J-PLUS: wide-field study of M15

Charles Bonatto (UFRGS),
Ana Chies-Santos(UFRGS), Paula Coelho (USP),
Jesus Varela (CEFCA) + J-PLUS team

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J-PLUS: wide-field study of the M 15 globular cluster

Charles Bonatto[1], Ana L. Chies Santos[1], Paula R. T. Coelho[2], Jesús Varela[3], Søren S. Larsen[4], A. Javier Cenarro[3], Izaskun San Roman[3], Antonio Marín-Franch[3], Claudia Mendes de Oliveira[2], Alberto Molino[2], Alessandro Ederoclite[3], Arianna Cortesi[2], Carlos López-San Juan[3], David Cristóbal-Hornillos[3], Héctor Vázquez Ramió[3], Laerte Sodré Jr[2], Laura Sampedro[2], Patrícia M. Novais[2], Renato Dupke[5,6], Roderik A. Overzier[5], Tiago Ribeiro[7], Walter A. Santos[2], and William Schoennell[2,8]

[1] Departamento de Astronomia, Instituto de Física, Universidade Federal do Rio Grande do Sul, Porto Alegre, RS, Brazil
e-mail: charles.bonatto,ana.chies@ufrgs.br
[2] Universidade de São Paulo, São Paulo, Instituto de Astronomia, Geofísica e Ciências Atmosféricas, SP, Brazil
[3] Centro de Estudios de Física del Cosmos de Aragón, Plaza San Juan 1, 44001 Teruel, Spain.
[4] Department of Astrophysics/IMAPP, Radboud University, Nijmegen, The Netherlands
[5] Observatório Nacional, RJ, Brazil
[6] University of Michigan, Ann Arbor, US
[7] Departamento de Física, Universidade Federal de Sergipe, Av. Marechal Rondon s/n, 49100-000 São Cristóvão, SE, Brazil
[8] AA-CSIC, Glorieta de la Astronomía S/N. E-18008, Granada, Spain

ABSTRACT

Context. As a consequence of internal and external dynamical processes, Galactic globular clusters (GCs) have properties that vary radially. Wide-field observations covering the entire projected area of GCs out to their tidal radii (r_{tidal}) can therefore give crucial information on these important relics of the Milky Way formation era.
Aims. The Javalambre Photometric Local Universe Survey (J-PLUS) provides wide field-of-view ($2\,deg^2$) images in 12 narrow, intermediate and broad-band filters optimized for stellar photometry. Here we test J-PLUS data for the first time for the study of Galactic GCs using science verification data obtained for the very metal-poor ([Fe/H] ≈ -2.3) GC M 15 located at ~ 10 kpc from the Sun. Previous studies based on spectroscopy found evidence of multiple stellar populations (MSPs) through their different abundances of C, N, O and Na. Our J-PLUS data provide low-resolution spectral energy distributions covering the near-UV to the near-IR, allowing us to instead search for MSPs based on pseudo-spectral fitting diagnostics.
Methods. We build and discuss the stellar radial density profile (RDP), luminosity functions (LFs) and surface brightness profiles (SBPs) reaching up to r_{tidal}. Since J-PLUS FoV is larger than M 15's r_{tidal}, the field contamination can be properly taken into account. We also demonstrate the power of J-PLUS unique filter system by showing colour-magnitude diagrams (CMDs) using different filter combinations and for different cluster regions.
Results. J-PLUS photometric quality and depth are good enough to reach the upper end of M 15's main-sequence. CMDs based on the colours ($u_{JAVA} - z_{SDSS}$) and (J0378 − J0861) are found to be particularly useful to search for splits in the sequences formed by the upper red giant branch (RGB) and Asymptotic Giant Branch (AGB) stars. We interpret these split sequences as evidence for the presence of MSPs. Furthermore, we show that the ($u_{JAVA} - z_{SDSS}$) × (J0378 − g_{SDSS}) colour-colour diagram allows us to distinguish clearly between field and M 15 stars, which is important to minimize the sample contamination.
Conclusions. J-PLUS is capable to distinguish different sequences in the upper RGB/AGB regions of the CMD of M 15, showing the feasibility of identifying MSPs without the need of spectroscopy. This demonstrates that the J-PLUS survey will have sufficient spatial coverage and spectral resolution to perform a large statistical study of GCs through multi-band photometry in the coming years.

Key words. (*Galaxy:*) globular clusters: general; (*Galaxy:*) globular clusters: individual: M 15; surveys

1. Introduction

Galactic globular clusters (GCs) are among the most interesting - and beautiful - relics of the Milky Way formation epoch. Given their long-lived nature, some intrinsic properties (e.g. age, metallicity and mass distribution) and the large-scale spatial distribution of GCs formed in the early phases of the Galaxy may provide clues to the Milky Way assembly process. In this sense, studies of GC properties can be used to set constraints to Galaxy formation models, as well as stellar and dynamical evolution theories.

In general, GCs are relatively isolated, self-gravitating and dynamically relaxed (e.g. Dabringhausen et al. 2008) multi-particle systems. There is scarce evidence of the presence of dark matter in GCs, which is consistent with expectations for small dark-matter halos and, besides, they have low mass-to-light ratios ($M/L_V \approx 0.5 - 3.5\,M_\odot/L_\odot$), probably because of the preferential loss of low-mass stars related to their advanced dynamical evolution (e.g. Dabringhausen et al. 2008).

Once considered as the prototypes of simple (or single) stellar populations and the building blocks of galaxies, GCs now have to be described by more complex - and theoretically challenging - scenarios, as shown by a growing number of works being published since the past decade (for recent reviews, see Gratton et al. 2012 and Bastian 2015). More specifically, high-quality spectroscopy (e.g. Carretta 2015) and precision photometry (e.g. Piotto et al. 2007) led to the unambiguous detection of multiple

Send offprint requests to: C. Bonatto

M15

- ~ 10kpc
- [Fe/H] ~ -2.3
- Core radius ~ 0.14' (~0.4pc)
- Tidal radius ~ 21.5' (~60pc)
- Evidence of MSPs

Observations

- Science Verification data
- Nov. 13 & 14, 2015
- PI: Ana Chies Santos
- Data reduction, ZP, co-adding: OAJ/CEFCA
- Photometric catalogues: DAOPHOT

Filter name	λ_{eff} [nm]	$\Delta\lambda$ [nm]	t_{sng} [sec]	Total [sec]	Seeing [$''$]	N (stars)	m_{lim} (mag)	Spectral Feature
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
u_{JAVA}	348.5	50.8	60	600	1.944	13451	22.2	
J0378	378.5	16.8	60	544	1.873	6289	20.2	[OII]
J0395	395.0	10.0	60	604	1.643	7532	19.2	Ca H+K
J0410	410.0	20.0	60	605	1.473	22522	21.6	H_δ
J0430	430.0	20.0	60	605	1.481	22959	21.7	G-band
g_{SDSS}	480.3	140.9	10	115	1.383	39427	22.6	
J0515	515.0	20.0	60	665	1.299	23968	21.6	Mgb
r_{SDSS}	625.4	138.8	10	105	1.179	53357	22.4	
J0660	660.0	13.8	60	605	1.214	22402	20.6	H_α
i_{SDSS}	766.8	153.5	10	105	1.117	57518	21.8	
J0861	861.0	40.0	60	675	1.211	40723	21.0	Ca-Trpl
z_{SDSS}	911.4	140.9	10	105	1.071	49510	21.2	

