Testing Photometric Metallicities with Milky Way Dwarf Spheroidal Companions

Sophia Lianou
University of Heidelberg

Eva Grebel (ARI) & Andreas Koch (LSW)

Motivation

- Several ways to derive metallicities of individual stars using spectroscopic or photometric methods
- Photometric metallicities provide the only way to derive stellar metallicities for more distant galaxies
- With HST at the distance of the Virgo cluster – brightest red giant stars have been resolved (e.g., Caldwell 2006)
- It is important to explore how reliable the photometric method of deriving metallicities can be

Stellar Metallicities

- Spectroscopy of red giant branch stars:
  - → usually Ca II triplet (e.g., Starkenburg et al. 2010)
  - → medium resolution and spectral synthesis (Kirby et al. 2008)
  - → high resolution (e.g., Koch et al. 2008; Battaglia et al. 2008)

- Photometry of red giant branch stars
  - → mean color of the red giant branch stars at M_I ~ -3 mag (Da Costa & Armandroff 1990; Lee et al. 1993)
  - → linear interpolation between isochrones
  - → application in old stellar populations (> 10Gyr)

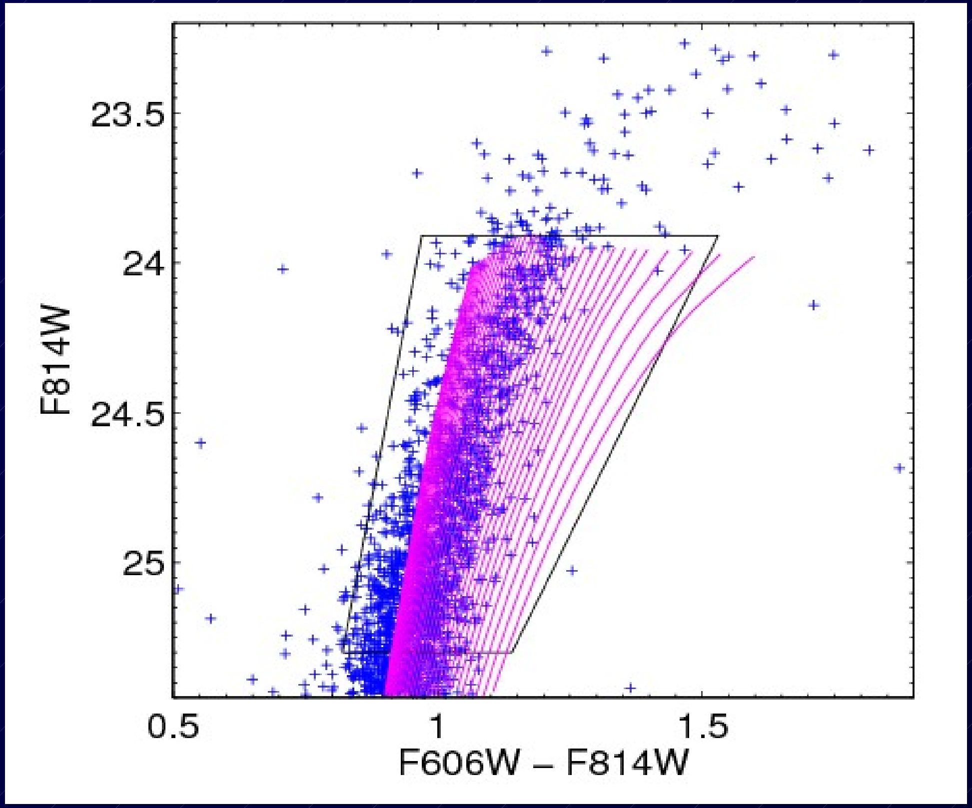
Photometric Metallicities Method

- Assume isochrones of a single old age (~12.5 Gyr)

- Assume a range in metallicities (from -2.5 to -0.5 dex in [Fe/H])

- Linear interpolation between Dartmouth isochrones (Dotter et al. 2007, 2008)

