Fresh UV Light on Globular Clusters

Alvio Renzini, INAF/OAPD

On behalf of the "Splitters": G Piotto, R Bedin, A Milone, A. Bellini, J Anderson)

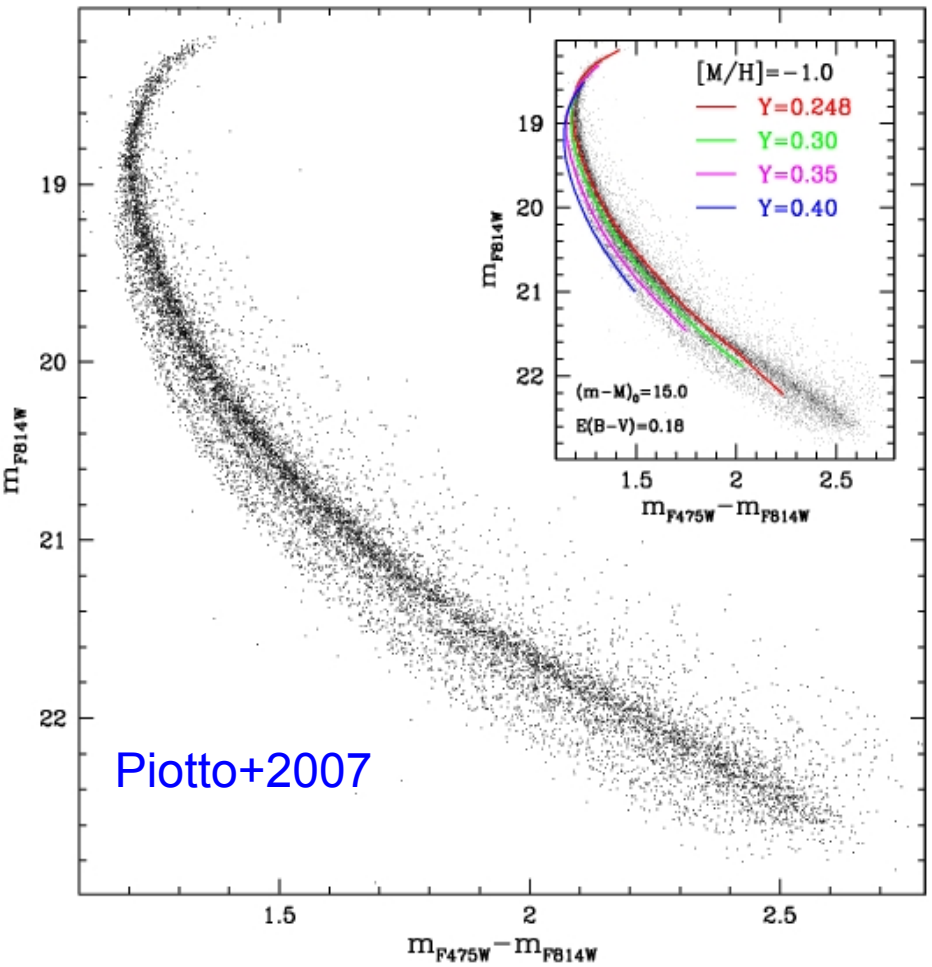
After the discovery of the ubiquity and complexities of multiple populations, we may just forget all said before about Globular Cluster formation (e.g. Peebles & Dicke 1968; Fall & Rees 1985, etc. etc.)

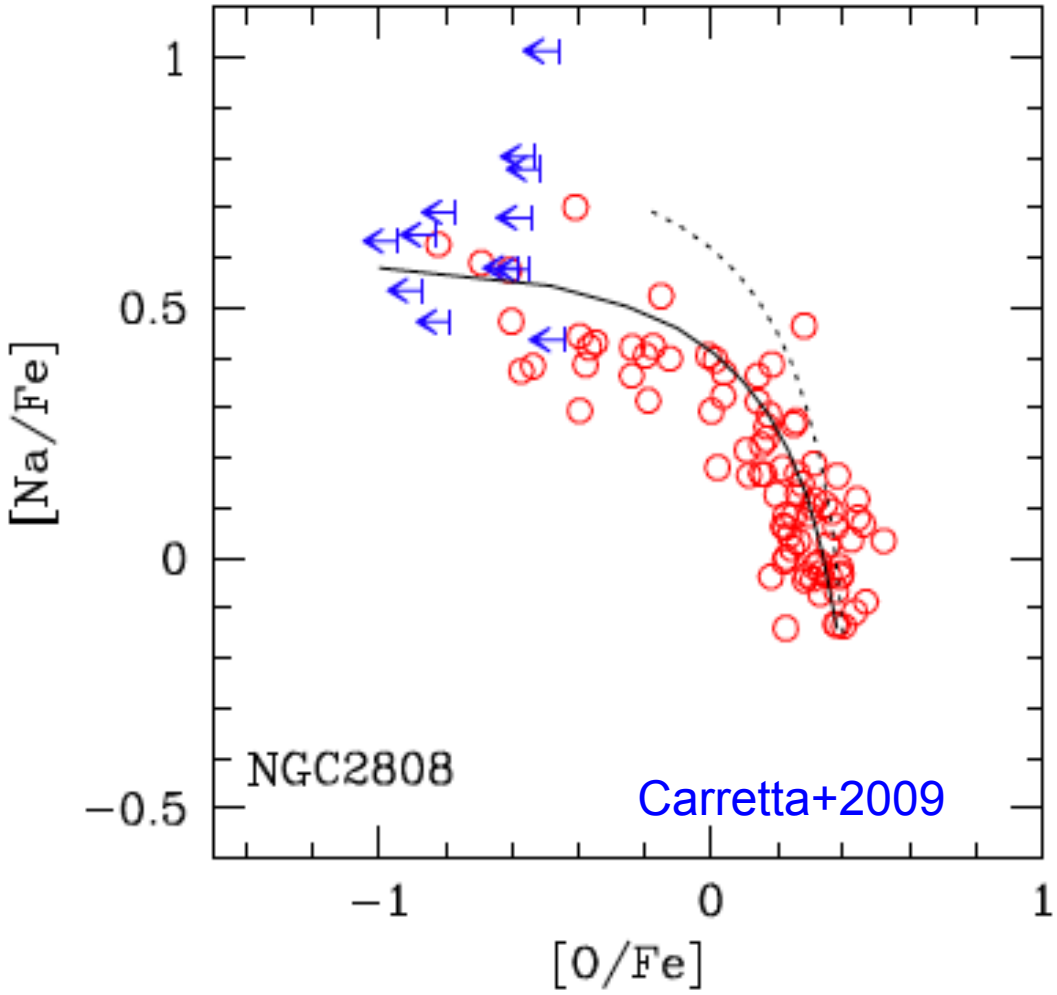
Now, let's look at the evidence, with emphasis on UV

