

MUFFIT: a Multi-Filter FITting code to explore the stellar content of galaxies in photometric surveys

ESO Workshop RASPUTIN 2014
(October 13th-17th)
Poster Pop-Up Session (Reg-Id 9)

Luis Alberto Díaz-García
CEFCA
A.J. Cenarro (supervisor)

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Introduction & Motivations

Nowadays, there is an increasing number of multi-filter surveys, e.g. ALHAMBRA (Moles et al. 2008), COSMOS (Ilbert et al. 2009), SHARDS (Perez-Gonzalez et al. 2013), J-PAS (Benitez et al. 2014), J-PLUS (Cenarro et al. 2014, *in prep.*); with a vast volume of high-quality data in which we can study the stellar content of galaxies.

This kind of surveys sample the spectral energy distribution (SED) of galaxies, and owing to their configurations, the retrieved SEDs are half-way between classical photometry and spectroscopy, being in practise a low-resolution spectrum.

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We *should* take advantage of these data to carry out stellar population studies at larger redshifts than typical spectroscopic data.

It would be very useful a tool designed to determine the main stellar population parameters of galaxies using their multi-filter SEDs.



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Posters Id
9 and 10



χ^2 -test
Mixture of 2 SSPs
Detection of emission lines
Monte Carlo approach

Further details in Díaz-García et al. (2014a, *in prep.*)

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Posters Id
9 and 10

Photometric
system

SSP Models

Photometry
+ errors



χ^2 -test
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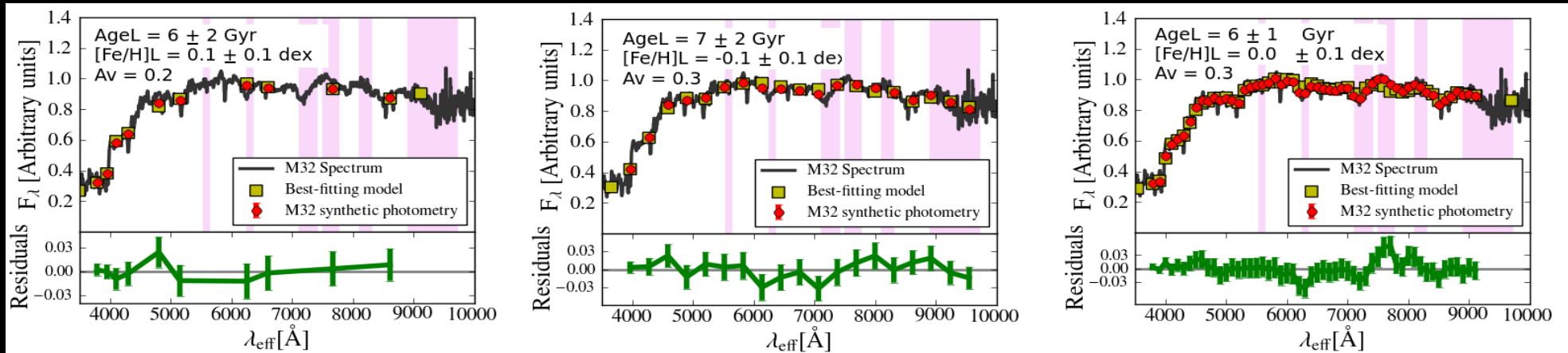
Age • Metallicity • Extinction • Redshift • Stellar mass • *k*-corrections
(for a more general case, IMF slope and α -abundances)

MUFFIT : a MULTI-Filter FITting code to explore the stellar content of galaxies in photometric surveys

MUFFIT: a MULTI-Filter FITting code Testing the code with ALHAMBRA galaxies

M32 at J-PLUS, ALHAMBRA, and J-PAS resolution

Synthetic photometry of M32 + MUFFIT
vs
Stellar population parameters from the literature

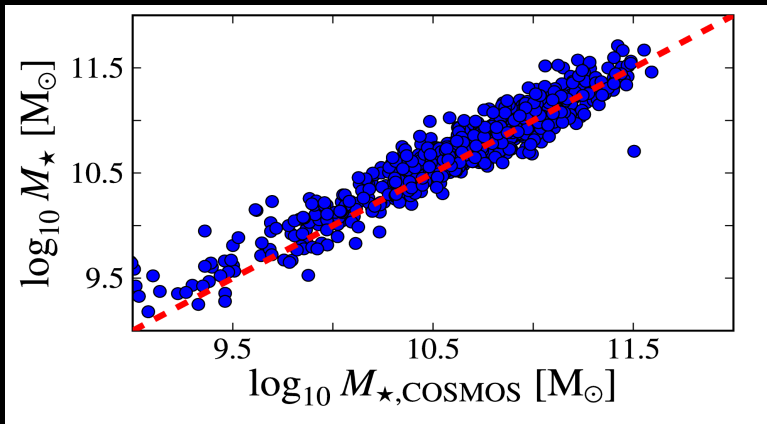


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Testing the code with ALHAMBRA galaxies



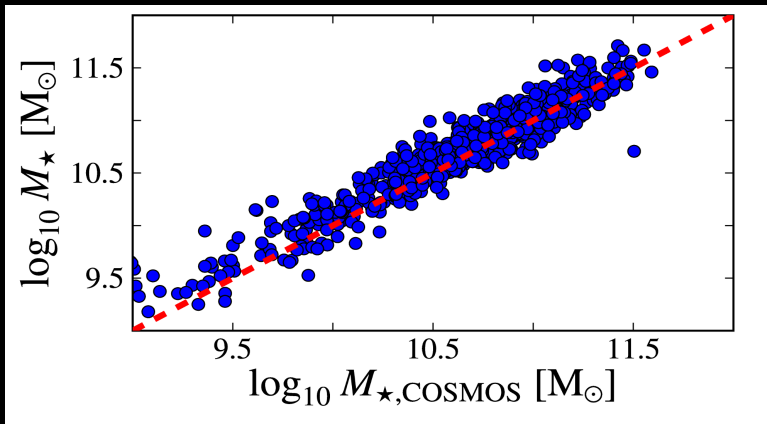
RS Galaxies

ALHAMBRA + MUFFIT stellar masses
vs
COSMOS stellar masses

More details in **Poster Reg-Id 9** and in **Díaz-García et al. (2014a, *in prep.*)**

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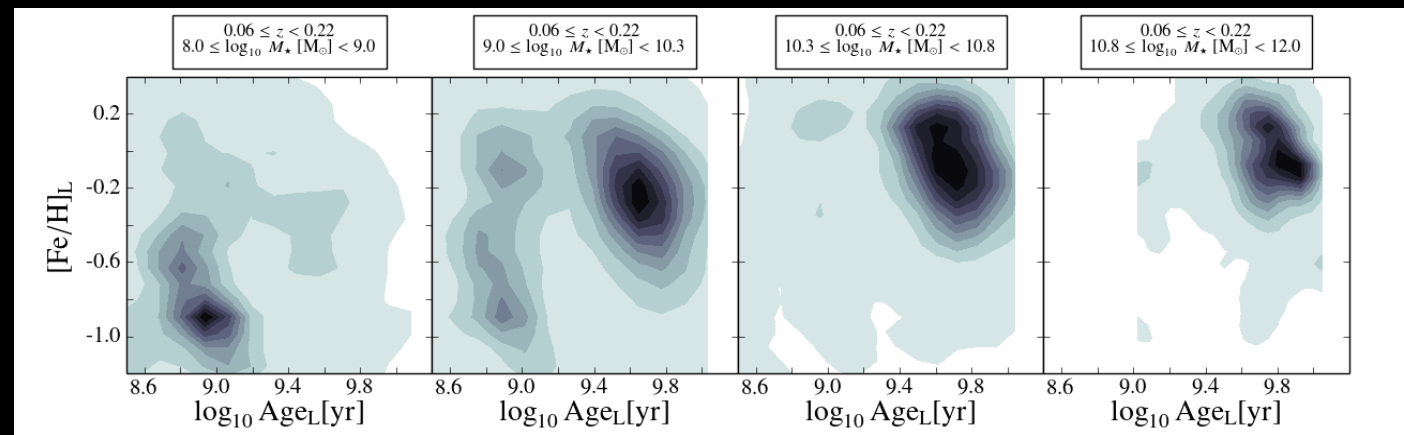


RS Galaxies

ALHAMBRA + MUFFIT stellar masses
vs
COSMOS stellar masses

Ellipticals

ALHAMBRA + MUFFIT
Age-Metallicity distributions
($0.06 \leq z \leq 0.22$)



More details in **Poster Reg-Id 9** and in **Díaz-García et al. (2014a, in prep.)**

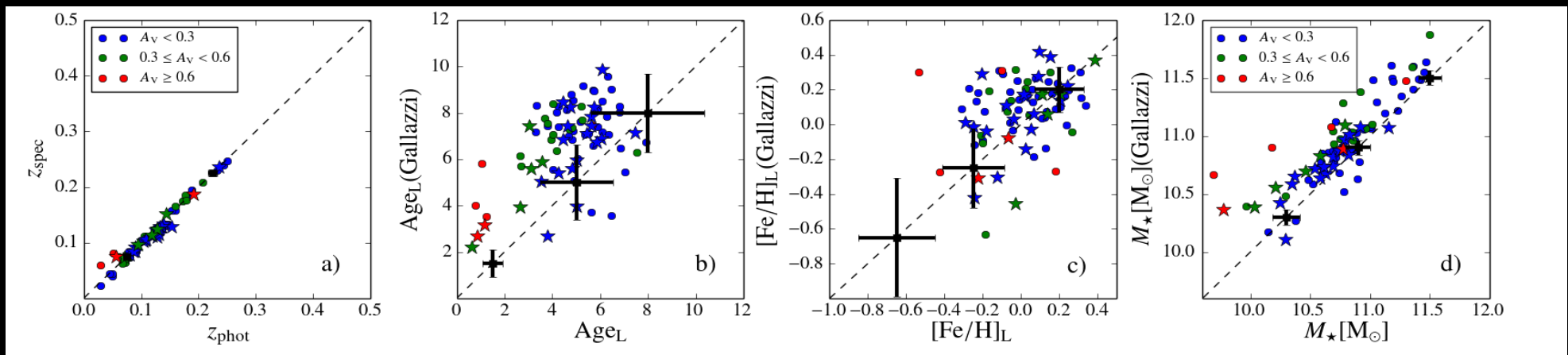
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RS Galaxies

ALHAMBRA + MUFFIT stellar population parameters
vs
SDSS + Line Index Strengths from Gallazzi et al. 2005



Redshifts

•

Age

•

Metallicities

•

Stellar masses

Sizes, formation epochs and stellar population properties of Red-Sequence galaxies up to $z \sim 1$

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The formation epochs and size effects of RS galaxies

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ALHAMBRA (20 optical bands):
Gold Catalogue
(complete up to $m_{F814W} = 23$)

BPZ2.0 photo- z constraints

Fitzpatrick's extinction law

Bruzual & Charlot SSP models

MUFFIT details in
Poster Reg-Id 9 and
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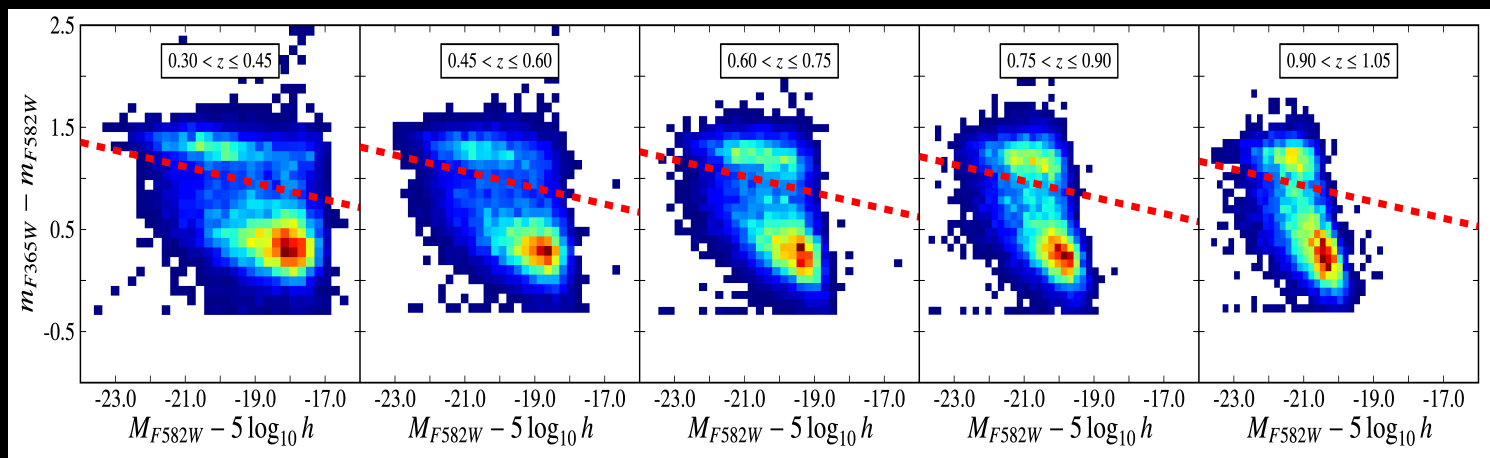
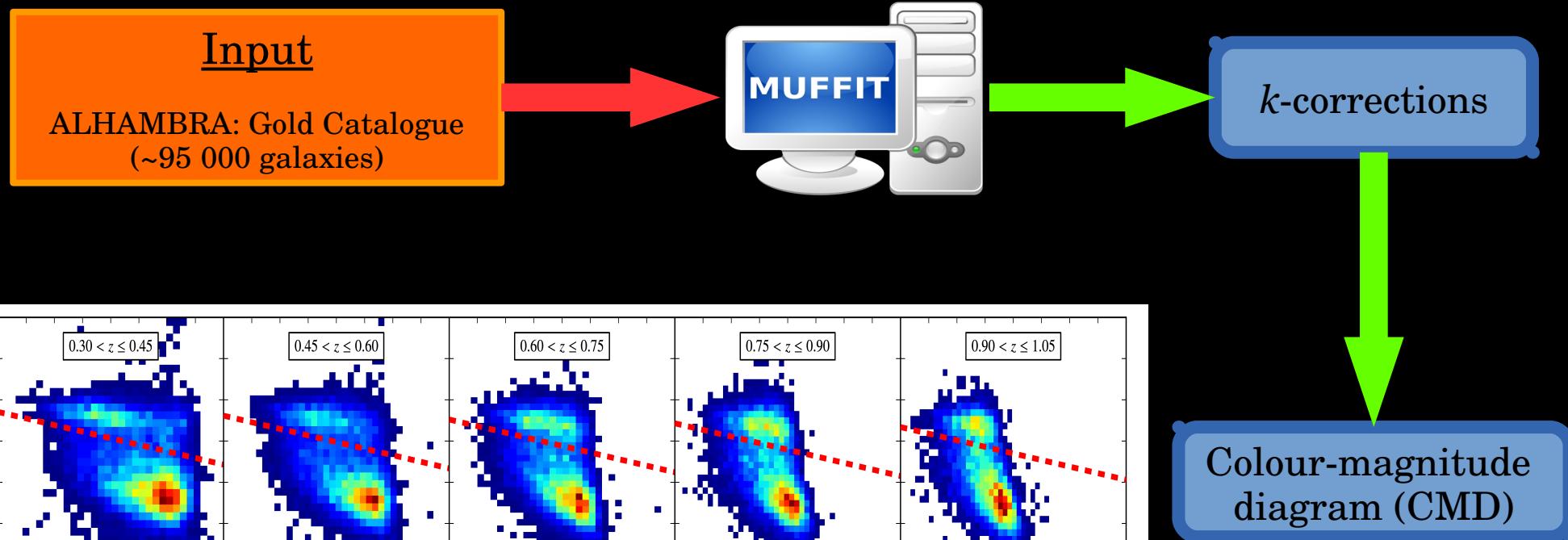
Formation Epochs of
RS Galaxies

MUFFIT

Galaxy size and
stellar populations
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More details in **Poster Reg-Id 10** and in **Díaz-García et al. (2014bc, *in prep.*)**

The formation epochs of RS galaxies (Definition of the sample)

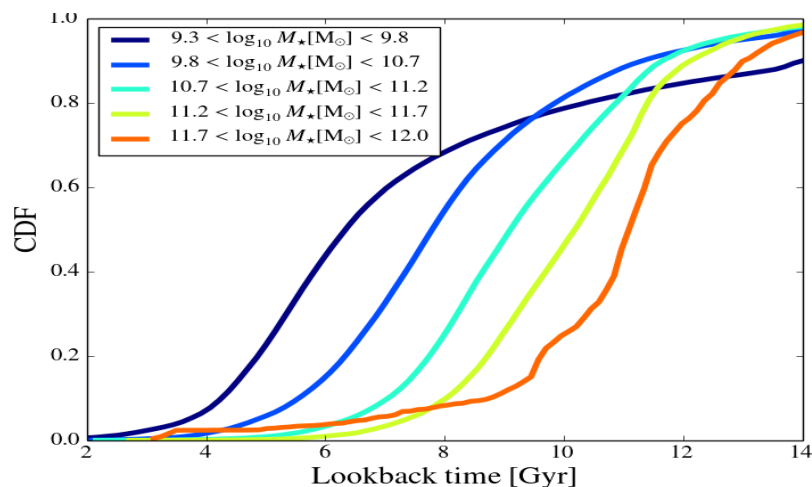
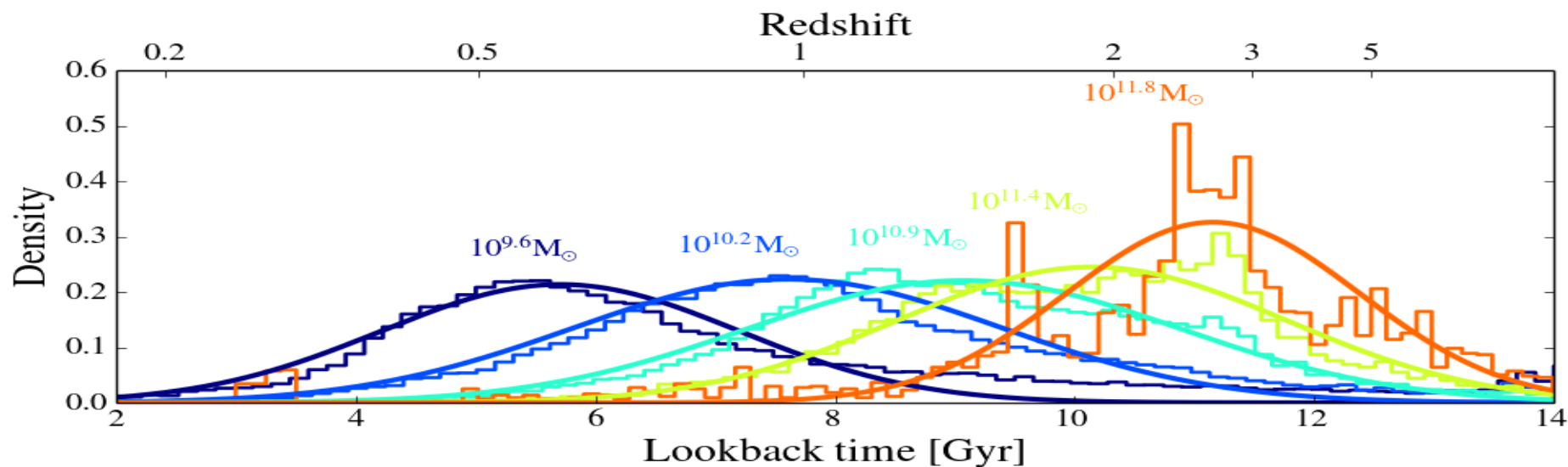


$$m_{F365W} - m_{F582W} = 1.15 - 0.3z - 0.08(M_{F582W} - 5 \log h + 20)$$

(RS galaxies, Bell et al. 2004 + Fritz et al. 2014)

~18000 RS-Galaxies
 $0.0 \leq z \leq 1.0$
 $M_{\star} \geq 10^{10} M_{\odot}$

The formation epochs of RS galaxies (Results)

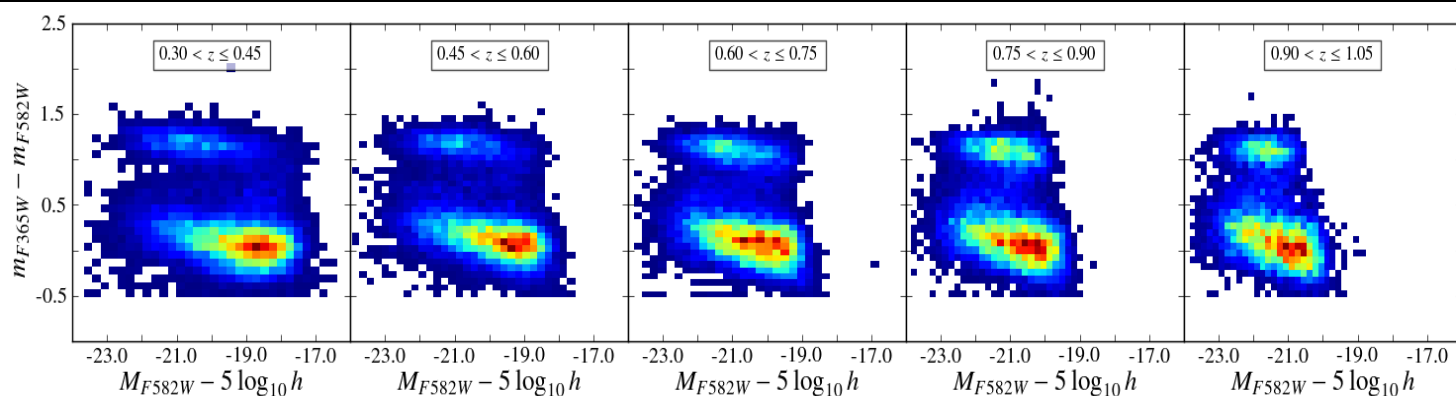
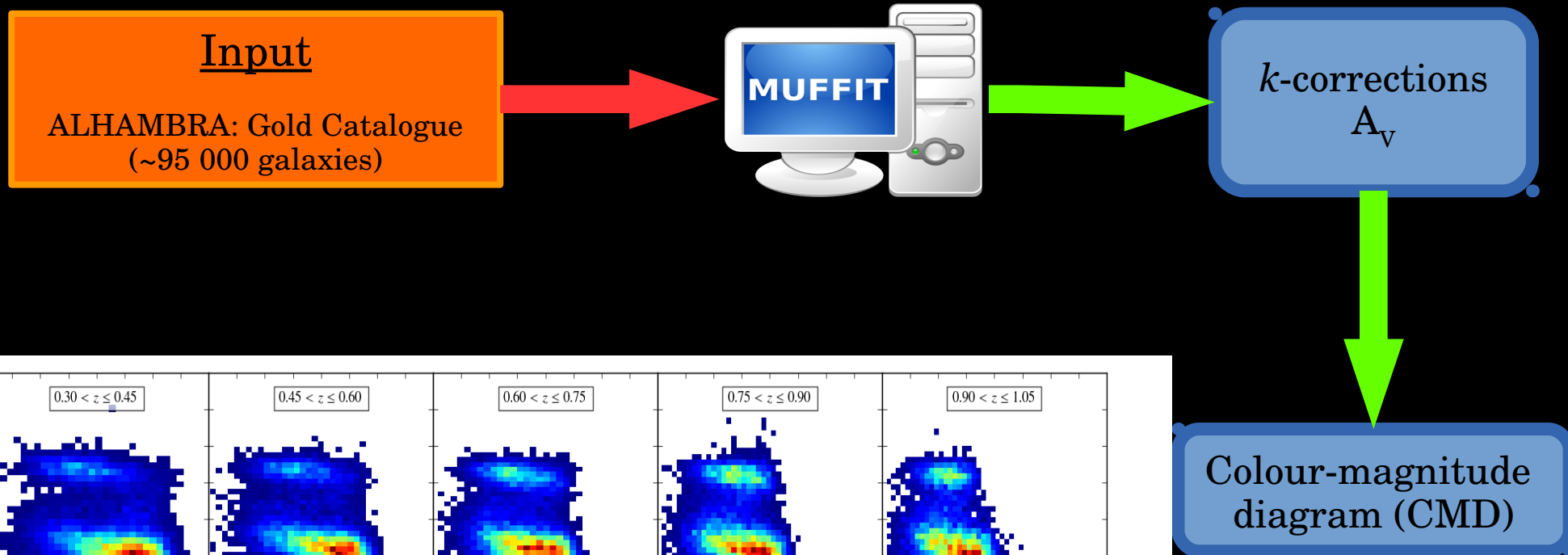


Massive galaxies were formed before in a more efficient way than their low mass counterparts. DOWNSIZING Scenario using ALHAMBRA+MUFFIT

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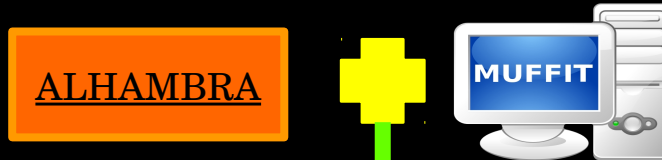
Size effects of RS galaxies (Definition of the sample)



Pure Red-Sequence galaxies (PRS)
(without red galaxies whose colour is due to a high dust content)

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¿SIZES?

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ALHAMBRA overlaps with *HST* fields
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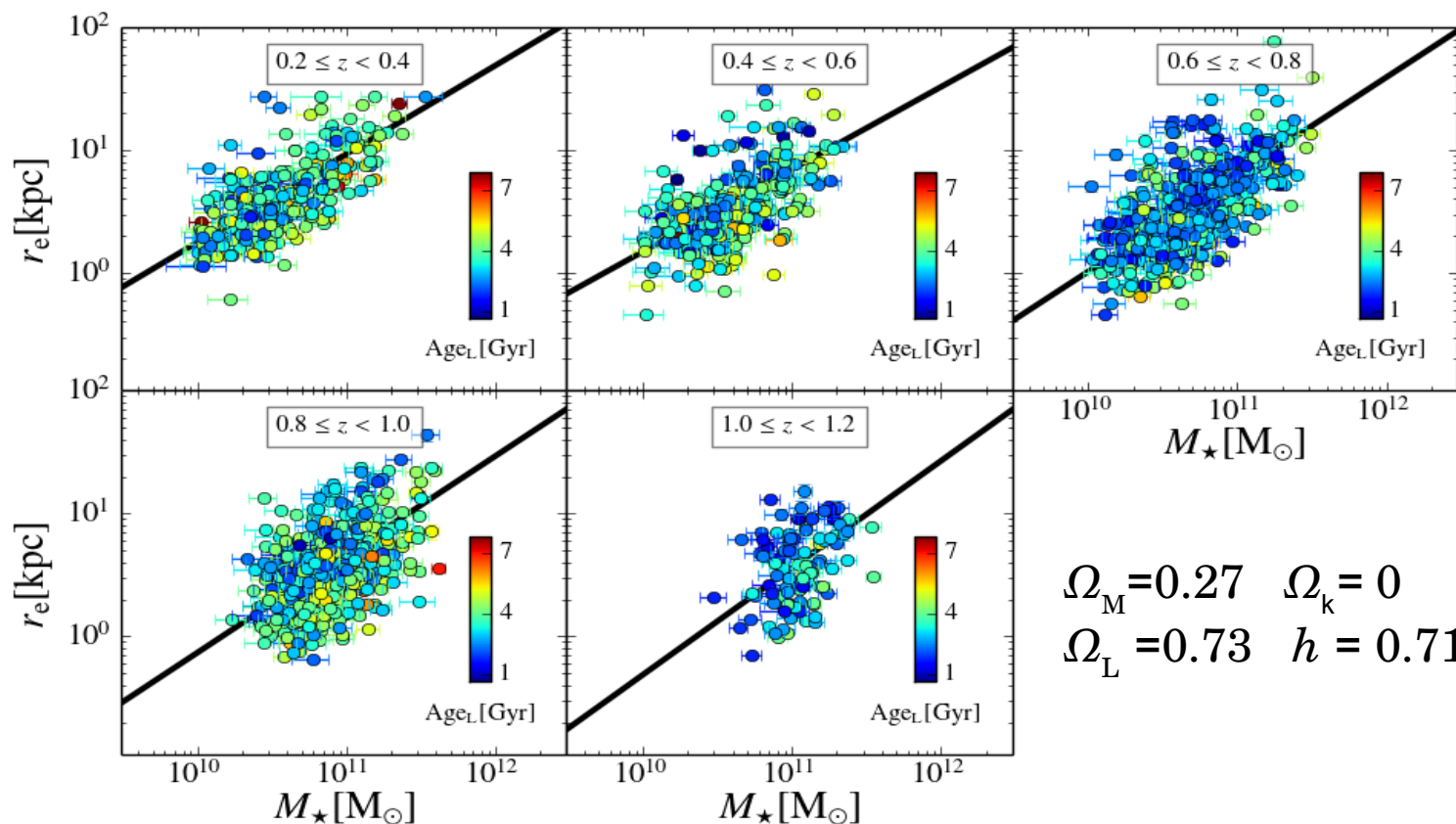
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ALHAMBRA



Sizes (*HST*/*ACS*)



$$\begin{aligned} \Omega_M &= 0.27 & \Omega_k &= 0 \\ \Omega_L &= 0.73 & h &= 0.71 \end{aligned}$$

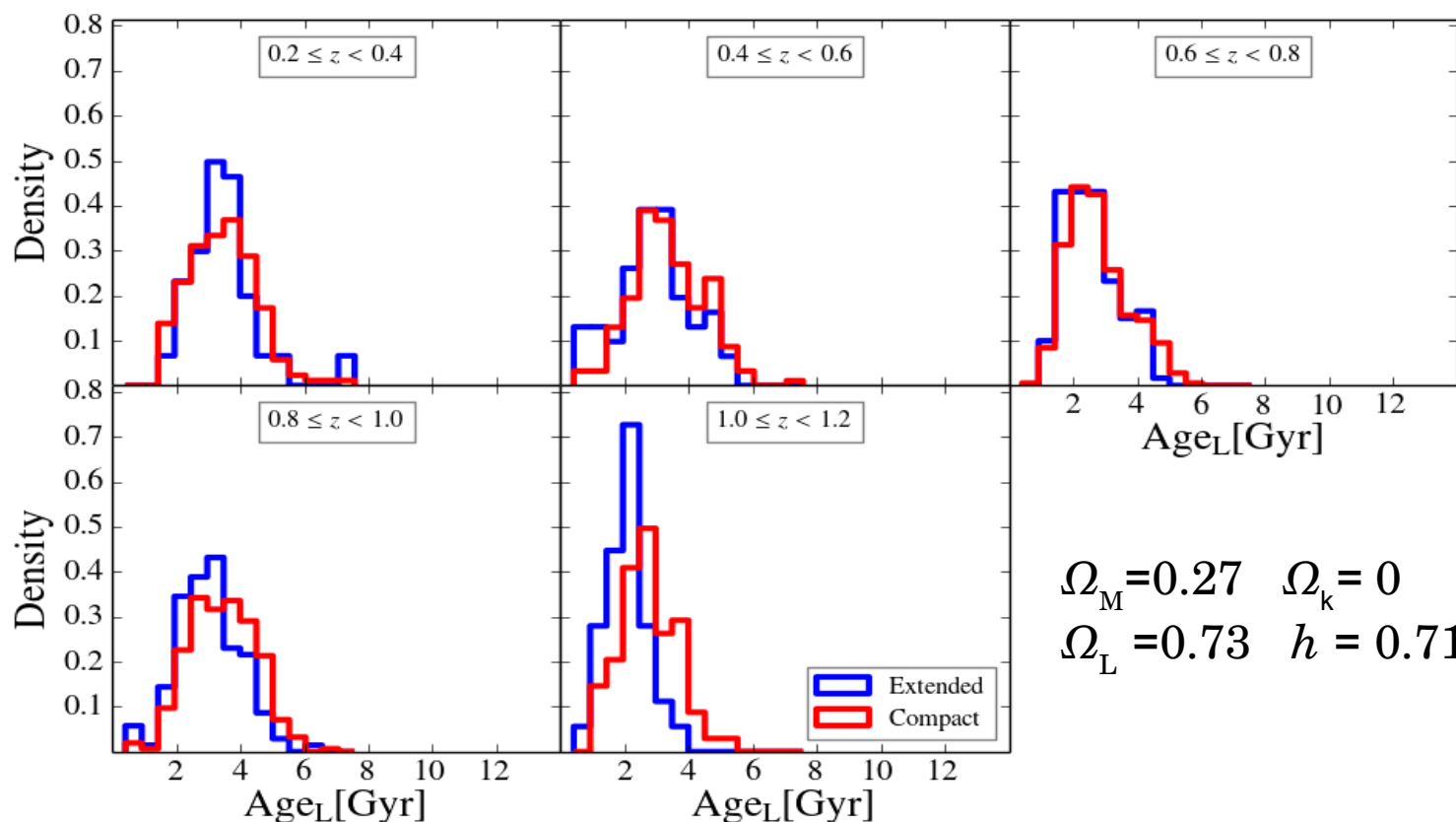
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No significant differences were found between the luminosity-weighted metallicities and extinctions of both populations. (*Preliminary results*)

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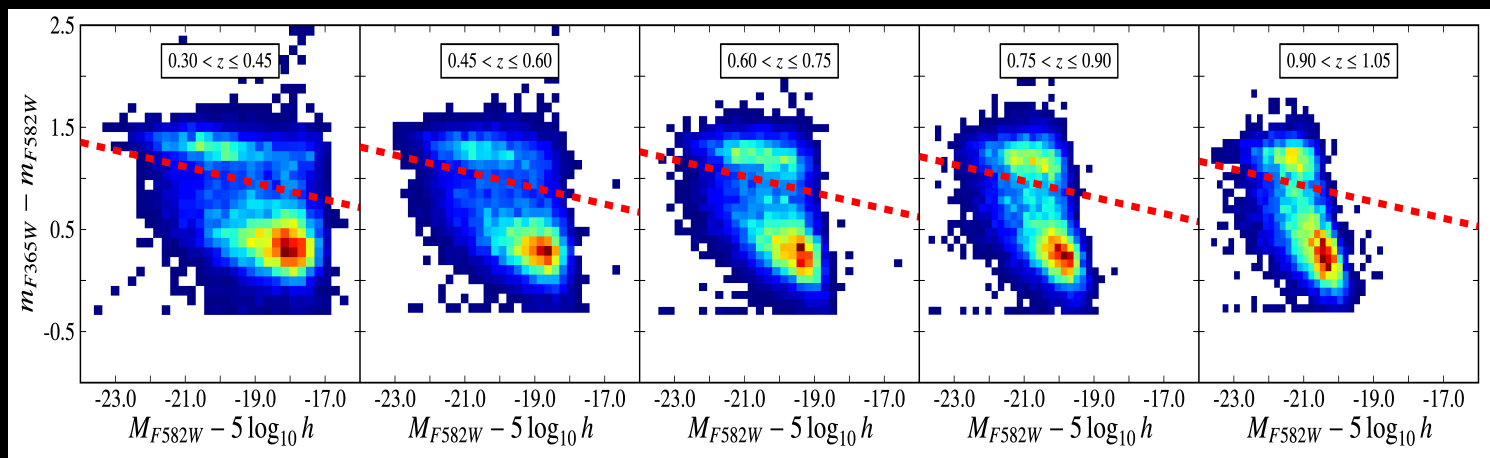
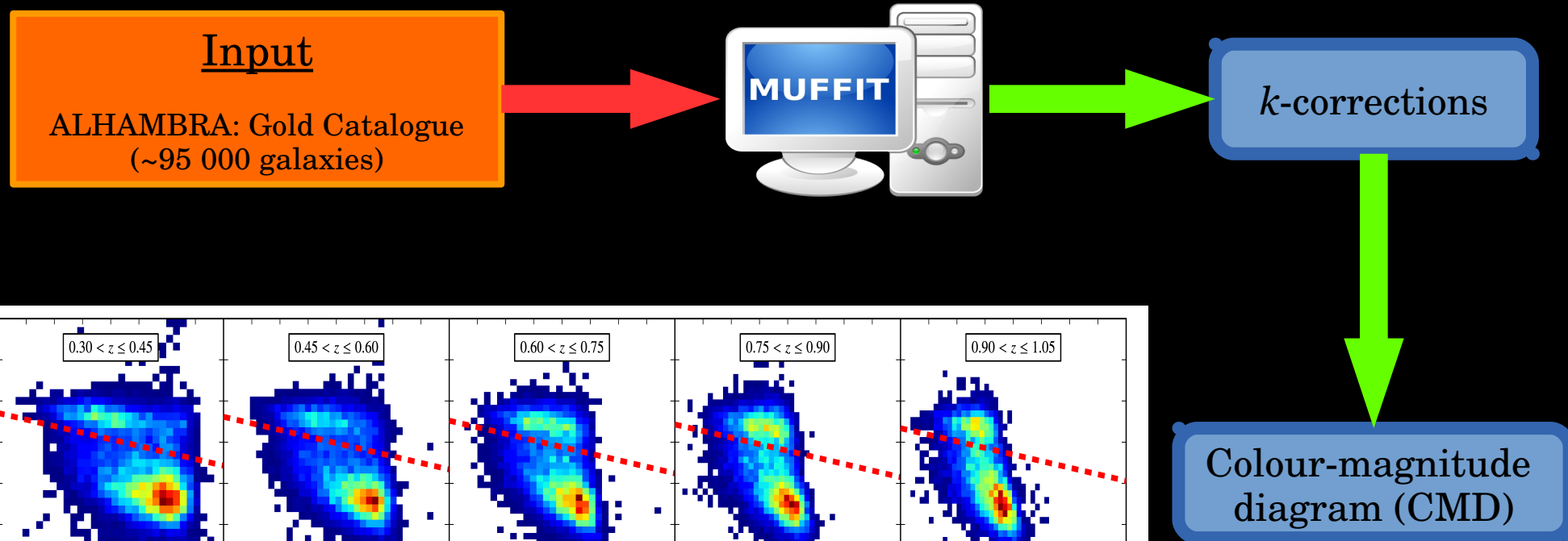
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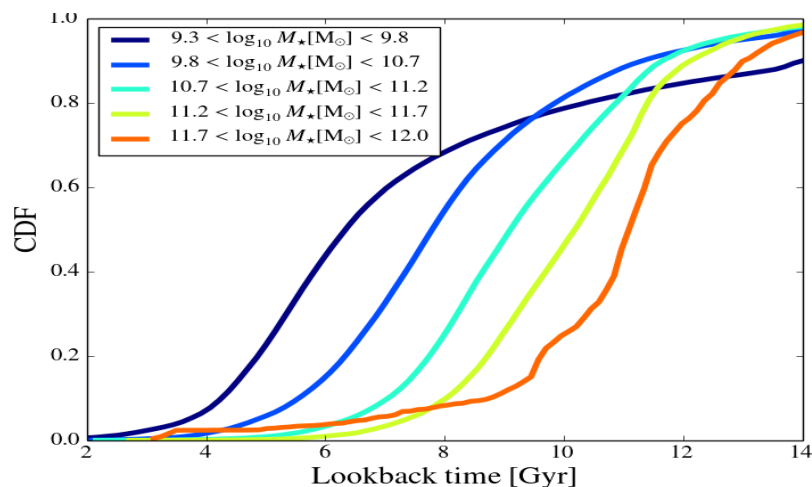
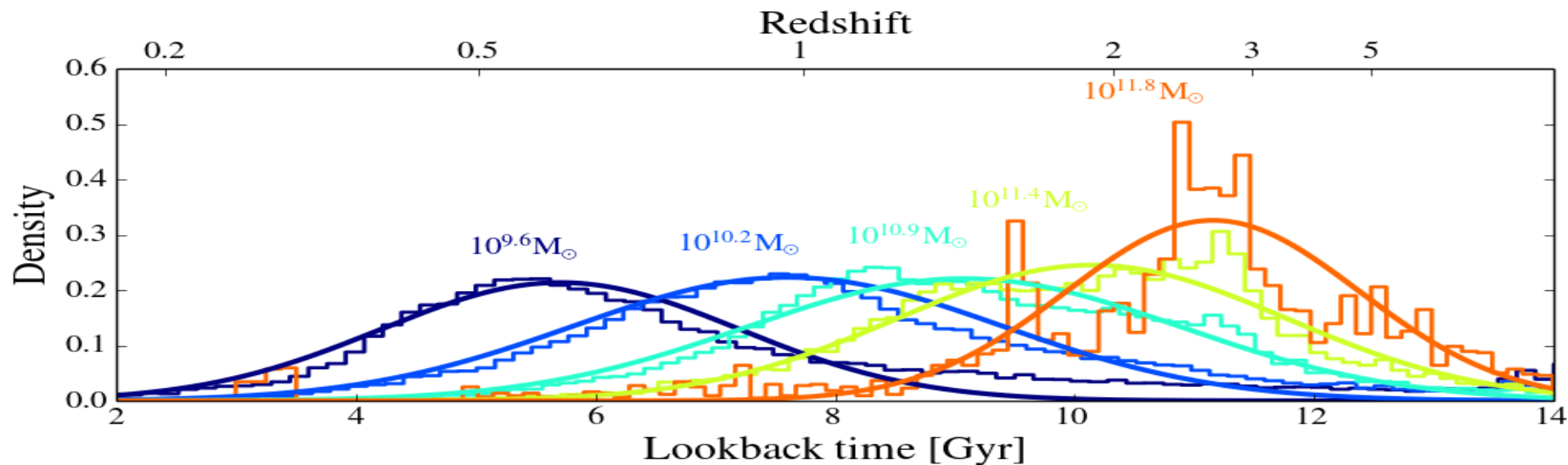


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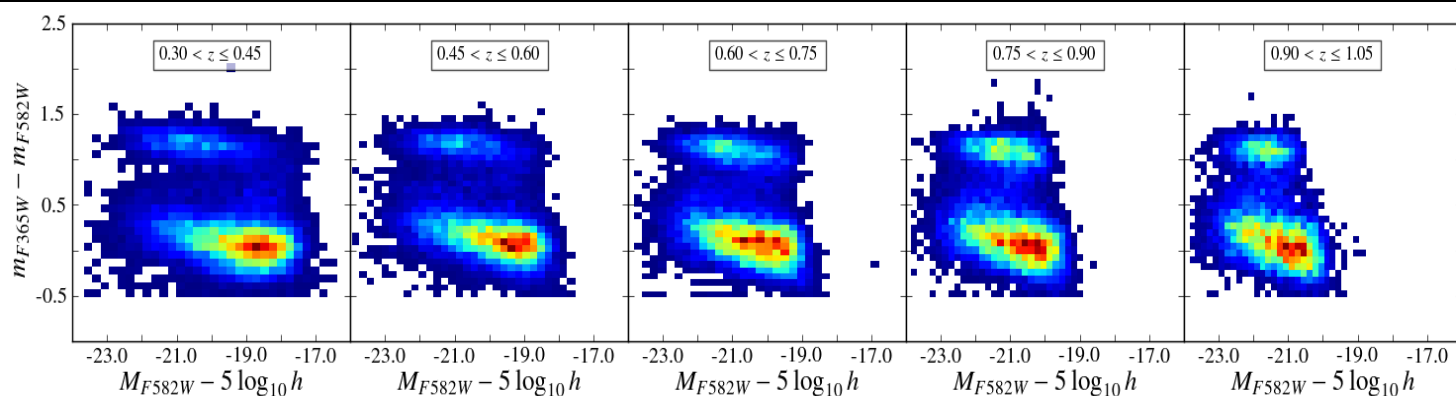
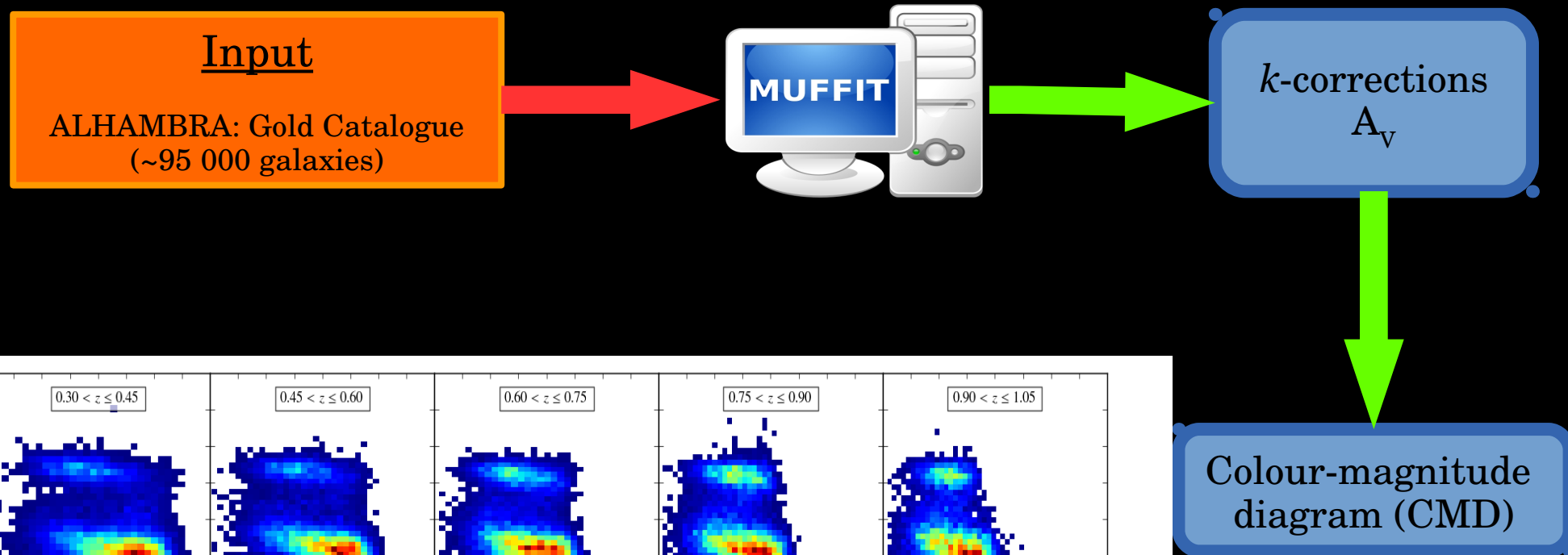


