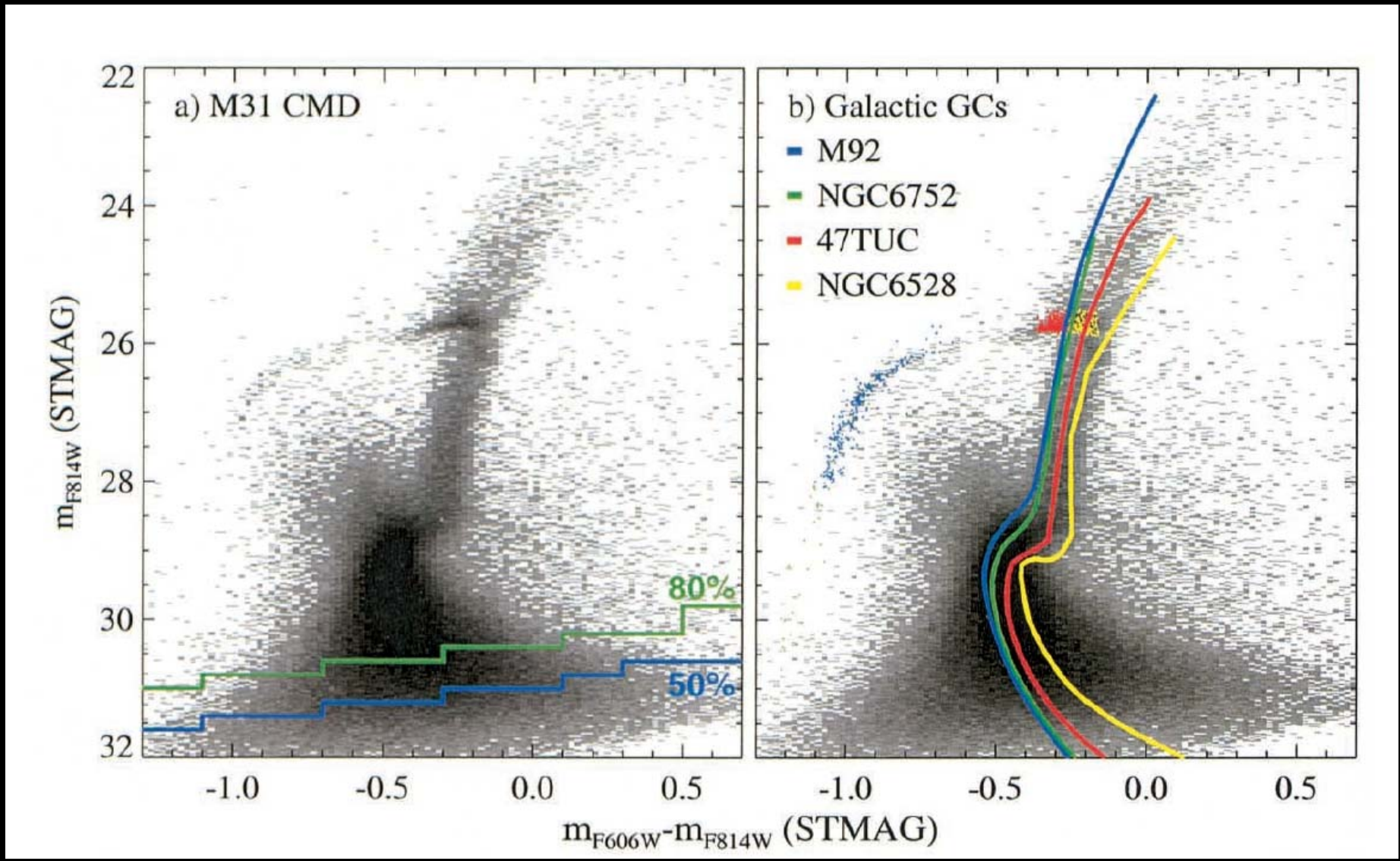
Resolved Stellar Populations: the near and far

Yazan Al Momany, Santiago. September 22.

A powerful investigation tool : Color-Magnitude Diagrams can tell us very much about simple or/and composite stellar populations.



M31: Brown et al. (2004)

Outline:

1. A quick highlight of personal research interest and results: playing with ultraviolet, optical and infrared color-magnitude diagrams and addressing different problematic at different distances (from few kpc to ~15 Mpc).
2. Focus on a particular and interesting problematic: concerning the Blue Stragglers production frequency in different environments, such as open clusters, globular clusters, Milky Way halo and dwarf galaxies.

PART #1: UV imaging of hot stars:

THE ASTROPHYSICAL JOURNAL, 576:L65–L68, 2002 September 1

A NEW FEATURE ALONG THE EXTENDED BLUE HORIZONTAL BRANCH OF NGC 6752[1]

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UV imaging of hot blue horizontal (HB) branch stars in Galactic Globular clusters. HB stars can reach 45000 K and show anomalies in Vrot, relative abundance, and surface gravities as well as discontinuites and gaps.

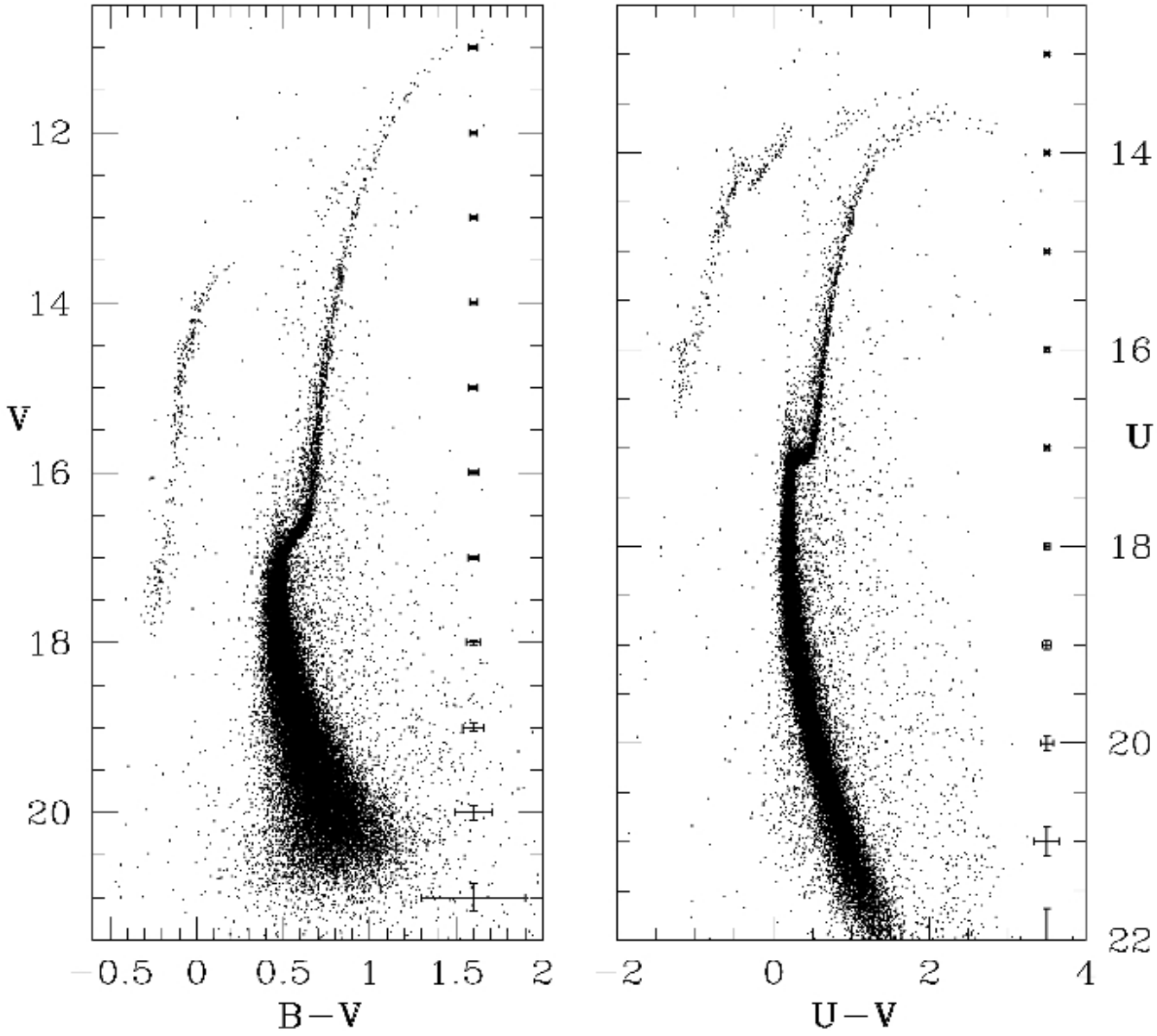
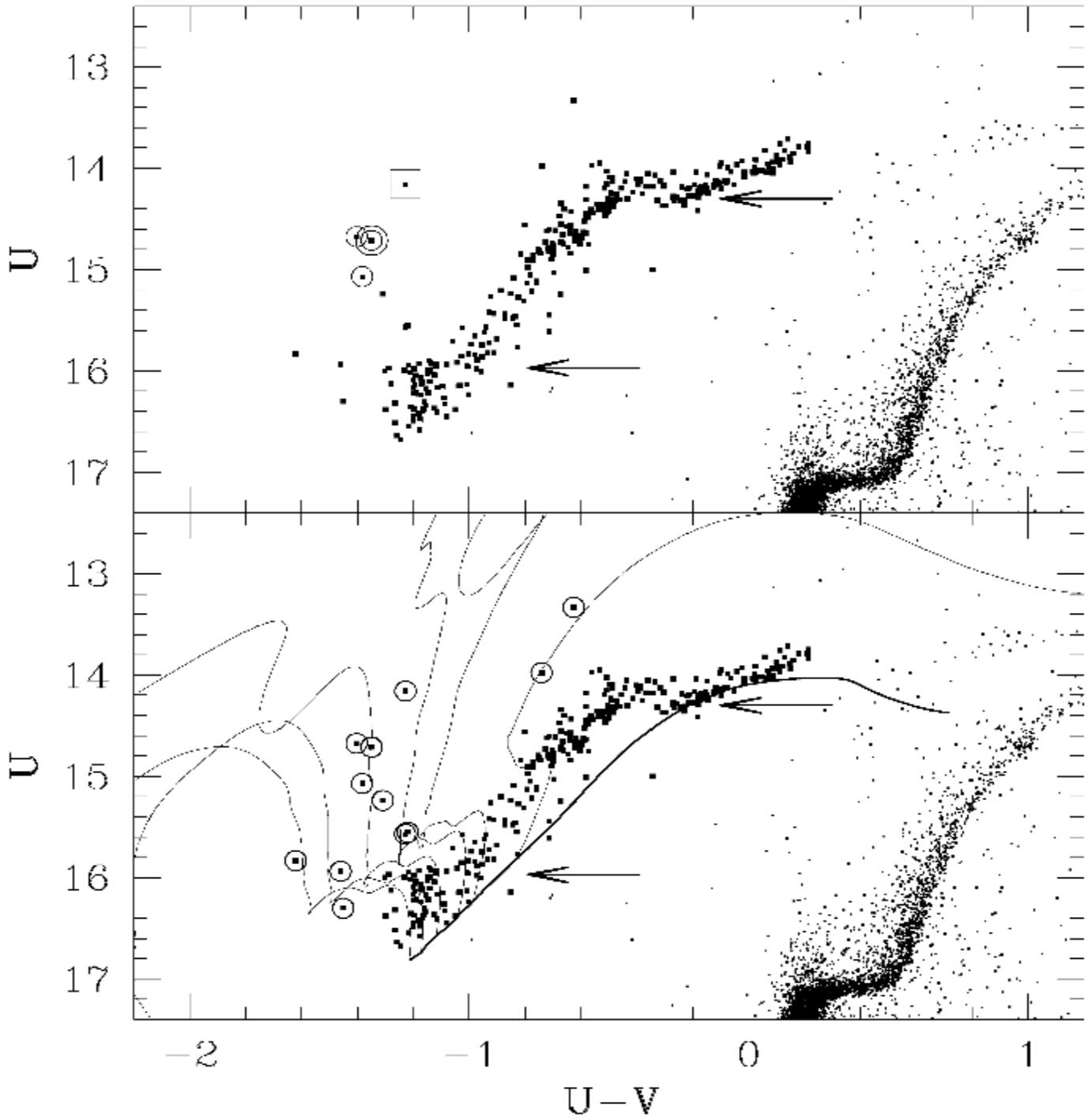


FIG. 1.—(V, $B-V$) and (U, $U-V$) CMDs for stars with $0'.3 < R < 13'.9$, where R is the projected distance from the cluster center. Photometric errors, as calculated by ALLFRAME, are shown on the right side of the two CMDs.

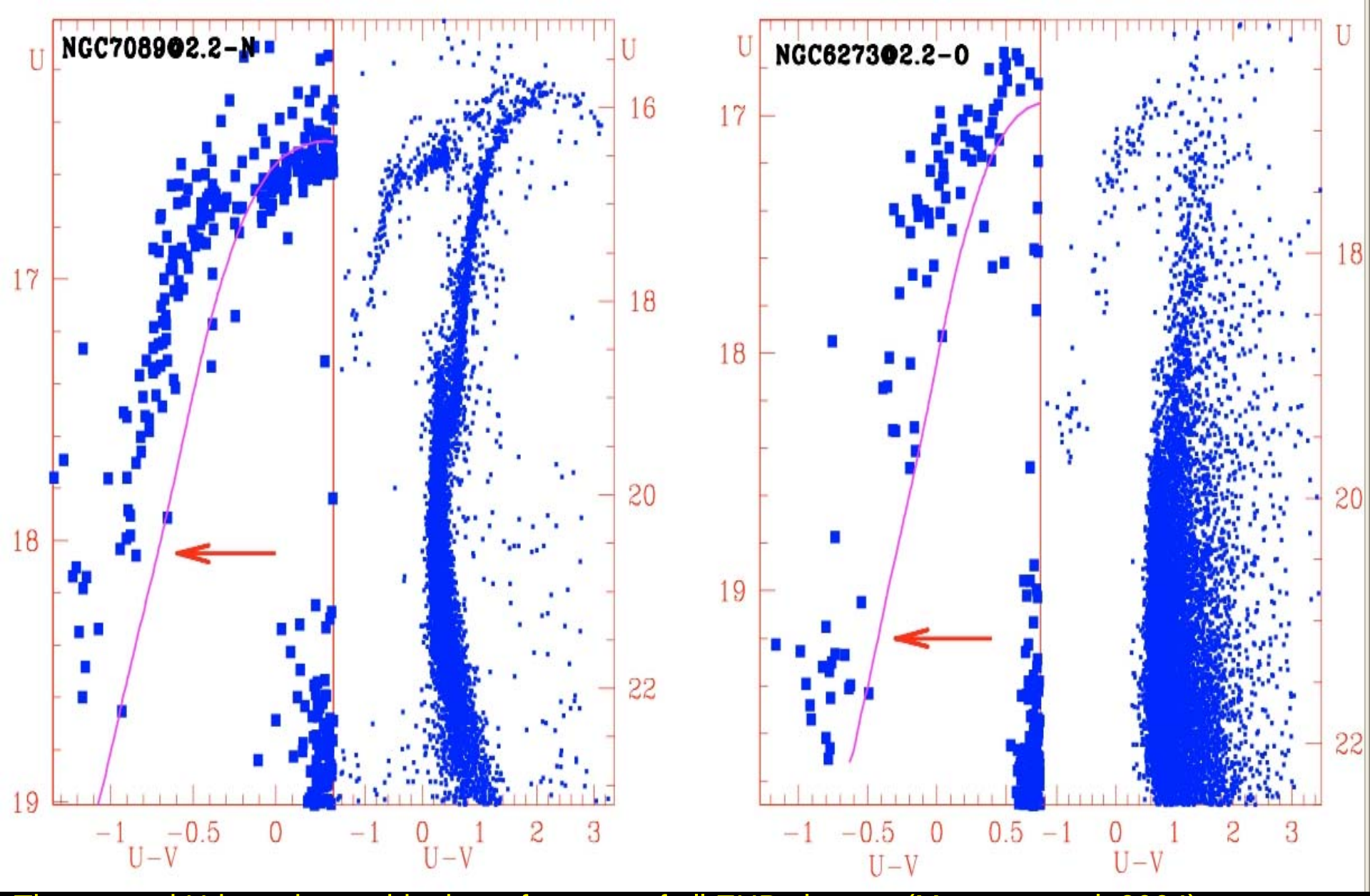
Classical optical diagrams (due to color saturation) are not appropriate for studying hot stars such as EHB. Thus, the UV!



