Near Infrared Photometric Parameters of Bulge Globular Clusters from the VVV Survey

Roger Cohen (U. de Concepción)

CTIO 50 Years: La Serena, Chile, May, 2013

Co-Workers Include:

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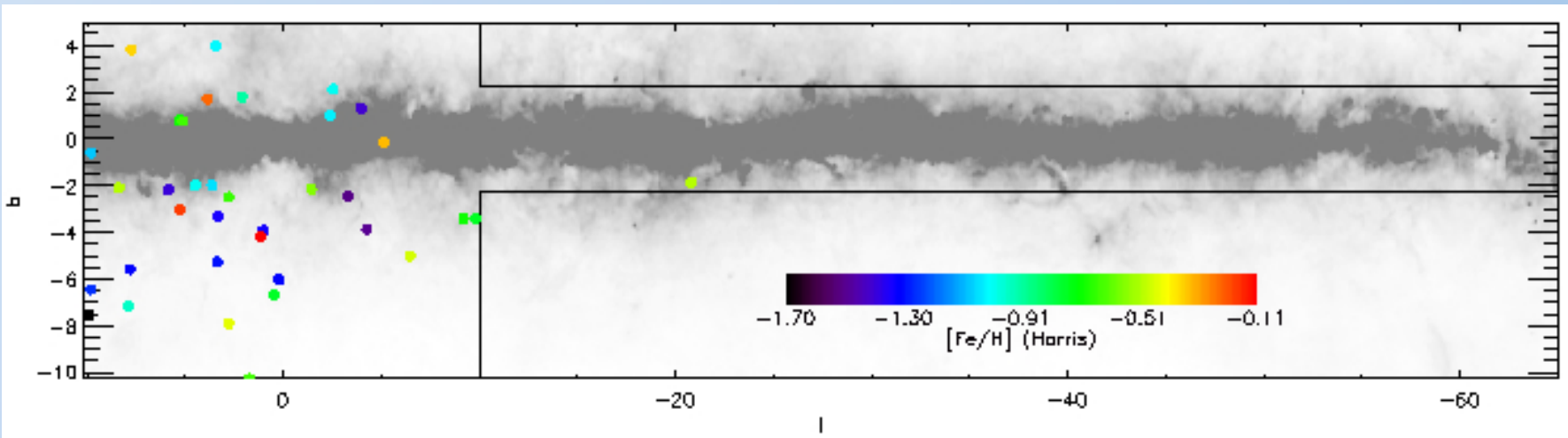
F. Mauro
A.-N. Chene
J. Cummings
S. Villanova
D. Geisler
J. Alonso
M.Catelan
M. Hempel
C. Bonatto
J. Vanderbeke
and more!

UNIVERSIDAD DE CONCEPCION



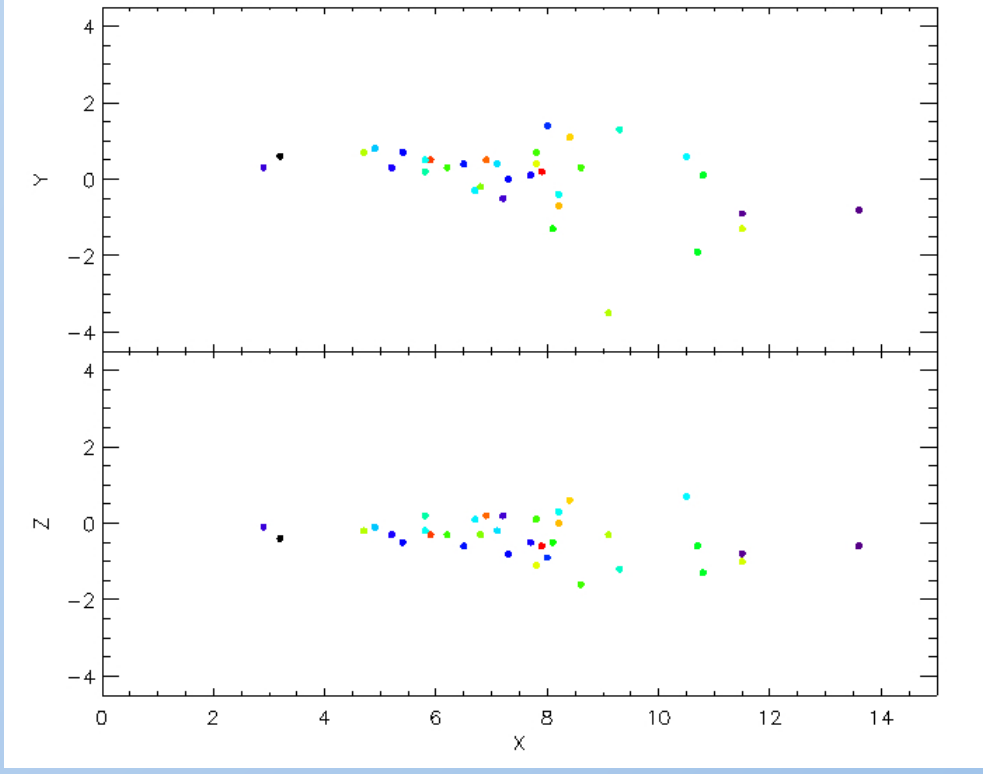
Bulge GGC formation/evolution is an open issue! (AMR)

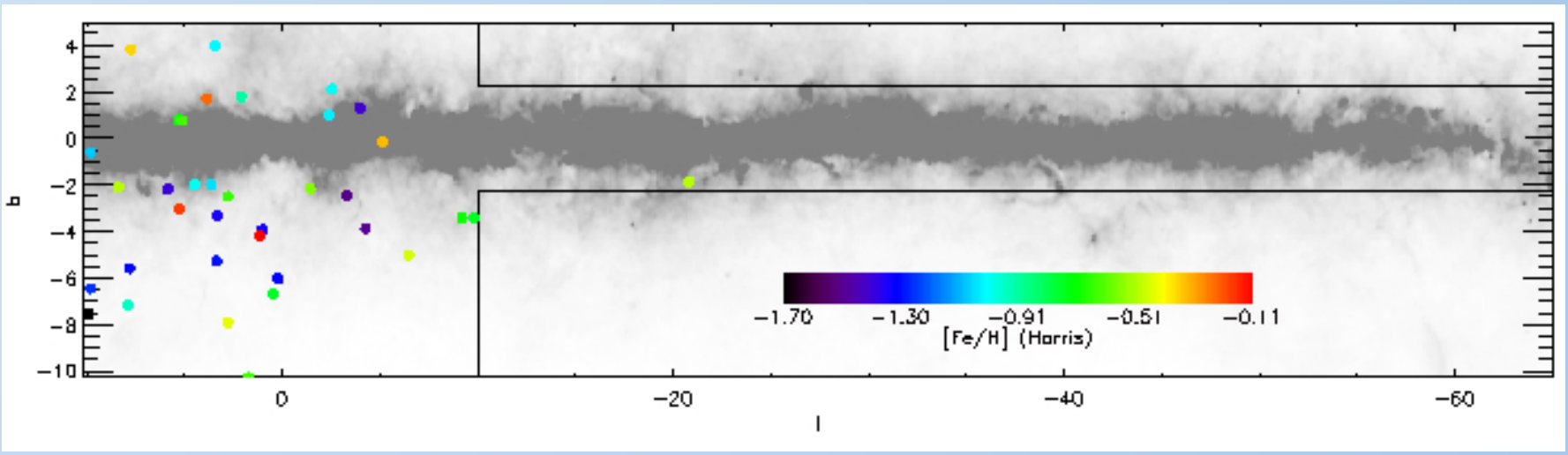
- Only 17/65 inside 4 kpc have *any* systematic age measured

De Angeli+05, Marin-Franch+09, Dotter+10

- Hi-res abundances [Fe/H],CaII

Carretta+09, Saviane+12, more coming!





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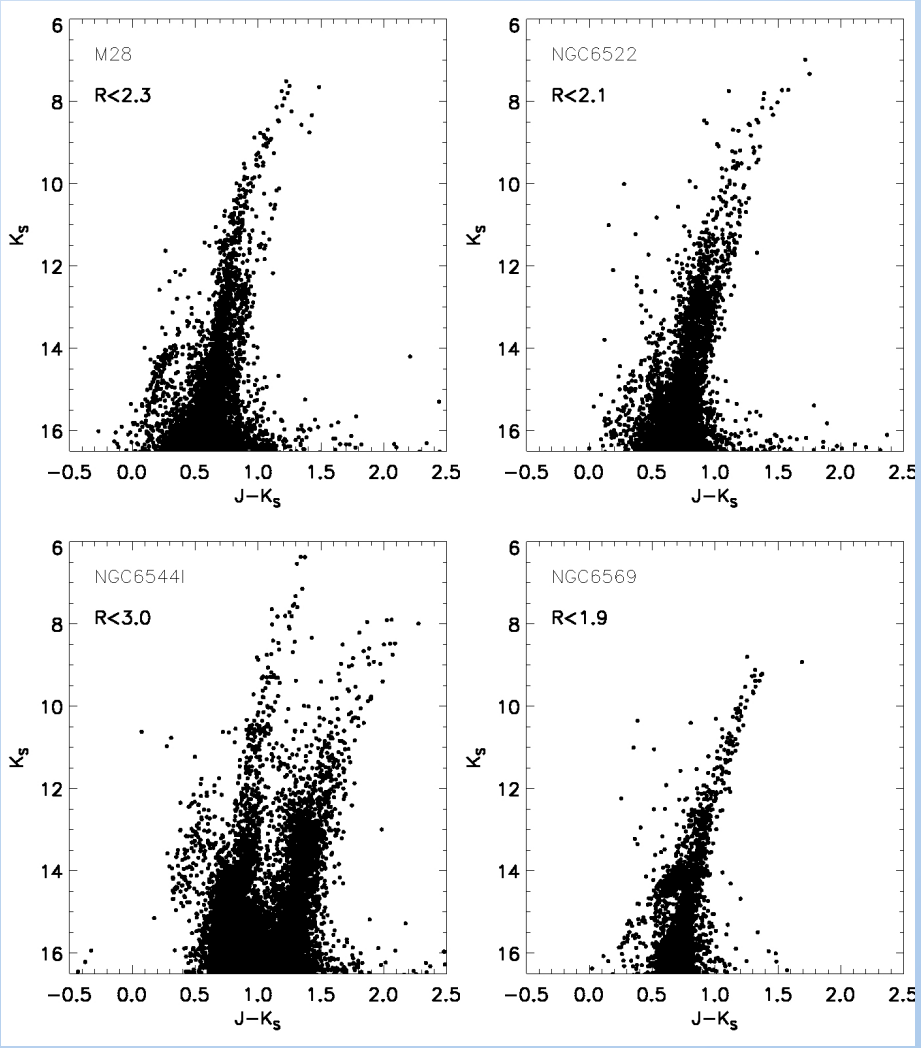
VVV!

- ~36 GGCs in VVV survey area
- ~16 have spectroscopic abundances
- PSF photometry, calibrated to 2MASS

(VVV-SkZ pipeline, Mauro+13)
photometric zpt uncertainty < 0.02 mag,
astrometric RMS ~0.2”

Red Giant Branch Analysis



- Known variables removed

Clement+01 update, Samus+09, others

- Reddening maps

Gonzalez+12, Alonso Garcia+12

- Radial cuts

Small scale reddening vs. more cluster stars

- Statistical field star decontamination

Subtraction efficiency > 93% for all clusters

cf. Bonatto et al.

