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Carbon in dwarf Sph galaxies

Matthew Shetrone

McDonald Observatory – Hobby-Eberly Telescope

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My collaborators in this work

The opinions, beliefs and viewpoints expressed in this presentation do not necessarily reflect the opinions, beliefs and viewpoints of my collaborators:

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Sarah Martell
Alan McConnachie
Vanessa Hill
Mike Siegel

Graeme Smith
Kim Venn
Pascale Jablonka
Martin Tafelmeyer
Howard Bond

Why Carbon is so difficult

Despite being the 4th most abundant element in the Universe, carbon evolution is poorly understood. Here are a few reasons why:

- In metal-poor stars the best C features are the CH band in the blue (not optimal for red giant stars).
- In metal-rich stars the CH band becomes to strong and badly blended with little continuum.
- One forbidden [C I] line is high excitation and not good for cool giants.
- Other C I lines are also high excitation and suffer from NLTE affects.
- Both C I and CH features are fairly sensitive to model atm. parameters and thus can suffer from bias issues from survey to survey.
- Giants destroy surface C abundance as they evolve.

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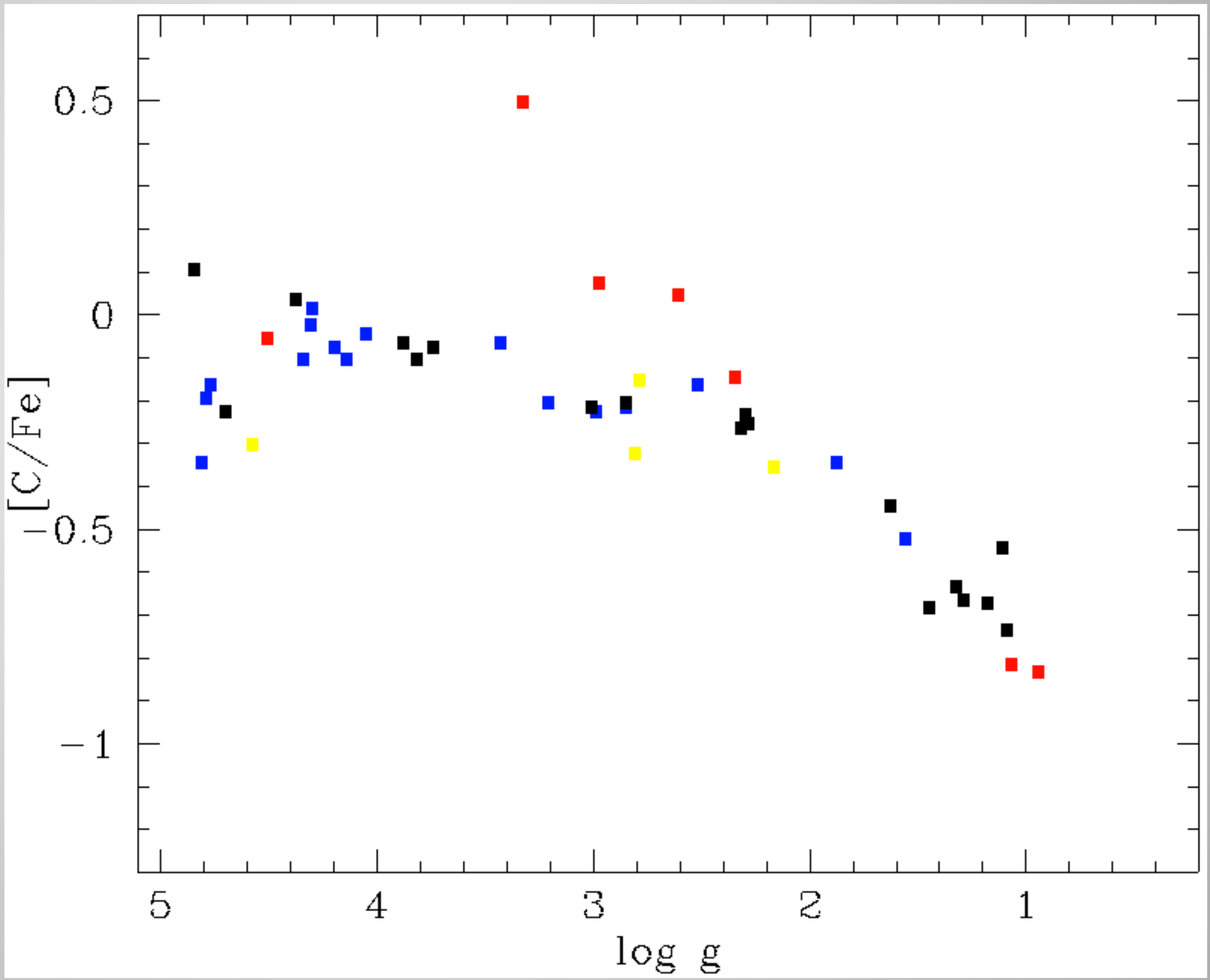
[C/Fe] depletion

From Gratton et al. 2000:

[Fe/H] > -1
-1.0 > [Fe/H] > -1.4
-1.4 > [Fe/H] > -1.8
[Fe/H] < -1.8



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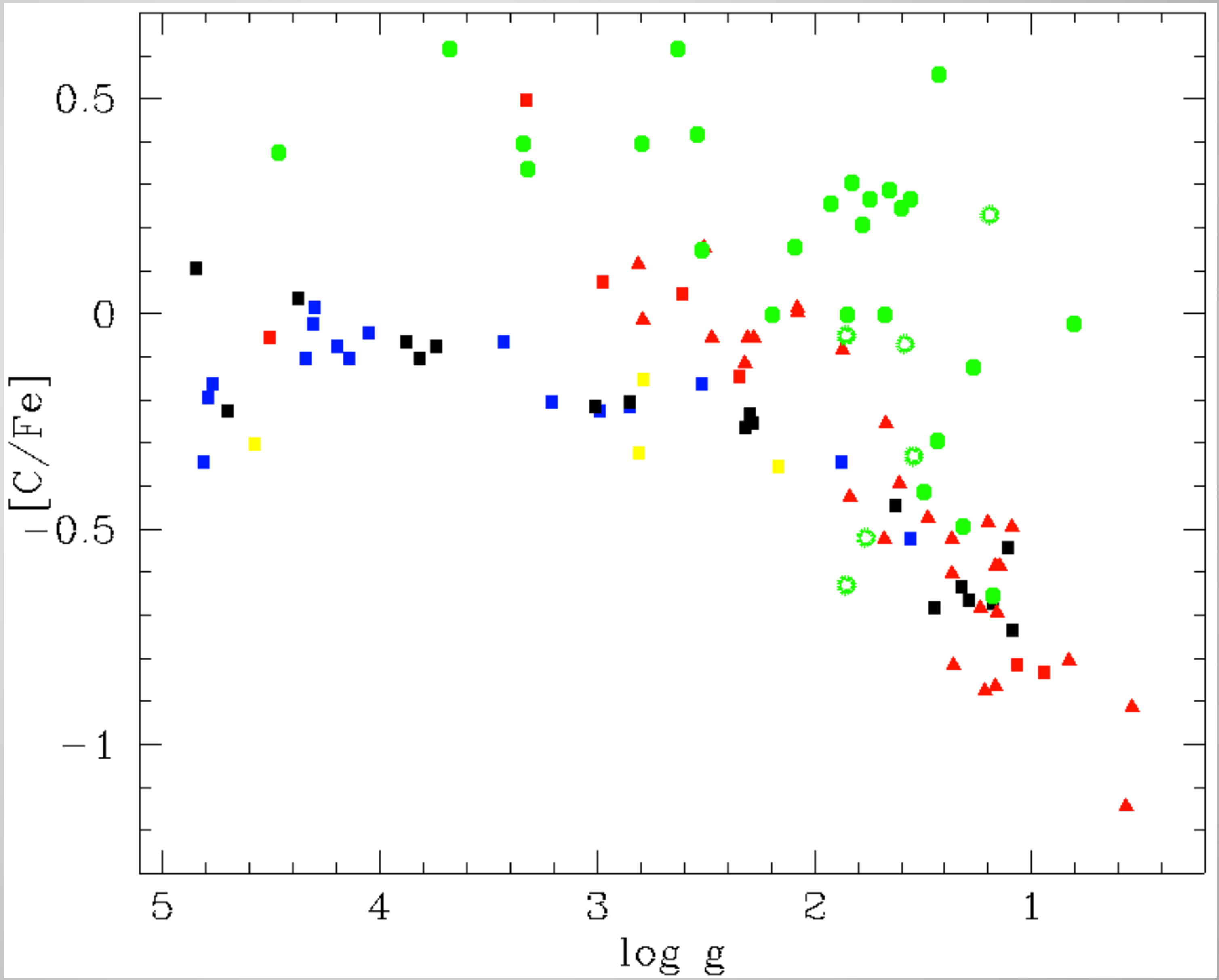
Adding in NGC5466 data from Shetrone et al. 2010

