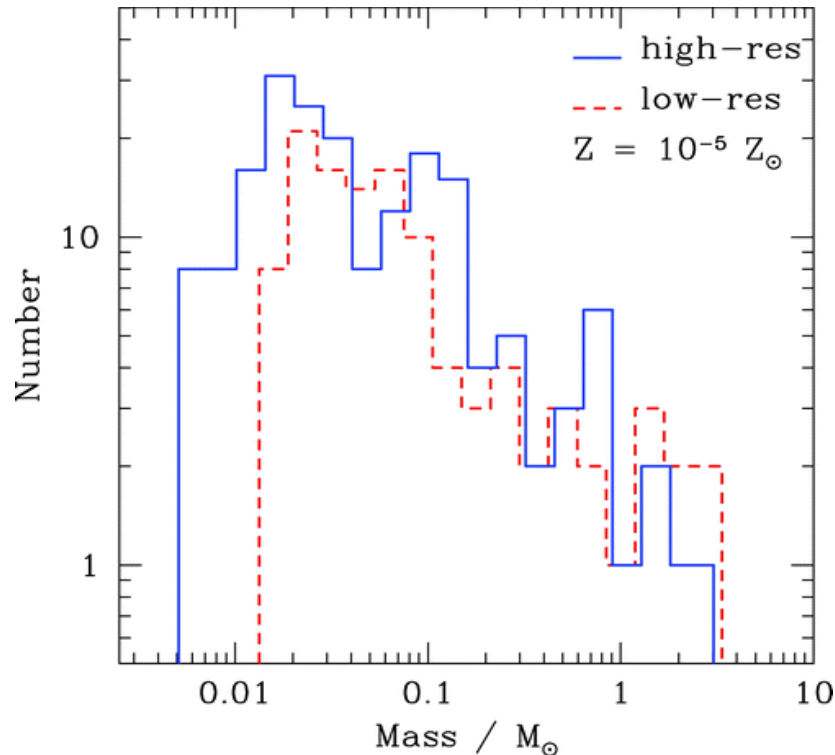**Sara Lucatello**

INAF – Padova Astronomical Observatory

BINARIES AT LOW METALLICITY

Why we care, what we know, what we do not know and what we are doing to improve that
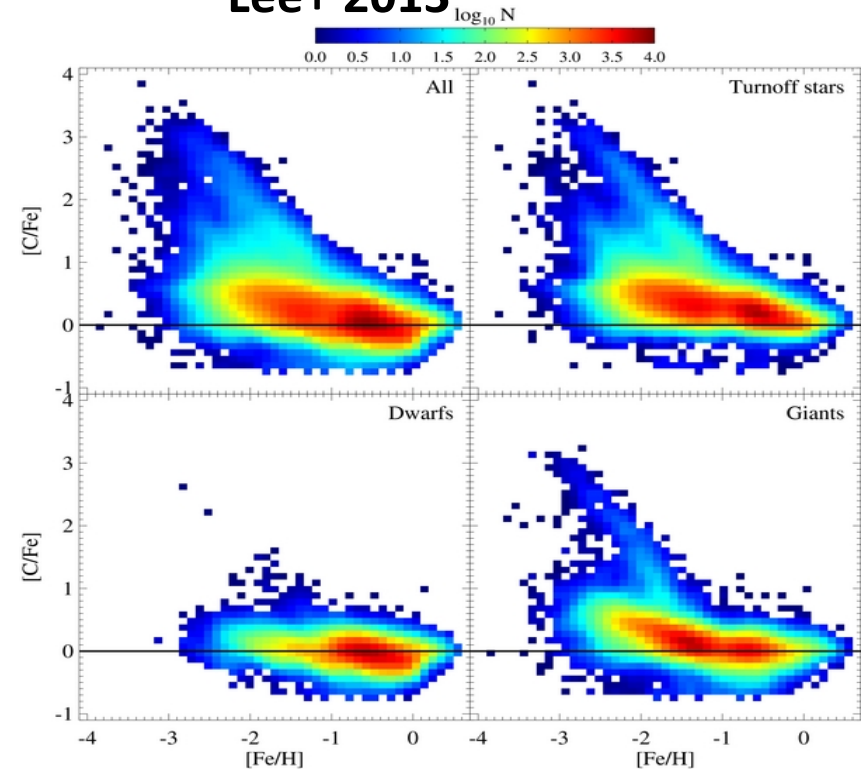
Why are binaries interesting?