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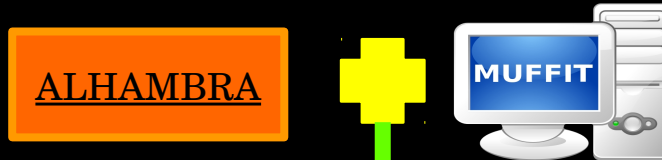
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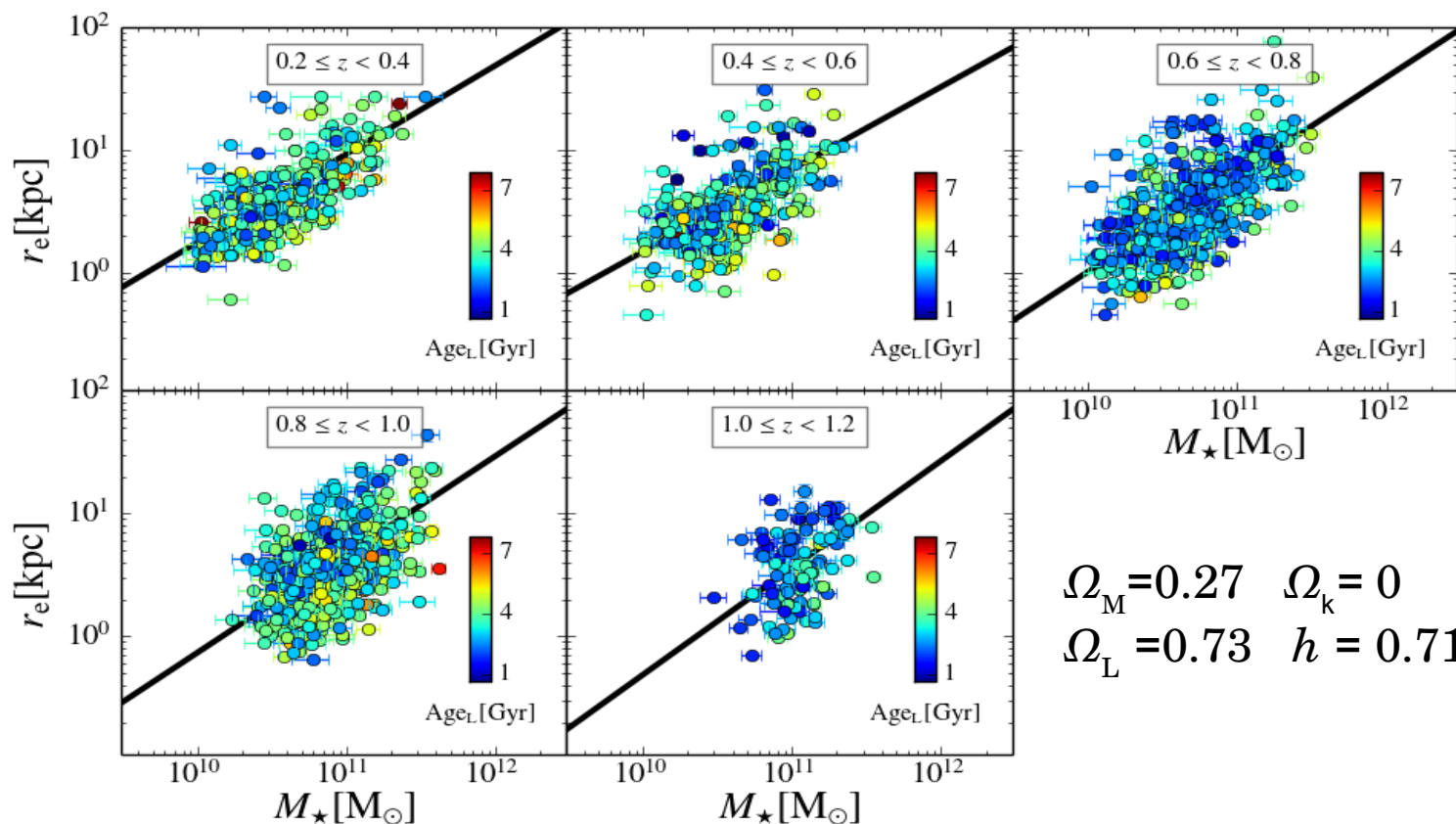
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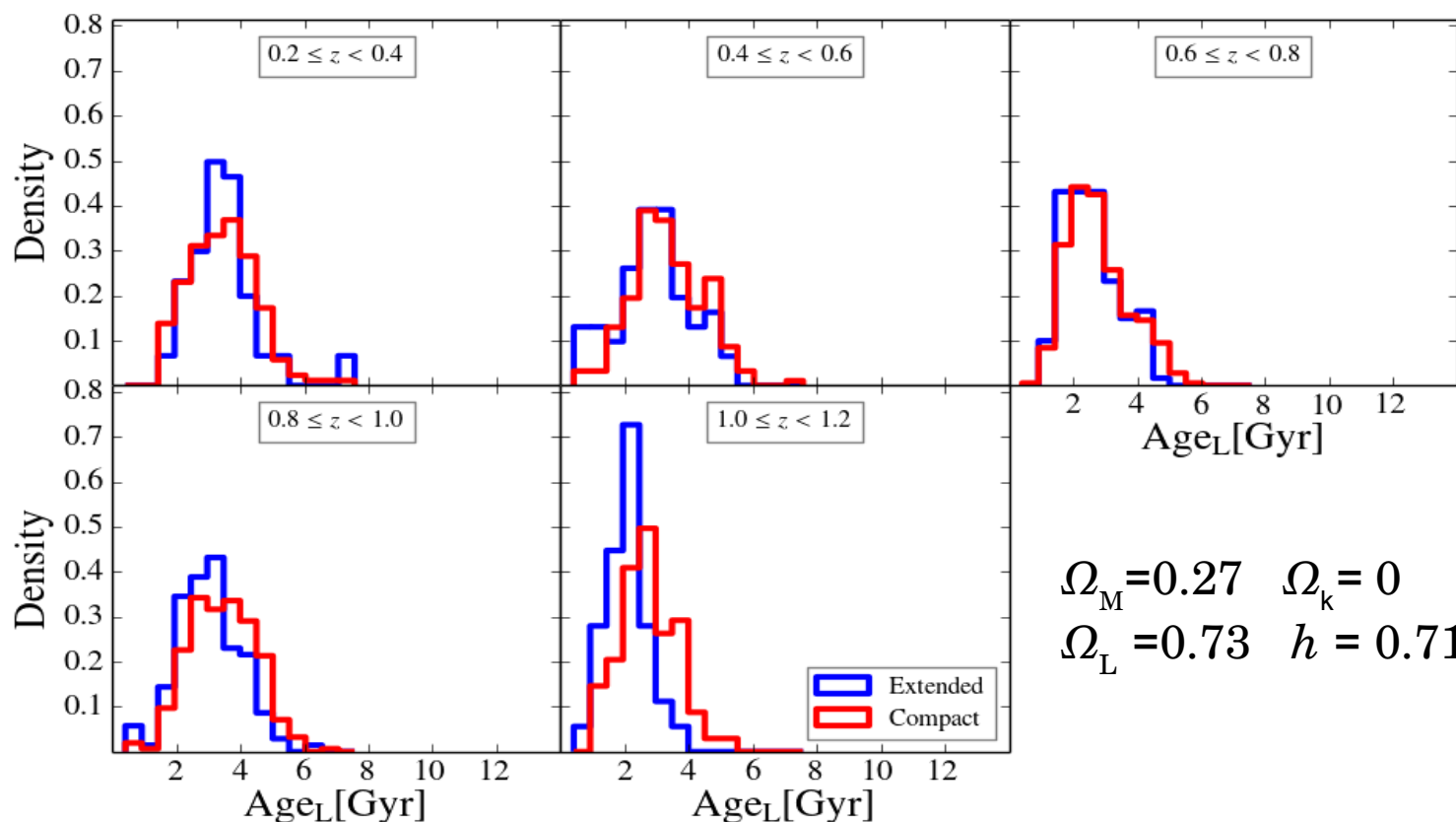
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The influence of the Galactic tidal field on the internal rotation of globular clusters

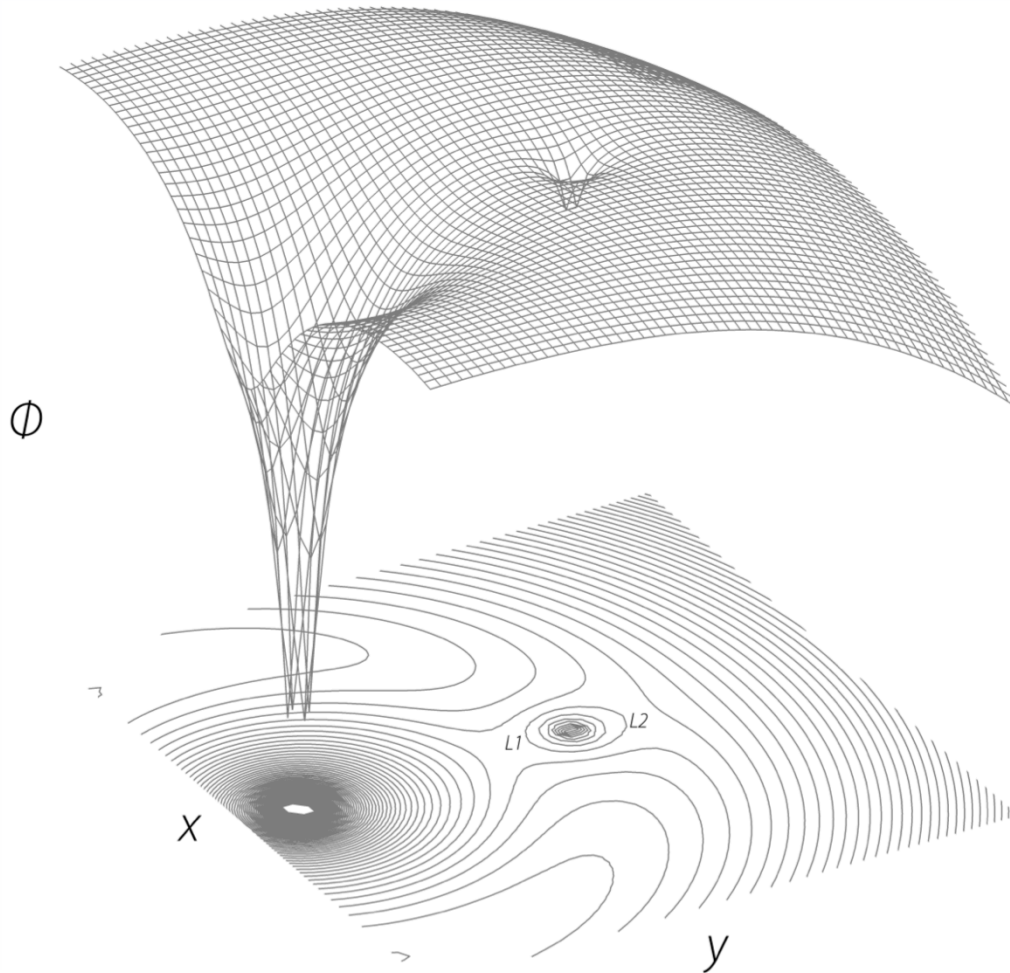
Nikolay Kacharov

Landessternwarte Heidelberg

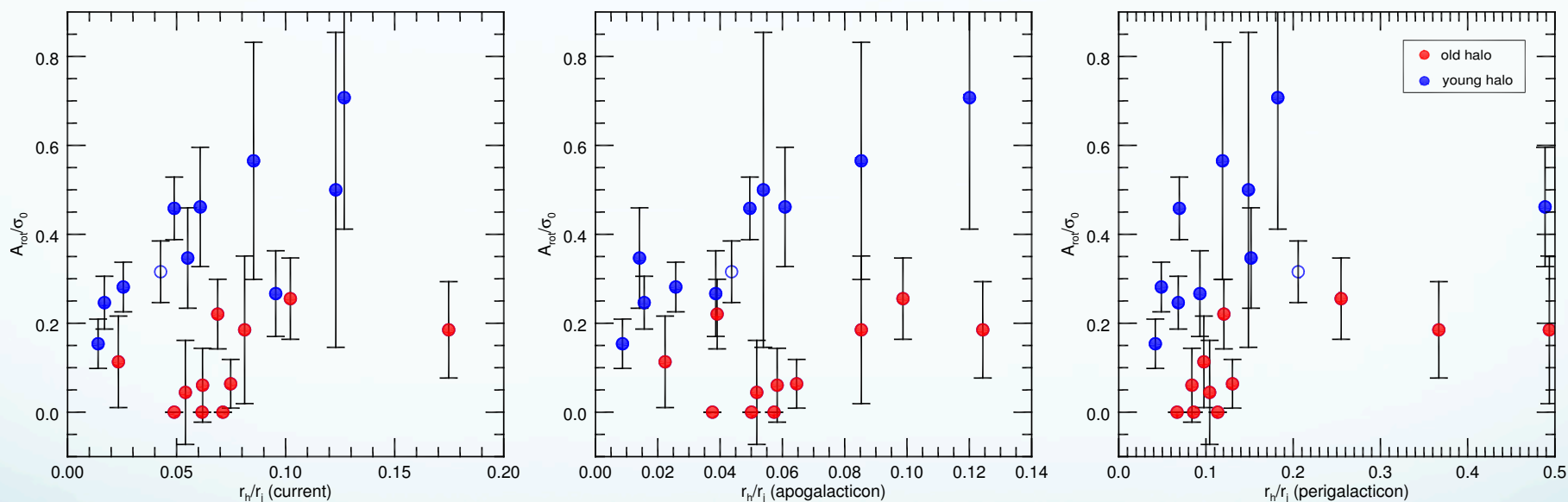
Poster 23

In collaboration with T. H. Puzia, N. Lützgendorf, A. Küpper, A. Koch, P. Bianchini and G. van de Ven

The influence of the Galactic tidal field on the internal rotation of globular clusters

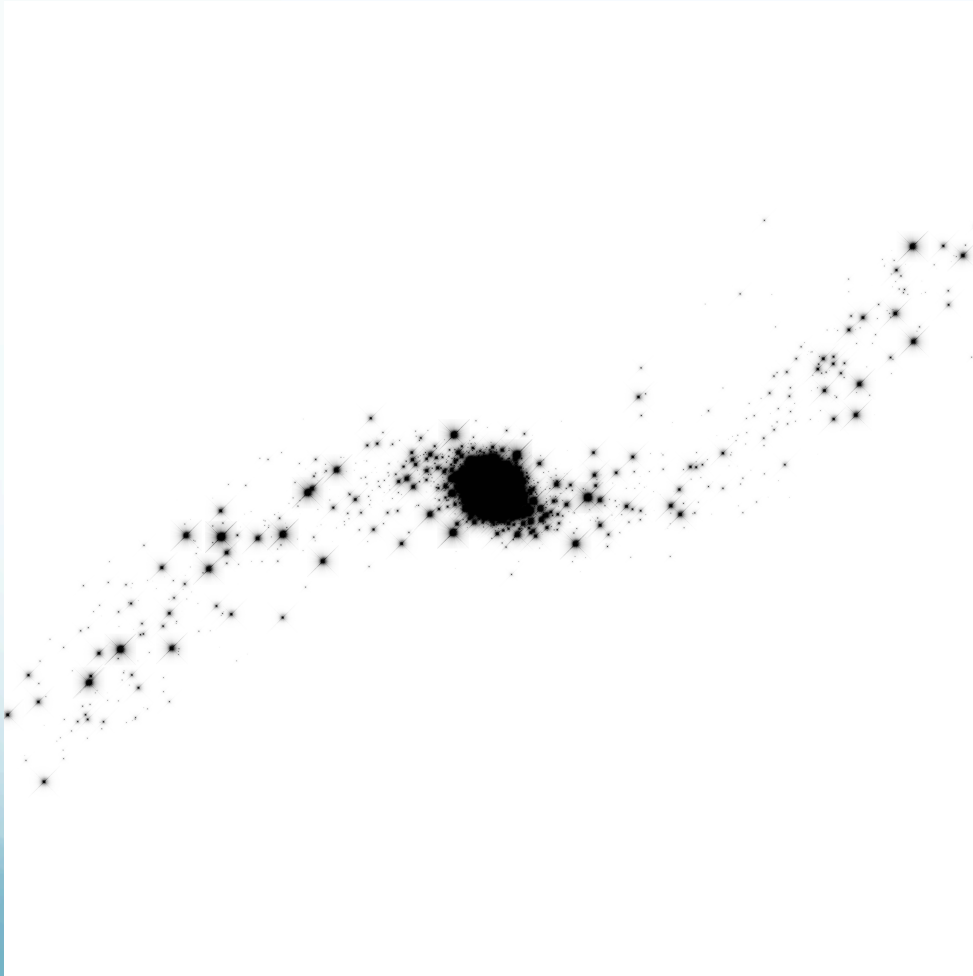


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Rotation properties from Bellazzini et al. 2012 and Kacharov et al. 2014

The influence of the Galactic tidal field on the internal rotation of globular clusters



Poster 23

*Thank You for your
attention!*

Poster session talk:

Counter-Rotating Stellar Populations in NGC 448

*Ivan Yu. Katkov*¹

Roman Uklein²

Oleg Egorov¹

Olga K. Sil'chenko¹

¹Sternberg Astronomical Institute

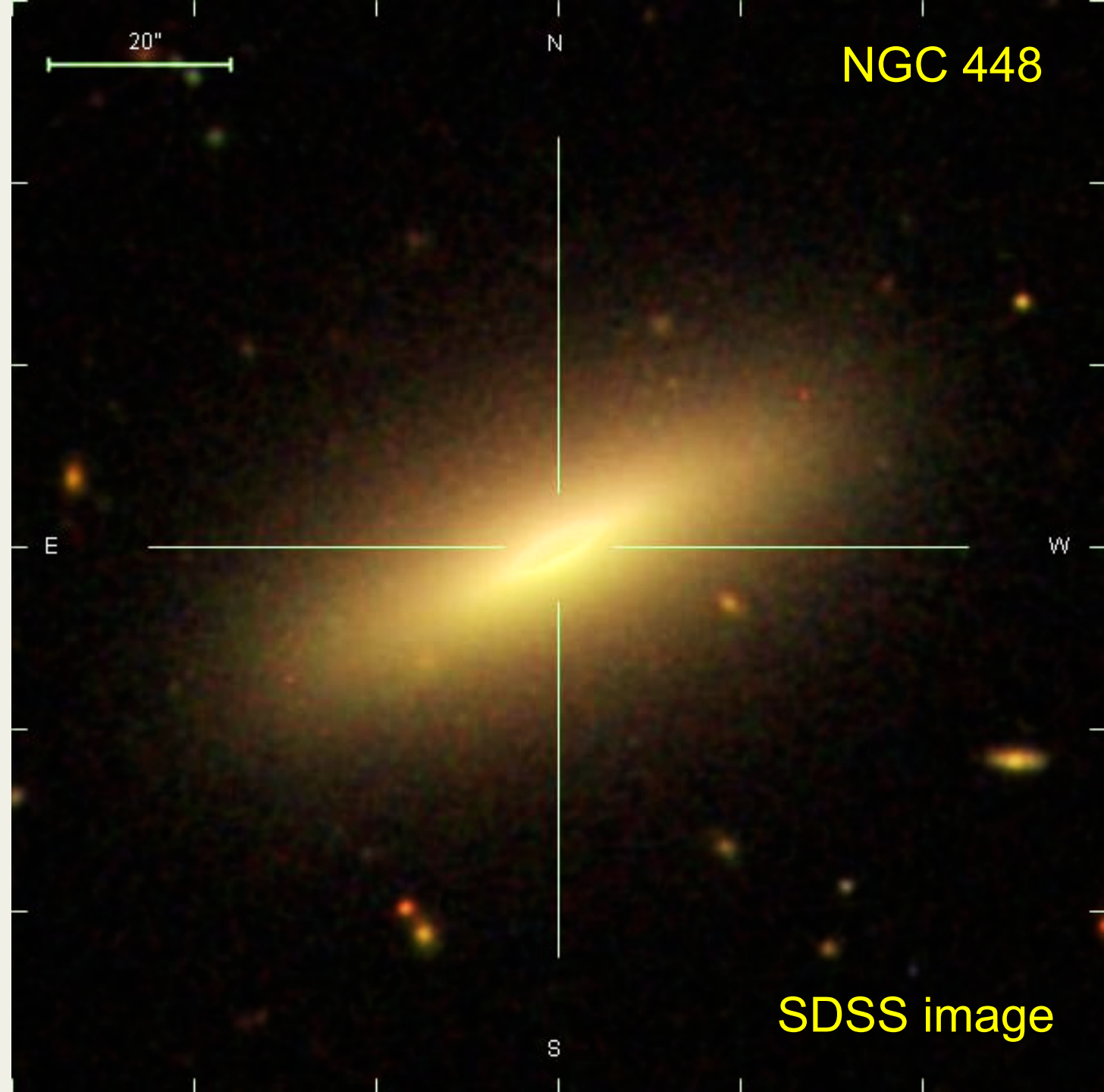
Lomonosov Moscow State University, Moscow, Russia

²Special Astrophysical Observatory, Nizhnii Arkhyz, Russia



RASPUTIN

October 2014



20"

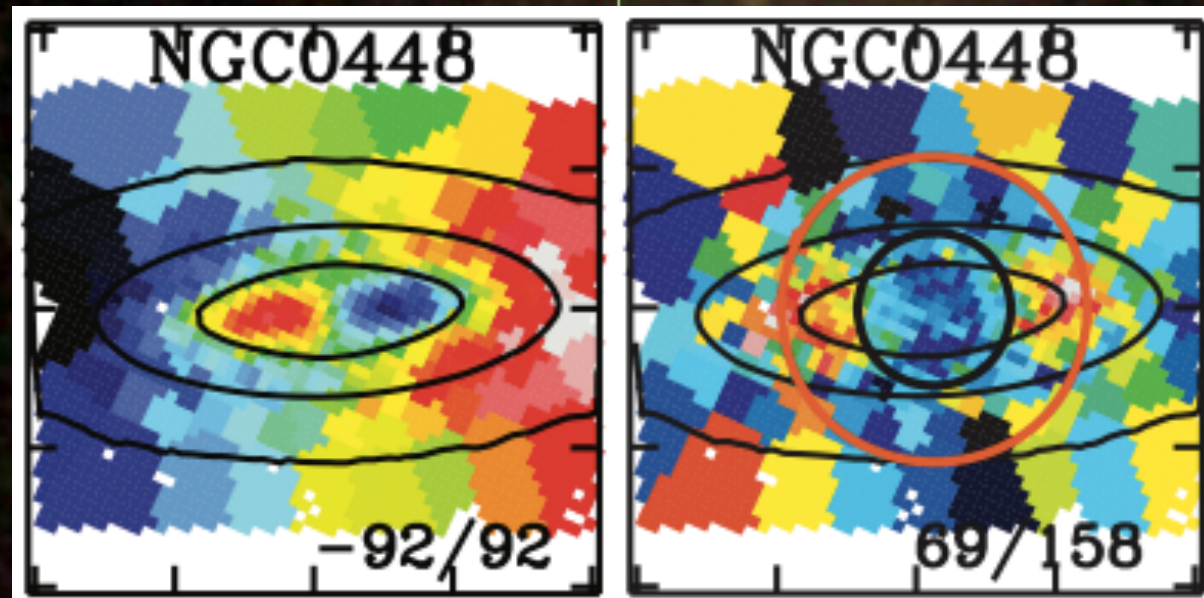
N

NGC 448

ATLAS3D

Krajnovic et al. (2011)

2σ peak galaxy



SDSS image

S

20"

N

NGC 448

6m BTA telescope



- 1" long-slit mode
- 4800-5550 Å
- Sp. Resolution $\sim 2.3 \text{ Å}$
- $\sigma_{\text{inst}} \sim 60 \text{ km/s}$
- $T_{\text{exp}} \sim 3^{\text{h}}$

SAURON

W

SDSS image

S

20"

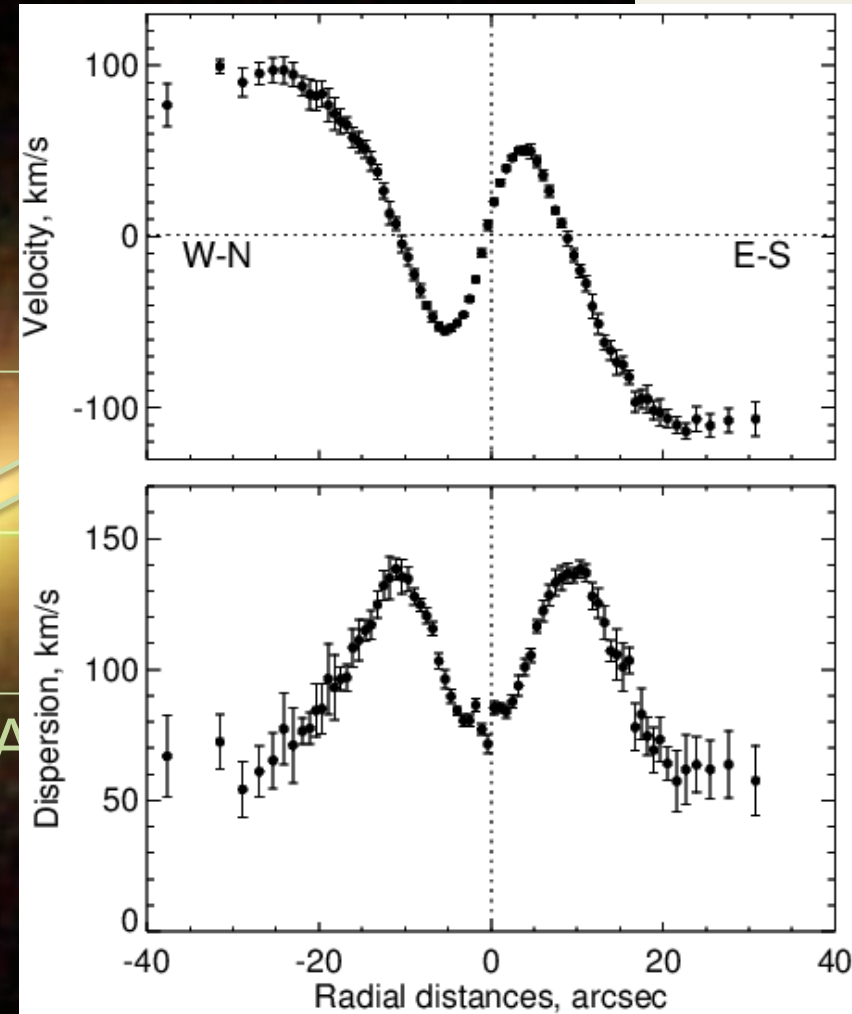
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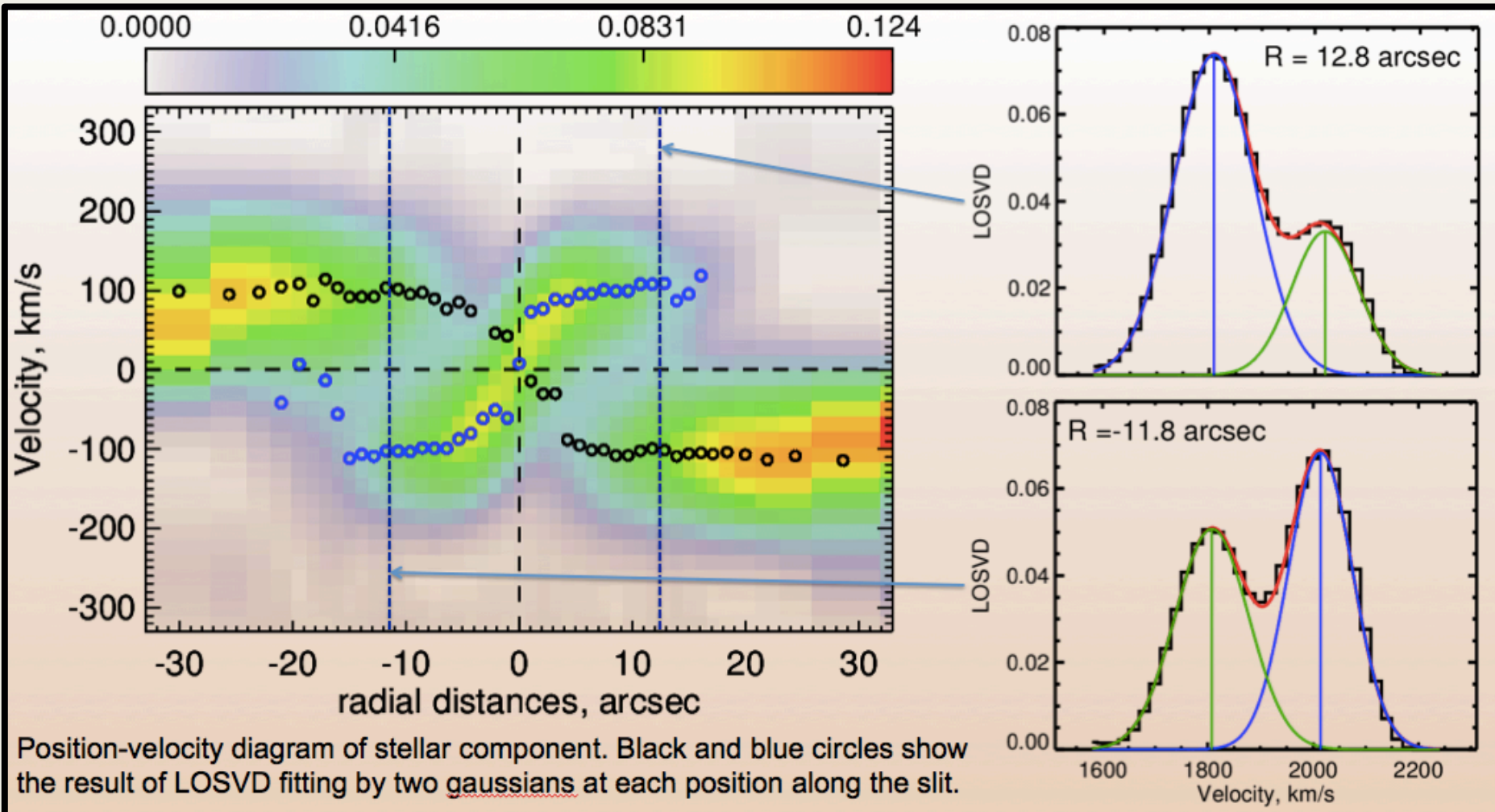
S-A

SDSS image

S

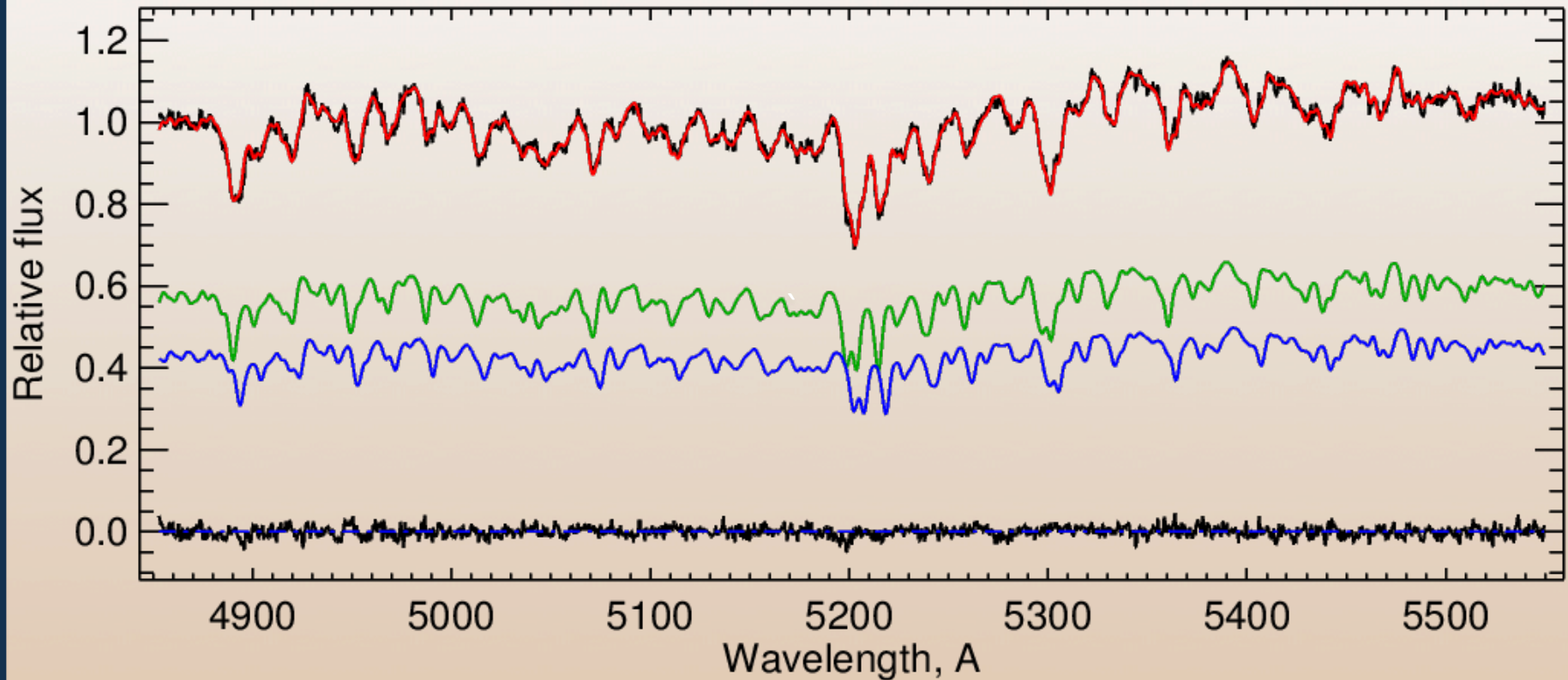
Non-parametric LOSVD

In order to solve ill-posed problem we use smoothing regularization: $\chi^2 + \lambda P[LOSVD]$



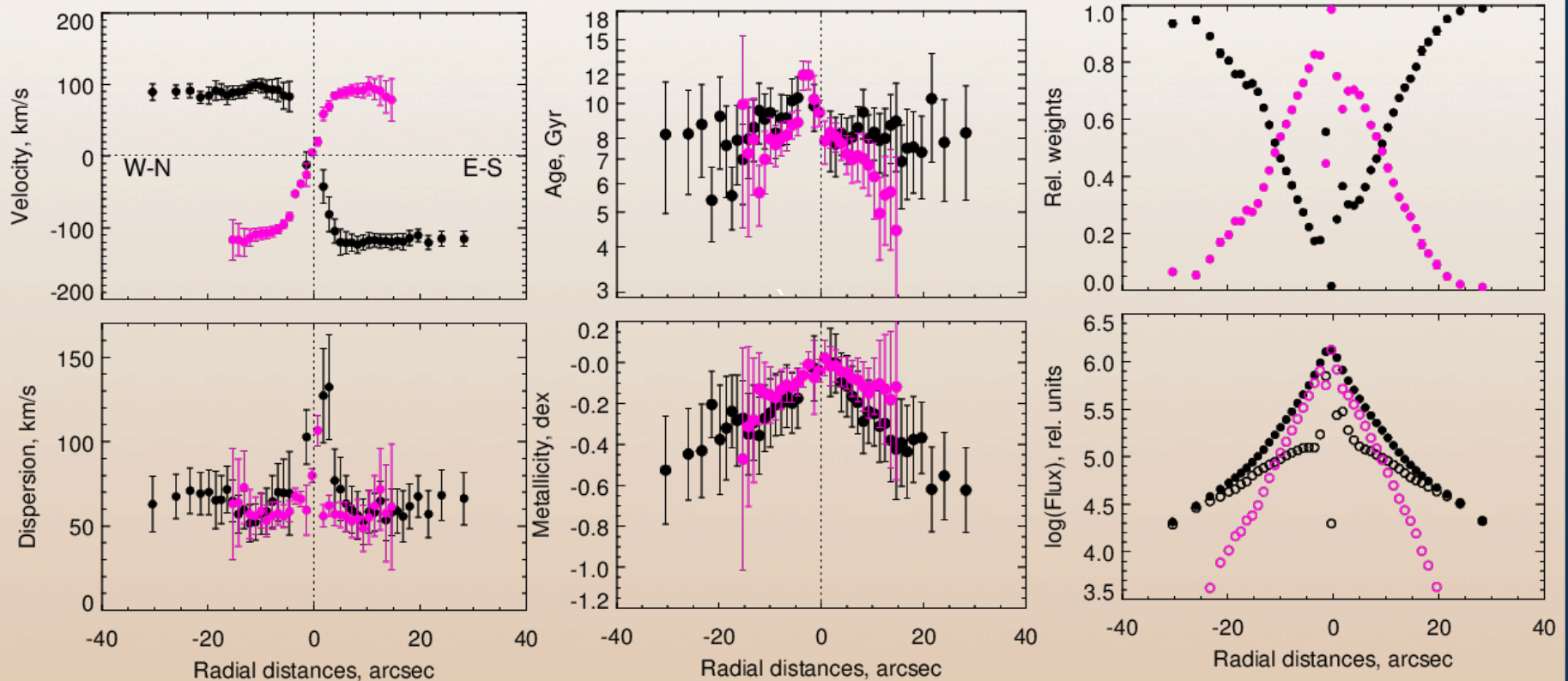
Spectral decomposition

$$S_{models} = W_1(L(\nu_1, \sigma_1) * T_1) + W_2(L(\nu_2, \sigma_2) * T_2)$$



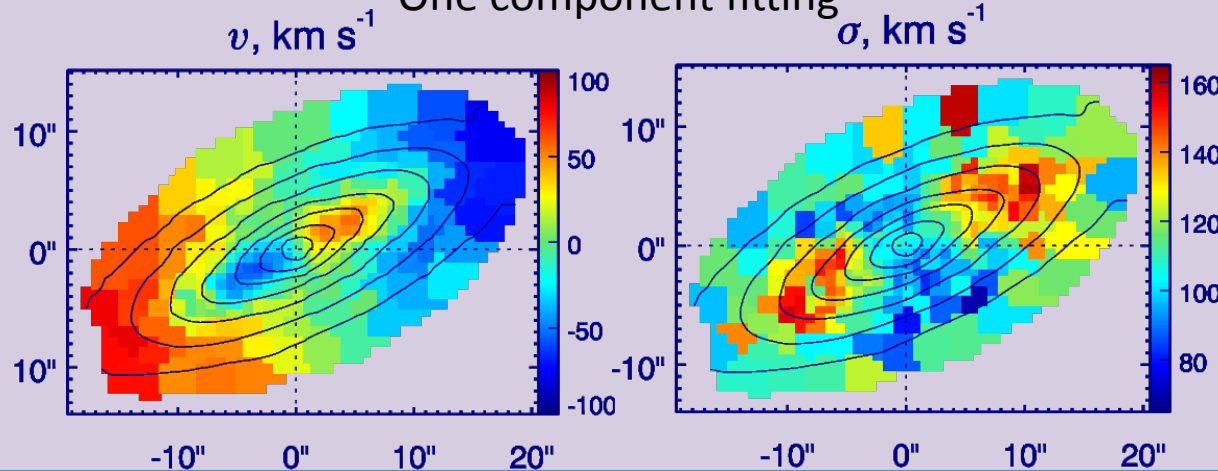
Spectral decomposition (long-slit)

$$S_{models} = W_1(L(v_1, \sigma_1) * T_1) + W_2(L(v_2, \sigma_2) * T_2)$$



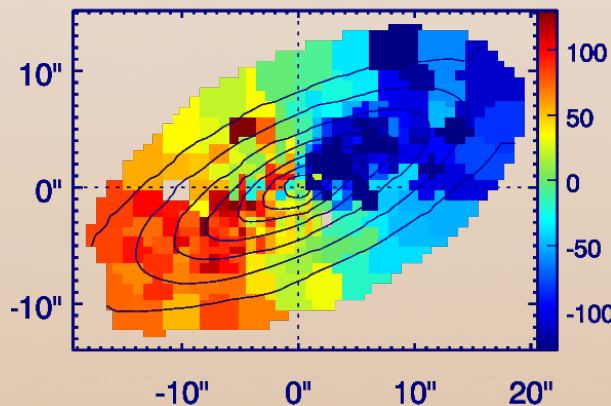
Spectral decomposition (IFU)

One component fitting

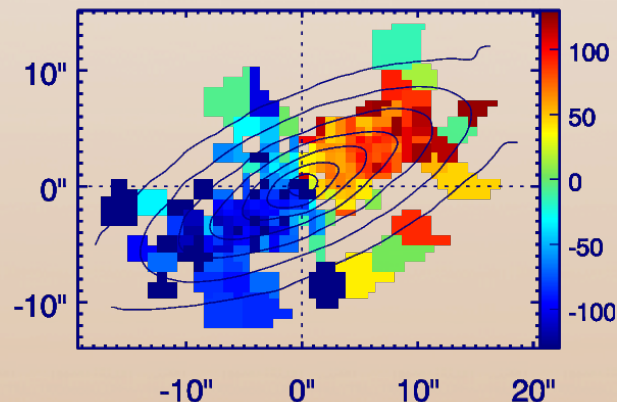


Decomposition of SAURON data is more complicated due to lower spectral resolution. In order to stabilize solution we fixed velocity dispersion on 70 km/s .

v , km s^{-1}

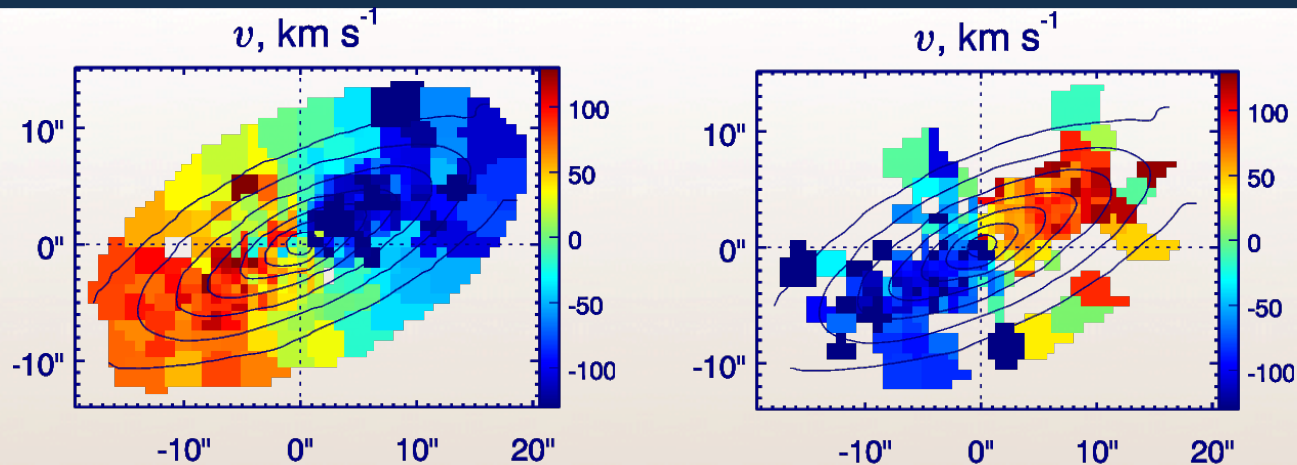


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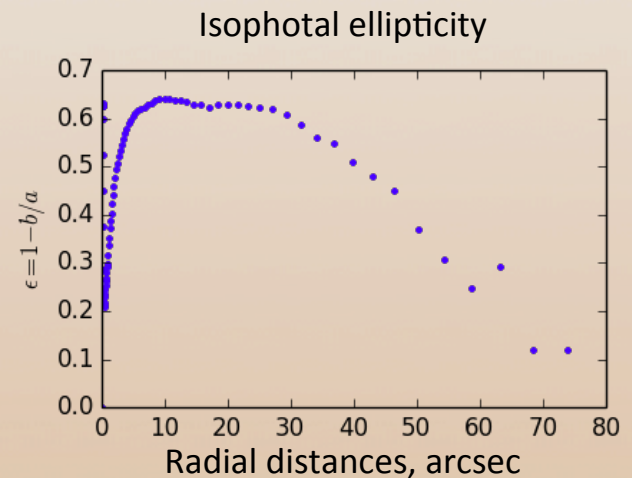
Two component fitting

Counter-rotation in the main plane or in the inclined one?