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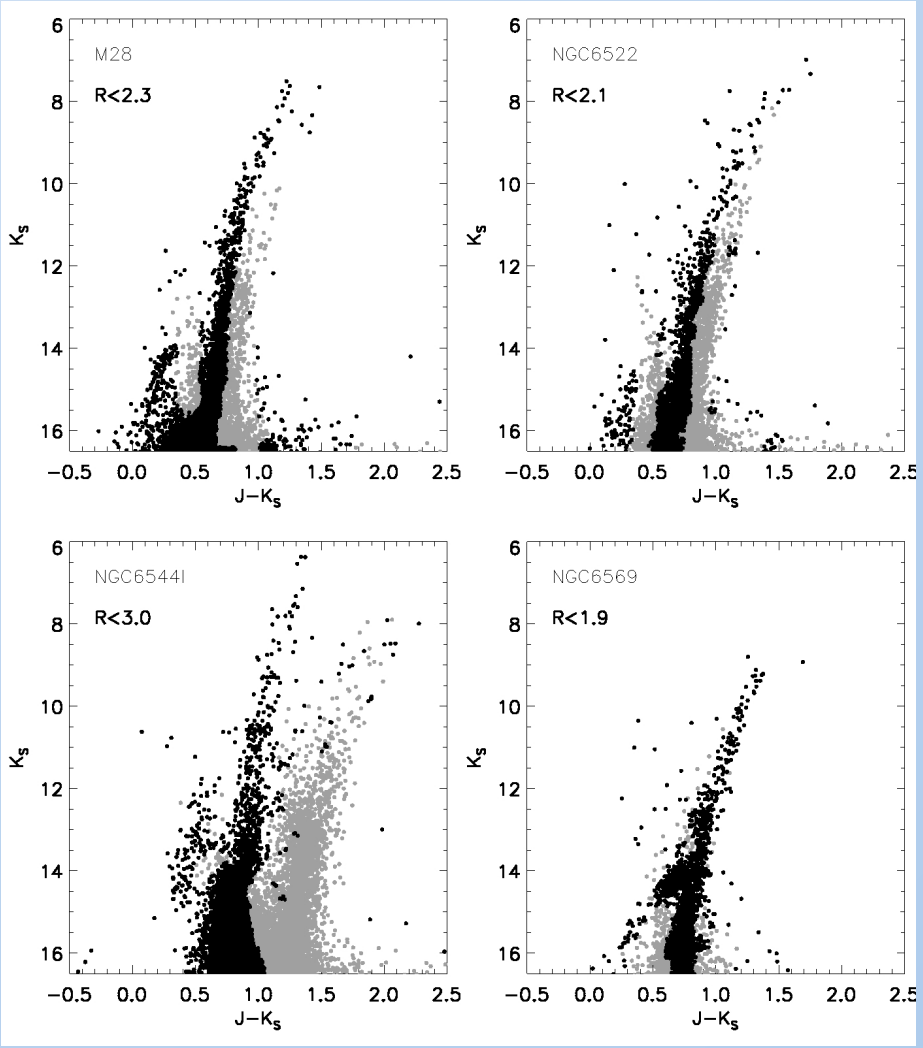

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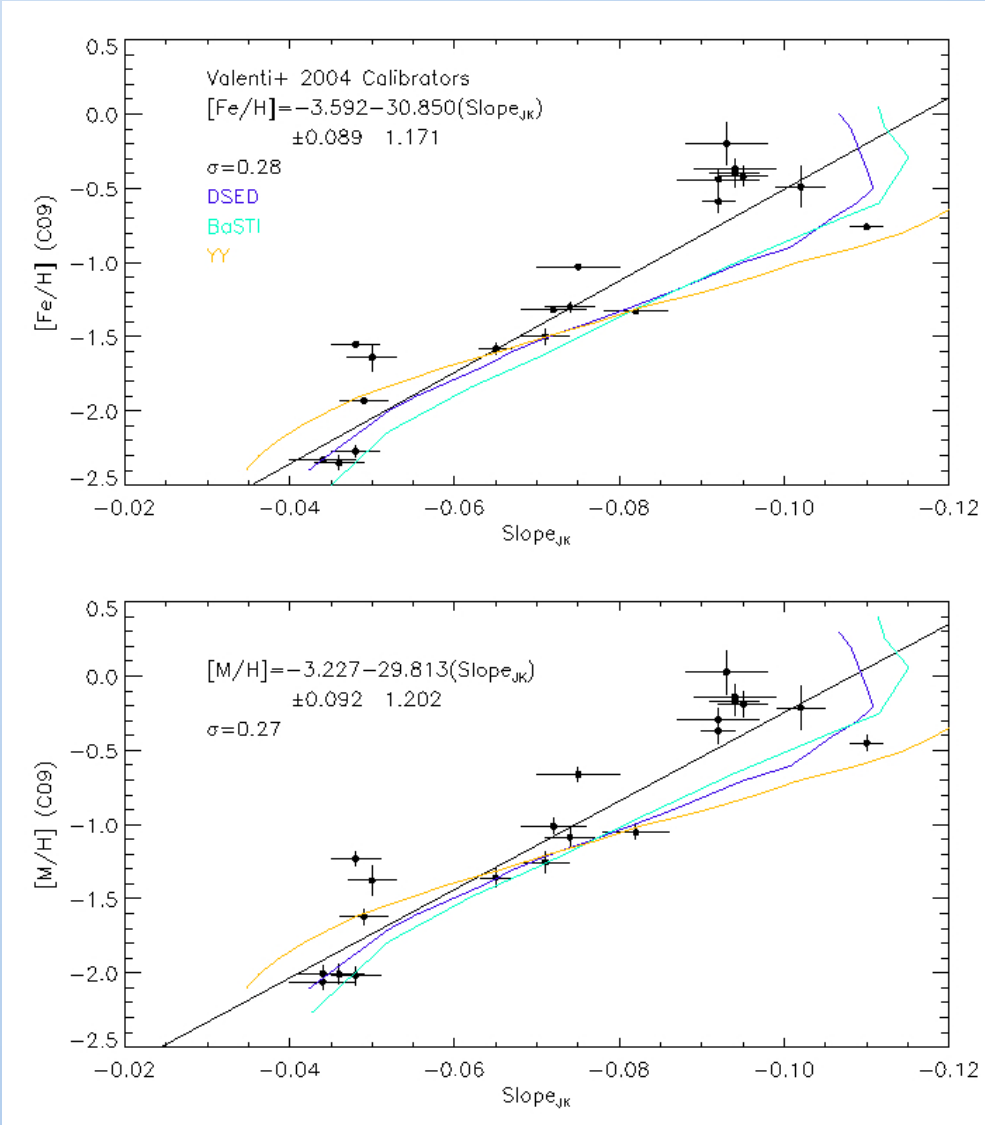
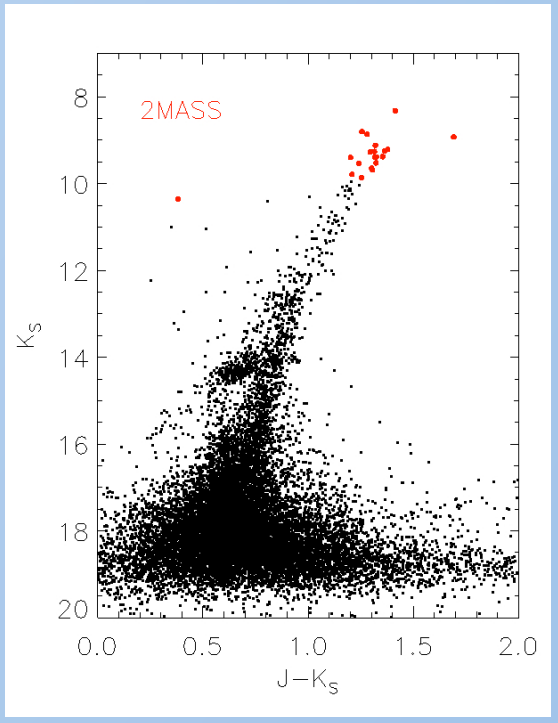
RGB Parameters: Slope



- ~14 GGCs in VVV have [Fe/H] measured spectroscopically
- Ktip+0.5 < Ks < Ktip+5 to avoid HB, RGB, AGB variables



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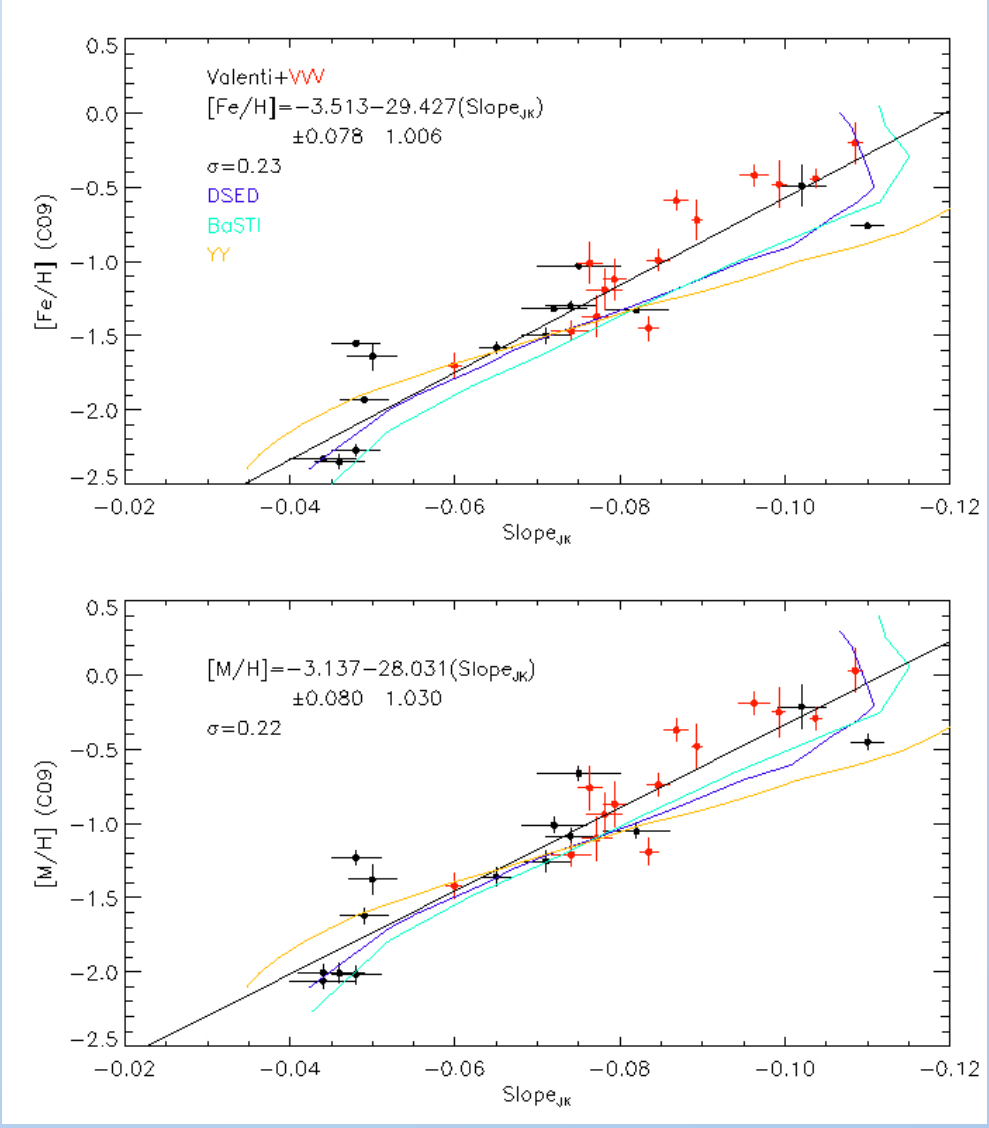