Challengies in UV Astronomy, ESO, Garching, October 8, 2013

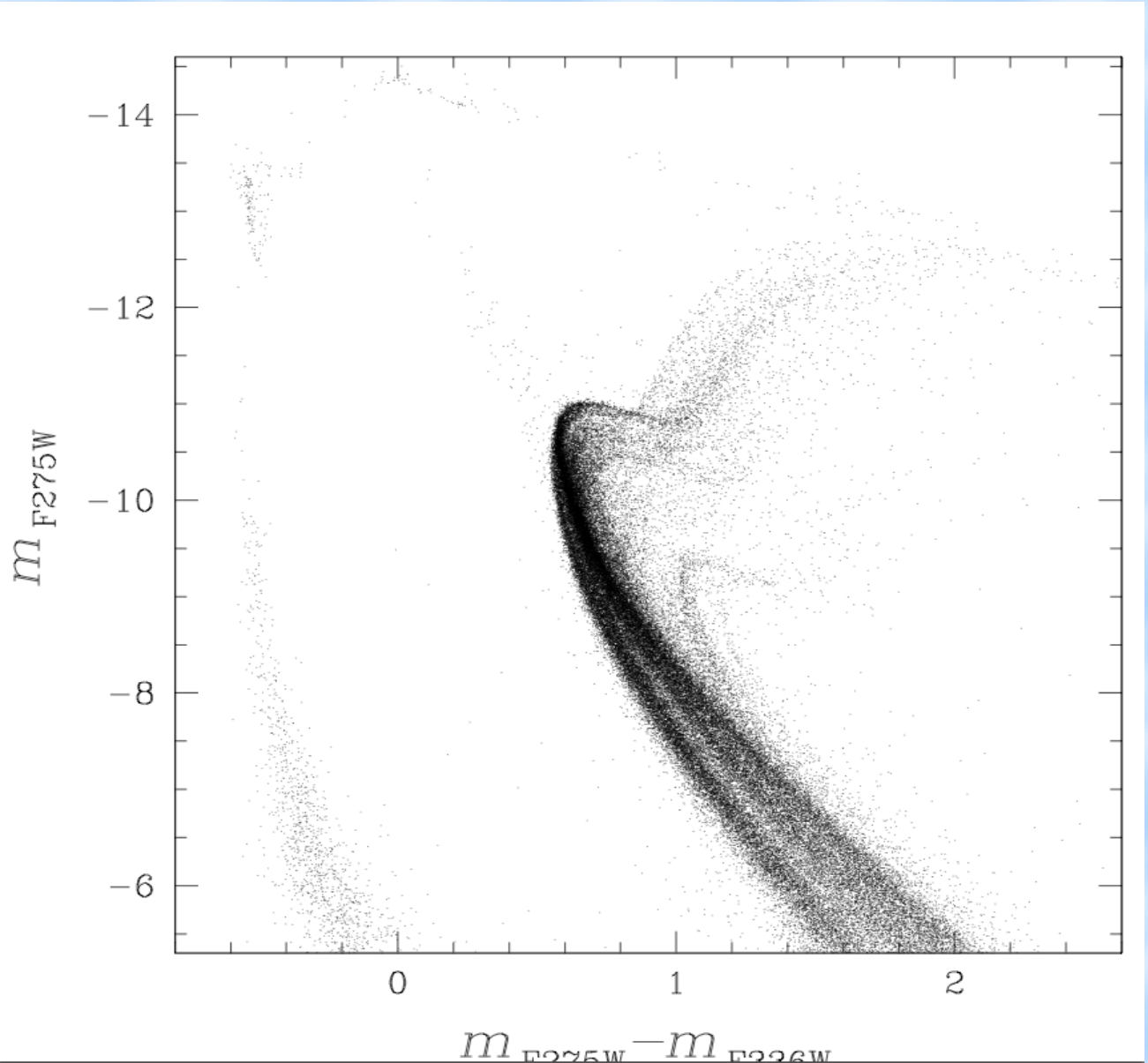
NGC 2808: at least 3 main sequences with the same metallicity: hence with different helium content:

Second (third) generation stars are made of material Exposed to high temperature (~10^8 K) *p*-captures





The most Extreme case: ω Cen



Color inversions when using UV bands

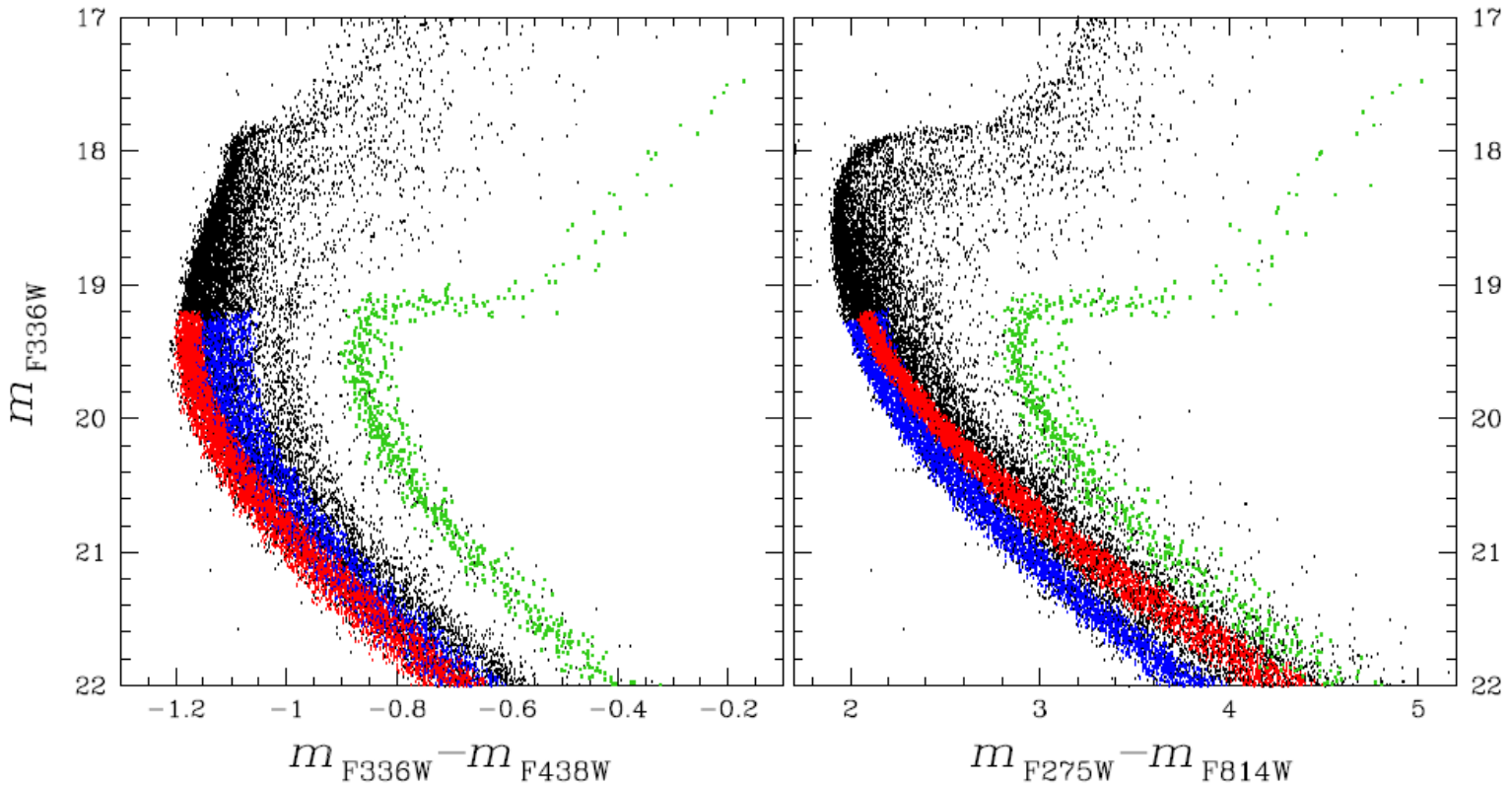
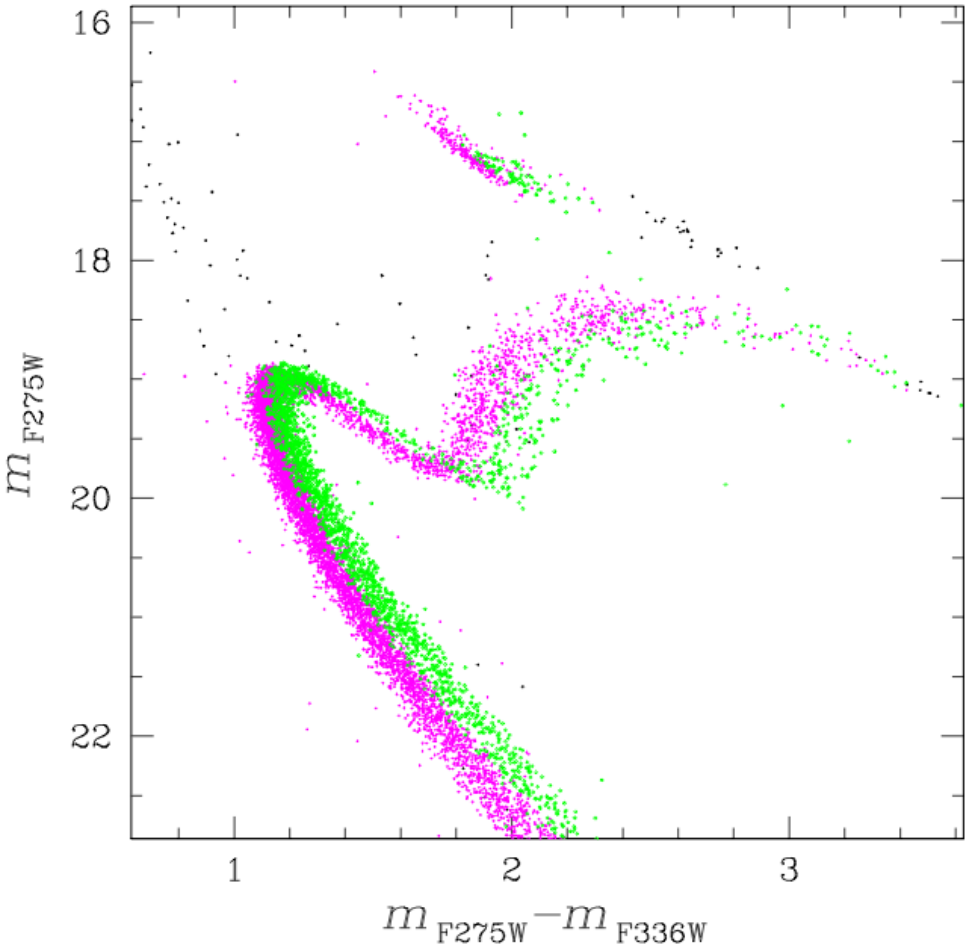
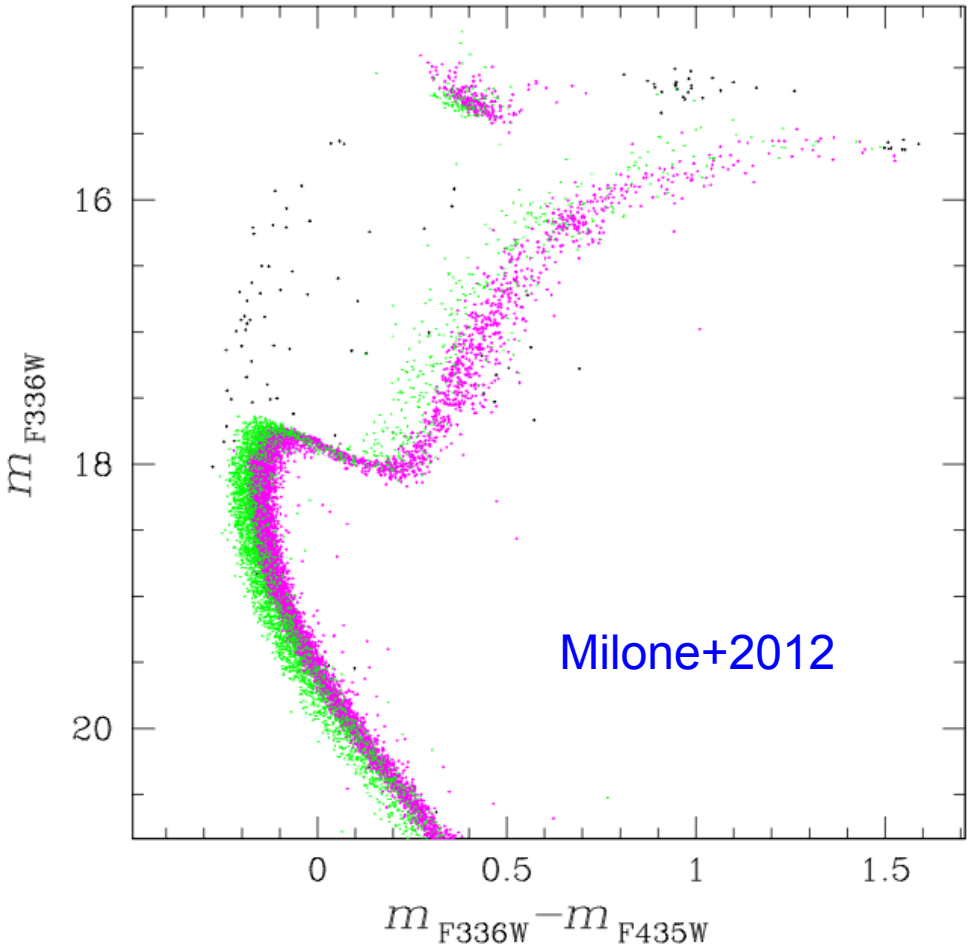