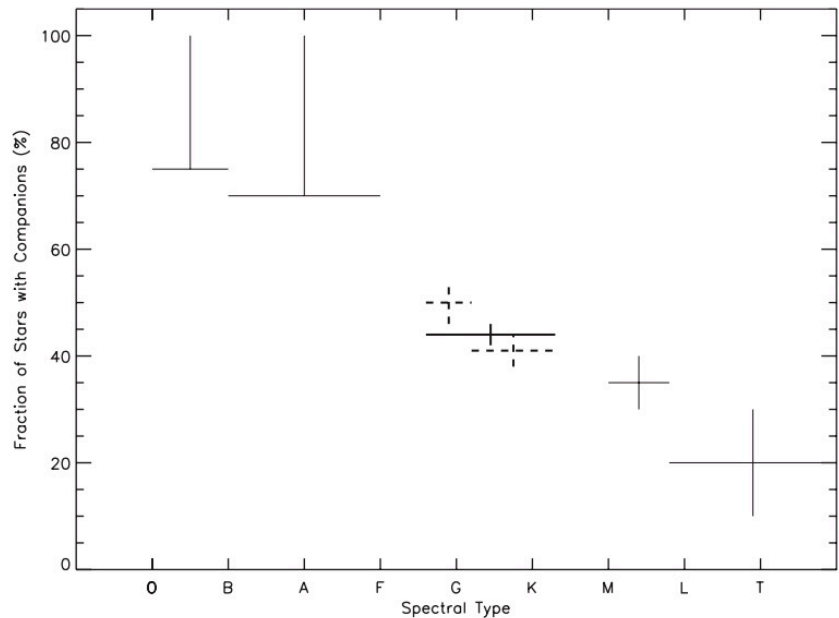**Clark+2008**

Lee+ 2013

Constrain star formation

Explain chemical anomalies, insight into nucleosynthesis
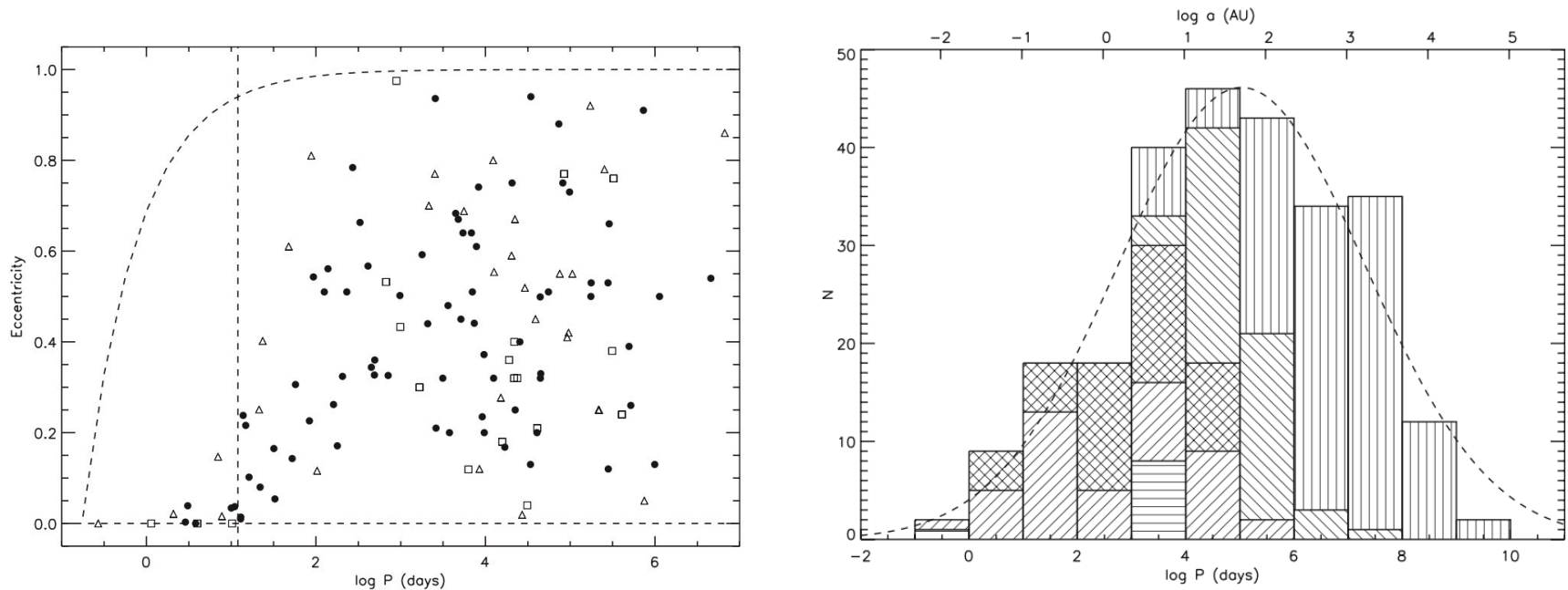
What we know: solar neighborhood

- A very large fraction of stars in the Solar Neighborhood are in multiple systems.

- Raghavan+ 2010 parallax limited survey targeted ~450 solar type stars, 44%+-4% in multiple systems (33% binaries)

Raghavan+ 2010

Orbital parameters distributions

Raghavan+ 2010

Early studies suggested binary fraction was low at low Z (e.g. Abt & Willmarth 87), imaging studies found no change over a large range (Zapatero-Osorio & Martin 04)

Spectroscopic surveys e.g. Carney+05

What we know about low Z binaries?