The G99 jump was explained as due to radiative levitation that causes a substantial increase in the metal content of the outermost layers.

Radiative levitation and diffusion are possible after the disappearance of the envelope convective layers located across the H and He I ionization regions, $T \sim 11000$ K.

Canonical models predict that the He II convective region approaches the stellar surface at $T \sim 23{,}000$ K.



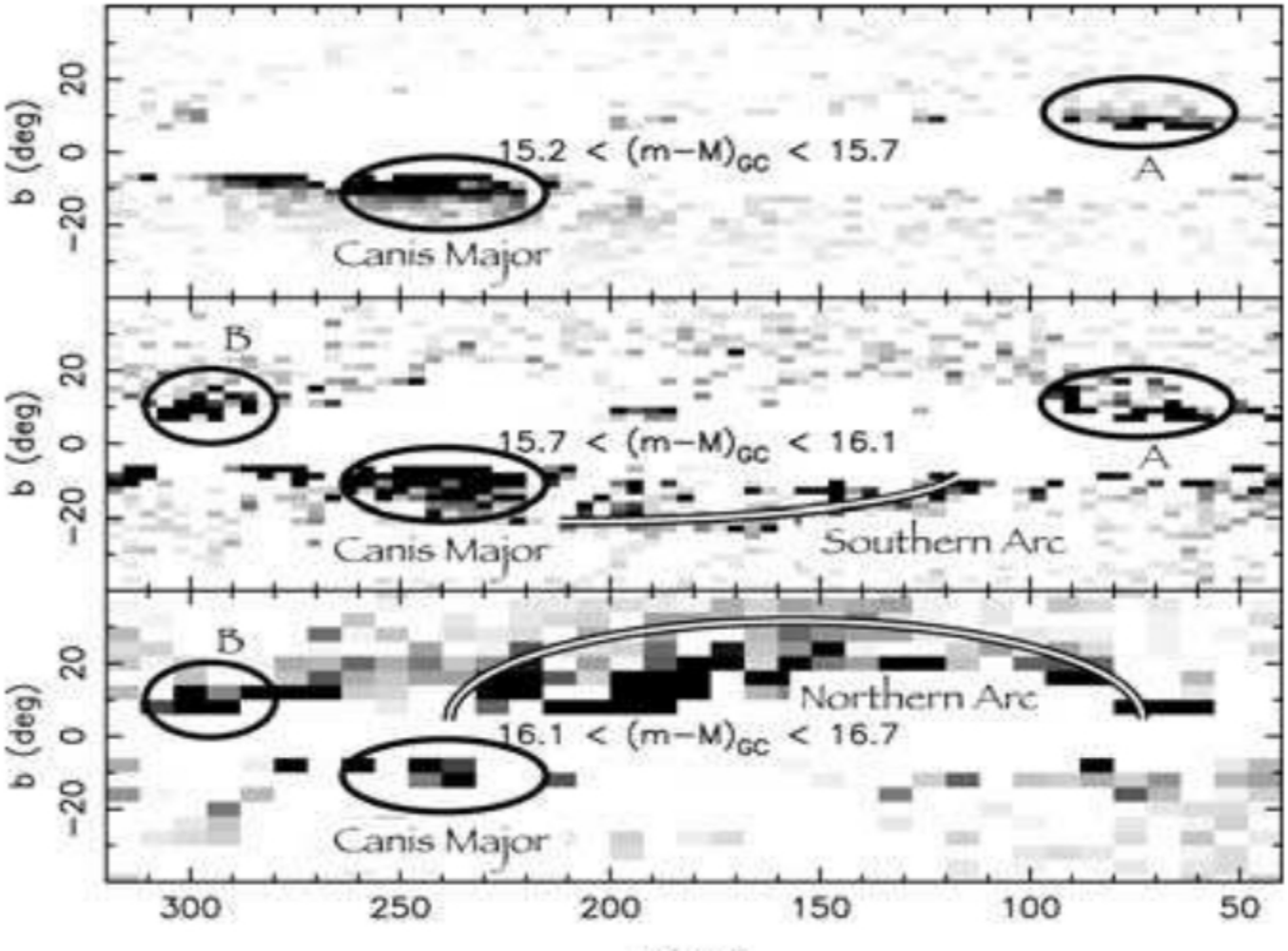
The second U-jump is an ubiquitous features of all EHB clusters (Momany et al. 2004)

PART #1: IR imaging of “cool” stars:

Recent 2MASS analysis of the Milky Way stellar disk suggested the presence of ….

A dwarf galaxy remnant in Canis Major: the fossil of an in-plane accretion on to the Milky Way

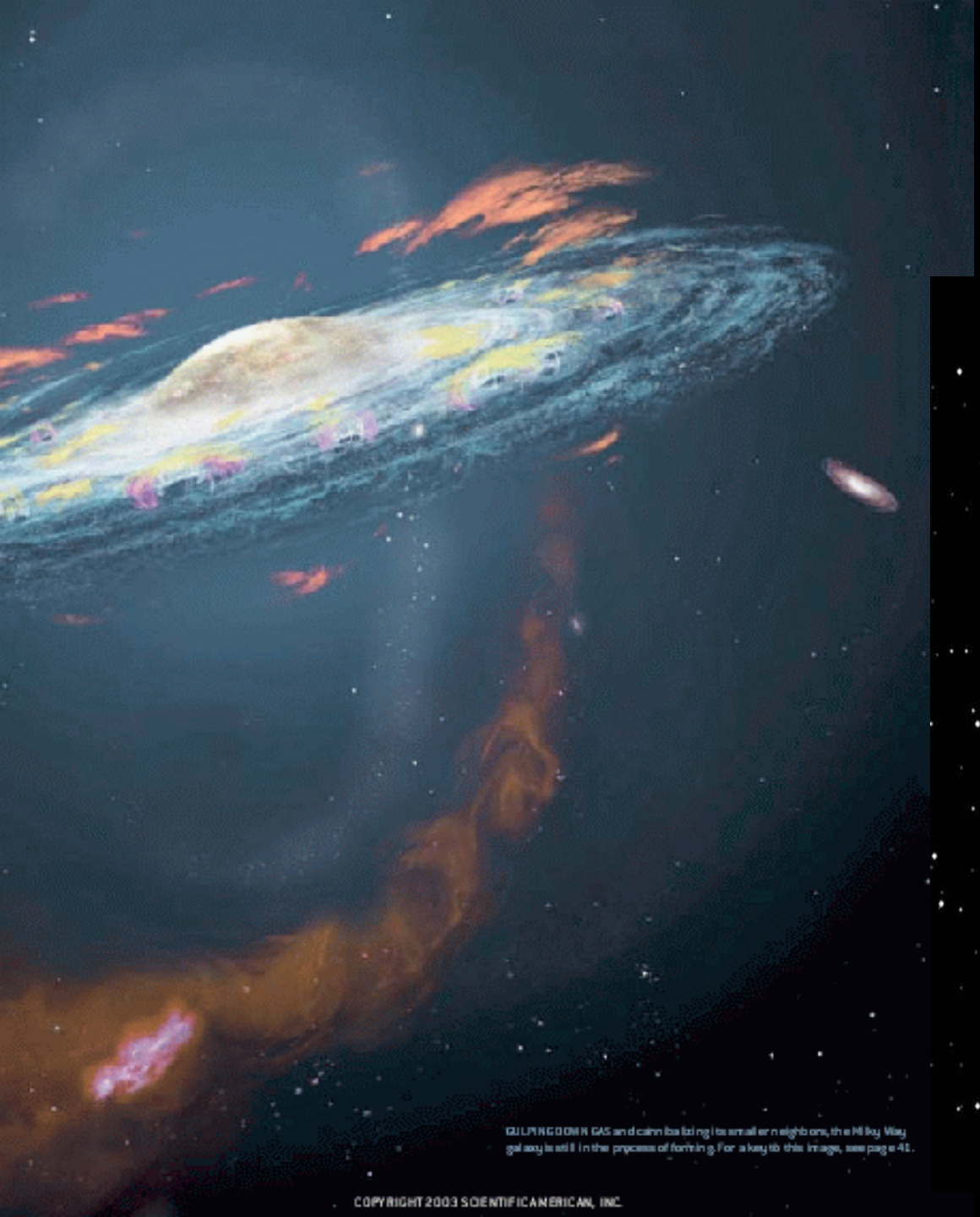
N. F. Martin,[1] R. A. Ibata,[1★] M. Bellazzini,[2] M. J. Irwin,[3] G. F. Lewis[4] and W. Dehnen[5]

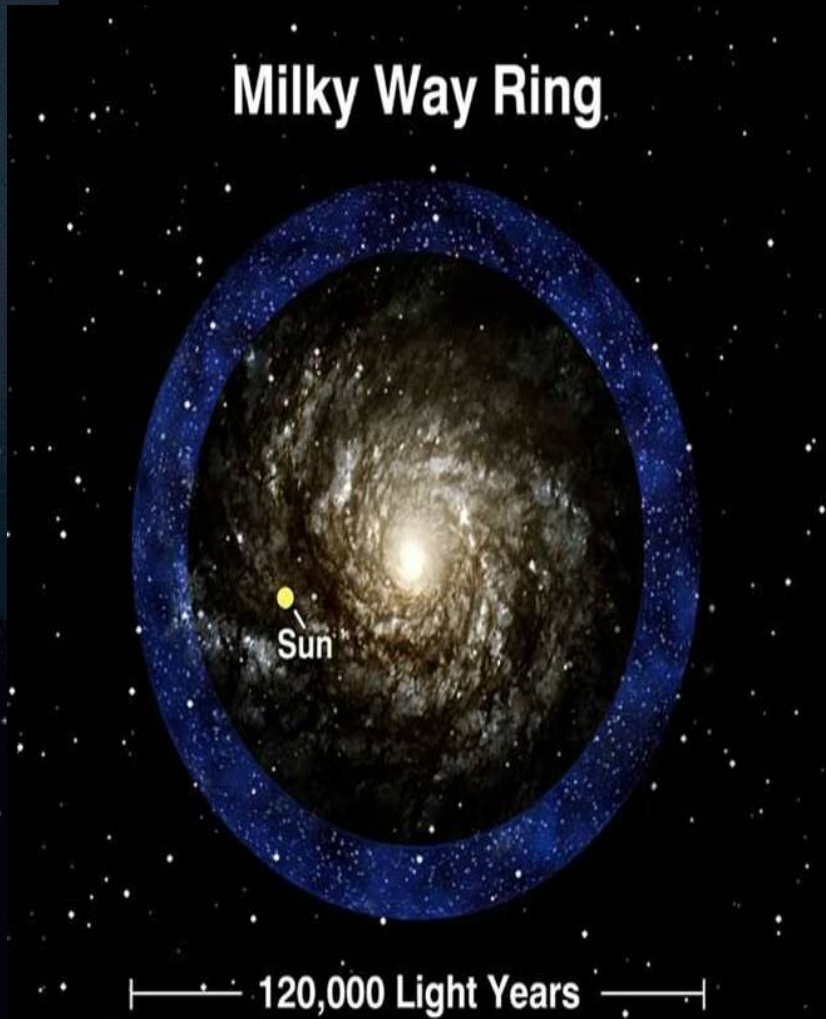


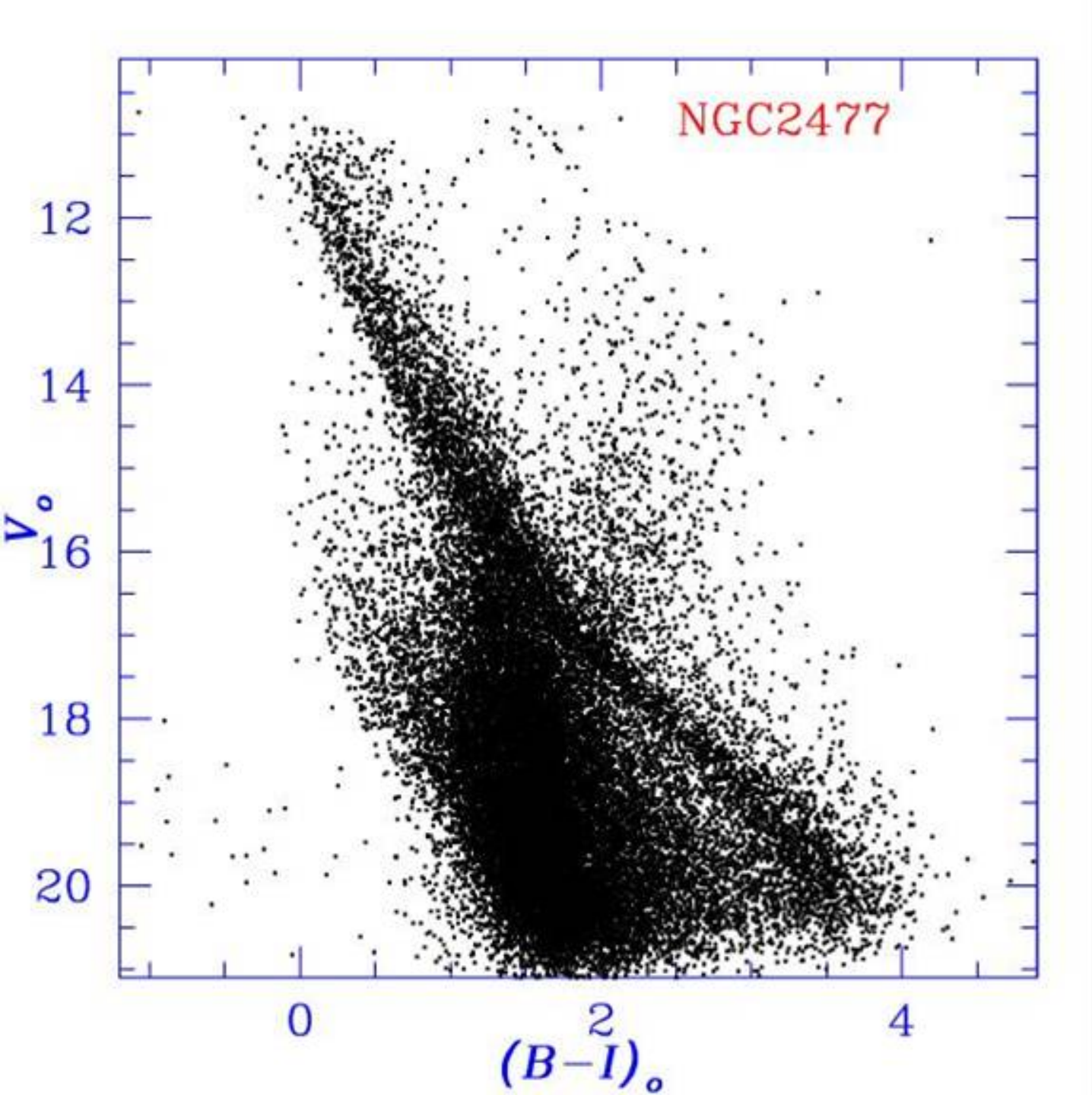
Subtracting the stellar counts of red giants in the 2 hemispheres shows a remnant stellar over-density, probably a dwarf galaxy.

The method HOWEVER!!! assumed perfect symmetry with respect to the Milky Way mid-plane.