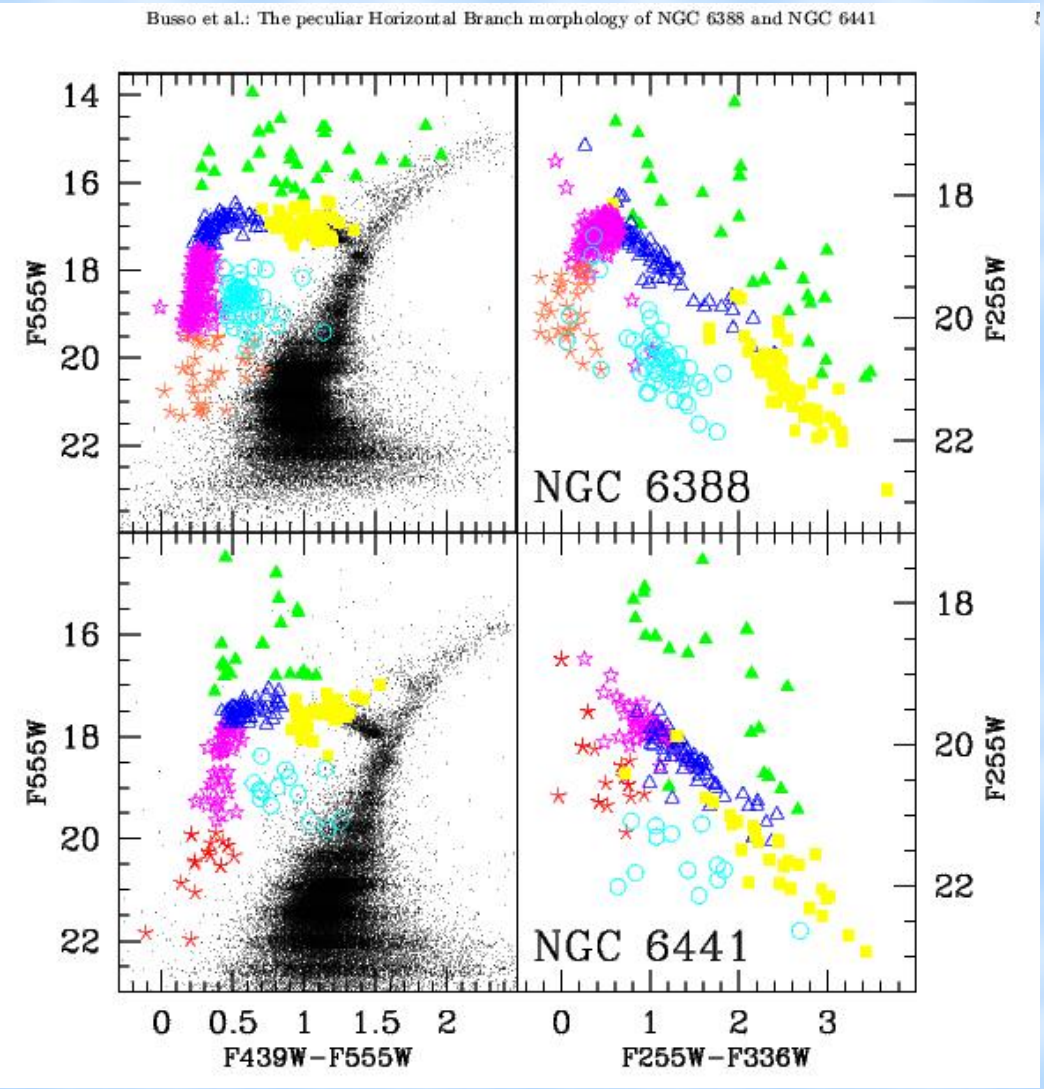
Figure 1: Two WFC3 color-magnitude diagrams of the turnoff region of the cluster ω Cen. The four stars proposed for STIS UV spectroscopy will be carefully chosen among the $m_{336\rm W} \simeq 19.5$ stars, each belonging to one sub-population, here marked red, blue, black and green.

