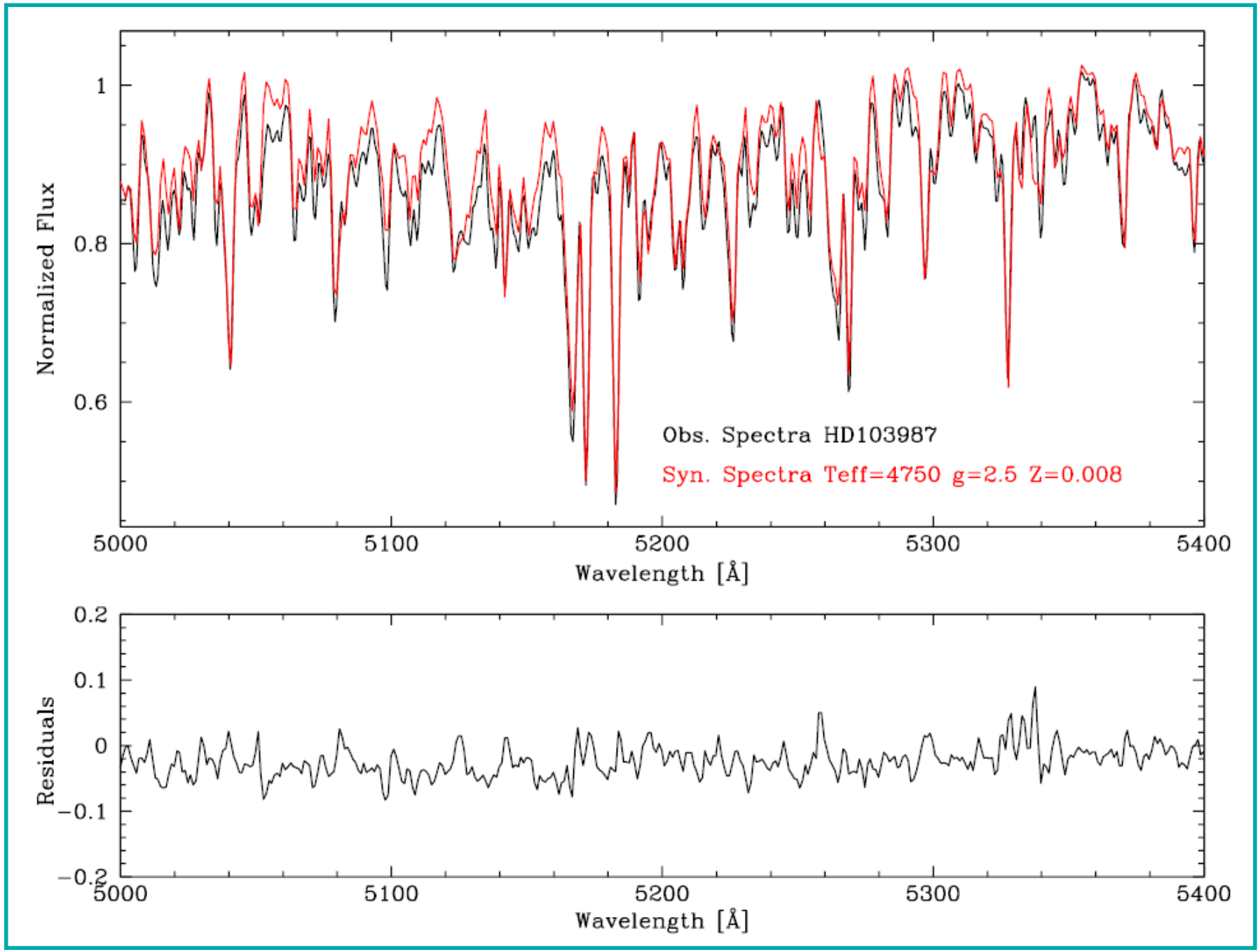
- The library based on Kurucz's codes that covers the 2500-10500 Å , a good coverage of all HR diagram, no predicted lines, and well tested for the ability to reproduce the lines in detail.

- 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.




Normalized Flux
1
0.8
0.6
Obs. Spectra HD103987
Syn. Spectra Teff=4750 g=2.5 Z=0.008
5000
5100
5200
5300
5400
Wavelength [Å]
Residuals
0.2
0.1
0
−0.1
−0.2
5000
5100
5200
5300
5400
Wavelength [Å]