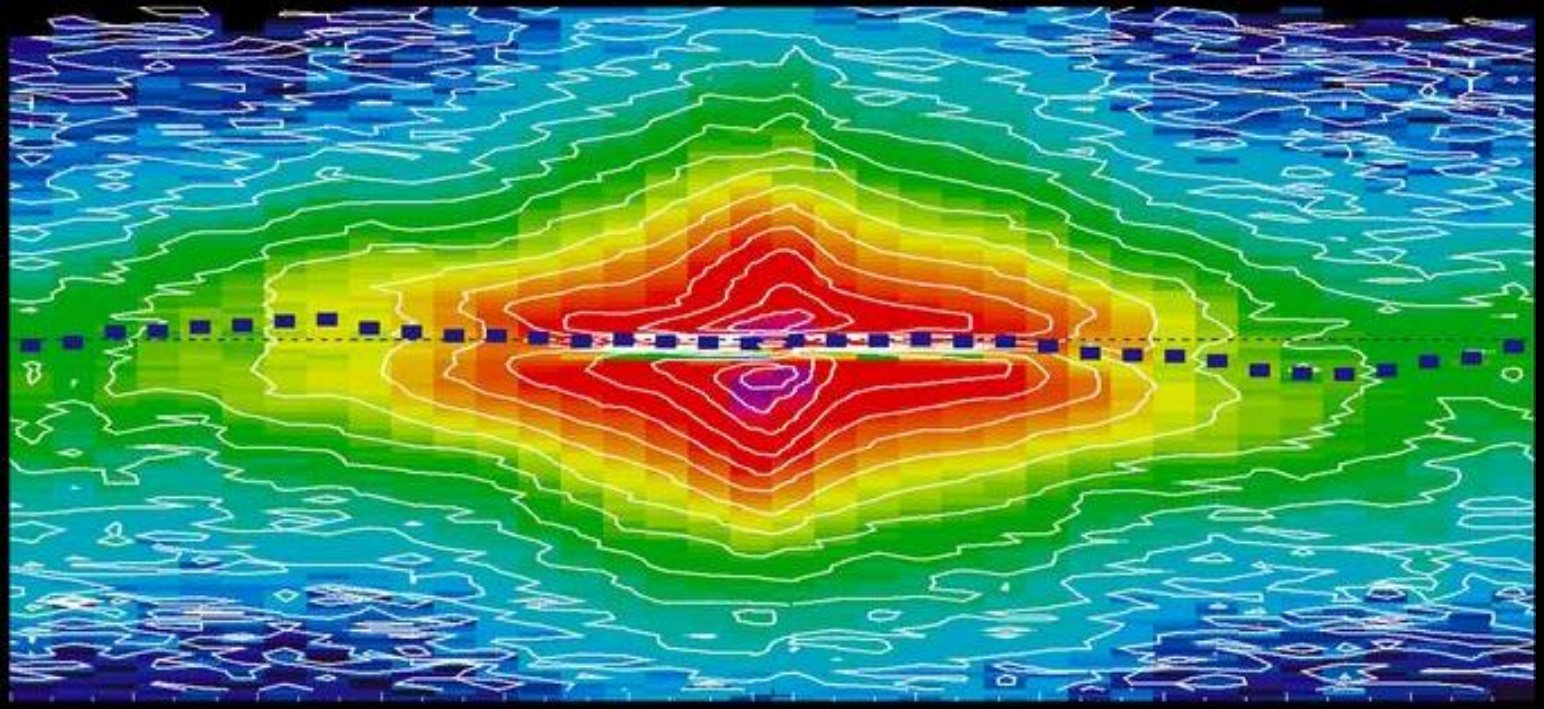
Is the Milky Way currently accreting a dwarf galaxy in its disk ?



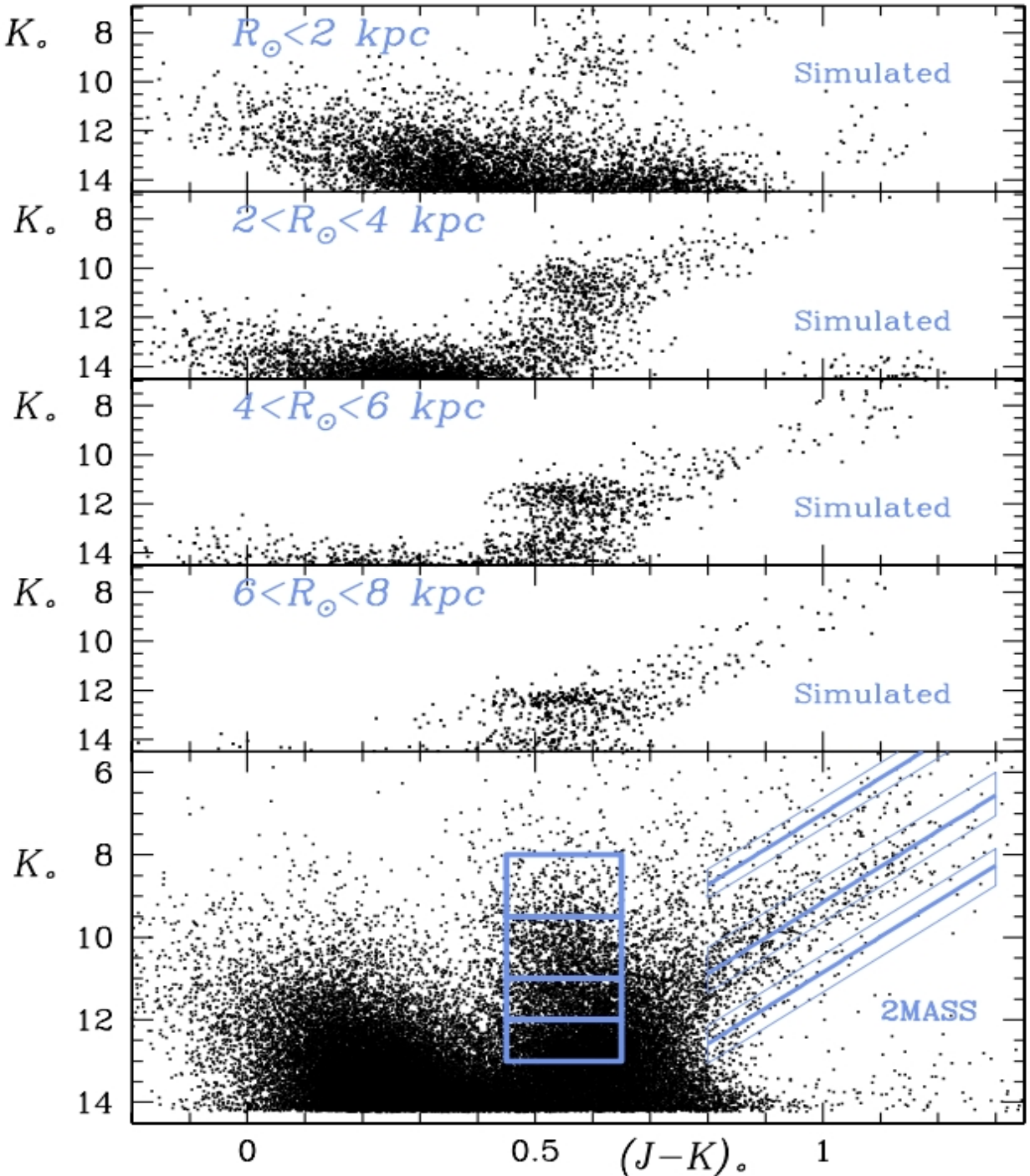




Color-magnitude diagrams of the CMa over-density: The MS & RGB sequences below the open cluster population.



However, once again, our MW Galaxy is known to be warped, as the majority of galaxies (Momany et al. 2004) and the Cma identification may simply trace the Galactic warp.



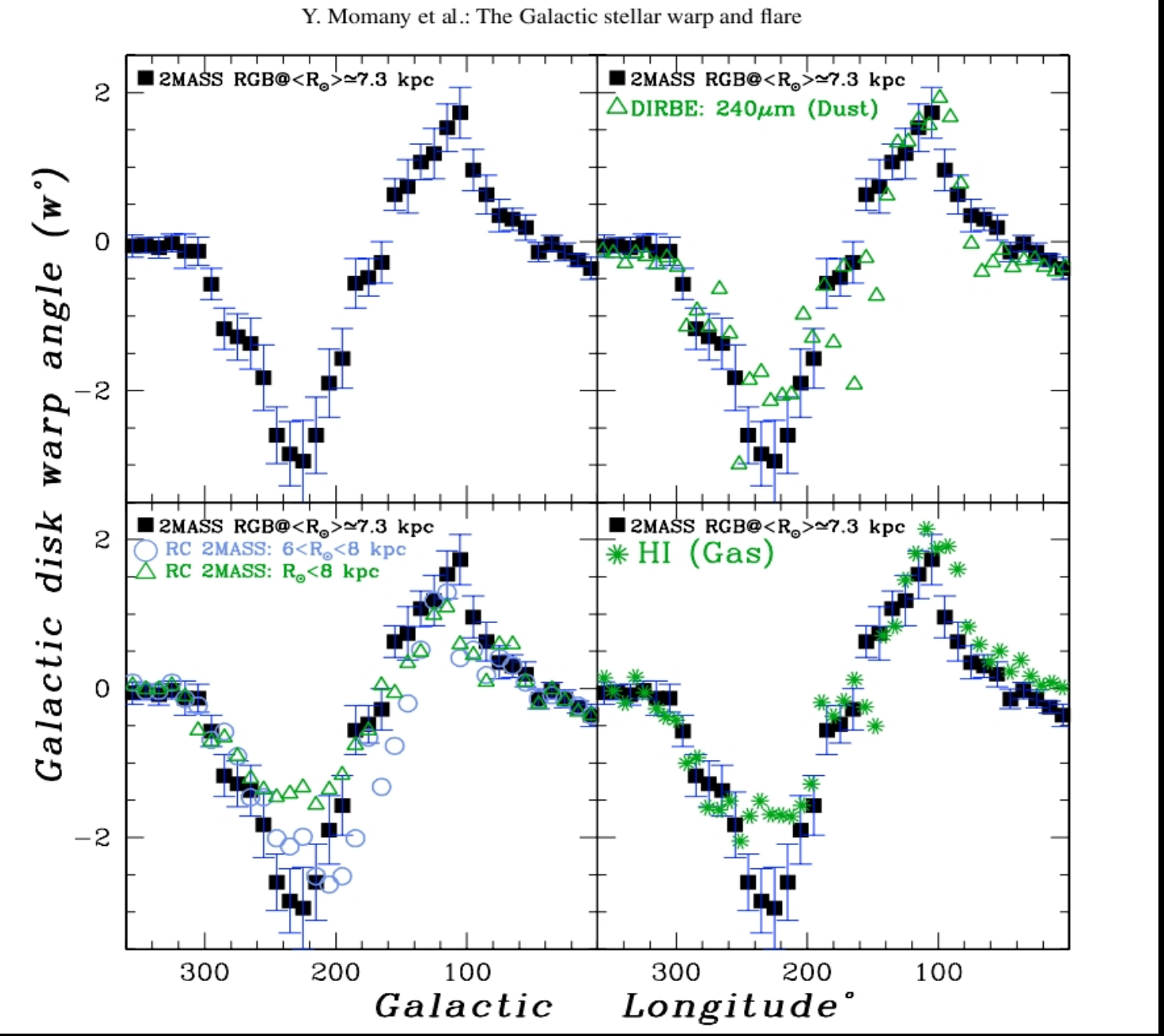
JHK 2MASS:

0<l<360

-30<b<30.

(~90 milion red giants)

Construct latitude stellar profiles of red giants (at specific distance intervals) and derive the symmetry plane for each selected longitude bin→ No N-S subtraction performed.



The (i) detection of a large scale feature (i.e. warp) for stars, dust and gas; (ii) the amplitude and phase angle agreement between these 3 Galactic components warp derivations; and (iii) the absence of Cma peculiar Vrad and Proper motion signature →

All argue against accretion of a dwarf galaxy in the disk (Momany et al. 2006).

See also Ahornian et al. (2008) for “no evidence of very high energy Gamma ray signal from Cma”.

PART #1: Optical imaging of dwarf irregular galaxies:

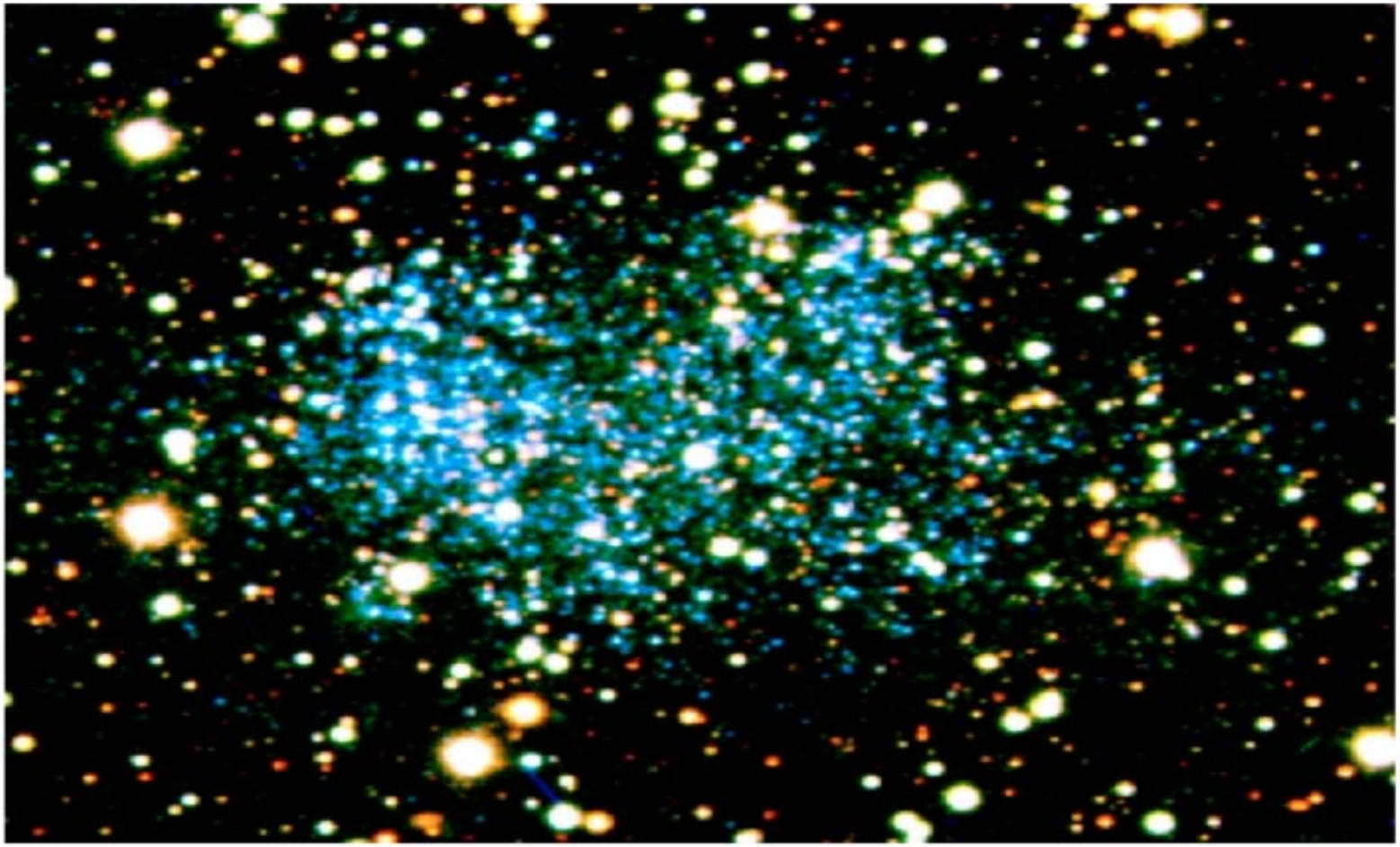
These gas-rich, isolated, star-forming, and metal poor galaxies are the ideal benchmark where the hypothesis of “young” galaxies can be tested.