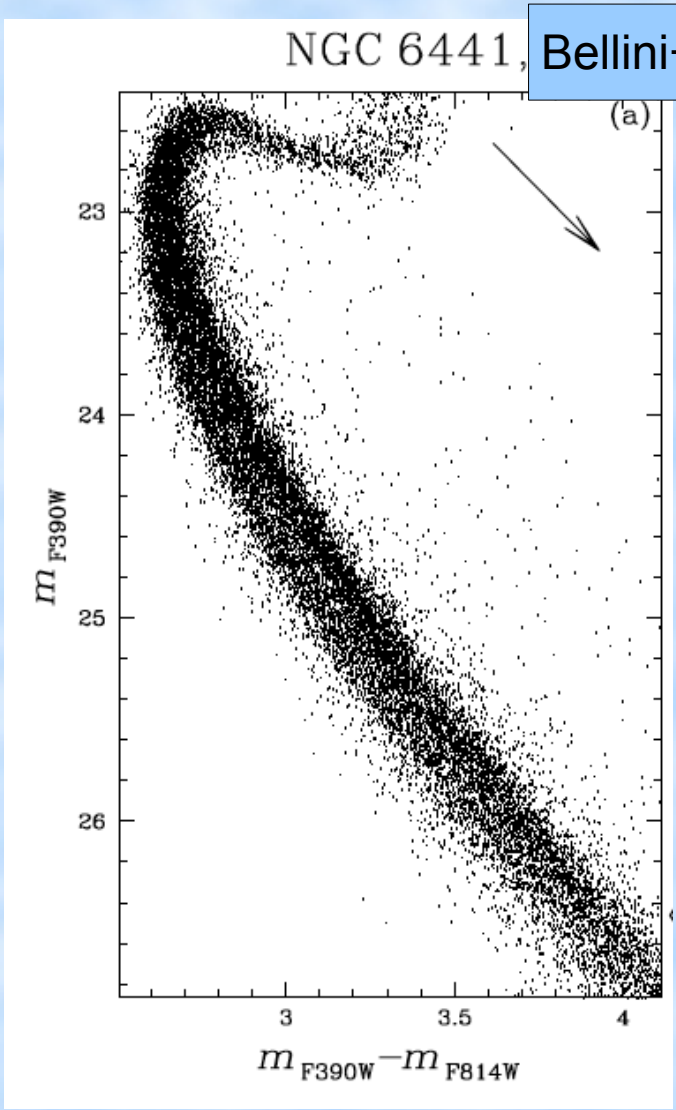
47 Tuc: a cluster that seemed to be made of a single population: all sequences are split in UV light





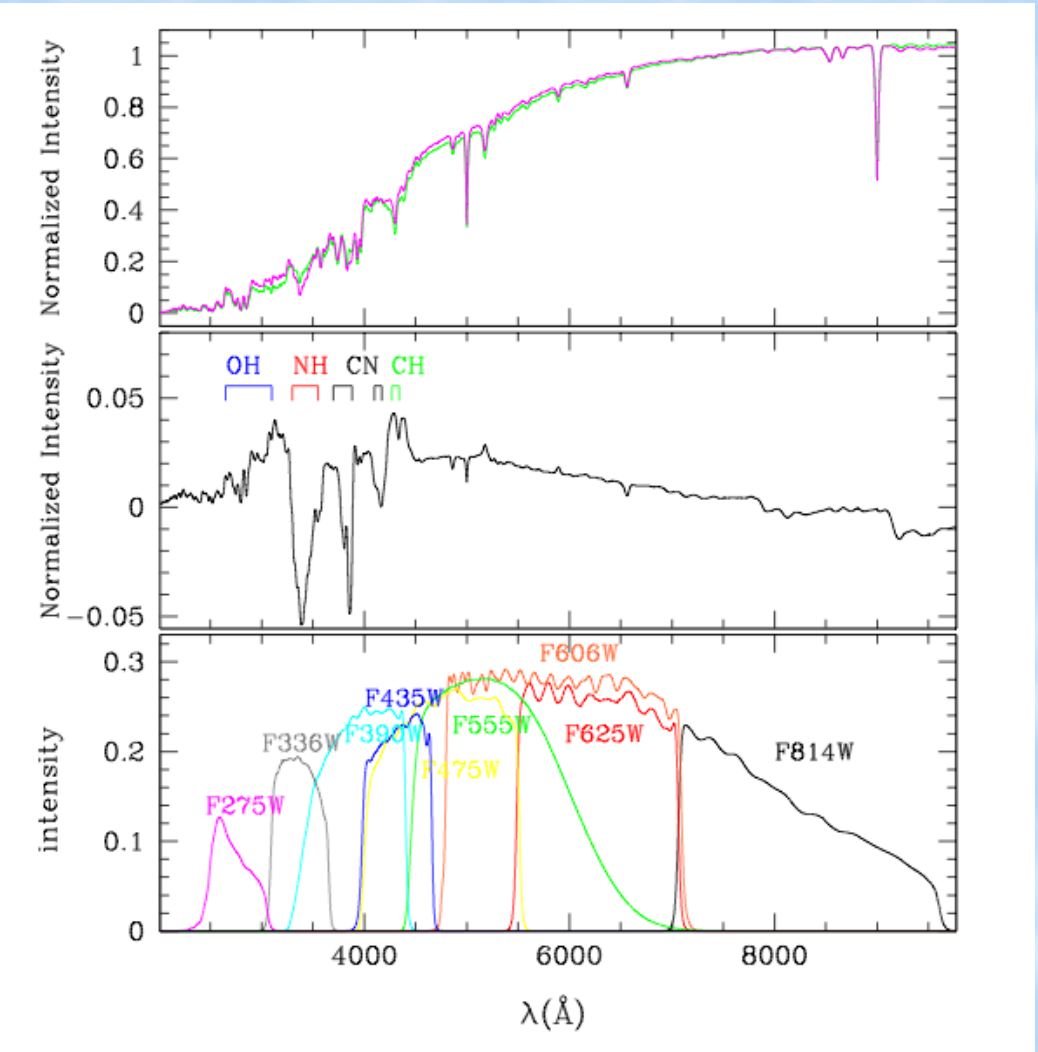
Multiple Populations also in two Bulge, highly-reddened, metal rich globular clusters