The tilted ring modeling of velocity maps probably helps us.

Isophotal analysis of image supports the inclined CR disc.

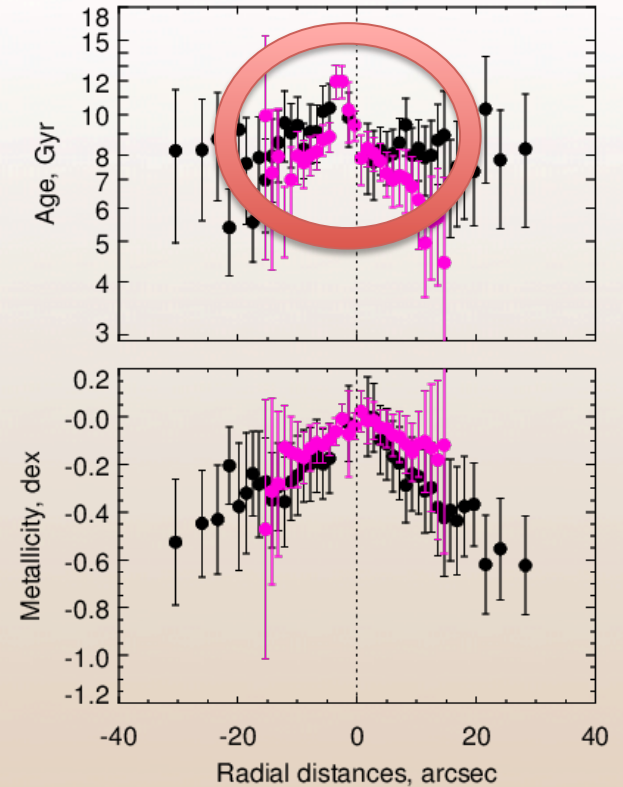


Origin and formation

- External gas accretion
- Satellite merger

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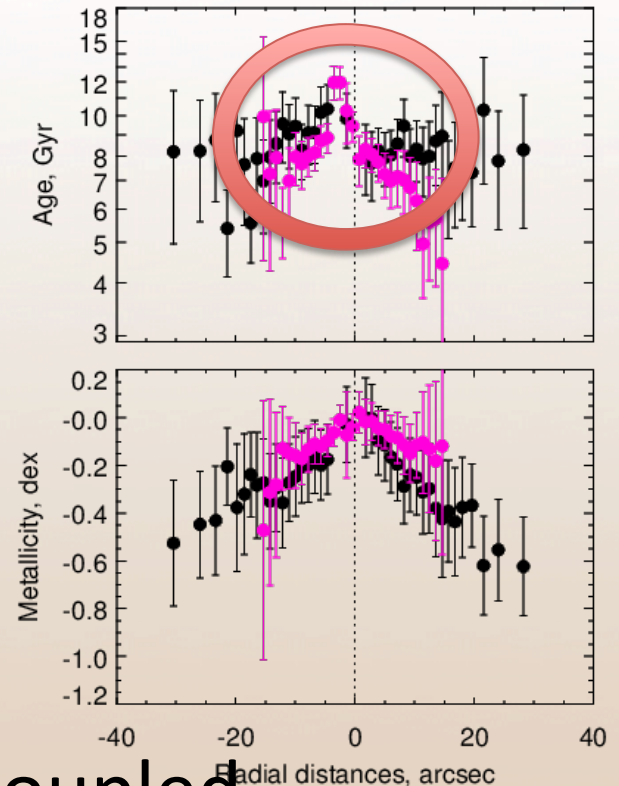


Origin and formation

- External gas accretion

- Satellite merger

- Such kind of kinematically decoupled structures are the brilliant laboratory for dynamical analysis.

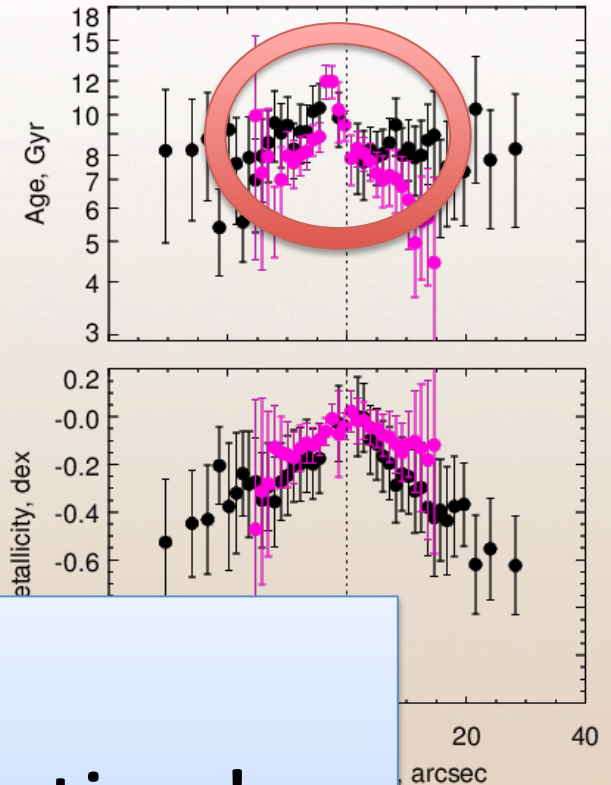


Origin and formation

- External gas accretion

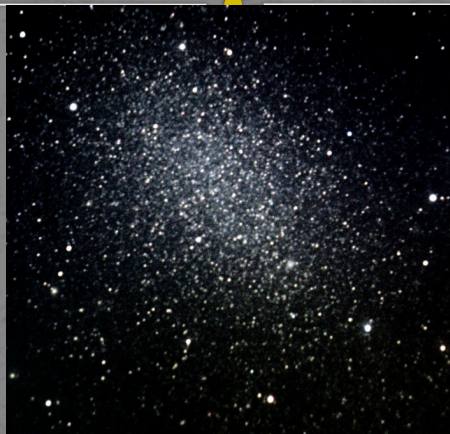
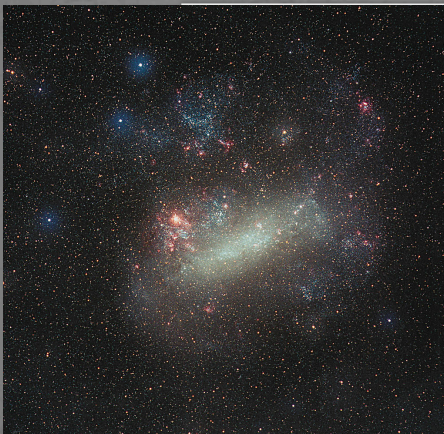
- Satellite merger

- Successive
structural
dynamical



Thank you for attention!

Stellar population properties of transition type galaxies in the Centaurus A group



Recall the talk of G. Battaglia



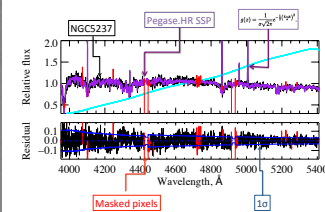
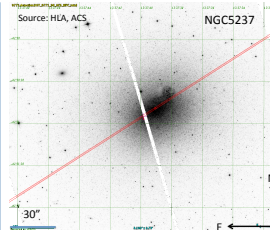
Stellar population properties of transition type galaxies in the Centaurus A group
M. Koleva¹, S. Côté², A. Bouchard³, Ph. Prugniel⁴, S.

N 25

Background

Dwarf galaxies are small and common, and as such they are handy tools for studying the star-formation mechanisms in galaxies. In particular, transition type dwarfs can be used as quenching signposts, but only if they are indeed at their mid-life crisis, or in the other words, if they are evolutionarily situated between the star-forming and quiescent dwarfs.

To test this hypothesis, we selected 4 galaxies in the Cen A group with stellar masses around $10^{10} M_{\odot}$. Besides their regular elliptical appearance, these galaxies possess an amount of neutral gas up to 10% of their stellar mass, and they are detected in H₂ (Côté et al. 2009).



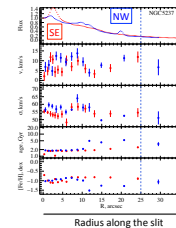
Data and Analysis

We conducted long slit optical observations with GMOS/Gemini (GS-2008-Q44). The slit width was set to 1", and together with the B1200 grating, this resulted in a spectral resolution (σ) of 61 km/s. The integration time varied between 1 and 6 h per object, reaching $S/N/pix \sim 15$ in the centres.

For the analysis we used the full spectrum fitting package ULYSS (Koleva et al. 2009). We plugged in Pegase.HR/Elodie3.2 SSPs. The emission lines were represented as independent Gaussians. These models were further broadened and shifted to the LOSVD of the galaxy.

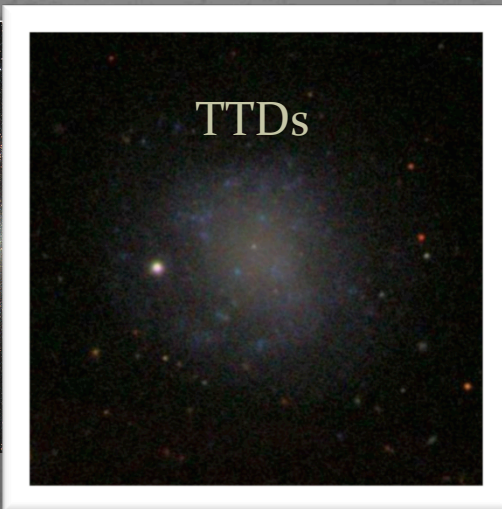
Results and Thoughts

Our preliminary results show that the systems are dispersion dominated with $v/\sigma < 1$, like most dwarf elliptical galaxies. They have prominent age gradients (SSP ages are changing from 50 Myr to 5 Gyr), hinting to shrinking star-formation regions with time as is observed also in late and early type dwarfs (Elmegreen et al. 2012, Koleva et al. 2011) as well as in the LG dwarfs. Their stellar metallicities are about -1 dex, consistent with the luminosity-metallicity relation of the Cen A and M81 dSph galaxies (Lianou et al. 2010; Crnojević et al. 2010). However, we do not observe changes of the metallicity with the radius, indicating mild metal enrichment and/or important metal losses.



Affiliations: ¹ University of Ghent, mira.koleva@ugent.be; ² Canadian Gemini Office, National Science Infrastructure, NRC; ³ Lost in east Canada; ⁴ Observatoire de Lyon

Stellar population properties of transition type galaxies in the Centaurus A group



TTDs



Recall the talk of G. Battaglia



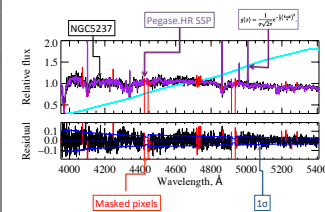
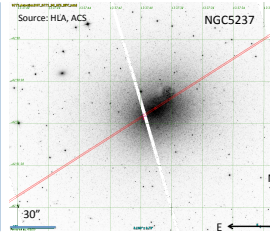
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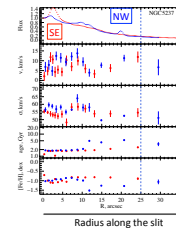
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For the analysis we used the full spectrum fitting package ULYSS (Koleva et al. 2009). We plugged in Pegase.HR/Elodie3.2 SSPs. The emission lines were represented as independent Gaussians. These models were further broadened and shifted to the LOSVD of the galaxy.

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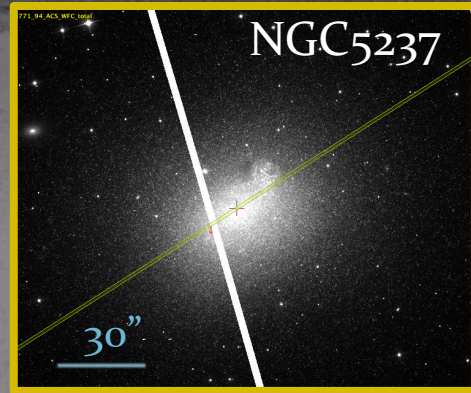
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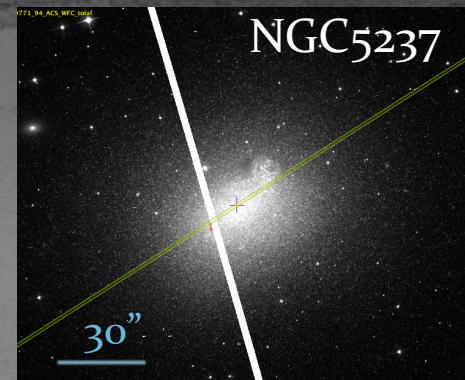
Sample, analysis, results*

- 4 transition type galaxies with $M \sim 10^8 M_{\odot}$
- 25h Long slit GMOS/GEMINI $\rightarrow S/N/p_{x_0} = 15$

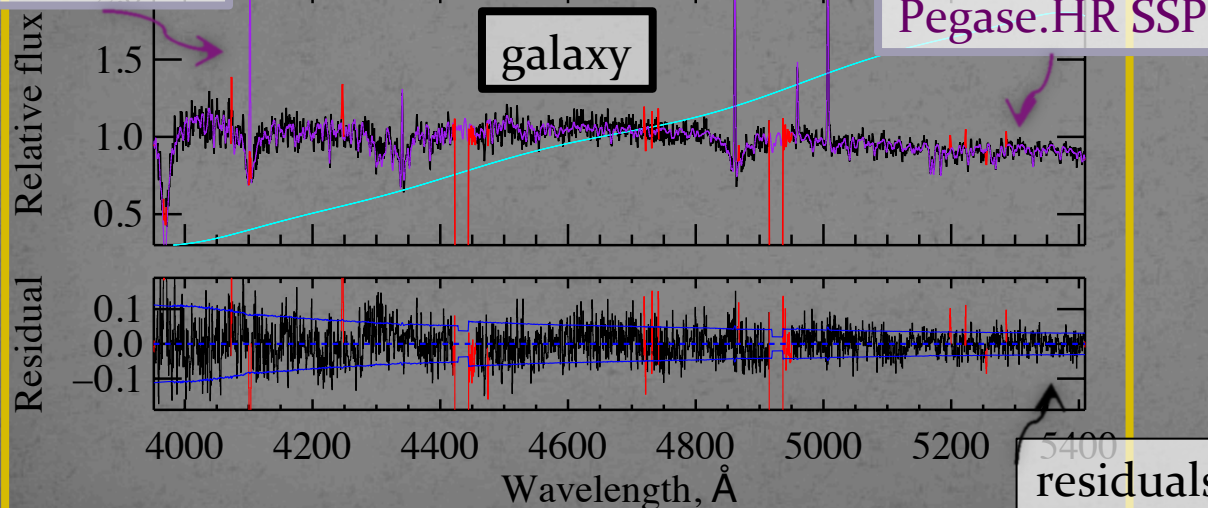


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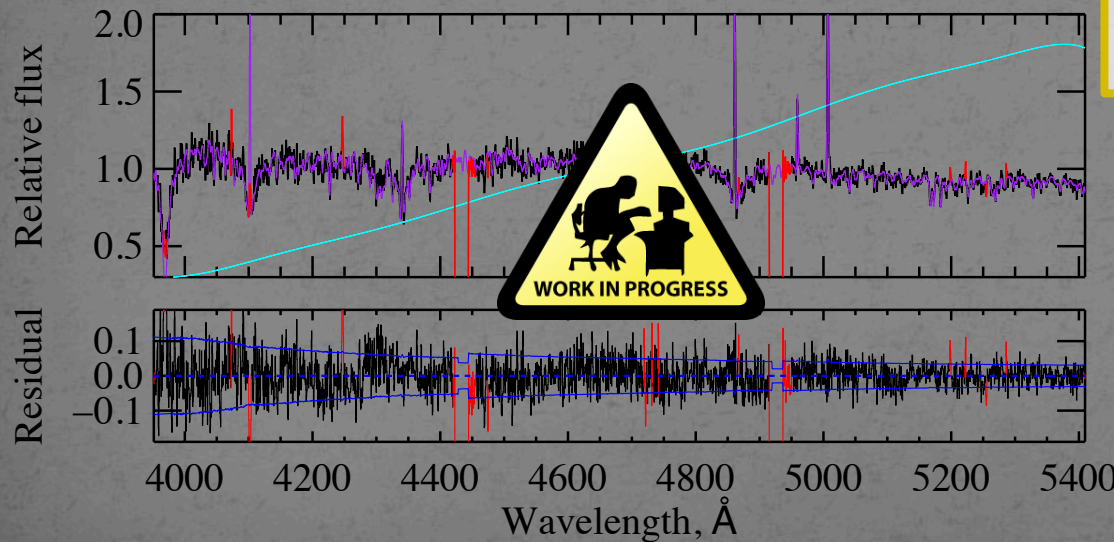
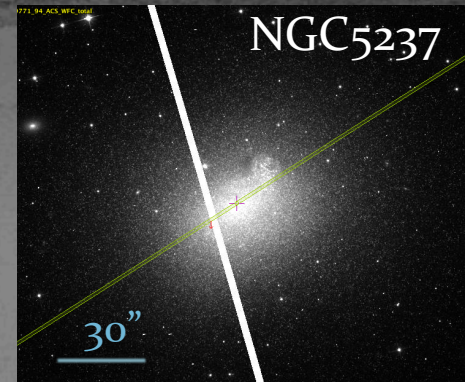


Gaussians

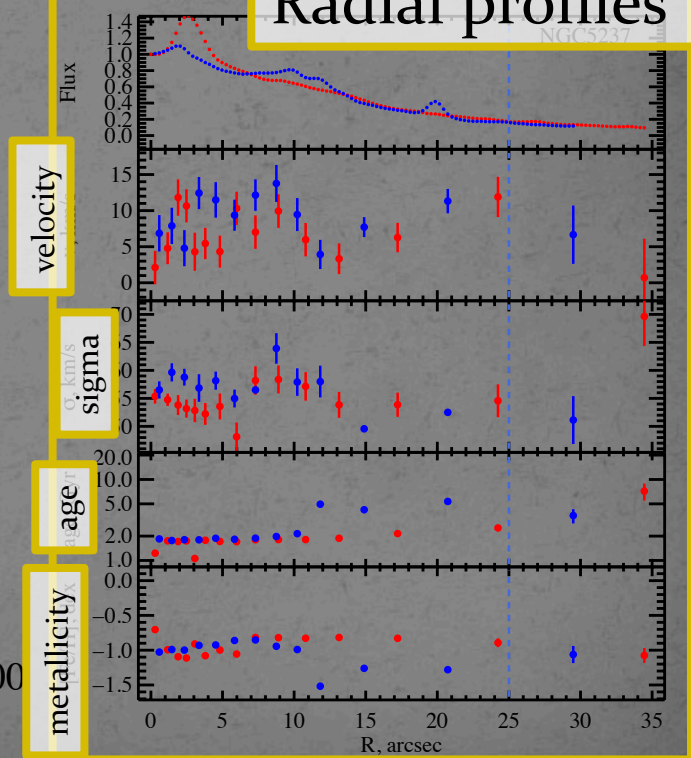


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Radial profiles*



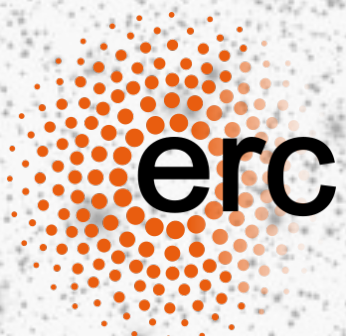
WFPC2 UV survey of GGCs The HB Temperature Distribution of M15

Lagioia E.P.¹ Dalessandro E.¹ Ferraro F.R.¹ Lanzoni B.¹ Salaris M.²

¹ Department of Physics and Astronomy, University of Bologna (Italy)

² Astrophysics Research Institute, Liverpool John Moores University (UK)

Poster no. 26

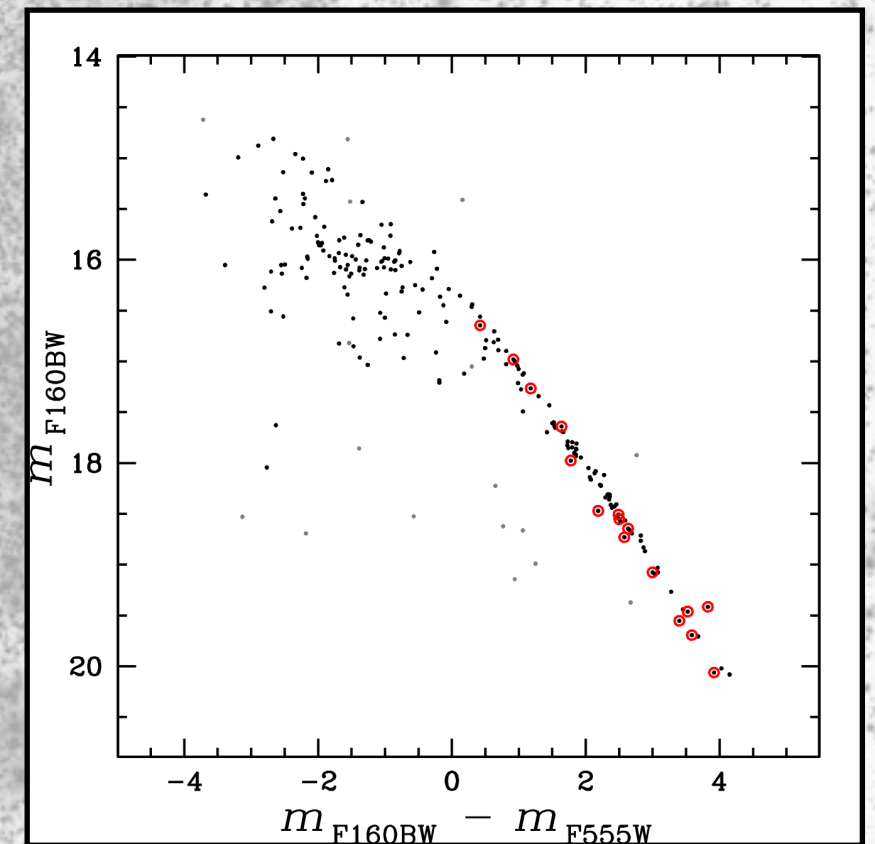
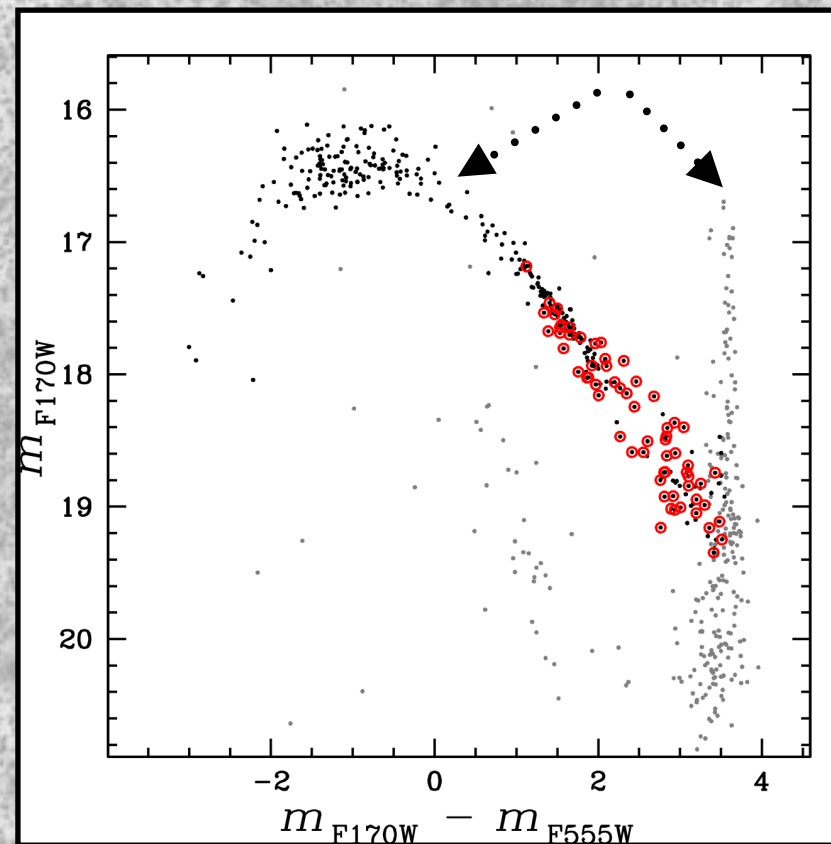
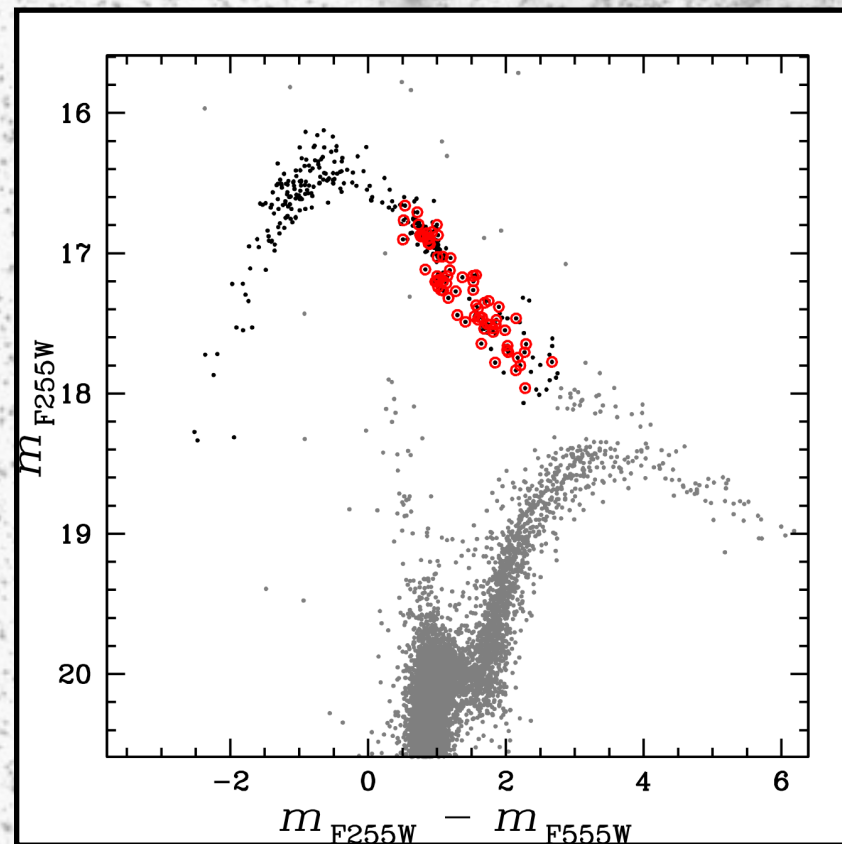


RASPUTIN – ESO Garching, 16 October 2014



UV-optical CMDs

Homogeneous photometric survey of 31 GGCs in far – mid UV and optical bands using WFPC2@HST (GO 11975, PI: F. Ferraro).



cool stars are as bright as BHBs in F170W filter

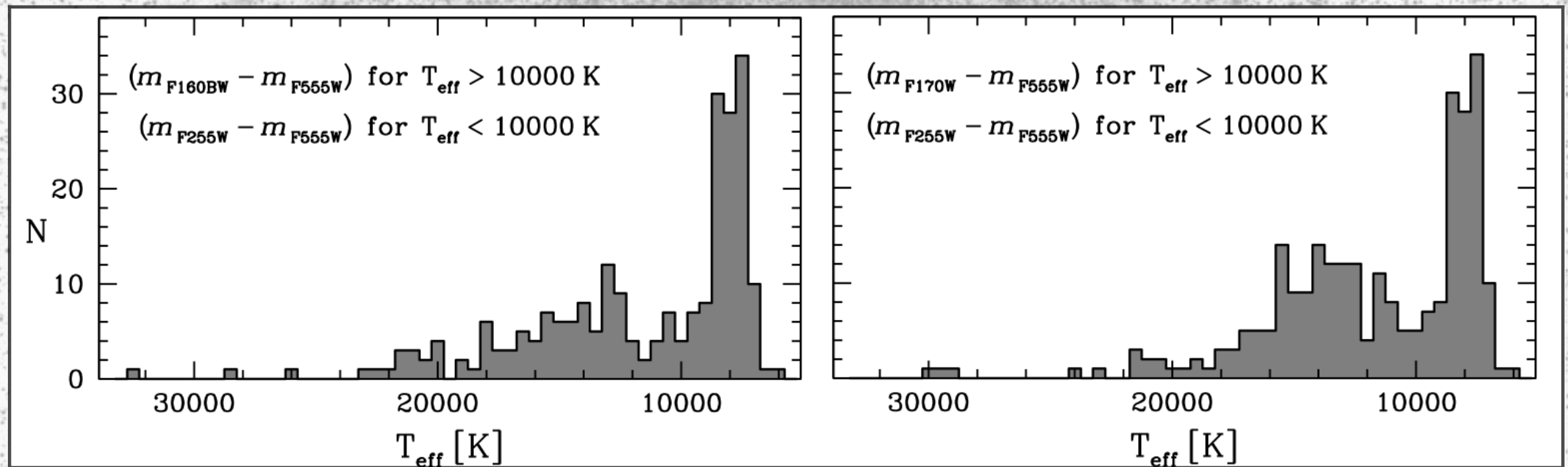
RR Lyrae from Clement+ 2001 catalogue

Poster
no. 26

RASPUTIN – ESO Garching, 16 October 2014
E.P. Lagioia



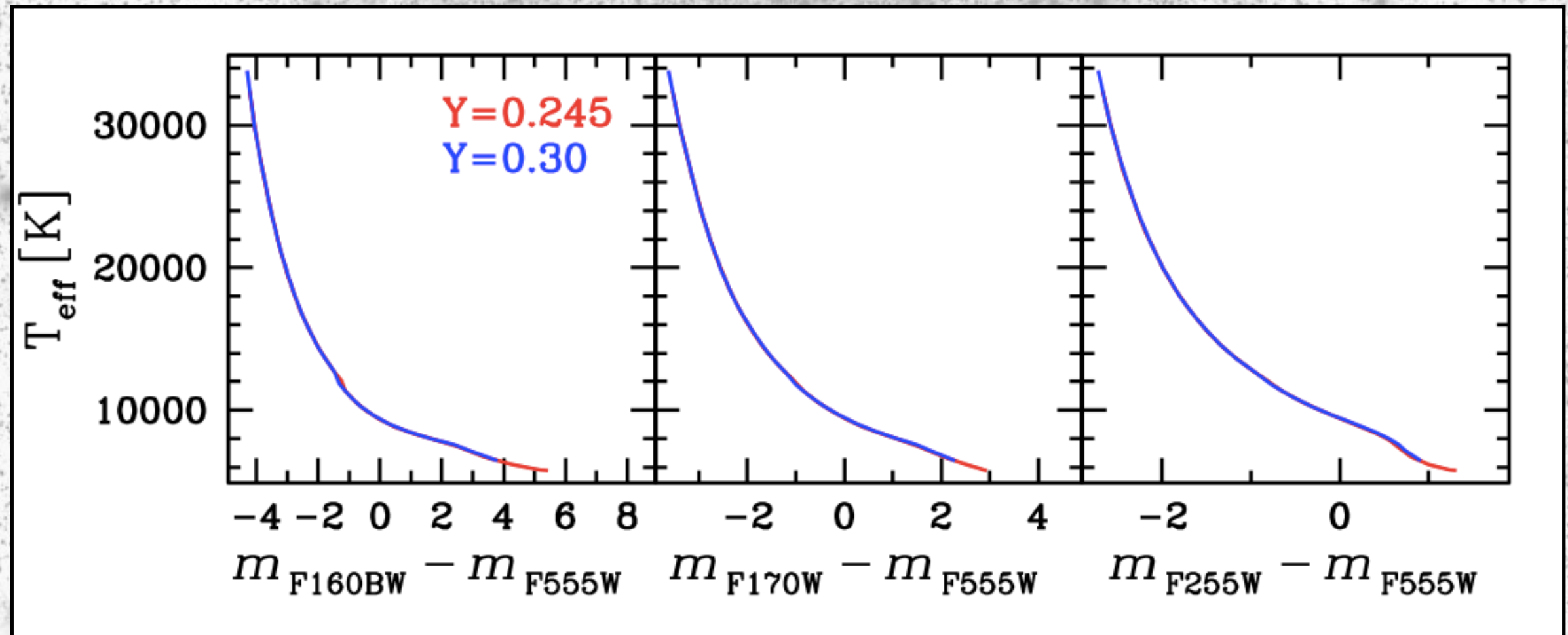
HB Temperature distribution



Multimodal distribution

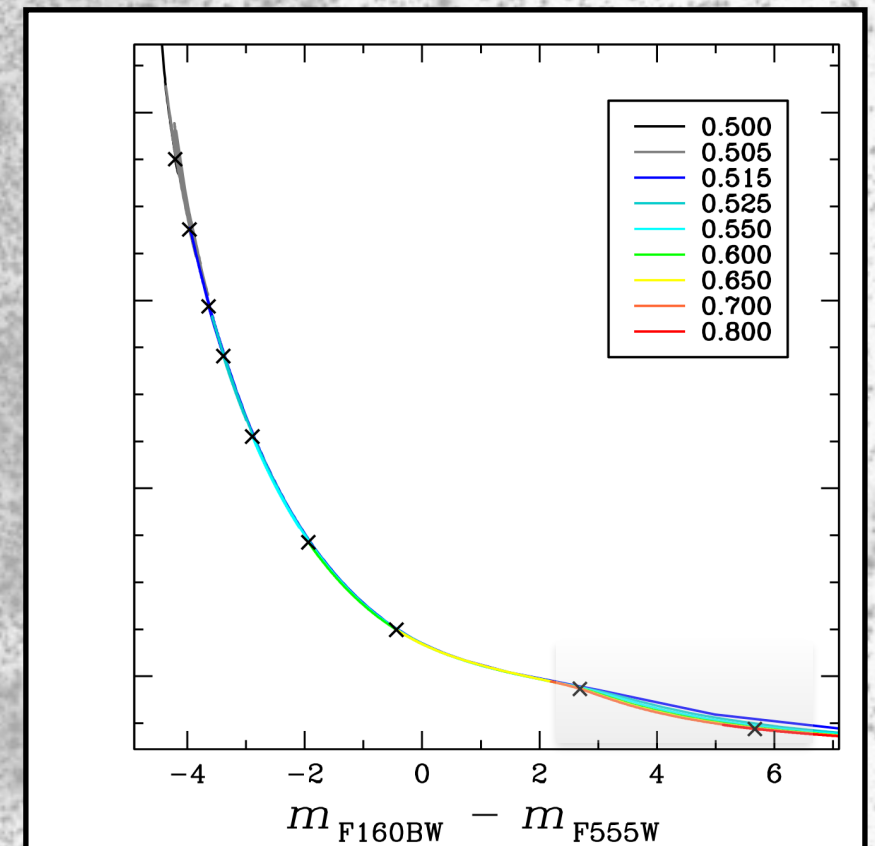
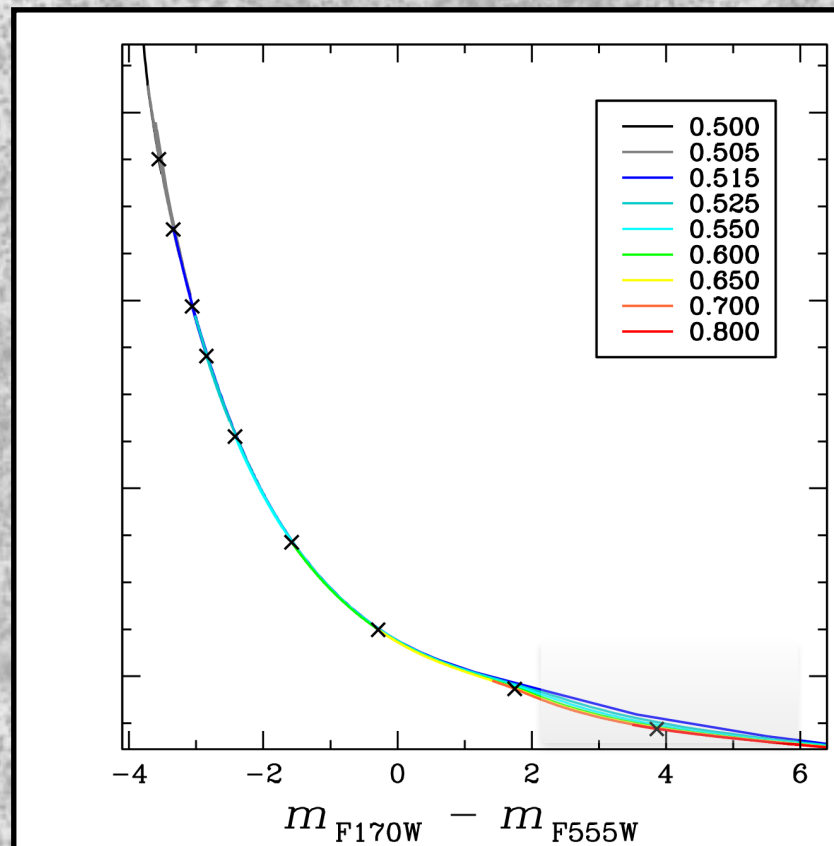
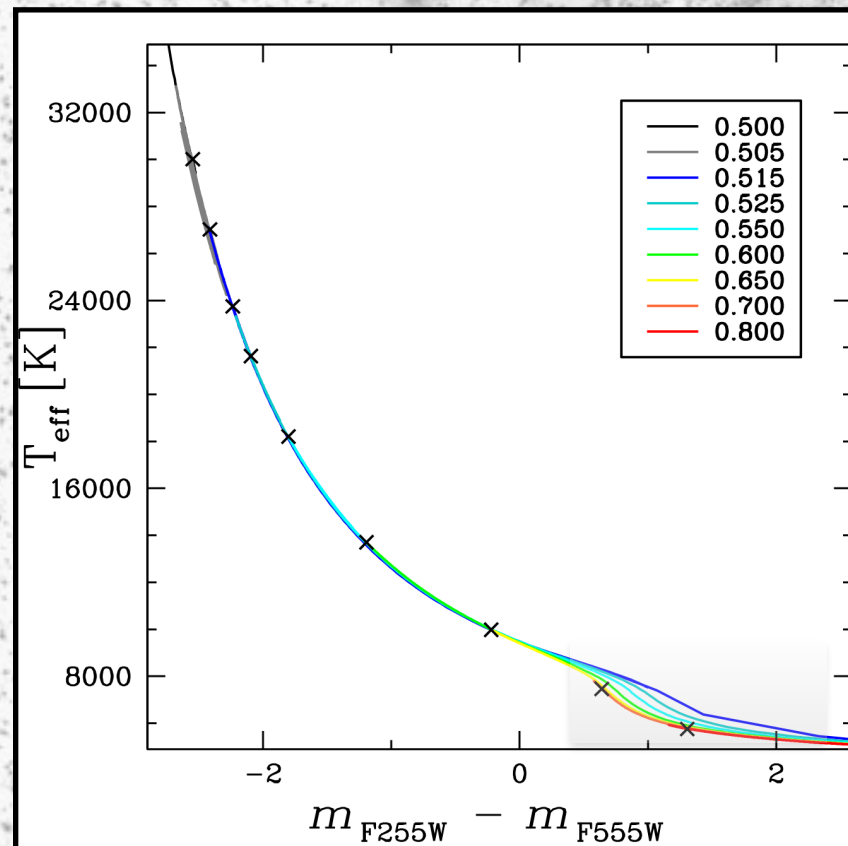
- from $T_{\text{eff}} \sim 6,000$ K to $\sim 30,000$ K
- main peak located at $T_{\text{eff}} \sim 8,000$ K and secondary at $\sim 14,000$ K
- About 95% of the cluster HB stars lie below $T_{\text{eff}} \sim 20,000$ K

Y variation



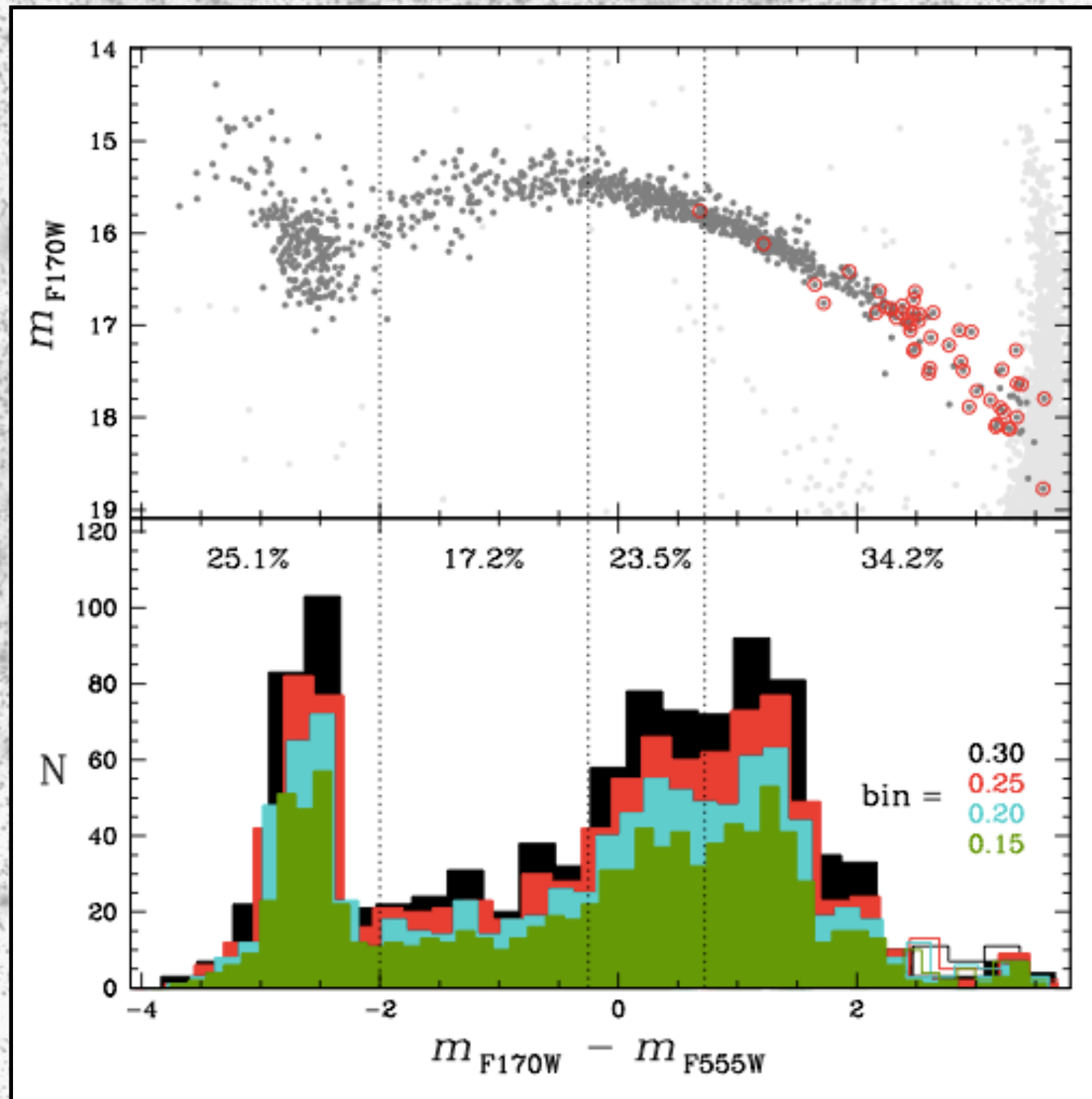
No effects on the color - T_{eff} relation

Evolutionary effects



~ 800 K for $T_{\text{eff}} < \sim 8000$ K $\longrightarrow$ $\sim 10\%$ error in
F255W color - T_{eff} relation