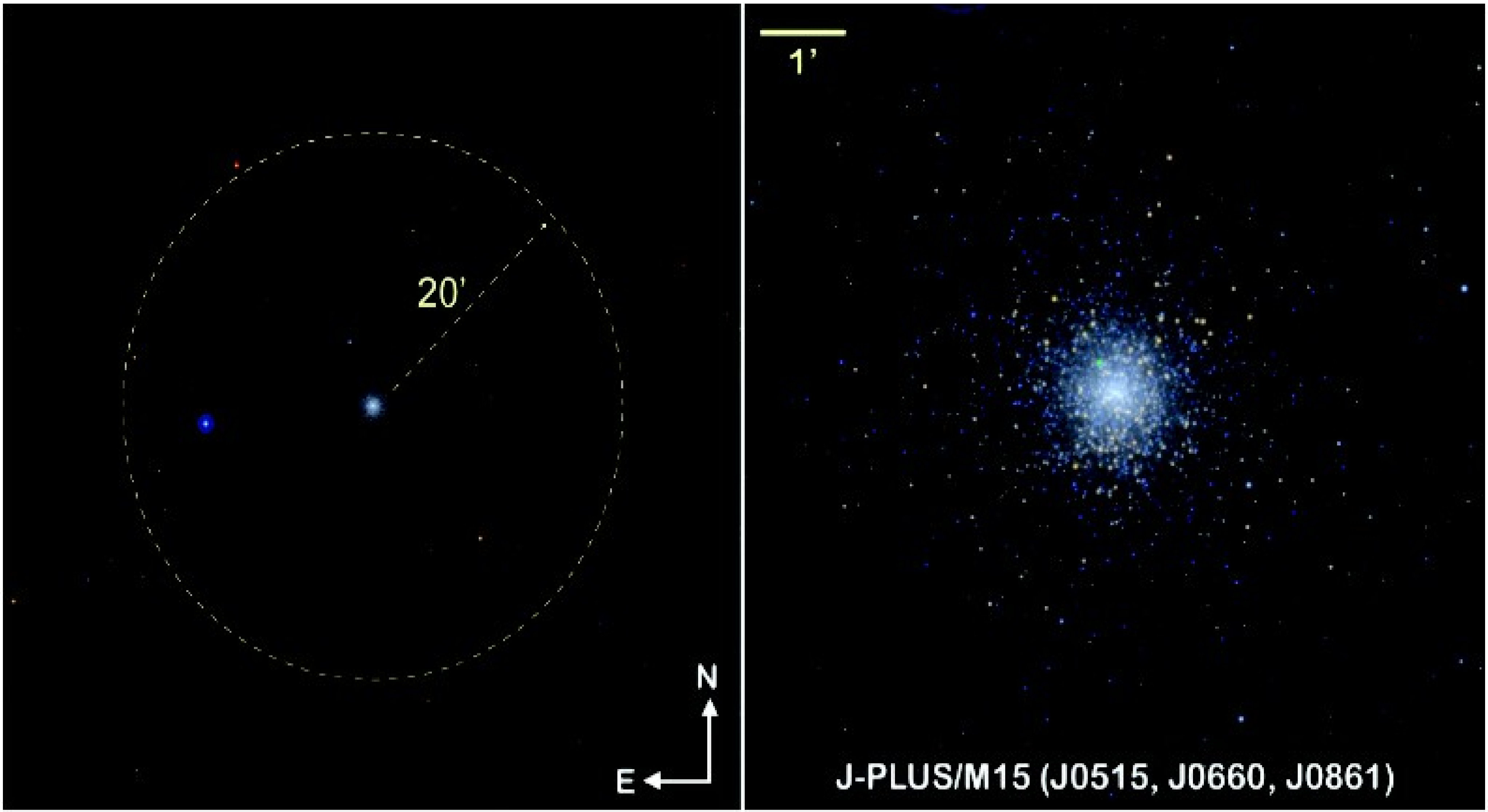
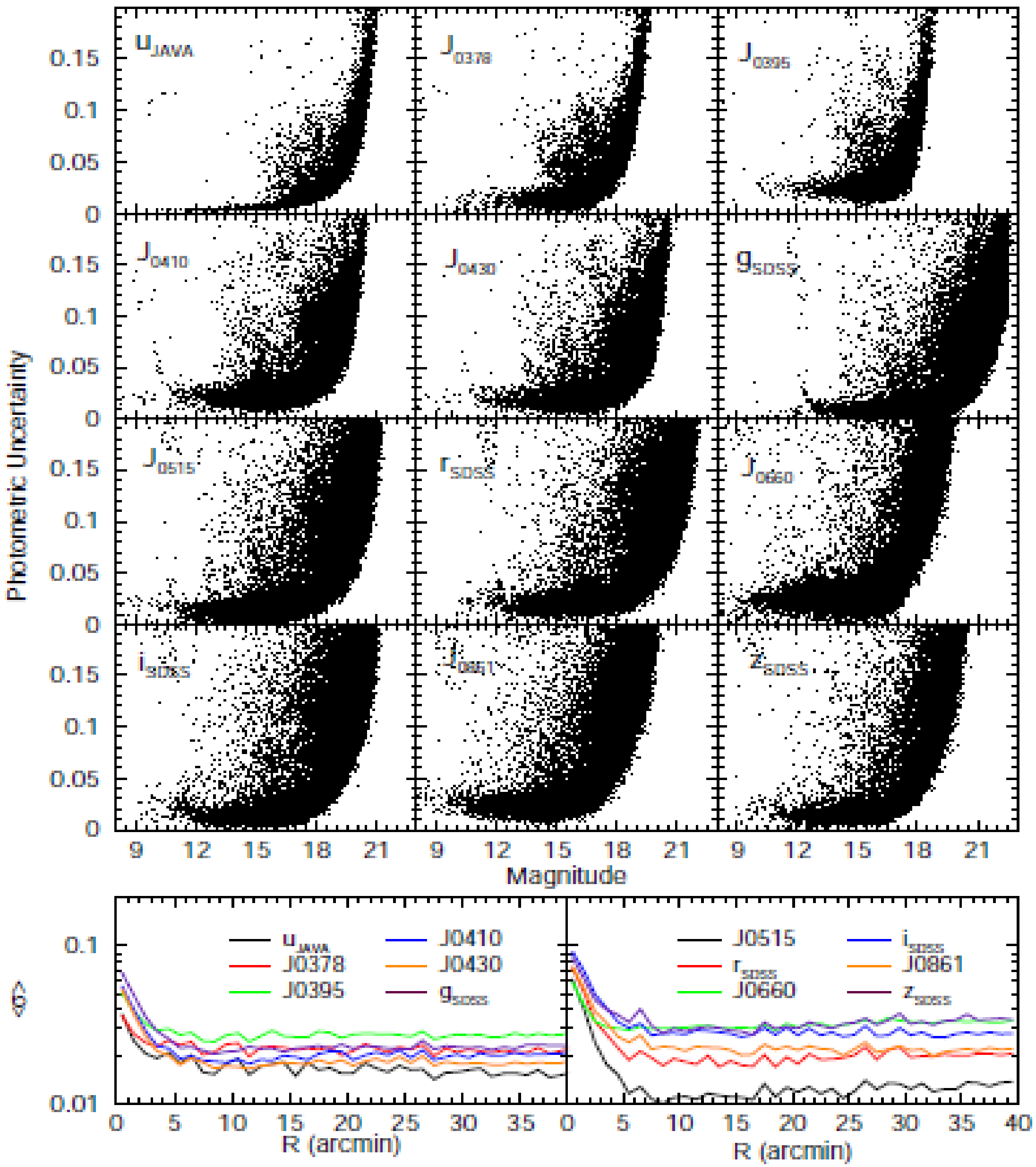