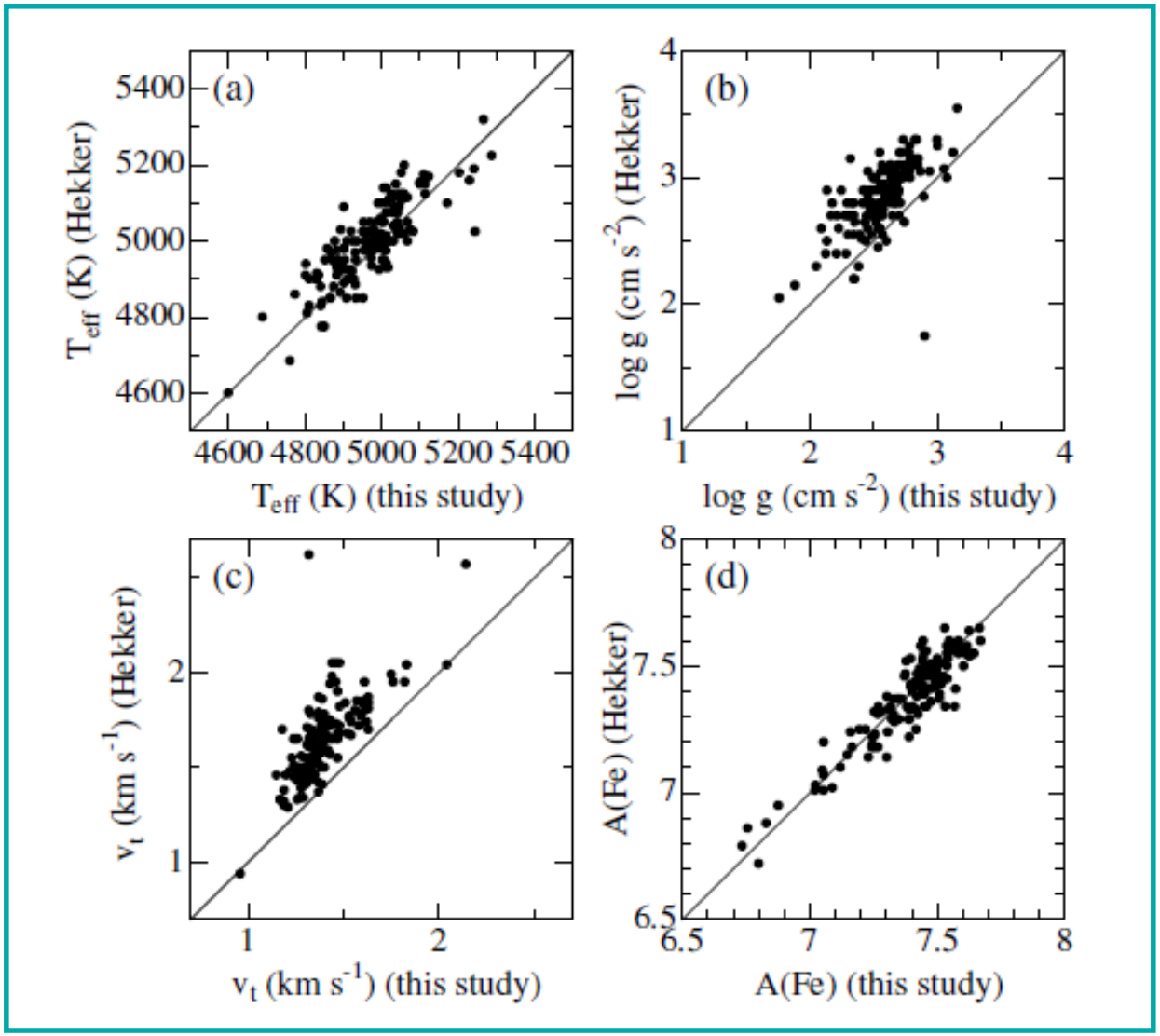
Tests On Chi2 Solutions For Atmospheric Parameters

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

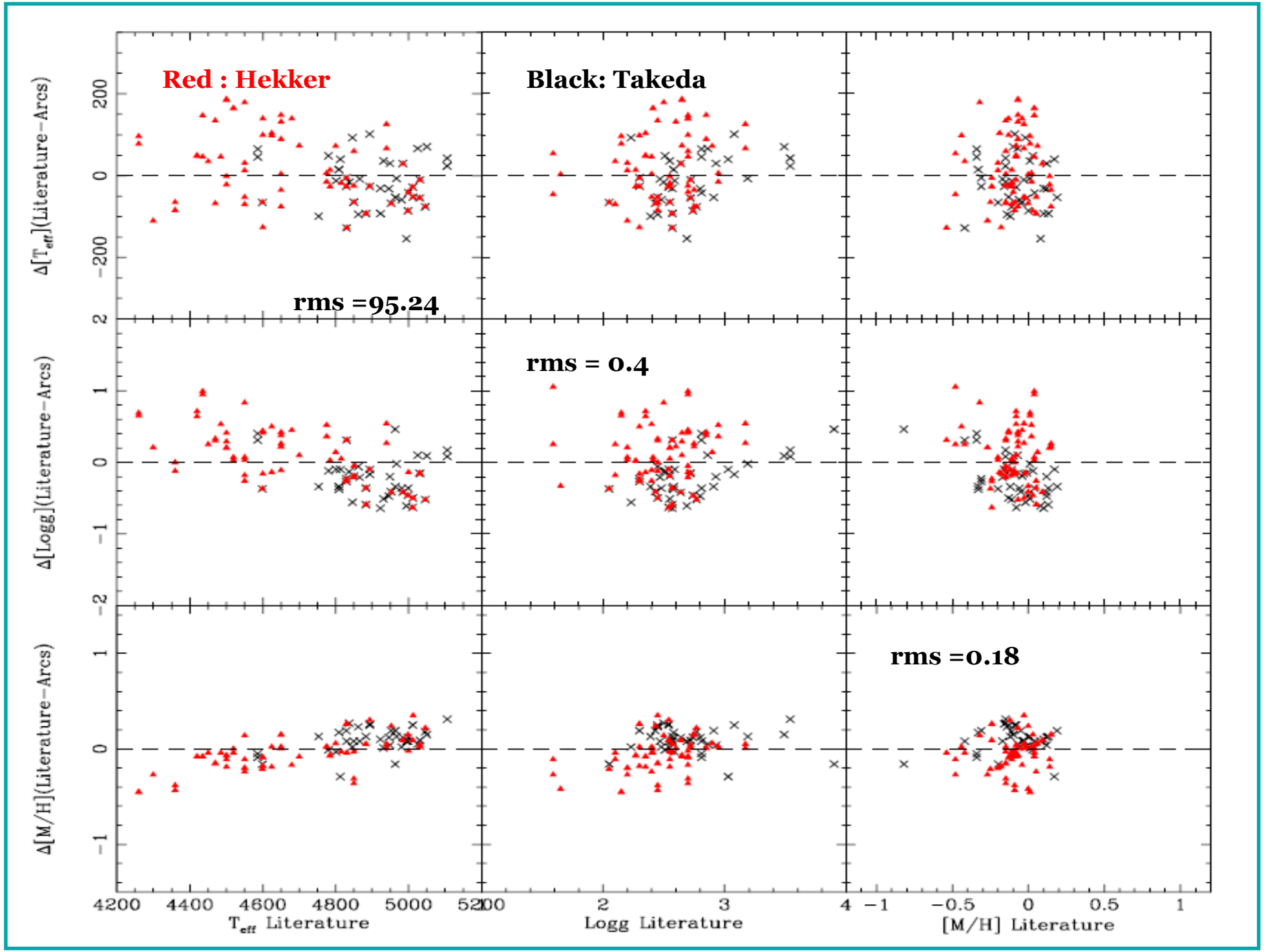
- 40 red clump stars from Hekker & Melendez 2007 catalogue.