A few old studies suggested low metallicity population deficient in binaries (Abt & Levy 1969; Abt & Willmarth 1987)

Imaging surveys, combine photometric and proper motion infos. Ryan 1991, Zapatero-Osorio & Martin 2004 find no change over about 2 dex

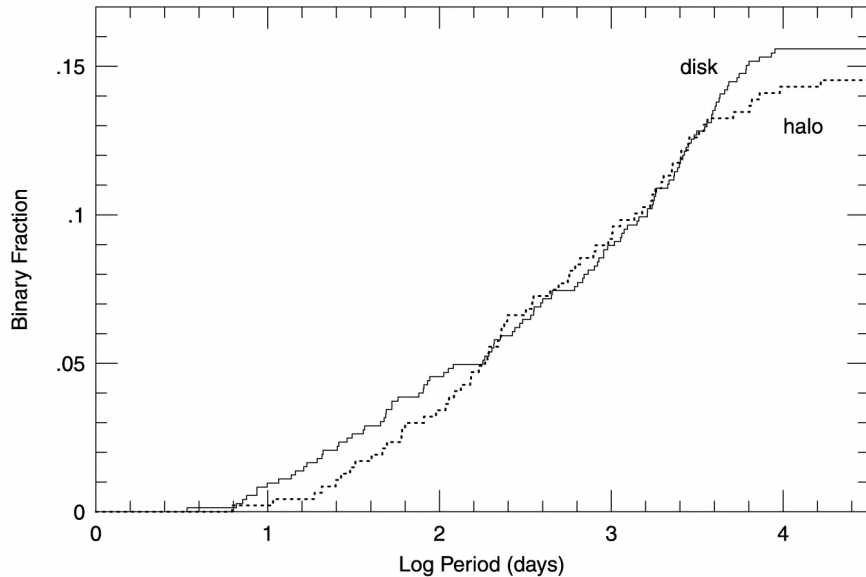Spectroscopic