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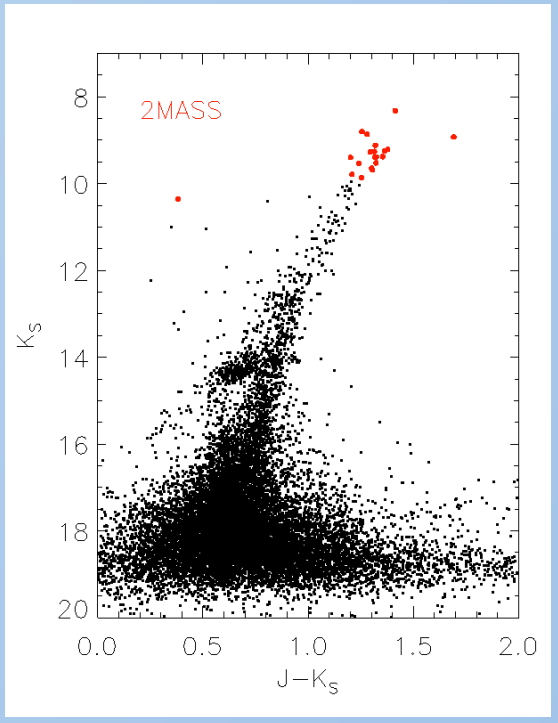
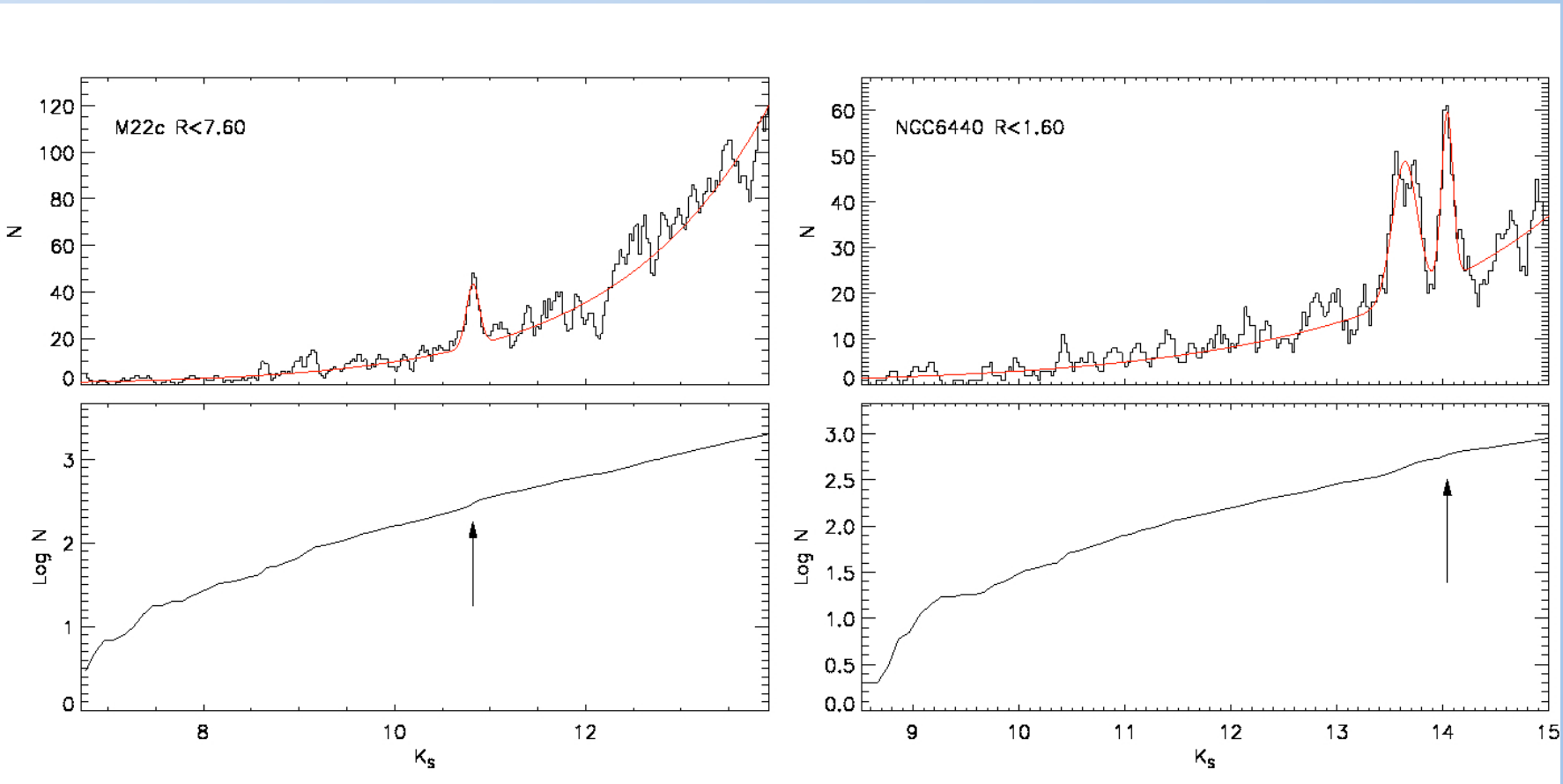
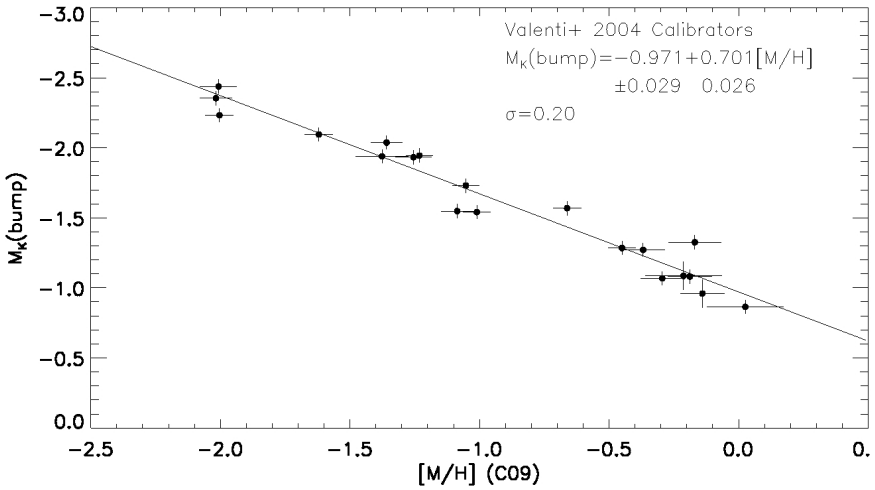


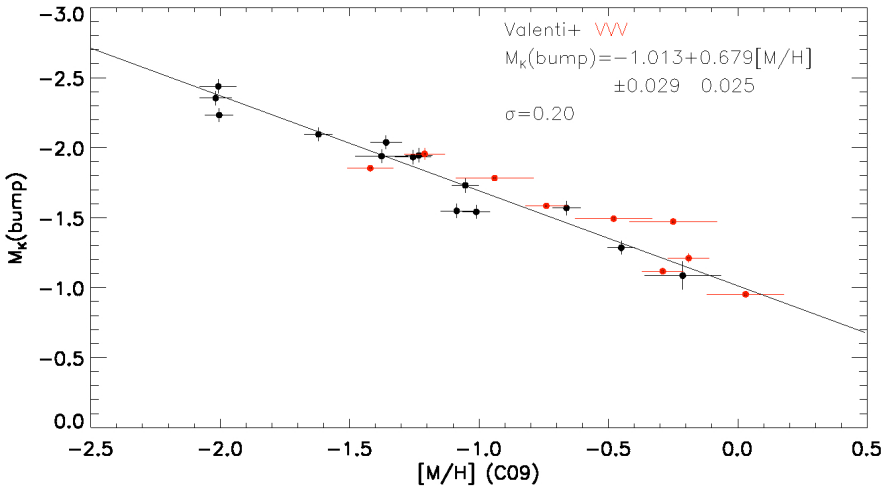
RGB Parameters: Luminosity Function

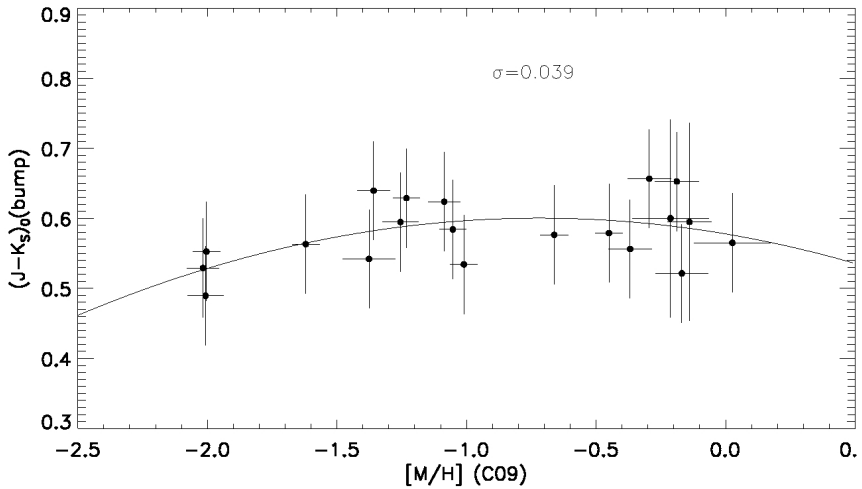


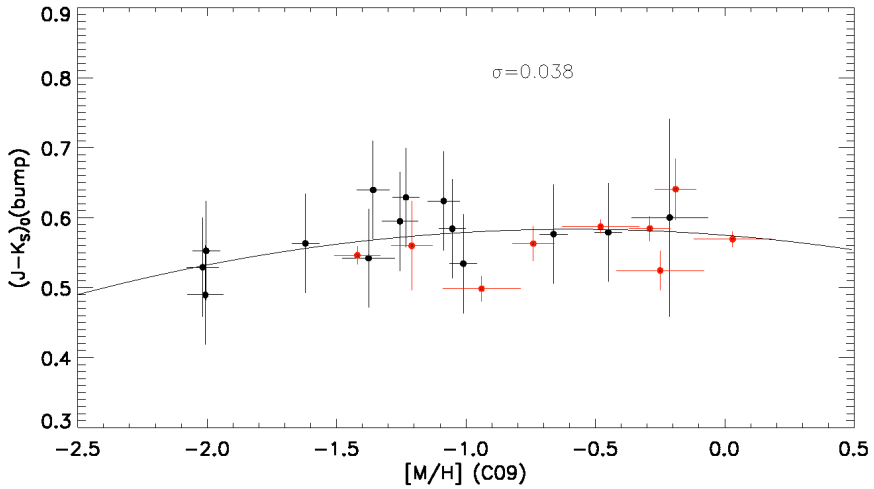
Fit with exponential + (double) Gaussian (cf. Nataf et al. 2013)