- 20 red clump stars from Soubian &Girard 2005

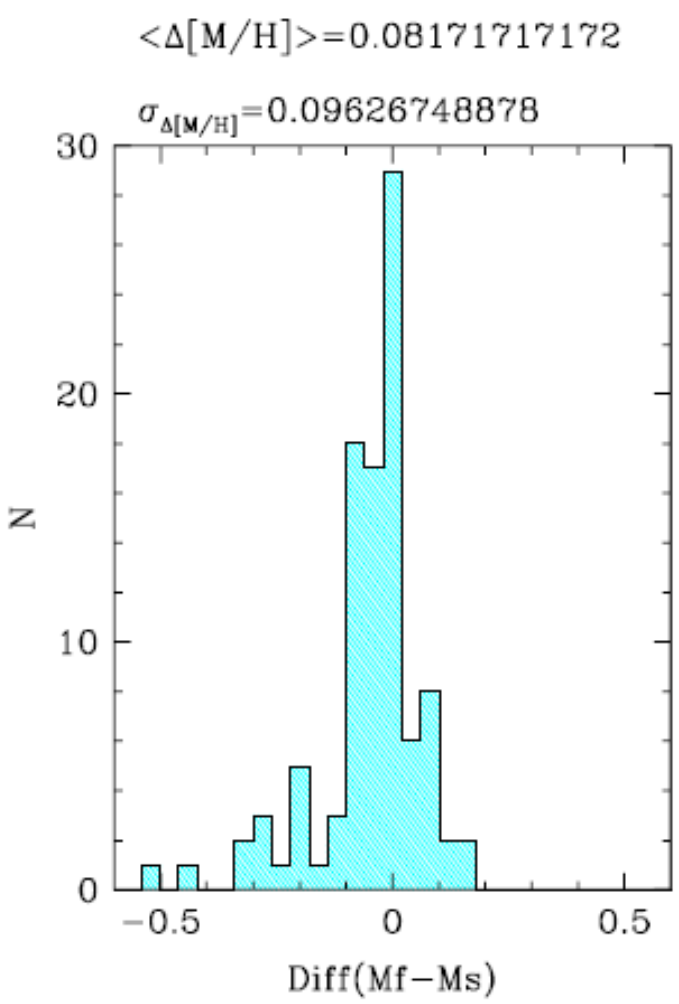
External Accuracies From Literature Catalogue Data