Adding in EMP compilation from Norris et al. 2013

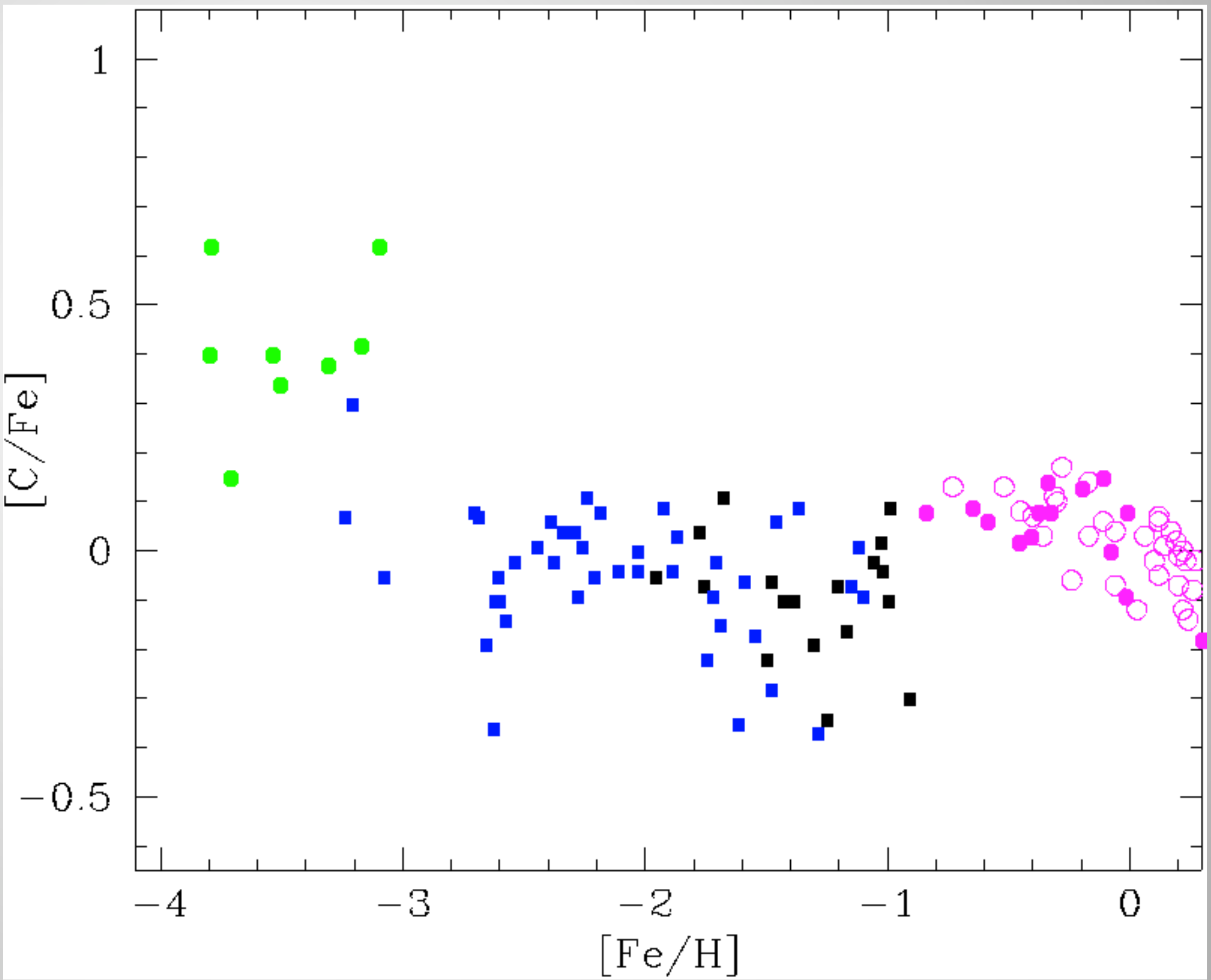
Conclusion: If you want to be sure use dwarf stars?



Milky Way [C/Fe] trends

Here we show the data only from dwarfs and subgiants which should not have significantly modified their initial carbon abundances:

Bensby & Feltzing 2006 thin disk sample open circles
Bensby & Feltzing 2006 thick disk sample as filled cirlces
Gratton et al. 2000 subgiant and dwarf sample as squares.
Fabbian et al. 2009 halo subgiant and dwarf sample as crosses.
Norris et al. 2013 compilation of EMP subgiants and dwarfs as circles.



Is the dip at [Fe/H] = -1.3 real?