RGB Parameters: RGB Bump

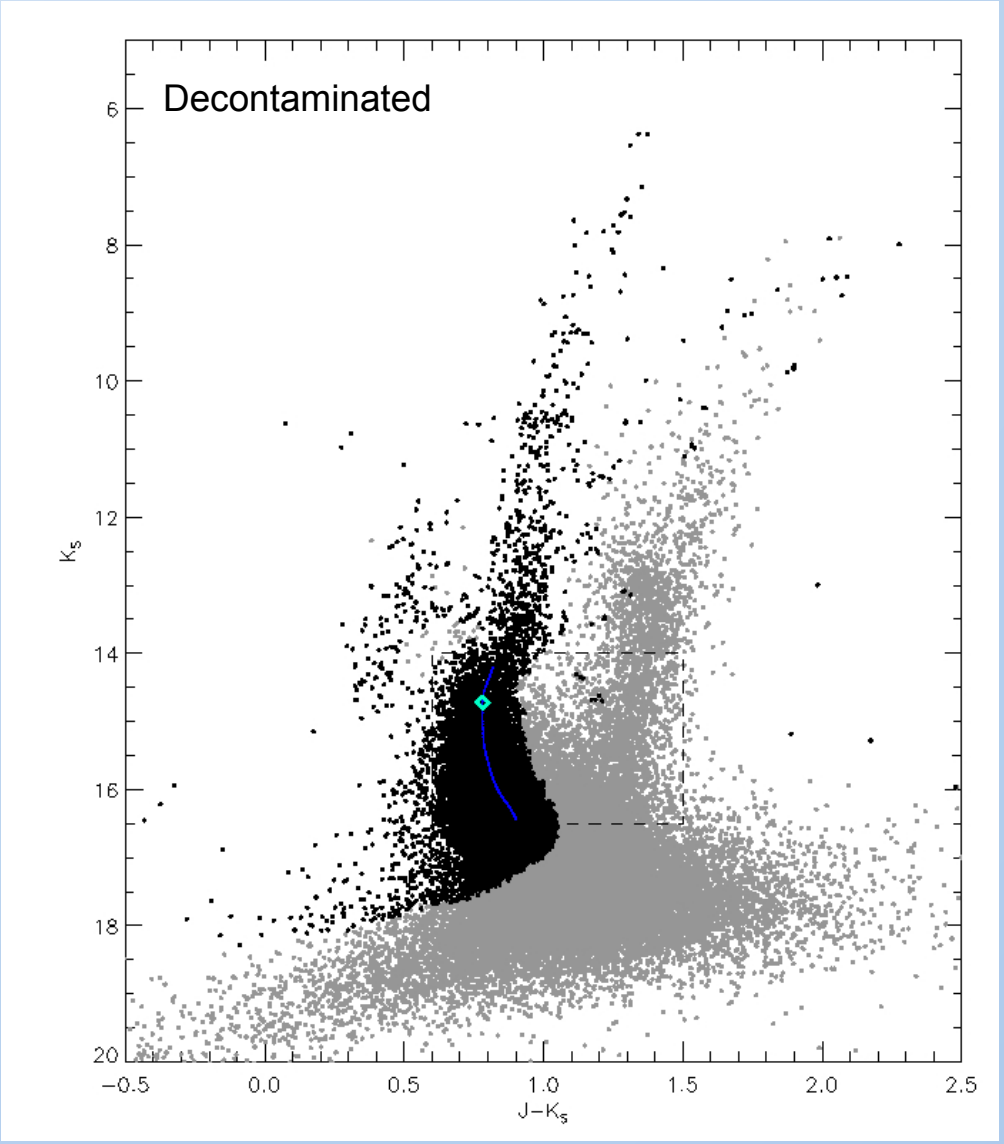








Ages of Metal-Poor GGCs in the Near IR



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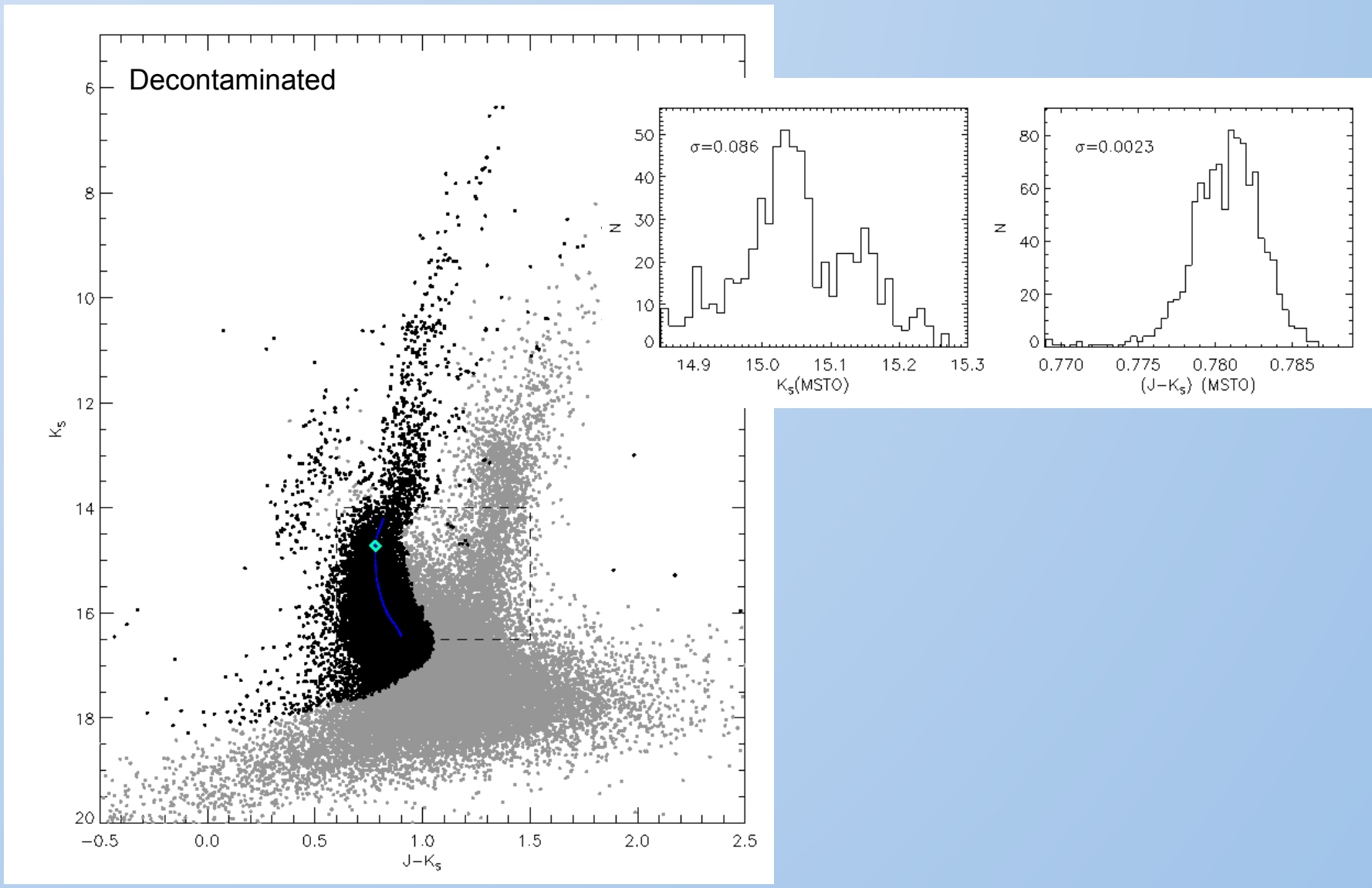

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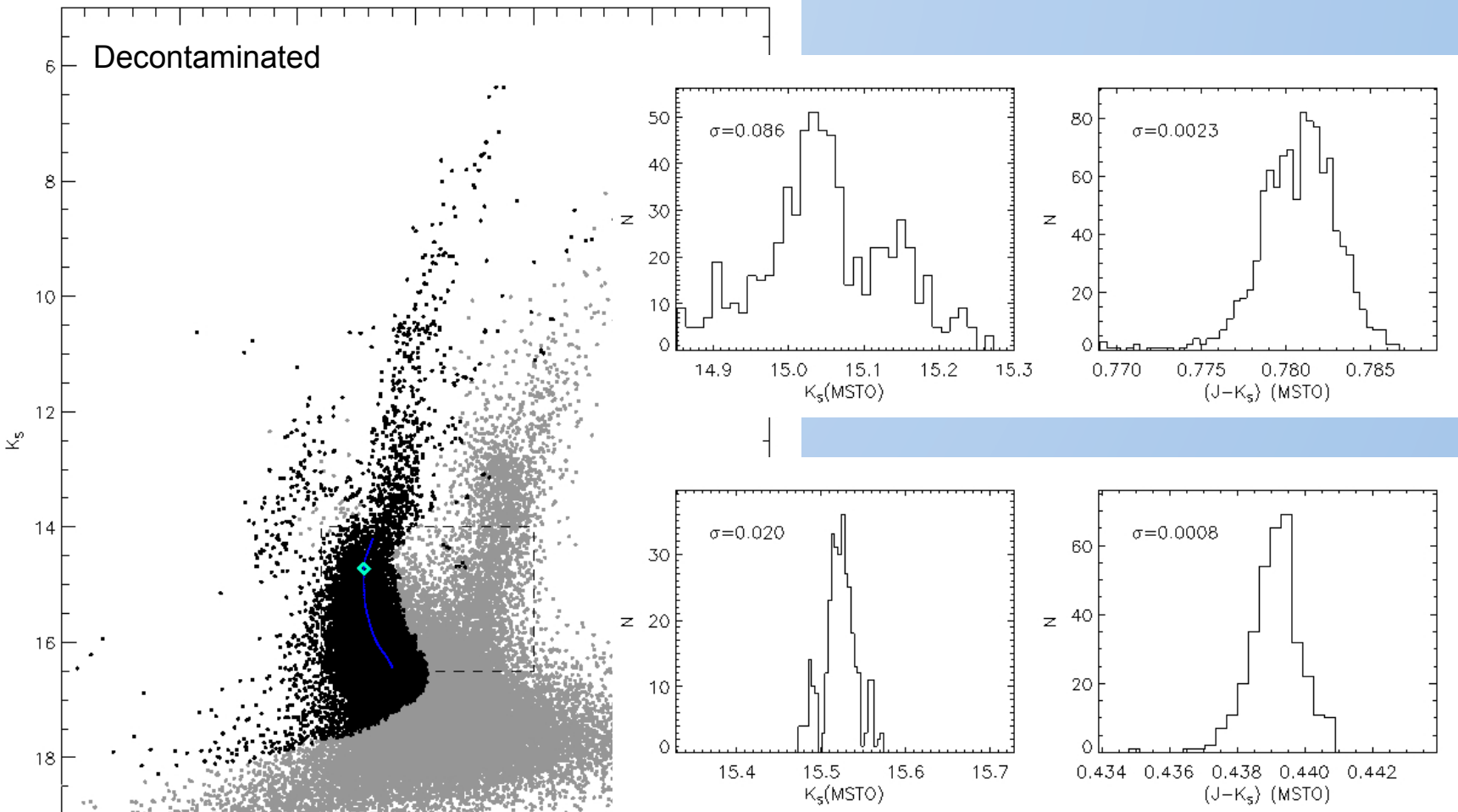
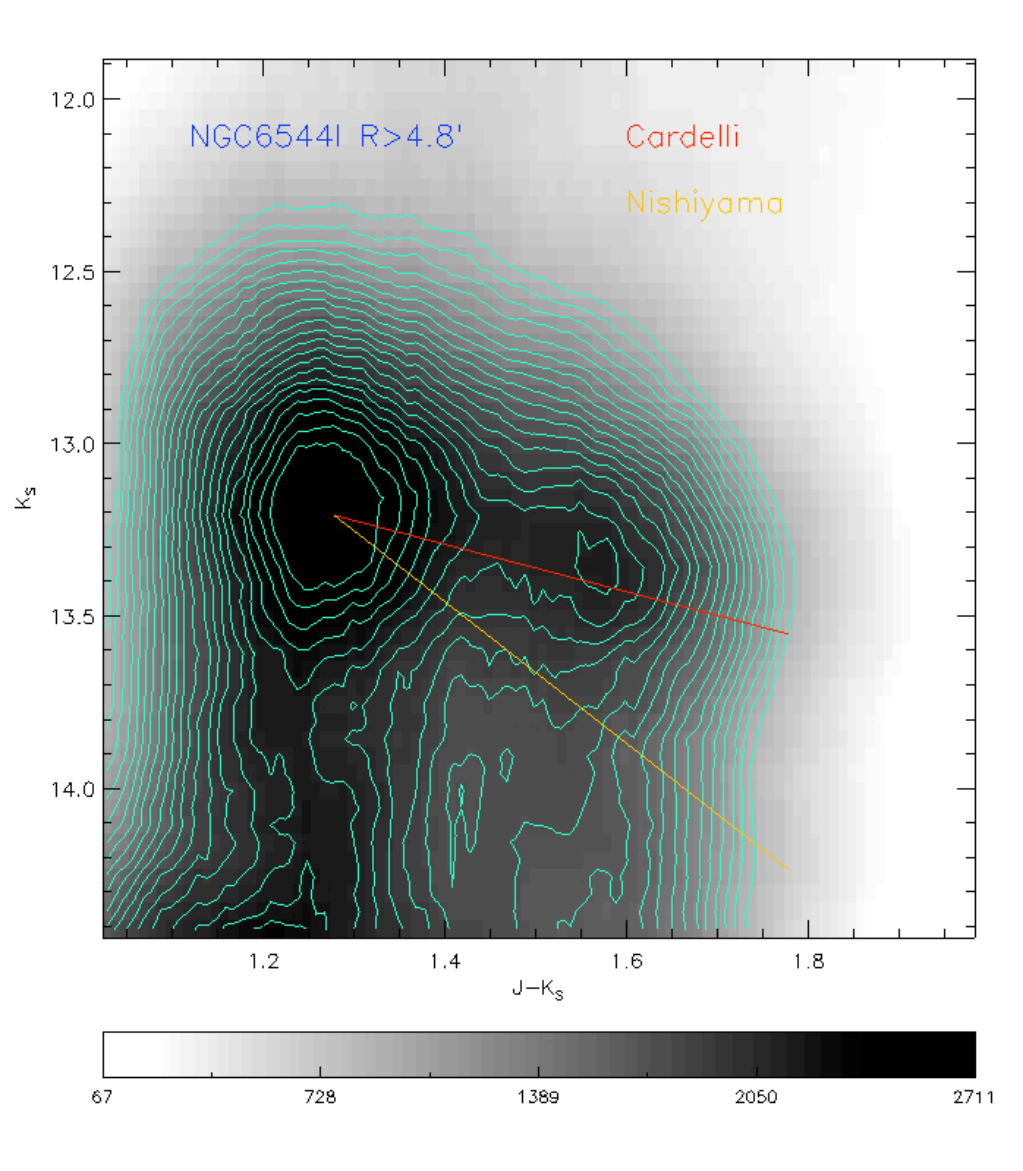


Distances and the Reddening Law



Cardelli et al. (1989):
Optical: Rv=3.1
IR: $A(\lambda) \sim \lambda^{-\alpha}$, α=1.61

Not true in the bulge!