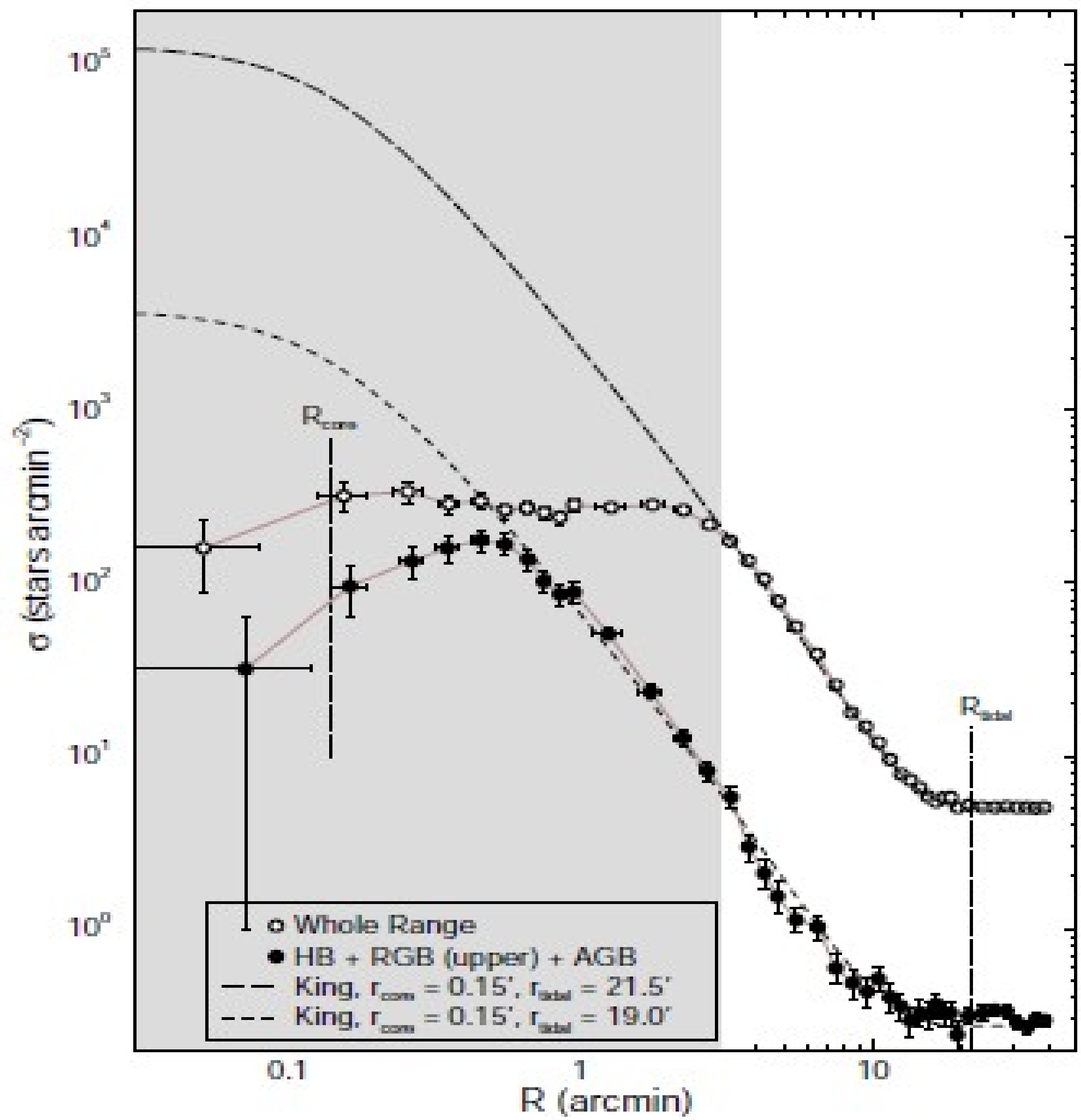
Fig. 1. Left panel: Composite 3-colour image of M 15 built with the J-PLUS filters J0515, J0660 and J0861; the tidal radius ($r_{tidal} \sim 21.5'$) is fully encompassed by the observation, which shows the complete FoV of the instrument. Right: Zoom in on the brightest part of M 15 ($R \sim 5'$).

DAOPHOT photometry

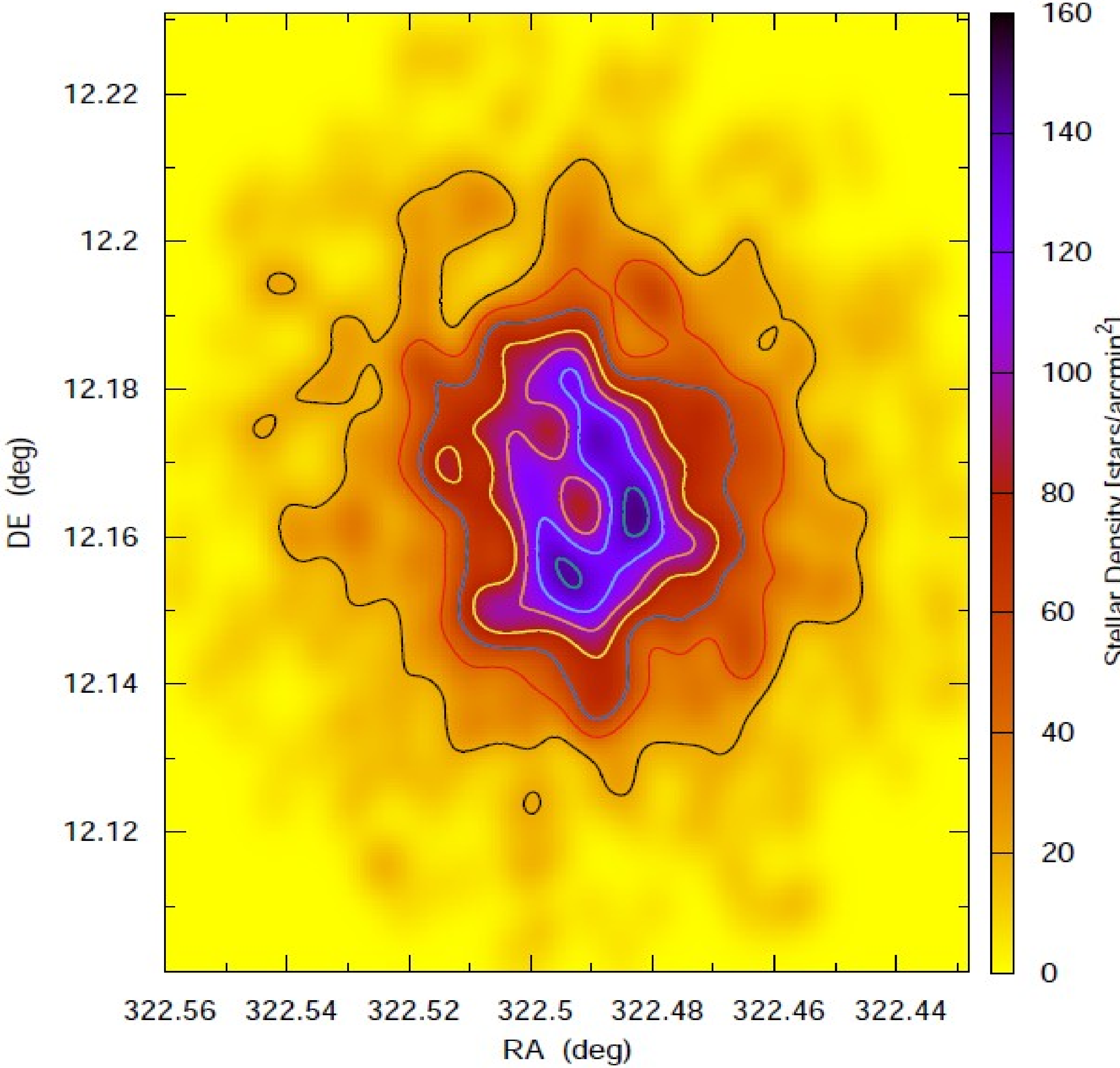
Photom. Uncert. vs magnitude and distance from the center