Here we show the same data for Milky Way dwarf stars:
Bensby & Feltzing 2006 thin disk sample open circles
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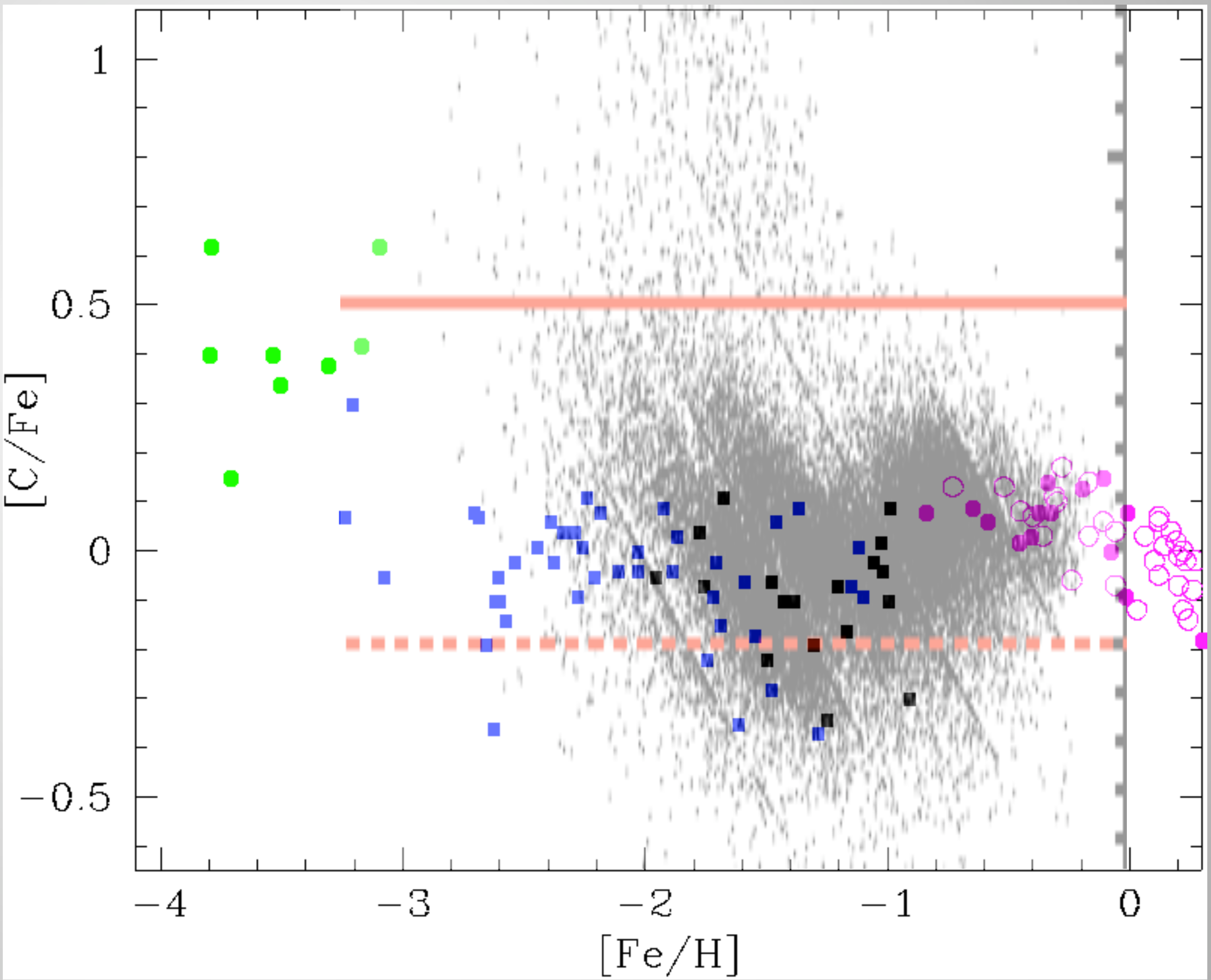
Overlaid on that we show the SDSS sample of Carollo et al. 2013 offset by 0.2 dex in [C/Fe]

The dip at -1.3 seems real.



Can we do as well in dSphs?

Dwarf stars in dwarf Sphs are just not an option.

However, perhaps we can correct for the depletion rate along the giant branch and recover the initial “unmixed” abundance ratio. This correction will have to be a function of metallicity

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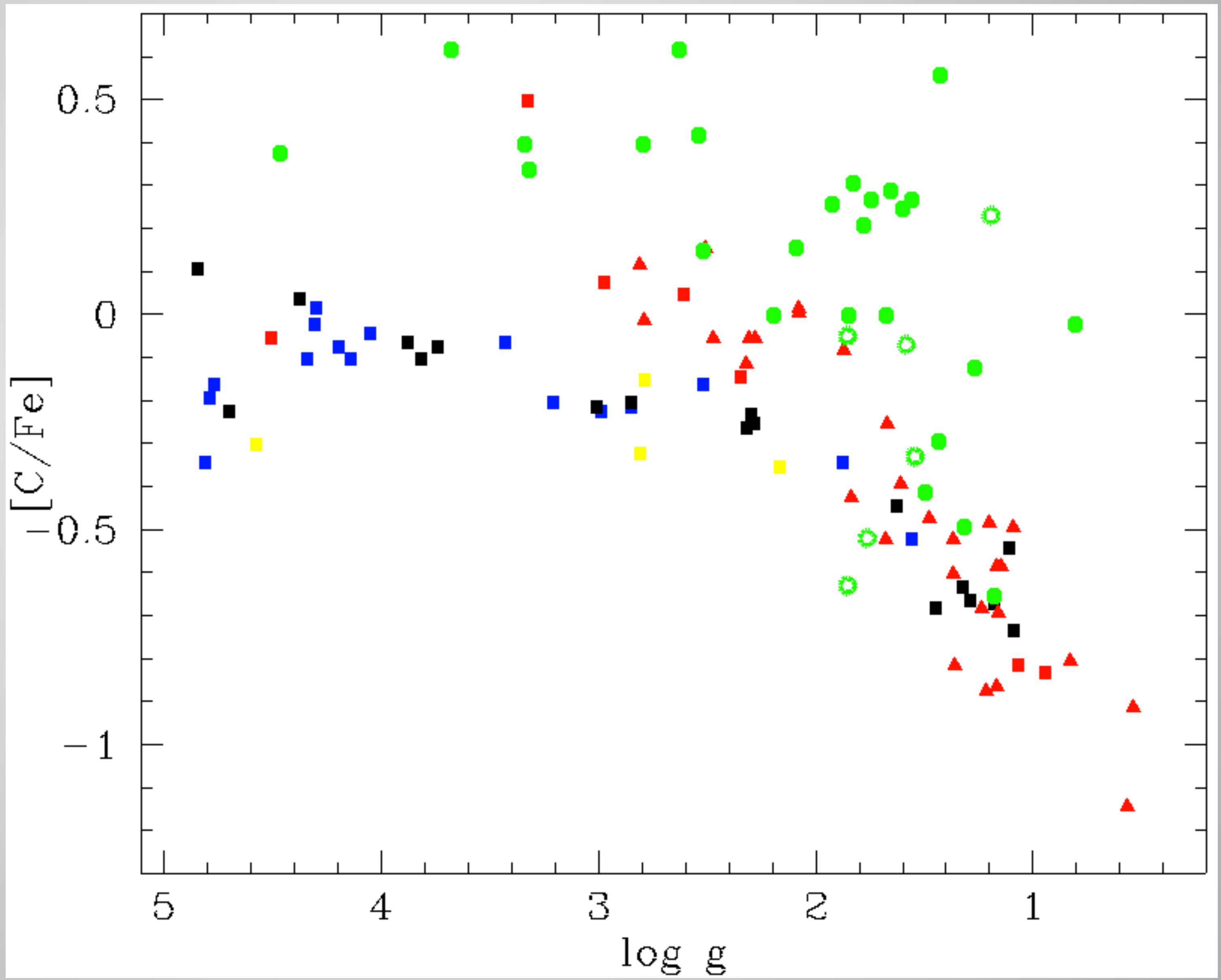