surveys. Carney, Latham etc targeted more than 1300 over 20 years (-2.5<[Fe/H]<0).

Carney & Latham survey
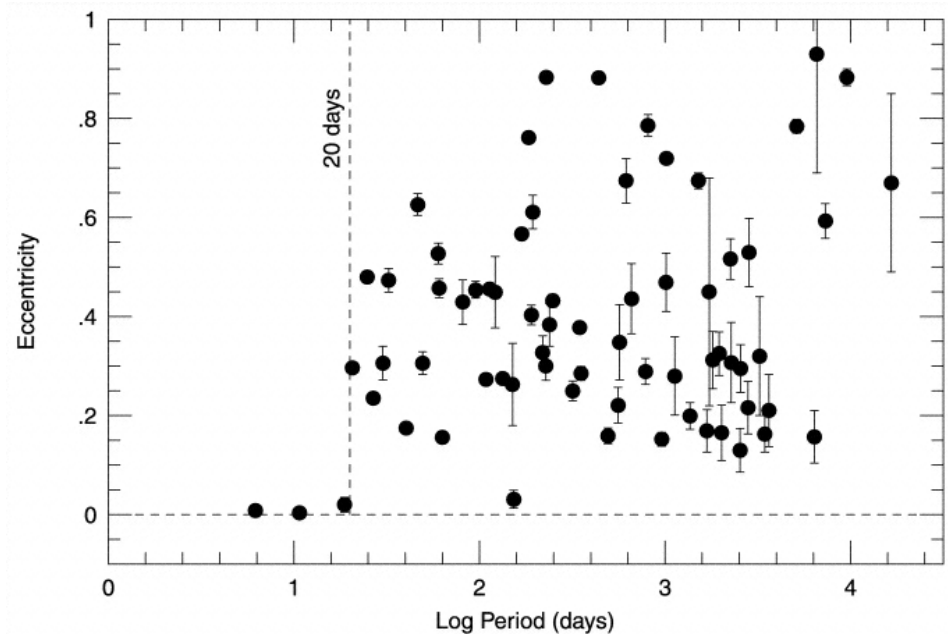
Carney+ 2005, ~1300 metal poor giants 20+ yr monitoring
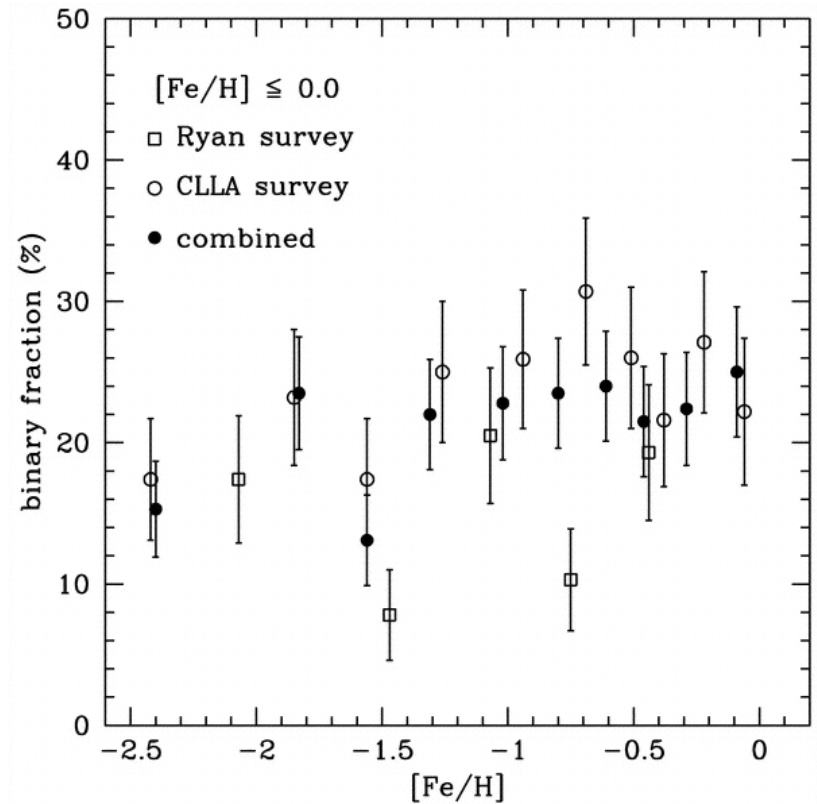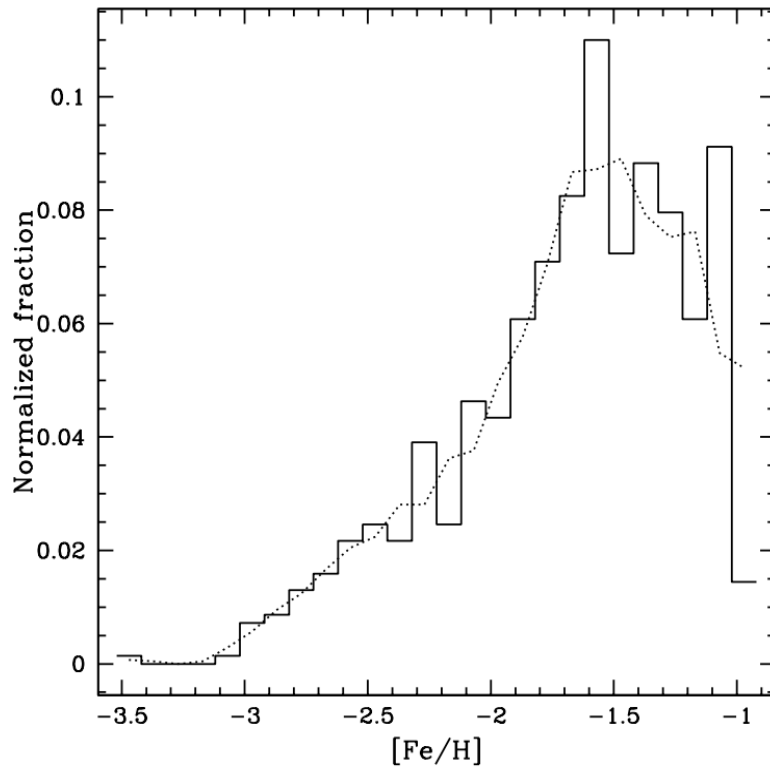
Carney & Latham survey