Optical: Rv~2.5 (Nataf+12)
"non standard and non uniform"
IR: α~2.0 (Nishiyama+06)
for $|l|<2$, $0.5<|b|<1$

ΔRv=0.6 for E(B-V)=1:
Δd~2 kpc near bulge!

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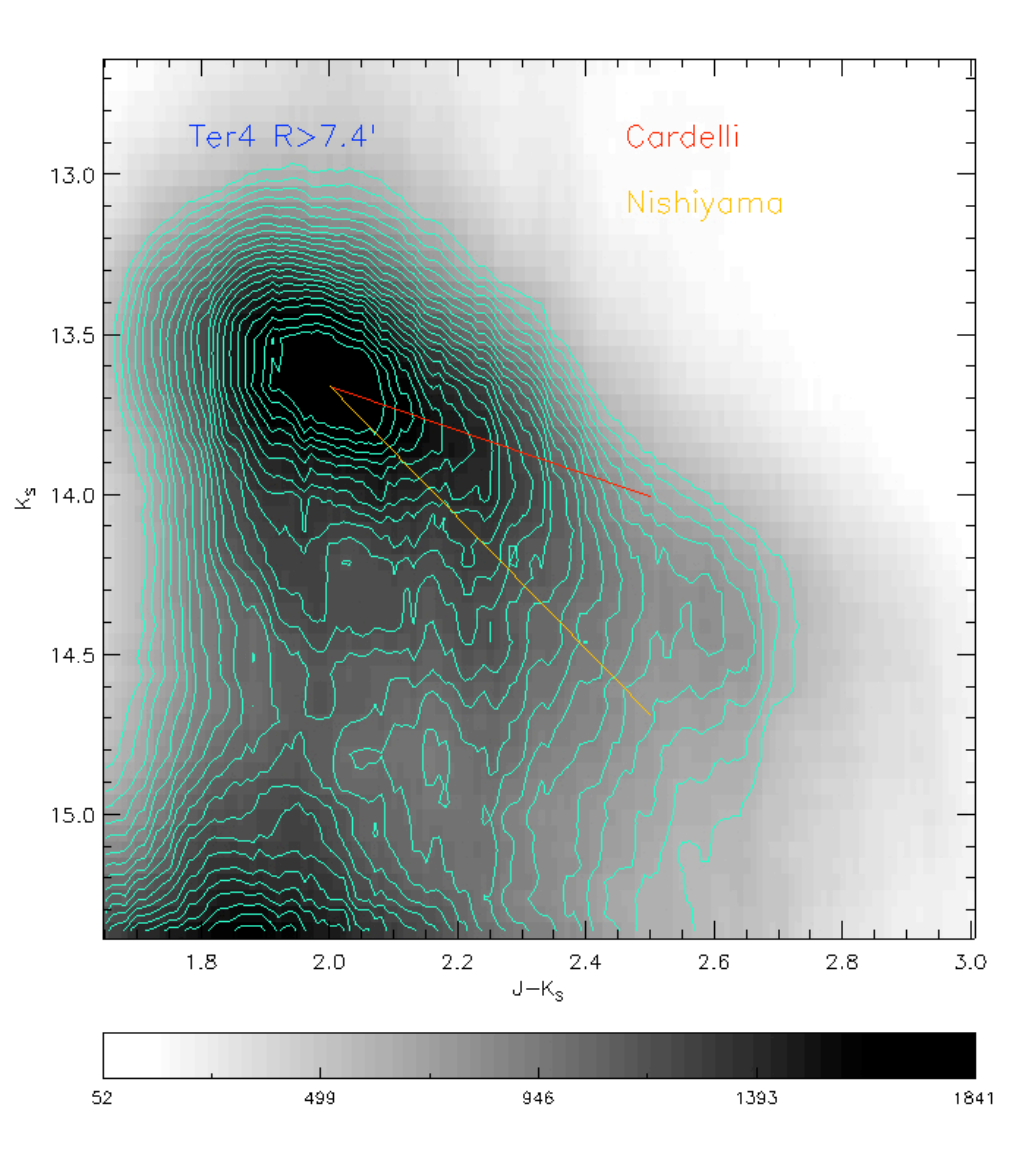

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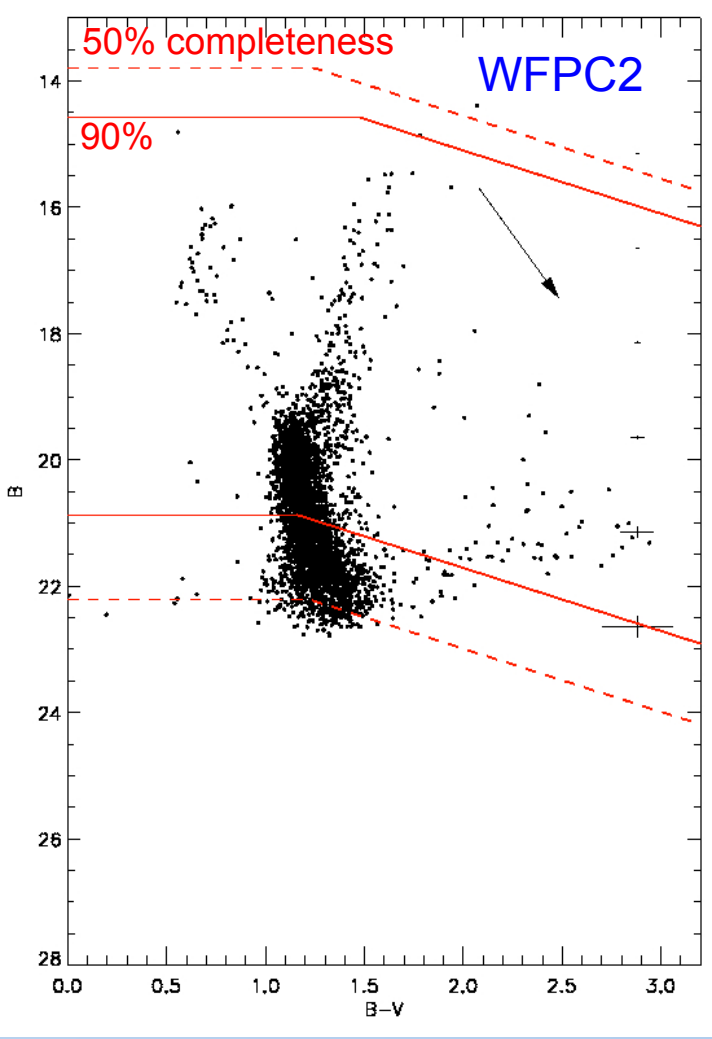

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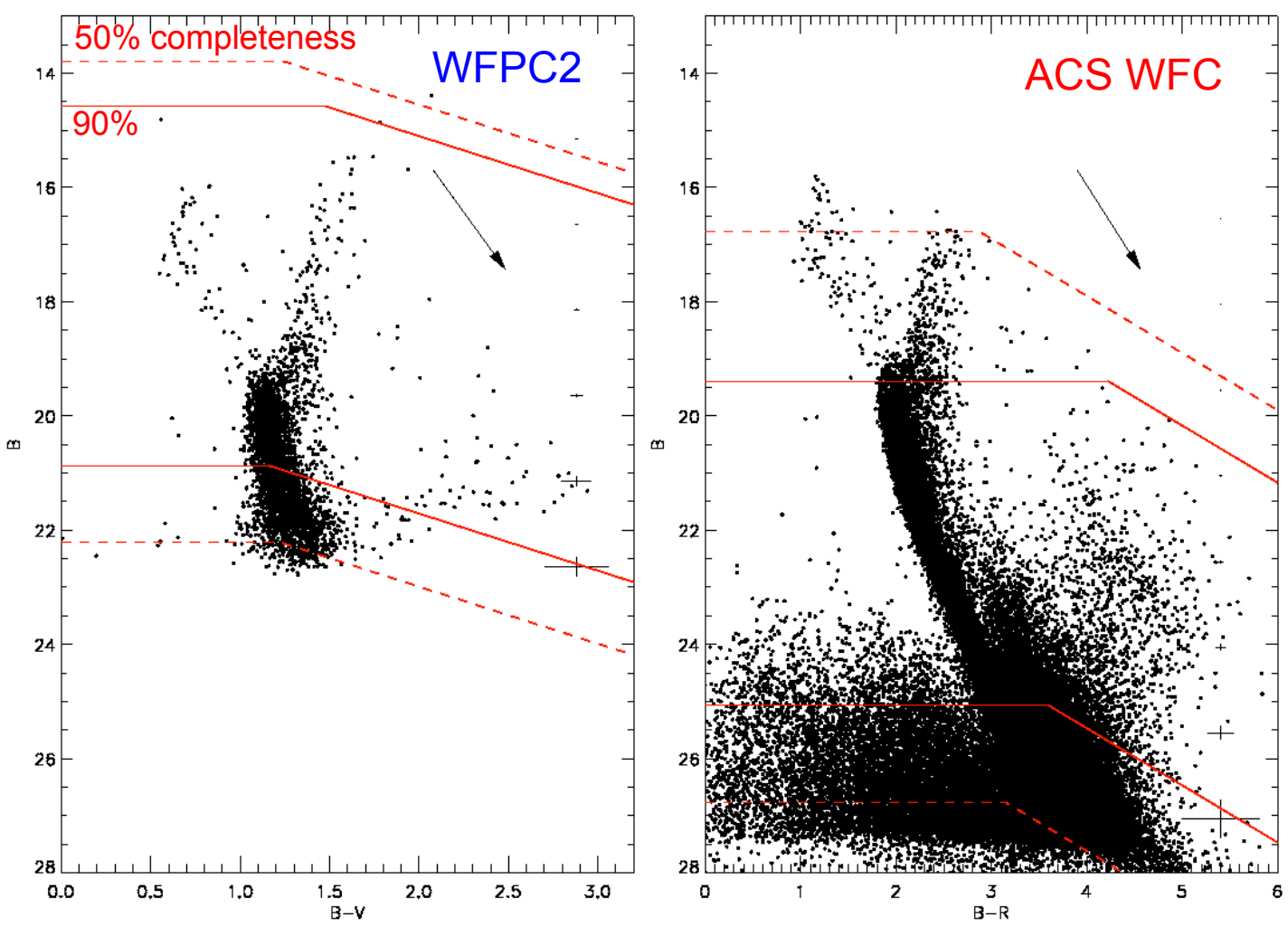