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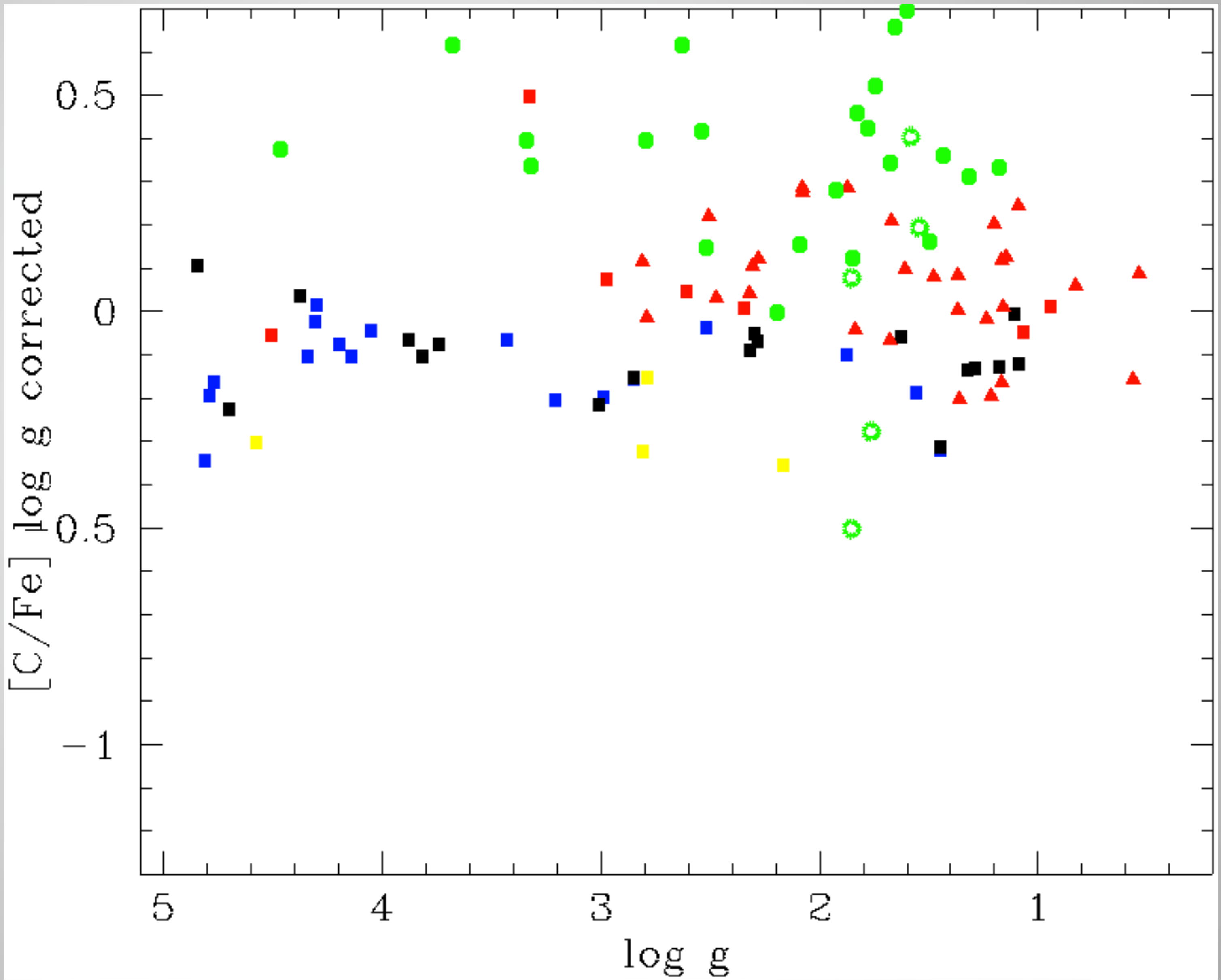

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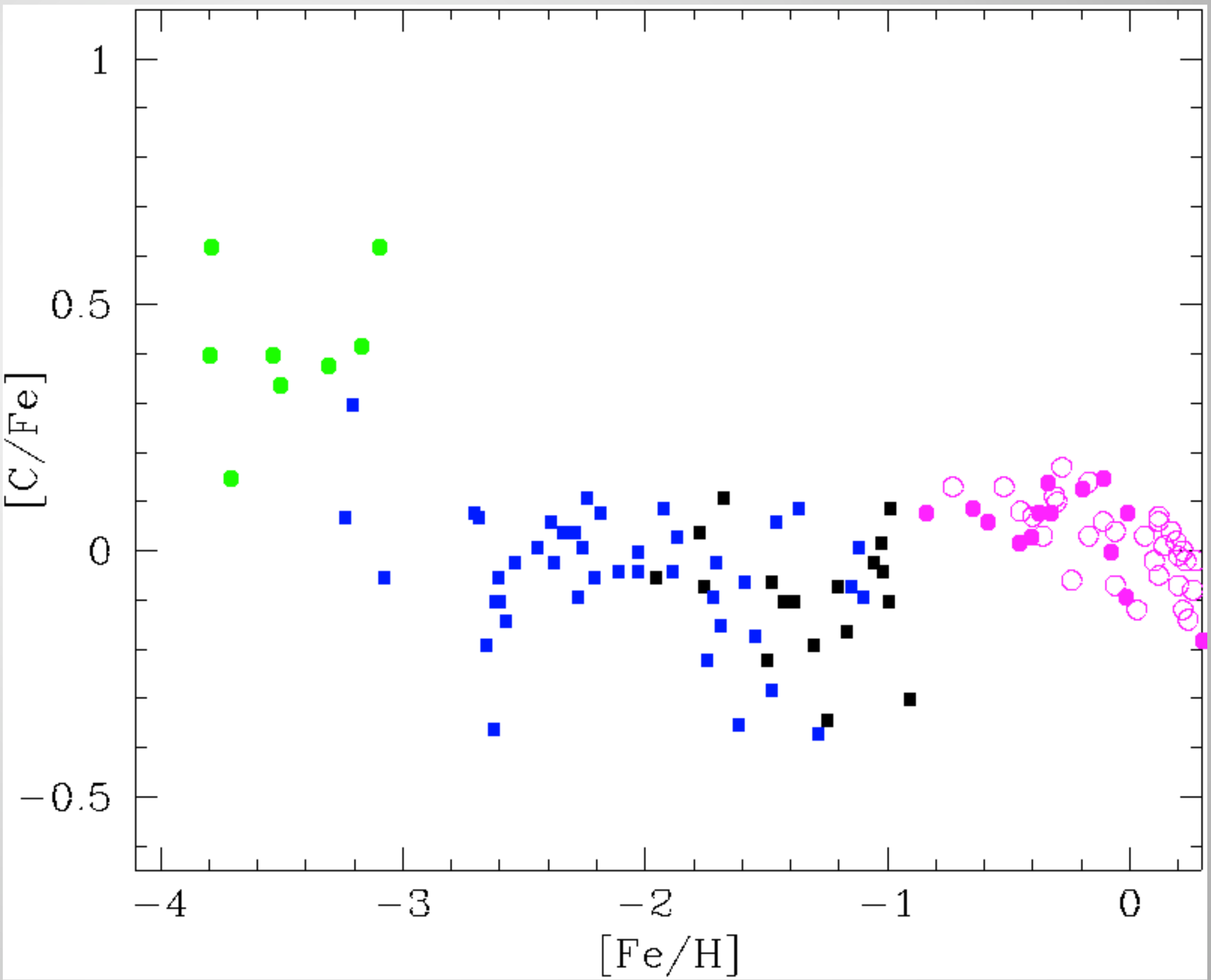

Milky Way [C/Fe] trends

Here we show the data from dwarfs and subgiants and corrected [C/Fe] for giants:

Bensby & Feltzing 2006 thin disk sample open circles
Bensby & Feltzing 2006 thick disk sample as filled cirlces
Gratton et al. 2000 subgiant and dwarf sample as squares.
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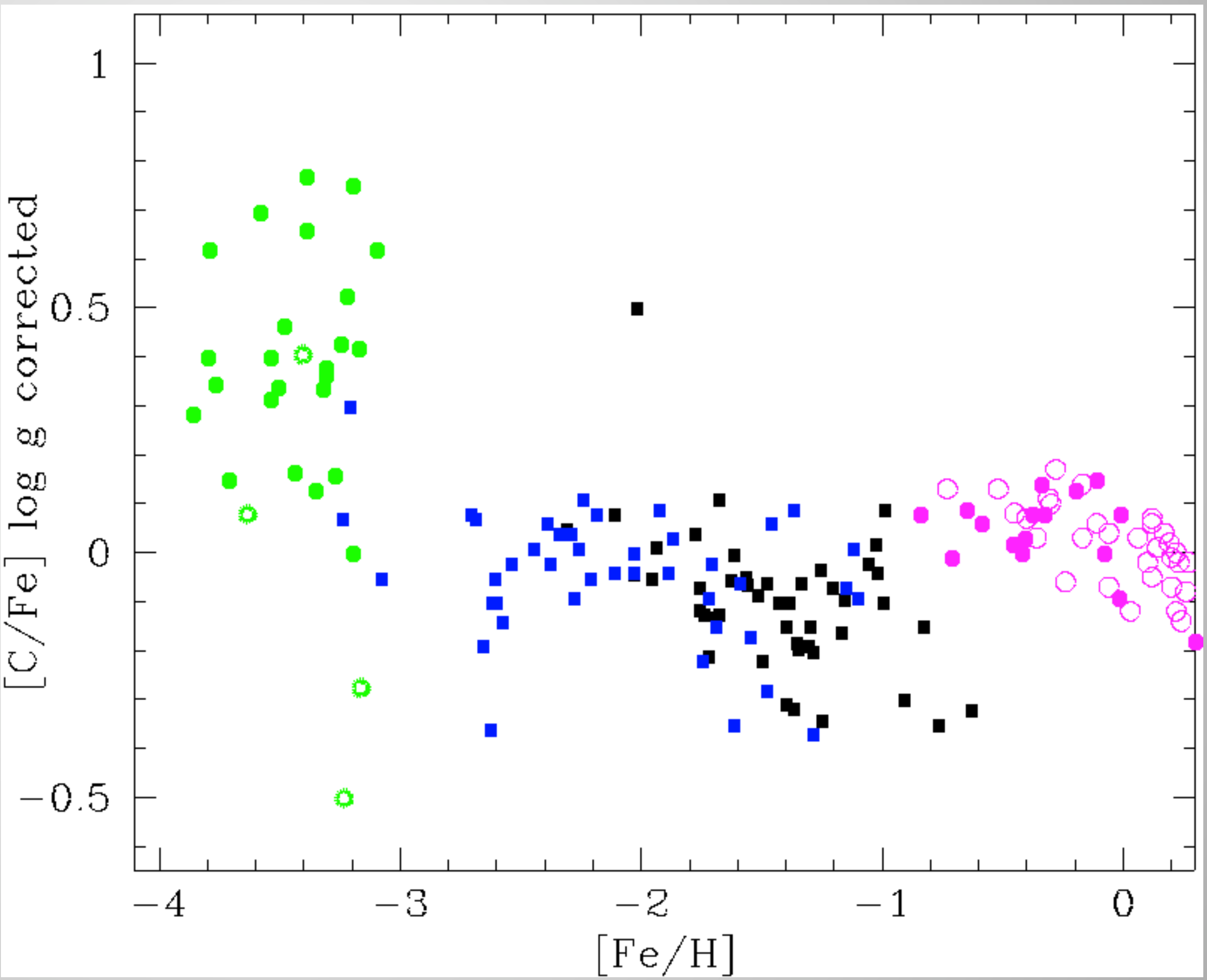

Correcting Draco dSph at [Fe/H] = -2

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Samples between -2.2 < [Fe/H] < -1.8

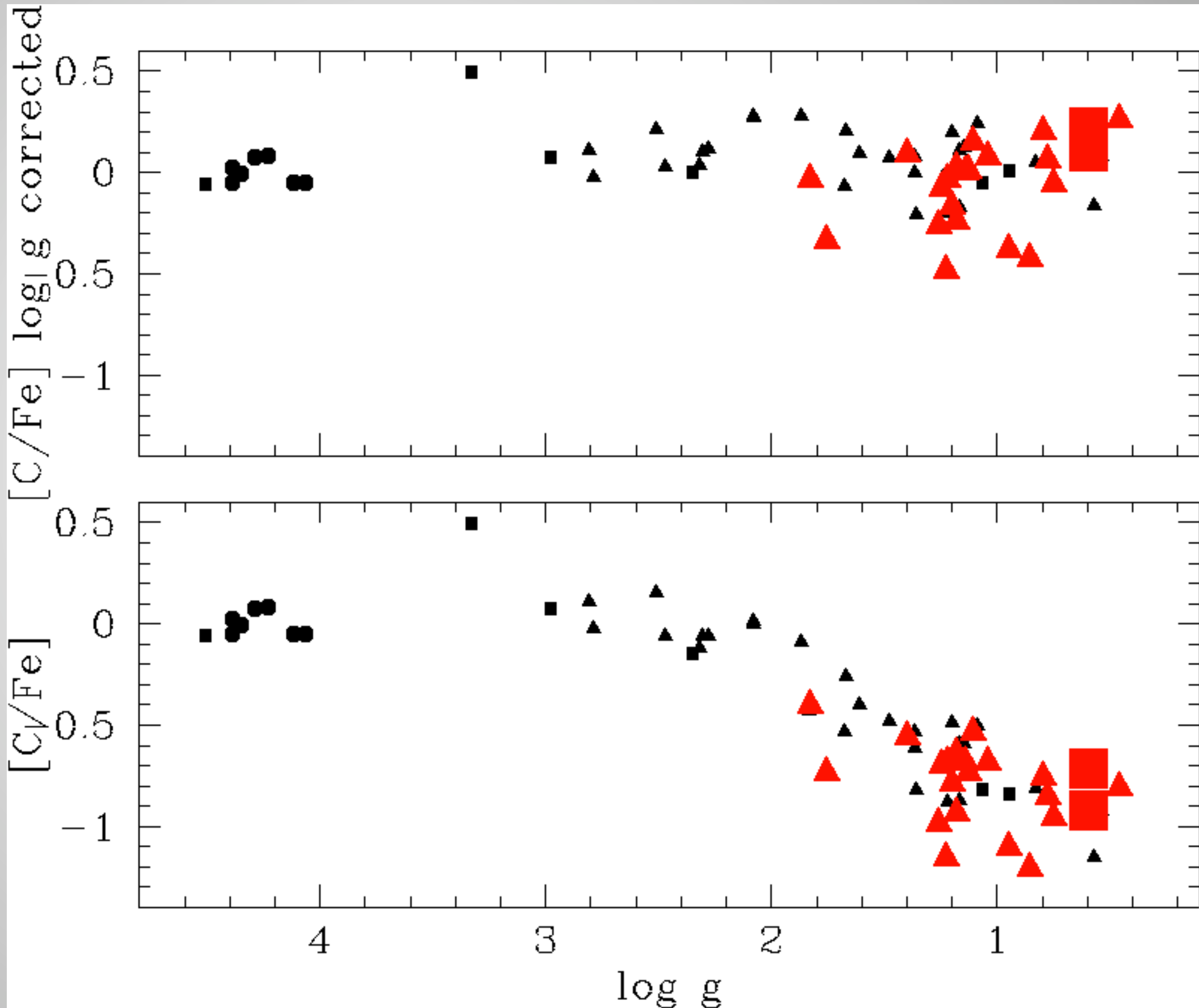
Black squares are from Gratton et al. 2000

Black circles from Fabian et al. 2009

Black triangles from Shetrone et al 2010

Red triangles from Draco stars in Shetrone et al. 2012

Red squares from Draco stars in Cohen et al. 2009 adjusted as in Shetrone et al. 2012.