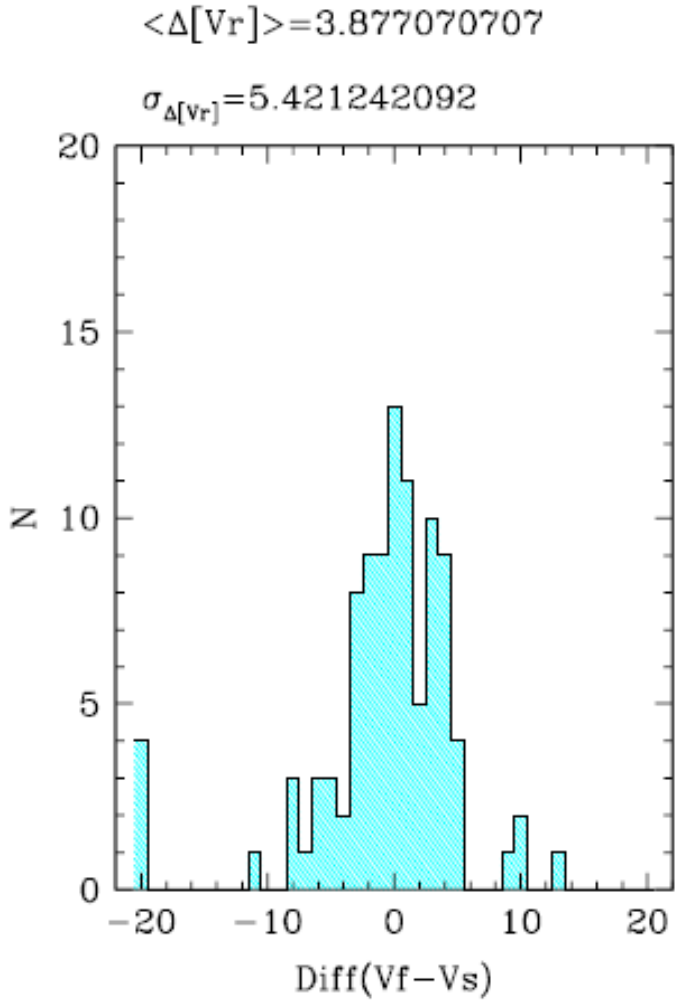


Comparison Of Parameters From Hekker & Takeda

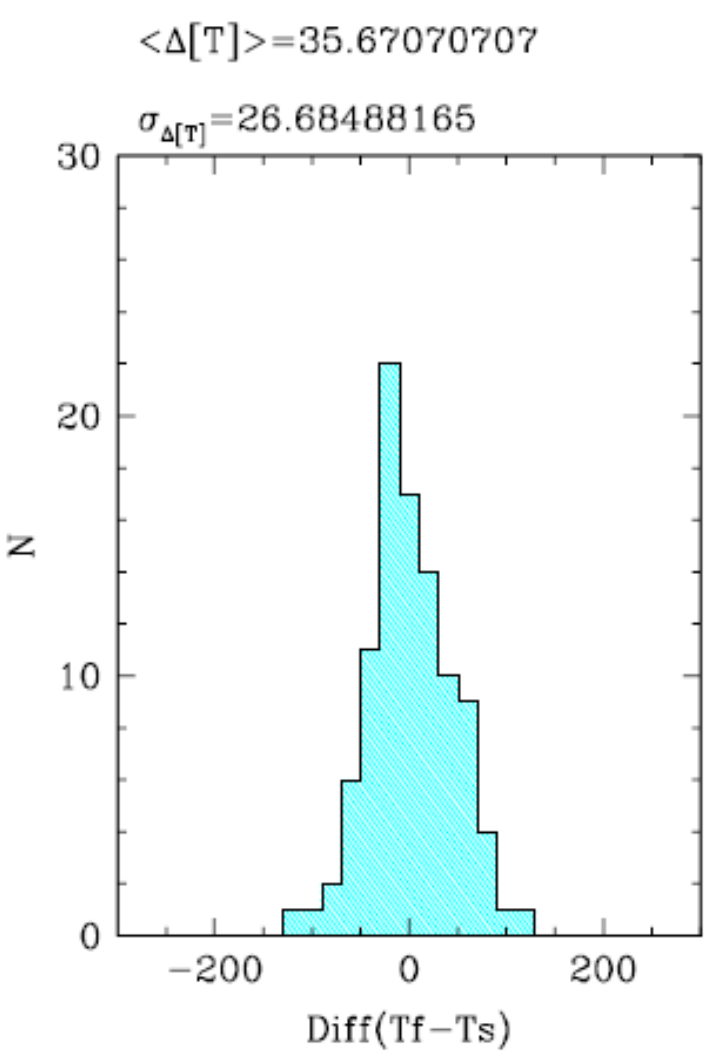

Red : Hekker
Black: Takeda
rms =95.24
rms = 0.4
rms =0.18
Δ[T_eff](Literature−Arcs)
Δ[Logg](Literature−Arcs)
Δ[M/H](Literature−Arcs)
T_eff Literature
Logg Literature
[M/H] Literature

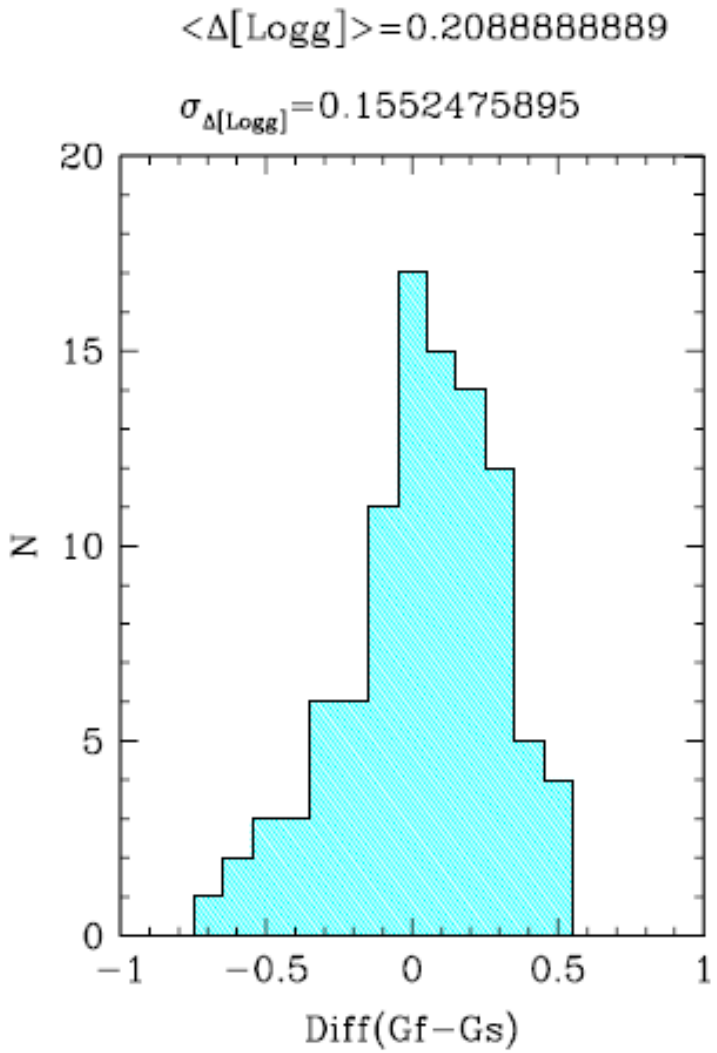
Internal Accuracies From Second Epoch Observations