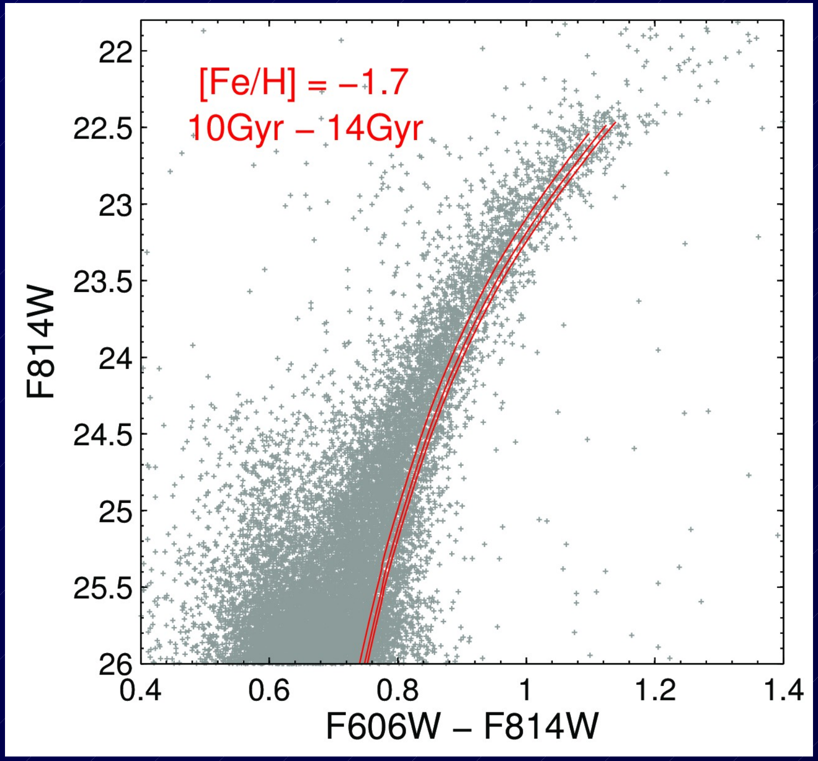
- Assign to each star a global metallicity [Fe/H]

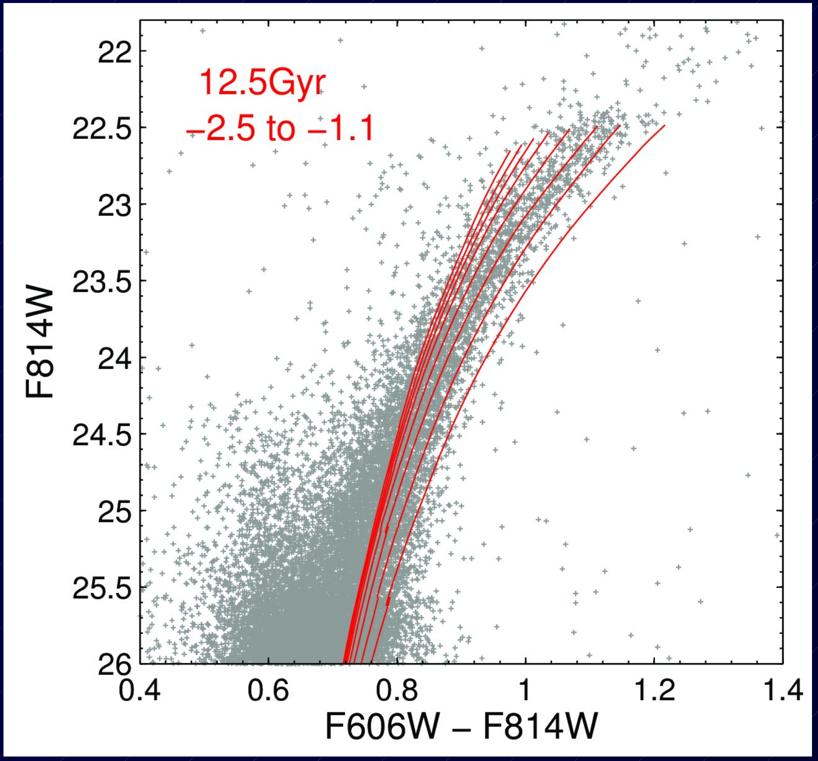


On the "Old Single Age" Assumption

- All Local Group dwarf galaxies so far studied contain old stars (Grebel & Gallagher 2004)

- Red giant branch width: metallicity spread rather than age spread





Is the "Old Single Age" Assumption Valid?

- Dwarf spheroidals may have an age spread of ~3Gyr (e.g., Marcolini et al. 2008)

- An age spread from 10 to 13 Gyr does not significantly alter the derived metallicities assuming a constant age (e.g., Lianou et al. 2010)

- The single age for old stellar populations gives results consistent ~0.1dex more metal-rich when using 10Gyr isochrones

Is the "Old Single Age" Assumption Valid?