Omega Cen UV-opt CMD: color distribution



Poster
no. 26

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E.P. Lagioia

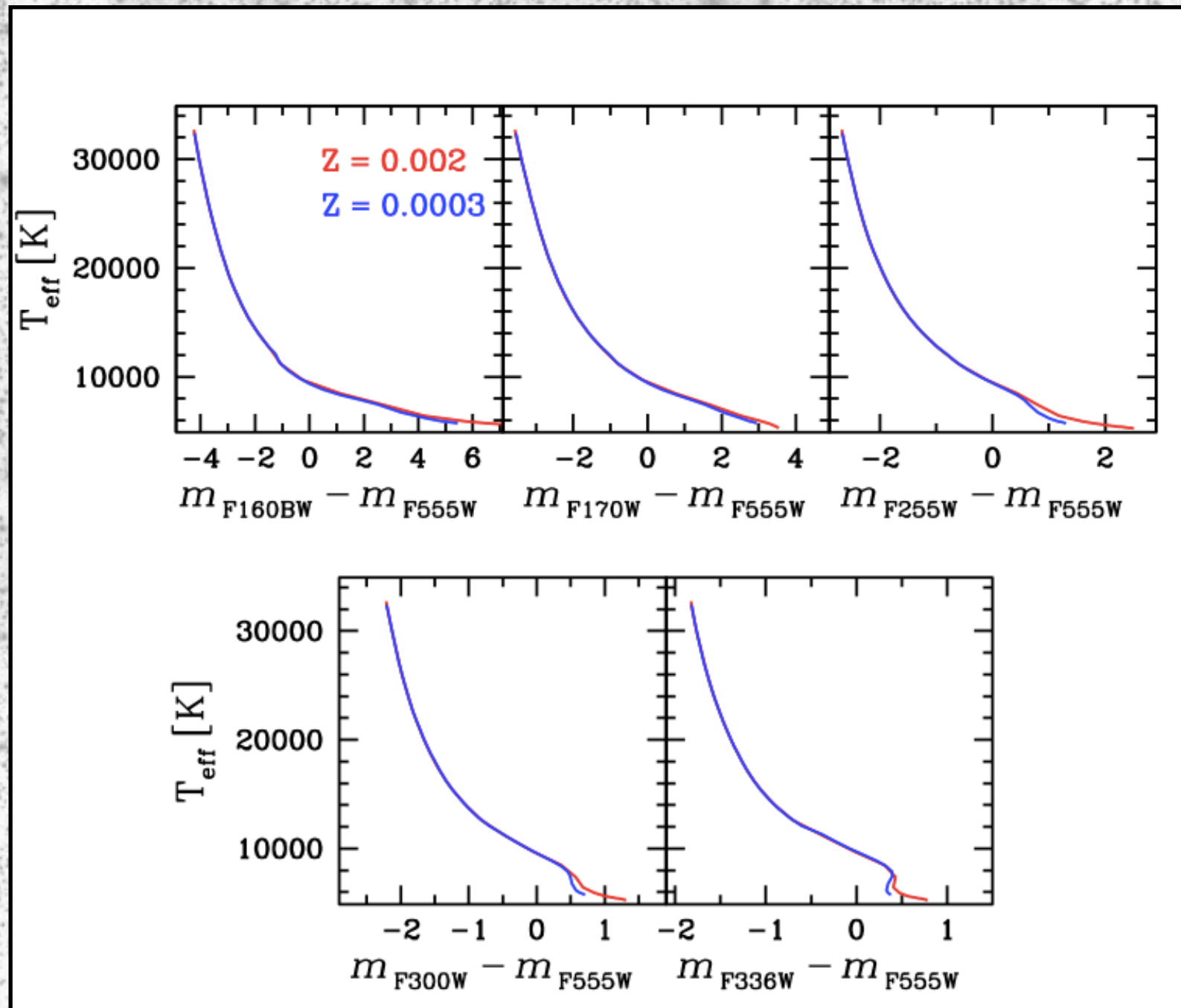
Thanks

Poster
no. 26

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E.P. Lagioia



Z variation



No effects on the color - T_{eff} relation

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E.P. Lagioia

Poster
no. 26





The extreme
outer regions
of M87. The
PN
perspective

A.Longobardi
O.Gerhard
M.Arnaboldi
R.Hanushik

Suprime-
Cam/FLAMES
Surveys

PN Spatial
Distribution
and Surface
Density
Profile

M87 halo and
IC PN
Luminosity
Function

M87 velocity
dispersion
profile

The extreme outer regions of M87. The PN perspective

A.Longobardi
O.Gerhard
M.Arnaboldi
R.Hanushik

RASPUTIN

ESO, 16th October 2014



The outer regions of M87

The extreme
outer regions
of M87. The
PN
perspective

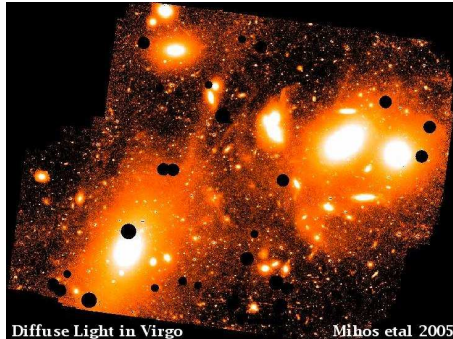
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Ultra-deep wide field ($1.5^\circ \times 1.5^\circ$) image of the Virgo cluster core
(Mihos et al. 2005)



Suprime-cam/FLAMES Surveys Survey: Imaging and Spectroscopy

The extreme outer regions of M87. The PN perspective

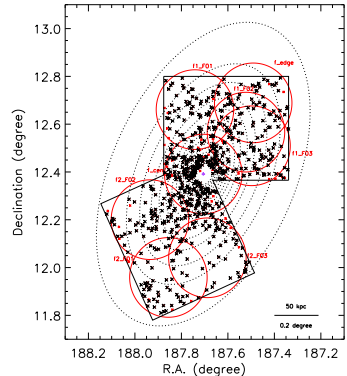
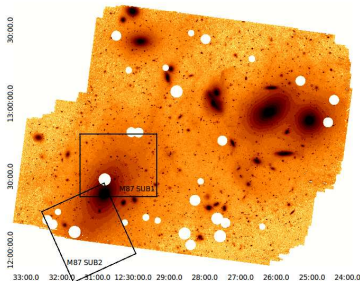
A.Longobardi
O.Gerhard
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R.Hanushik

Suprime-Cam/FLAMES Surveys

PN Spatial Distribution and Surface Density Profile

M87 halo and IC PN Luminosity Function

M87 velocity dispersion profile





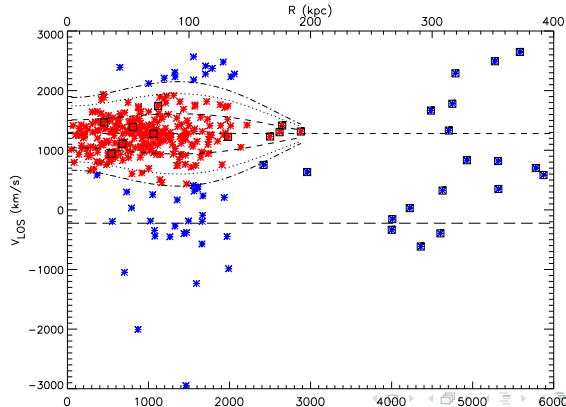
The PNe projected phase-space distribution, VLOS-R: separating the M87 halo and ICL components

Sample of ~ 350 spectroscopically confirmed PNe

Red stars: halo PNe (bound)

Blue stars: intracluster PNe (unbound)

Black squares: data from Doherty et al. 2009





Surface Density profile (Longobardi et al. 2014)

The extreme
outer regions
of M87. The
PN
perspective

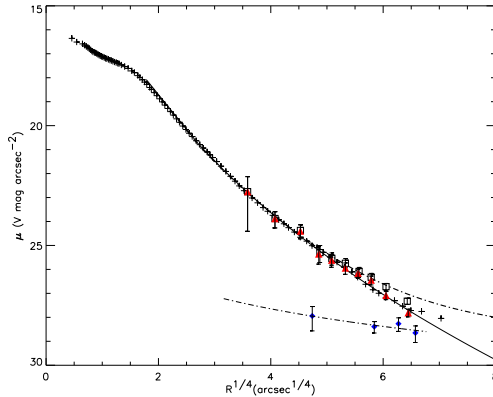
A.Longobardi
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PN Spatial
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M87 velocity
dispersion
profile



$$\alpha_{\text{halo}} = 1.05 \times 10^{-8} N_{\text{PN}} L_{\odot, \text{bol}}^{-1}$$

$$\alpha_{\text{ICL}} = 2.4 \times 10^{-8} N_{\text{PN}} L_{\odot, \text{bol}}^{-1}$$



Planetary Nebula Luminosity Function (Longobardi et al. 2014)

The extreme
outer regions
of M87. The
PN
perspective

A.Longobardi
O.Gerhard
M.Arnaboldi
R.Hanushik

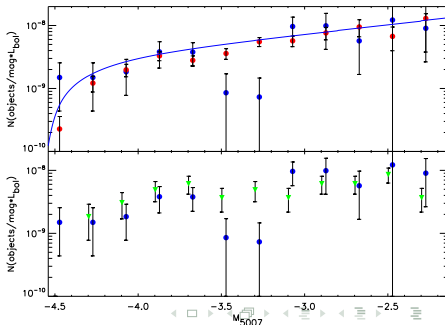
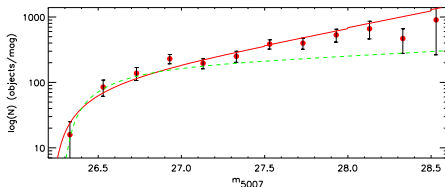
Suprime-
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M87 halo and
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Luminosity
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M87 velocity
dispersion
profile

Red: halo PNe
Blue: intracluster PNe
Green: M33 PNe from
Ciardullo et al. 2004





M87 velocity dispersion profile

The extreme
outer regions
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PN
perspective

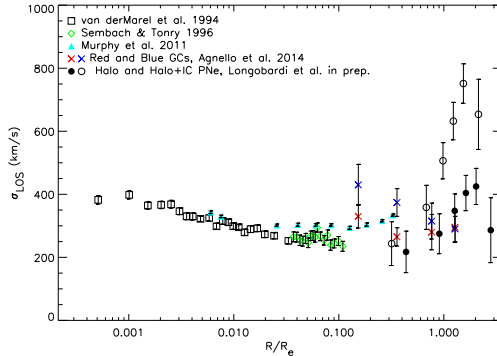
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Suprime-
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PN Spatial
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Density
Profile

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IC PN
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M87 velocity
dispersion
profile





ULL

Universidad
de La Laguna

RR Lyrae stars in Local Group dwarf galaxies (*poster #28*)

Clara E. Martínez-Vázquez
cmartinez@iac.es

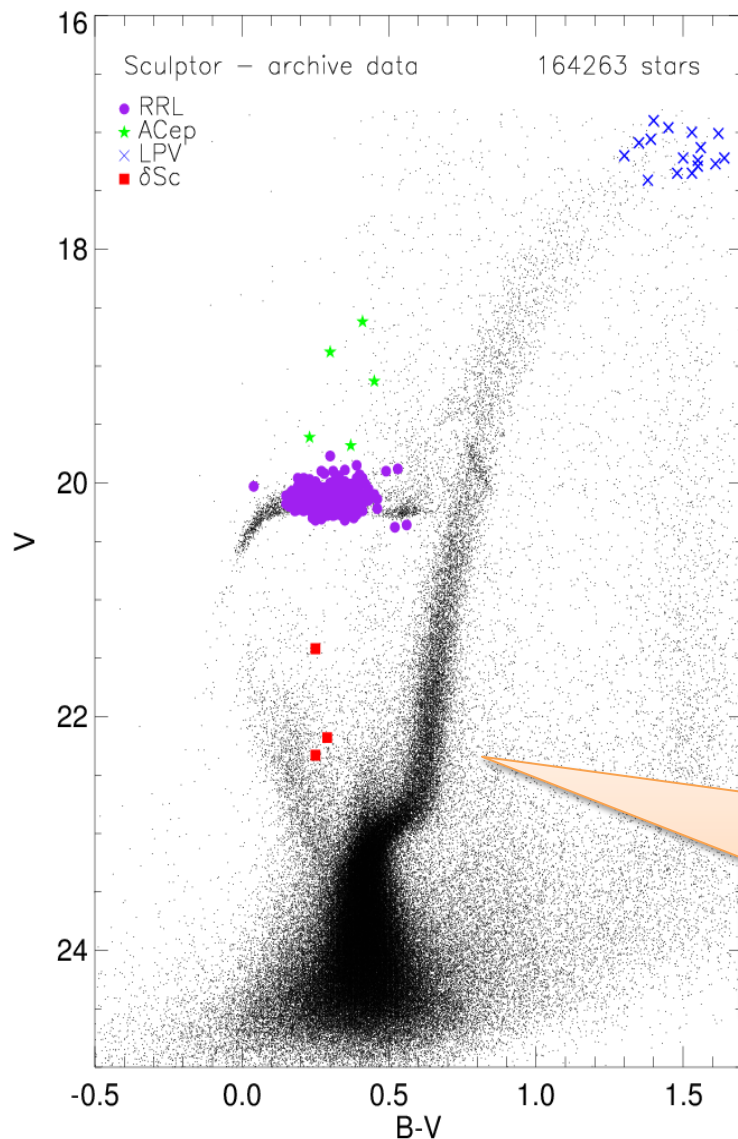
Instituto de Astrofísica de Canarias (IAC)
Universidad de La Laguna (ULL)

M. Monelli, P. B. Stetson , E. J. Bernard,
C. Gallart , G. Fiorentino and G. Bono

Our Project

- RR Lyrae stars are:
 - tracers of old-population (> 10 Gyr)
 - excellent probes of the environmental conditions of the first stages of galaxy evolution
 - Comparative study of the properties of RR Lyrae stars in the surviving MW satellites and in the Halo
- Are the current nearby satellites the surviving representatives of the Halo's building-blocks?

First results for Sculptor dSph

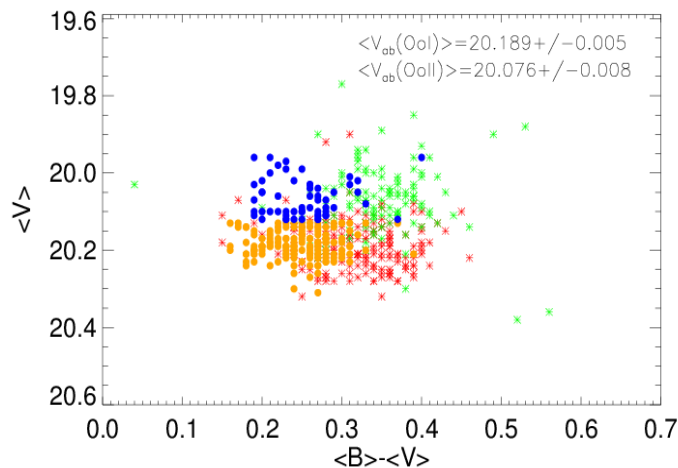
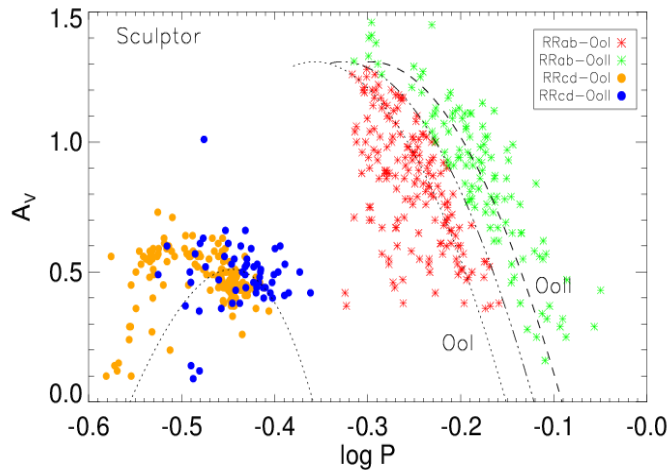


- $d=86$ Kpc (MW satellite)
- 2517 images (~ 1.3 sq.deg)
- Many ground-telescopes
- Time baseline ~ 25 years
- $\langle B \rangle, \langle V \rangle, \langle I \rangle = 46, 52, 26$

We have found **506 RRL**, **5 ACep**, **18 LPV** and **3 δ Sc** (283 of them are new discoveries).

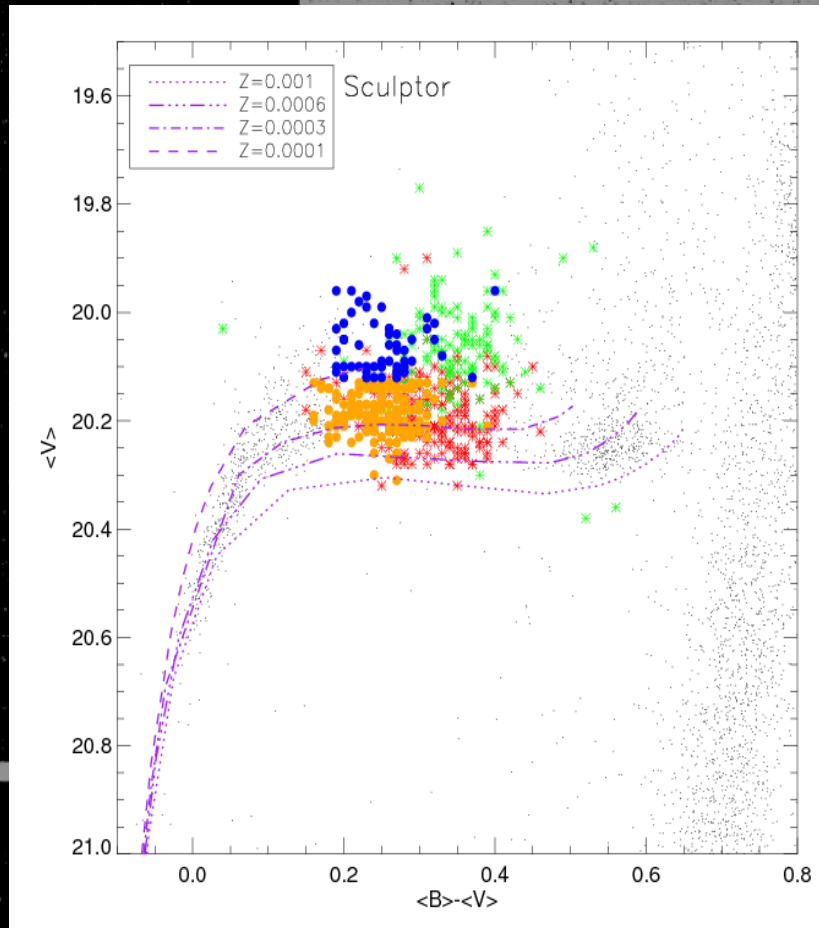
(Martínez-Vázquez et al. in prep.)

Period-Amplitude diagram



- Lines mark the locus of the Ool and Ooll stars defined by Cacciari et al. (2005)
- RR_{ab} stars show systematically different mean magnitude:
 - Ool: $\langle V \rangle = 20.19$ mag
 - Ooll: $\langle V \rangle = 20.07$ mag
- RR_{cd} stars (split at $V = 20.13$) show a similar trend

Evidence of metallicity spread



➤ The mean magnitude of the OoII RR_{ab} OoII is ~ 0.12 mag brighter than for the OoI stars

➔ $\Delta[Fe/H] \sim 0.5$ dex (Clementini et al. 2003; Bono et al. 2007)

➤ Spectroscopic data (Clementini et al. 2005 - ΔS technique) suggests a smaller metallicity difference (~ 0.1 dex, lacking the most metal-poor stars, Starkenburg et al. 2013)

➔ Work is in progress to understand this discrepancy

Conclusions

- The aim is to investigate the nature of building-blocks of the MW through the study of RR Lyrae stars
- We observe an evidence of metallicity spread in the RR Lyrae of Sculptor dSph
- And II might present a similar behavior (see poster)

Thanks for your attention!

POSTER
#28



RR Lyrae stars in Local Group dwarf galaxies

C. E. Martínez-Vázquez^{1,2}, M. Monelli^{1,2}, P. B. Stetson³, E. J. Bernard⁴, C. Gallart^{1,2}, G. Fiorentino⁵ and G. Bono^{6,7}

¹ IAC Instituto de Astrofísica de Canarias (Tenerife, Spain) ² ULL Universidad de La Laguna (Tenerife, Spain) ³ Dominion Radio Astrophysical Observatory (Victoria, Canada) ⁴ University of Toronto, Institute for Astronomy (Burlington, Ontario, Canada) ⁵ INF - Osservatorio Astronomico di Bologna (Bologna, Italy) ⁶ Università di Roma Tor Vergata (Rome, Italy) ⁷ INF - Osservatorio Astronomico di Roma (Monte Porzio Catone, Italy)



martinez@iac.es

ABSTRACT

RR Lyrae stars are the best tracers of old stellar populations (> 10 Gyr), and are excellent probes of the environmental conditions of the first stages of galaxy evolution. The present study is part of a long-term project aimed at deriving homogeneous and complete photometry of the variable stars populations in nearby Local Group galaxies. In particular, we focus here on the Sculptor and And II dSph galaxies. The analysis of their pulsational properties will allow us to study if these resemble the small systems that accreted on the Galactic Halo.

INTRODUCTION AND PROJECT PRESENTATION

- The Λ CDM framework and the accretion of satellites evidence supports that the mass assembly in giant galaxies proceed through the merging of smaller systems. However, the **protogalactic fragments have not been firmly characterized** yet (Venn et al. 2004; Madau & Dickinson 2014).
- Stars that we observe today as **RR Lyrae stars (RRL)** were already in place at early epochs when most of the assembling of the Milky Way (MW) Halo took place. Therefore, a comparative study of the properties of RRL in the surviving MW satellites and the halo can bring important **insight on the MW formation**.
- We are carrying out a **long-term project** aimed at deriving **homogeneous photometry** for nearby stellar systems. This will allow us to build a **large data base of variable stars in nearby galaxies of the Local Group (LG)**, to be compared with existing large surveys of variable stars in the Milky Way Halo (Fiorentino et al. 2012; Stetson et al. 2014).
- Our main aim is to investigate whether the **current nearby satellites** are the surviving representatives of the **Halo's building-blocks** (Tolstoy et al. 2009).
- In particular, the current study focuses on two galaxies: **Sculptor and And II** (Martínez-Vázquez et al. in prep.)

COLOUR-MAGNITUDE DIAGRAM

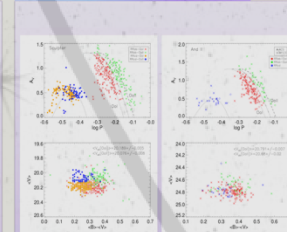
Left figure shows the CMD of the central regions in Sculptor dSph (d=86 Kpc) through 2517 calibrated images (~1.3 sq. deg, black dots). These data covers a time baseline of ~25 years in many ground-telescopes. The mean number of the images in B, V, and I are 46, 52 and 26, respectively.

Right figure shows the CMD of And II dSph (d=652 Kpc, M31 satellite) based on HST data (ACS-WFC3, 17 orbits). Note the well separated red giant branches, suggesting the existence of at least two stellar components with different age and/or metallicity.

We have found 506 RRL, 5 Anomalous Cepheids (Acep), 18 Long Period Variables (LPV) and 3 δ Scuti (283 of them are new discoveries).

We have found 192 RRL and 4 Acep. We have not detected LPV stars, due to the short time baseline.

PERIOD-AMPLITUDE DIAGRAMS



Top panels show the **period-amplitude (or Bailey) diagram** in the V band for the RRL in the two galaxies. The dotted and dashed lines mark the locus of the Ool and Ool stars defined by Cacciari et al. (2005). The dashed-dotted-dotted line is used to separate the RRL stars belonging to each Oo-type (Ool: red asterisk, Ool: green asterisk). Bona-fide RRcd stars are also plotted. Bottom panels show a **zoom-in on the HB**. Stars selected in the Bailey diagram clearly show systematically different mean magnitude (as labeled). In the case of Sculptor, stars close to the Ool sequence are brighter ($V=20.09$) than Ool stars ($V=20.18$). When splitting the RRL stars at $V=20.13$, they show a similar trend. Interestingly, the two samples selected in And II present the same difference as in Sculptor. The ratio $RRcd/RRab$ (0.14) is significantly lower in And II than the Sculptor (0.72). For this reason we are not able to split the And II RRcd stars in analogous subgroups.

EVIDENCE OF METALLICITY SPREAD

The plot in this box shows a zoom-in on the HB of Sculptor. The purple lines represent ZAHB loci and tracks of solar-scaled models from the BaSTI library (Pietrinferni et al. 2004). They have been plotted assuming $E(B-V)=0.018$ and $(m-M)_0=19.67$ (McConnachie et al. 2012). They cover all the HB. The difference of the mean magnitude between each Oo-type in RRL is ~0.12. By assuming the luminosity-metallicity relation from Clementini et al. 2003, this suggests a difference in the mean metallicity of the two sample of the order of 0.5 dex in $[Fe/H]$. A similar large spread is supported deriving the mean metallicity using the method presented in Bono et al. 2007. However, the spectroscopic data presented by Clementini et al. 2005 and based on the δS technique suggests a smaller metallicity difference between the two groups, of the order of 0.1 dex. Work is in progress to understand this discrepancy.

We note the magnitude difference between the two groups of stars selected in And II present a similar mean V magnitude difference of 0.12 mag. This might suggest that a metallicity spread is also present within the old population of this galaxy. Future work will investigate if a correlation exists with the stellar substructures detected by Amorisco et al. 2014.

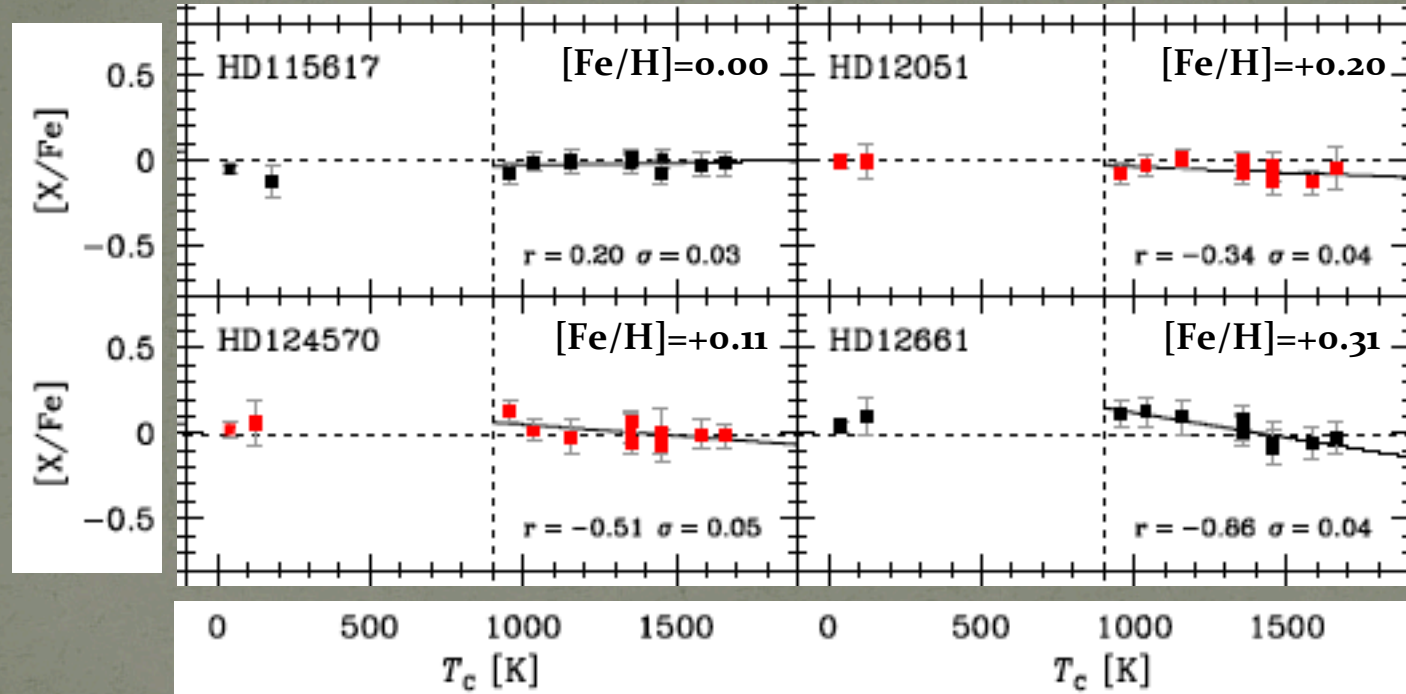
CONCLUSIONS

Our project targets variables stars, and in particular RR Lyrae stars, in nearby galaxies, with the aim to investigate the nature of the building blocks of the MW. This field will greatly benefit from the advent of the next generation of extremely large telescopes. In particular, the **first generation E-ELT spectrographs** will allow direct abundance measurements of HB stars in most LG galaxies.

Detailed elemental abundances of nearby thin disc G-K dwarfs: Galactic chemical evolution effects for exoplanet studies

A. de C. Milone (andre.milone@inpe.br) & R. da Silva (ronaldo.dasilva@roma2.infn.it)

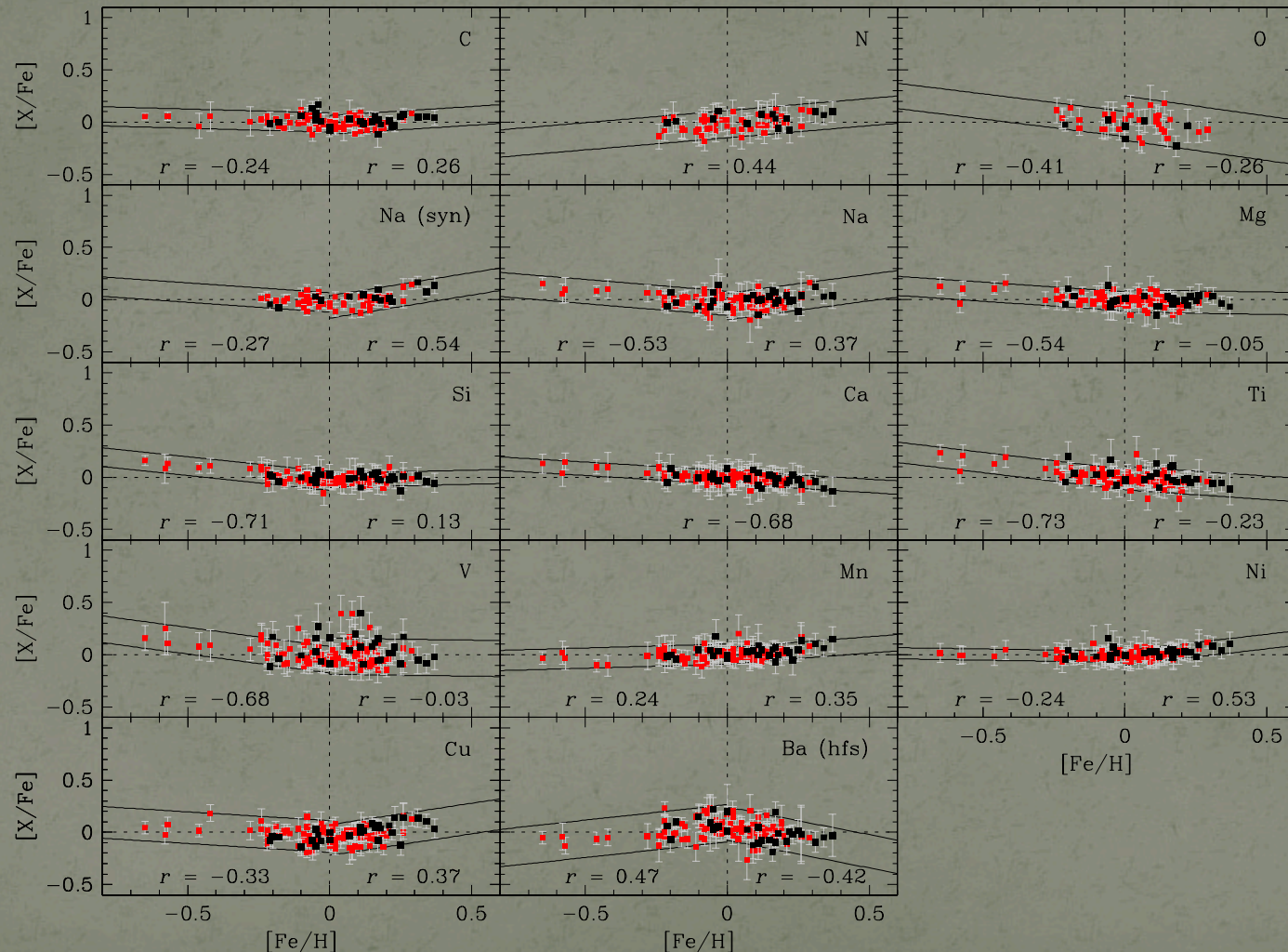
GOAL: accounting for the Galaxy's chemical evolution effects on the $[X/Fe]$ analysis as a function of X's condensation temperature



Dwarfs without giant planets and **dwarfs with giant planets**.

HOW? Two procedures to account for the effects on $[X/Fe]$

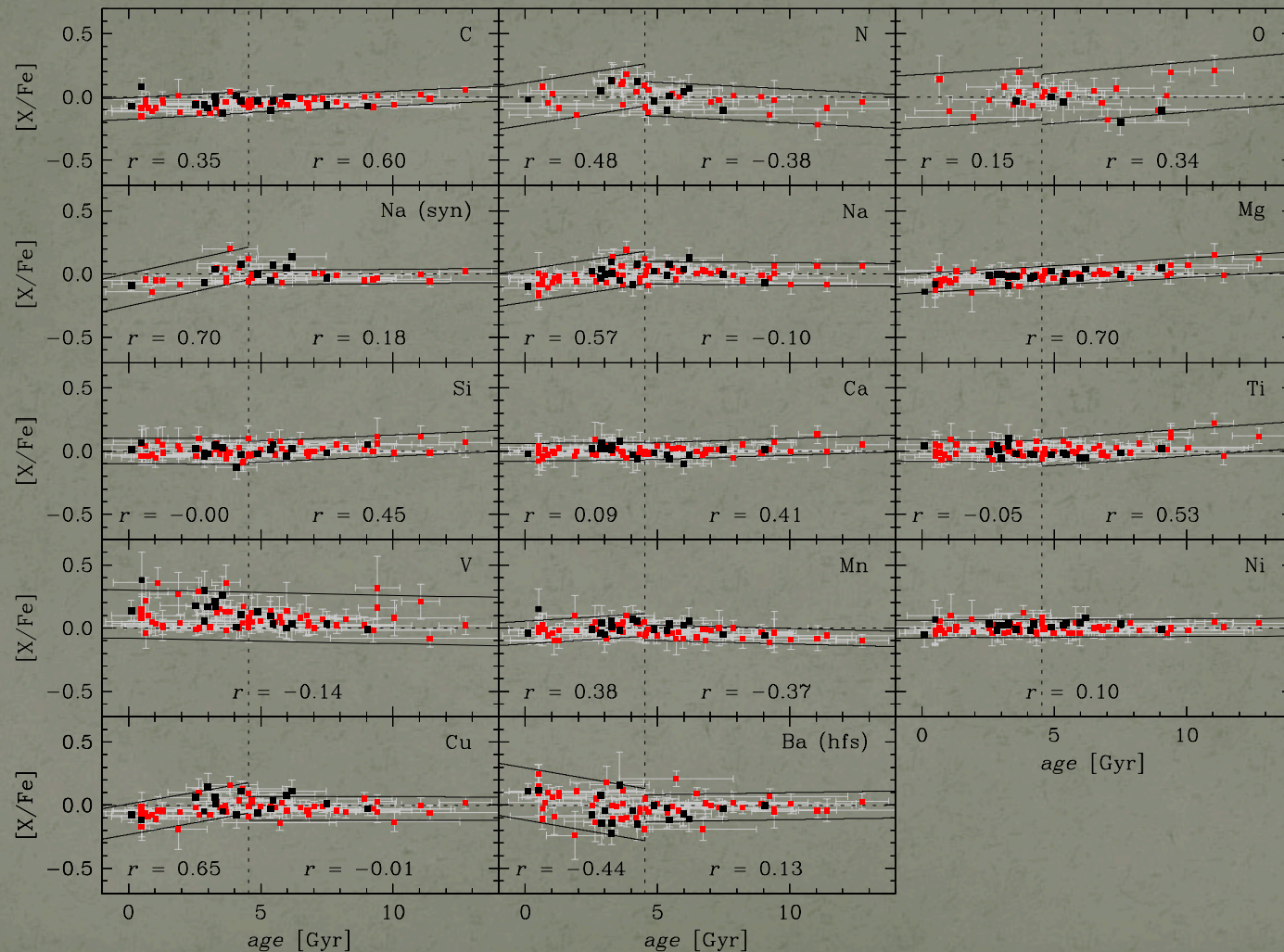
ONE: residuals over $[X/Fe]$ - $[Fe/H]$ relations (homogeneous data)



Linear fits for **dwarfs without giant planets** adopting solar value as a transition.

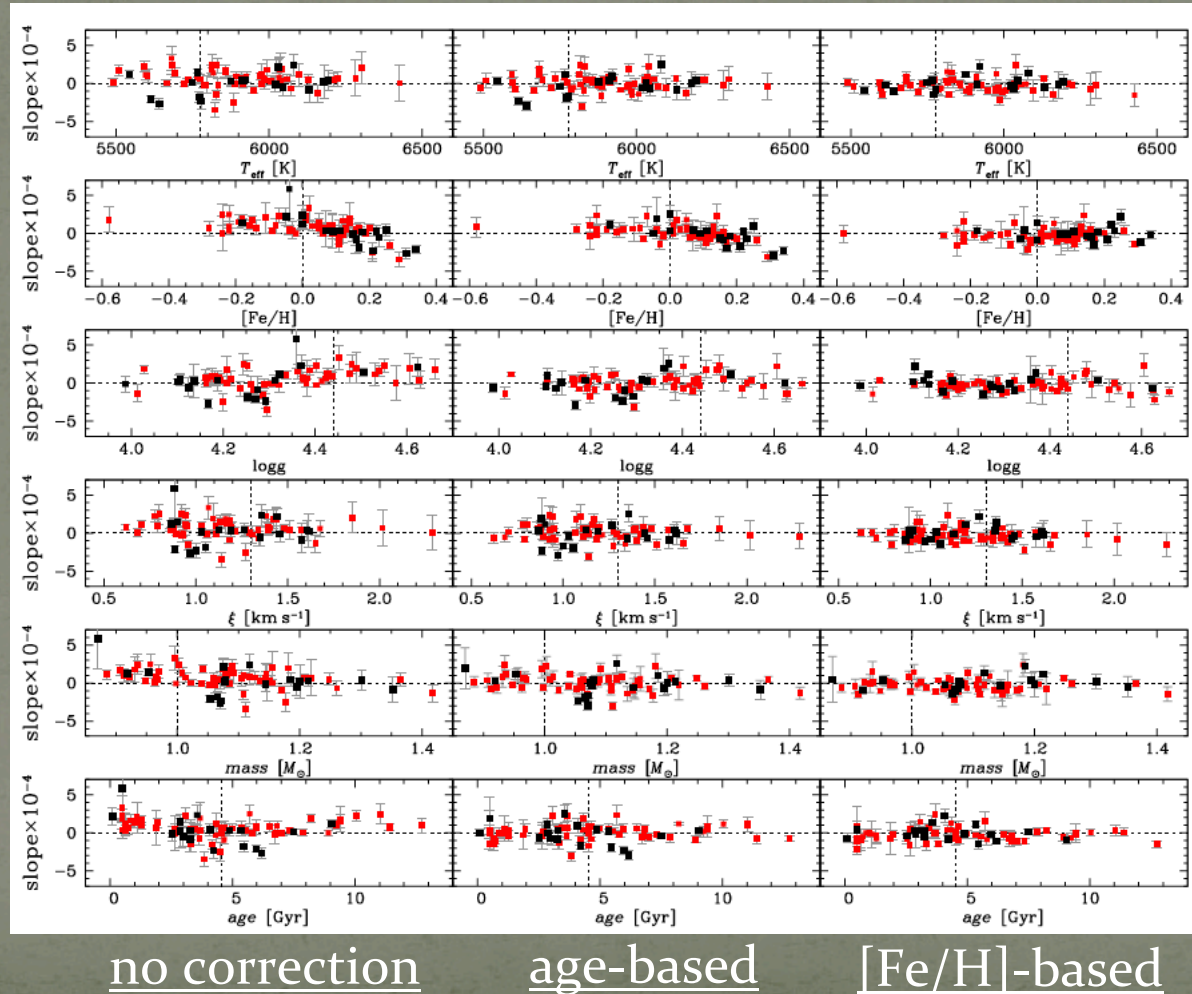
HOW? Two procedures to account for the effects on $[X/Fe]$

OTHER: residuals over $[X/Fe]$ -age relations



Linear fits for **dwarfs without giant planets** adopting solar value as a transition.

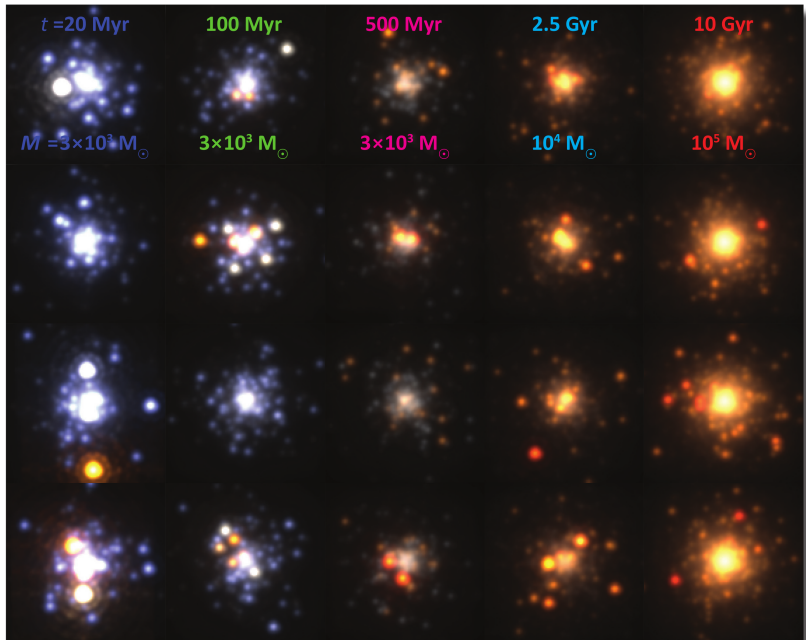
RESULTS: the correction based on $[X/Fe]$ - $[Fe/H]$ relations removes the dependence of $[X/Fe]$ - T_c 's slope on $[Fe/H]$ at metal-rich regime where we find more thin disc G-K dwarfs with giant planets; *WHY?*



#32 Stochastic Effects in Star Clusters

Donatas Narbutis, P. de Meulenaer, R. Stonkutė,
T. Mineikis, V. Vansevičius

Lithuania



Variety of simulated star clusters @ M31 with *HST/ACS* resolution

1 of 2

Integrated photometry

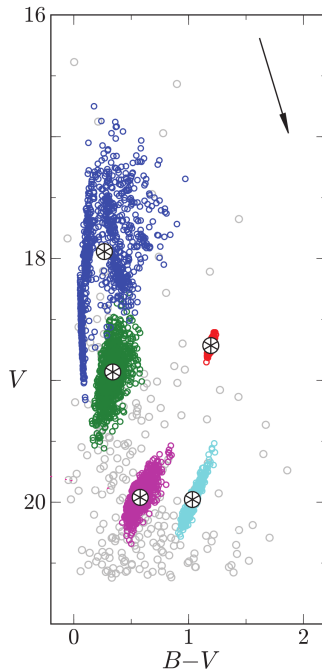
→ age, mass, extinction

Model grid

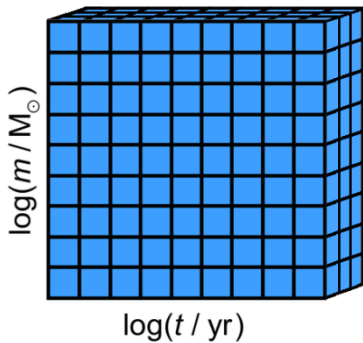
- ▶ age, mass,
extinction, metallicity
- initial mass function
- isochrones
- photometric system

1000 clusters @ node

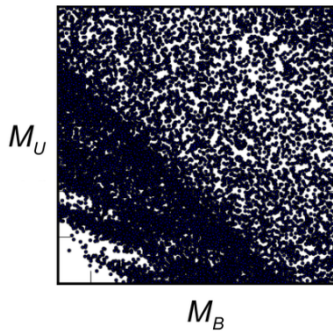
Non-Gaussian!