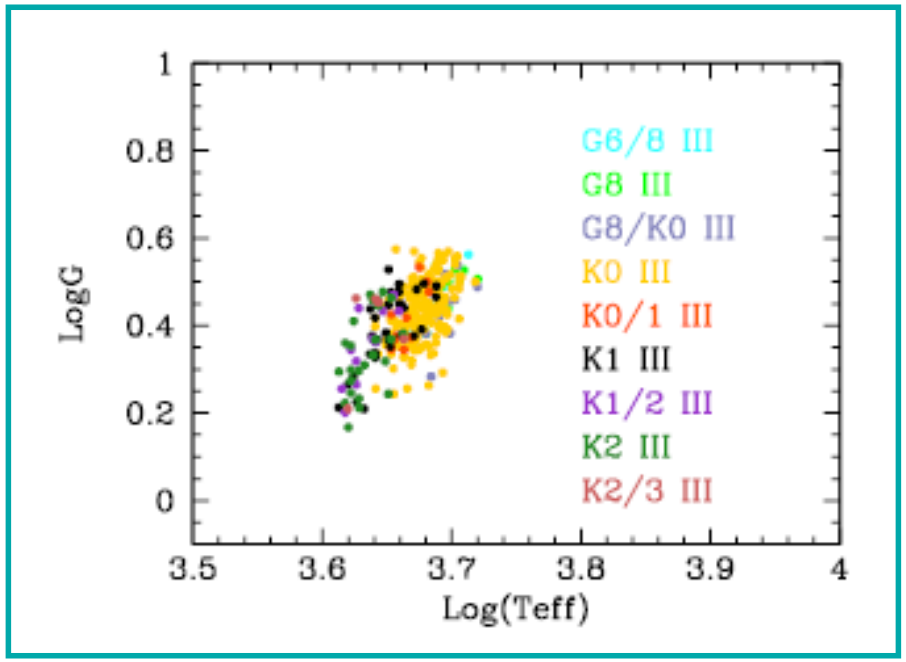


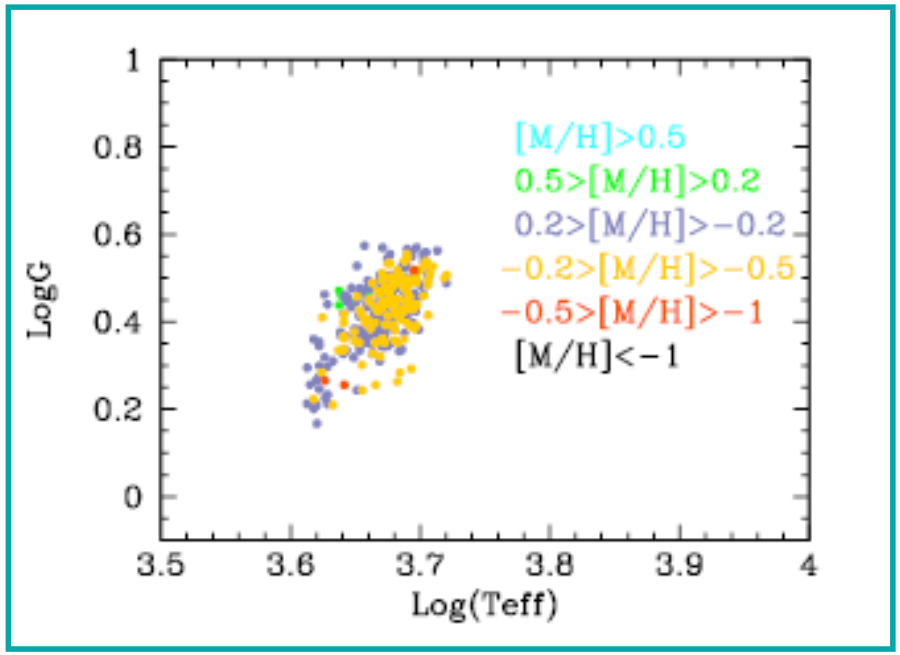


Internal Accuracies From Second Epoch Observations









The Scientific Applications

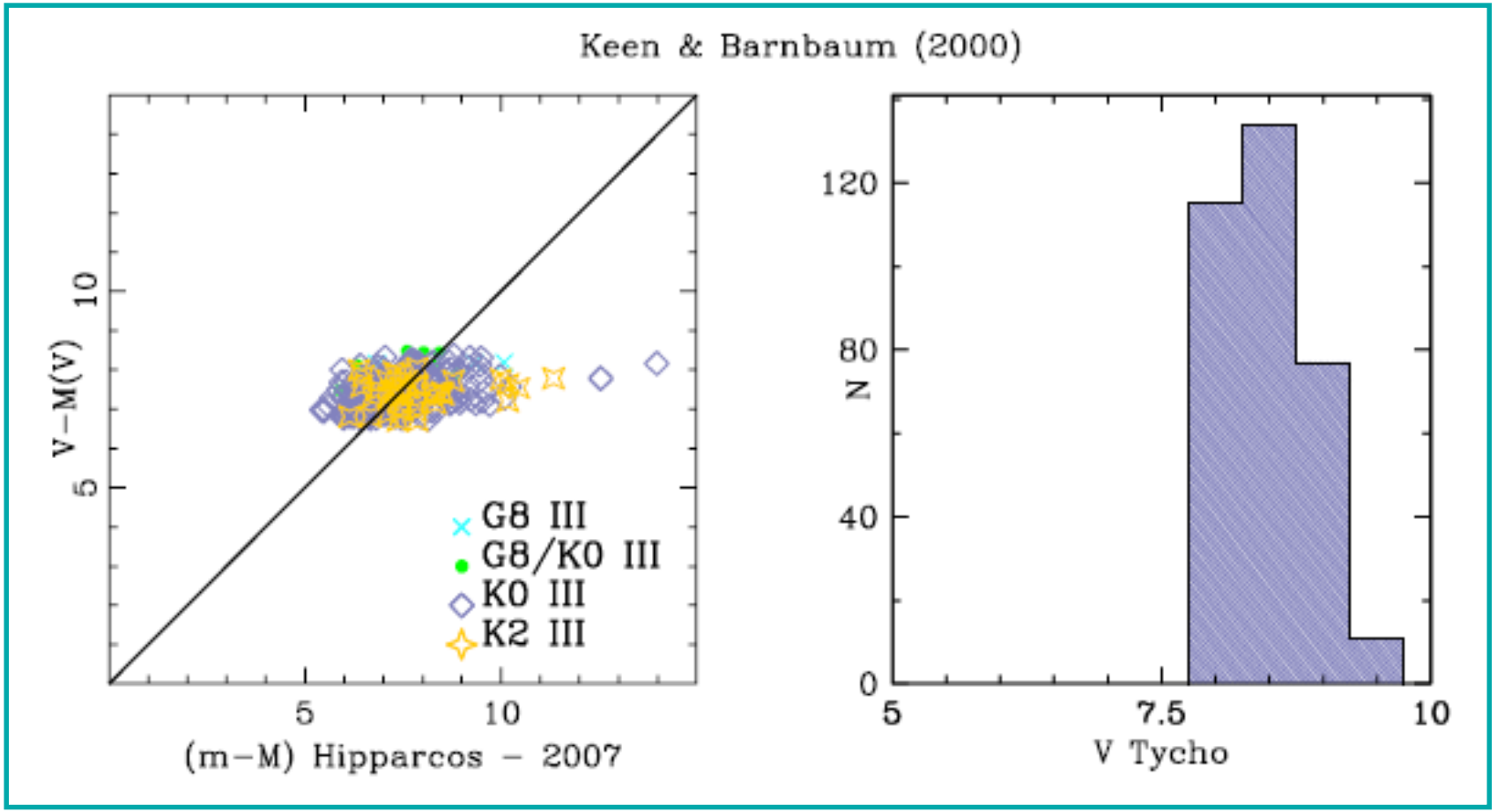
- Disk kinematics can be examined in detail with a typical analysis of the distribution of stars in the UVW space.