- Young stars: age < ~1Gyr
  Intermediate-age stars: ~1Gyr < age < ~10Gyr
  Old stars: age > ~10Gyr

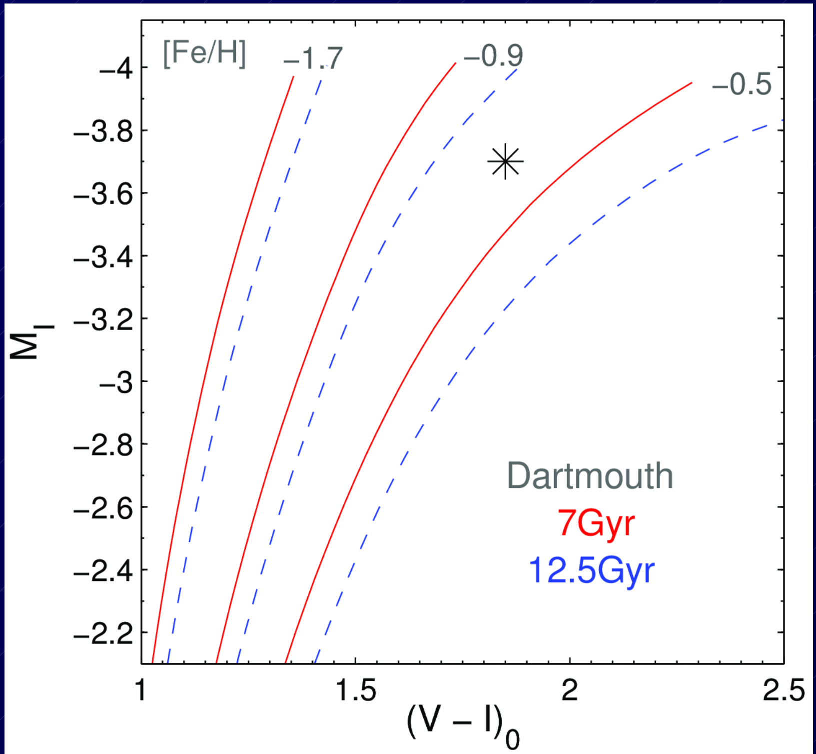
- Many Local Group dwarf spheroidals contain stars as young as 100Myr (e.g., Fornax: Grebel & Stetson 1999)

- Implication for the red giant branch: not purely old stars with intermediate-age stars contaminating it

- The old isochrone age assumption is not necessarily valid in the case of dwarfs galaxies with complex Star Formation Histories (SFH) due to age-metallicity degeneracies

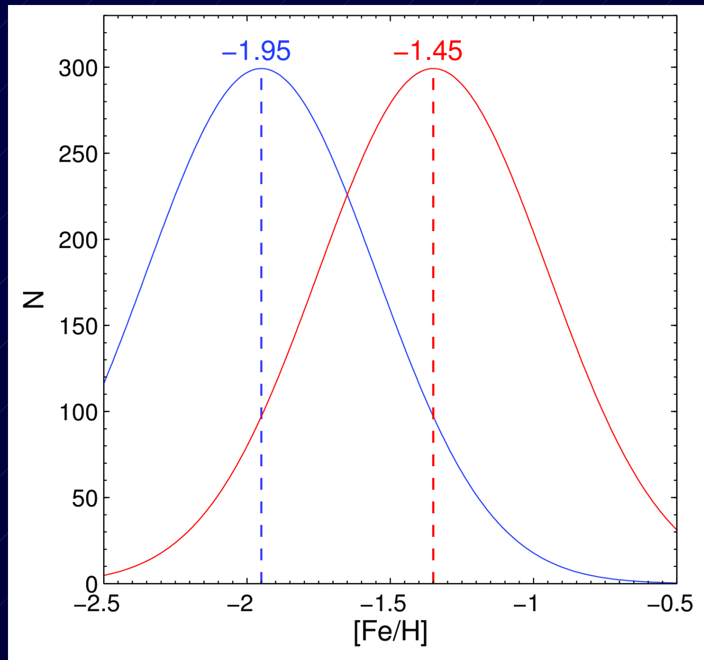
Age – Metallicity Degeneracy

- Galaxies –> mixture of stellar populations of different ages



So, a star on the giant branch is:

- Old and metal – poor?
- Young and metal–rich?