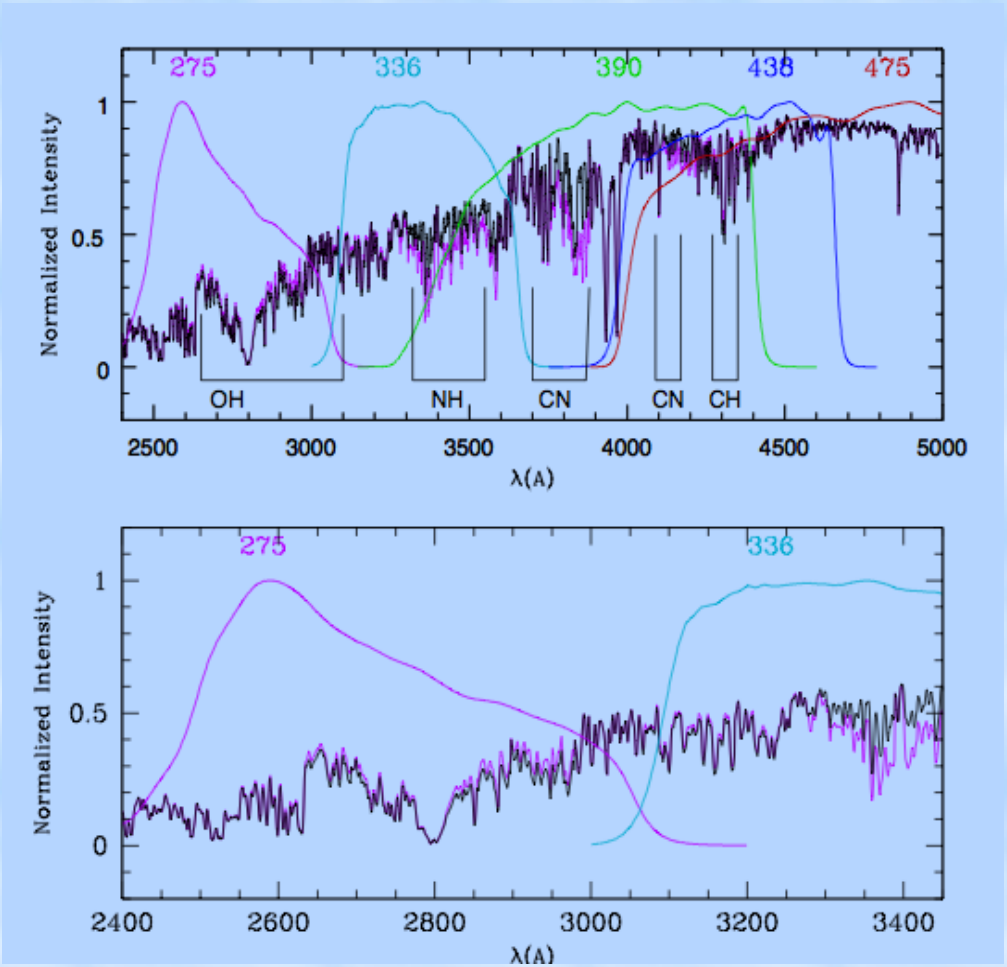




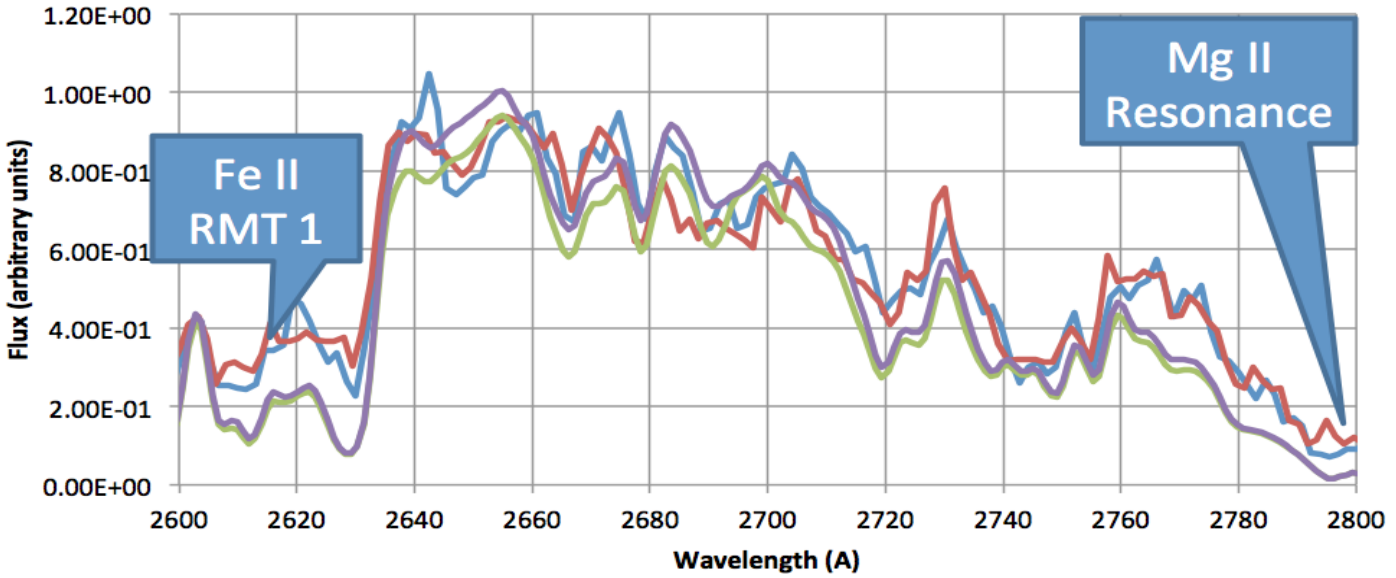
Bellini+2013

Why UV is so *magic*?

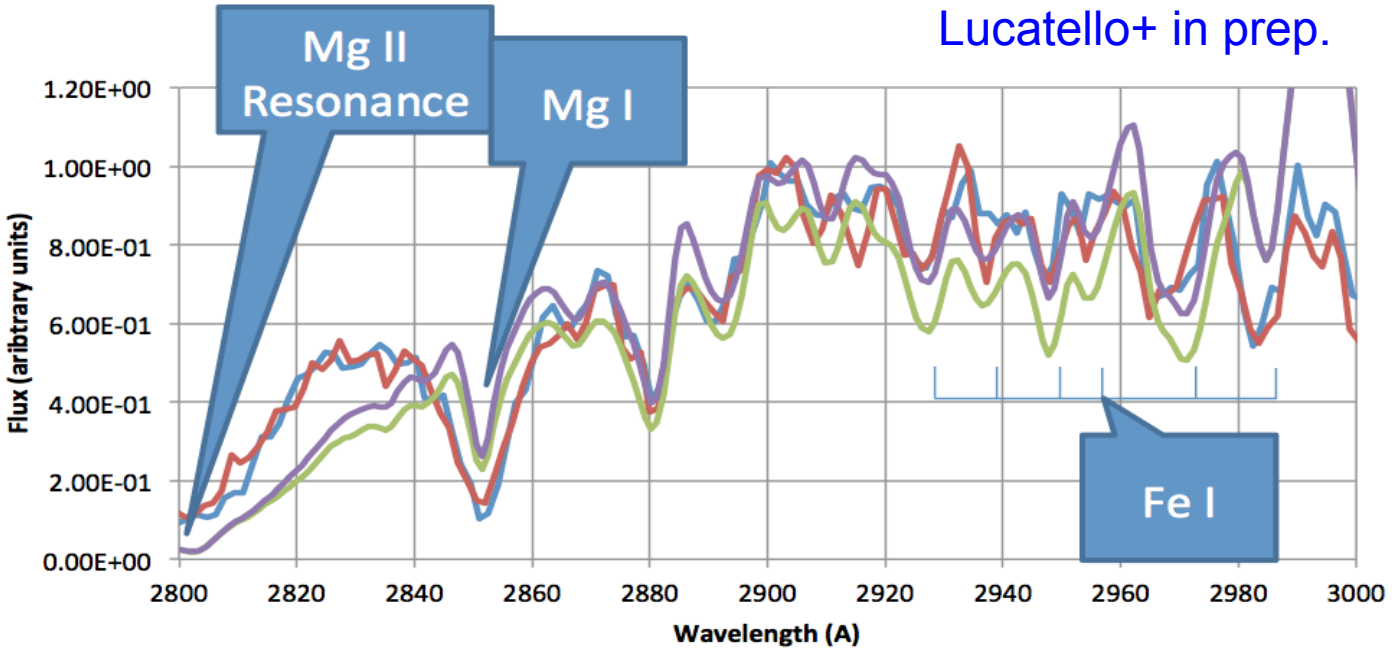




STIS/MAMA spectra of stars in 47Tuc in the range 2600-3000 Å (preliminary)



Lucatello+ in prep.