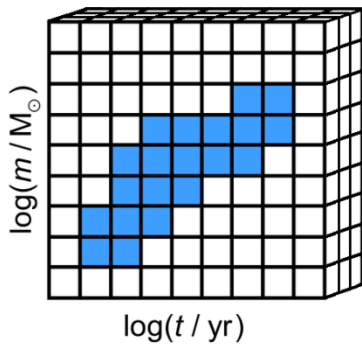
Physical



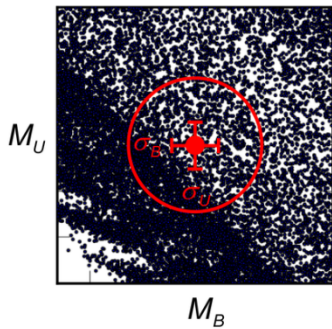
Photometric



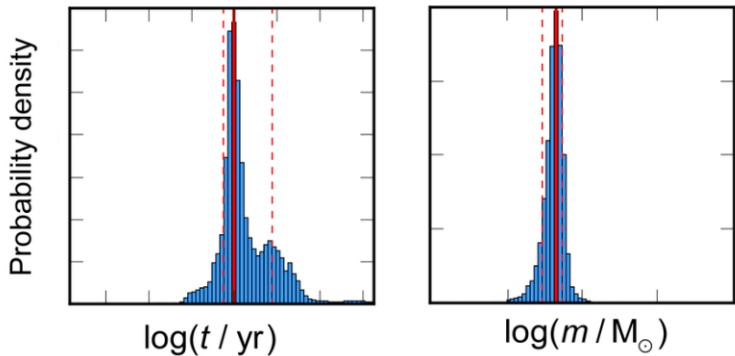
Likelihood



Observations



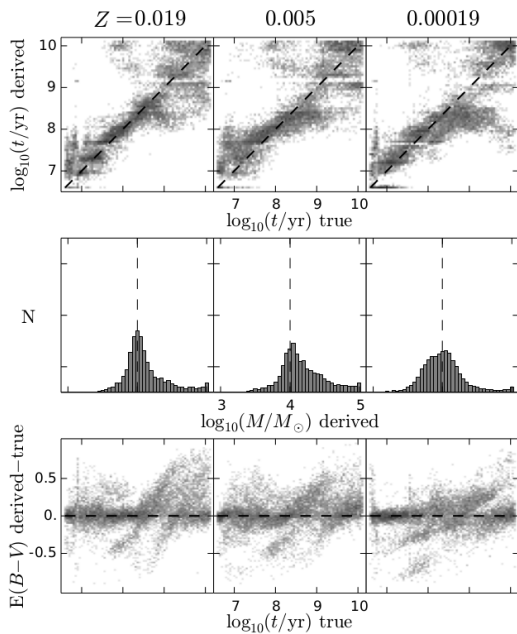
Most likely parameter values



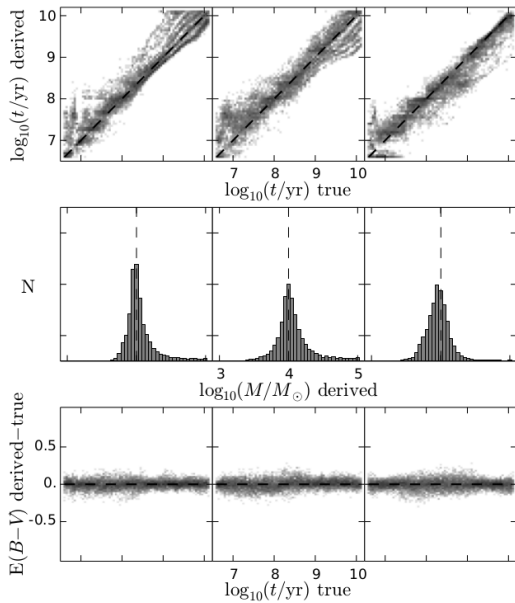
How accurate?

make 10,000 artificial clusters
with uniform age & extinction
of $10^4 M_{\odot}$ mass & 3 metallicities
add photometric $\sigma = 0.05$ mag noise

analyze



$UBVRI \sigma = 0.05 \text{ mag}$



$$\sigma = 0.15 \text{ mag GALEX} + UBVR I \sigma = 0.05 \text{ mag}$$

Compare integrated photometry to
stochastic model grid

→ derive parameters

given the IMF & isochrones

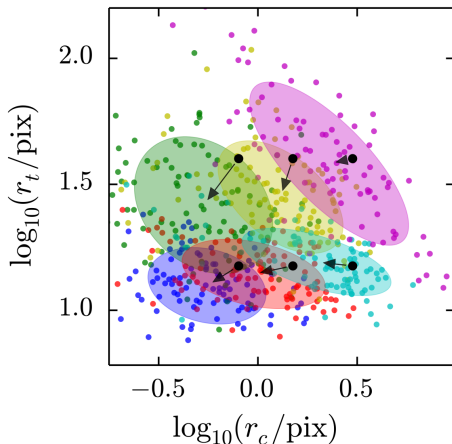
artificial samples for bias and uncertainty

2 of 2

Surface brightness distribution

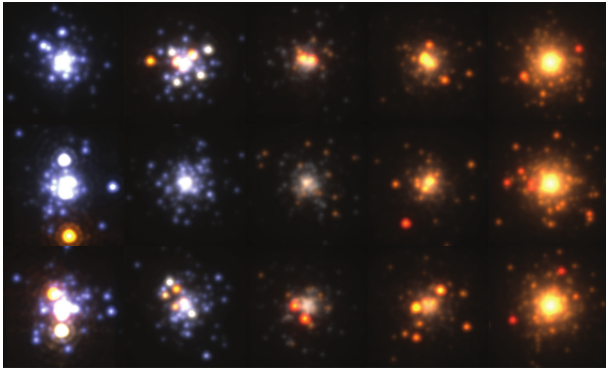
→ structural parameters

King model uncertainty and bias



larger than “formal” fitting errors!

#32 Stochastic Effects in Star Clusters



Thank you!

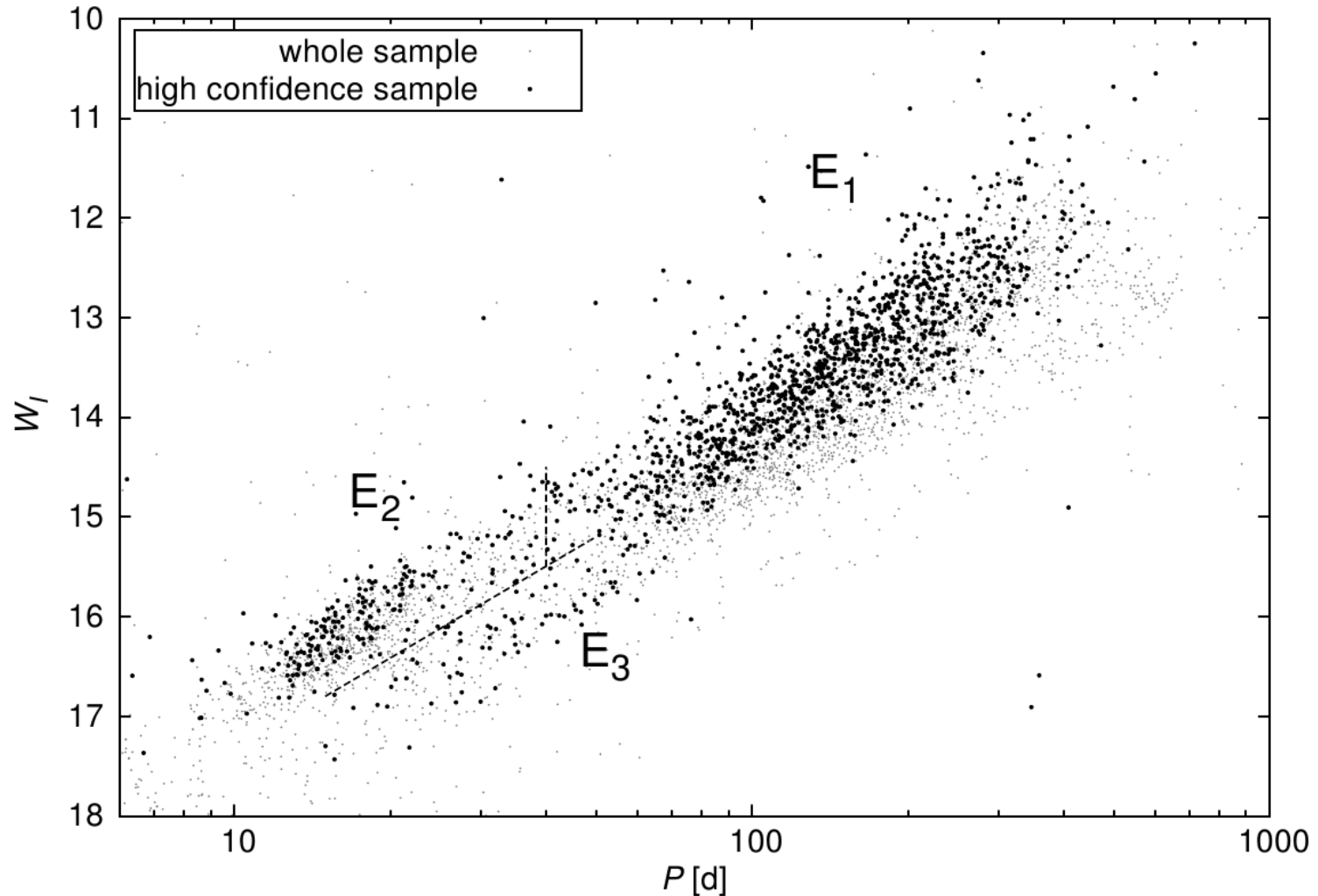


GIANT-GIANT AND GIANT-DWARF ELLIPSOIDAL BINARY SYSTEMS IN THE LARGE MAGELLANIC CLOUD

M. Pawlak, I. Soszyński, P. Pietrukowicz, J. Skowron, A. Udalski, M. Szymański, M. Kubiak, G. Pietrzyński, Ł. Wyrzykowski, K. Ulaczyk, S. Kozłowski, D. Skowron
Warsaw University Astronomical Observatory

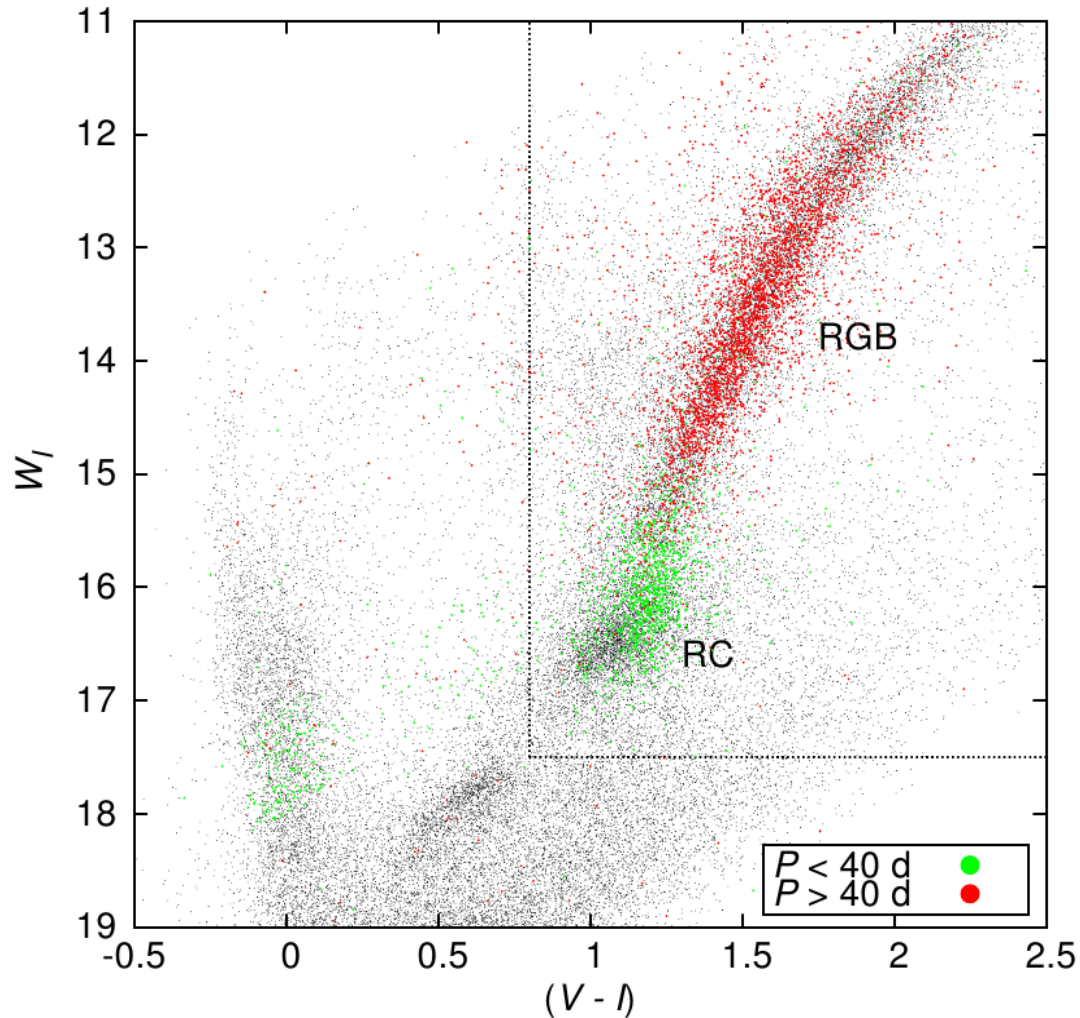
RASPUTIN: Resolved And unresolved Stellar PopUlaTioNs
ESO Garching, October 13 - 17, 2014

P-L diagram for ellipsoidal binaries in the LMC



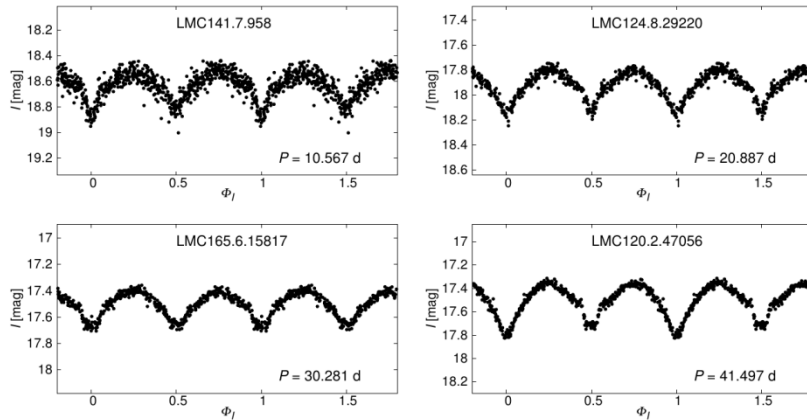
Giant-giant and giant-dwarf binary system in the LMC

Position of ellipsoidal binaries on the CMD

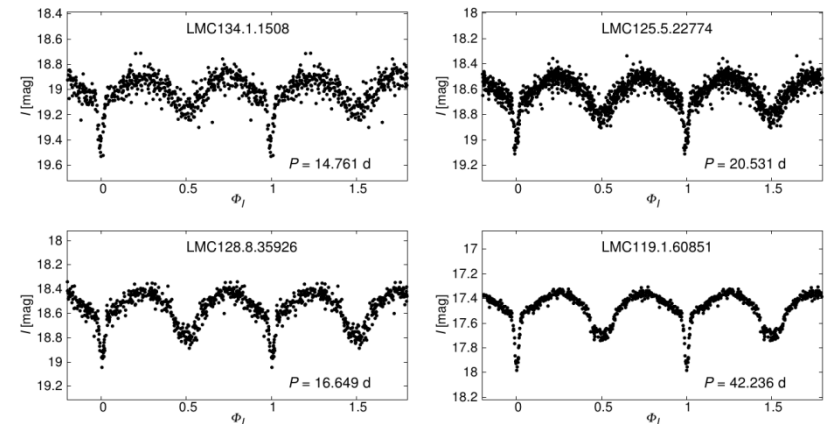


Giant-giant and giant-dwarf binary system in the LMC

Light curves of eclipsing ellipsoidal binaries



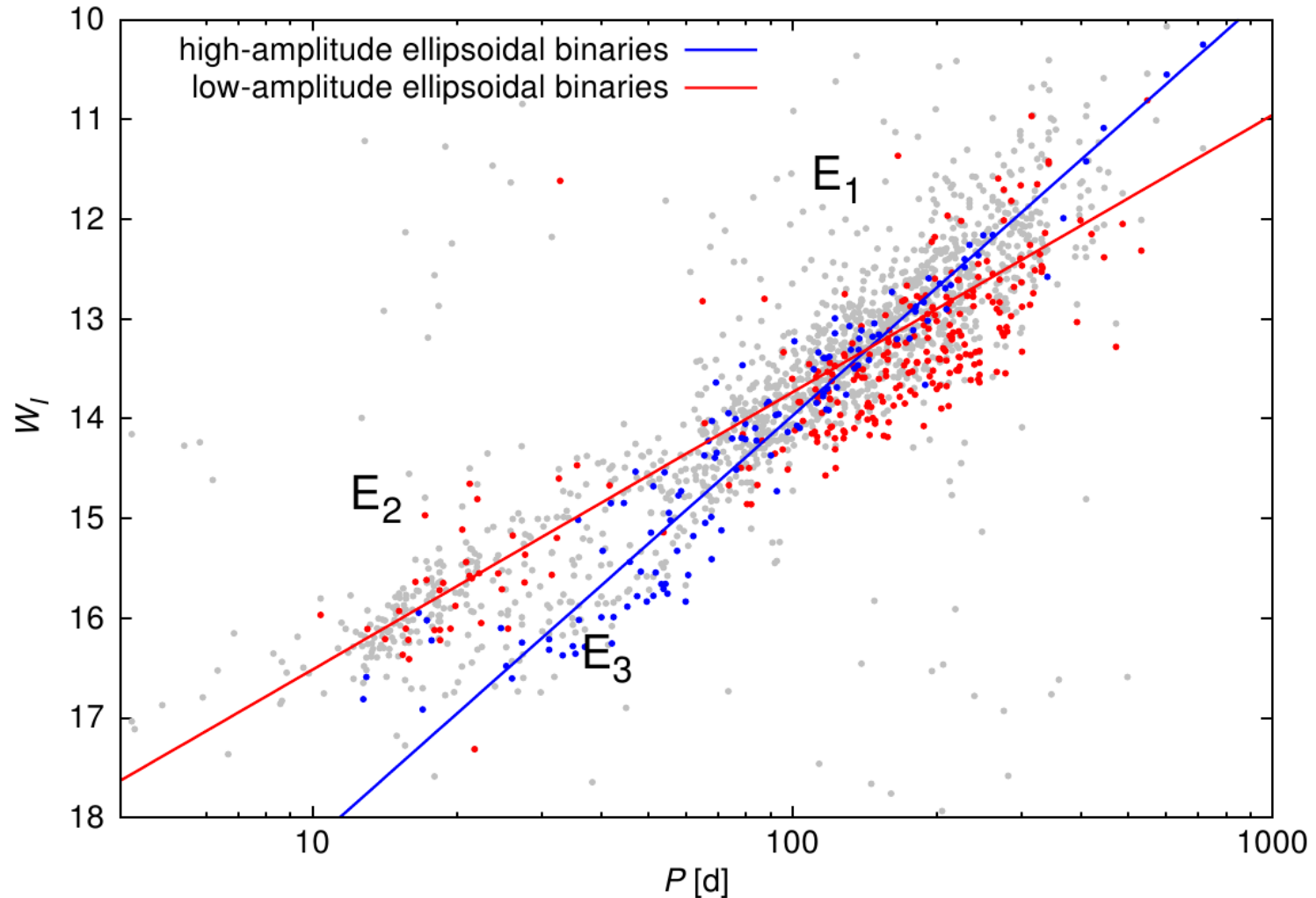
Example eclipsing binary lightcurves from E₂.
Most likely giant-giant systems.



Example eclipsing binary lightcurves from E₃.
Most likely giant-dwarf systems.



P-L relations for giant-giant and giant-dwarf ellipsoidal binaries

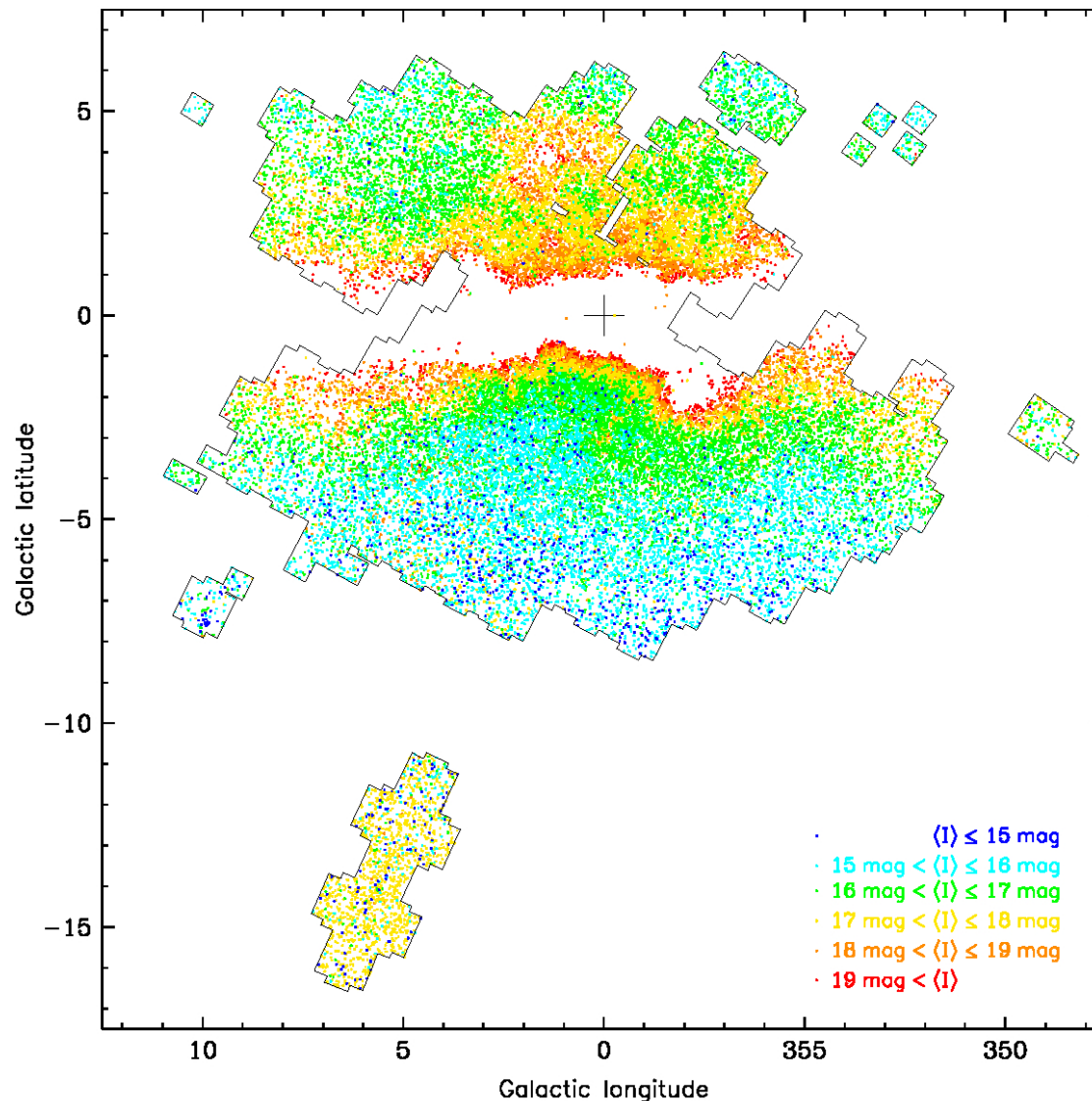


Giant-giant and giant-dwarf binary system in the LMC

The old Galactic Bulge as seen in RR Lyrae stars from OGLE

Pawel Pietrukowicz

ogle.astrouw.edu.pl



Coverage: **182 deg²**

Number of detected stars:

27,258 R Rab

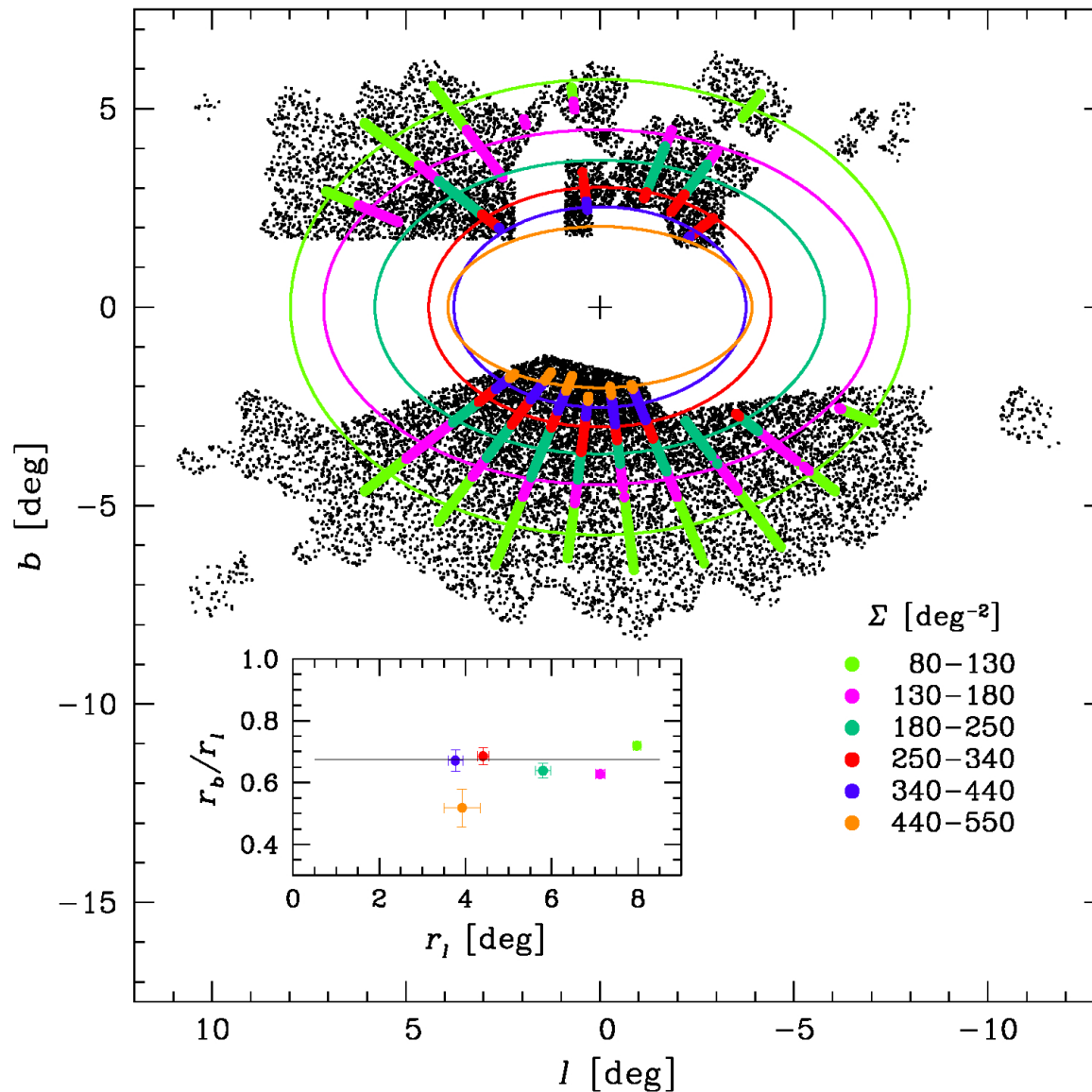
10,825 RRc

174 RRd

38,257 total

Soszyński et al. (2014)

Flattening of the old Bulge



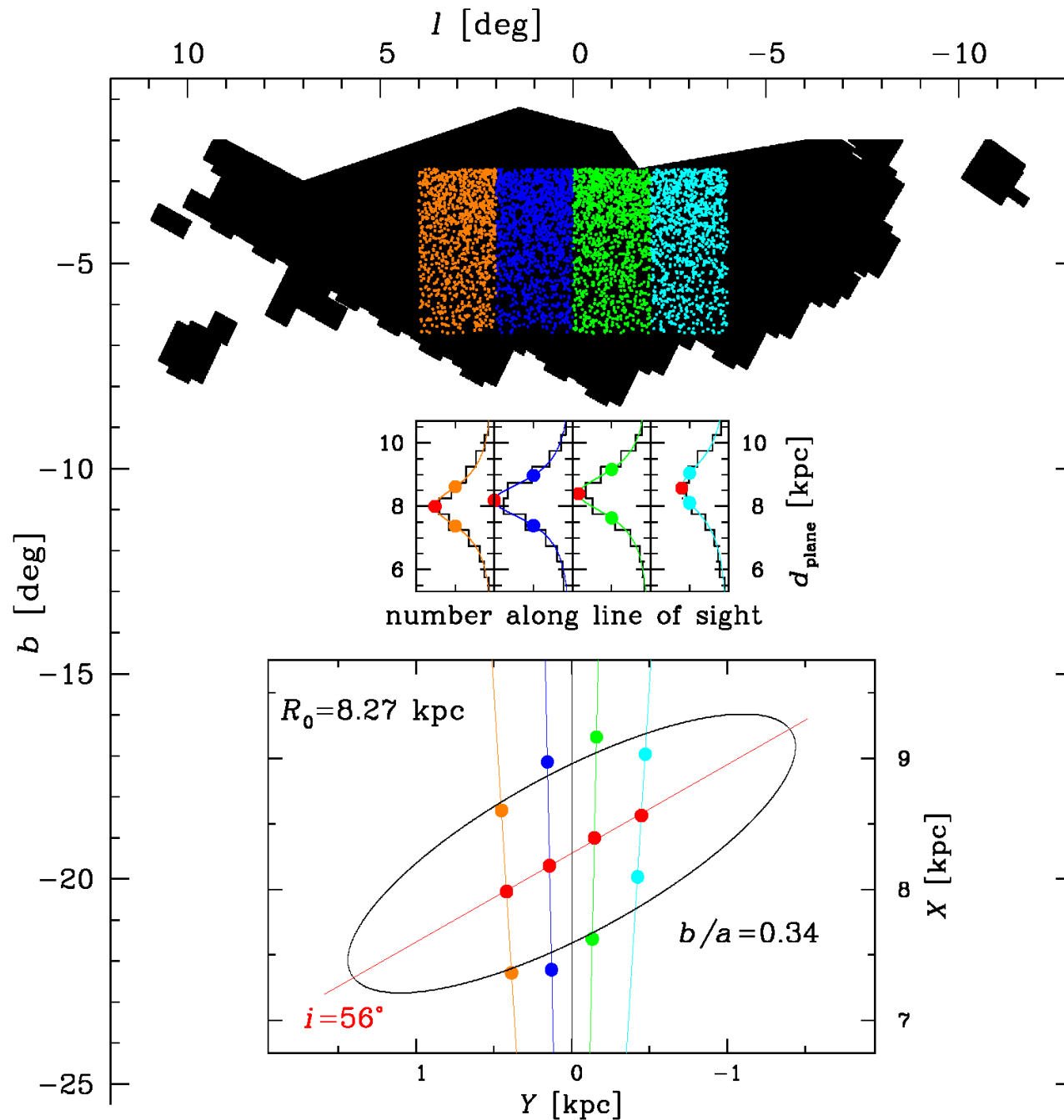
Observed ellipticity:

$$e = 0.33 \pm 0.02$$

OGLE

Pietrukowicz *et al.* (2014)

The old Bulge as a triaxial ellipsoid



Final parameters:

$$R_0 = 8.27 \text{ kpc}$$

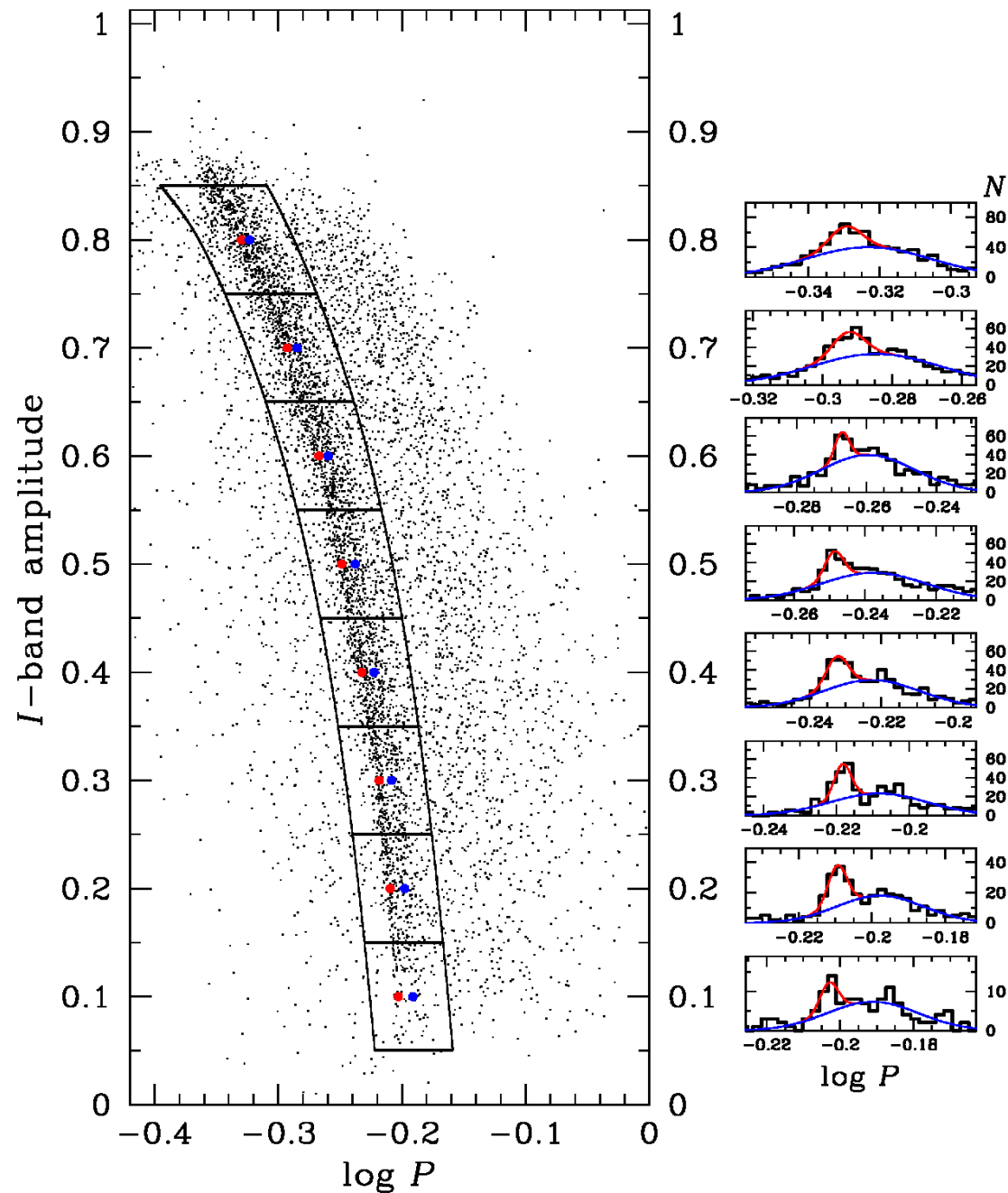
$$a : b : c = 1 : 0.45 : 0.47$$

$$i = 53 \pm 1^\circ$$

OGLE

Pietrukowicz *et al.* (2014)

Multiple populations of the old Bulge

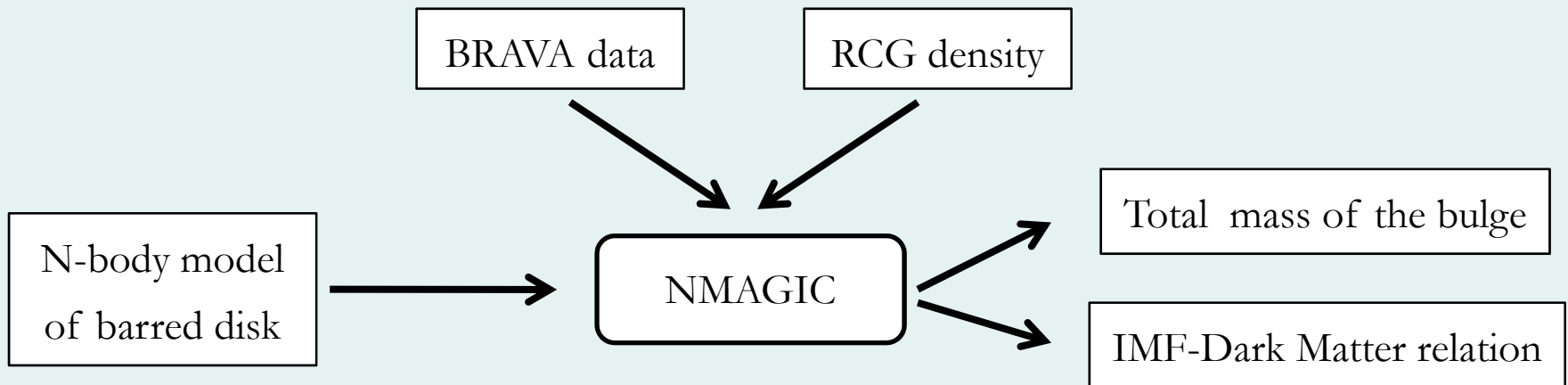


Population	Abundance
A	13 %
B	47 %
other	40 %

OGLE

Pietrukowicz *et al.* (2014)

Dynamical modelling of the Galactic bulge: Mass and IMF



Dynamical modelling of the Galactic bulge:

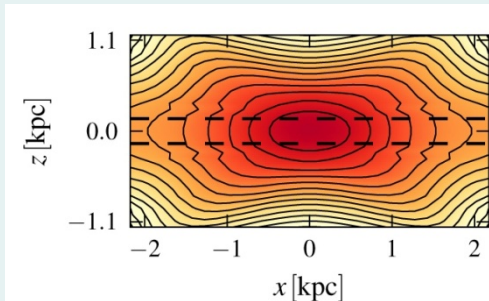
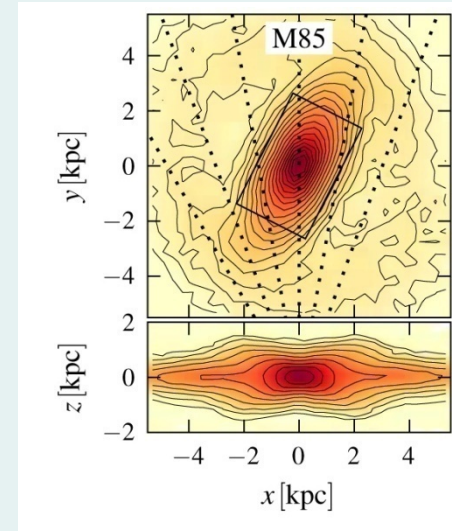
Mass and IMF



■ We construct a set of N-body models of barred disk by evolving a stellar disk embedded in different dark matter halos.

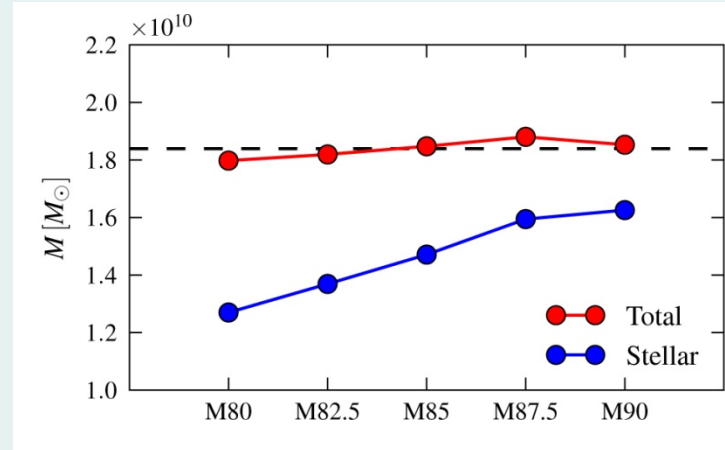
■ All models form a bar that buckles and creates a Boxy/Peanut bulge.

■ Using the Made-to-Measure method, we constrain the models to match Milky-Way bulge data: 3D density of Red Clump stars (Wegg & Gerhard 2013) and BRAVA kinematics (Kunder et al. 2012)



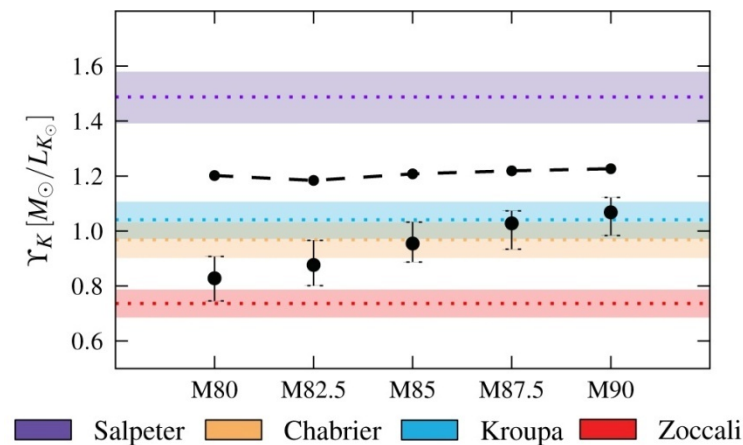
We can recover the bulge stellar mass needed in the model to match the BRAVA dispersion

All our models give the same estimate of the **total** mass of the Galactic bulge of $1.84 \times 10^{10} M_{\odot}$ with a $<5\%$ accuracy.



We predict mass-to-light ratio from our models and compare them to population synthesis models

We rule out the Salpeter IMF and show that matching the Zoccali IMF would require about 40% dark matter in the bulge.



Uncertainties in grid-based estimates of stellar ages

Pier Giorgio Prada Moroni

Dipartimento di Fisica “E. Fermi”

INFN – Sezione di Pisa

in collaboration with:

Matteo Dell’Omodarme

Giada Valle

Scilla Degl’Innocenti

- Techniques to obtain the **stellar characteristics** from data in a **fast** and **automated** way
- Fitting the data to pre-computed **grid of stellar models** (*see Stello et al. 2009, Basu et al. 2010, Quirion et al. 2010, Gai et al. 2011*)

SCEPtER

(Stellar Characteristics Pisa Estimation gRid)

- Estimate the stellar **mass**, **radius**, and **age** given:

$$q^S \equiv \{T_{\text{eff},S}, [\text{Fe}/\text{H}]_S, \Delta\nu_S, \nu_{\text{max},S}\}$$

and relying on a **grid** of pre-computed **stellar models**

- **Maximum likelihood** technique following the same scheme described in Valle et al. 2014a (*A&A* 561, A125)

- The **accuracy** and **precision** of the parameters of **stars** inferred by means of **any** grid-based technique depend on the **reliability** degree of the adopted **stellar models**

Stellar models depend on...