- ARCS 1.22 survey is a local survey on RC stars located :

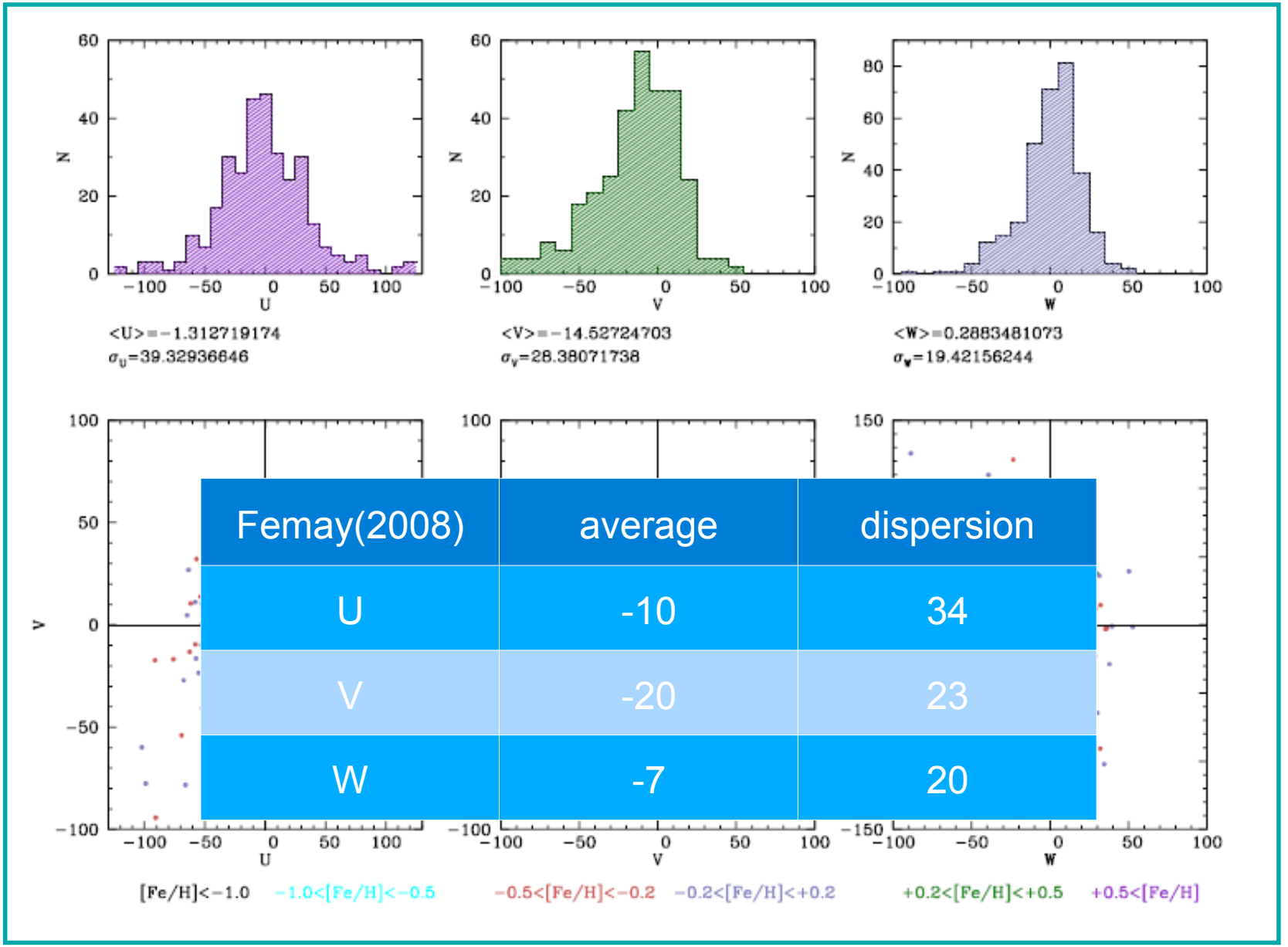
  $70 < d < 600$ pc

  $40 < z < 1200$ pc.