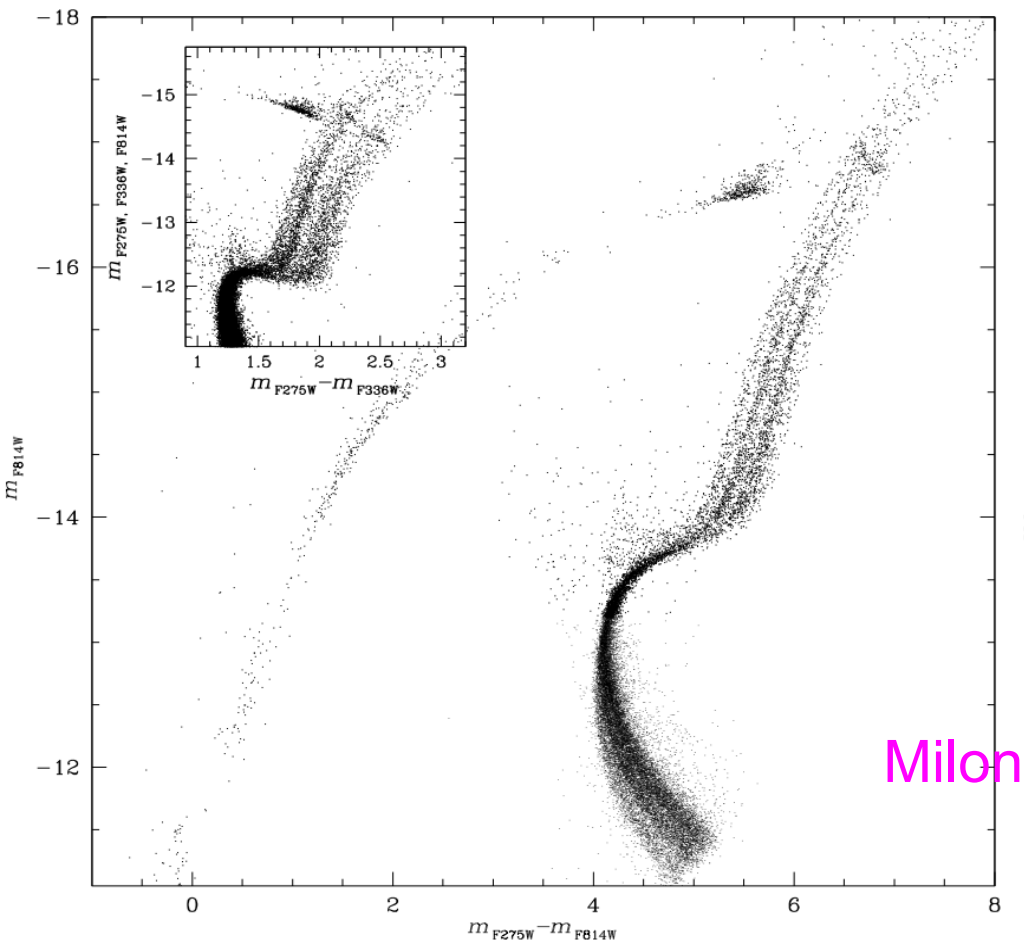


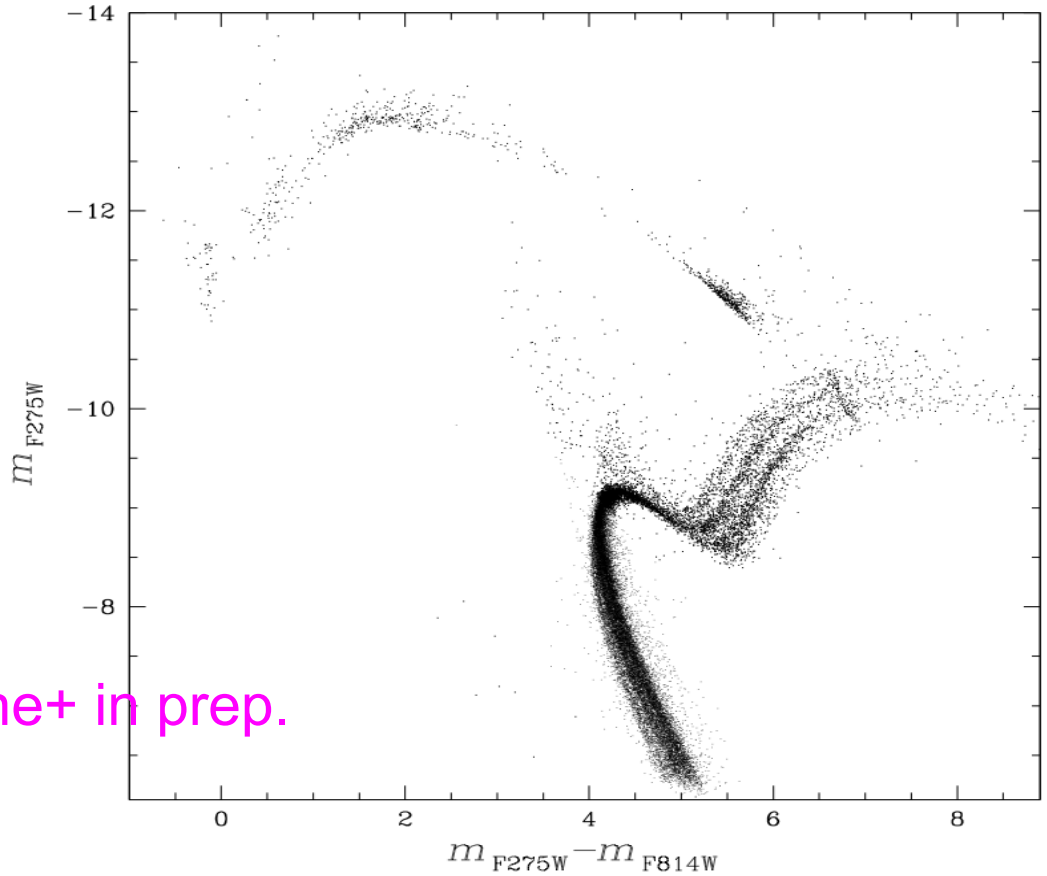
Lucatello+ (in prep.)

A just started HST/WFC3-UVIS Treasury Program to secure UV data for 47 GCs (PI GP Piotto)