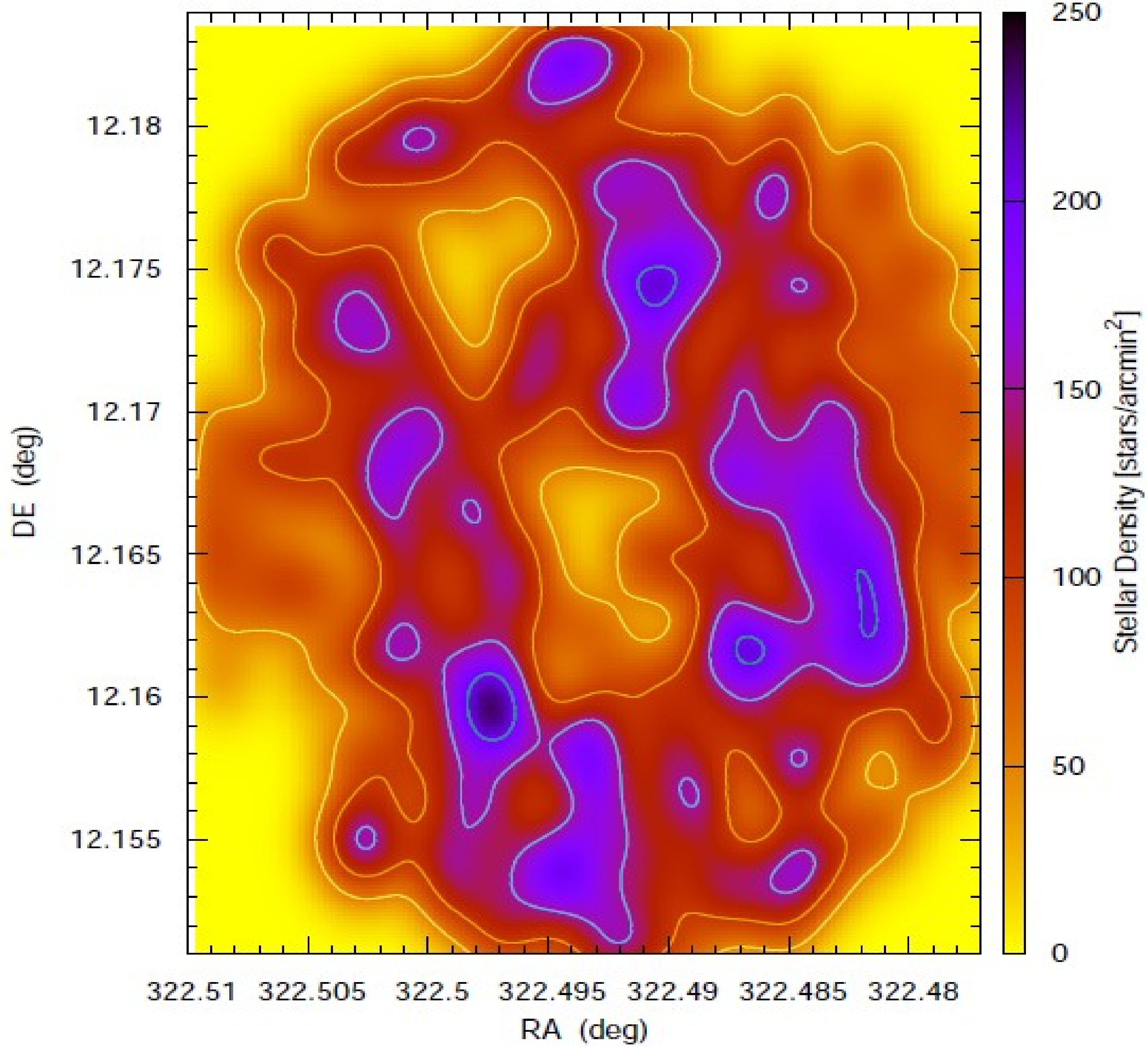
Stellar Radial Density



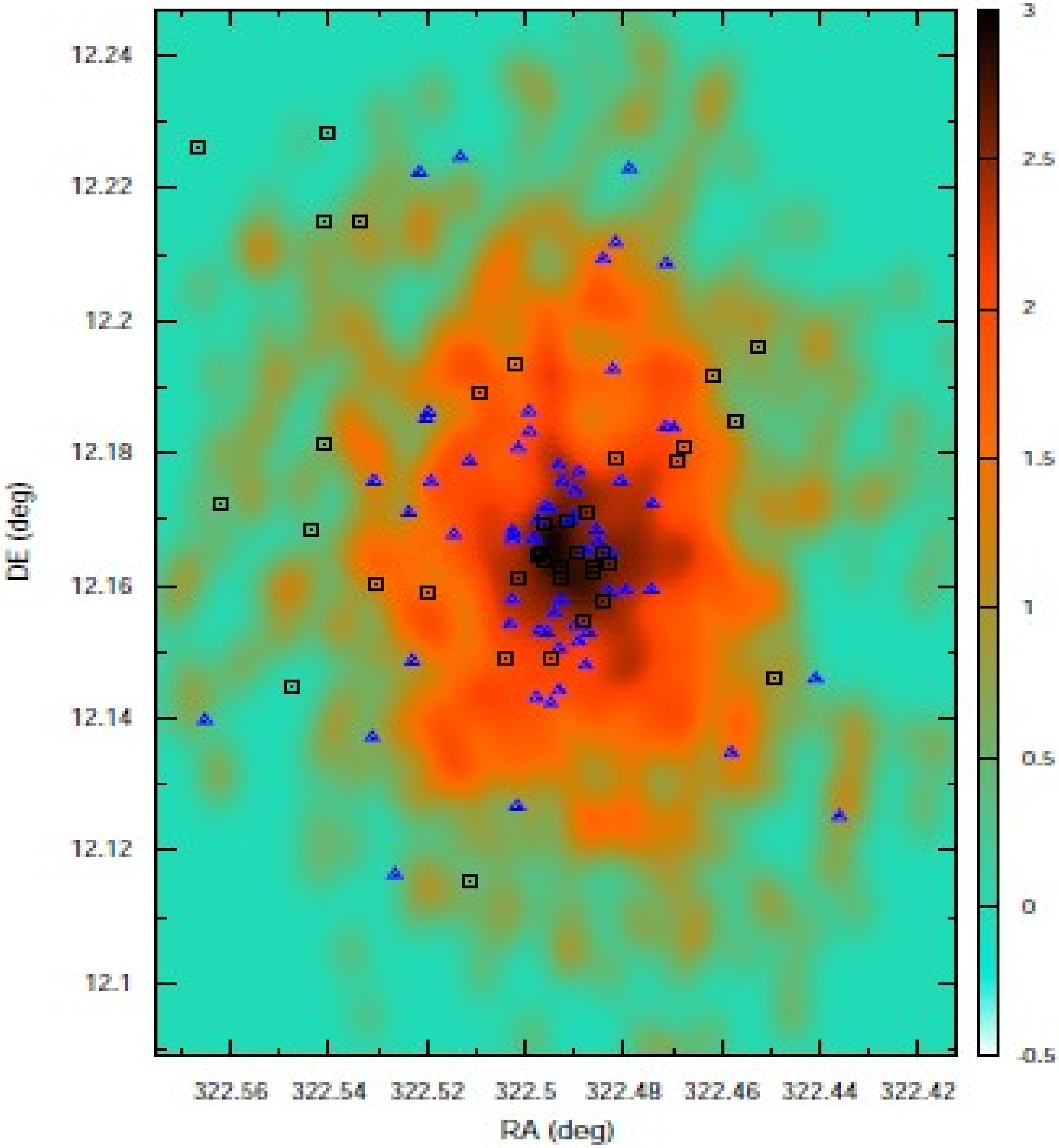
8' x 8' region in J0378



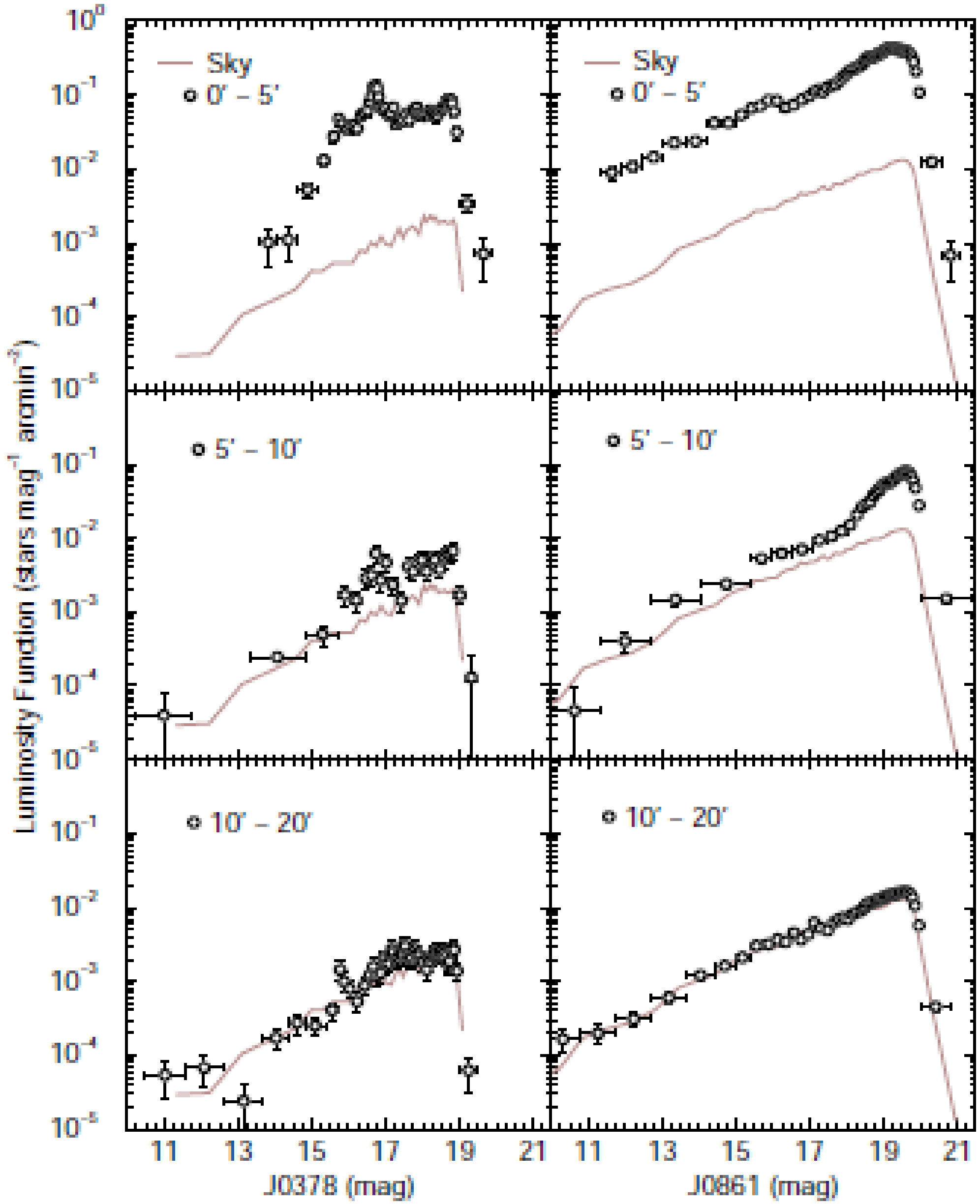
A closer look on the central 1' x 1' region