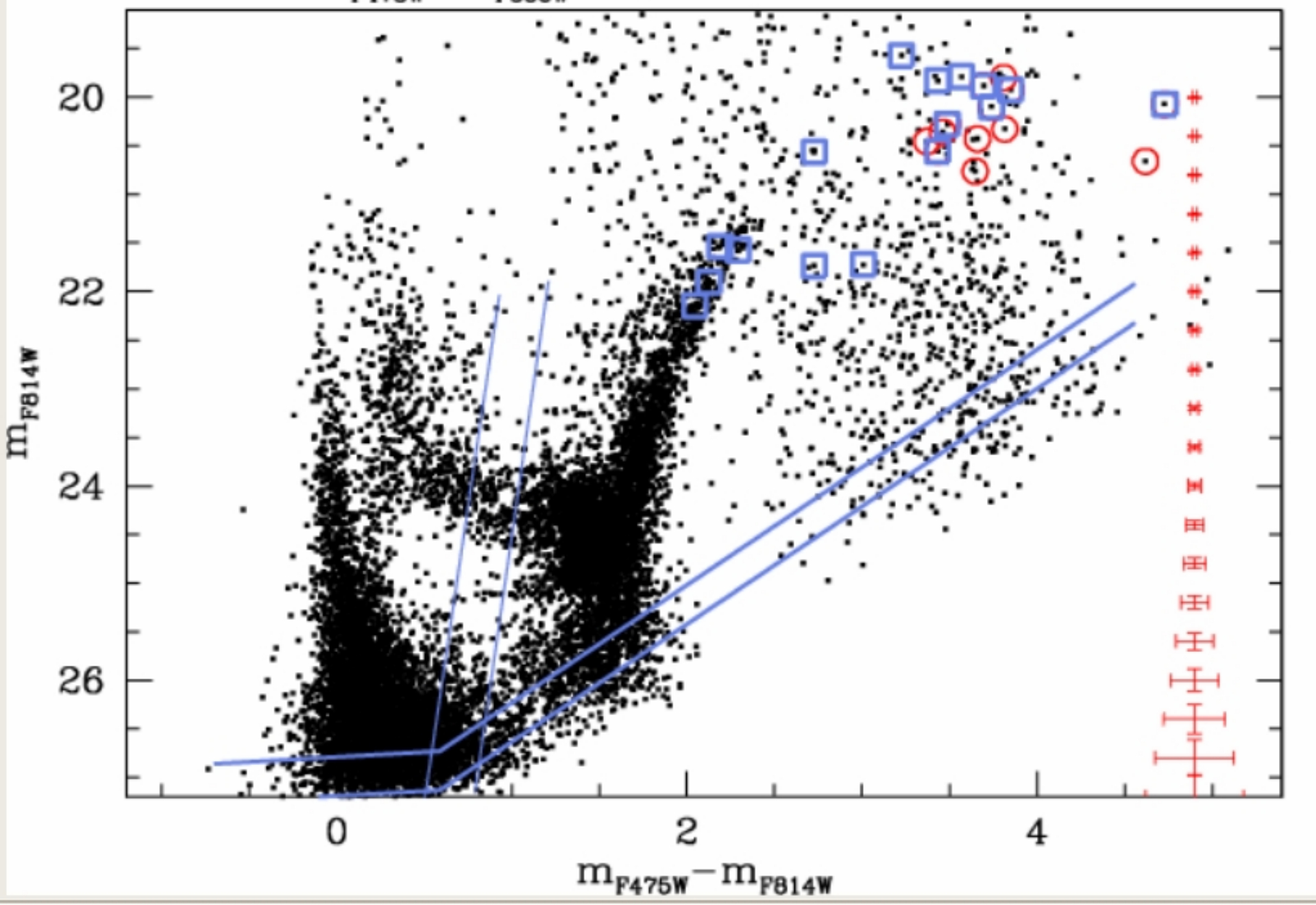
A&A 439, 111–127 (2005)
DOI: 10.1051/0004-6361:20052747

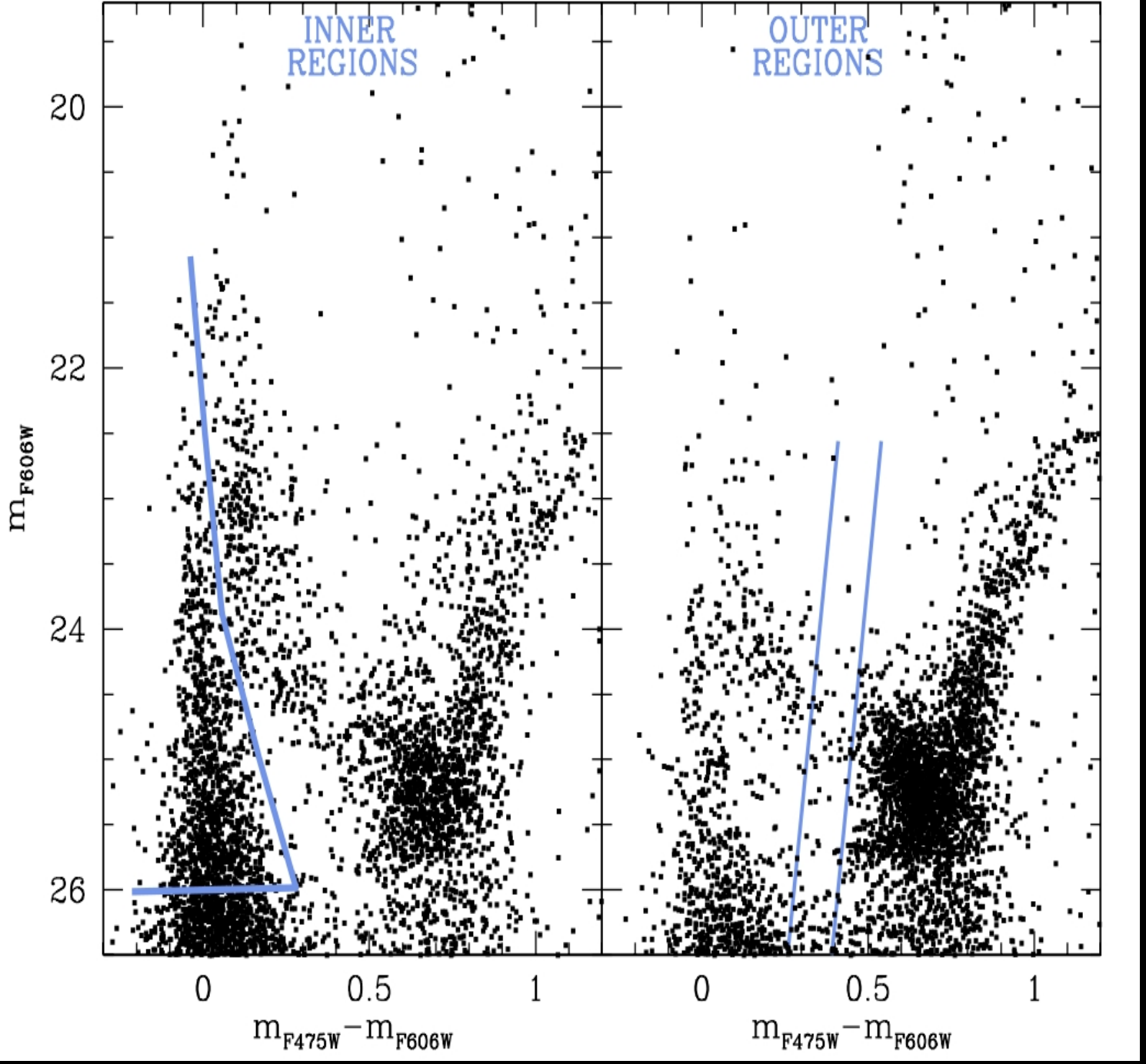
Astronomy & Astrophysics

HST/ACS observations of the old and metal-poor Sagittarius dwarf irregular galaxy⋆

Y. Momany[1], E. V. Held[2], I. Saviane[3], L. R. Bedin[1,4], M. Gullieuszik[1,2], M. Clemens[2], L. Rizzi[5], M. R. Rich[6], and K. Kuijken[7]



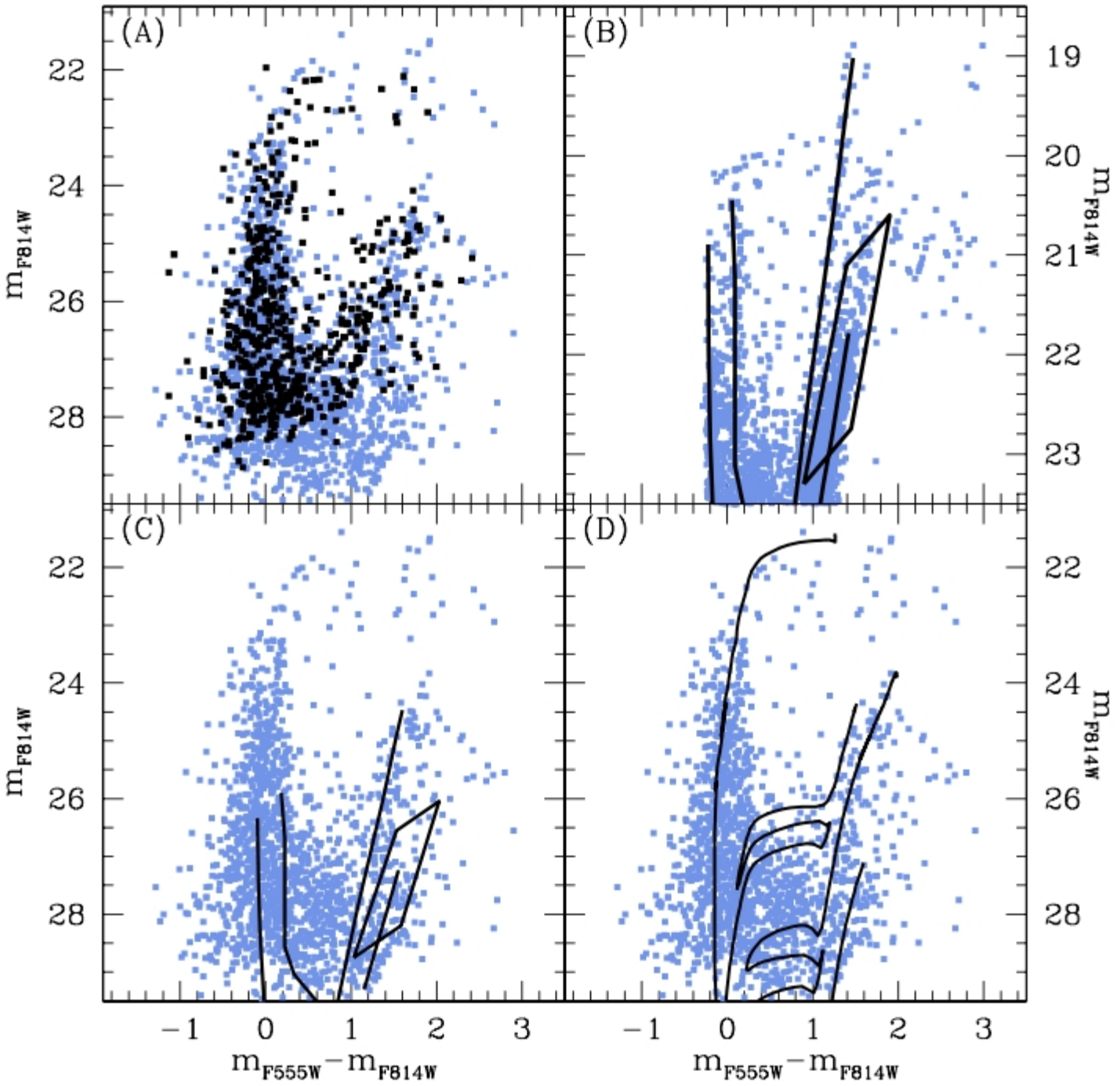

20
22
24
26
m_{F814W}
0
2
4
$m_{F475W} - m_{F814W}$



Detection of HB stars indicates that a very metal poor galaxy ([Fe/H]=-2.20) may still be very old (~9 Gyr).

Image: I Zwicky 18: Possibly the Youngest Galaxy Ever Seen

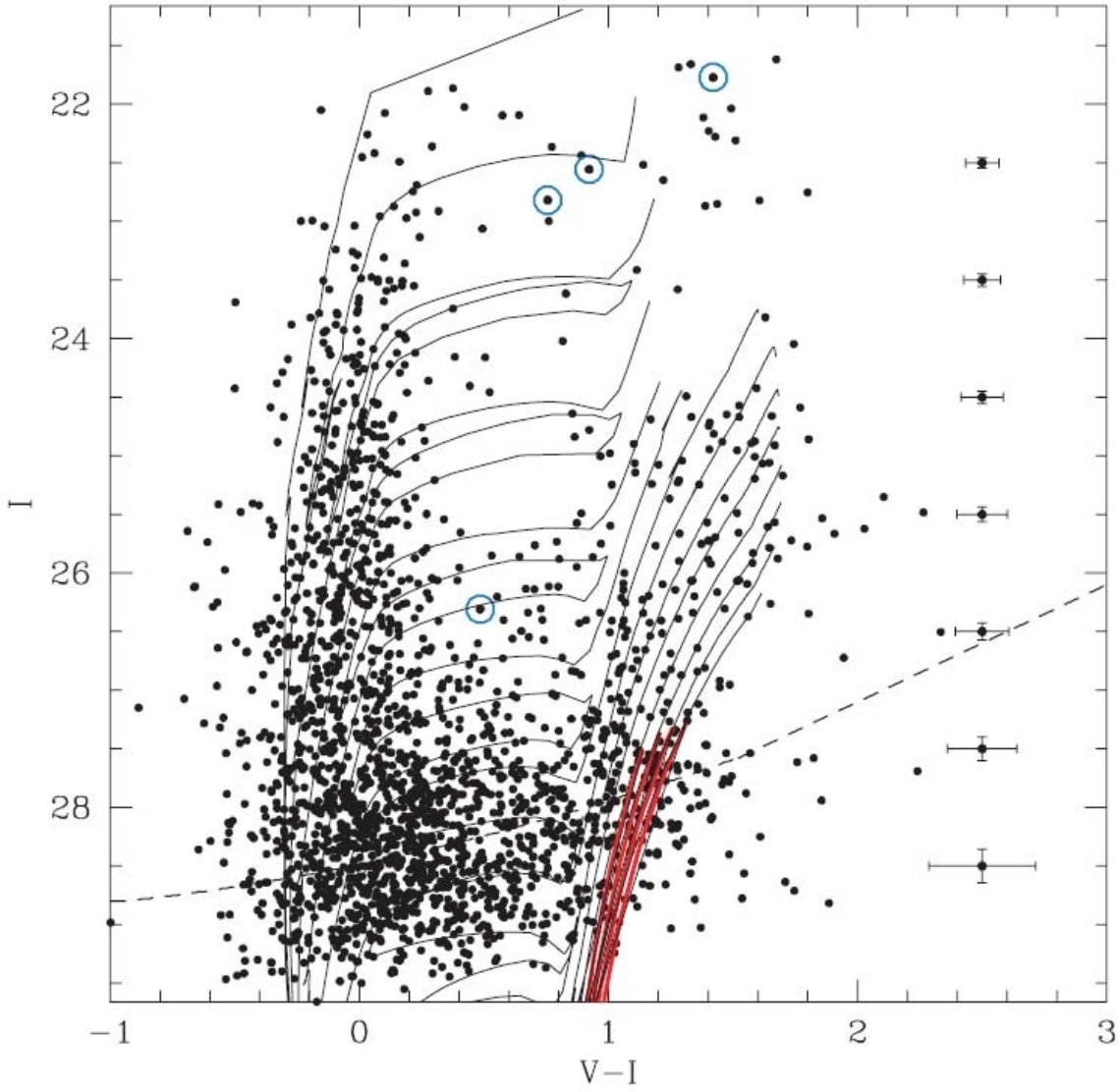
IZW18 at 15 Mpc was proposed as proto-type young (<~2 Gyr) galaxy, however a re-analysis of the HST data suggests the propable presence of older population.

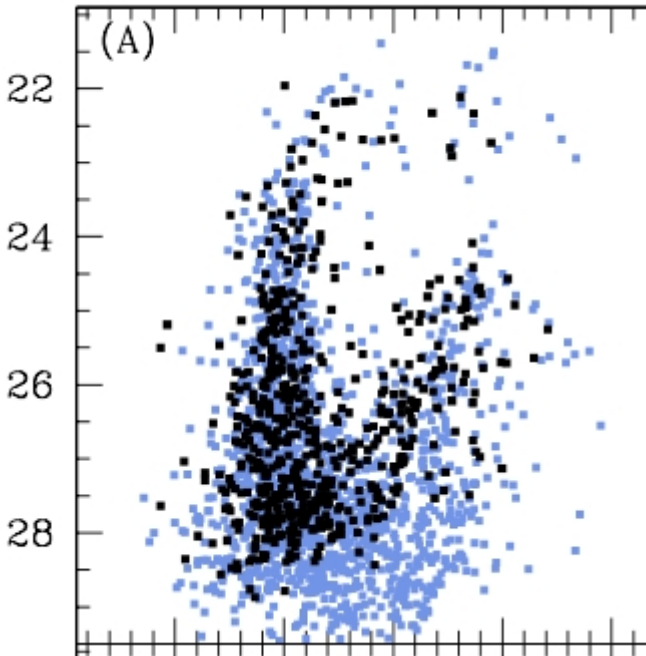


Black dots show clear incompleteness of cool red giants.

Thus, it is unlikely that IZW18 is experiencing its first star formation episode.