- Metallicity Distribution Function:
  expect a "Metal–poor bias" →

Testing Photometric Metallicities

- 5 Milky Way dwarf spheroidal companions with variety in SFHs

- Why Milky Way dwarfs? → Nearby enough to have accurate SFH, as well as spectroscopic metallicity measurements

- Compare metallicities derived from two independent methods:
  - – Spectroscopic (CaT and MRS; literature)
  - – Photometric (our work)

Comparing Metallicities: Mean Values

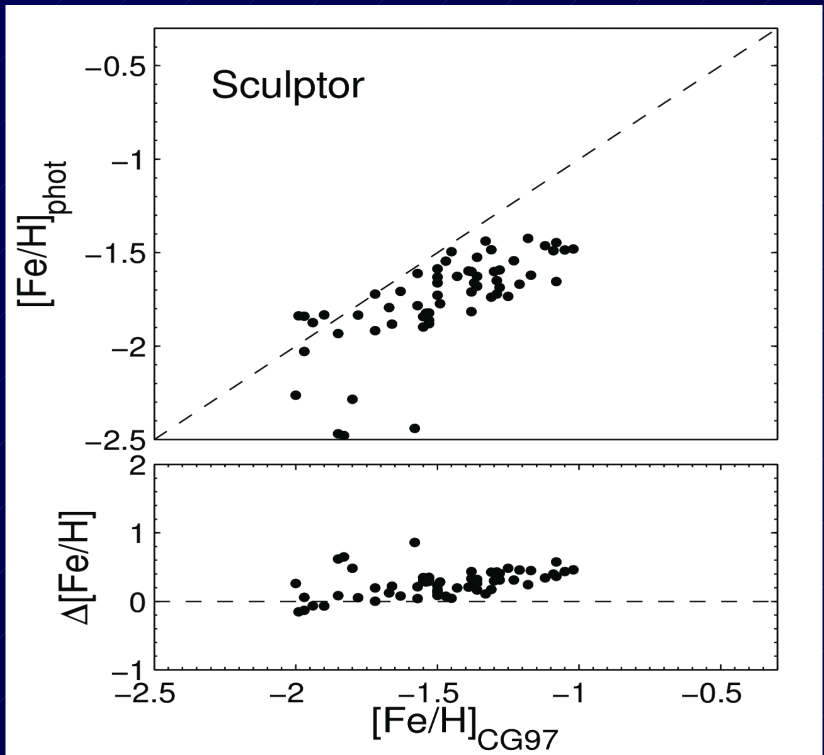
- First compare the global mean values as derived from each method

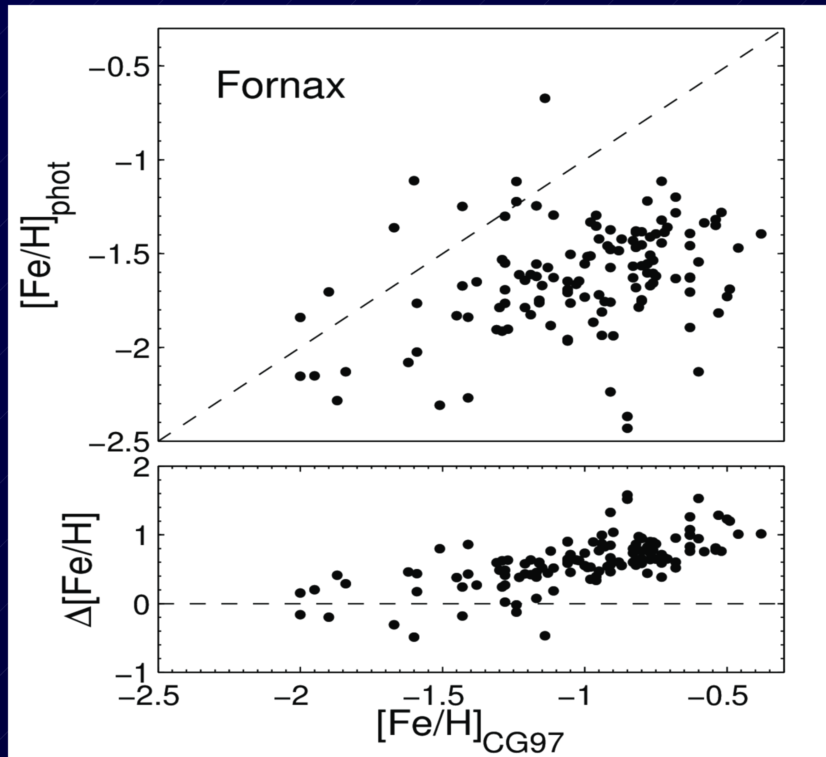
– For those dwarfs with a small fraction of intermediate-age stars (Sextans or Sculptor; < ~15%), mean metallicities agree within ~0.1 dex

– For those dwarfs with a higher fraction of intermediate-age stars, the discrepancy between spectroscopic and photometric metallicities is larger, of the order of 0.4 dex