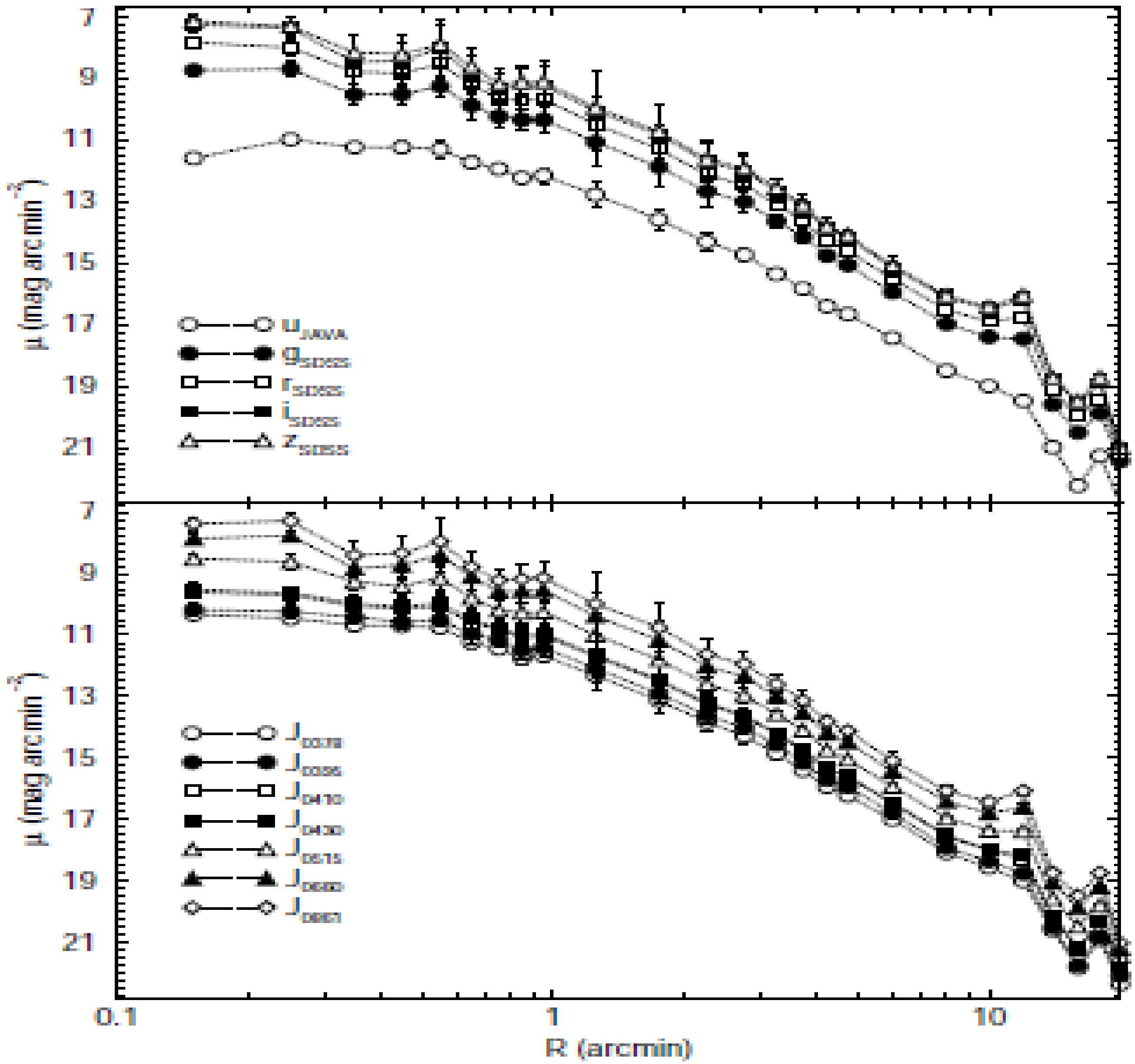
Colour Map


12.24
12.22
12.2
12.18
12.16
12.14
12.12
12.1
DE (deg)
322.56
322.54
322.52
322.5
322.48
322.46
322.44
322.42
RA (deg)
3
2.5
2
1.5
1
0.5
0
-0.5