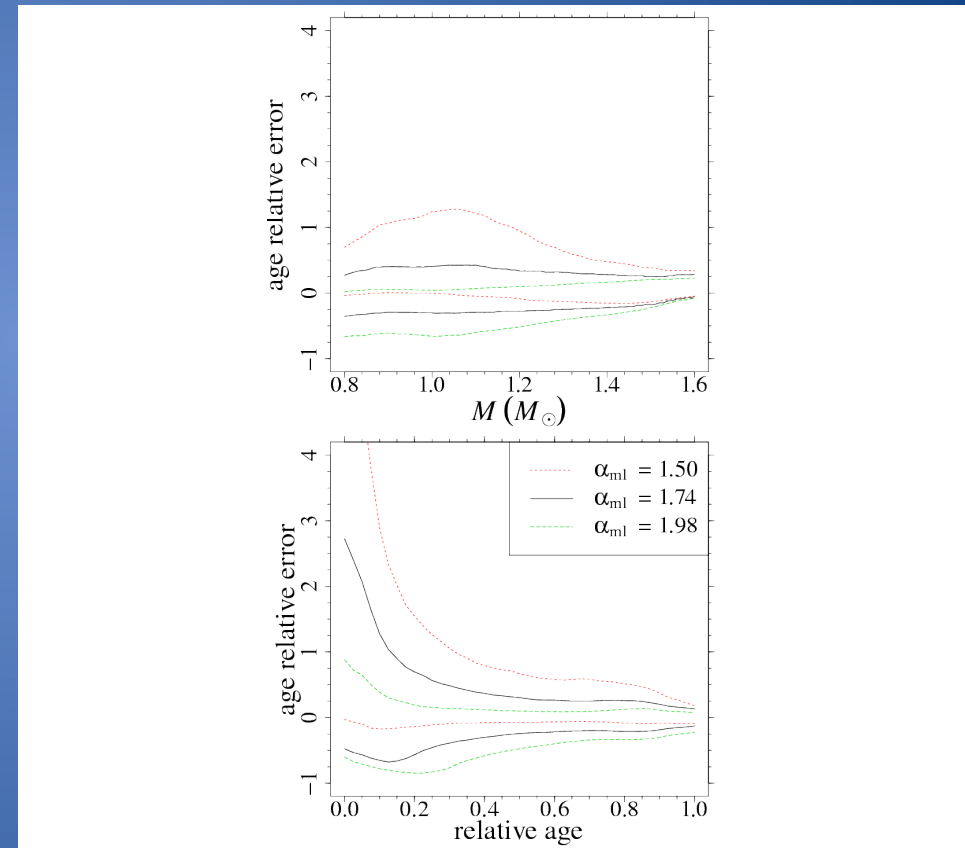
- **input physics** (radiative opacity, nuclear reaction cross sections, etc.)
- **macroscopic processes** (super-adiabatic convection, overshooting, etc.)
- **initial chemical composition** (Y , Z , elements mixture)

We investigated the effect of varying:

- Radiative opacity
- Mixing-length parameter
- Convective core overshooting
- Element diffusion
- Initial He abundance

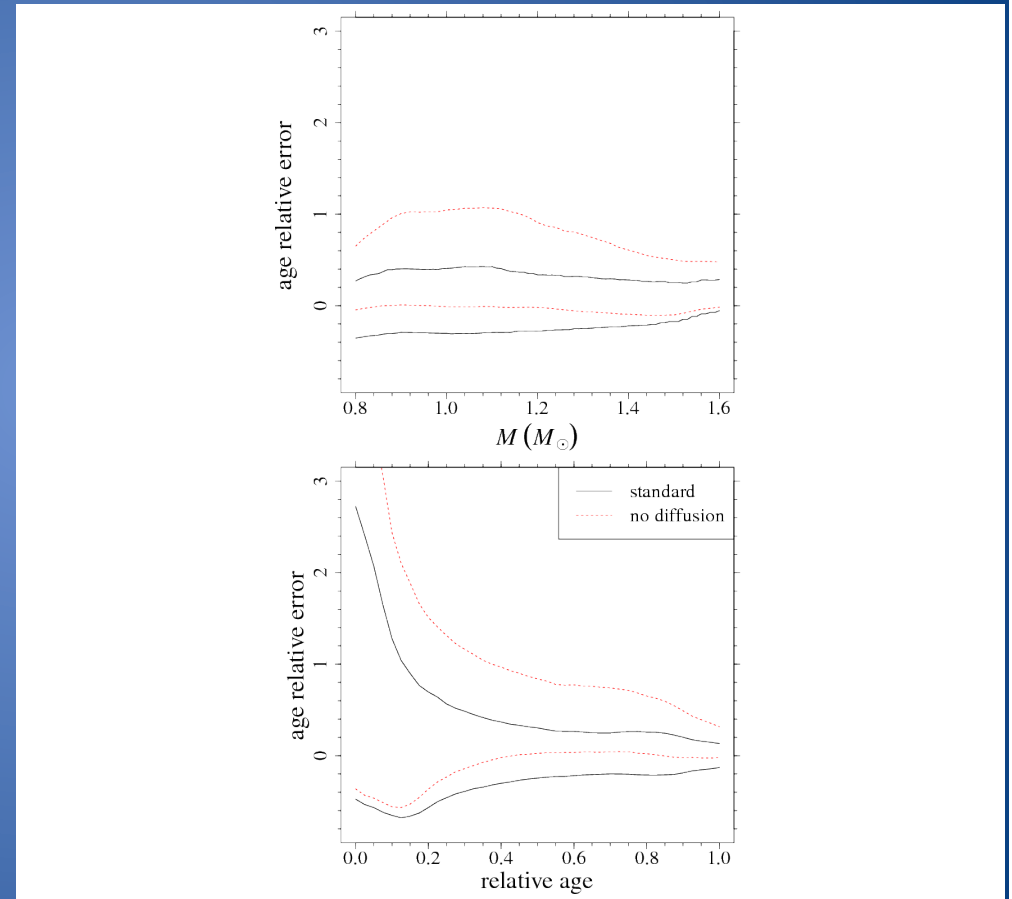
Mixing-length parameter

- Large bias: $-/+ 20\text{-}30\%$
- Comparable to the 1σ random uncertainty



Microscopic diffusion

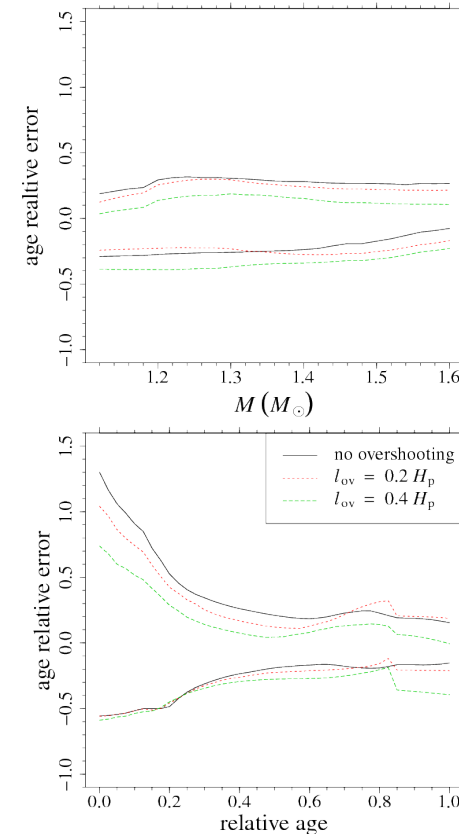
- Large bias: 40% for $M \leq 1.1 M_{\odot}$
- Comparable to the 1σ random uncertainty



Core overshooting parameter

Bias:

- -7 % for $\beta_{\text{ov}} = 0.2$
- -13% for $\beta_{\text{ov}} = 0.4$



Thanks

Internal accuracy

- **Synthetic dataset** by sampling **50000** artificial stars from the **standard grid** of models and adding a **gaussian noise** in all the observed quantities
- $\sigma_{\text{Te}} = 100 \text{ K}$, $\sigma_{[\text{Fe}/\text{H}]} = 0.1 \text{ dex}$, $\sigma_{\Delta v} = 2.5\%$, $\sigma_{v_{\text{max}}} = 5\%$ (*Gai et al. 2011, Valle et al. 2014*)

Maximum likelihood

$$\mathcal{L}_j = \left(\prod_{i=1}^4 \frac{1}{\sqrt{2\pi}\sigma_i} \right) \times \exp\left(-\frac{\chi^2}{2}\right)$$

where

$$\chi^2 = \sum_{i=1}^4 \left(\frac{q_i^S - q_i^j}{\sigma_i} \right)^2$$

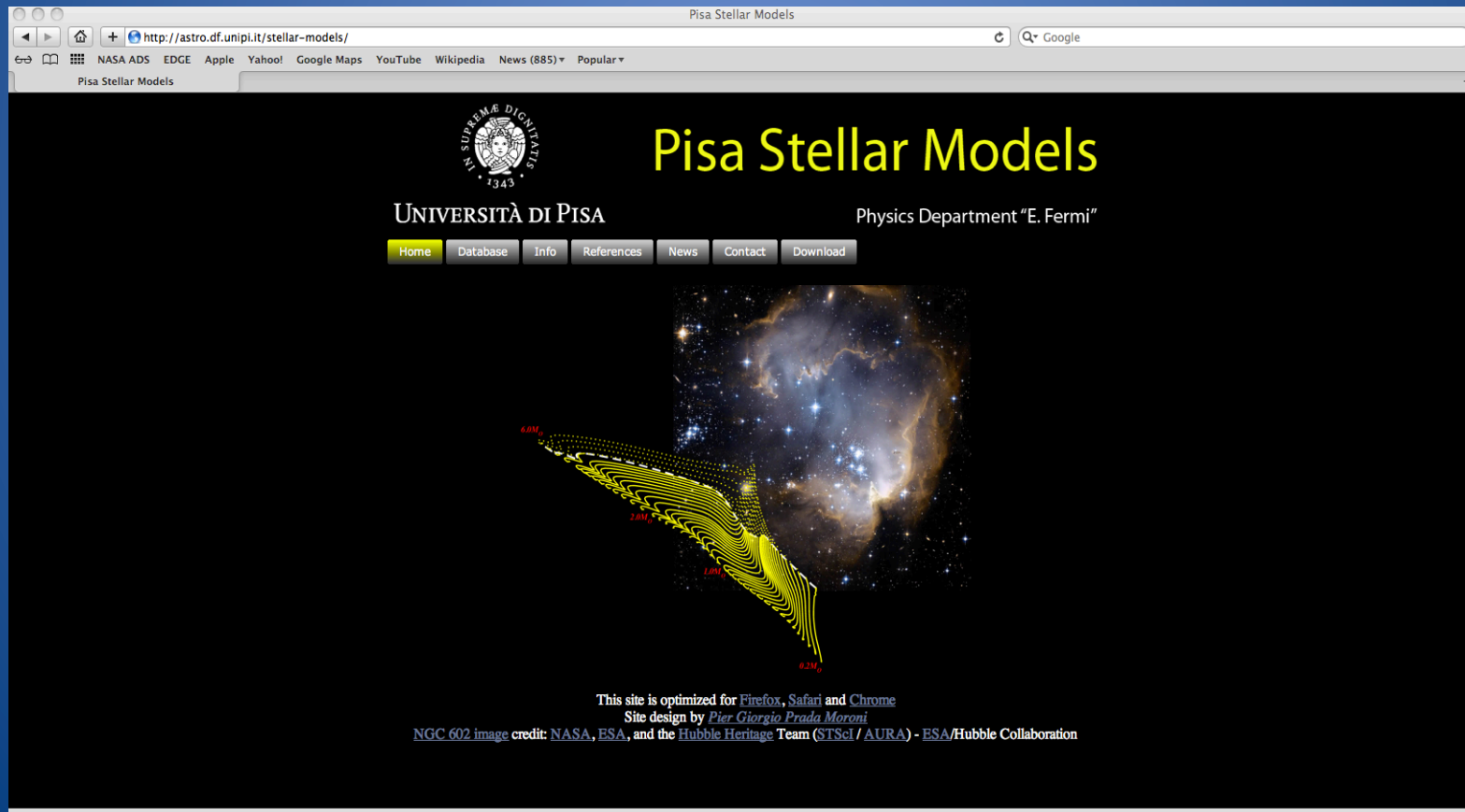
$$\frac{\Delta\nu}{\Delta\nu_{\odot}} = \sqrt{\frac{M/M_{\odot}}{(R/R_{\odot})^3}} \quad ,$$

$$\frac{\nu_{\max}}{\nu_{\max,\odot}} = \frac{M/M_{\odot}}{(R/R_{\odot})^2 \sqrt{T_{\text{eff}}/T_{\text{eff},\odot}}}$$

Standard estimation grid

- **FRANEC** code (*Dell'Omodarme et al. 2012*)
- Pisa Stellar Evolution Data Base

<http://astro.df.unipi.it/stellar-models/>



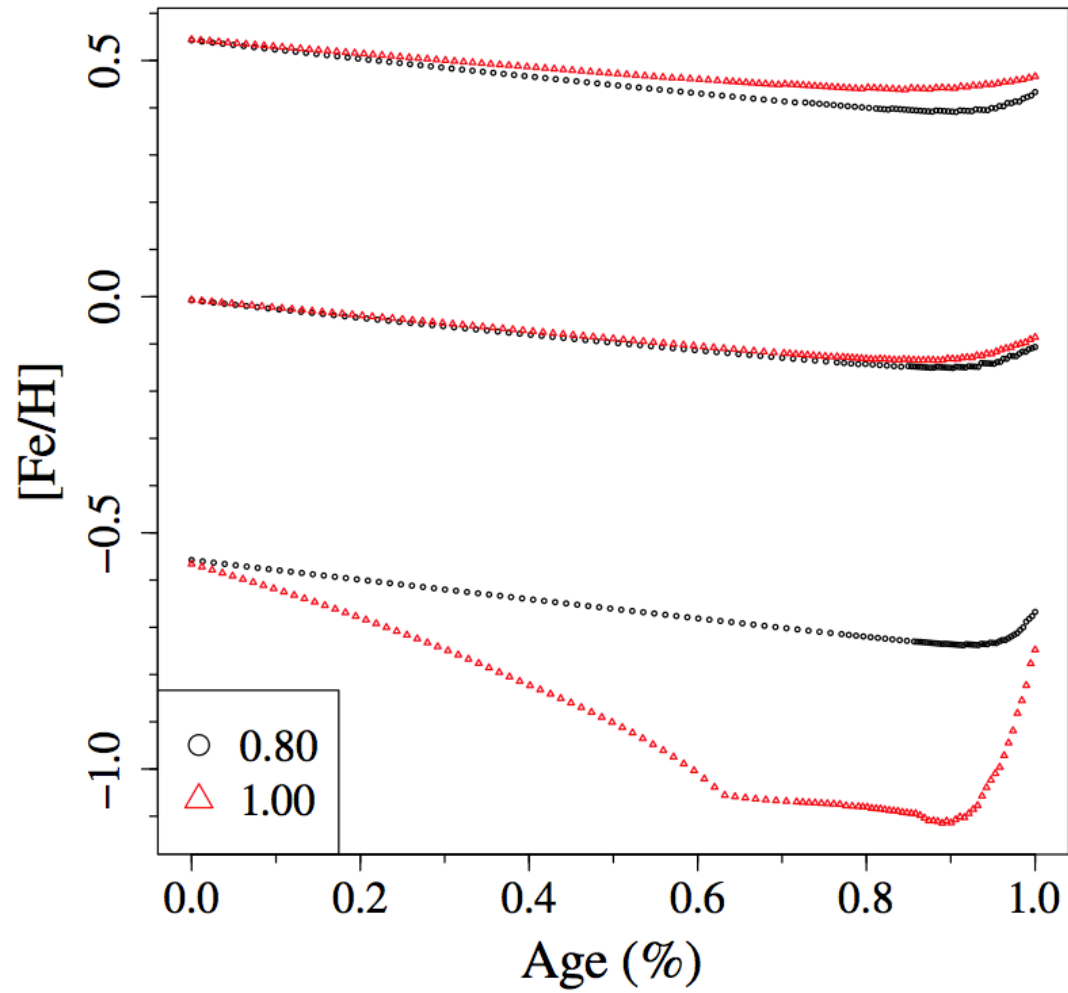
Standard estimation grid

- Tracks from ZAMS to the central H-exhaustion
- **Mass range:** $0.8 \div 1.6 M_{\odot}$, step $0.01 M_{\odot}$
- **[Fe/H]:** $-0.55 \div 0.55$, step 0.05 dex

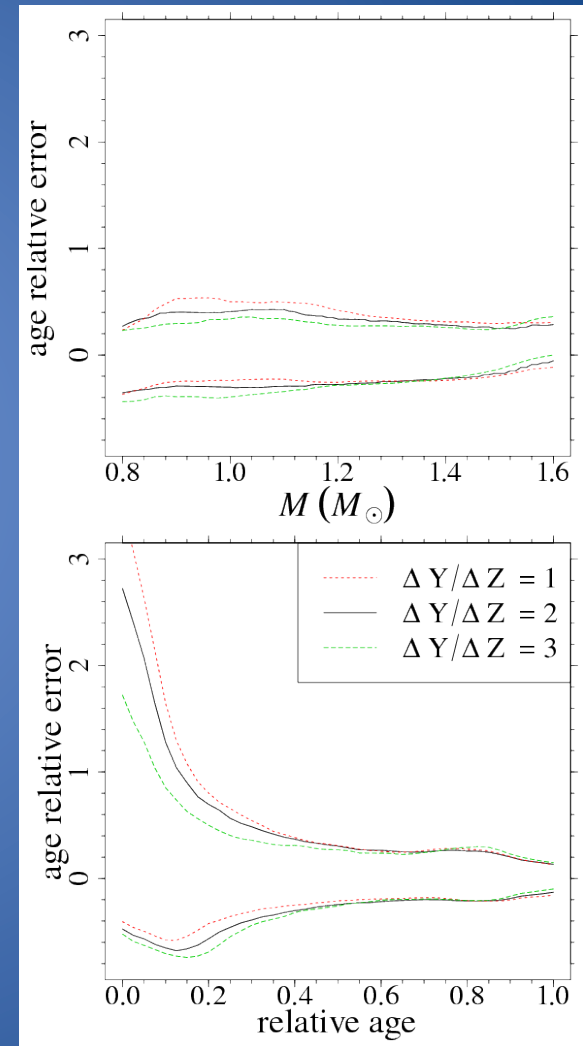
$$Y = Y_p + \frac{\Delta Y}{\Delta Z} Z$$

- $Y_p = 0.2485$ and $\Delta Y / \Delta Z = 2$

Microscopic diffusion



Initial helium abundance



The VST survey of the SMC and the Magellanic Bridge (STEP): first results

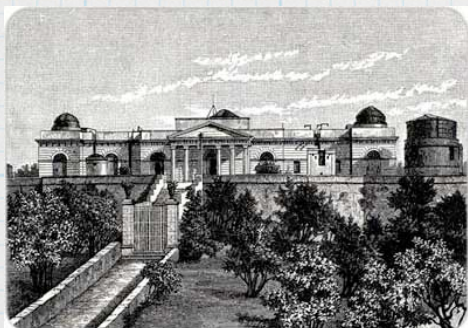
Poster number 39

V. Ripepi

INAF-Osservatorio Astronomico di Capodimonte, Napoli

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M. Tosi	<i>INAF-OABO - Italy</i>
M. Marconi	<i>INAF-OACN - Italy</i>
I. Musella	<i>INAF-OACN - Italy</i>
A. Grado	<i>INAF-OACN - Italy</i>
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M. Dall'Ora	<i>INAF-OACN - Italy</i>
J. S. Gallagher III	<i>Univ. Wisconsin - USA</i>
E. K. Grebel	<i>Universitat Heidelberg</i>
A. Nota	<i>STSCI - USA</i>
F. Palla	<i>INAF-OAArcetri - Italy</i>
D. Romano	<i>INAF-OABO - Italy</i>
G. Raimondo	<i>INAF-OATE - Italy</i>
E. Sabbi	<i>STSCI - USA</i>



Ripepi et al. 2014, MNRAS, 442, 1897;
Ripepi et al. 2014, ESO Messenger, in press



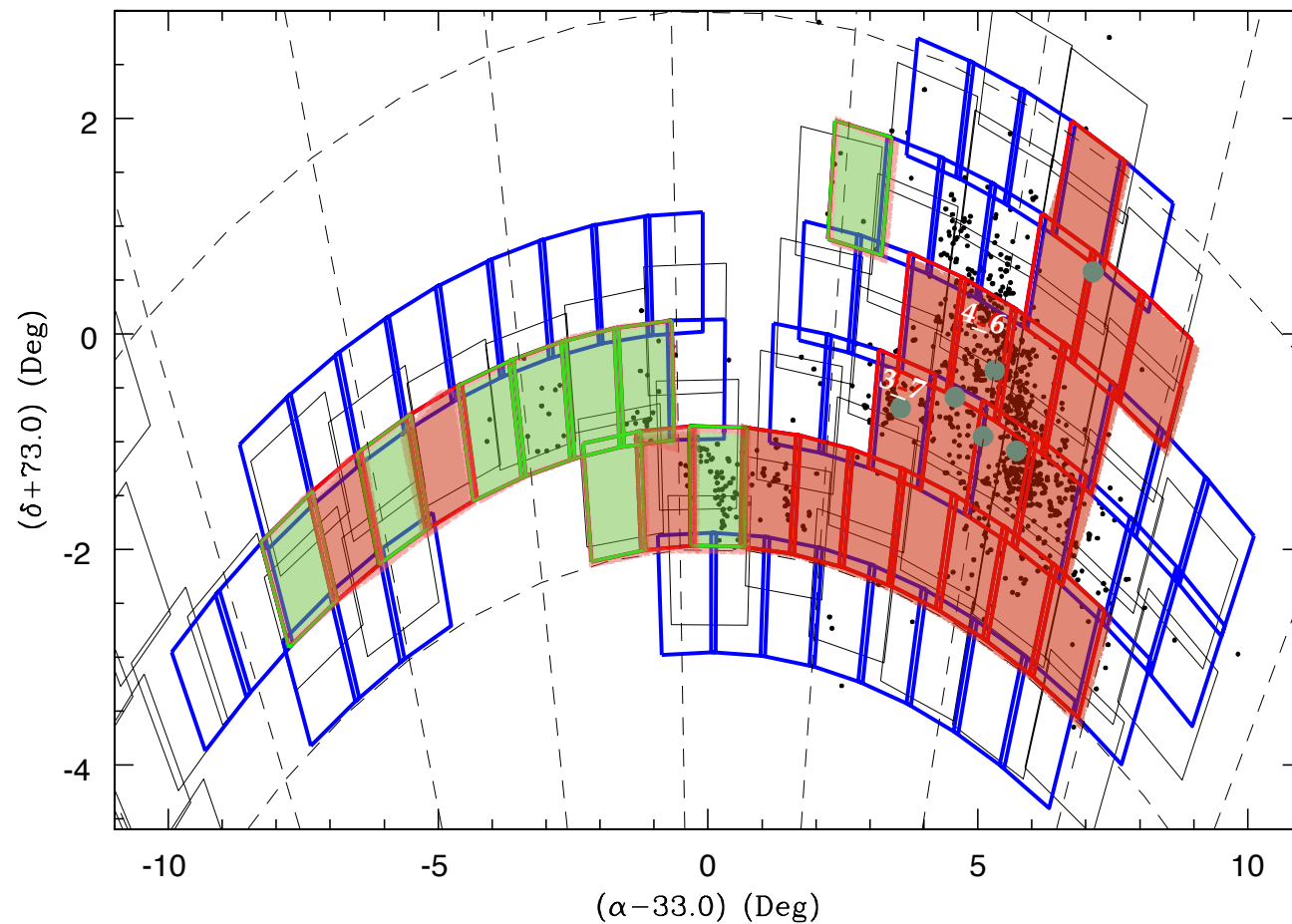
Aims

- a. **Study of SFH of SMC and of its stellar cluster component:** trends with position? Connection with interaction history? Cluster and Field Age-Metallicity relations?
- b. **Systematic investigation of the Bridge populations:** SFH of the intra-cloud population; How did the stellar component of the Bridge form?
- c. **Impact of metallicity on PMS accretion and on the global properties of star formation** (star formation rate and efficiency; IMF)

Need to reach 1-2 magnitude below the Turn-Off of the oldest population

Complementary projects

- 1. HST photometry on selected fields, old and young clusters (P.I. J. Gallagher/A. Nota).
- 2. VLT spectroscopy (CaII triplet) on several SMC fields (P.I. E. Grebel).
- 3. VMC@VISTA ESO Public survey (P.I: M.R. Cioni): YHKs photometry of the Magellanic System (LMC, SMC, Bridge, Stream): 184 sq. deg. at Ks=20.3 mag.



STEP Characteristics:

- ✓ g,i photometry to $g \sim 24$ (AB mag) with $S/N \sim 10$
- ✓ $r, H\alpha$ photometry to $r \sim 23$ mag with $S/N = 5$.
- ✓ Time-series photometry (~ 24 epochs) on selected fields of the Bridge: $g \sim 19.0$ mag (RR Lyrae) with $S/N = 100 \Rightarrow g \sim 24$ (AB mag) with $S/N \sim 10$. Only 8 “tiles” with TS because of low efficiency of these observations.

Data reduction:

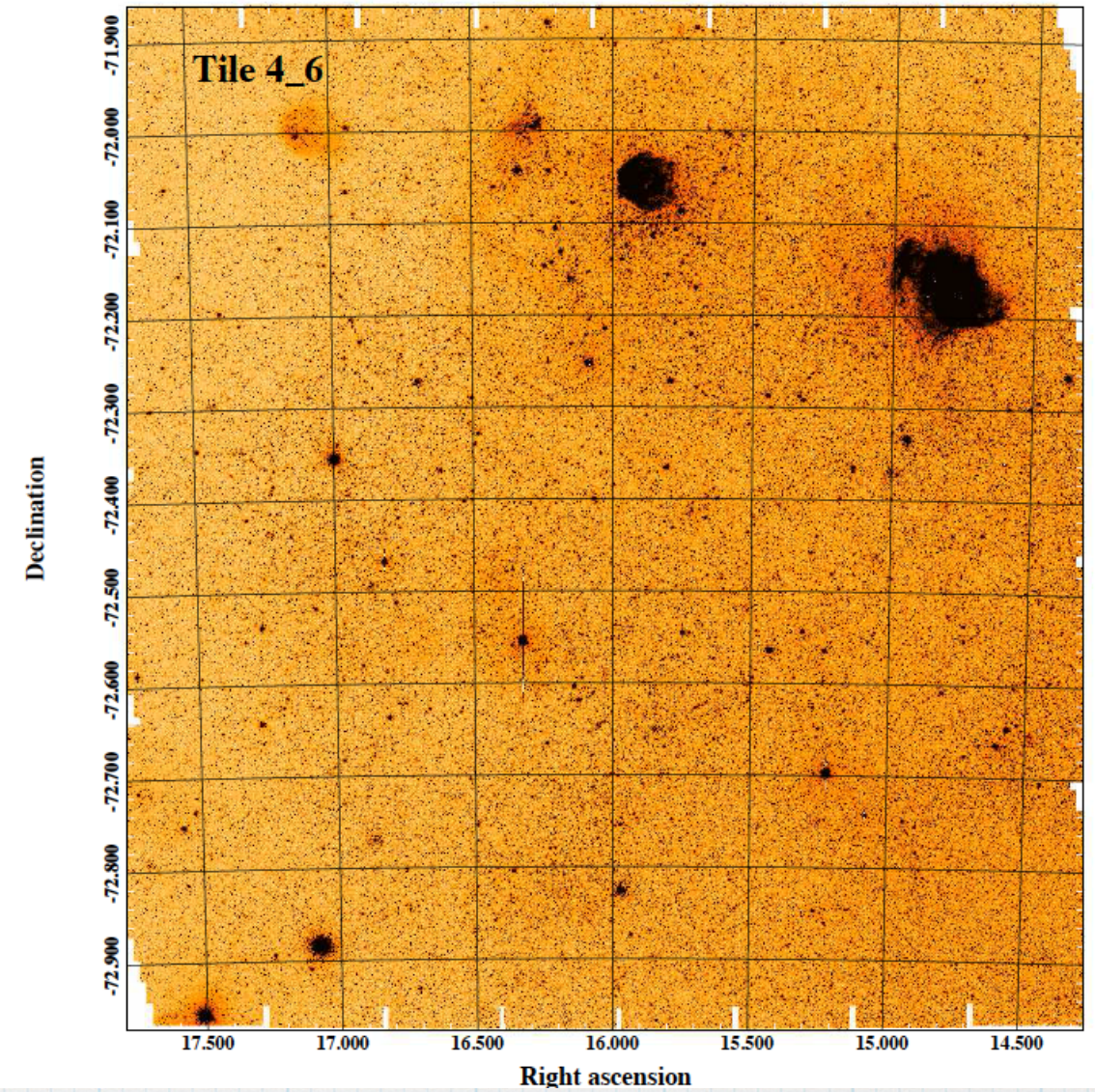
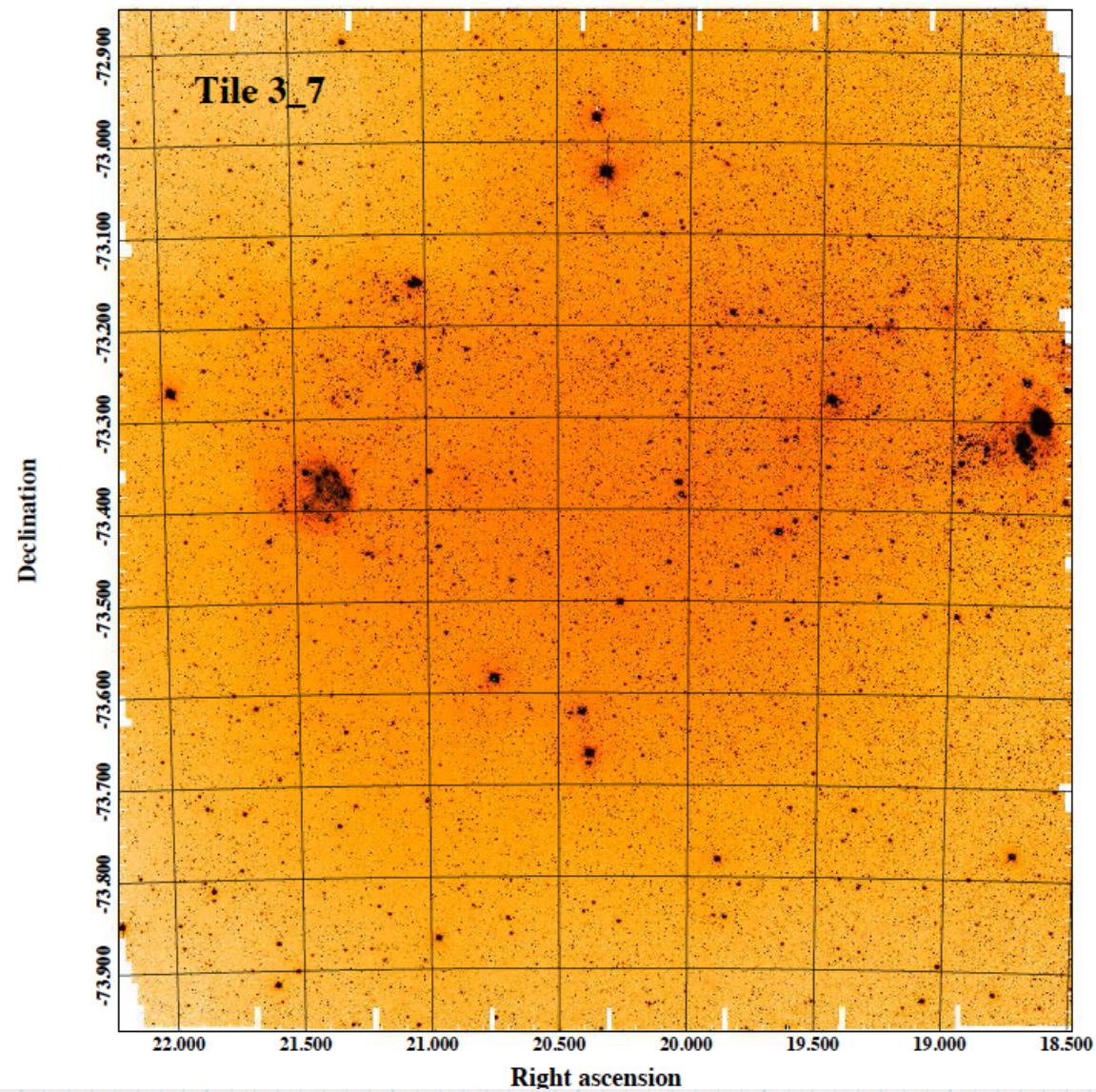
- ✓ Prereduction and astrometry with VSTTube (Grado et al. MemSait Suppl. 19, 362);
- ✓ PSF photometry with P. Stetson’s DAOPHOT IV/ALLSTAR.

Survey status:

Hours observed/allocated (P88-93): $\sim 51 \%$

Completion: $g,i \sim 43\% ; r, H\alpha \sim 7 \%$

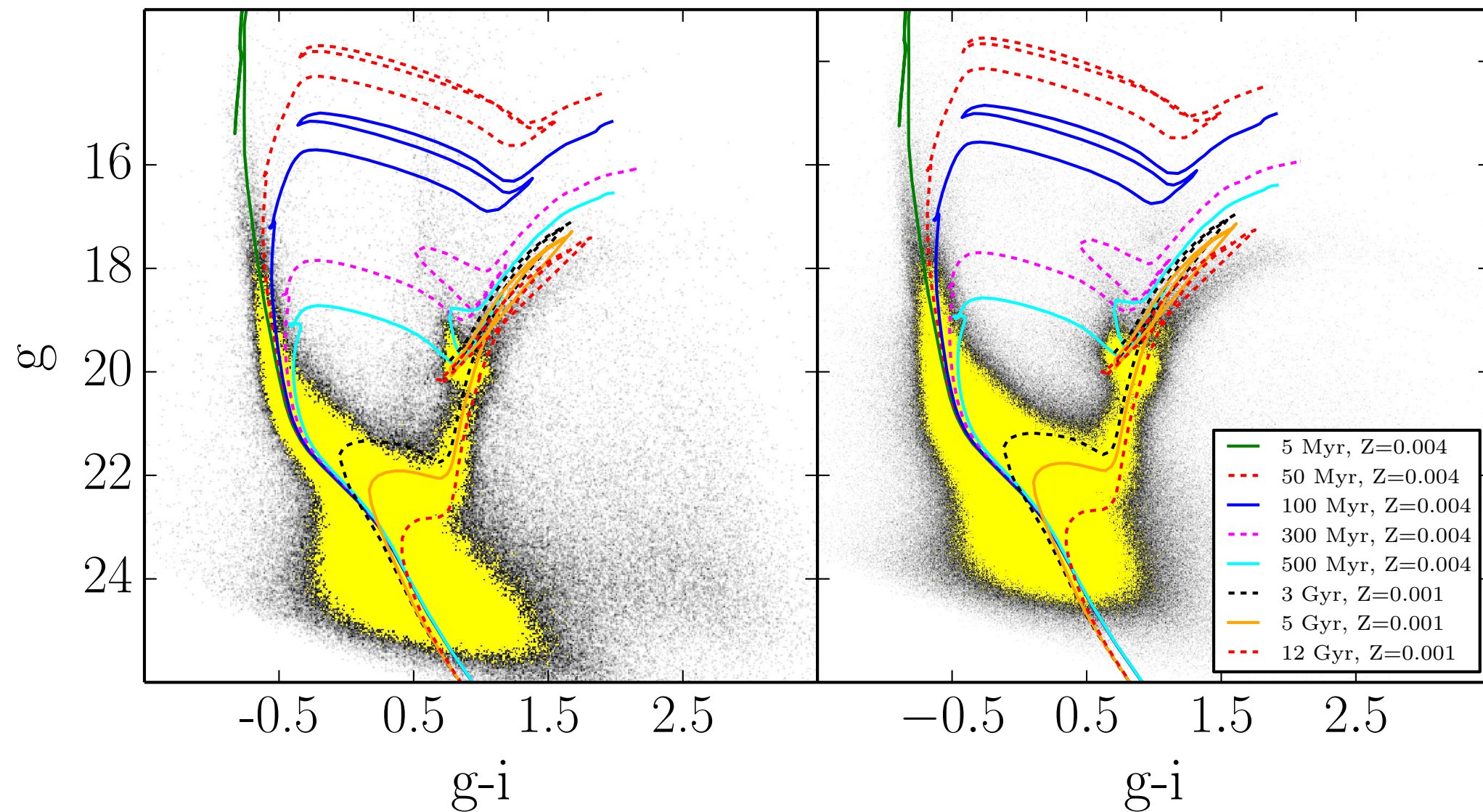
First results for two tiles



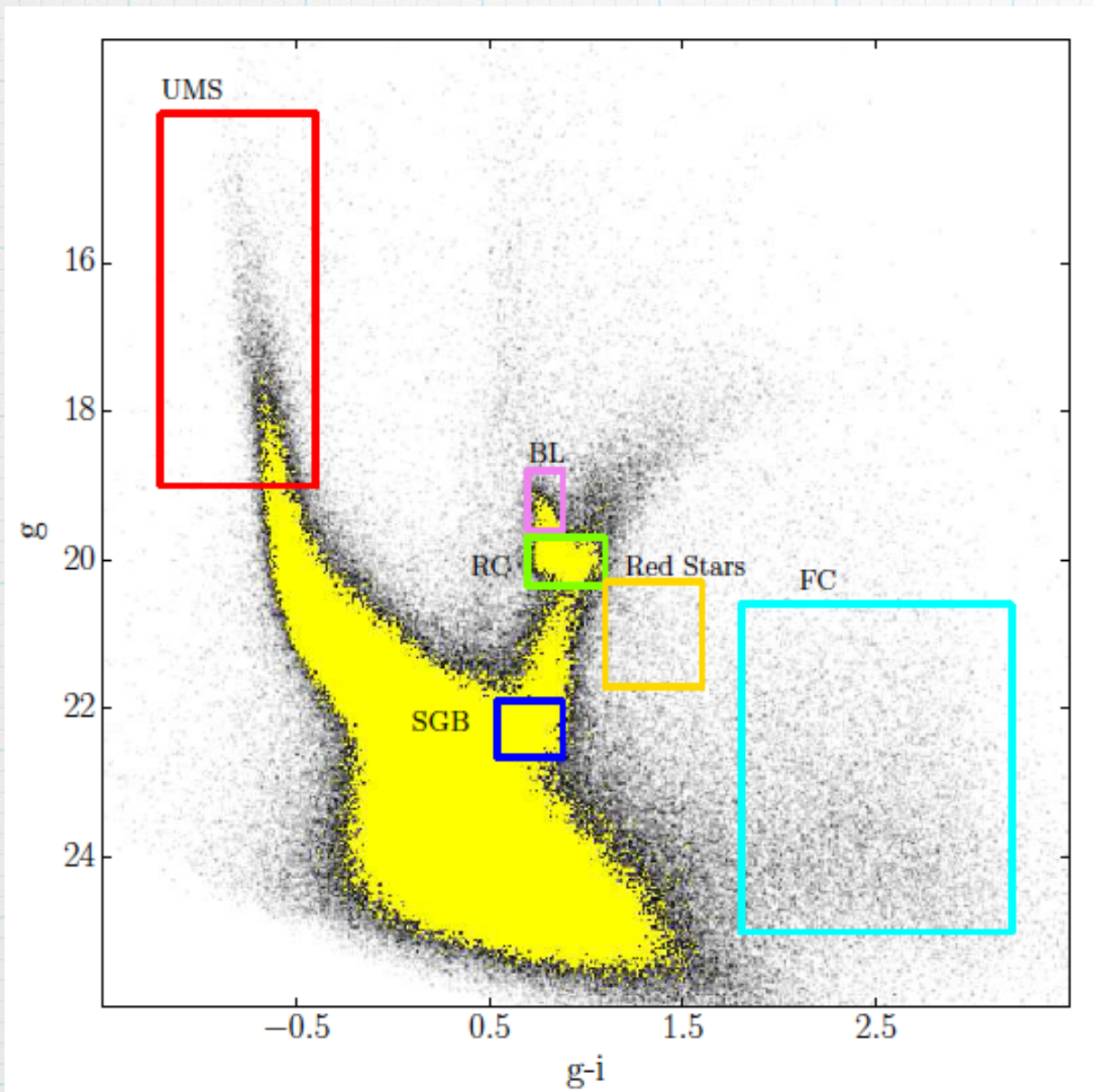
Color Magnitude Diagrams

Tile 3_7 SMC wing

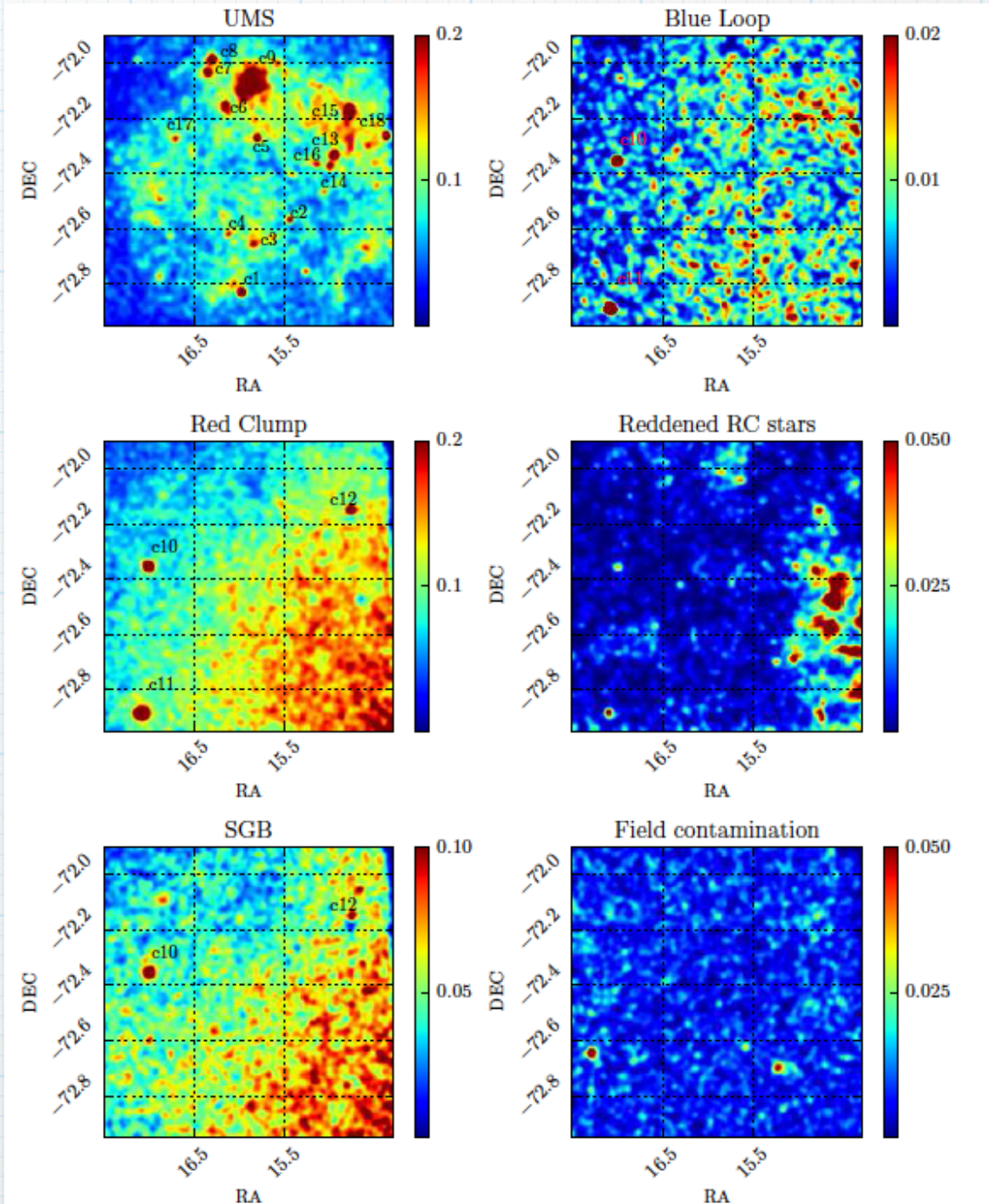
Tile 4_6 SMC body



Spatial distribution

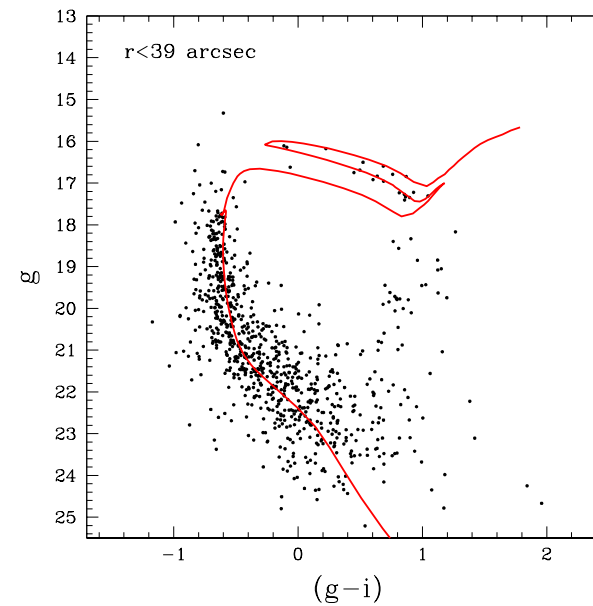
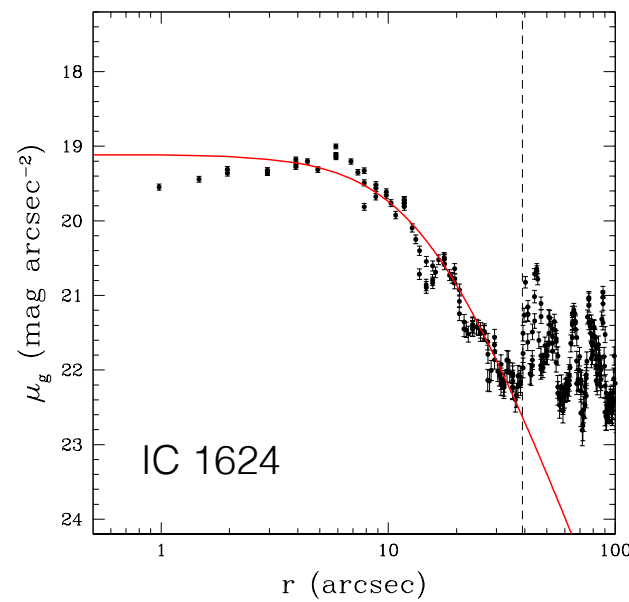
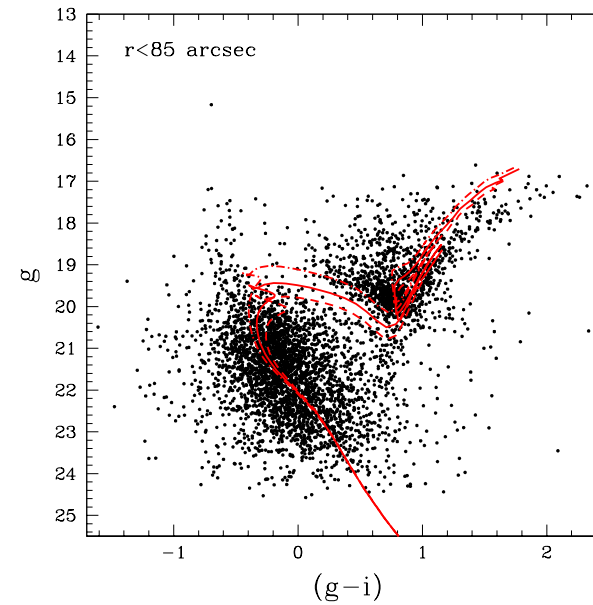
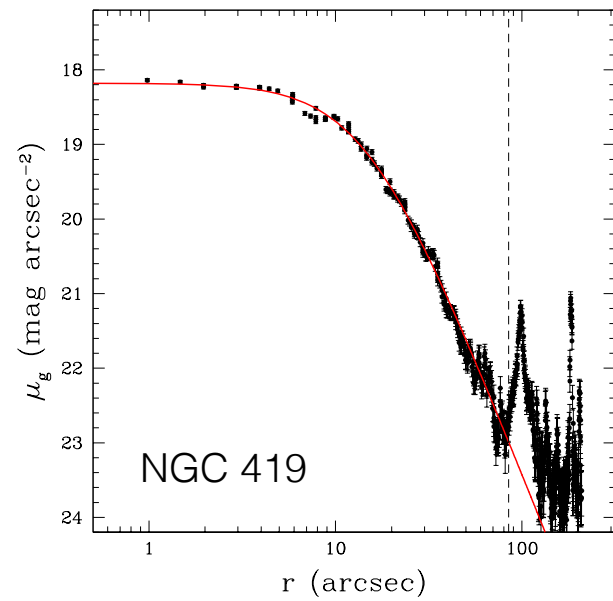


The spatial distribution of stars in different evolutionary stages $\Rightarrow$ important clues on the SF processes over the region.