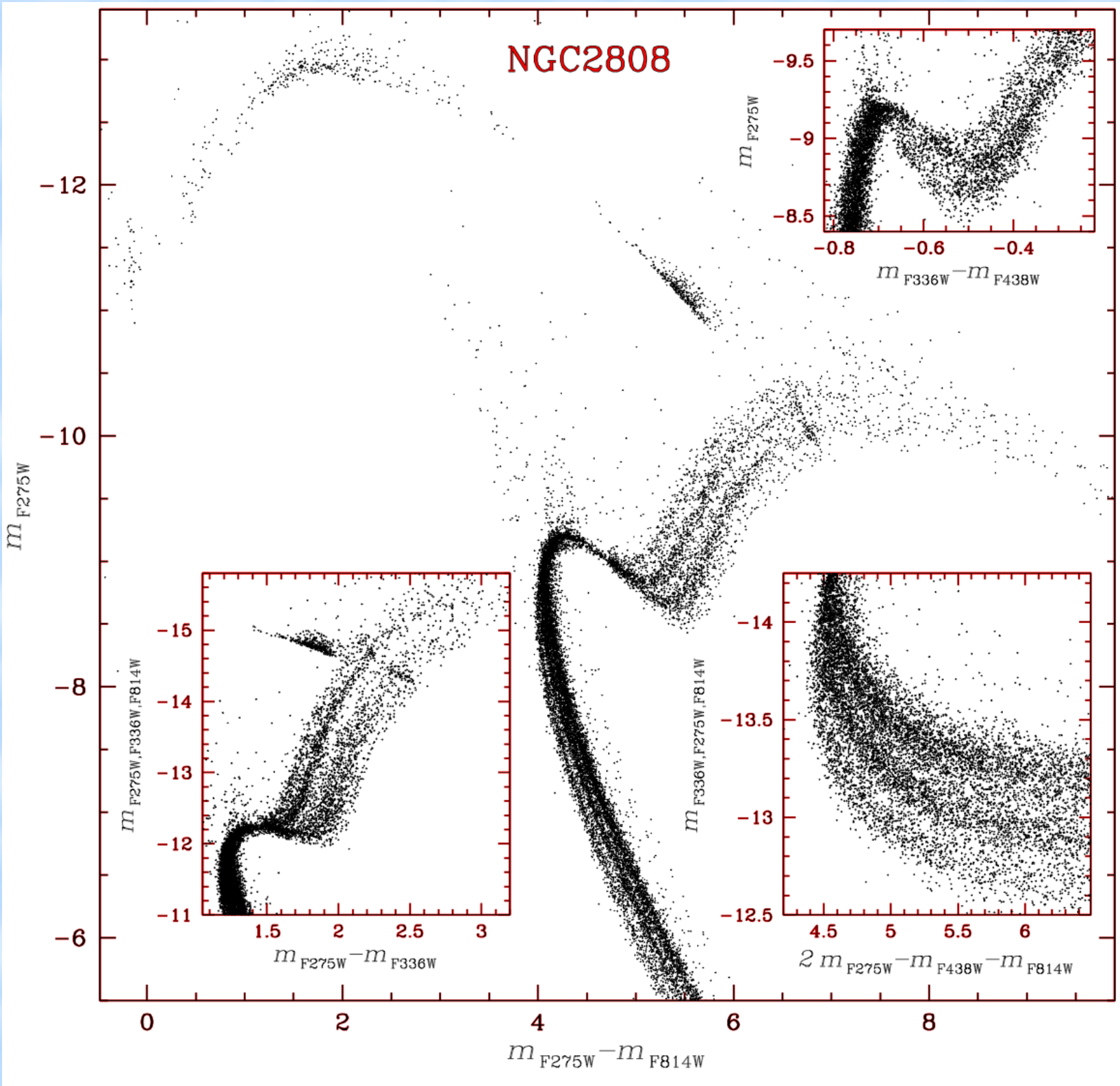
Bringing to 60 the GCs with UVIS data

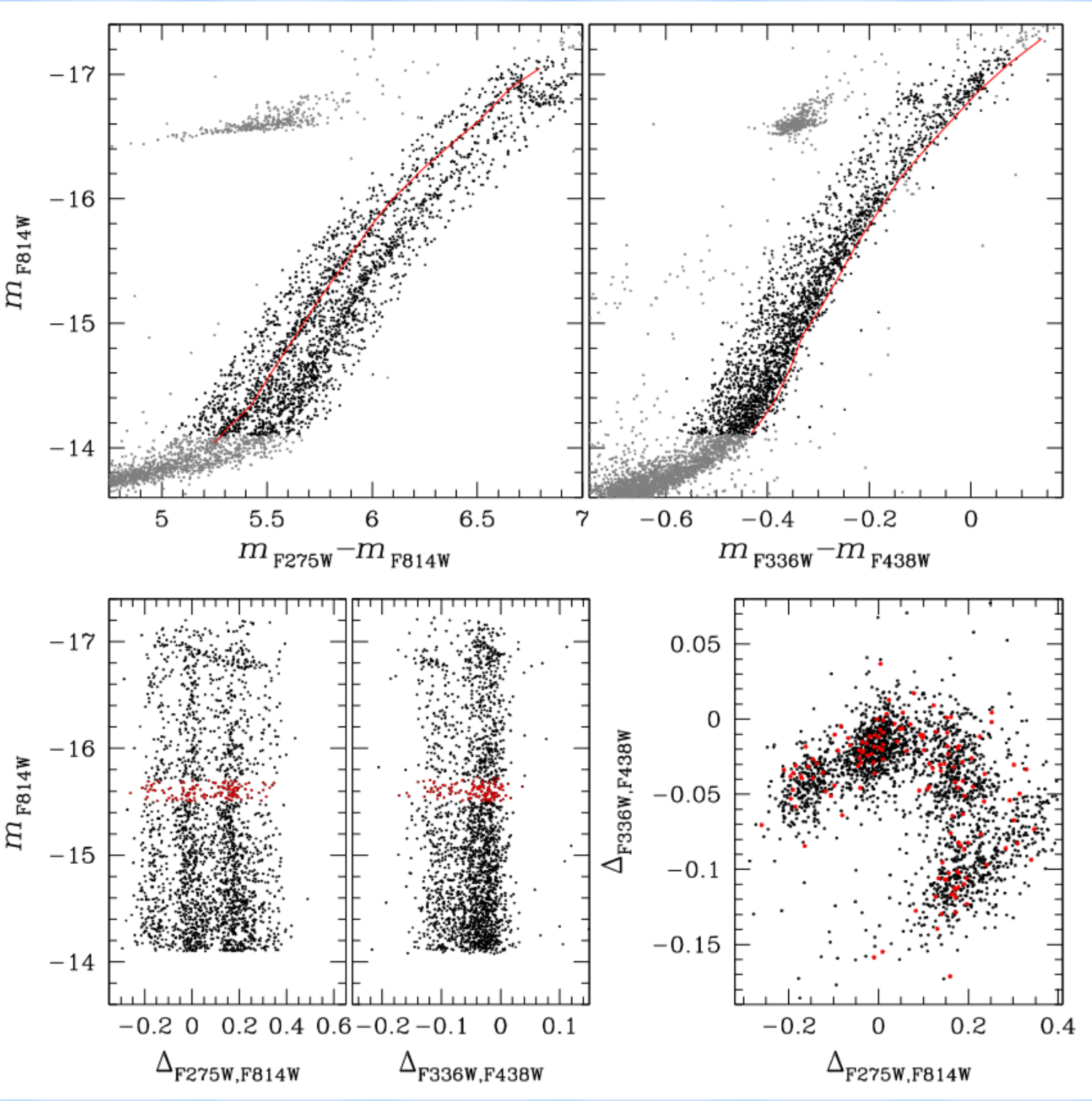
First, preliminary results from fresh data: NGC 2808





Milone+ in prep.


NGC2808
m_{F275W}
$m_{F275W}-m_{F814W}$
$m_{F275W}-m_{F336W}$
$m_{F275W,F336W,F814W}$
$m_{F336W}-m_{F438W}$
$m_{F275W,F275W,F814W}$
$2\,m_{F275W}-m_{F438W}-m_{F814W}$

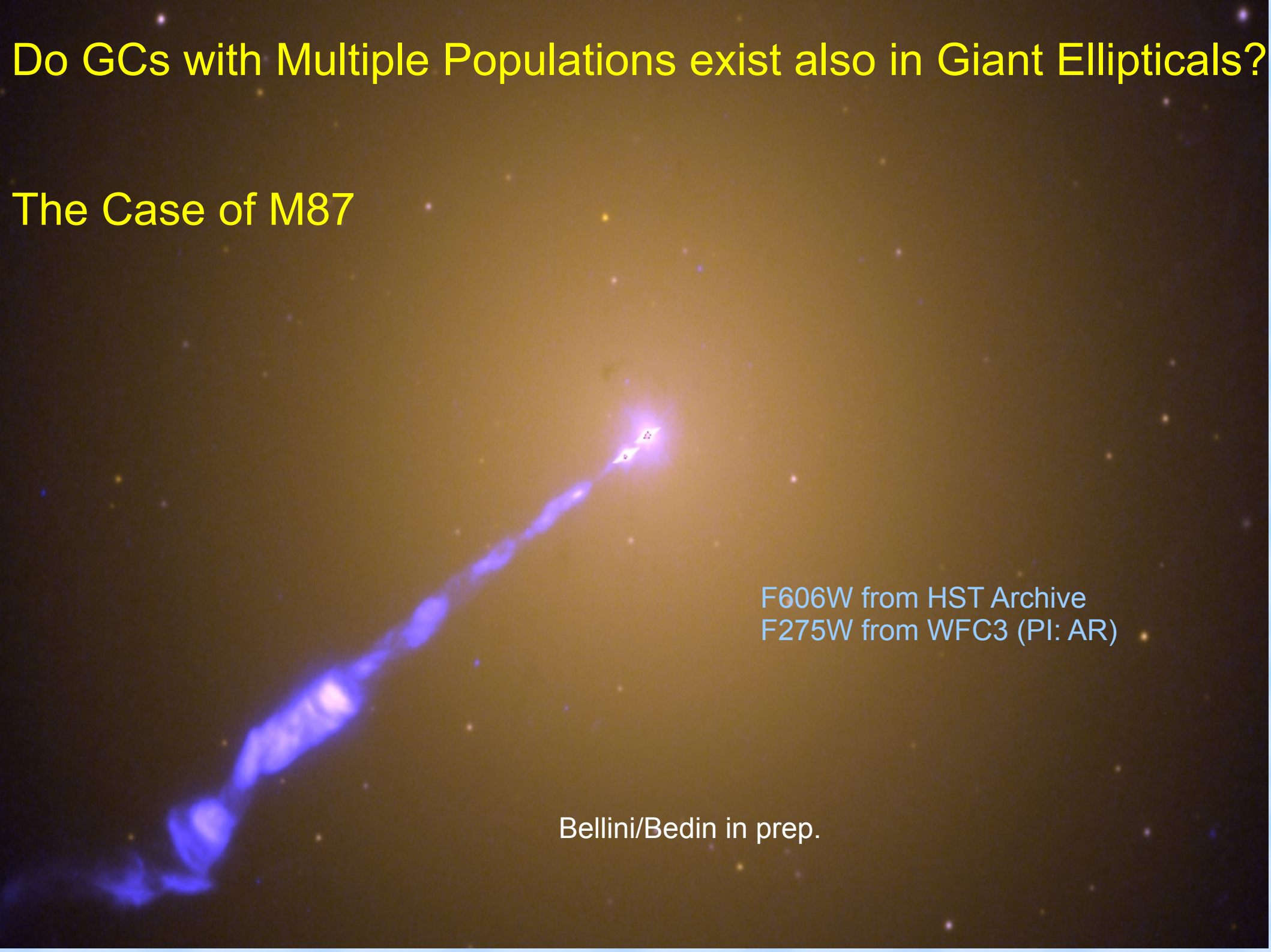


Next steps:

High-resolution FLAMES spectroscopy of stars in each of the 5 photometric sequences

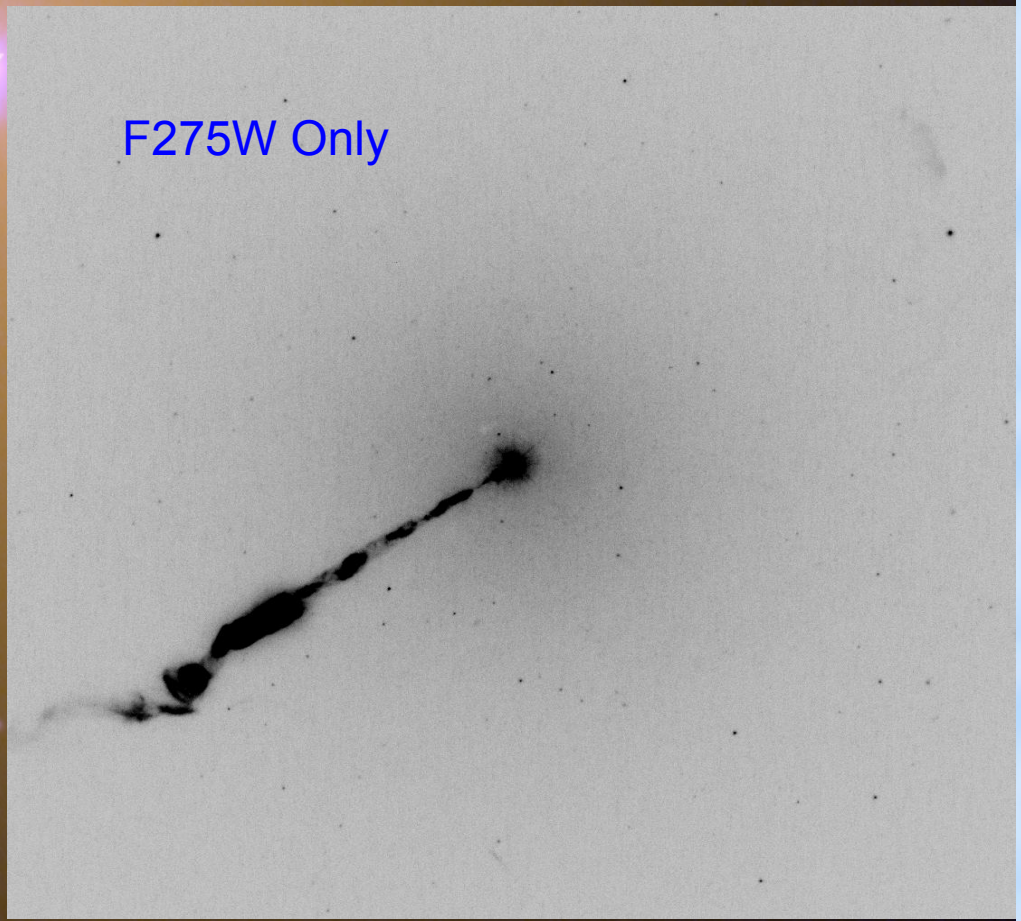
Do GCs with Multiple Populations exist also in Giant Ellipticals?