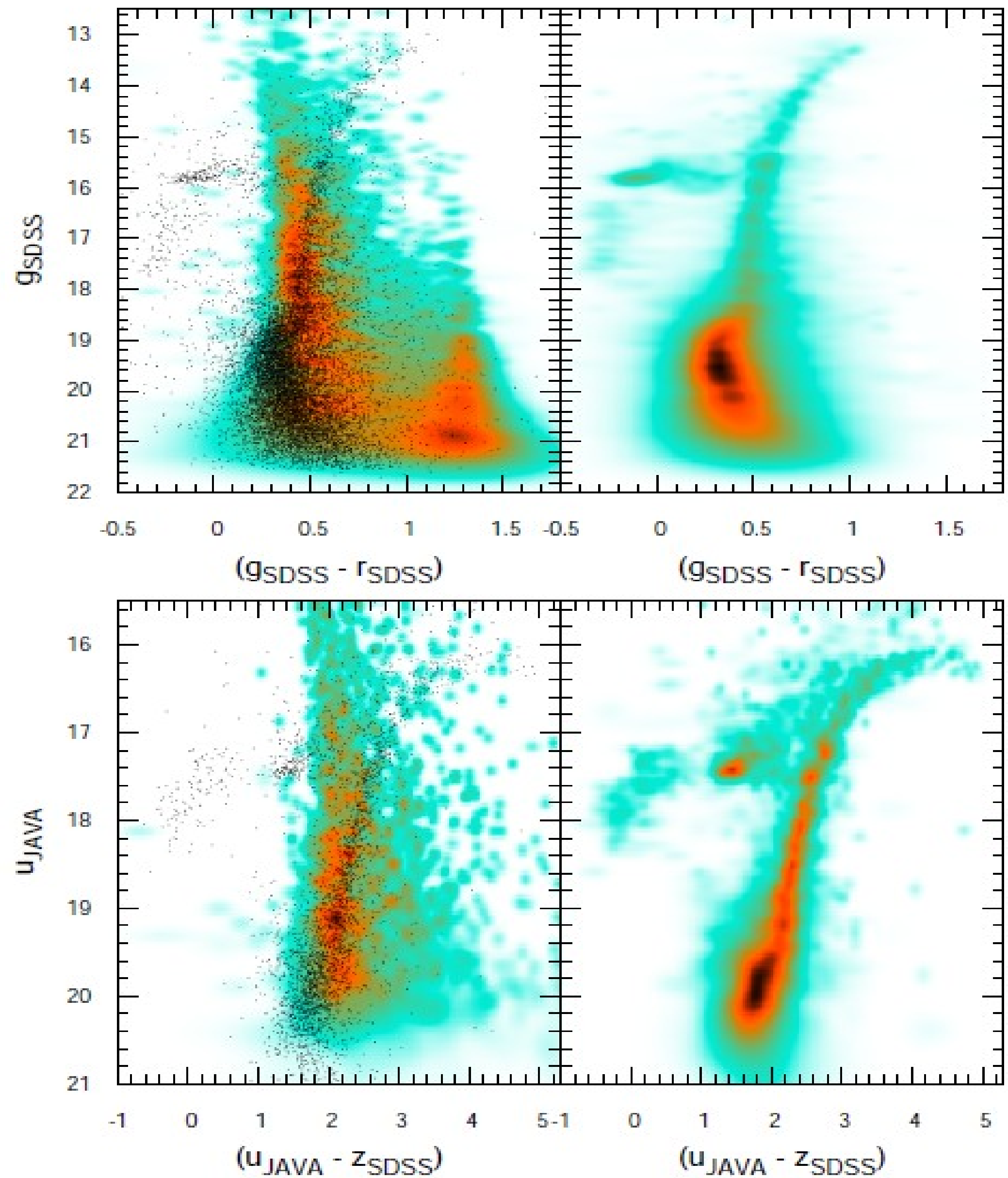
Luminosity Functions



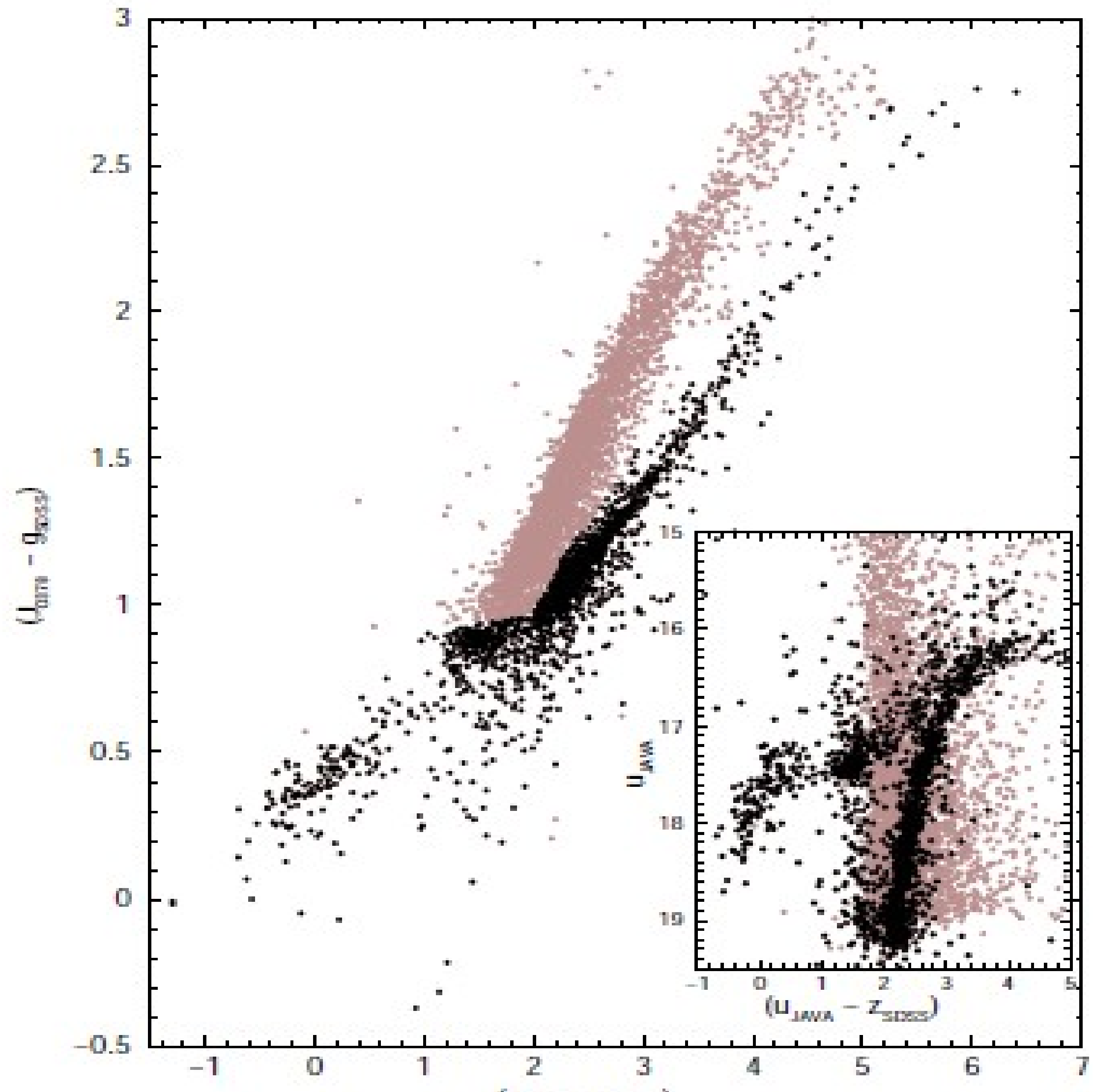
Surface Brightness Profiles



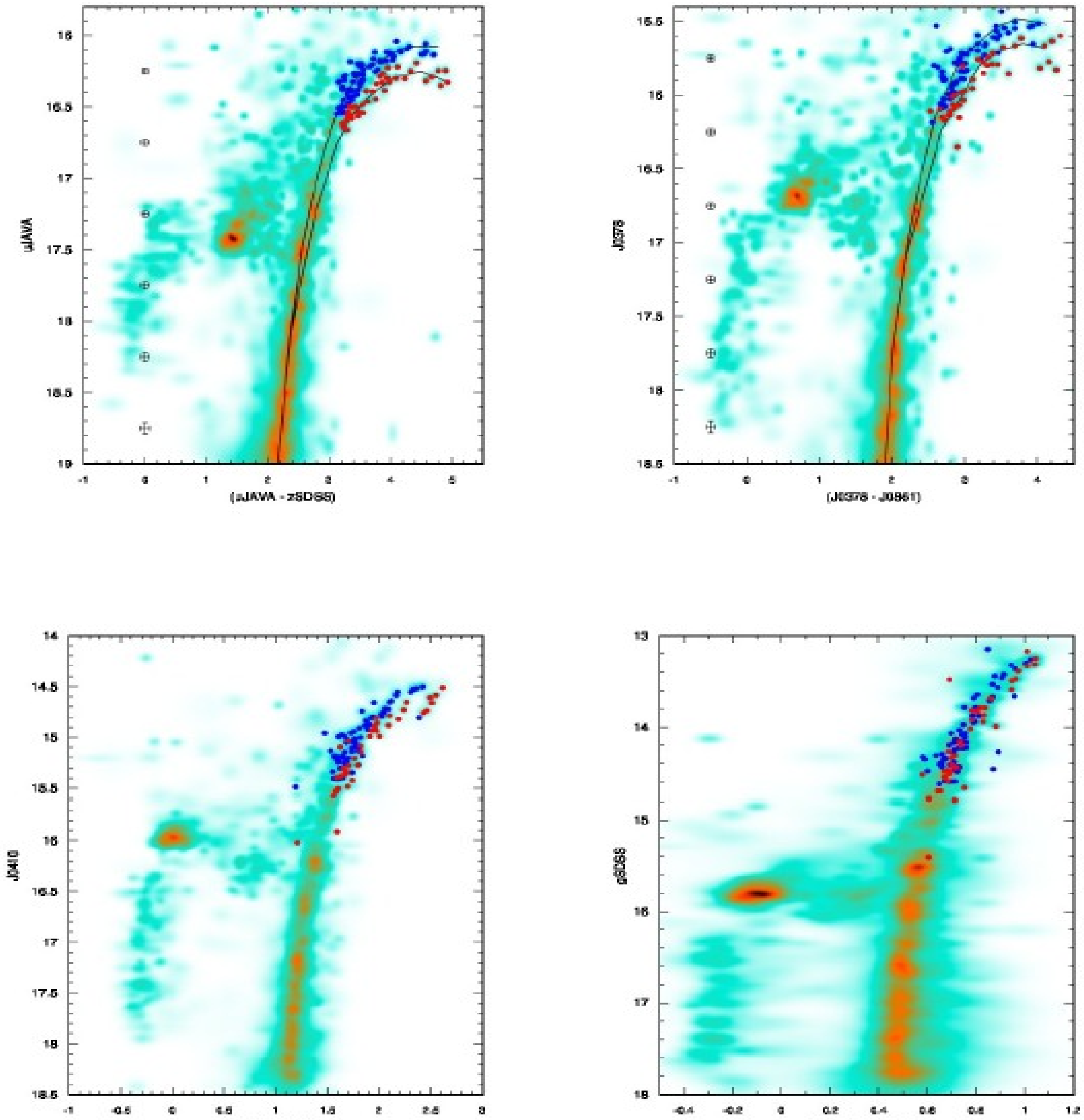
Field-star contamination in different colours