Clusters

- Ages, age-metallicity relation, spatial distribution.
- Structural parameters



The J-PLUS Survey: Understanding the Formation and Evolution of M33

*I. San Roman, A. Marin-Franch, A. Ederoclite, A. J. Cenarro, H. Vazquez Ramio,
and the J-PLUS Team*

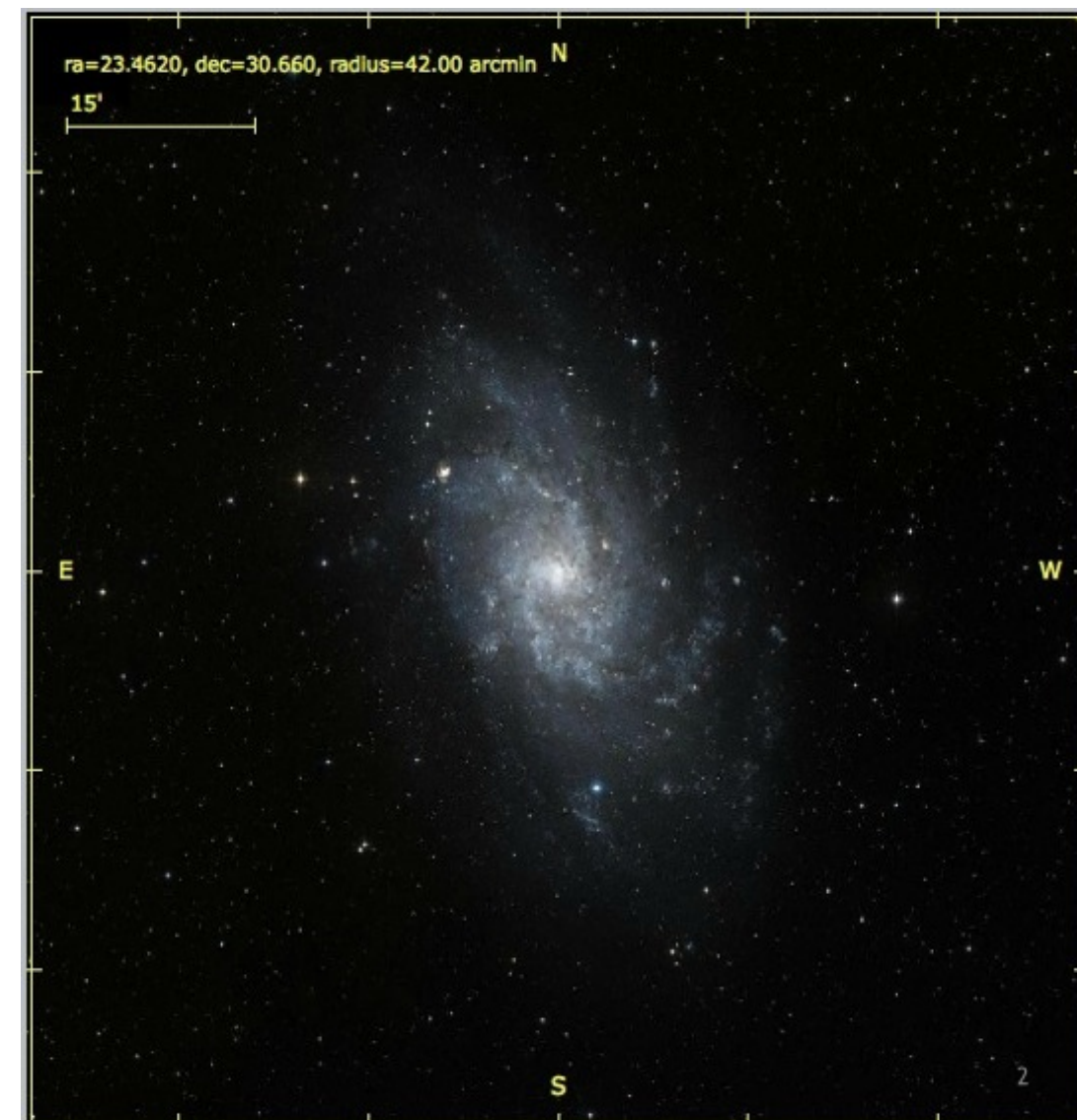


Abstract

We propose to perform a detailed photometric analysis of the resolved and unresolved stellar population of M33 using data from the Javalambre Photometric Local Universe Survey (J-PLUS).

⦿ J-PLUS Survey:

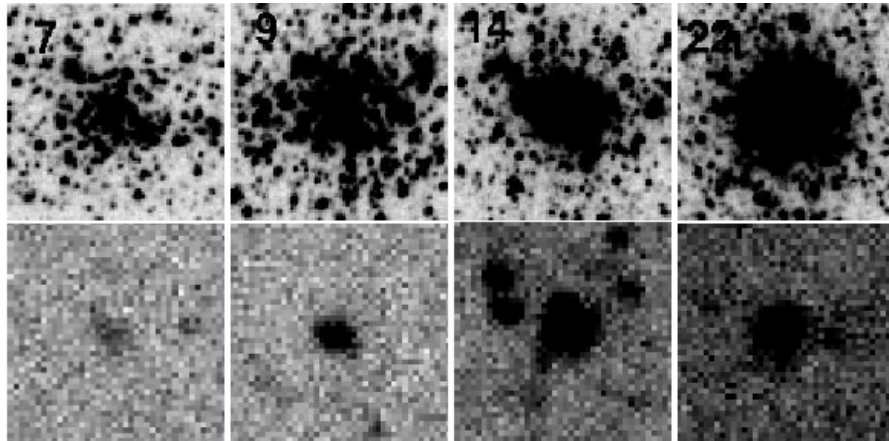
- ⦿ A large photometric survey at Observatorio Astrofísico de Javalambre in Teruel, Spain
- ⦿ Scheduled as part of the commissioning and scientific verification of the survey → Fall 2014
- ⦿ Filter Set: 12 Broad-, intermediate- and narrow-band filters (330 - 1000 nm)
- ⦿ IFU-like capabilities
- ⦿ FOV: $1.4^\circ \times 1.4^\circ$



The J-PLUS Survey: Understanding the Formation and Evolution of M33



*I. San Roman, A. Marin-Franch, A. Ederoclite, A. J. Cenarro, H. Vazquez Ramio,
and the J-PLUS Team*

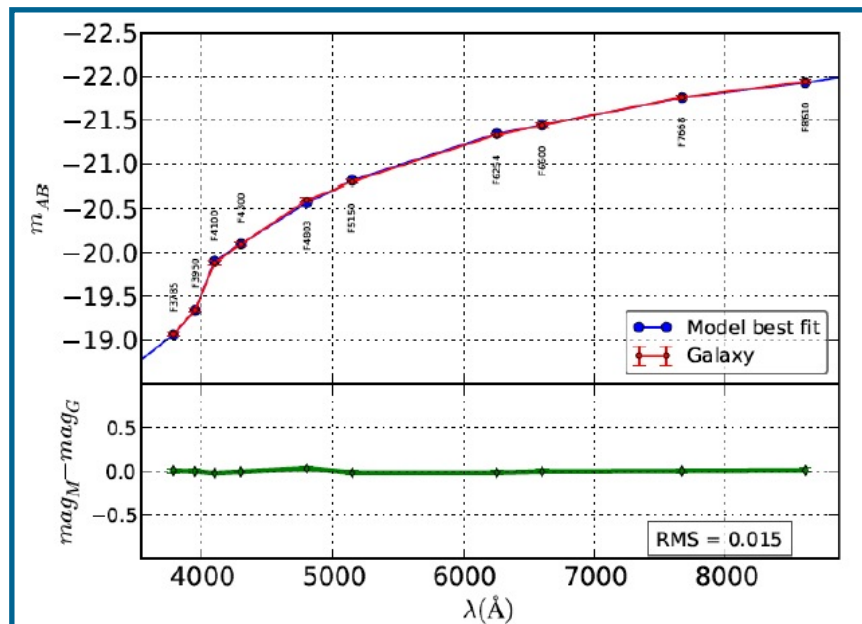


M33 Star Cluster System

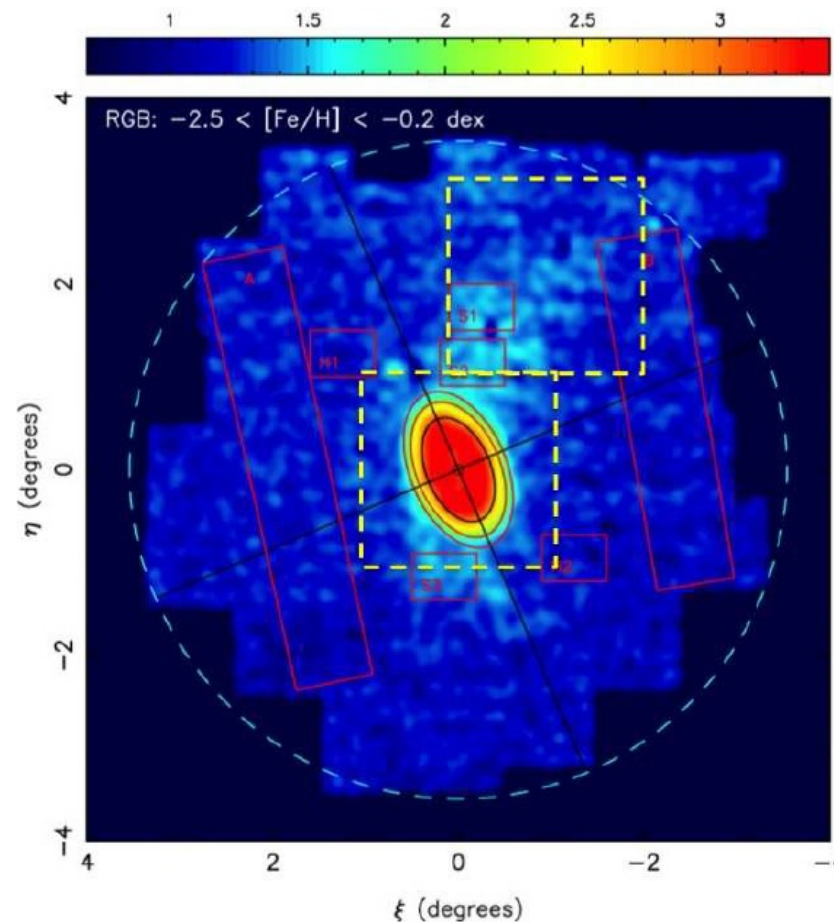
- SEDs over a wide range of wavelengths
- Ages and metallicities of clusters using SED fitting
- The sample size of clusters with age and metallicity will rival those presently in existence in the MW and M31

Unresolved Stellar Population

- A 2D analysis of the underlying stellar population
Tessellation + SEDs fitting



M31-M33 Interaction



- Mapping 2 regions:
 - M33 Center
 - M33-M31 Stream

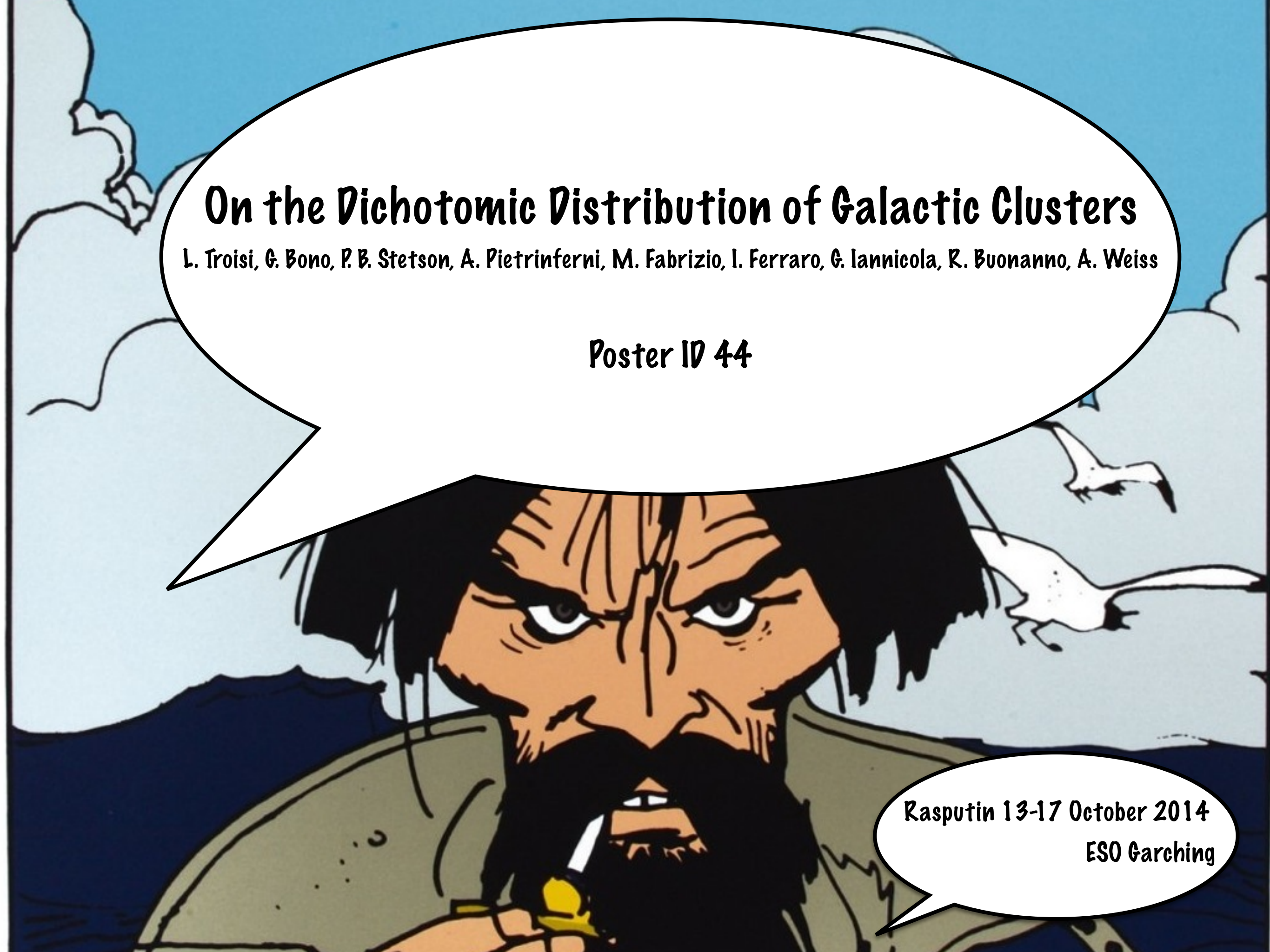
The J-PLUS Survey: Understanding the Formation and Evolution of M33

*I. San Roman, A. Marin-Franch, A. Ederoclite, A. J. Cenarro, H. Vazquez Ramio,
and the J-PLUS Team*



- ⦿ Spectral fitting diagnostics of the resolved and unresolved populations will allow us to determine ages, metallicities and masses of the galactic disk, spheroidal component and cluster system:
 - ⦿ Are there any indications of substructure in the disk and halo of M33?
 - ⦿ Where is the disk/halo transition and how far out from the center can we trace the halo?
 - ⦿ Does the disk metallicity gradient change slope at large galactocentric radii?
 - ⦿ Do the identified tidal streams have clusters associated to them?

The combination of the number of filters, the sky coverage and the depth of this survey will make this project an unprecedented experiment for stellar population studies.

A cartoon illustration of a man with a large black beard and mustache, wearing a brown jacket, looking intensely at the viewer. In the background, a white seagull is flying over a dark blue body of water under a light blue sky with white clouds.

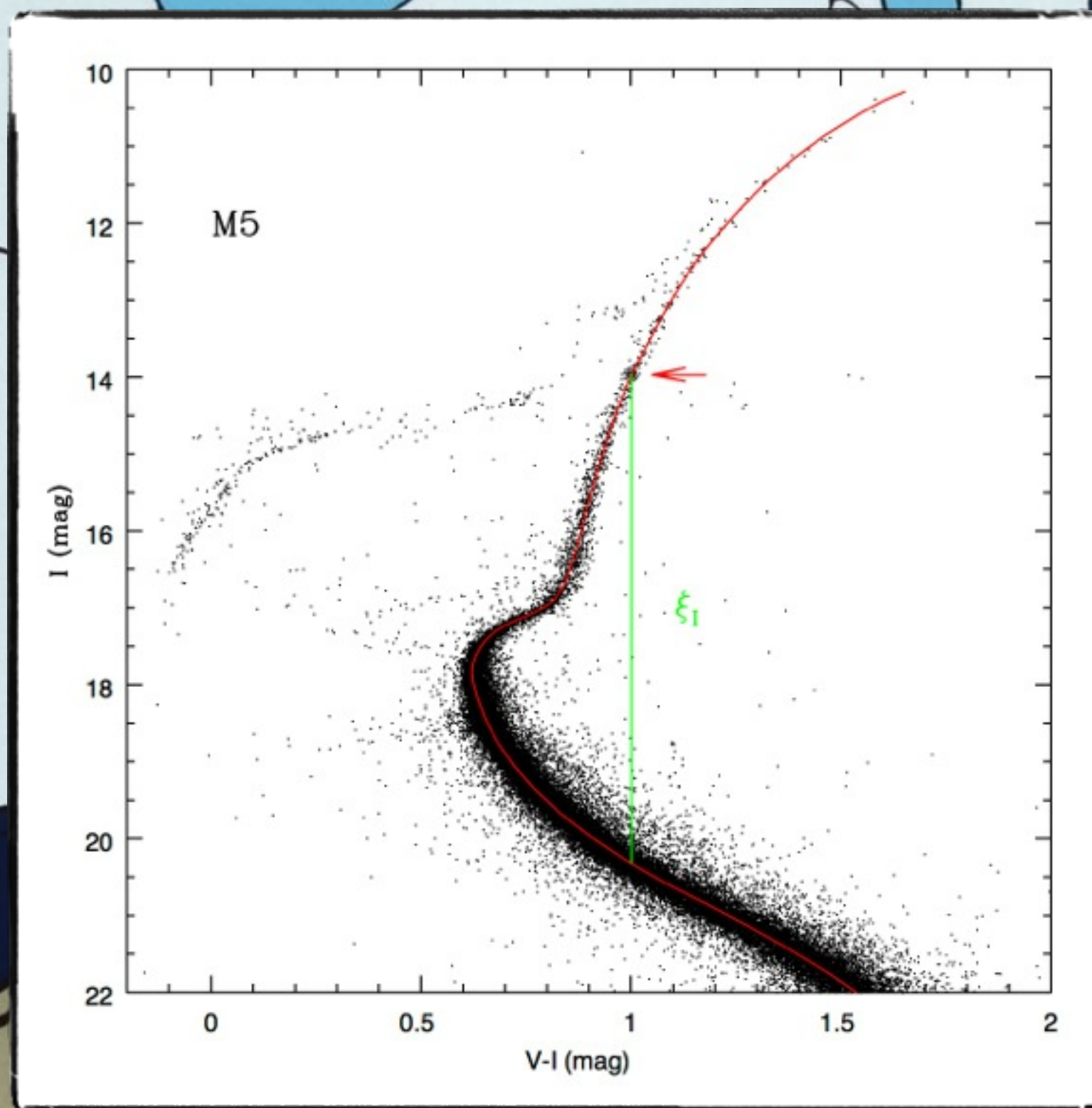
On the Dichotomic Distribution of Galactic Clusters

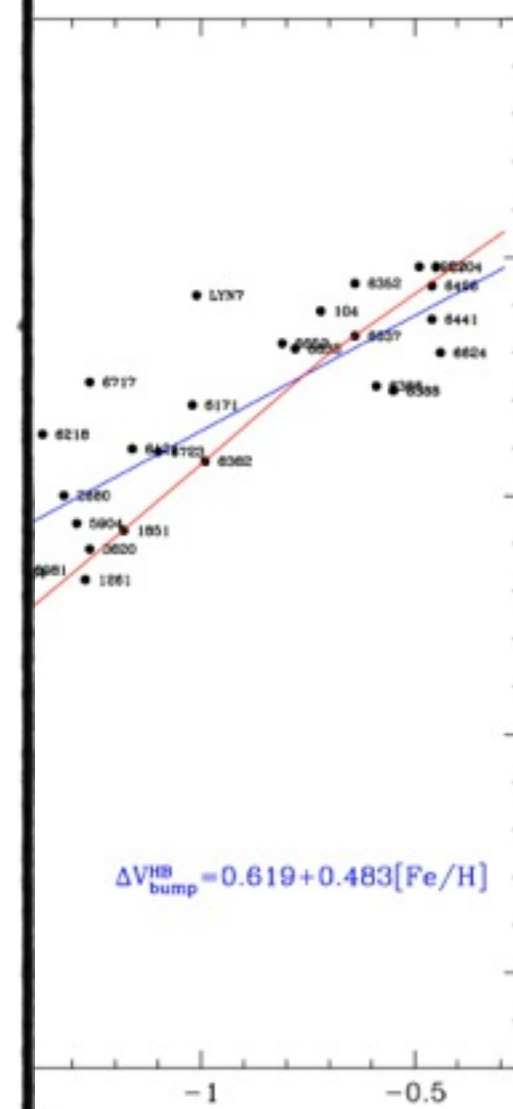
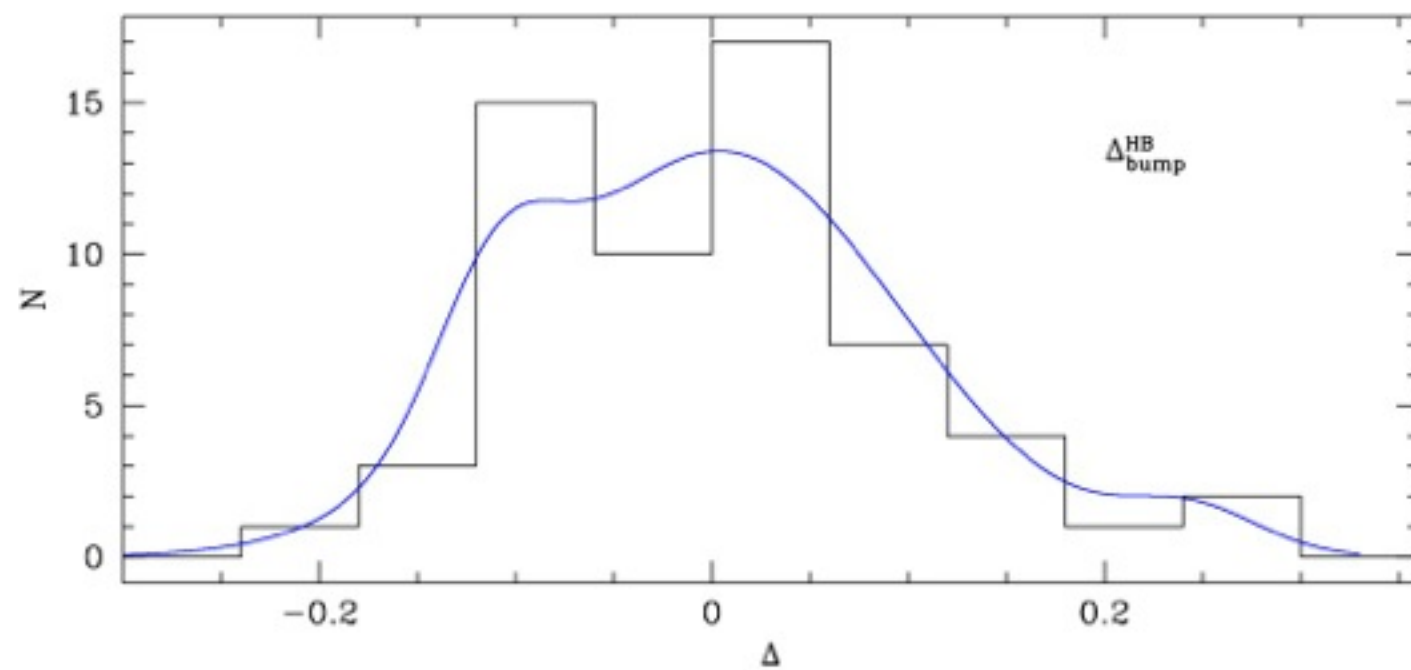
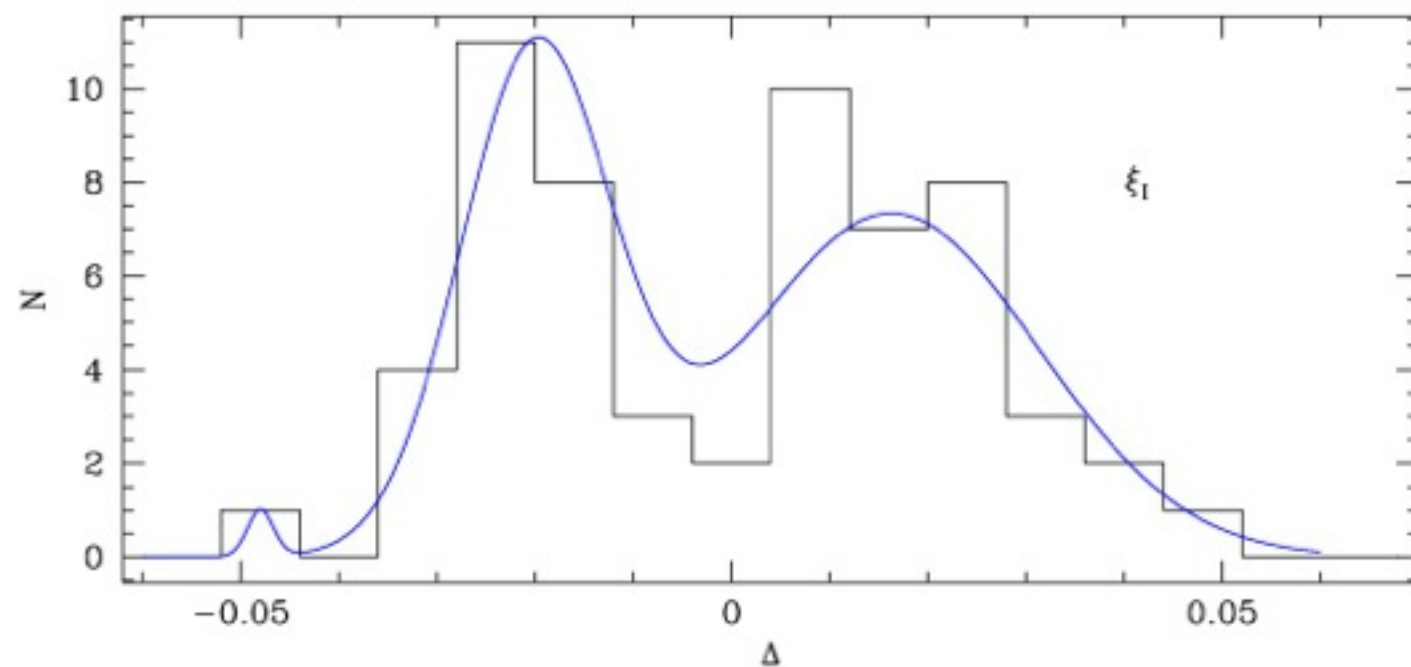
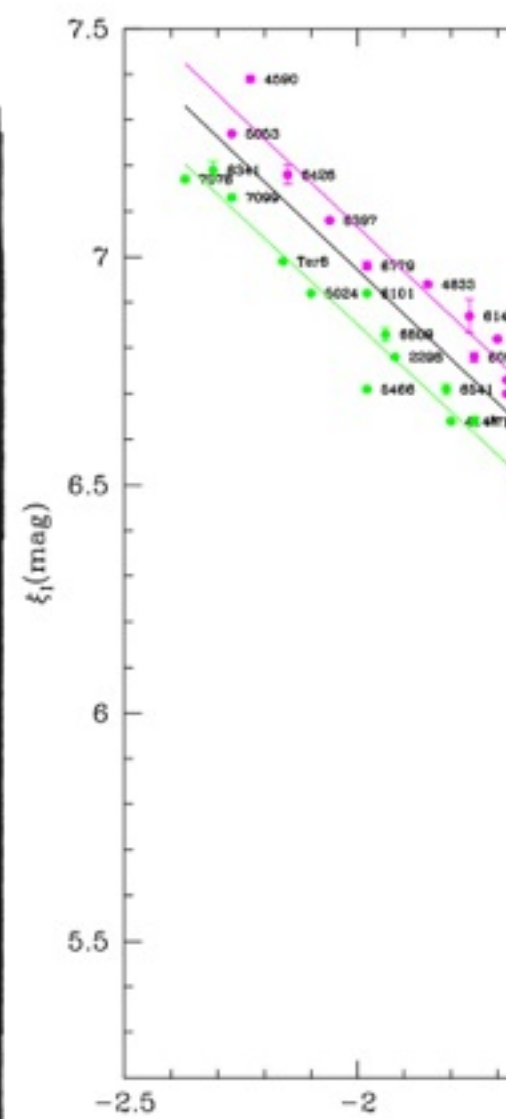
L. Troisi, G. Bono, P. B. Stetson, A. Pietrinferni, M. Fabrizio, I. Ferraro, G. Iannicola, R. Buonanno, A. Weiss

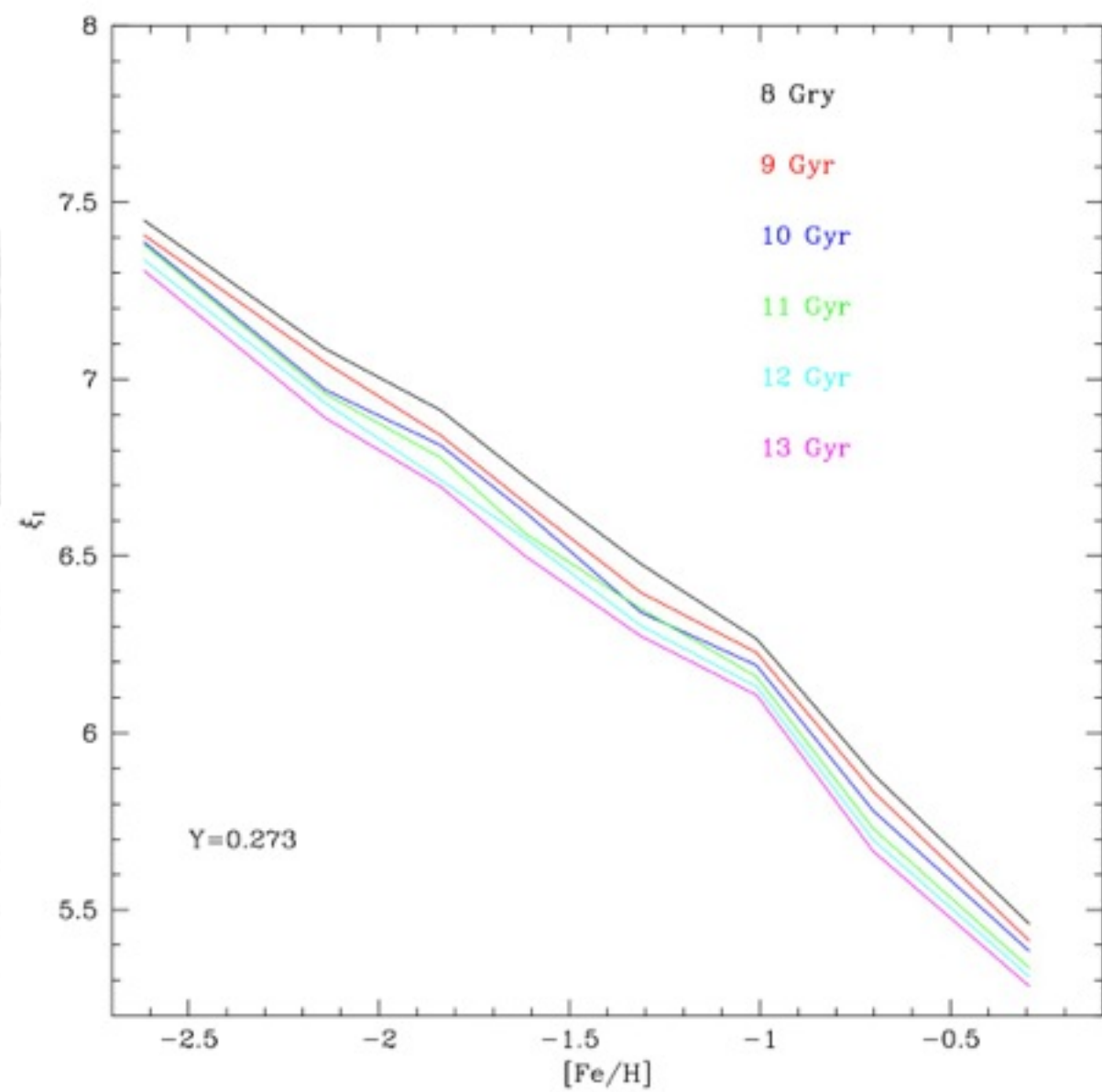
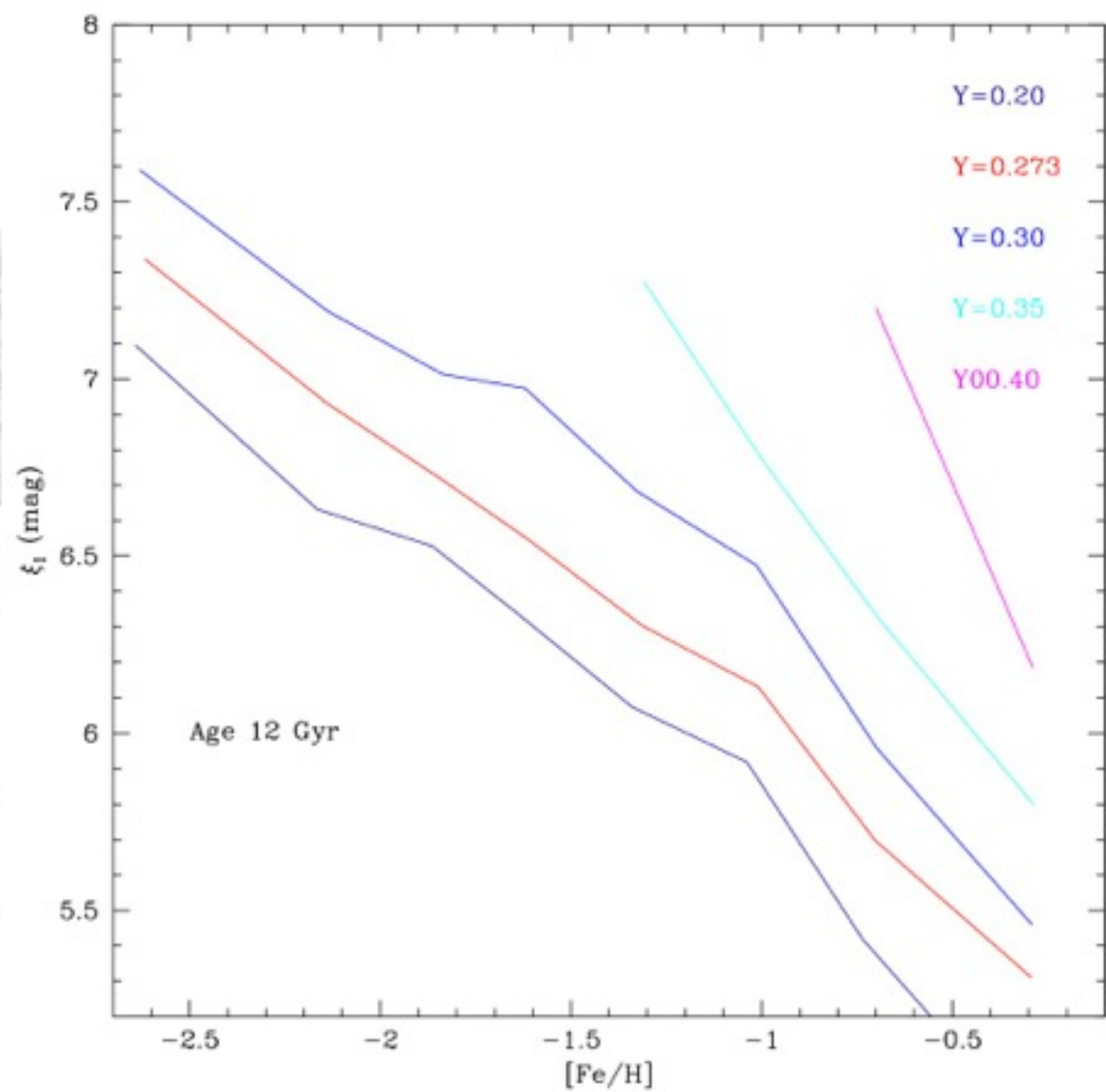
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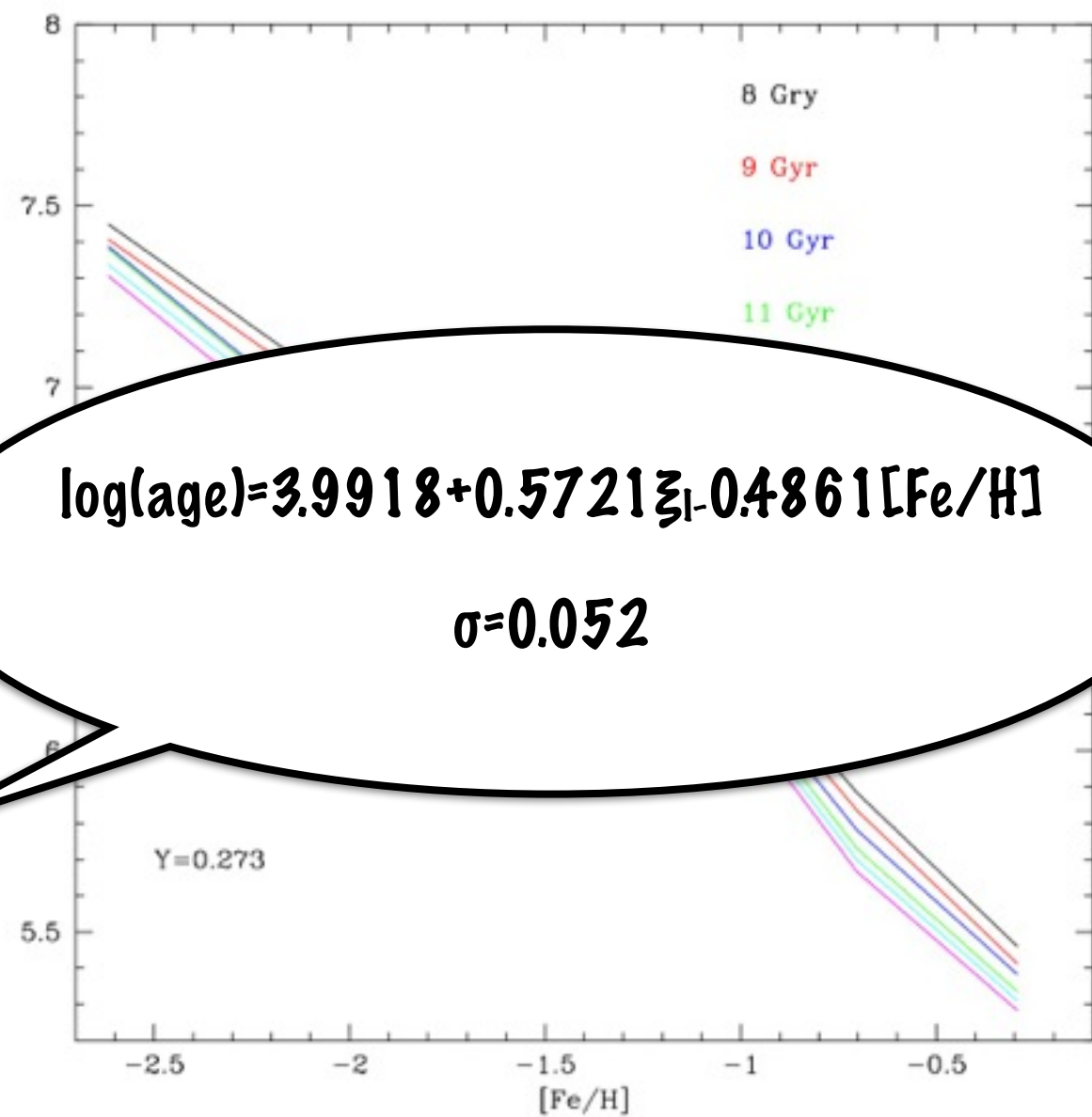
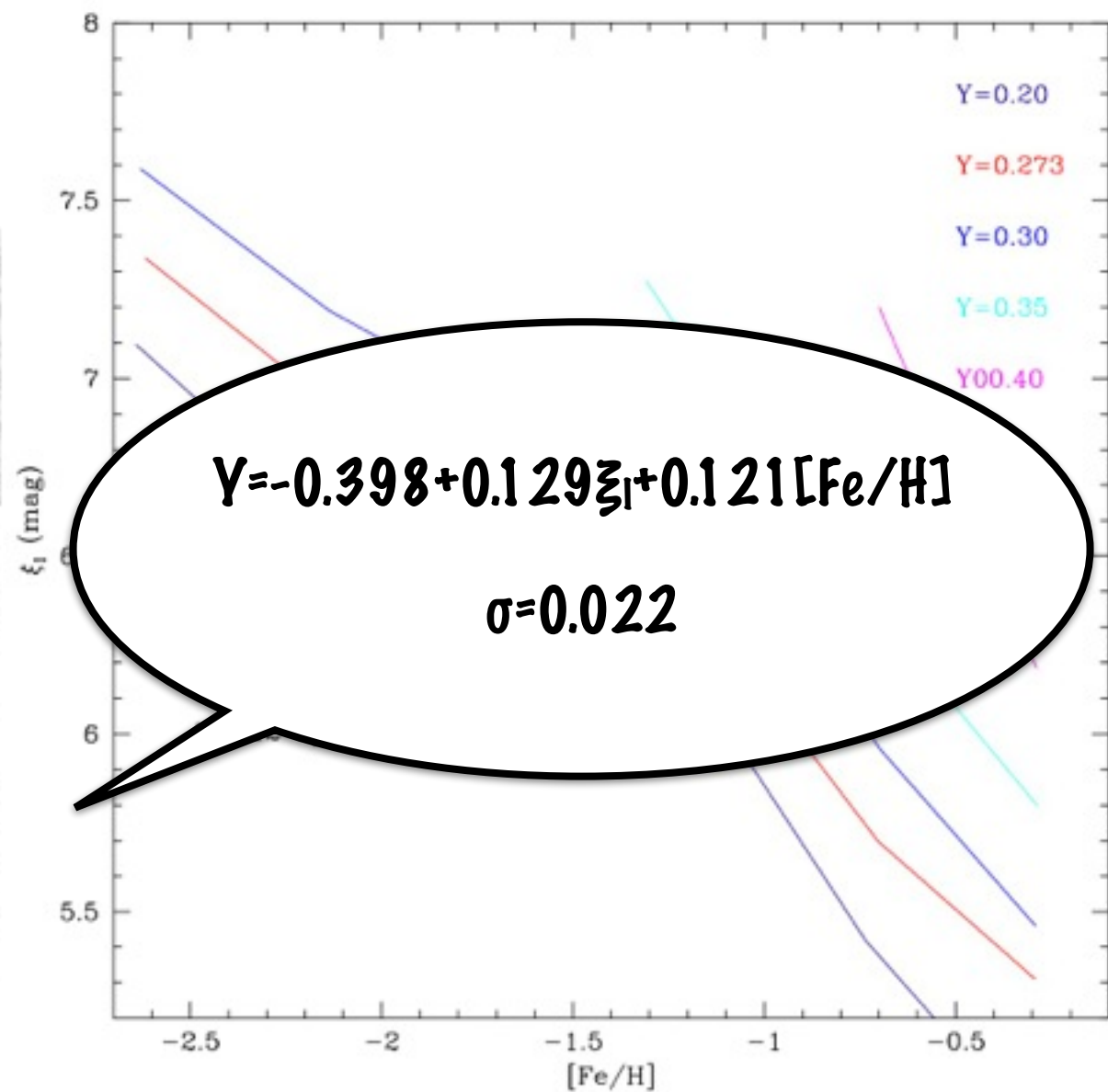
Rasputin 13-17 October 2014