Spectrophotometric Distances

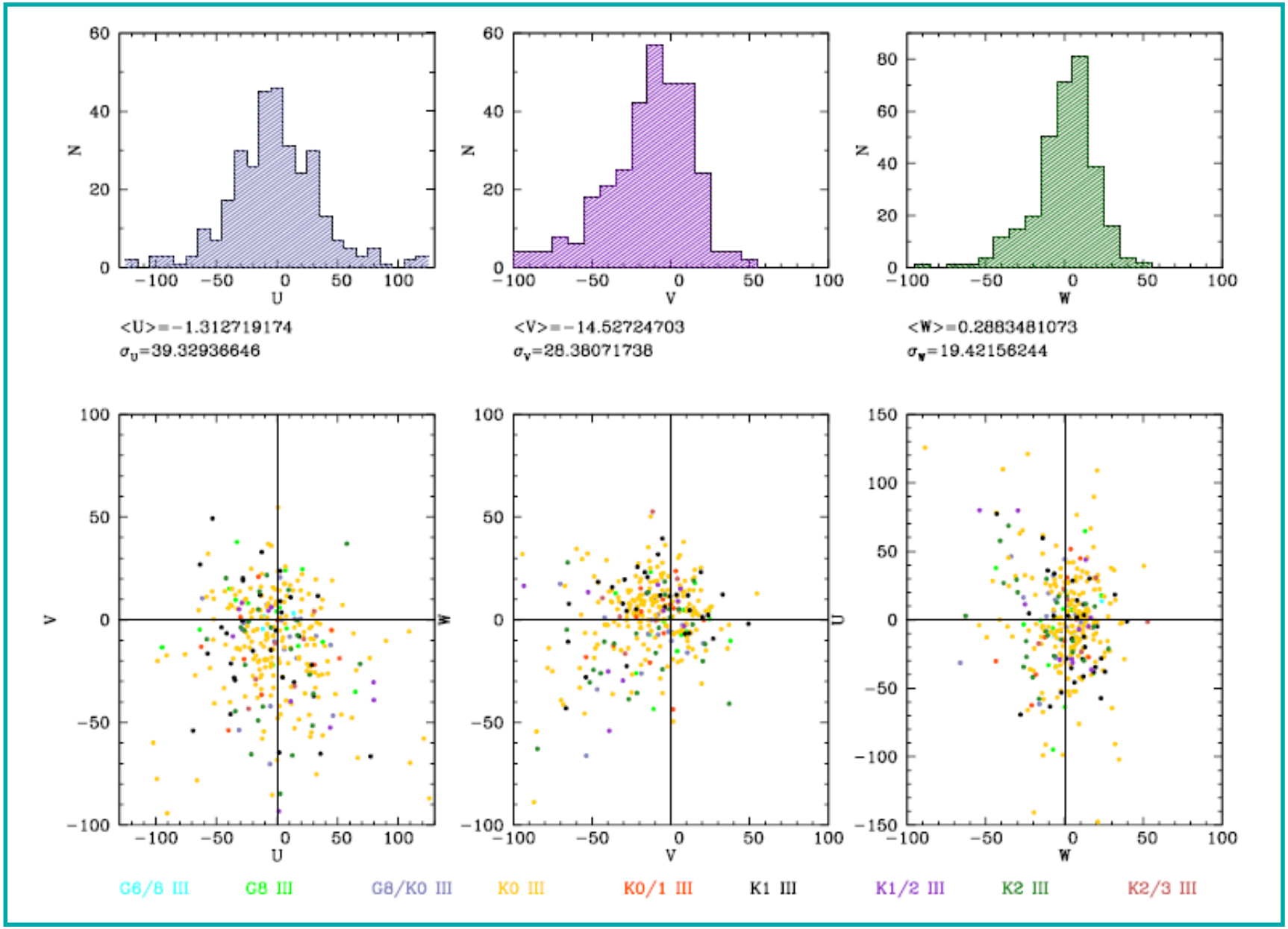


Space Velocity Components For RC Sample



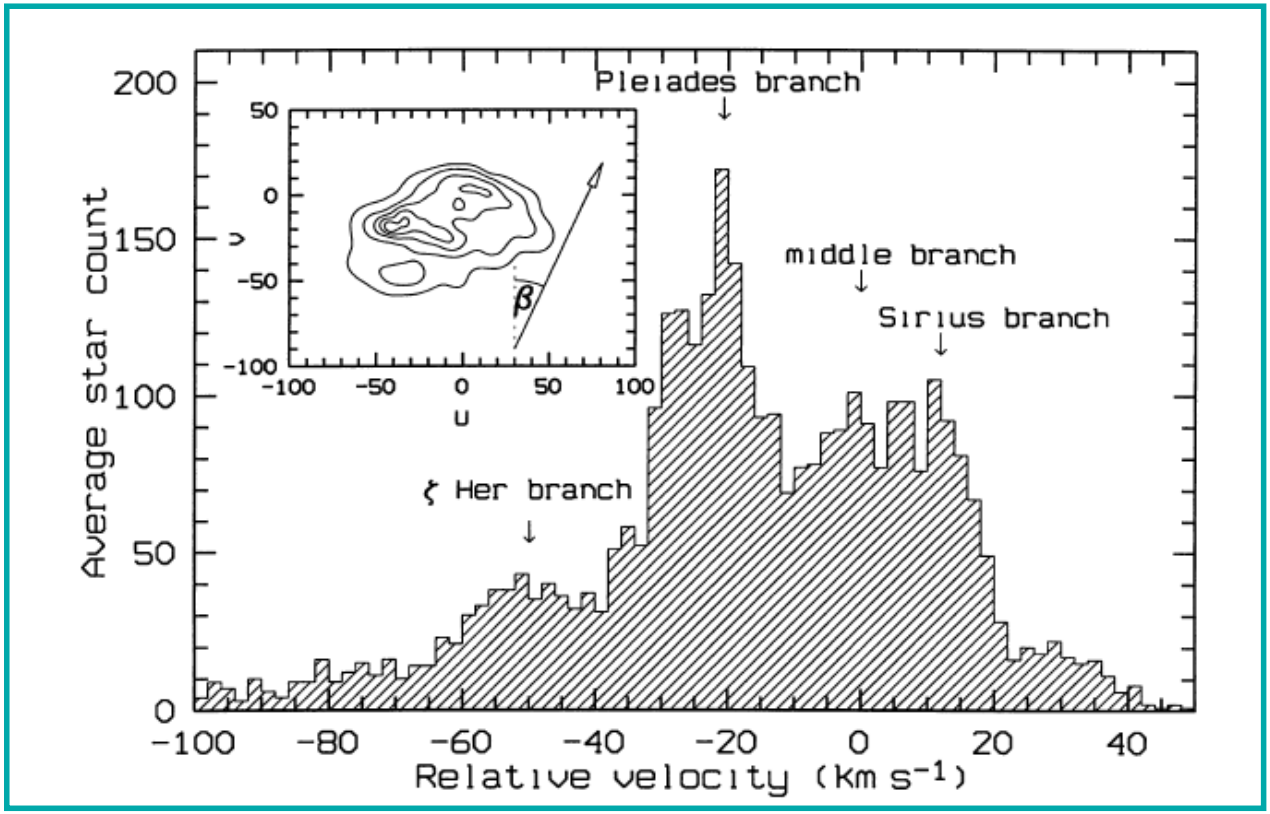
Femay(2008)	average	dispersion
U	-10	34
V	-20	23
W	-7	20