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Draco [C/Fe] evolution

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Black circles from Fabian et al. 2009

Black triangles from Shetrone et al 2010

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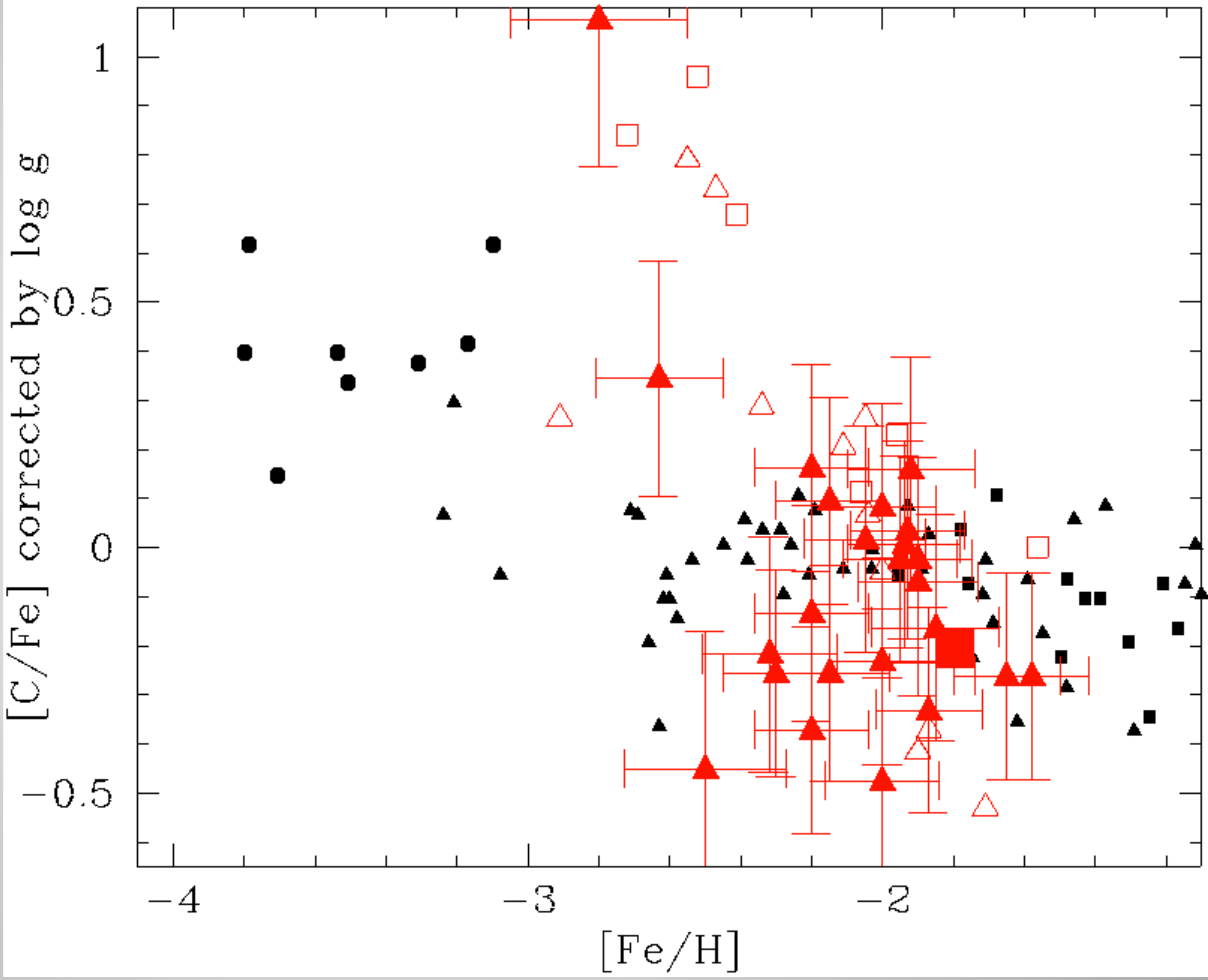
Open symbols are log g < 1.0



Draco [C/Fe] evolution

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Blue squares from Draco stars in Cohen et al. 2010 adjusted as in Shetrone et al. 2012.

Open symbols are
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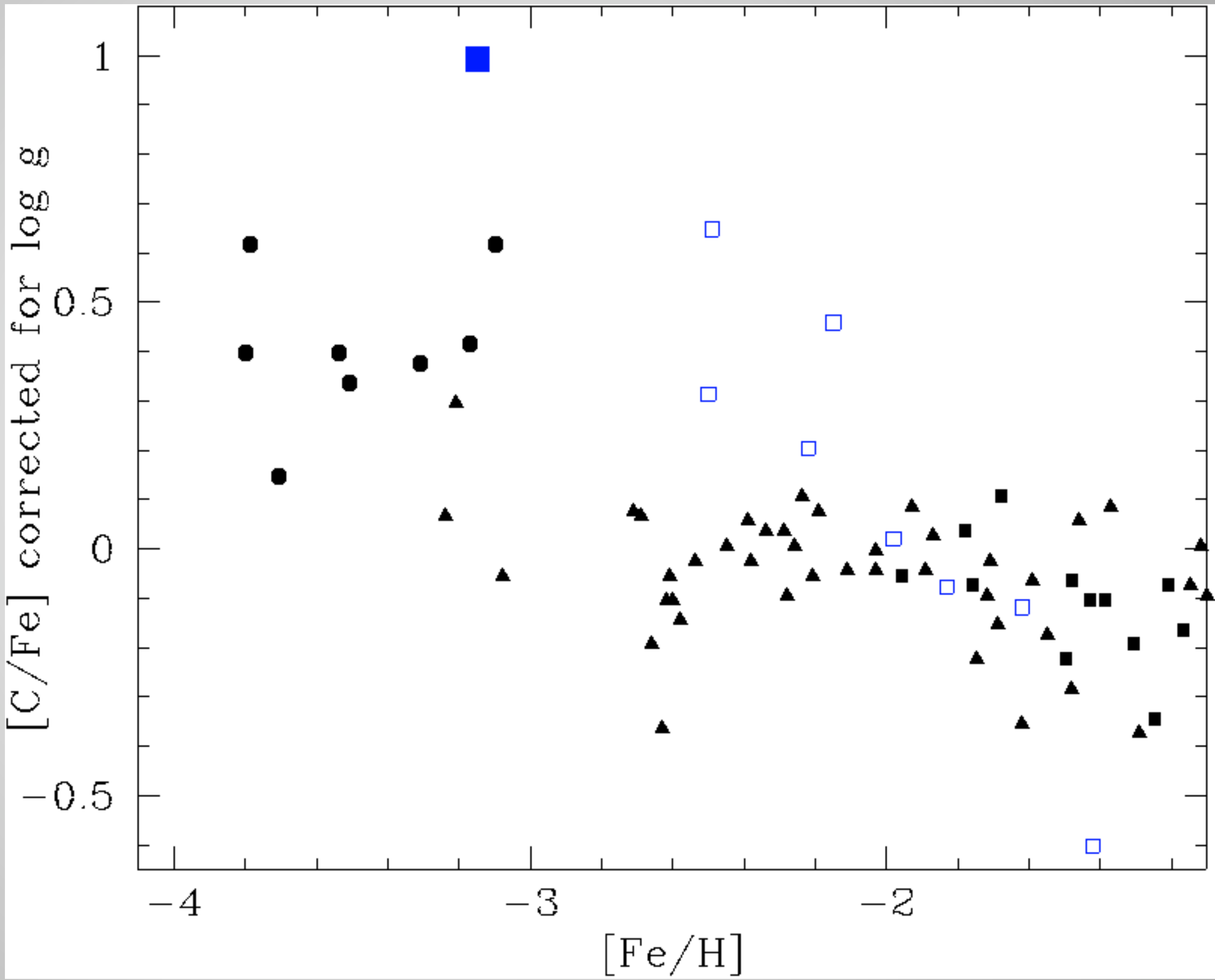