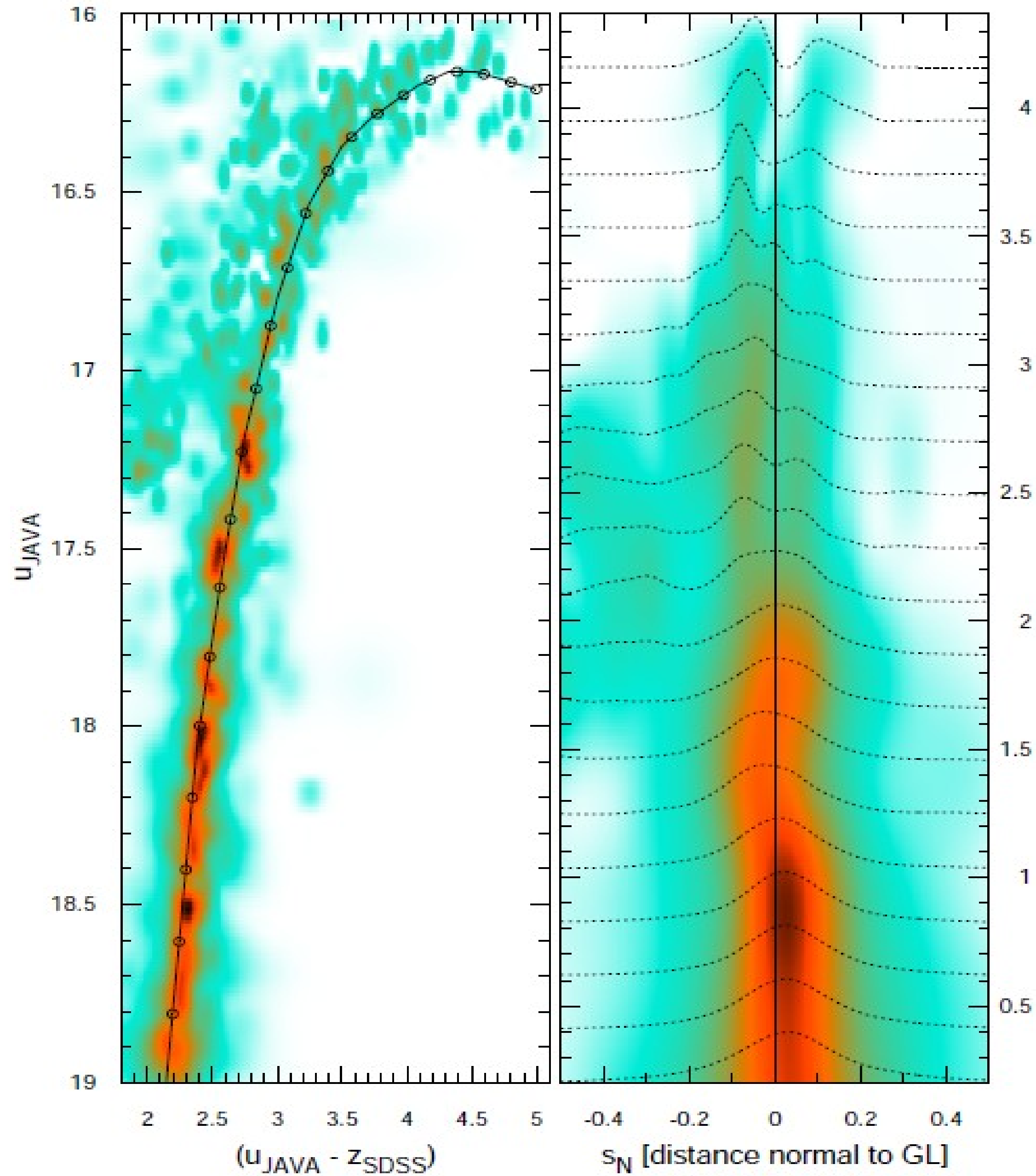
A “natural” decontamination



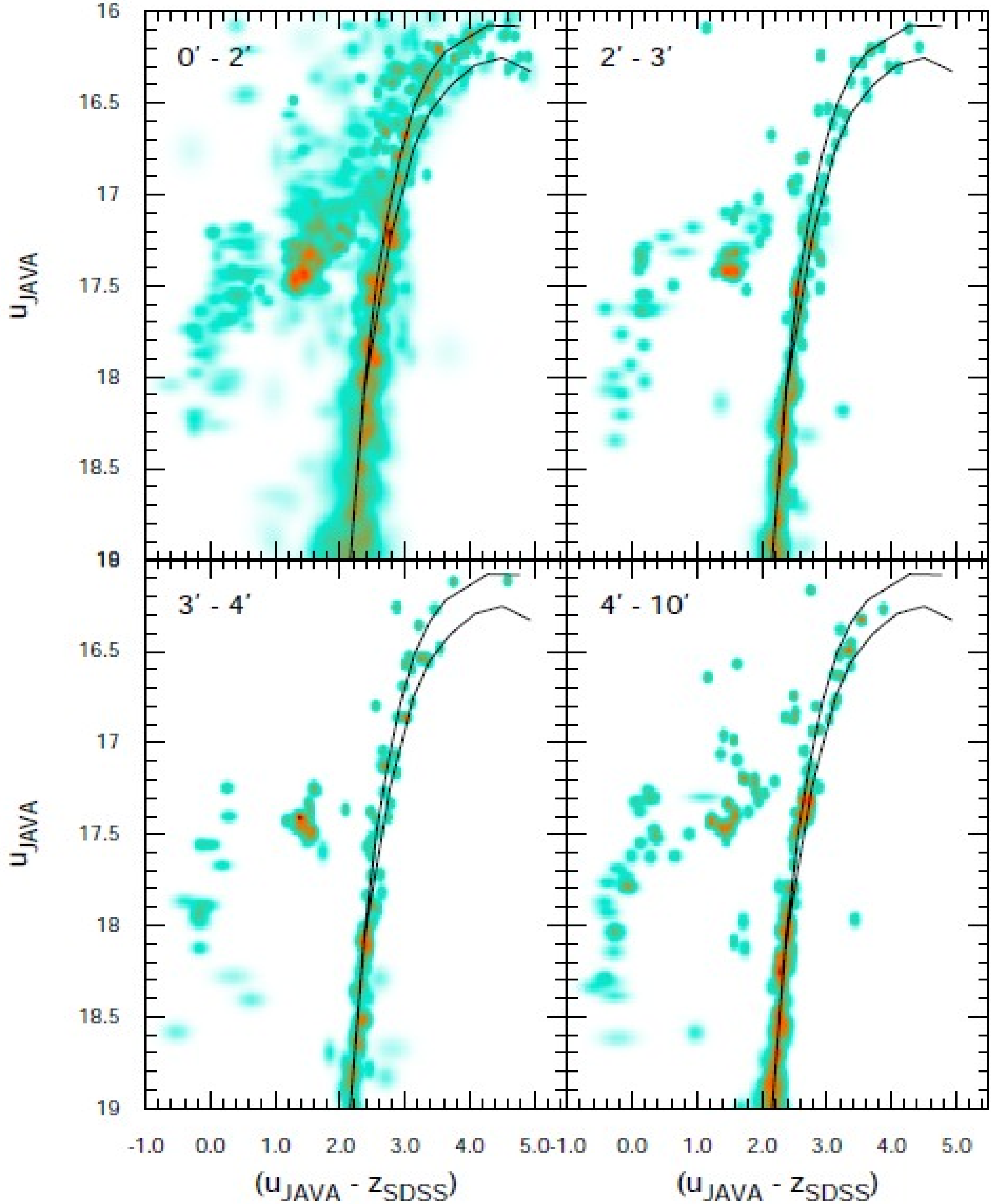
RGB separation in diff. colours



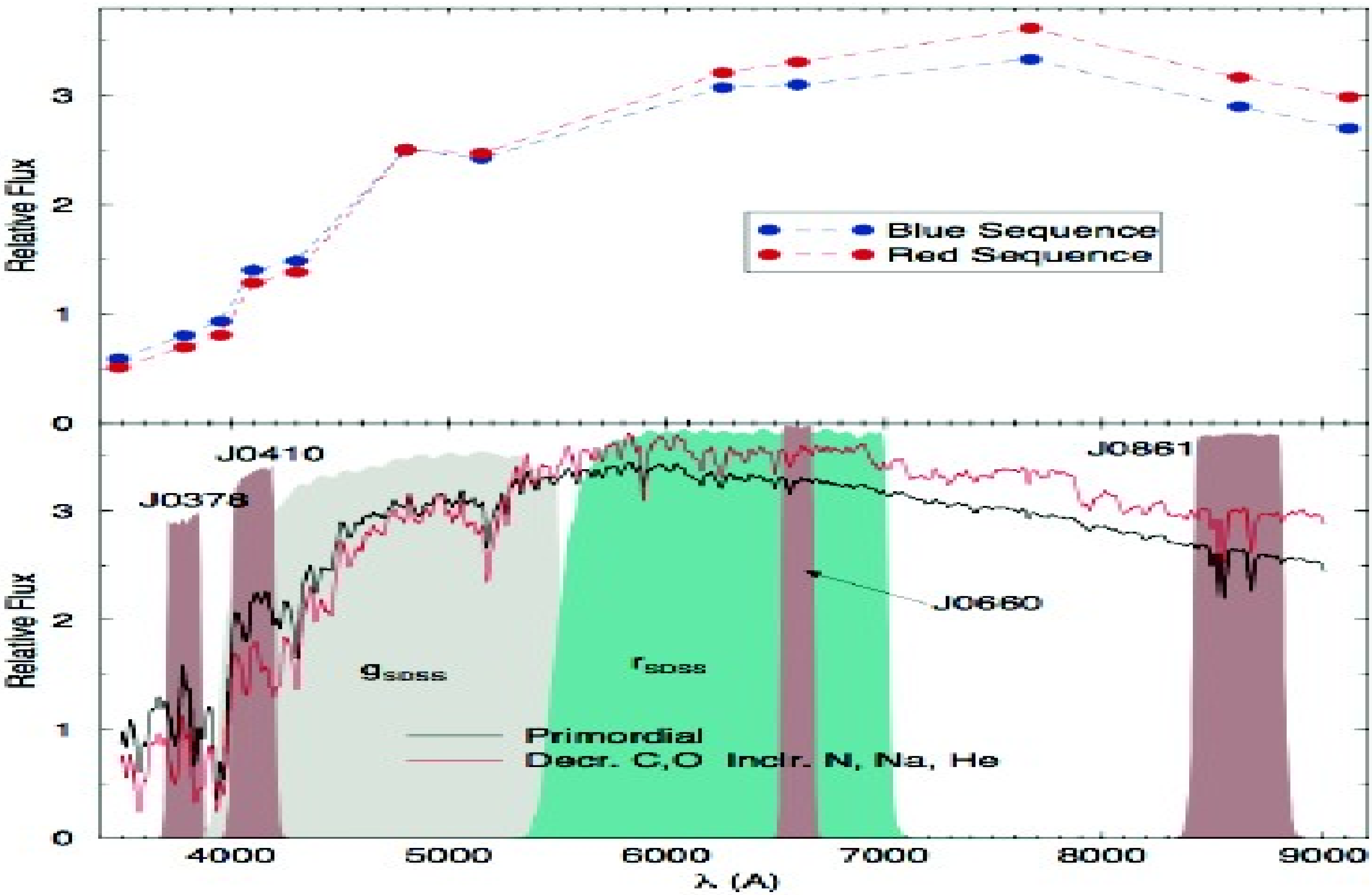
RGB Verticalization



MSPs in diff. sectors



Average J-PLUS SEDs of blue & red M15 SPs



GC	dSun (kpc)	[Fe/H]	Decl (deg)
NGC6366	3.5	-0.59	-05
NGC6838	4.0	-0.78	+18
NGC0104	4.5	-0.72	-72
Terz12	4.8	-0.50	-22
IC1276	5.4	-0.75	-07
NGC6352	5.6	-0.64	-48
Pal6	5.8	-0.91	-26
Pal10	5.9	-0.10	+18
NGC6304	5.9	-0.45	-29
NGC6553	6.0	-0.18	-25
NGC6760	7.4	-0.40	+01
NGC6362	7.6	-0.99	-67
NGC5927	7.7	-0.49	-50
NGC6539	7.8	-0.63	-07
NGC6624	7.9	-0.44	-30
NGC6528	7.9	-0.11	-30
NGC6342	8.5	-0.55	-19
NGC6440	8.5	-0.36	-20
NGC6637	8.8	-0.64	-32
NGC6638	9.4	-0.95	-25
NGC6388	9.9	-0.55	-44
NGC6652	9.9	-0.81	-32

Gracias!

Integrated J-PLUS colours of GCs x metallicity

- A probe of metallicity for extra-gal GCs?