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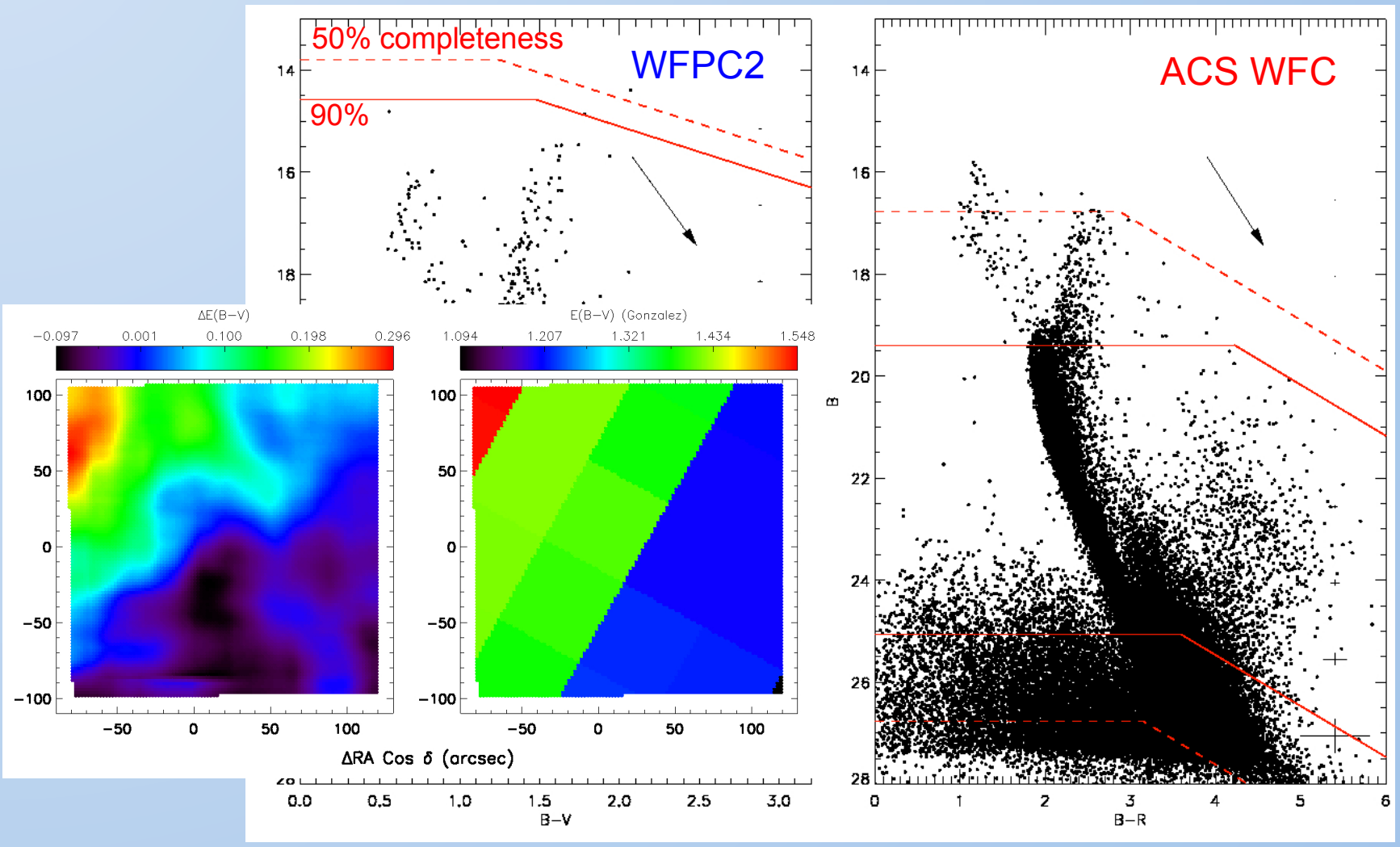
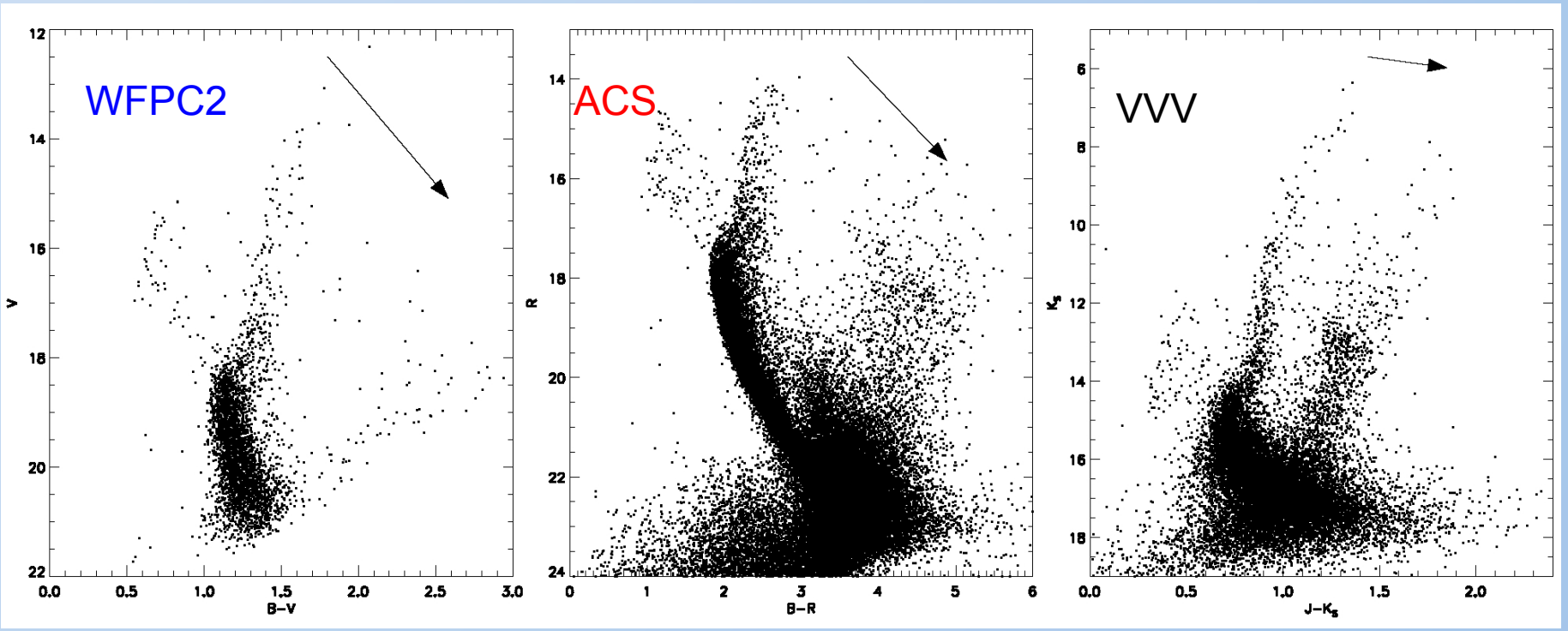


Exploit reddening sensitivity of deep optical photometry (e.g. Alonso Garcia+11,12)

VVV + Optical Photometry



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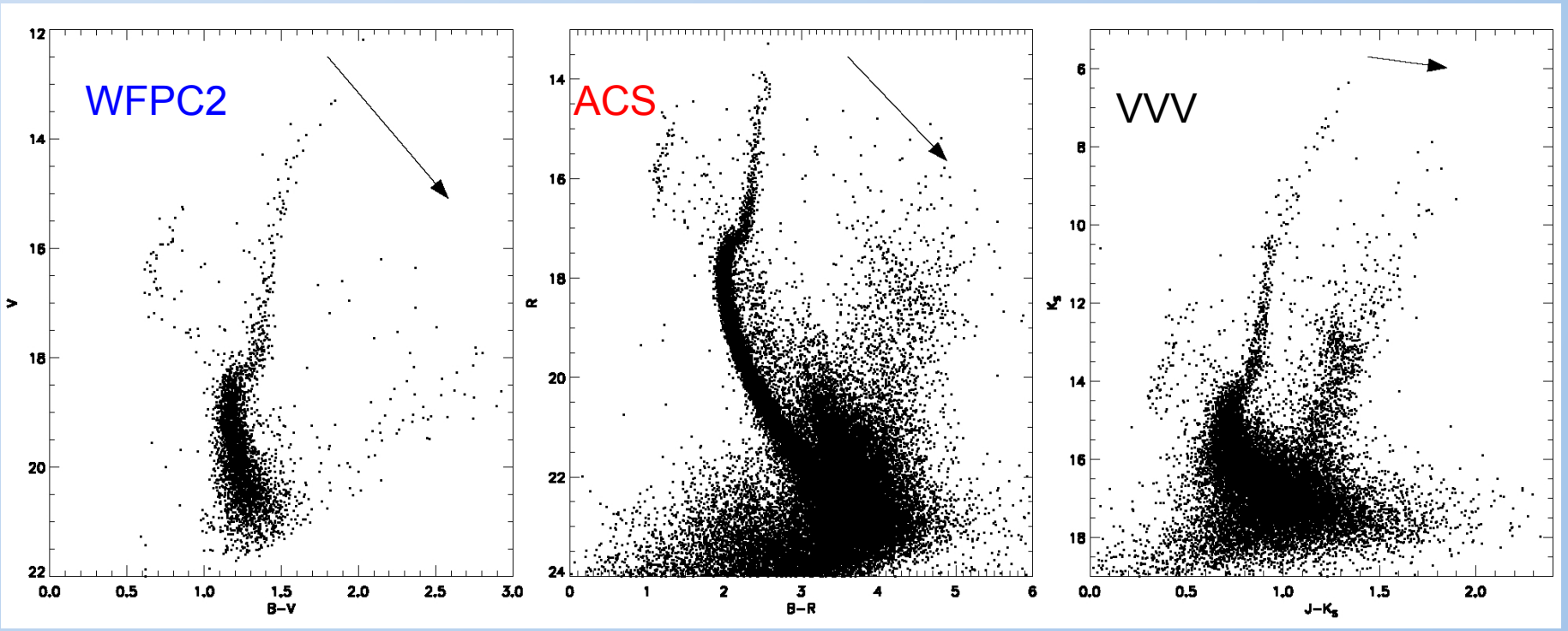