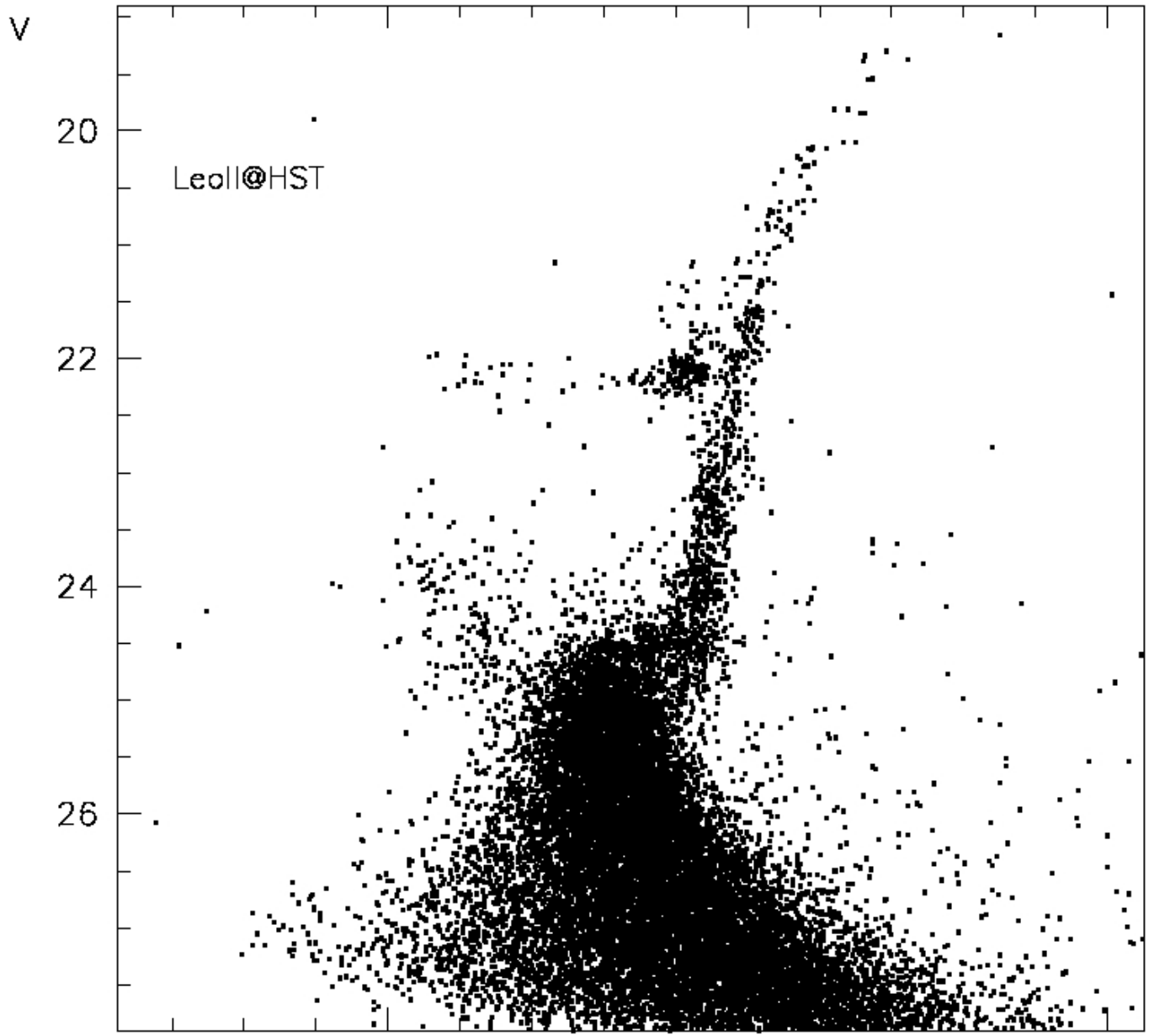
Aloisi et al. (2007) .



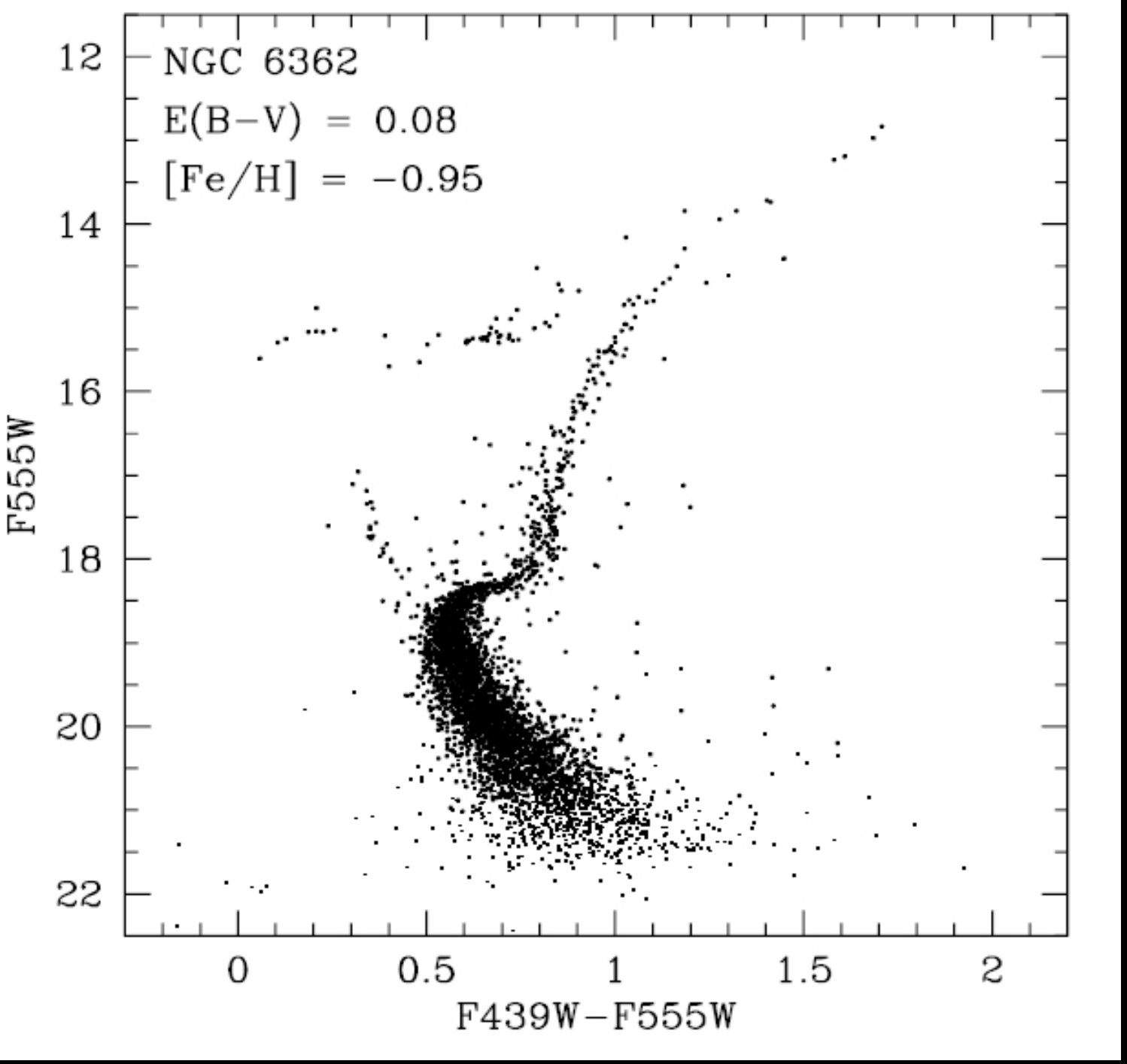


PART II: The blue plume population in dwarf spheroidal galaxies: Geniune blue stragglers or young stellar population ?

Momany et al. (2007)

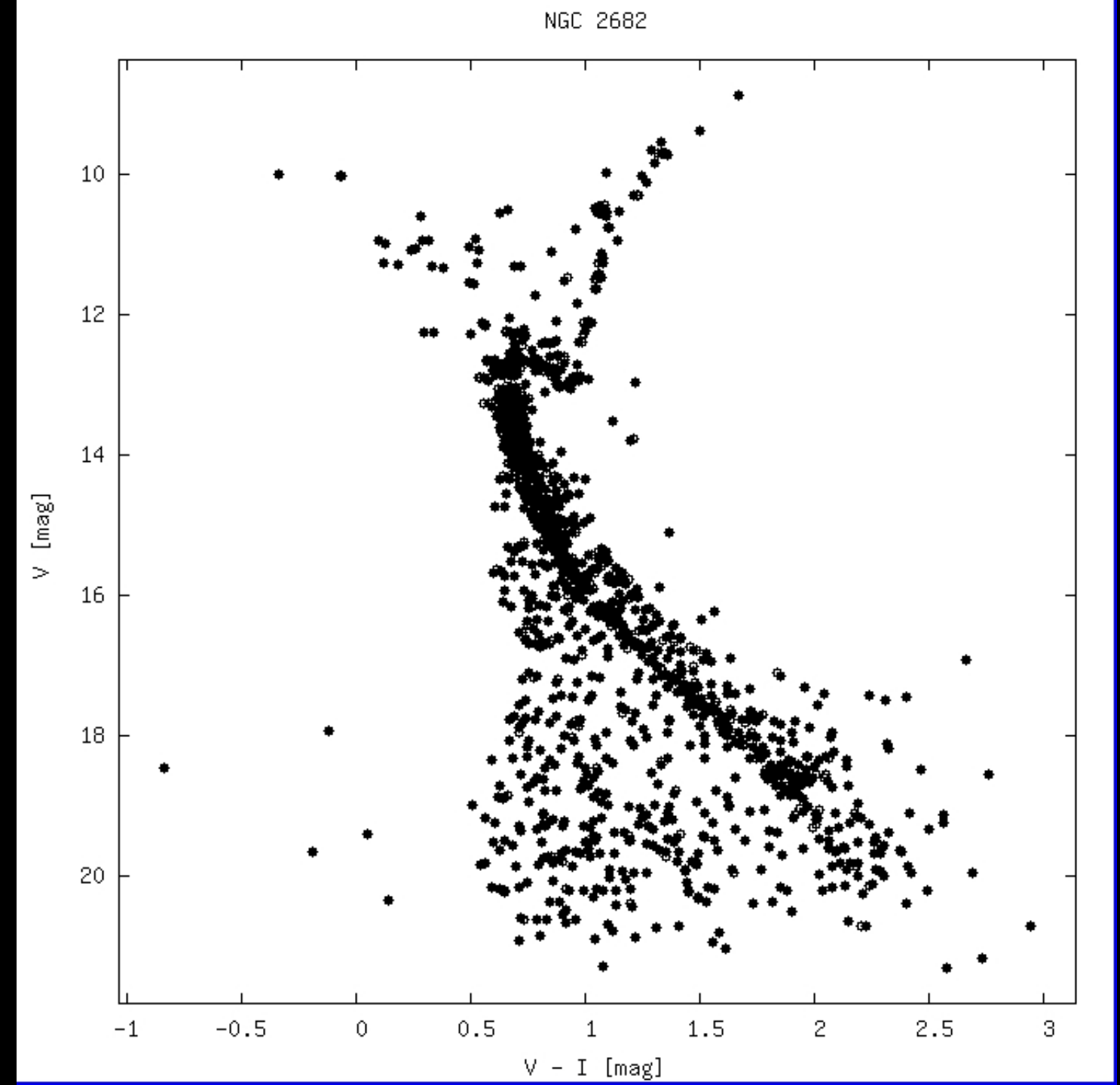


Dwarf galaxies: what is the blue plume made of ?

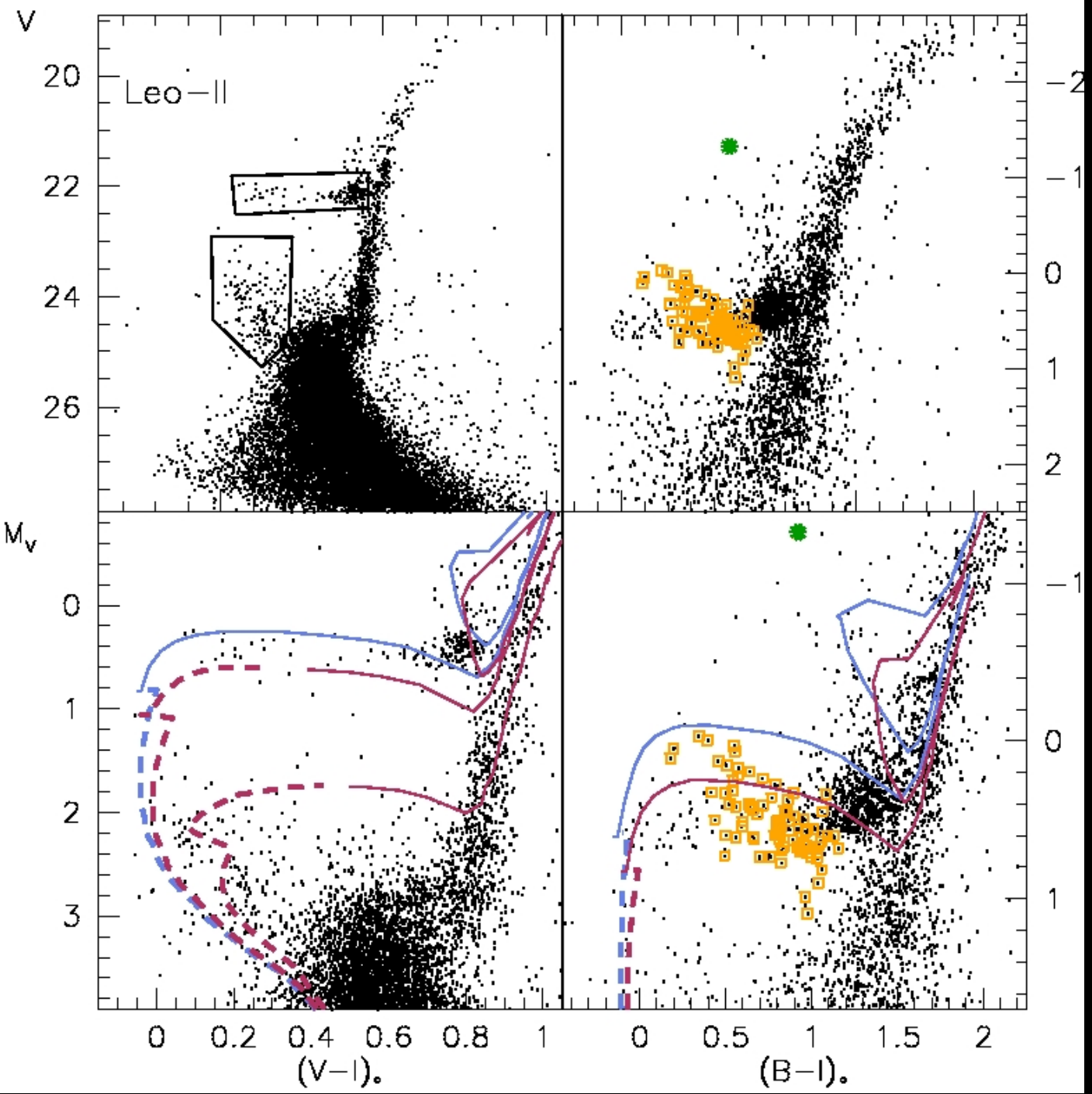


In the Globular clusters context the blue plume are BSS.

BSS: a hotter & bluer extension of the normal MS. The origin is to be sought in primordial binaries (coeval with the cluster formation epoch) or to a continuous production of collisional binaries experimented by single/binary stars.



Open clusters.