Space Velocity Components For RC Sample



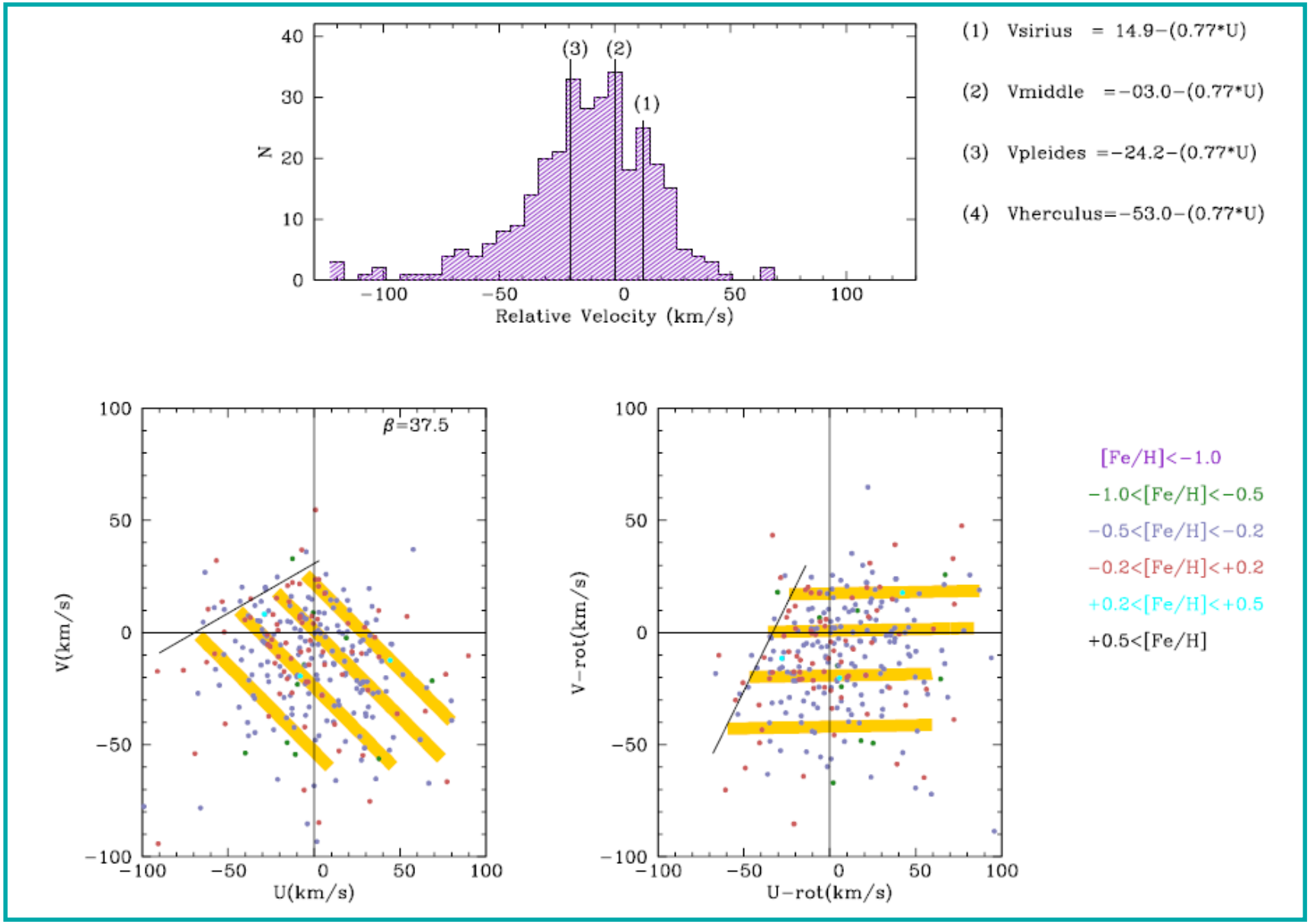
Comparison With Skuljan et.al. 1999

Velocity Distribution Of stars In The Solar Neighbouhood



4000 stars with parallaxes > 10 mas and Rv data existing in Hipparcos input catalog .

Moving Groups In ARCS RC Sample



The Catalogue …

- Page containing literature data

HD	HIP	TYC-2	α	δ	b	T.Sp.	V_J	$(B-V)_J$	d	σ_d	M_V	σ_{M_V}	J_{2MASS}	σ_J	H_{2MASS}	σ_H	K_{2MASS}	σ_K	qual	I_{DENIS}	σ_I
7736	6000	20 595 1	01 17 09.788	+02 00 55.0	–60.2	G8/K0 III	7.260	1.019	260	0.26	0.18	0.48	5.553	0.024	5.061	0.031	4.903	0.016	AAA	9.050	0.040
8337	6428	4684 660 1	01 22 34.065	–03 48 01.1	–65.5	K0 III	7.620	1.175	203	0.18	1.08	0.36	5.734	0.018	5.162	0.027	4.993	0.020	AAA	8.907	0.040
9261	7059	4687 2122 1	01 30 59.765	–04 57 34.8	–65.9	K0 III	7.050	0.973	146	0.14	1.23	0.28	5.377	0.019	4.962	0.018	4.764	0.020	AEA		
9959	7546	4687 1863 1	01 37 13.255	–04 08 34.2	–64.5	K0 III	7.790	1.045	342	0.40	0.12	0.66	5.965	0.032	5.391	0.034	5.263	0.023	AAA		
12254	9352	4692 363 1	02 00 08.351	–04 17 00.8	–61.9	K0 III	7.860	1.144	176	0.21	1.63	0.39	5.968	0.018	5.392	0.034	5.248	0.021	AAA		
18682	14003	55 1280 1	03 00 17.440	+00 58 13.4	–48.2	K0 III	7.800	1.055	272	0.36	0.62	0.61	5.853	0.023	5.321	0.034	5.170	0.033	AAA	8.531	0.020
19847	14835	59 470 1	03 11 34.383	+04 43 23.7	–43.5	G8 III	7.930	0.904	210	0.21	1.32	0.39	6.286	0.020	5.858	0.031	5.742	0.018	AAA		
21976	16515	67 233 1	03 32 38.725	+03 08 59.8	–40.7	K2/3 III	7.820	1.230	176	0.20	1.59	0.39	5.757	0.024	5.198	0.021	4.995	0.018	AAA		
22149	16651	67 1056 1	03 34 13.637	+03 25 56.2	–40.3	K1 III	7.510	1.133	171	0.19	1.35	0.36	5.630	0.020	5.183	0.061	4.926	0.018	AAA		
26606	19657	80 822 1	04 12 43.452	+05 01 51.1	–31.7	G8 III	7.290	1.192	207	0.34	0.71	0.59	5.153	0.032	4.670	0.076	4.437	0.018	AEA		
27146	19994	77 21 1	04 17 17.390	+02 31 46.8	–32.3	K0 III	7.230	1.025	253	0.34	0.21	0.59	5.381	0.026	5.012	0.055	4.729	0.018	AEA		
27324	20125	74 487 1	04 18 54.910	+01 46 24.4	–32.4	K0 III	7.870	1.022	326	0.46	0.31	0.72	6.086	0.029	5.593	0.046	5.452	0.021	AAA	8.751	0.040
27351	20127	4726 860 1	04 18 55.053	–00 55 27.4	–33.8	G8/K0 III	7.790	0.929	296	0.36	0.43	0.61	6.223	0.026	5.751	0.026	5.648	0.021	AAA	8.723	0.040
27719	20422	4727 669 1	04 22 28.058	–00 33 06.7	–32.9	K0 III	7.270	1.089	228	0.28	0.48	0.51	5.454	0.030	5.011	0.076	4.767	0.016	EEA		

- Page containing ARCS results
- **Tempereture (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 over densities possibly associated with moving groups, but to be 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 ...