Comparing Metallicities: Common Stars

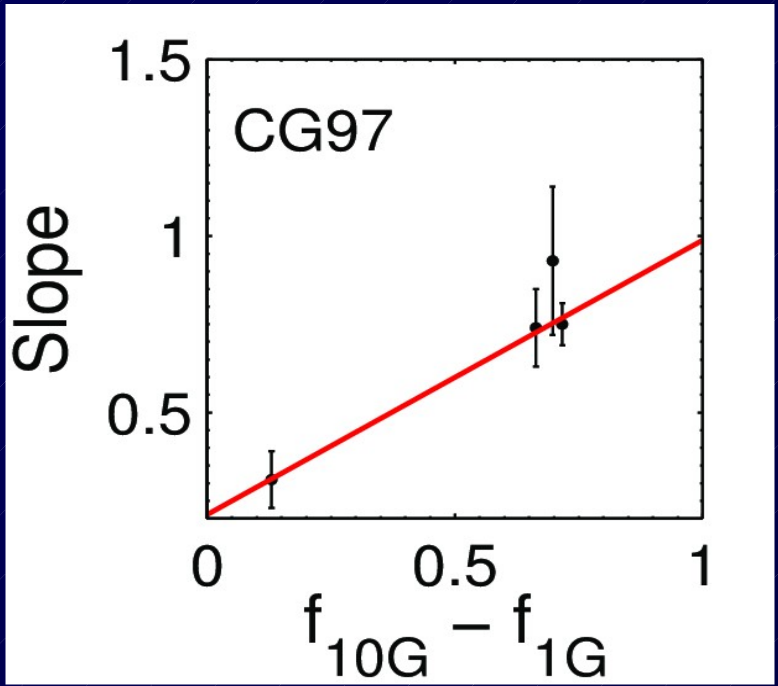
- There is a relatively good agreement between -2 to -1.5 dex
- Same trend in all of them: towards the metal-rich end, there is a high discrepancy between the results of the two methods

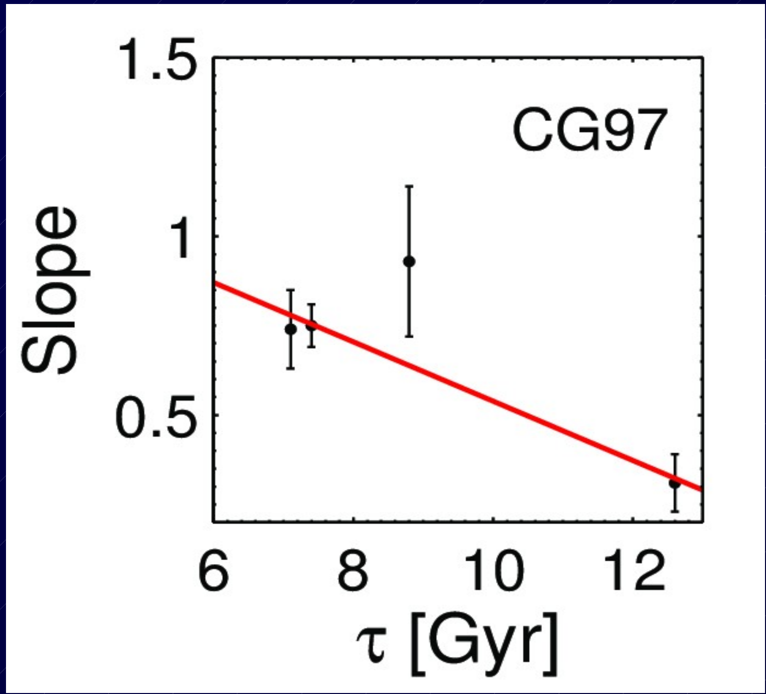




Comparing Metallicities: Common Stars

➢ Increasing the intermediate-age of stars present, the slope of the residuals increases → dependence on the SFH





(fractions f and mean stellar ages τ from Orban et al. 2008)

Conclusions

- Between -2 to -1.5 dex good agreement independent of SFHs
  Overall, the more complex the SFH is, the higher the discrepancy

- Estimating the fraction of intermediate-age stars present is important in order to quantify the amount of age-metallicity degeneracy present, affecting for instance the photometric metallicities

- In more distant galaxies only the brightest stars can be resolved – thus one has to rely on the luminous asymptotic giant branch stars as tracers of the intermediate-age populations present

- Calibrate the number of luminous asymptotic giant branch stars as a function of the fraction of intermediate-age stars present, with the latter derived from accurate SFHs (Lianou 2011, in prep)