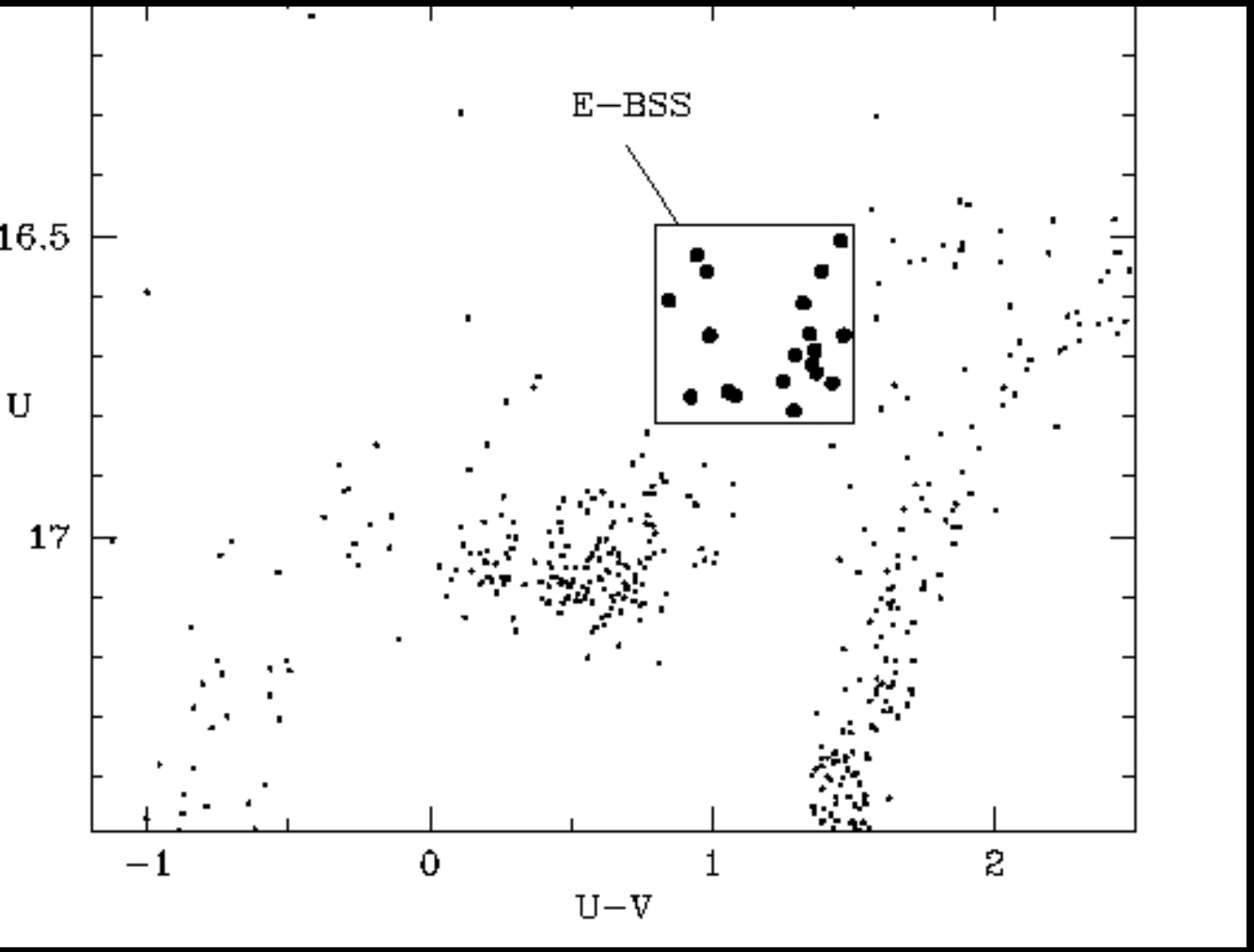


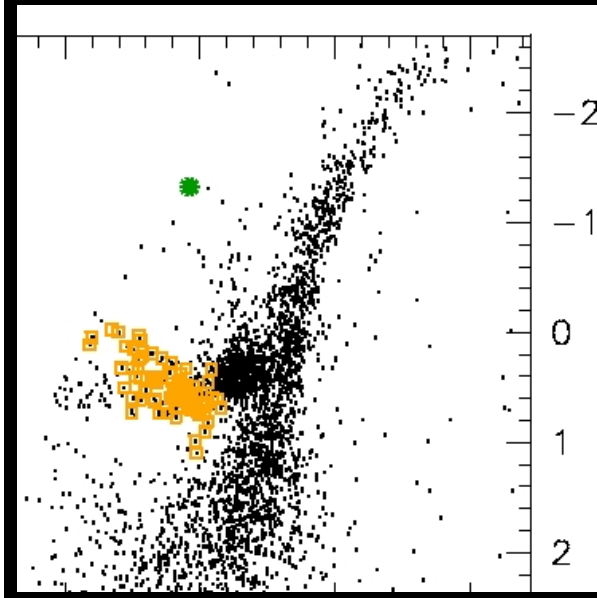
1.0, 1.2 and 1.5 Gyr, [Fe/H]=-1.3 isochrones (Girardi et al. (2002).

Vertical clump (Gallart et al. 2005): few hundred Myr to ~ 1 Gyr old, helium-burning stars.

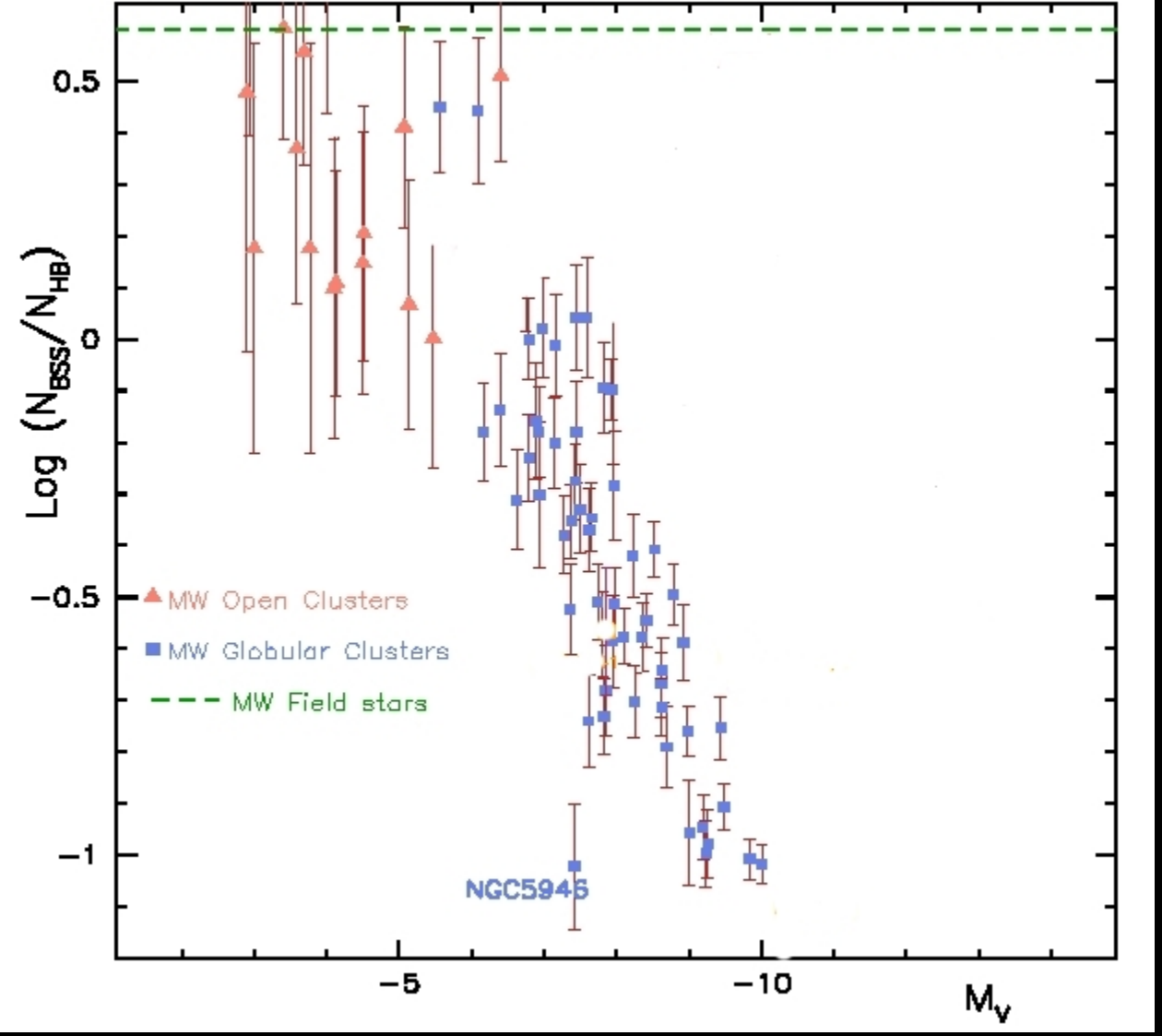
Anomalous Cepheids: due to either low-metallicity variables or mass-transfer in close binaries.

Vertical clump stars or Evolved- BSS ?





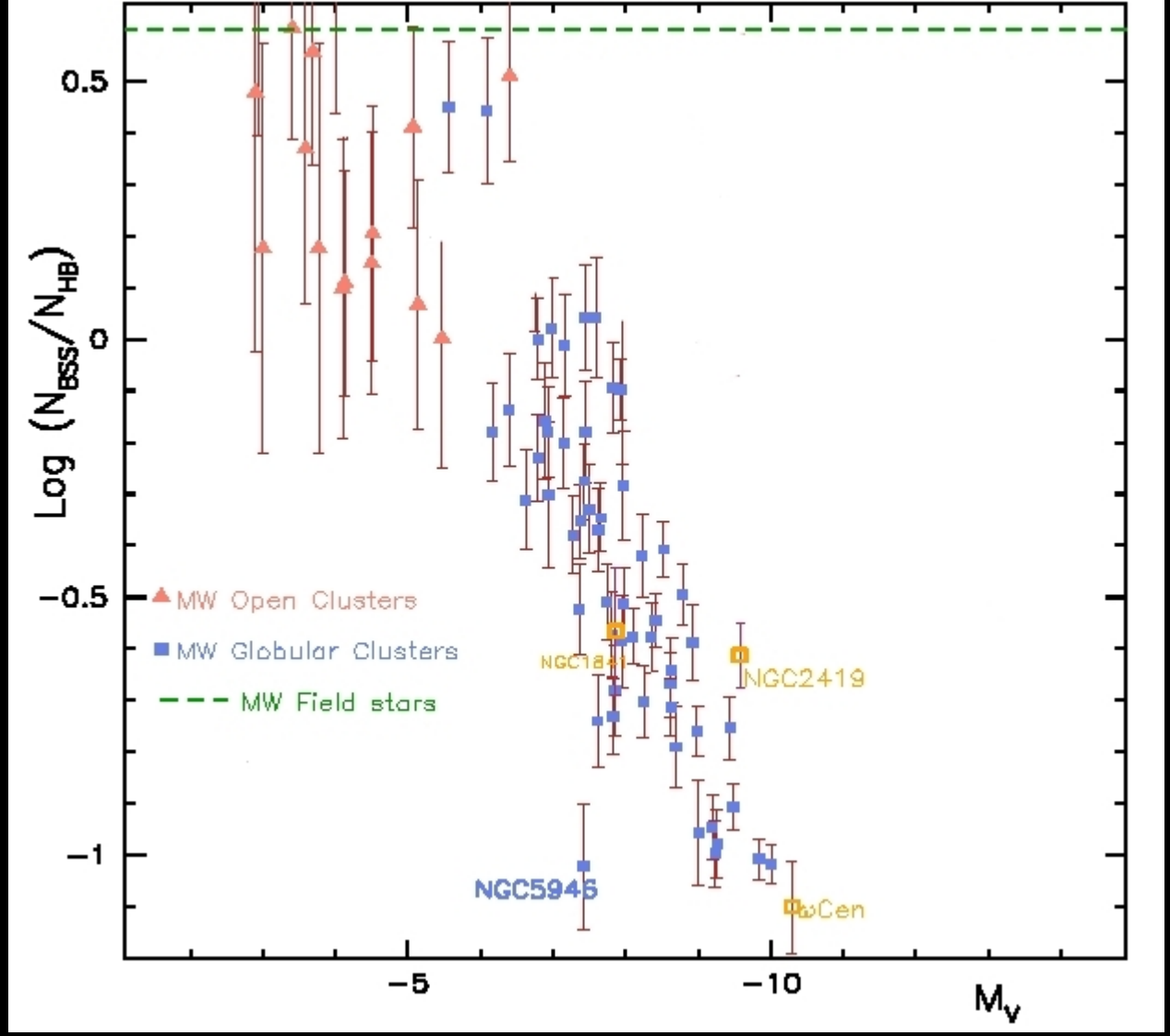
Ferraro et al. (1999): BSS/evolved-BSS ~ 7, consistent with that for LeoII (~8).



What is known for the BSS frequency in Globular and Open clusters…

- 56 GCs (Piotto et al. 2004): The total absolute luminosity (Mv)-BSS frequency anti-correlation.
- No correlation between BSS frequency & the respective cluster collision rate.
- Davies et al. (2004): while massive GC produce more coll. Binaries, they also destroy primordial binaries.

“Peculiar”systems indicate that the Anti-correlation is universal!



- NGC5139 (Ferrarro et al. 2006).
- NGC2419: Milky Way globular cluster at 90 kpc.
- NGC1841: LMC globular cluster. The most metal-poor and most distant.

The dwarf galaxy sample:

. Leo II: NTT and HST data.

• Sagittarius: 1 square degree field, WFI@2.2m.

• Carina: Monelli et al. (2003).

• Sextans: Lee et al. (2003).

• Ursa Minor: Carrera et al. (2003).

• Draco: Aparicio et al. (2001).

• Sculptor: Rizzi et al. (2003).

• Ursa Major: Willman et al. (2005).

• Bootes: Belokurov et al. (2006).

- No star-forming or gas-rich galaxy (except Carina).

- Catalogs extending to & beyond the half light radius (except, of course, Sagittarius for which we sample ~6% of its stellar populations).

- the galaxies span a distance from ~25-200 kpc.

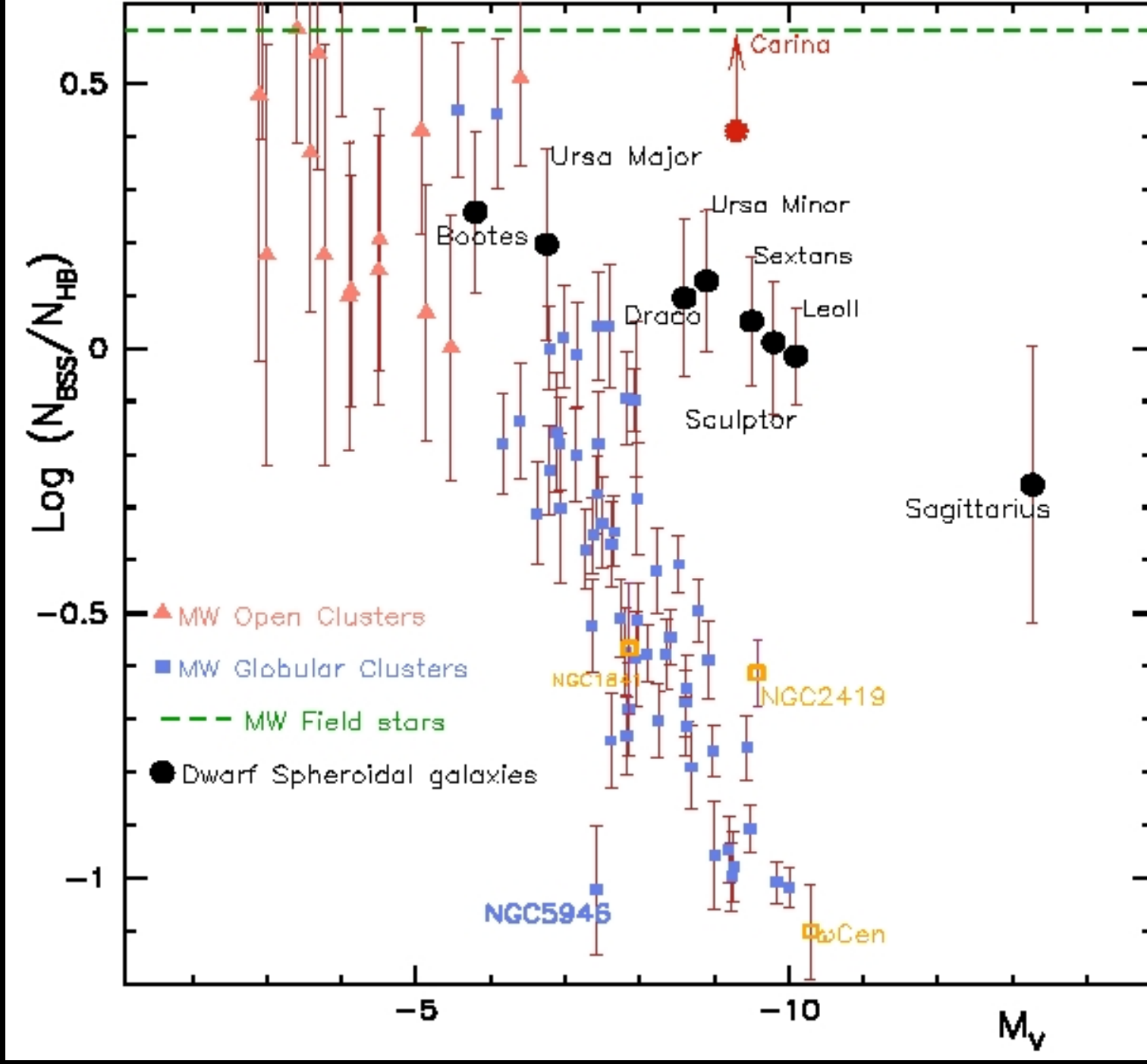
- Foreground contamination: estimated via synthetic Trilegal CMDs (Girardi et al. 2005).

RESULT #1:

Assuming that the BP is made of (only) BSS, then it is always higher in dwarf galaxies with respect to globulars && there is a hint for an anti correlation as found for globulars.