Carney+ 2005

171 SB1 and 34 SB2 (one eclipsing)

Going for EMP stars

SAGA Metallicity distribution

~987 [Fe/H]<-2.5
~198 [C/Fe]> 0.7
20% CEMP fraction

82 (61 CEMP) multi
epoch RV
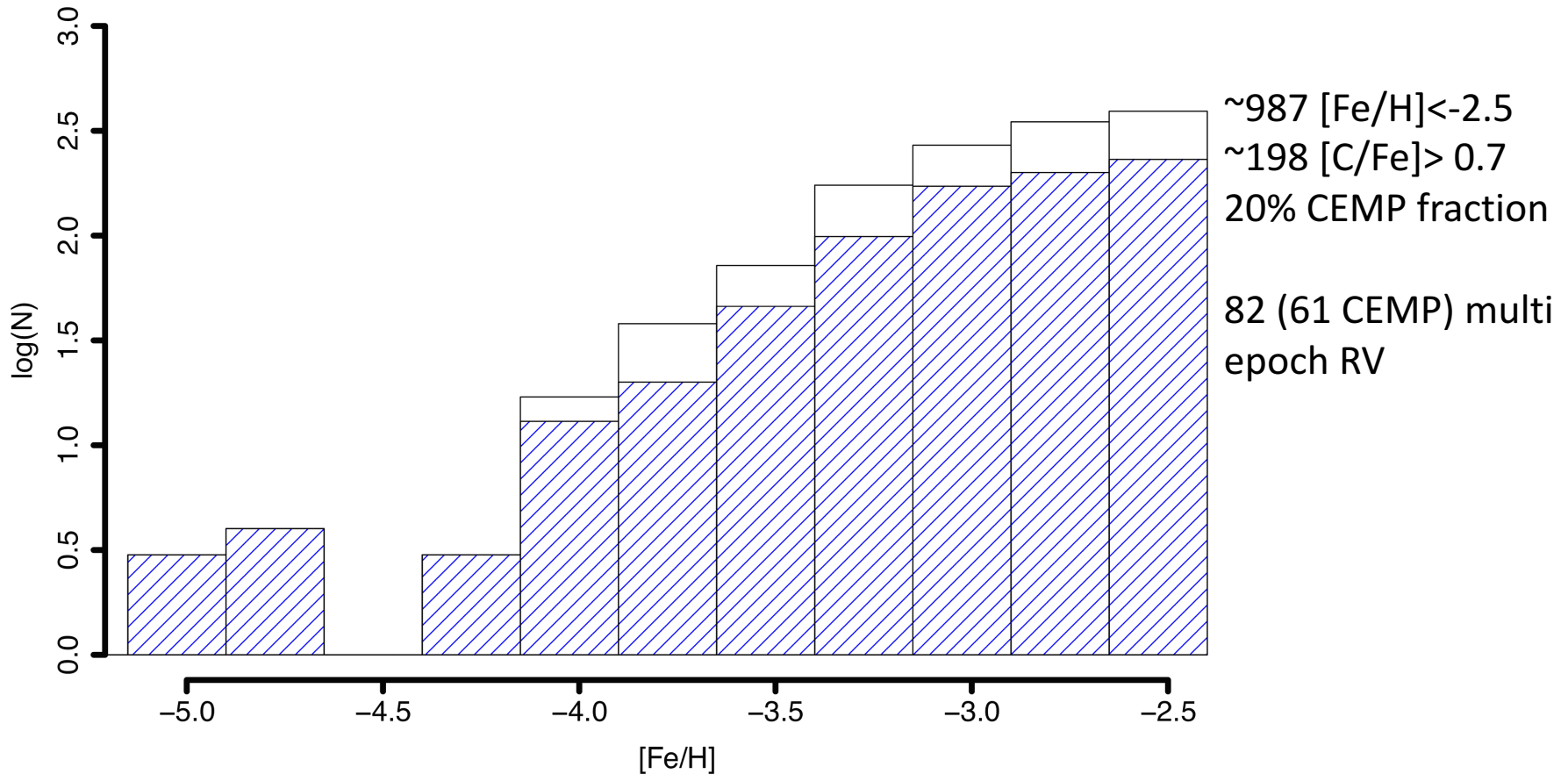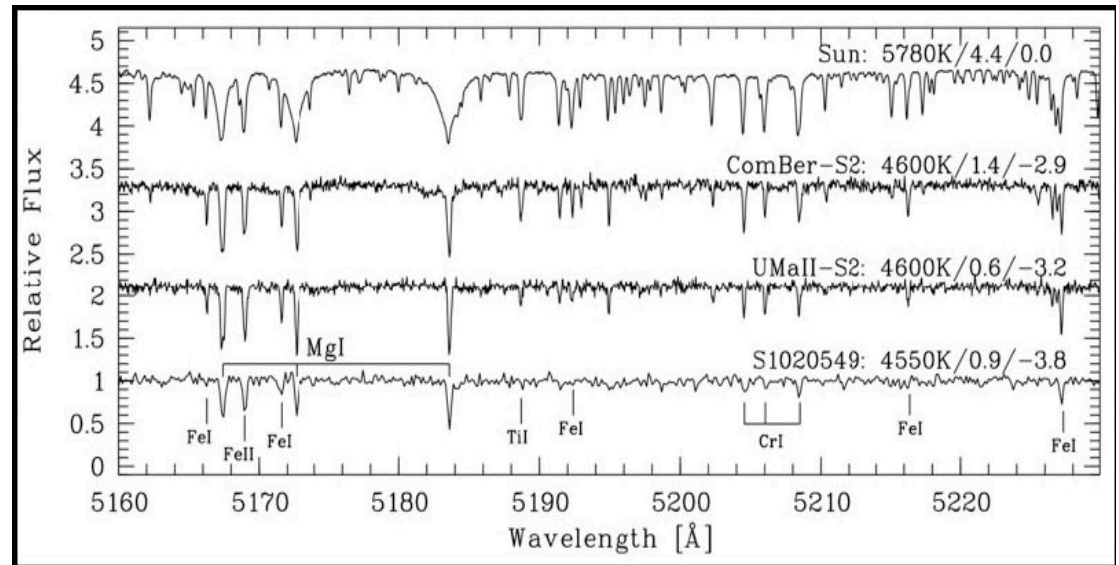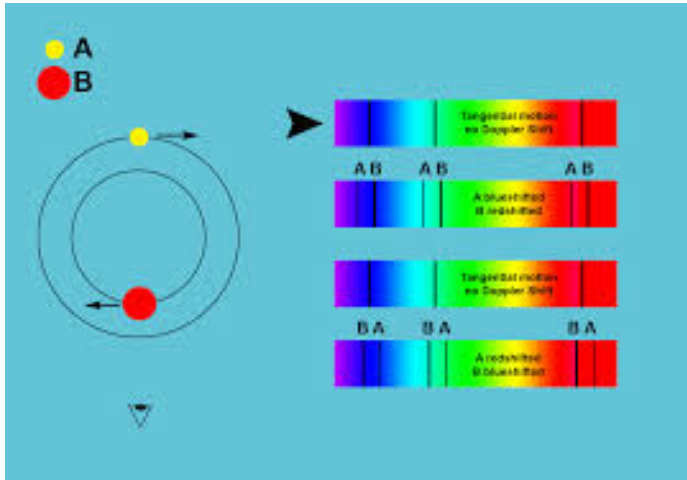
CEMP-s(r/s) likely originate from binaries (Lucatello+05,Starkenberg+14,Hansen+16,Jorissen +16)

30 have orbital solution
18 are for CEMP stars

Subaru RV monitoring includes EMP stars
Aoki+2015 detected RV Variations in 10% of 109 TO EMP stars in 1.5yr (P<1000d)

The Lick EMP binary survey

Mike Bolte (UCSC), Jennifer Johnson(OSU), Sara Lucatello (OAPD-INAF)
(formerly David Lai and Debra Fischer)