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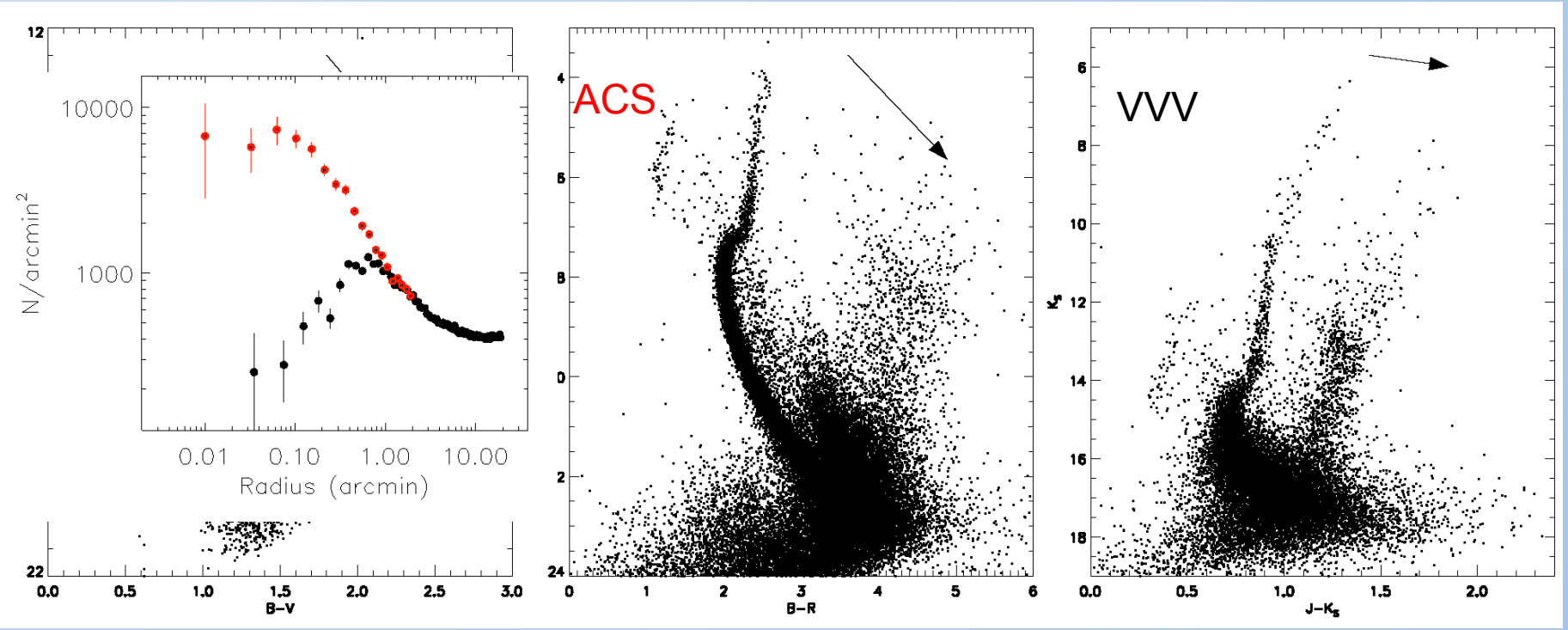


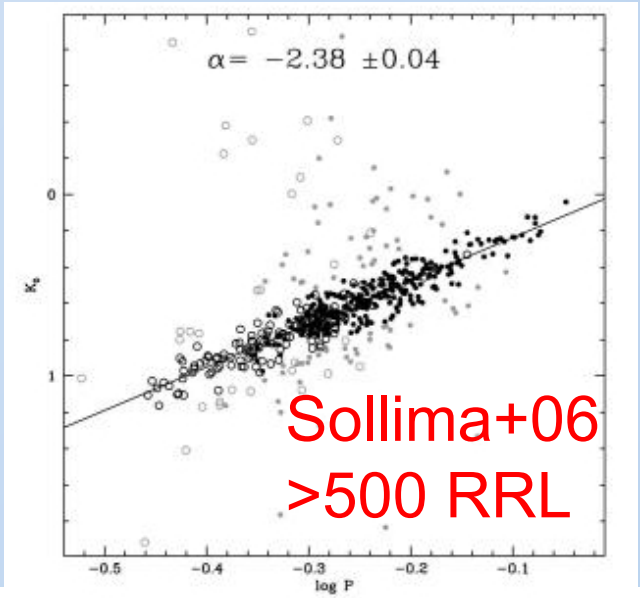
Summary and Future Plans

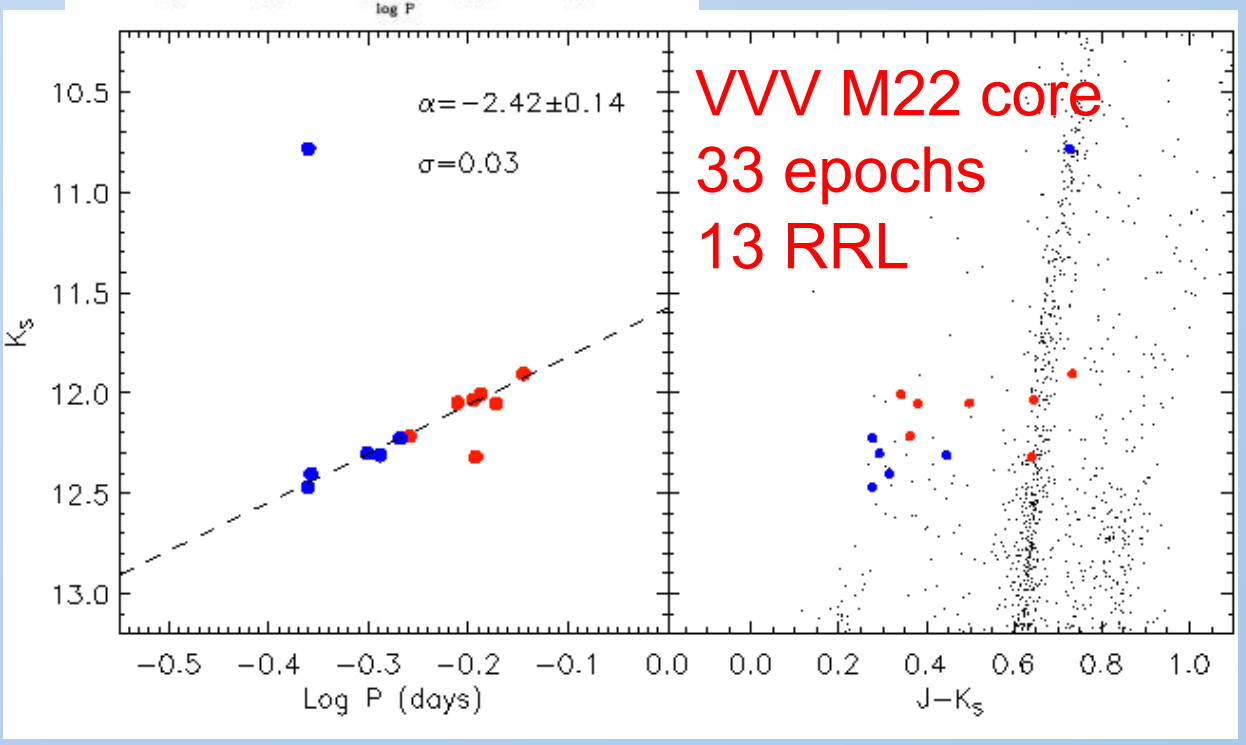
- JHKs PSF photometry catalogs for all clusters VVV-SkZ pipeline, Mauro+13
- Follow-up spectroscopy, photometry (deep AO)
- RGB calibrations: Apply to clusters without spectroscopic abundances
- Structural parameters
- Optical-IR calibrations

Long term:

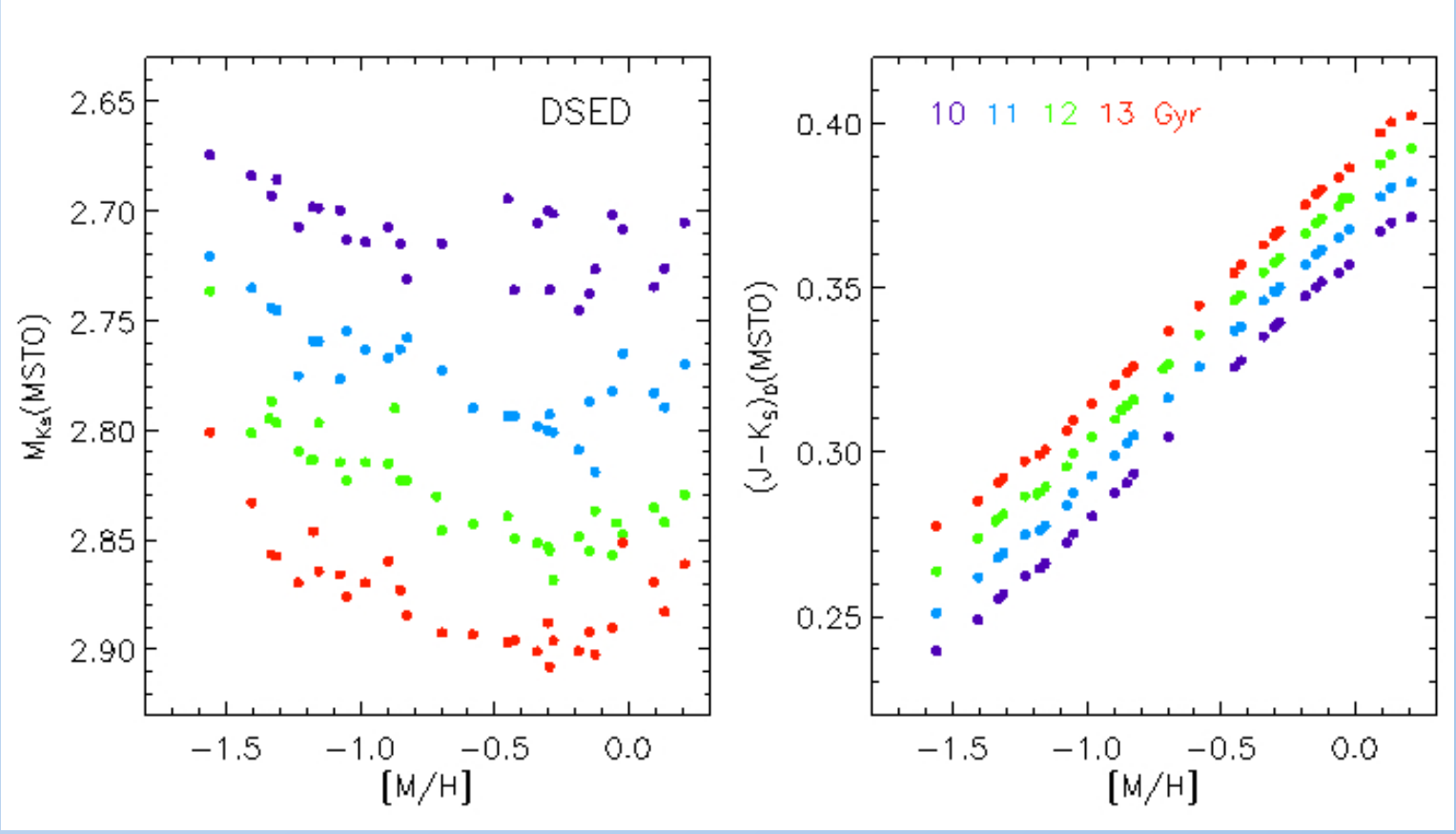
- Variability, period-luminosity relations (J. Alonso et al.)
- Relative proper motions (J. C. Beamin et al.)