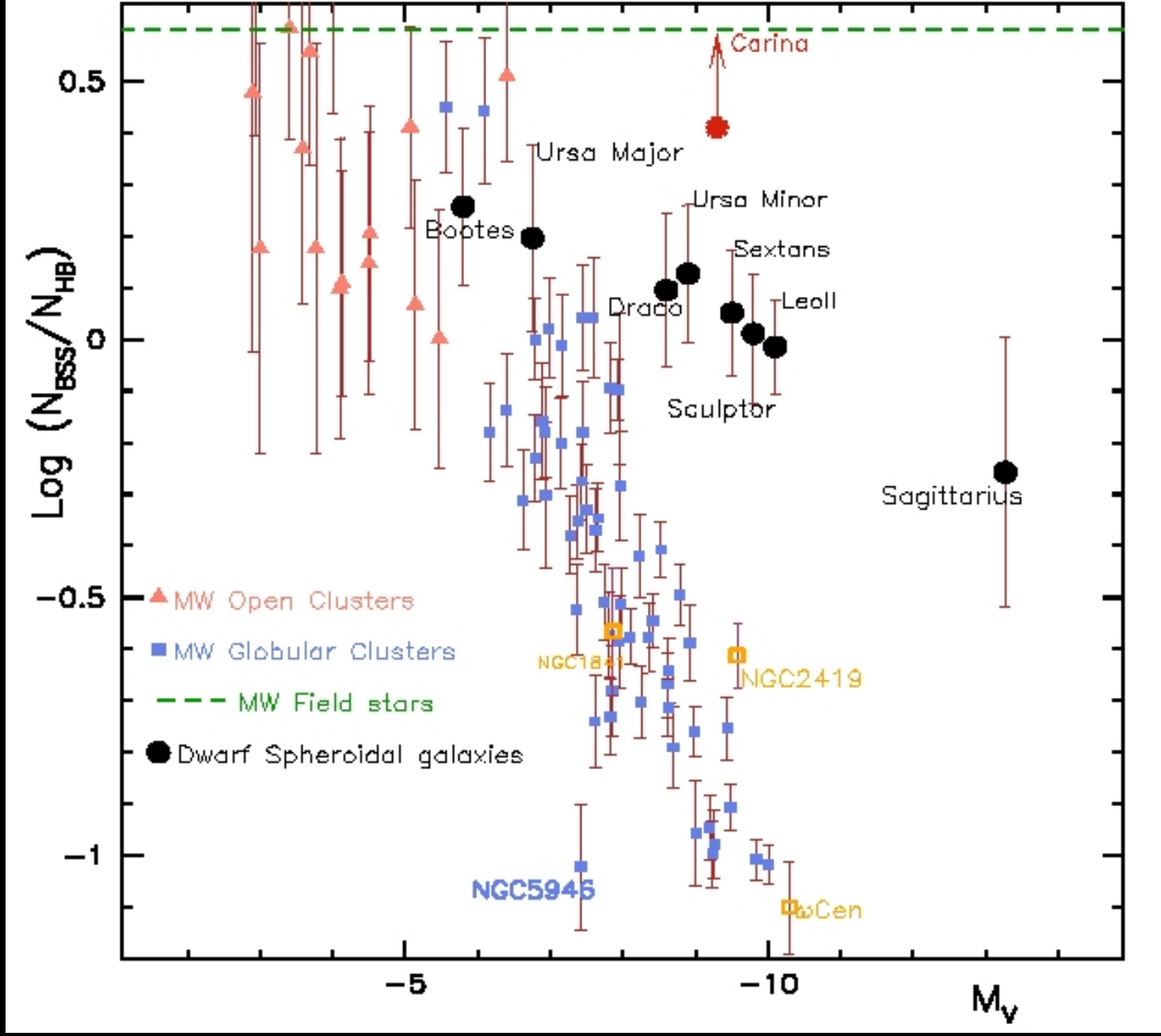
A correlation coef. Of 0.984 & 0.972 was derived, and the probability that the frequency would randomly correlate is < 10**-6 and 10**-4.

So what???



RESULT #2:

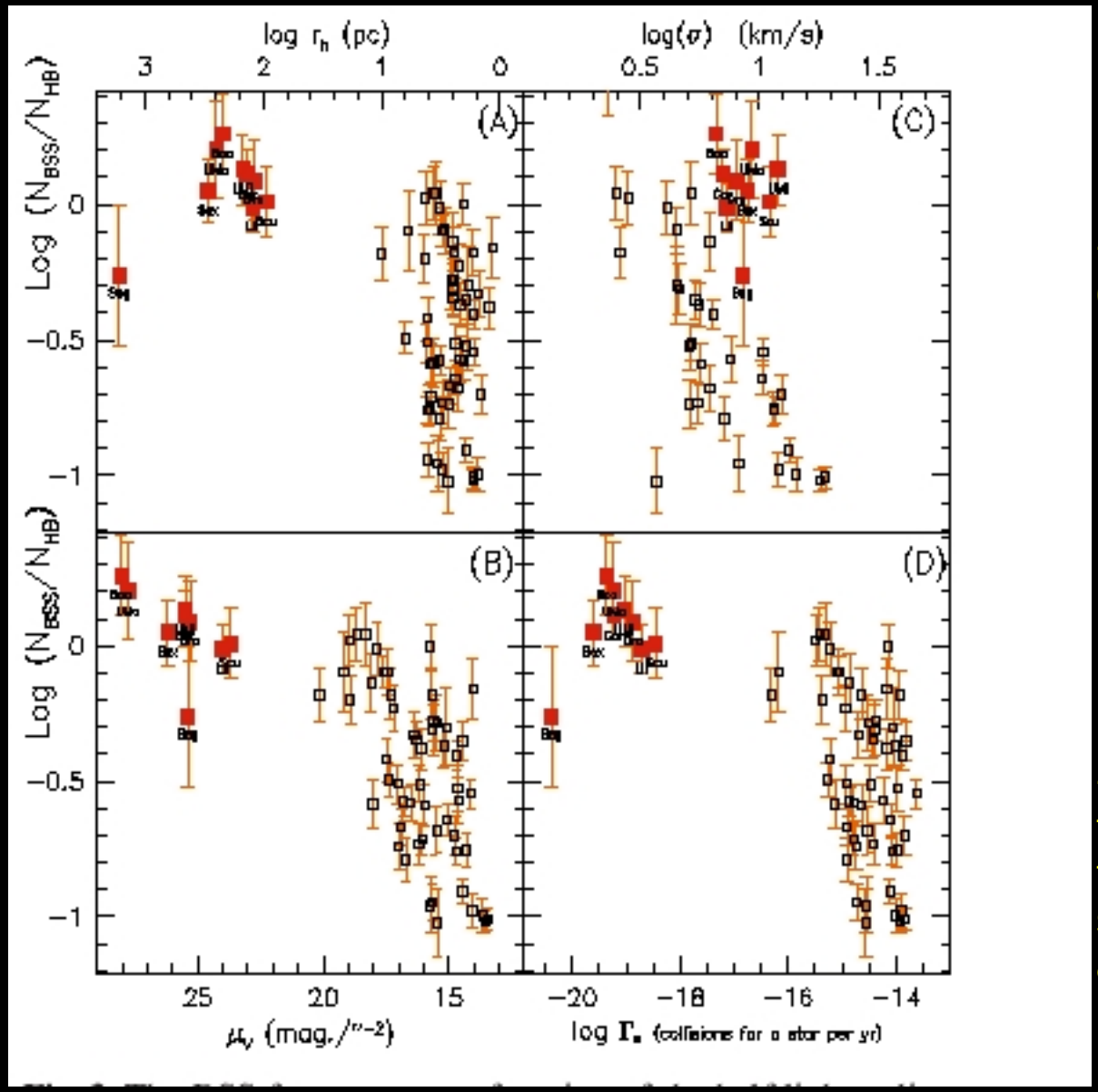
Assuming that the BP is made of BSS, For the lowest-lum. galaxies, the BSS frequency is compatable with that observed in the MW field (0.6, Preston & Sneden 2000) and open clusters.



- Preston & Sneden: 62 blue metal-poor stars at different line of sights and distances.
- Thus, dwarf galaxies & OC might set a realistic upper limit on the frequency of primordial BSS in stellar systems.

RESULT #3:

-Half light radius



-Velocity dispersion

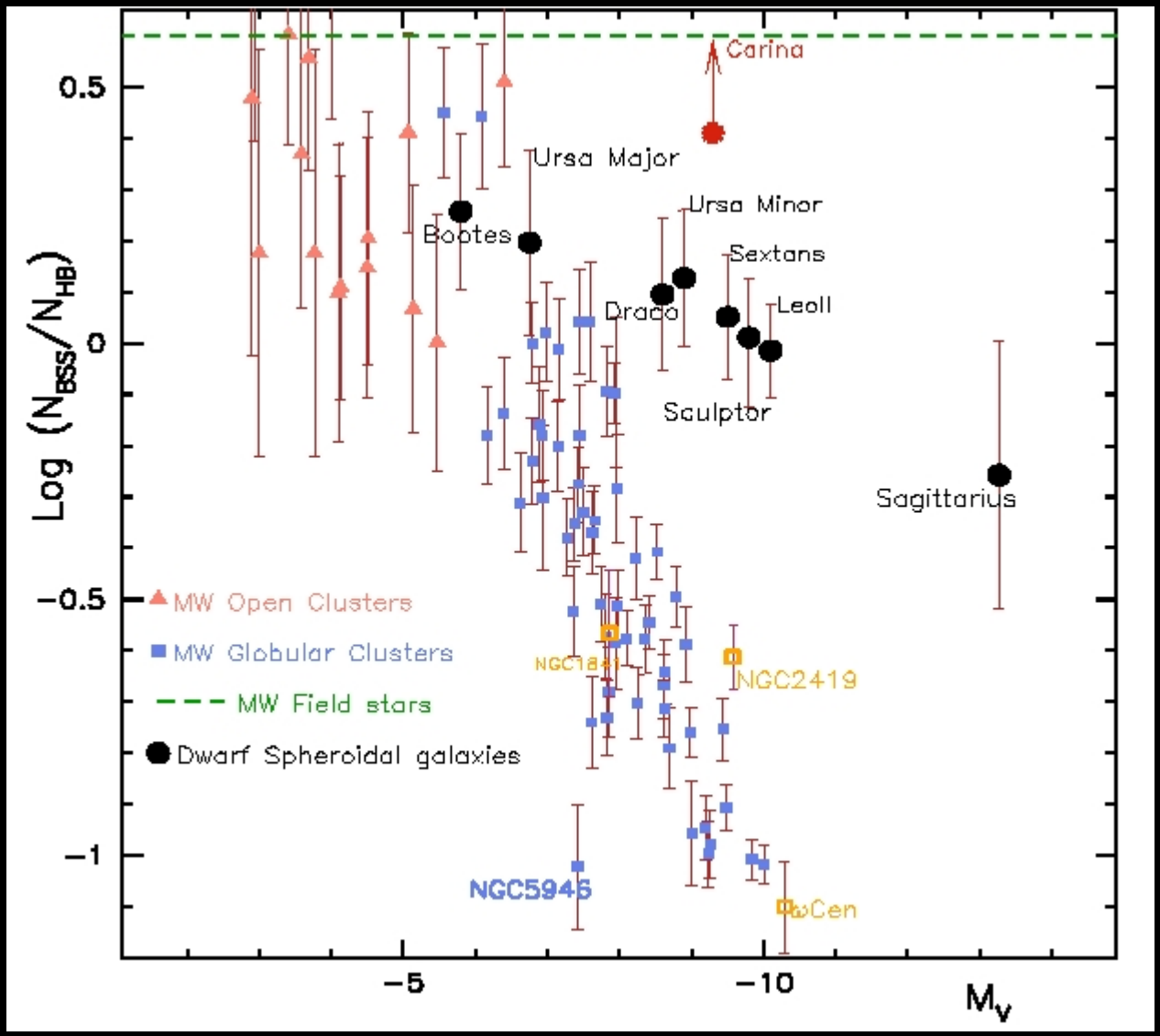
- central surface brightness.

-Stellar collision factor: estimated from the central surface density & core size.

• Should the BP be a BSS sequence, are there collisional BSS ? NO. The number of collisions per star per year is 10**-5 times lower in a dwarf galaxy.

• Thus the obvious: genuine BSS in dwarf galaxies are mainly made of primordial binaries.

Back to the original question: is the dwarf galaxies blue plume made of a BSS sequence ?



Had the BP been made of geniune MS or even contaminated by the residuals of a recent star formation episode then one would have expected a correlation (at most)…Not an anti-correlation.

Conclusions:

- The dwarf galaxies BSS frequency is always higher than in GC.
- It agrees with that of OC, at the low-luminosity regime, and both probably set a realistic upper limit to the frequency of primordial binaries in stellar systems.
- There is a numerically significant anti-correlation for dwarf galaxies, which point to a BSS-nature of the BP. Either way, the dwarf galaxies ample must be extended (e.g. LCID survey: Tucana, Cetus).
- Dwarf galaxies harbour mainly primordial binaries.

Future work: the implications of a ~1-1 BSS-HB correlations on the integral photometric properties of un-resolved far far away elliptical galaxies:

#1 under-estimating age: SEDs are bluer.

Implications of a ~1-1 BSS-HB correlations on the integral photometric properties of un-resolved far far away galaxies:

How binary interactions affect spectral stellar population synthesis

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ABSTRACT

Binary interactions make stellar populations less luminous and bluer, affecting age Lick indices (Hb), and metallicity (MgFe)→ underestimating both.

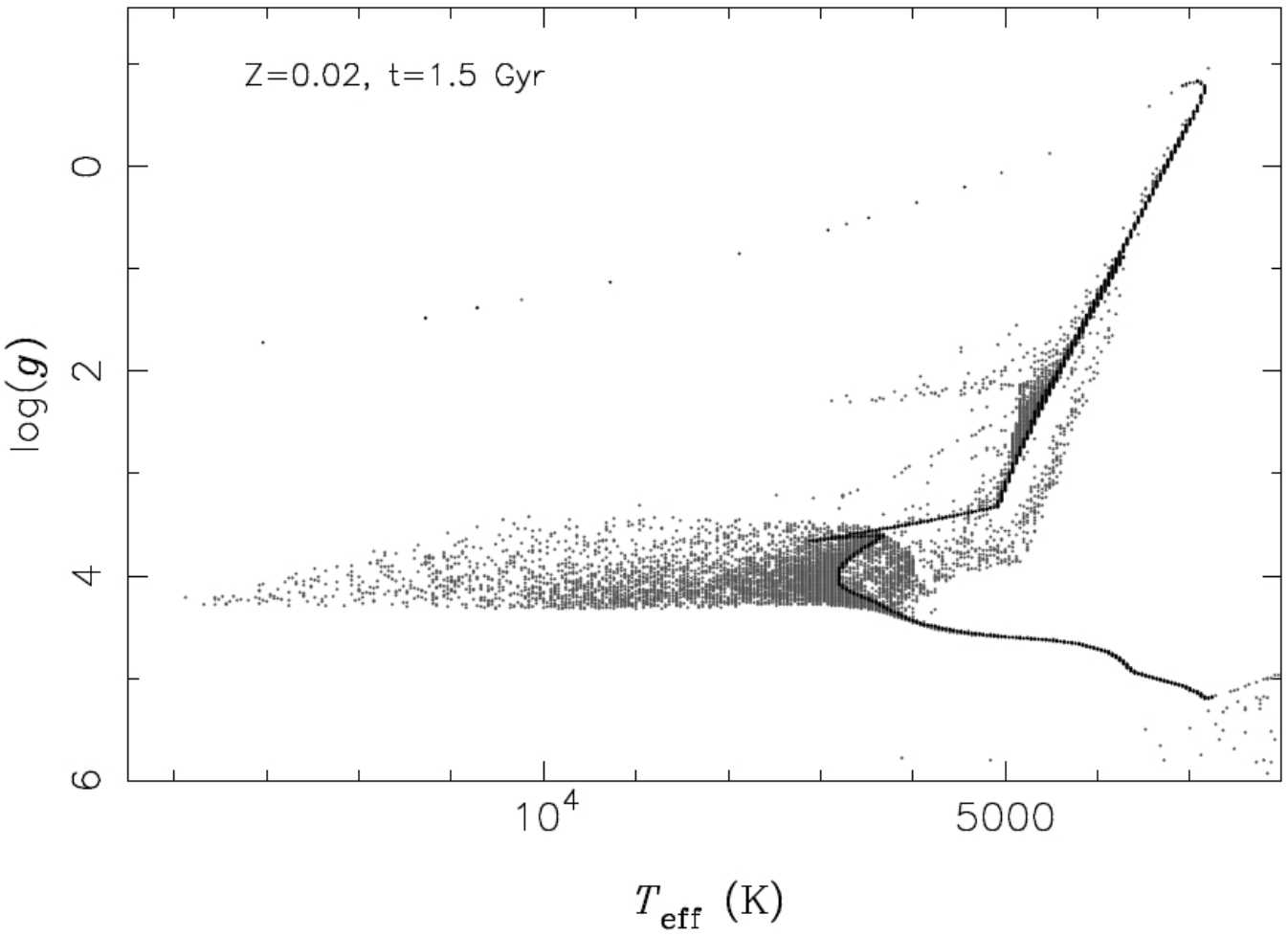


Fig. 1.— Comparison of the shapes of the isochrones of a pair of solar-metallicity ($Z = 0.02$) bsSSP and ssSSP. The figure is plotted by putting the isochrones of the bsSSP and ssSSP together. Black points show the isochrone of the ssSSP, and gray points the isochrone of the bsSSP.