- Aimed at determining binary fraction and orbital properties of EMP stars using Hamspec and Automatic Planet Finder
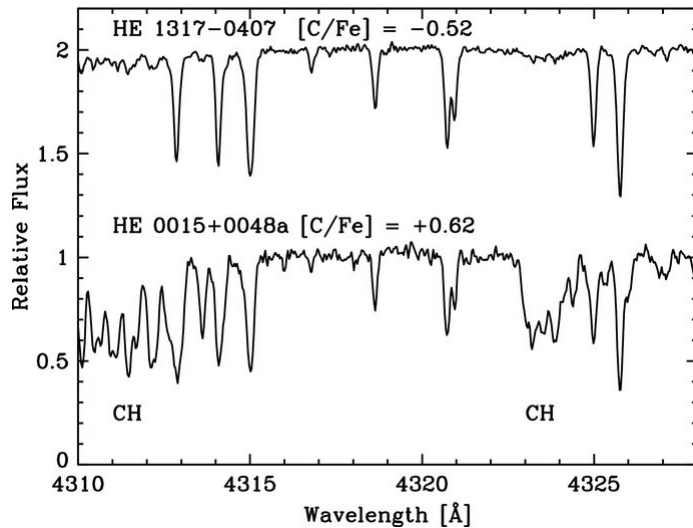
- Initially used hamspec+ iodine cell, not anymore.

- Sample made up of fairly bright (8<V<14) stars with [Fe/H]<-2.5

- Monitoring 45 stars non C-rich stars

# Early results

- Total sample (literature+ours): 61 non C-rich stars
  16 out of 61 stars 26%±8% of our sample
  (Carney+05 sample ~17%±2%)

- Preliminary data indicate higher binary fraction that at higher ([Fe/H]≈-2) metallicity. Consistent with the findings of Aoki+ 2015

- What binary fraction is our detection fraction consistent with?

EMP monitoring MDF
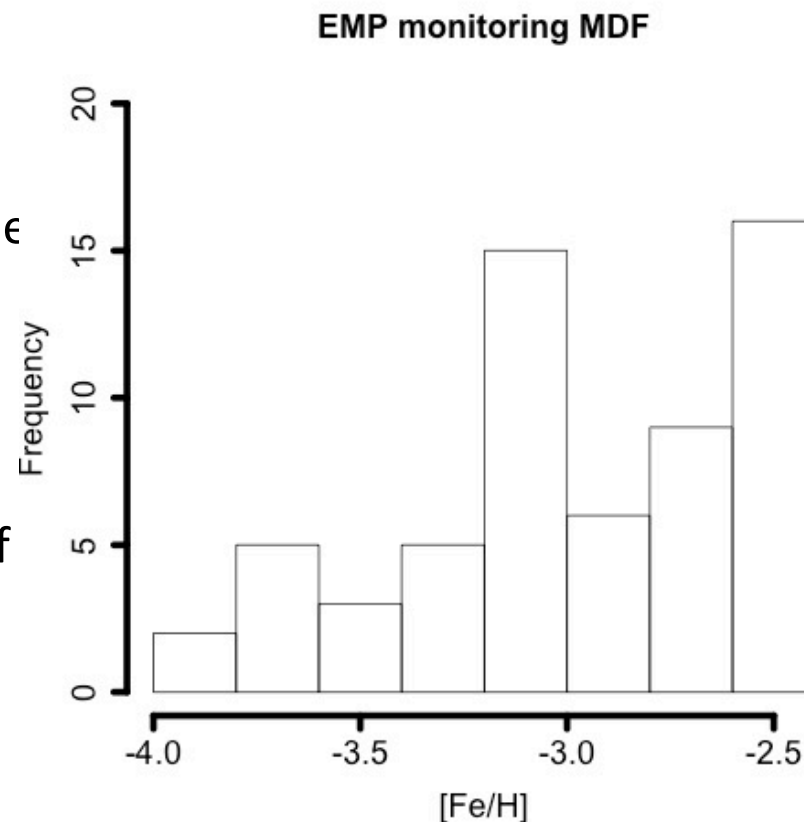
The Lick EMP binary survey: simulations
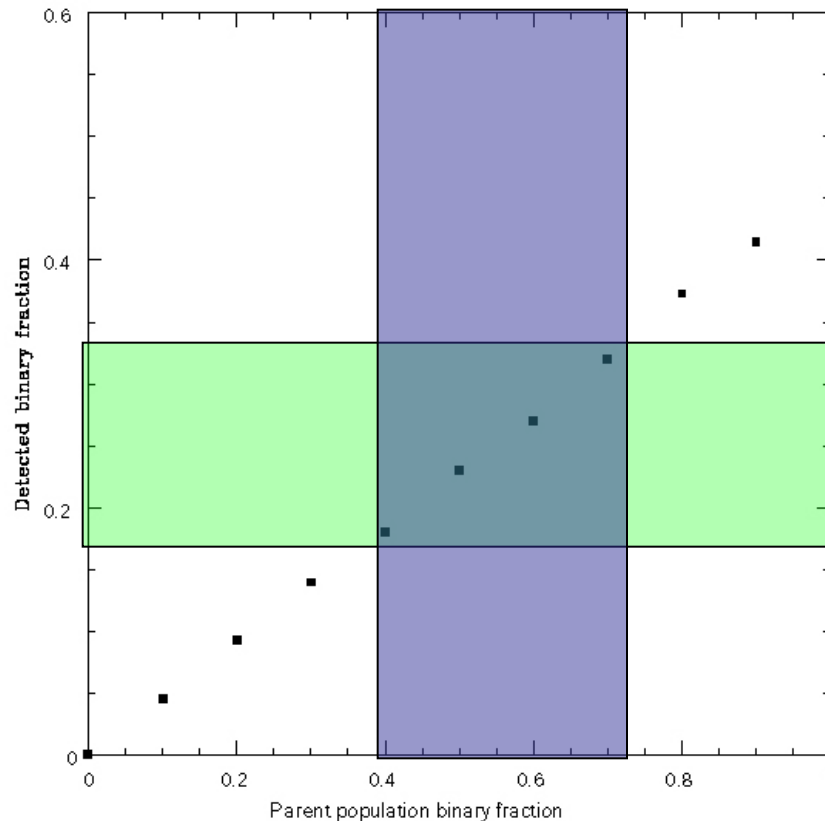
Monte Carlo simulations of detection fraction as a fun-ction of binary fraction with present observational pattern show that the results are consistent with a fairly range of values (40-70% parent population)