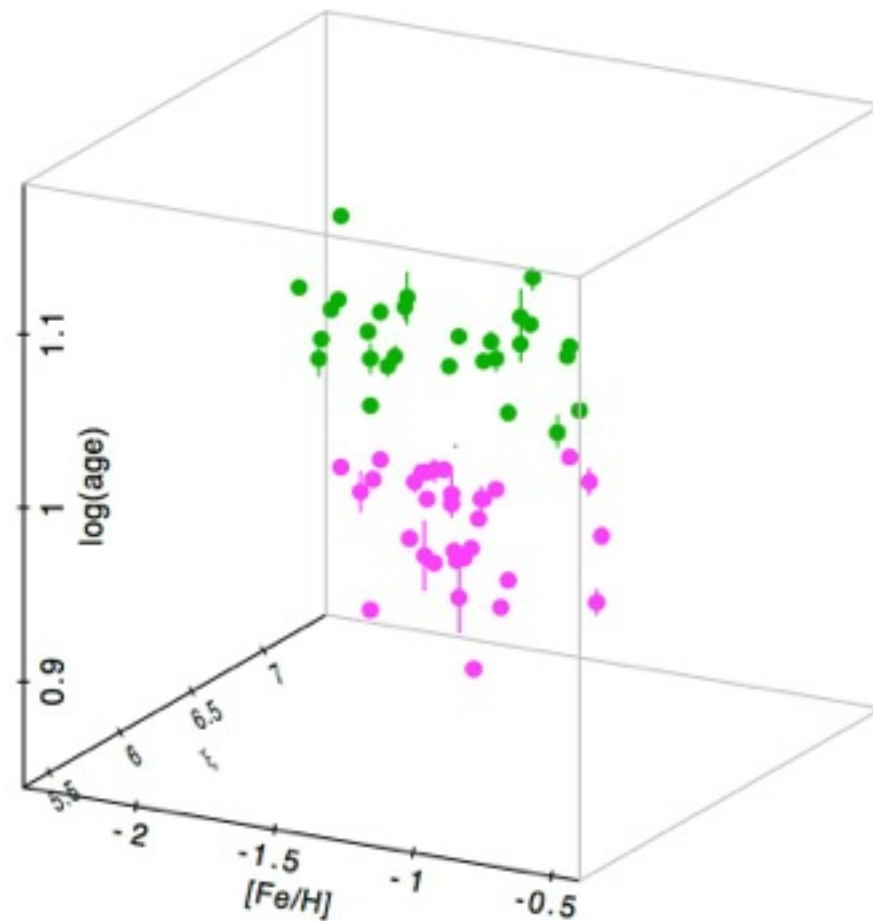
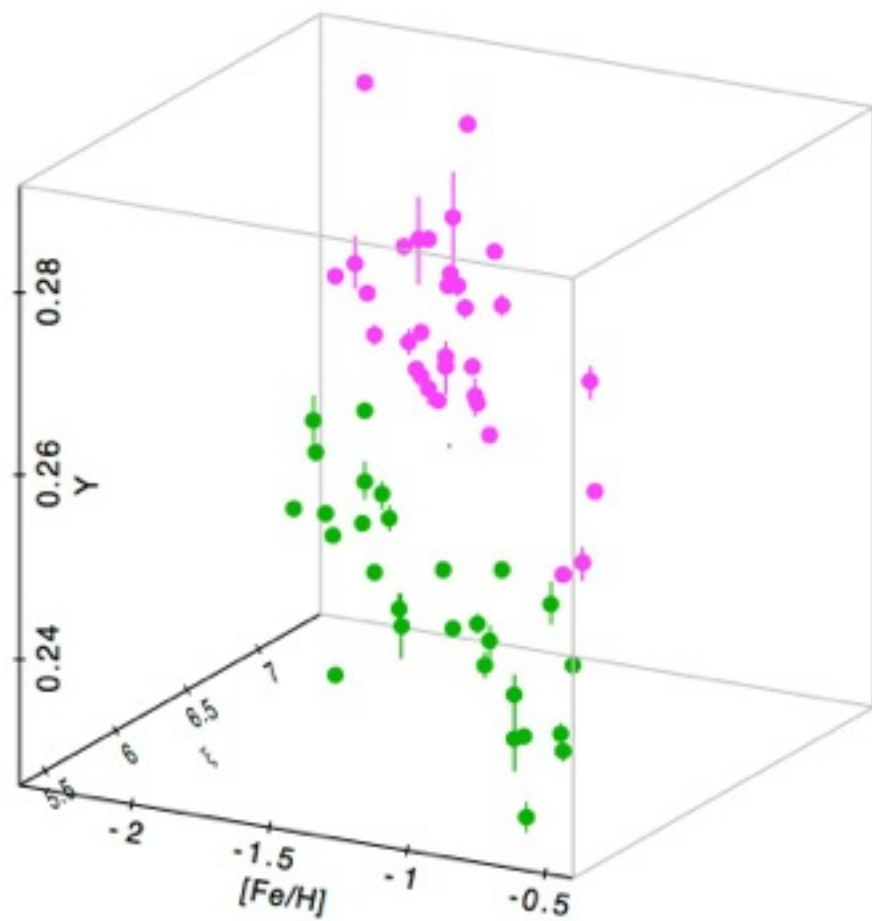
ESO Garching









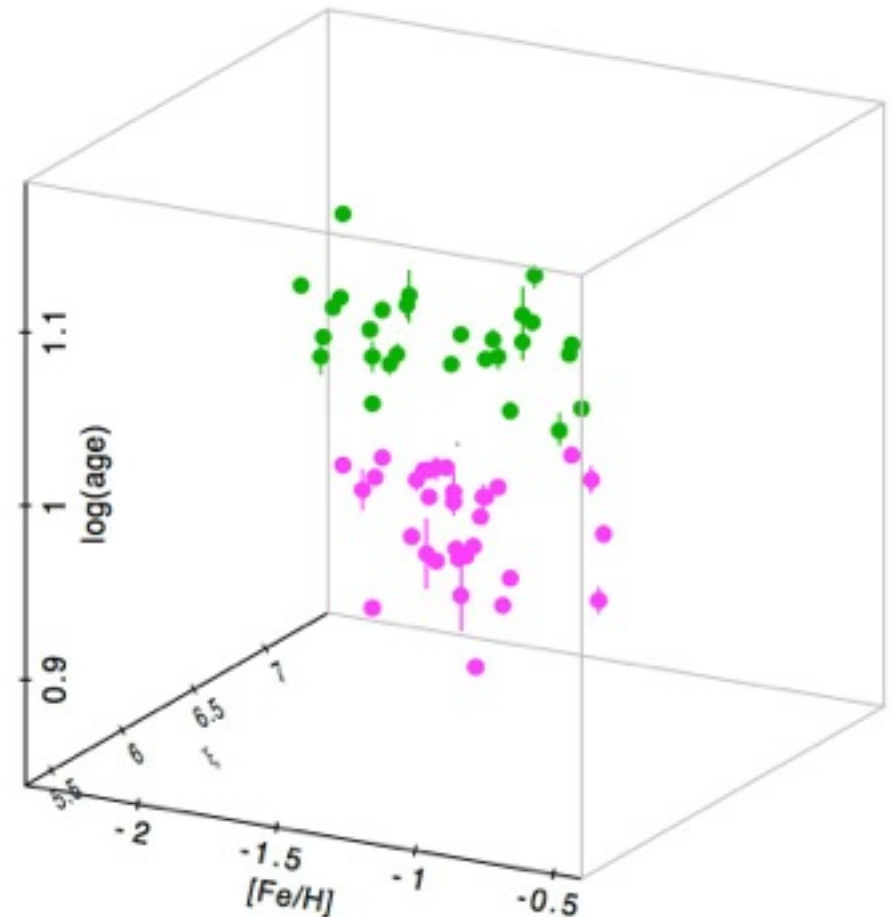
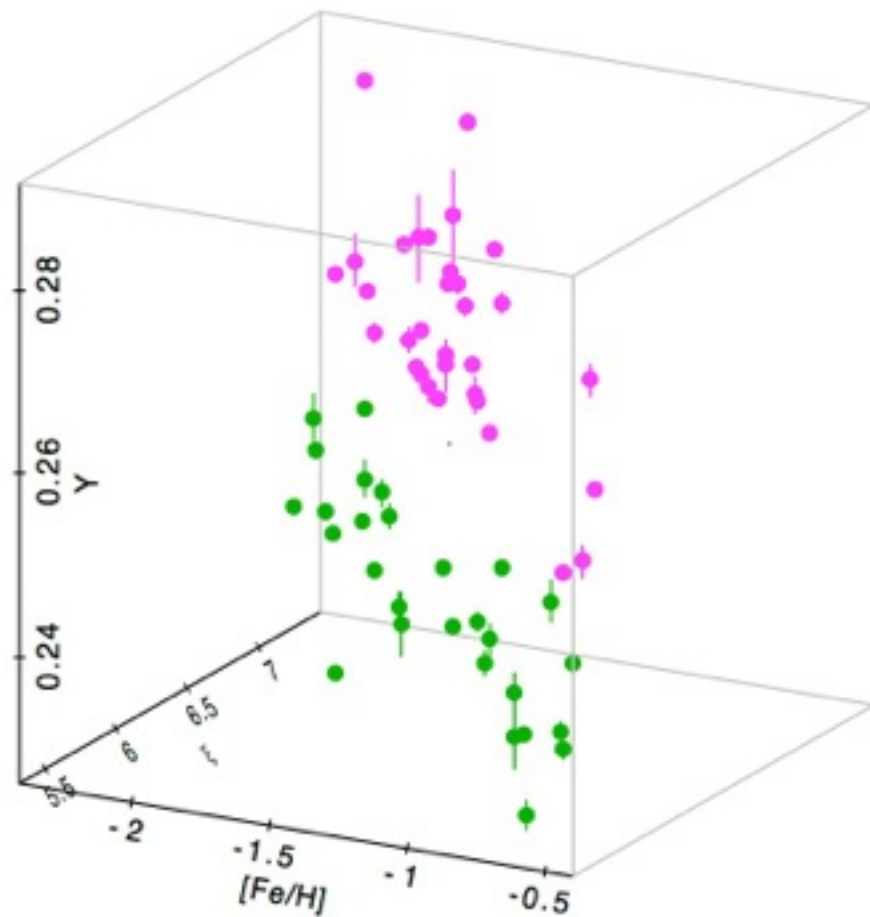


$Y(\alpha)^{\text{mean}} = 0.243 \ (\sigma=0.008)$

$Y(\beta)^{\text{mean}} = 0.270 \ (\sigma=0.006)$

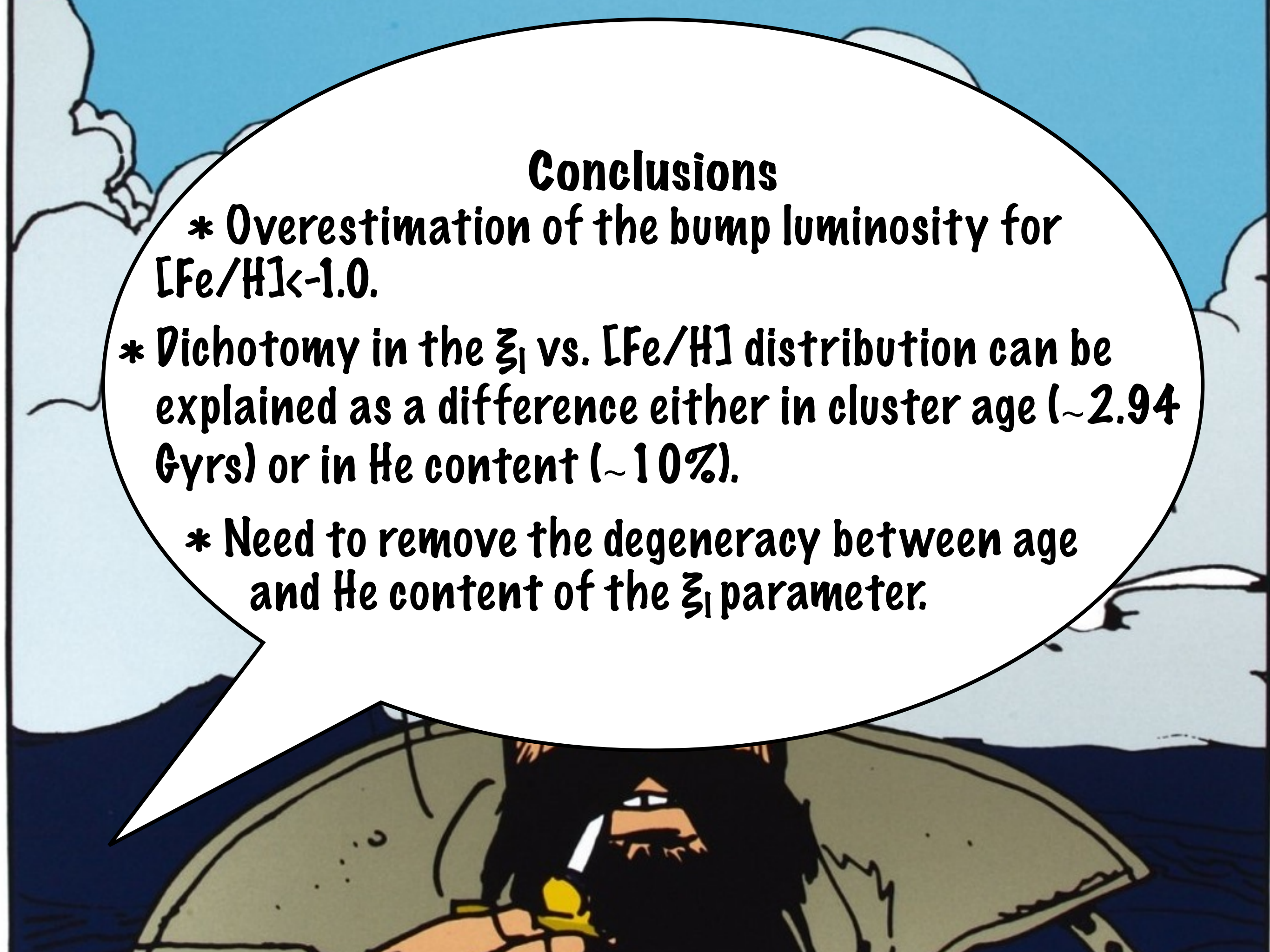
$\log(\text{age})_{\alpha}^{\text{mean}} = 1.079 \ (\sigma=0.045)$

$\log(\text{age})_{\beta}^{\text{mean}} = 0.957 \ (\sigma=0.045)$



Conclusions

- * Overestimation of the bump luminosity for $[\text{Fe}/\text{H}] < -1.0$.
- * Dichotomy in the ξ_1 vs. $[\text{Fe}/\text{H}]$ distribution can be explained as a difference either in cluster age (~ 2.94 Gyrs) or in He content ($\sim 10\%$).
- * Need to remove the degeneracy between age and He content of the ξ_1 parameter.



A cartoon illustration of a man with a beard and a yellow hat on a boat, looking up at a large speech bubble. The background features a blue sky with white clouds and a seagull flying. The man is wearing a dark jacket and has a white shirt visible at the collar. The boat is brown and has some details like a railing and a small yellow object. The speech bubble is white with a black outline and contains the text "Thanks for your attention!" and "Poster ID 44".

Thanks for your attention!

Poster ID 44



RASPUTIN

ESO Garching

October 13 - 17, 2014

Do globular clusters have Na-rich AGB stars?

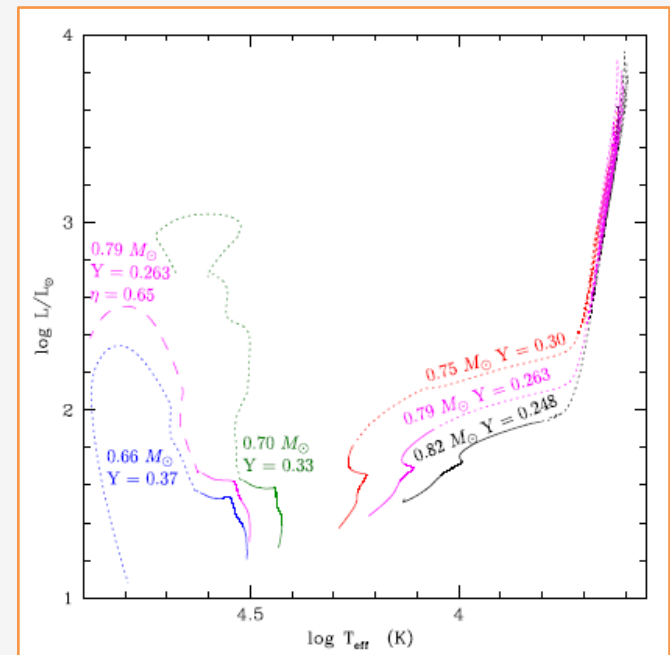
Metallicity distribution of AGB and RGB
stars in NGC 2808

Yue Wang
Francesca Primas
Corinne Charbonnel

45

Do globular clusters have Na-rich AGB stars?

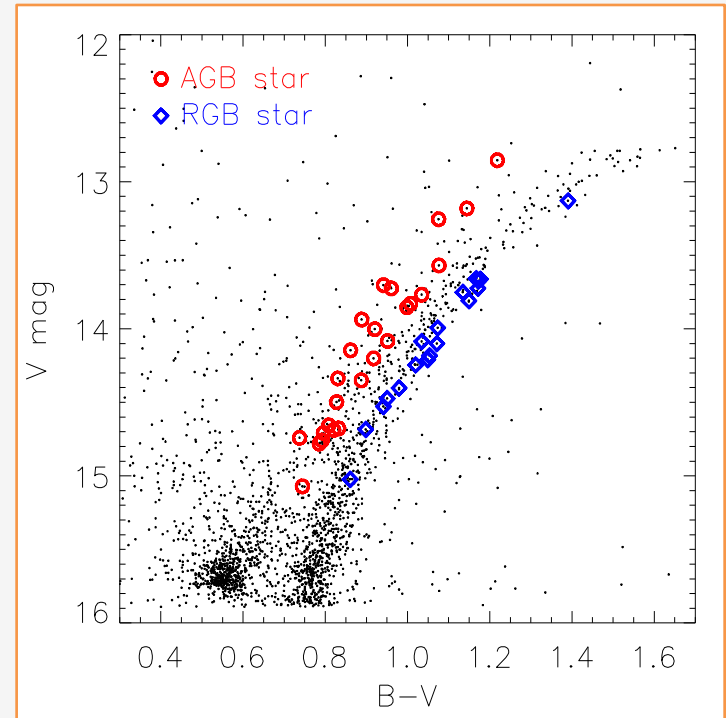
- ◇ Multiple populations in GCs
 - 1st generation: Na abundances are similar to those of halo stars of similar metallicity.
 - 2nd generation: Na-rich
- ◇ No Na-rich, 2nd-generation stars along the early-AGB of NGC 6752 (Campbell et al. 2013)
- ◇ Fast Rotating Massive Stars (FRMS) pollution model can provide a simple explanation. (Charbonnel et al. 2013)



Charbonnel et al. 2013

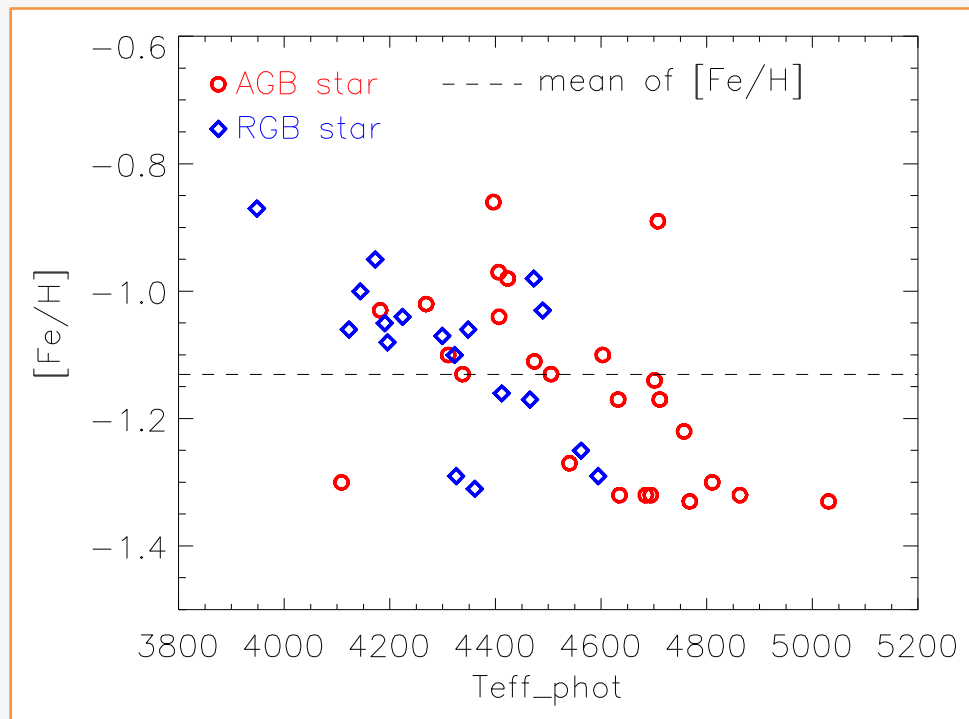
Do globular clusters have Na-rich AGB stars?

- ◇ Sample: AGB & RGB stars in NGC 2808
- ◇ FLAMES/GIRAFFE @ VLT/ESO
- ◇ Three setups:
HR13 (612.0-640.5nm, R=22500)
HR15 (660.7-696.5nm, R=19300)
HR19 (774.5-833.5nm, R=13867)
- ◇ $S/N > \sim 150$



Do globular clusters have Na-rich AGB stars?

- ◇ Metallicity distribution (preliminary)



- ◇ Next step: accurate Fe, Na and O abundances

SUBARU/IRCS Near-Infrared Spectroscopy of the Young Cluster GLIMPSE9 in the inner Galaxy



Ryo Yamamoto
(University of Tokyo)

KEI FUKUE, NORIYUKI MATSUNAGA, CHIKAKO YASUI,
SATOSHI HAMANO, NAOTO KOBAYASHI
(UNIVERSITY OF TOKYO),
TAKUJI TSUJIMOTO
(NATIONAL ASTRONOMICAL OBSERVATORY OF JAPAN),
SOHEI KONDO, YUJI IKEDA
(KYOTO SANGYO UNIVERSITY)

The Metallicity Distribution of The Open Clusters

Investigating the **metallicity** distribution in the inner Galaxy

- It is important for investigating the Galactic evolution

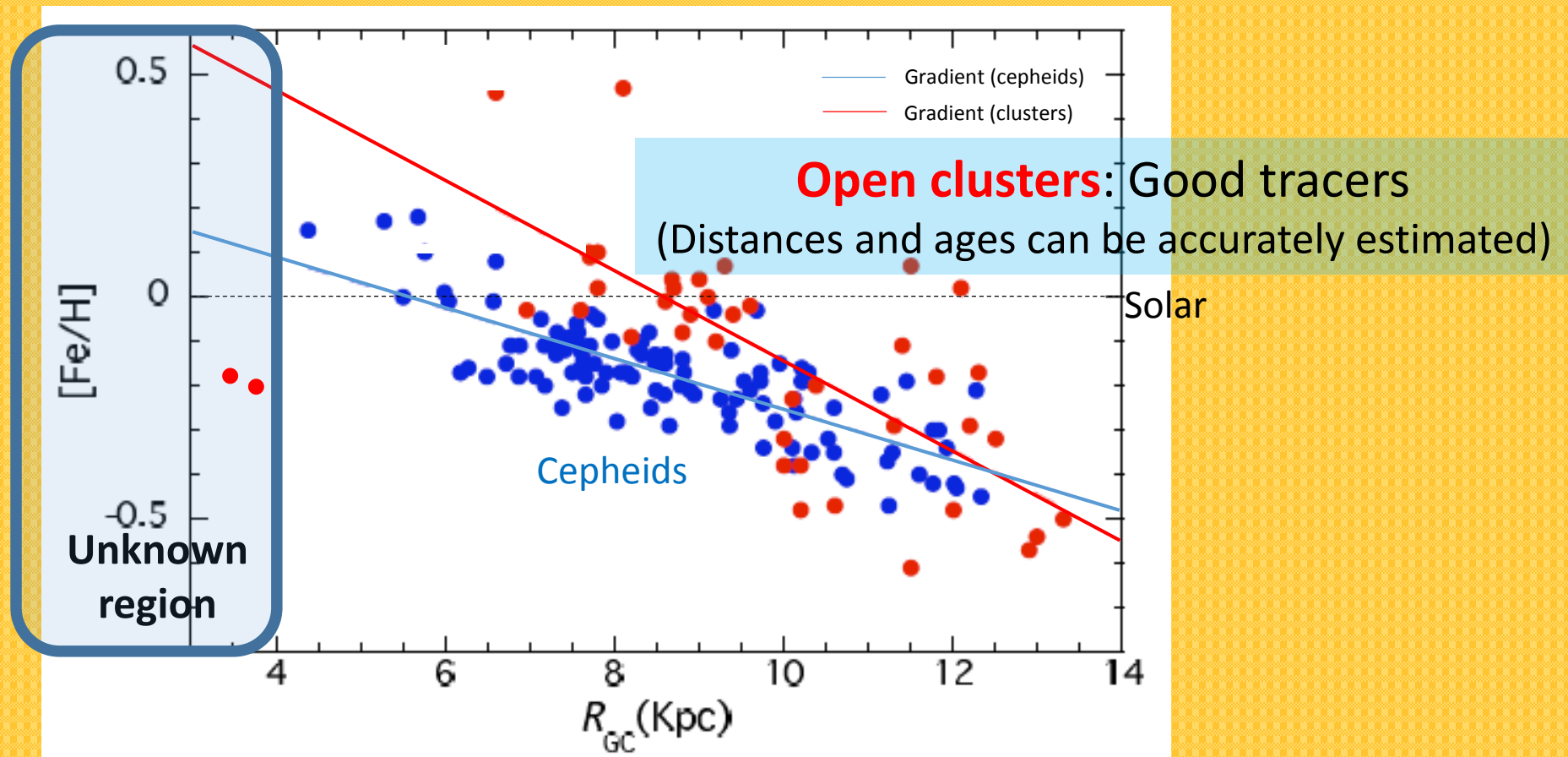


Figure. The Galactocentric distance vs the metallicity (Tsujiimoto et al. 2009)

Study with Near-infrared High Resolution Spectroscopy

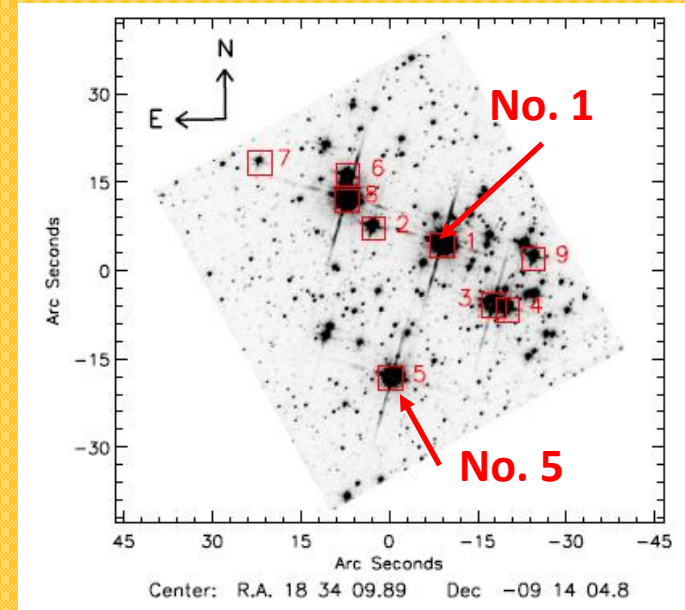
◆ Target in this work

GLIMPSE9 cluster No.1 and 5 (M0-2I)

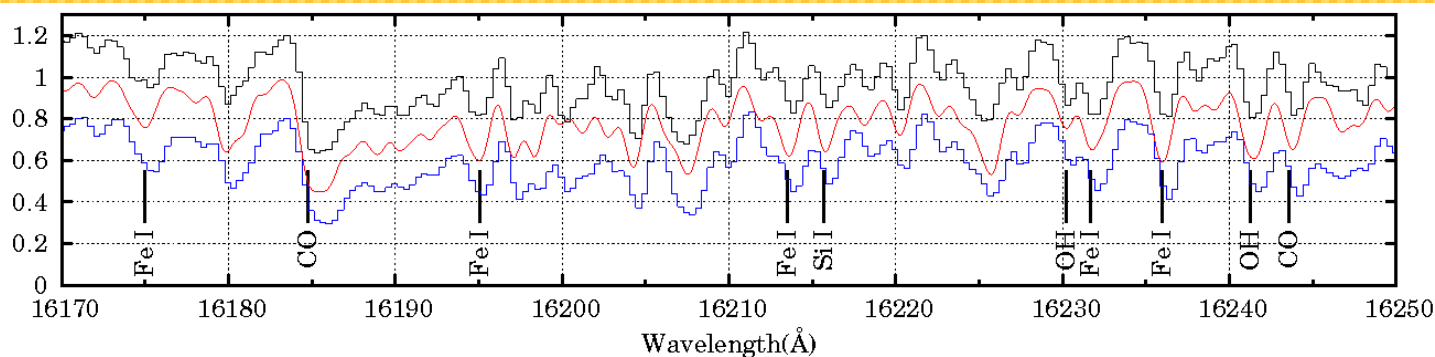
- $R_{GC} \sim 4$ kpc (innermost Galactic disk)
- $M_{cl} \sim 10^3 M_{\odot}$ (typical mass of open clusters)
- Age ~ 21 Myr

◆ Observation

SUBARU 8.2 m telescope / IRCS spectrograph
H-band ($1.47 - 1.79 \mu\text{m}$), $R \sim 20000$



Mosaic of GLIMPSE9 clusters
(Messineo et al. 2009)



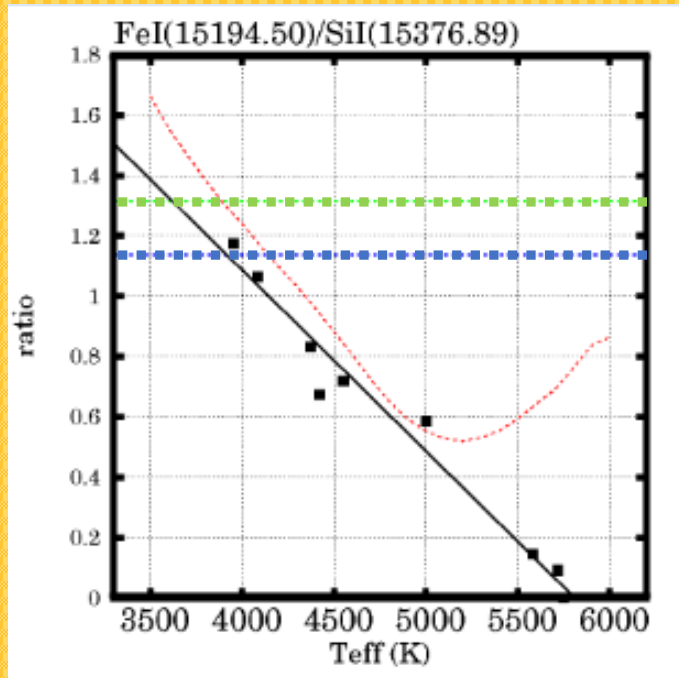
Black: GLIMPSE9 No. 1
Red: Synthetic spectrum
Blue: GLIMPSE9 No. 5

Fig. A part of spectra.

The Method to Derive Stellar Parameters

◆ Effective temperature T_{eff}

T_{eff} are estimated from line-depth ratios



- Ratios of two lines with low- and high-excitation potentials depend on T_{eff}
- We use 7 pairs of lines to estimate

Fig. Line-depth ratio plotted as a function of T_{eff}

- : ratio of star No. 1
- : ratio of star No. 5
- : linear fitted line for observational data
- : ratios of metal standard stars observed with IRCS
- : derived ratio from synthetic spectra

◆ Surface gravity $\log g$

$$\log g = \log M + 4 \log T_{eff} - \log L - 10.61$$

(M : mass, L : luminosity)

The Method to Derive Stellar Parameters

◆ Microturbulence ξ and Metallicity $\log \epsilon(\text{Fe})$

The microturbulence is determined when $\log(\epsilon)\text{Fe}$ becomes independent of X -factor

$$X = \log gf - E.P. \times 5860/T_{eff} \quad (\text{Gratton et al. 2009})$$

Metallicity is simultaneously derived.

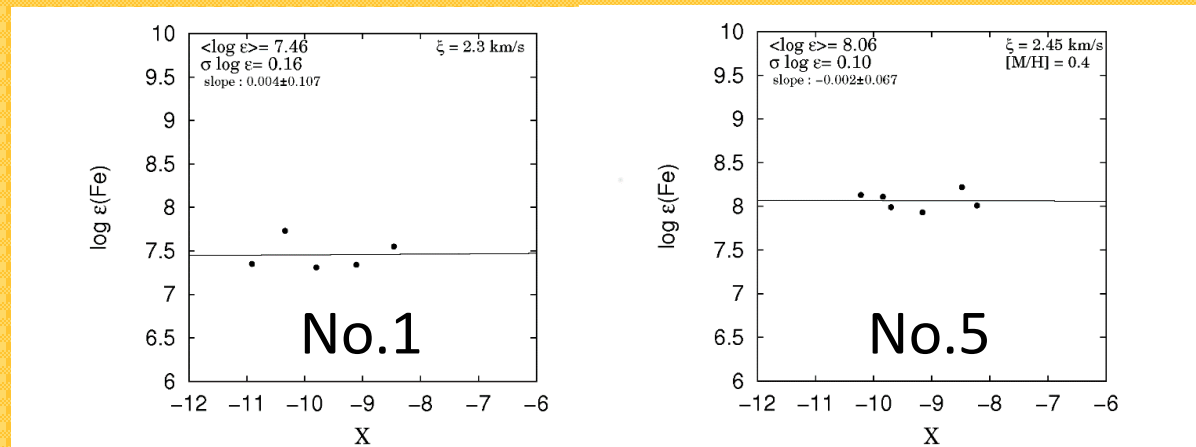


Fig. Metallicity of each line plotted as a function of X -factor

◆ Abundances of other elements

Abundances are derived by fitting synthetic spectra to observed ones

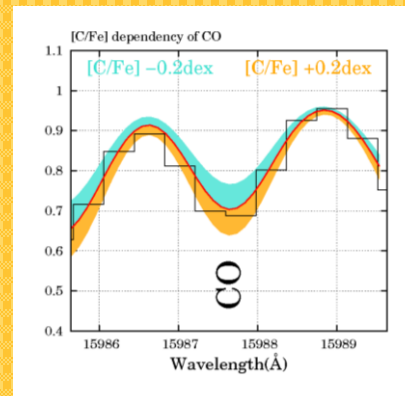


Fig.
A variation of a CO line by shifts of $[\text{C}/\text{Fe}]$ indicated in the panel

Preliminary Results of This Work

	[Fe/H]	[C/Fe]	[N/Fe]	[O/Fe]	T_{eff} (K)	$\log g$	ξ (km/s)
No.1	-0.04 ± 0.08	+0.31	+0.14	-0.27	3601 ± 64	1.25	2.30
No.5	$+0.56$ ± 0.04	-0.56	+0.34	-0.25	3855 ± 44	0.75	2.45

We present details of the analysis in the poster!!

Poster #47

Thanks!

Poster #47

ID 47

SUBARU/IRCS Near-Infrared Spectroscopy of the Young Cluster GLIMPSE9 in the inner Galaxy

RYO YAMAMOTO, KEI FUKUE, NORIYUKI MATSUNAGA, CHIKAKO YASUI, SATOSHI HAMANO, NAOTO KOBAYASHI (THE UNIVERSITY OF TOKYO), TAKUJI TSUJIMOTO (NATIONAL ASTRONOMICAL OBSERVATORY OF JAPAN), SOHEI KONDO, YUI IKEDA (KYOTO SANGYO UNIVERSITY)

ABSTRACT

We are investigating the metallicity distribution in the inner Galaxy with near-infrared (NIR) high-resolution spectroscopy of star clusters, which are significant tracers with accurately estimated distances and ages. We present spectral analysis for two red supergiant stars in GLIMPSE9 cluster, which is a young cluster with a typical mass of open clusters and located at around the Galactocentric distance of 4.2 kpc. Based on NIR spectra (1.47 – 1.79 μm , $R \sim 20000$) obtained with IRCS spectrograph + AO188 at SUBARU 8.2 m telescope, we have estimated the metallicities and stellar parameters (e.g. effective temperature, surface gravity and microturbulence) of the targets. The preliminary results are $[\text{Fe}/\text{H}] = -0.04$ and $+0.56$ dex of the two stars. We still need to check details of the abundance analysis.

INTRODUCTION

◆ Goal:

Finding out the metallicity distribution in the Galactic innermost disk ($R_{GC} < 5$ kpc)

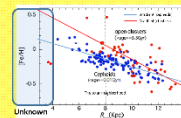


Fig. 1. The Galactocentric distance vs. the metallicity (Hamano et al. 2009)

$R_{GC} > 5$ kpc: Metallicities increase toward the Galactic plane
 $R_{GC} < 5$ kpc: Metallicities are hardly given

Among a few previous studies, Davies et al. (2009) found that RSGC1.2 ($R_{GC} \sim 3.5$ kpc) have the similar low metallicity $[\text{Fe}/\text{H}] \sim -0.20$

◆ Method

High-resolution spectroscopy in the near-infrared

• Interstellar extinction prevents us, especially with optical observing, from investigating metallicity distribution in the inner Galaxy.



Fig. 2. Left: Distribution of the open clusters. Location of GLIMPSE9 (No. 1) is (72° 26', -0° 40'). Right: GALP cluster taken by M01 camera (Messineo et al. 2010)

◆ Target

GLIMPSE9 cluster ($\sim 10^3 M_{\odot}$, $R_{GC} \sim 4$ kpc)

• It is located in the Galactic innermost disk.

• It has a typical mass as a young open cluster.

• Spectral types of the members have been reported (Messineo et al. 2010).

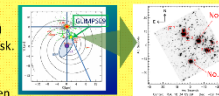


Fig. 3. Left: Distribution of the open clusters. Location of GLIMPSE9 (No. 1) is (72° 26', -0° 40'). Right: GALP cluster taken by M01 camera (Messineo et al. 2010)

OBSERVATION

◆ Instrument

IRCS+AO188 spectrograph, SUBARU 8.2m telescope

• Wave length: H-band 14700 – 17900 Å → Wide coverage and many metal lines

• Resolution: $R \sim 20,000$ → High resolution required to derive metallicities

◆ Target

Target	Date	SpType	H	Exposure (s)
GLIMPSE9 No.1	2010/06/20	M0-2I	8.80	250 X 4
GLIMPSE9 No.5	2010/06/20	M0-2I	8.43	300 X 4

SIOA PI Matsunaga

ANALYSIS

◆ The method of analysis

Deriving stellar parameters from observed and synthetic spectra

★ Data of synthetic spectra

• Model atmosphere ••• ATLAS9 by Kurucz

• Line database ••• Atom: Melendez et al. (1999),

Molecule (CN, OH): Kurucz database (1993)

Molecule (CO): Goorvitch et al. (1994)

• Solar abundance ••• Grevesse ($\log \epsilon(\text{Fe}) = 7.501$)

◆ Tools

SPTOOL (by Y. Takeda): making synthetic spectra and deriving abundances

★ SPSHOW

Making synthetic spectra for given input parameters of stars

★ MPFIT

Deriving abundances by searching for best-fit synthetic spectra for chosen lines

◆ Input stellar parameters to make synthetic spectra

Atmospheric parameters
Effective temperature T_{eff} (K)
Surface gravity $\log g$
Microturbulence ξ (km/s)
Macro-turbulence V_{mac} (km/s)
Global metallicity $[\text{M}/\text{H}]$

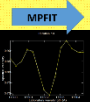


Fig. 4. profile of MPFIT

Output parameters

$[\text{Fe}/\text{H}]$ (& V_{mac})

ABUNDANCE ANALYSIS

◆ Effective temperature T_{eff} :

T_{eff} is estimated by the method of line depth ratio (see Poster ID 15 by Fukue)

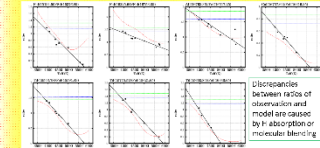


Fig. 5. The depth ratios for some pairs of lines as functions of effective temperature. The line depth ratio is defined as follows: $R = \log(I_{\text{Fe}} - I_{\text{H}}) / \log(I_{\text{Fe}} - I_{\text{H}}) / T_{\text{eff}}$ where I is statistical weight, F is oscillator strength and E_F is ionization potential.

◆ Surface gravity $\log g$:

The surface gravities were calculated using the following equation:

$$\log g = \log M + 4 \log T_{\text{eff}} - \log L - 10.61 \quad (M: \text{mass}, L: \text{luminosity})$$

Target	$\log g$	$M (M_{\odot})$	H mag	K mag	B_{C}	T_{eff} (K)	D (kpc)
No.1	1.25	10.5 ± 1.5	7.700	7.154	2.84	3600 ± 64	4.2
No.5	0.75	10.5 ± 1.5	8.375	6.977	2.64	3855 ± 44	4.2

Note. We assumed that the mass of No. 1 is the same as that of No. 5. B_{C} is bolometric correction. The unit of $\log g$ is cm s^{-2} . D is the assumed distance from Ref. 1. References are 1: Messineo et al. (2010), 2: Zuckerman et al. (2000).

◆ $[\text{M}/\text{H}]$, microturbulence ξ , macro-turbulence V_{mac} :

We estimate the microturbulence with which $\log \epsilon(\text{Fe})$ becomes independent of X -factor. And then we can derive the metallicities and macro-turbulence by using MPFIT.

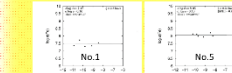


Fig. 6. Metallicity vs. X -factor of each line for No. 1 (left panel) and No. 5 (right panel). X -factor is defined as follows: $X = \log(I_{\text{Fe}} - I_{\text{H}}) / \log(I_{\text{Fe}} - I_{\text{H}}) / T_{\text{eff}}$ where I is statistical weight, F is oscillator strength and E_F is ionization potential.

◆ The effect of stellar parameters on absorption lines

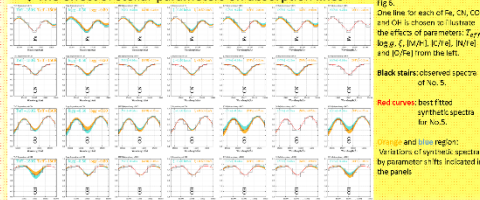


Fig. 7. One line for each of Fe, Ca, and Ca. Left column is to illustrate the effects of parameters: T_{eff} , $\log g$, ξ , V_{mac} , $[\text{Fe}/\text{H}]$ and $[\text{Ca}/\text{H}]$ from the left. Black stars: observed spectra of No. 5. Red curves: best-fit synthetic spectra for No. 5. Orange and blue regions: deviations of synthetic spectra by parameter in the indicated in the panels.

RESULT

◆ Metallicities and stellar parameters

	No.1	No.5
$[\text{Fe}/\text{H}]$	-0.04 ± 0.08	$+0.56 \pm 0.04$
$[\text{C}/\text{Fe}]$	+0.27	-0.40
$[\text{N}/\text{Fe}]$	+0.10	+0.50
$[\text{O}/\text{Fe}]$	-0.31	-0.09
T_{eff} (K)	3601 ± 64	3855 ± 44
$\log g$	1.25	0.75
ξ (km/s)	2.30	2.45
V_{mac} (km/s)	6.58 ± 0.13	10.02 ± 0.16
V_{LSR} (km/s)	21.89 ± 0.13	25.32 ± 0.16

◆ Derived iron abundance from each line for both stars

Wavelength (Å)	$[\text{Fe}/\text{H}]$ No.1	$[\text{Fe}/\text{H}]$ No.5
15194.50	+0.05	+0.51
16171.92	-0.15	+0.63
16486.69	-0.16	+0.72
16561.80	-0.19	+0.43
17166.20	-	+0.61
17695.94	+0.23	+0.49

FUTURE WORK

- ◆ We need to estimate velocities and distances of other stars in GLIMPSE9 cluster.
- ◆ We are going to major metallicities of clusters at the innermost disk and to study the metallicity distribution of stars across the disk necessary for revealing the Galactic evolution.