A considerable BSS population would imply even brighter and bluer colors.

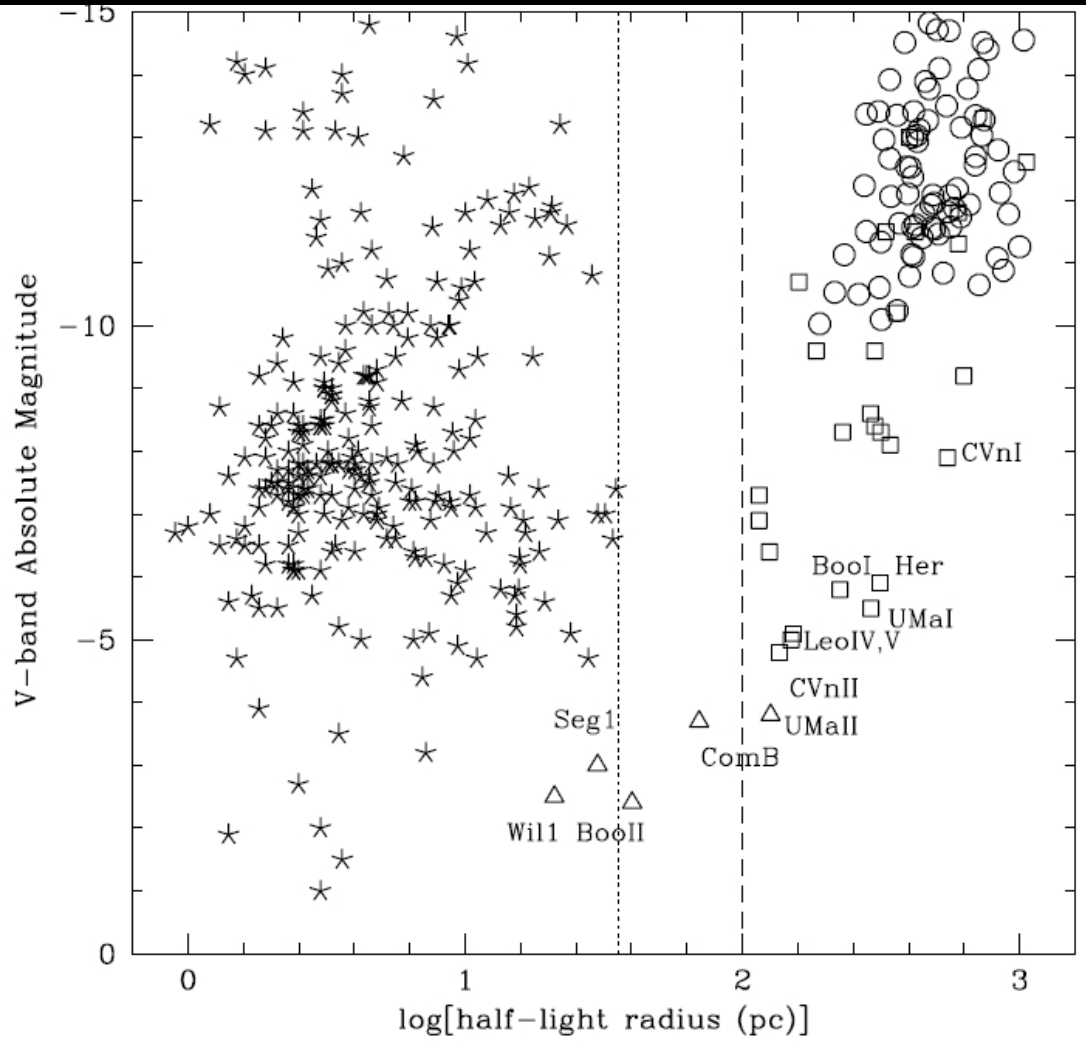
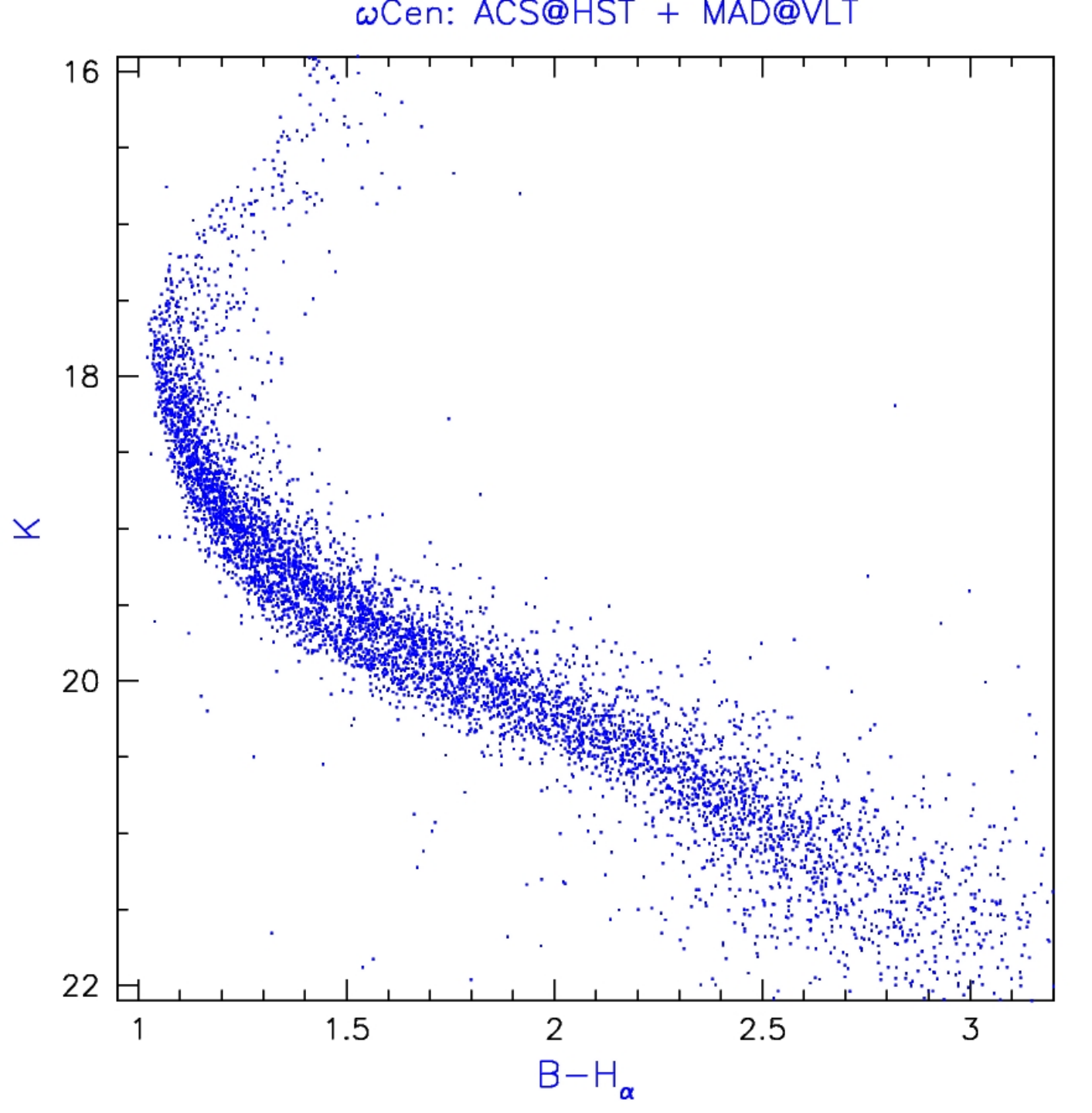


Figure 1. The relation between absolute luminosity and luminous half-light radius for small stellar systems in the local Universe. Globular clusters from several host galaxies, Ultra Compact Dwarfs, and galactic nuclei star clusters, are represented as asterisks. Local Group dSph galaxies, with the most newly discovered identified by name, are shown as open squares. Galaxies from the Local Volume survey of Sharina etal (2008) are shown as open circles. Milky Way satellites of unknown equilibrium status are shown as open triangles (see Fig 2). All equilibrium galaxies have half-light radii larger than the minimum size line at 100pc. All apparently purely stellar systems have half-light radii smaller than about 30pc. Further details are in

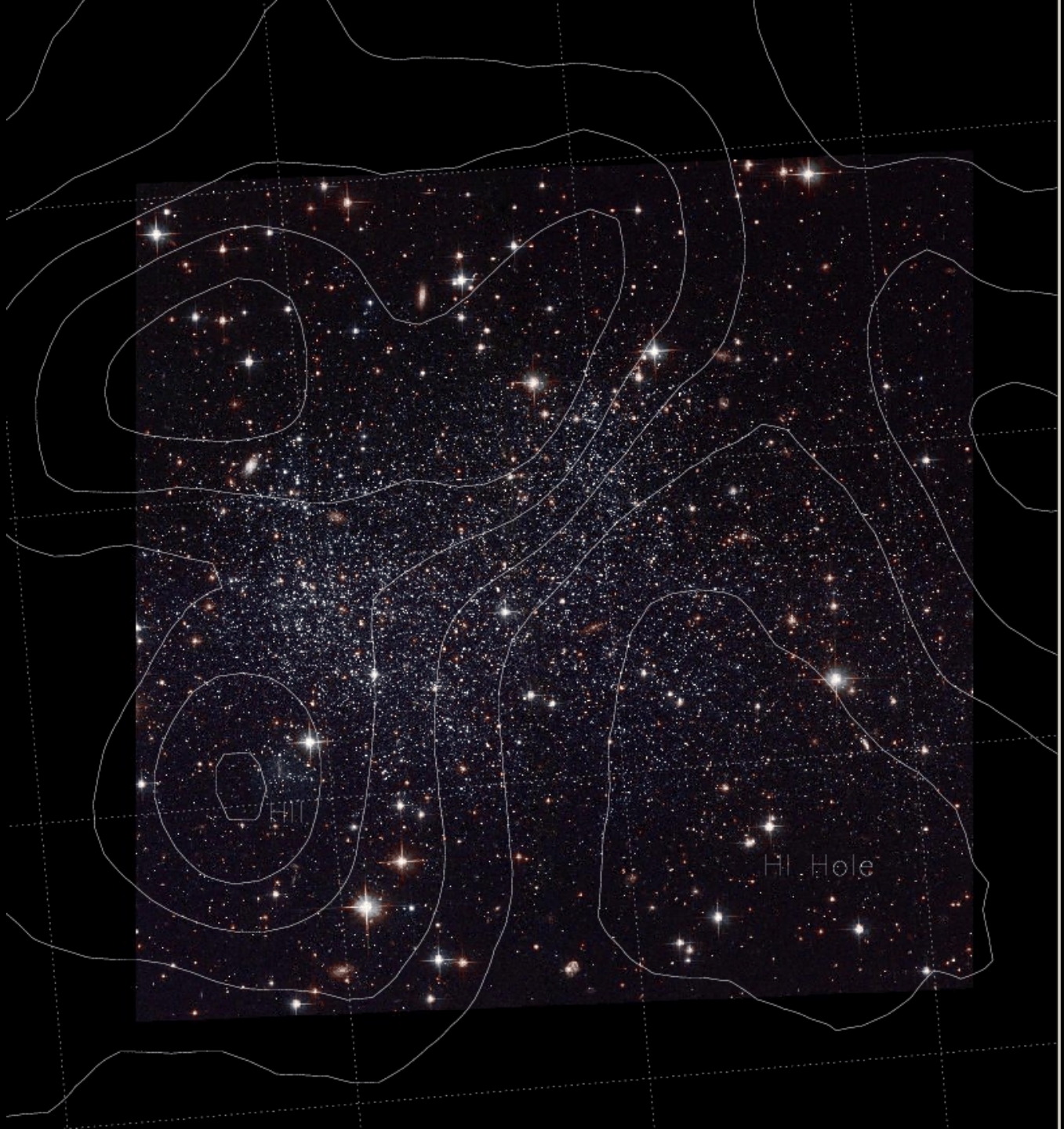
TBD: all equilibrium galaxies (with dark matter halos) have hlr > 100pc, whereas all purely stellar systems have hlr <30 pc.

Where do open clusters fit?

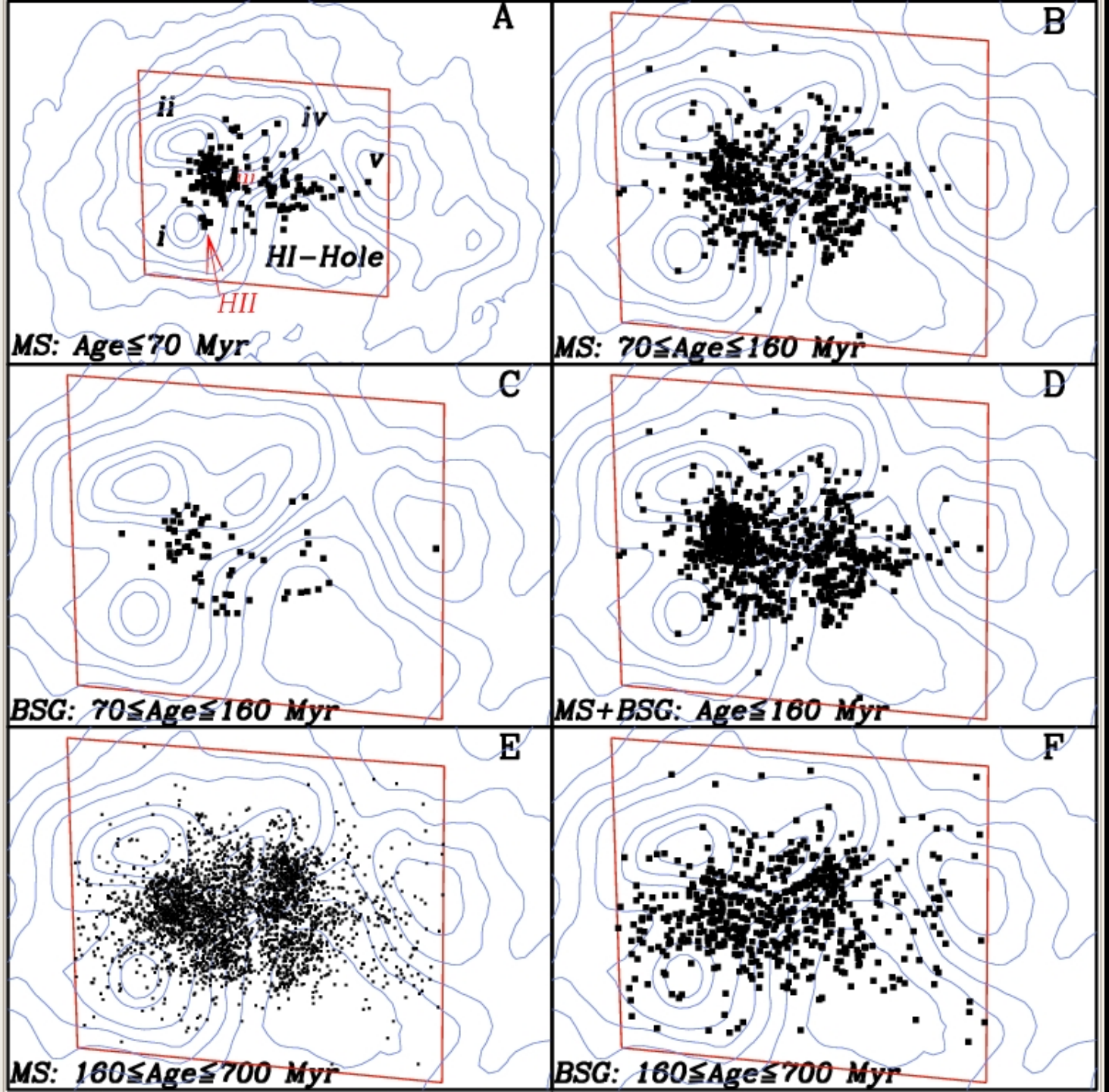
END....



EXTRA STUFF: Combined optical-NIR diagrams confirm the presence of multiple MS in Wcen.



EXTRA STUFF: the creation of a HI hole in gas-rich dwarf irregular galaxies (e.g. SagDIG).



Correlating stars ages with the HI morphplog in SagDIG. The HI hole ????