Globular cluster RRL period-luminosity relation with VVV Ks time series

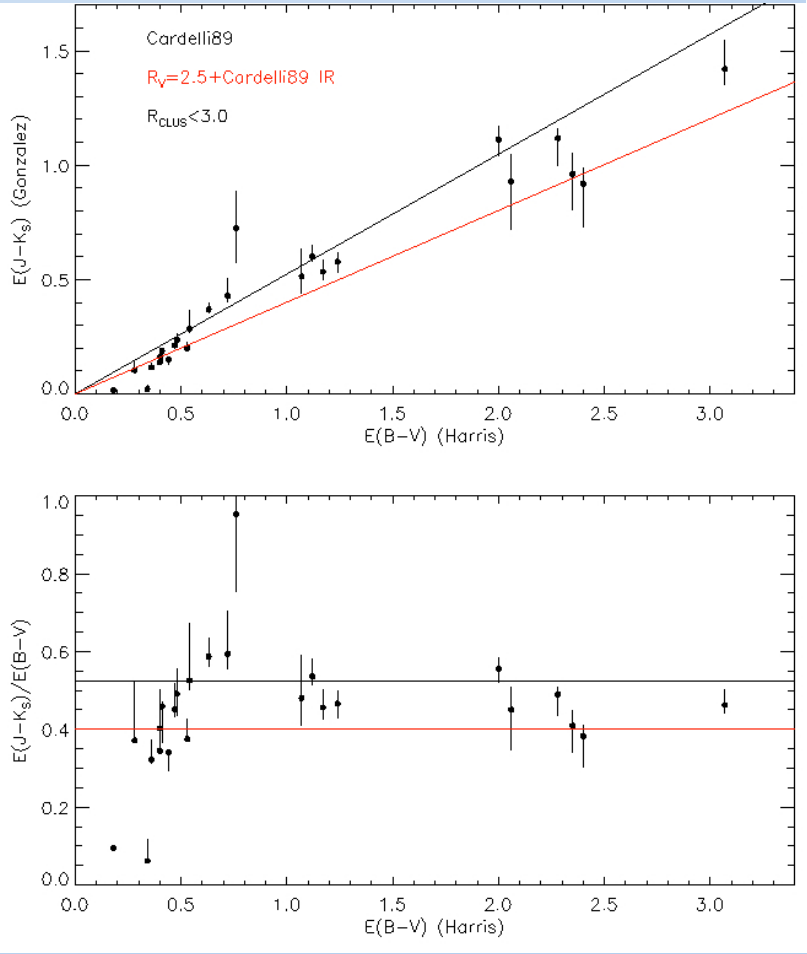


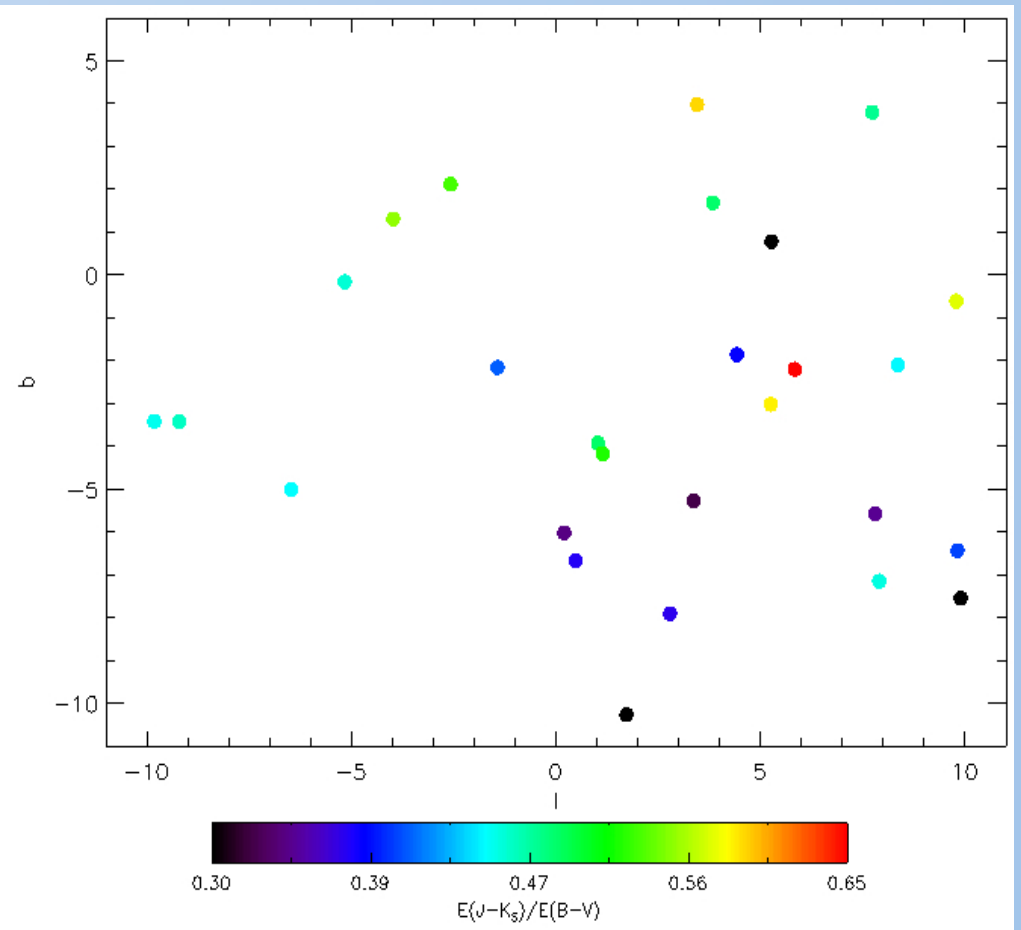


MSTO Color, Mag vs. Age

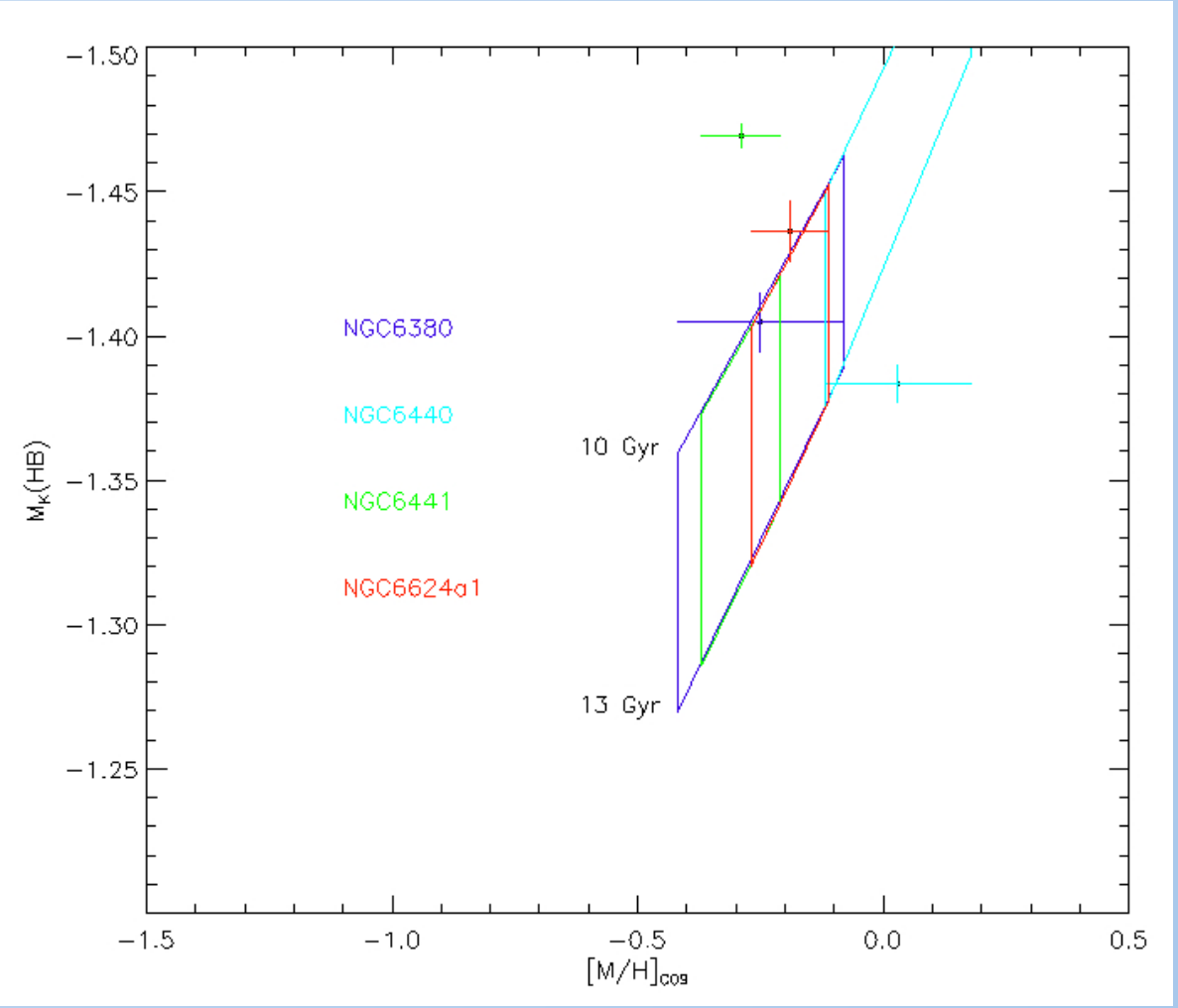


Optical vs. IR Reddening

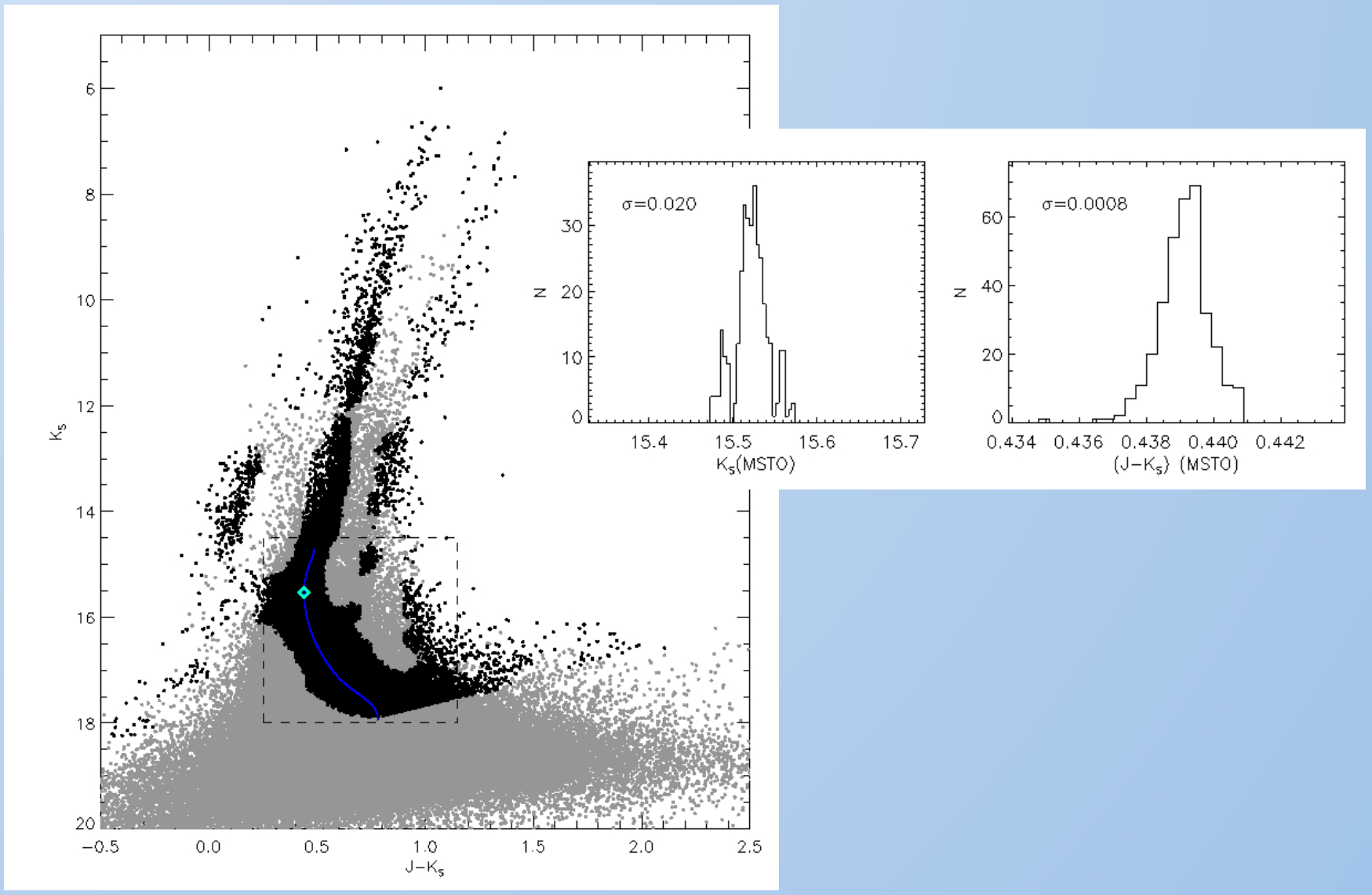




Red Clump Magnitude



M22 Turnoff


6
8
10
12
14
16
18
20
K_s
−0.5
0.0
0.5
1.0
1.5
2.0
2.5
$J-K_s$
σ=0.020
N
30
20
10
0
15.4
15.5
15.6
15.7
K_s(MSTO)
σ=0.0008
N
60
40
20
0
0.434
0.436
0.438
0.440
0.442
$(J-K_s)$ (MSTO)