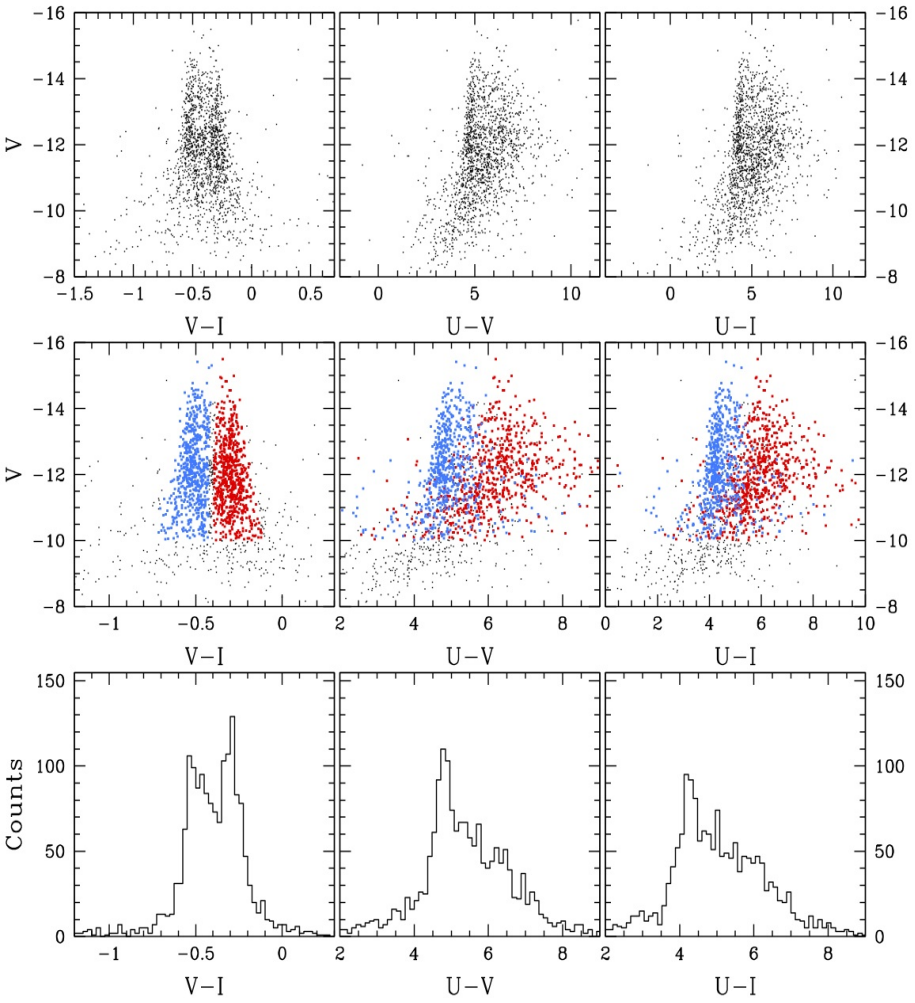
The Case of M87



Do Globulars in a giant elliptical (M87) share the multiple population syndrome?

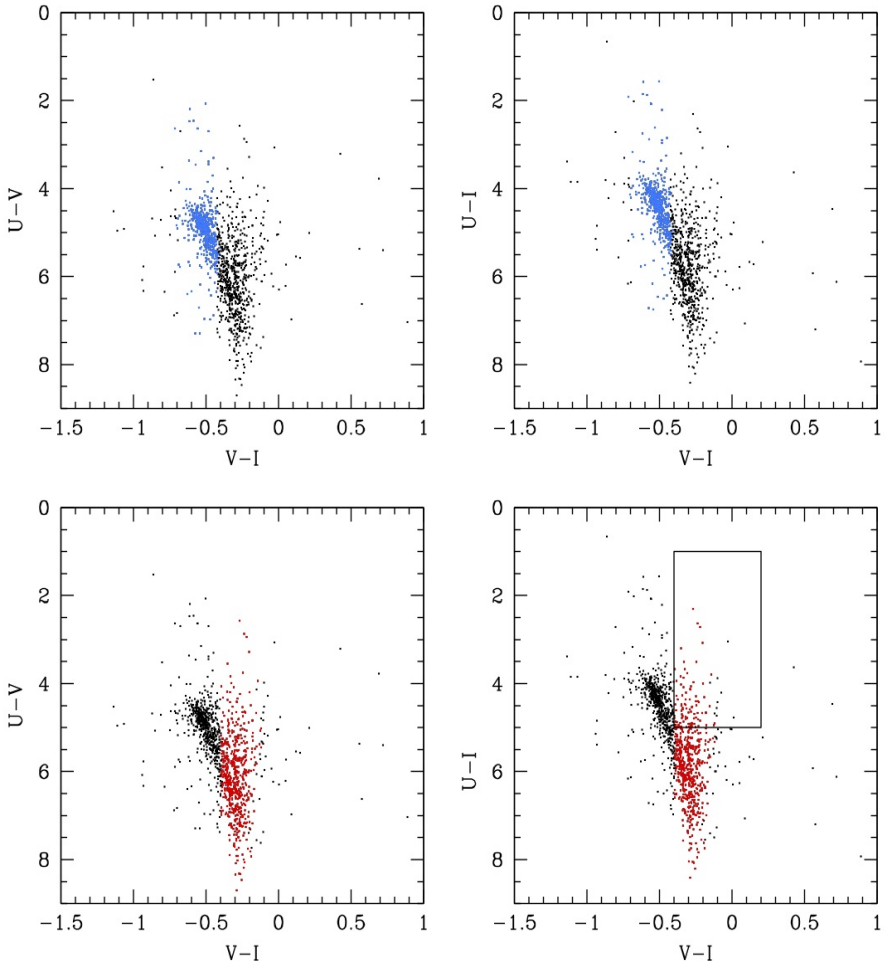
F275W+F606W





Here U stands for F275W

Bellini+ in prep.



Why all this matters?

- Because the formation of GCs has become a terrifying puzzle
- Where was the helium-rich, Na-rich & O-poor material made?
- How was it turned into stars without being contaminated by supernovae?
- Are AGB stars sufficient to make such oddities?
- What was the nature of a GC precursor and how massive was it?
- How to make new stars in in a space with already > 10^5 stars/pc^3?
- Will JWST see young/forming GCs at z ~ 3-10?
-

1) The mass budget problem & the nature of the progenitor

Only ~5% of the mass of the FG comes out as mass return with the *right* composition (He, p-processes) to make the SG:

Mass of the progenitor = M_{SG}(today) x 20 x $\varepsilon^{-2} \simeq$

With ε=0.1 $\simeq 10^5 \times 20 \times 100 = 2\ 10^8\ M_\odot$

(or ~4 10^9 $M_\odot$ for ω Cen)

Times ~200 one gets ~4 10^{10} $M_\odot$ for the amount of gas needed to form all the MW globulars with

4 10^9 $M_\odot$ of dissolved FG stars (the whole Halo?)

Future prospects for Globulars in UV Light

Short Term:

- UV spectroscopy to calibrate UV-optical colors in terms of C, N, O and He abundances
- UV imaging of GCs in other galaxies (is the multi-pop phenomenon universal?

Medium/Long Term:

- Need for a Post-HST UV capability
- Welcome to CUBES!


Thank You!