Sculptor and Carina

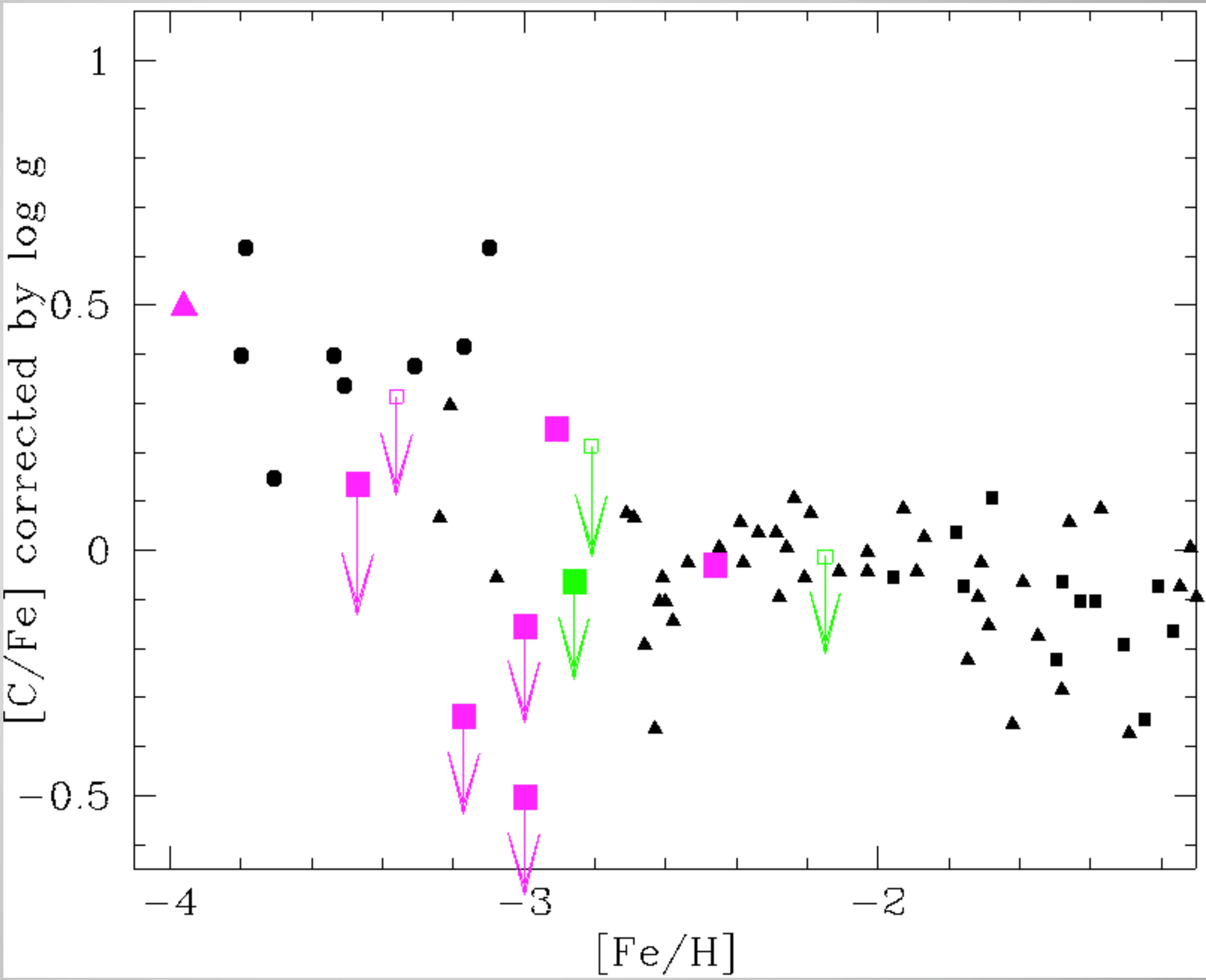
Black squares are from Gratton et al. 2000
Black circles from Fabian et al. 2009
Black triangles from Shetrone et al 2010

Magenta triangles from SCL stars in Tafelmyer et al. 2010

Magenta squares from Draco stars in Starkenburg et al. 2013

Green squares from Venn et al 2012.

Open symbols are log g < 1.0



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CEMP stars in dSph

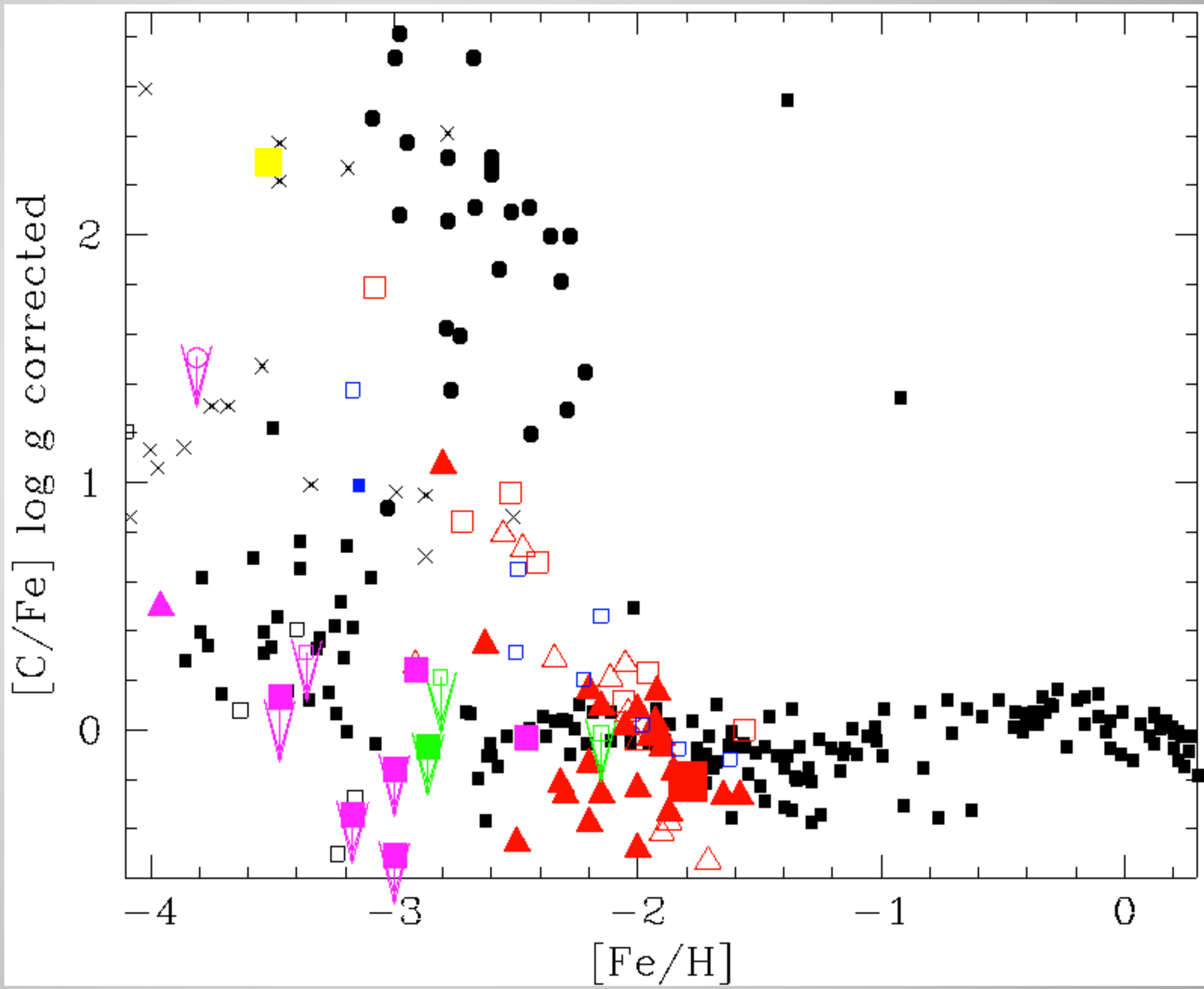
The entire samples including CEMP stars.