Adopted Raghavan+ 2010 P distribution, time baseline (4.5 yr) very small with respect to typical P

Summary & Conclusions

Binarity properties seem to remarkably metallicity independent over a large range -2.5<[Fe/H]<0;

First results suggest that EMP binary fraction might be higher and P distribution skewed towards lower values

In a few years will be able to constrain EMP binary properties (as a function of metallicity): fraction, P and e distribution

For now, exert plenty of caution!

Why are binaries interesting?

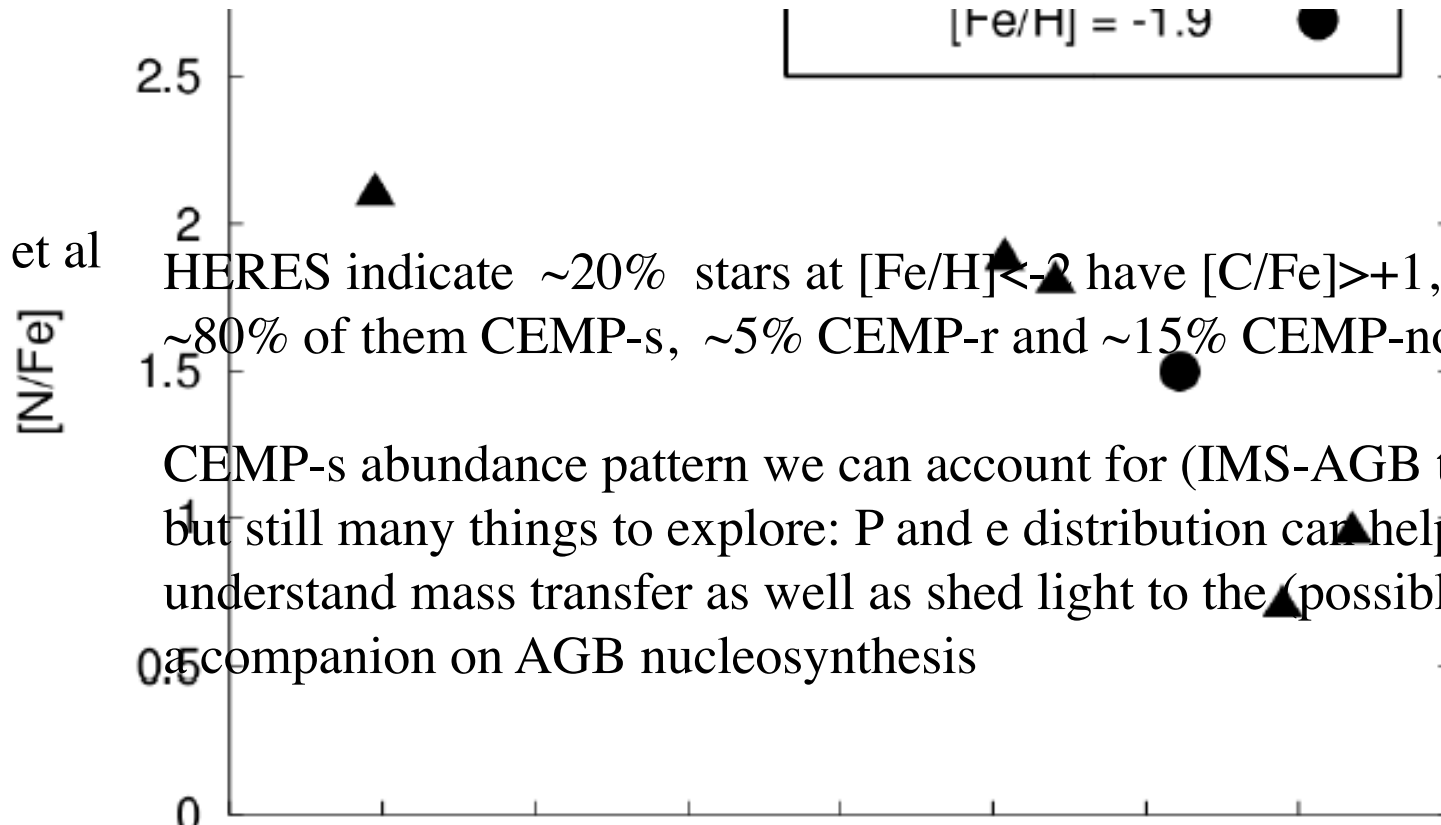They retain lots of information about the star formation process provide a wealth of constraints to star formation theory which must reproduce the observed statistics (P, e and mass ratios distributions etc)

For double lines eclipsing binaries, can measure directly masses;

Explanation for peculiar abundance patterns;

So, are binary characteristics at low Z different from their solar metallicity counterpart?