Clear CEMP stars in

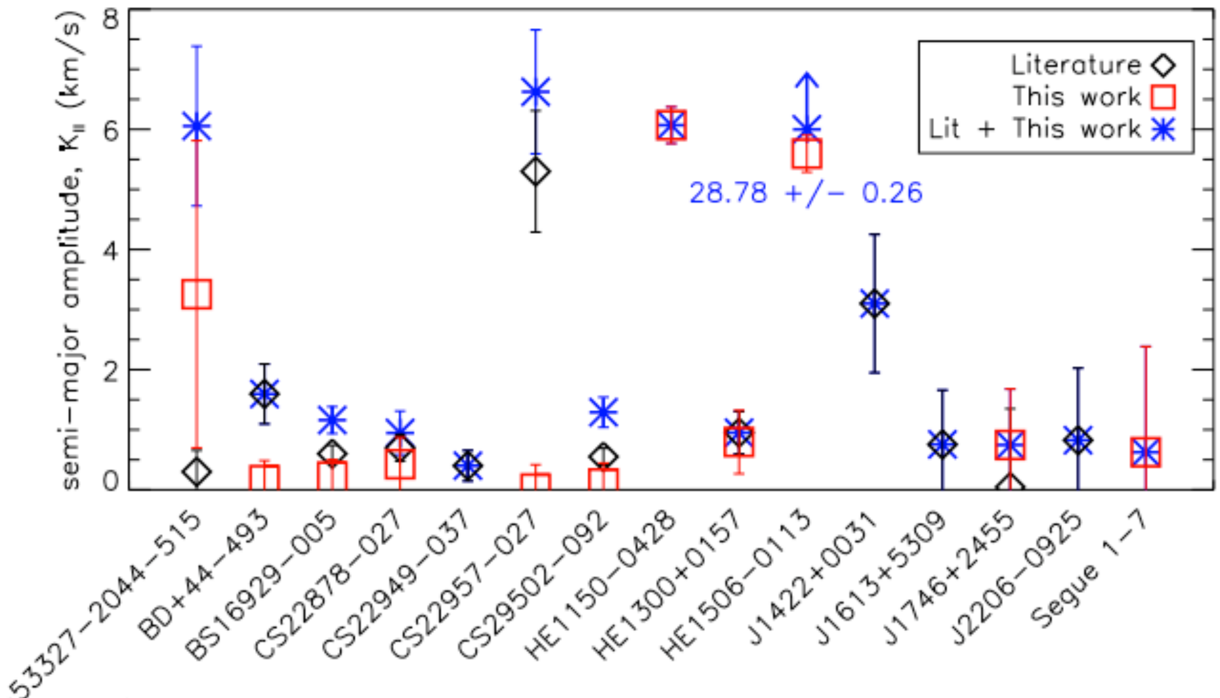
Draco, U Mi and Segue

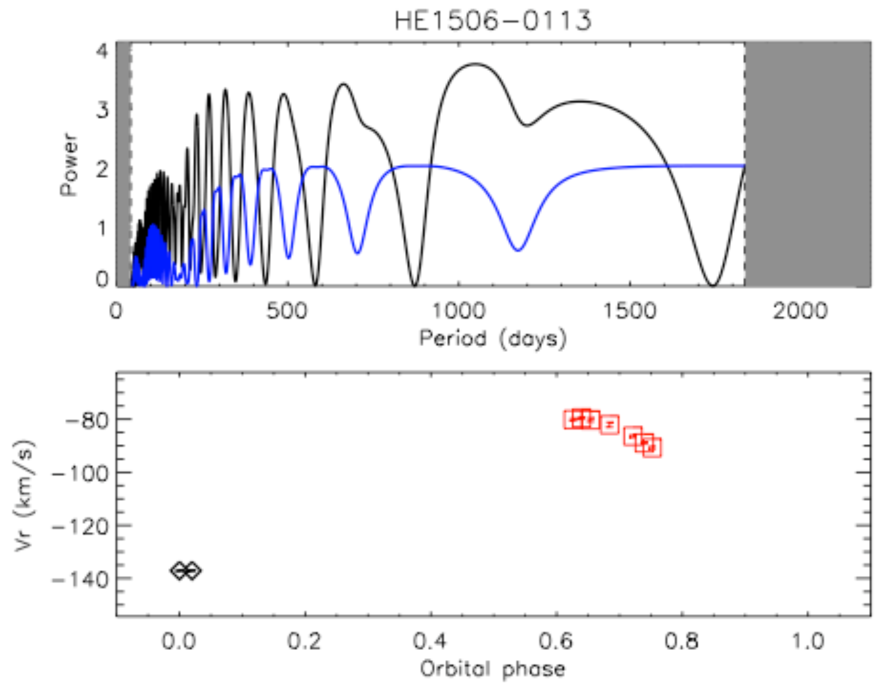
More CH, & C-stars known but with unknown metallicities and [C/Fe] values from:

Armandroff et al. 1995
Shetrone et al. 1998
Shetrone et al. 2001
And others.



CEMP-no stars





91% of literature CEMP-no stars have less than 5 RV measurements
43% of literature CEMP-no stars have only 1 RV measurement

We have a program on HET, SALT and CFHT to measure RV observations.
Preliminary estimates suggest that their binary fraction is “normal”.

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Conclusions

It may be possible to get "un-diluted" [C/Fe] values from giants if enough care is given to how mixing occurs on the giant branch as a function of metallicitiy.

The dSph seem to fill parts of [C/Fe] vs. [Fe/H] space than the Halo but there is some suggestion that this varies from galaxy to galaxy.

Need modelers help to interpret trends.

CEMP stars do exist in dSph stars. Reanalysis of the literature C and CH stars may uncover more.