Herwig et al 2004

HERES indicate ~20% stars at [Fe/H]<-2 have [C/Fe]>+1, ~80% of them CEMP-s, ~5% CEMP-r and ~15% CEMP-no

CEMP-s abundance pattern we can account for (IMS-AGB transfer) but still many things to explore: P and e distribution can help understand mass transfer as well as shed light to the (possible) effect of a companion on AGB nucleosynthesis
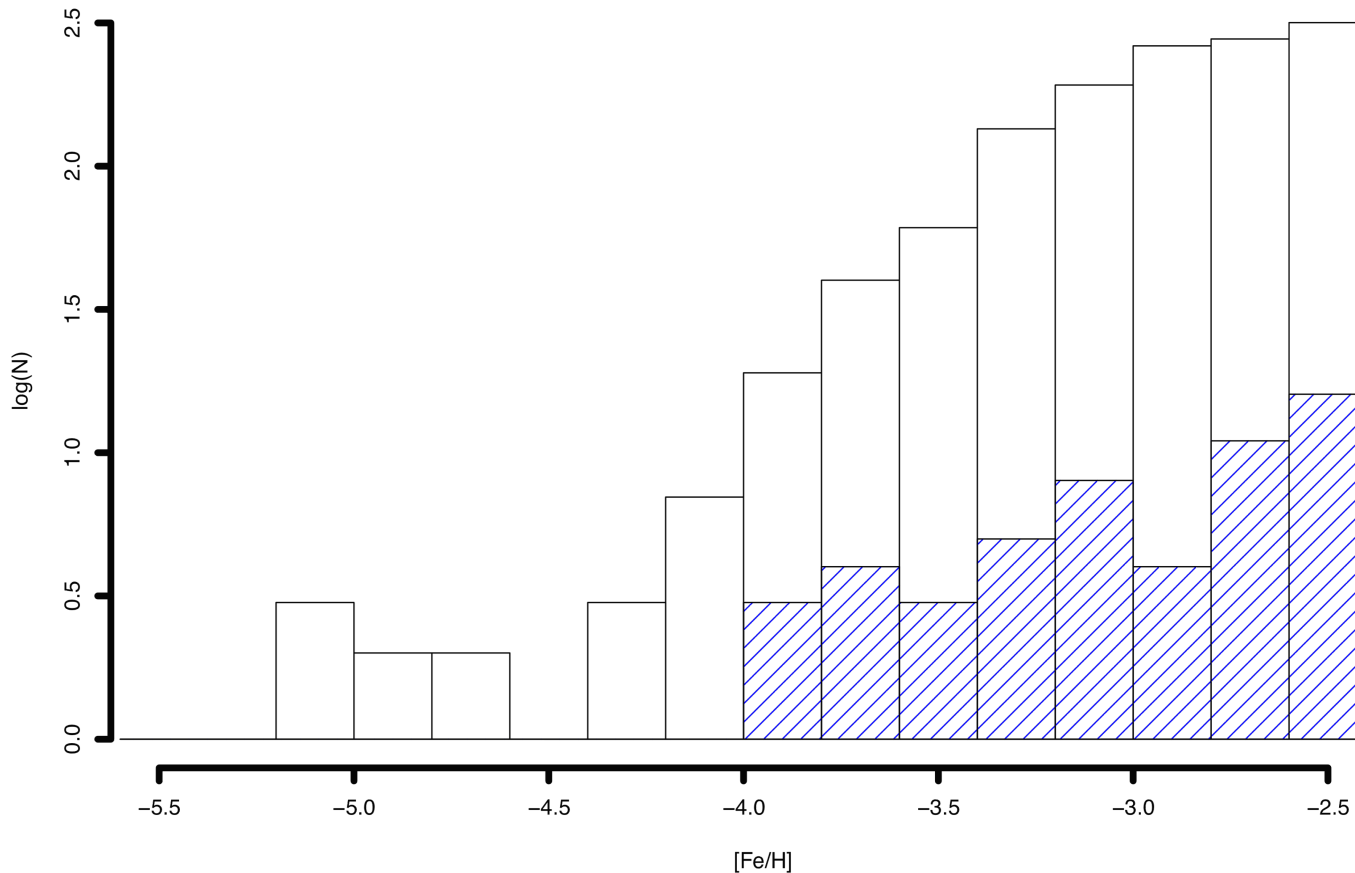
C-stars at low metallicity and binaries

Going for EMP stars

SAGA Metallicity distribution

~1000 [Fe/H]<-2.4
~100 have multiple RV
 30 have orbital solution

Aoki+2015 detect RV
Variations in 10%
among 109 TO EMP stars

C-rich stars and binaries

CEMP-no and CEMP-r origin still a mystery, but it could very well be that binarity plays a role in these cases too, but so far we have not enough data to be able to assess whether this is the case

Multi telescope program (ESO FEROS at 2.2, UVES at VLT, HDS at Subaru, SARG at TNG, UES at WH, UCLES at AAT).

About 50 CEMP stars (s, r and no) monitored over about 3 yr, still ongoing

Typical precision ~0.2-0.3 km/s takes longer baseline to detect Vrad variations, hopefully first results in 1-2 years

Orbital parameters distributions
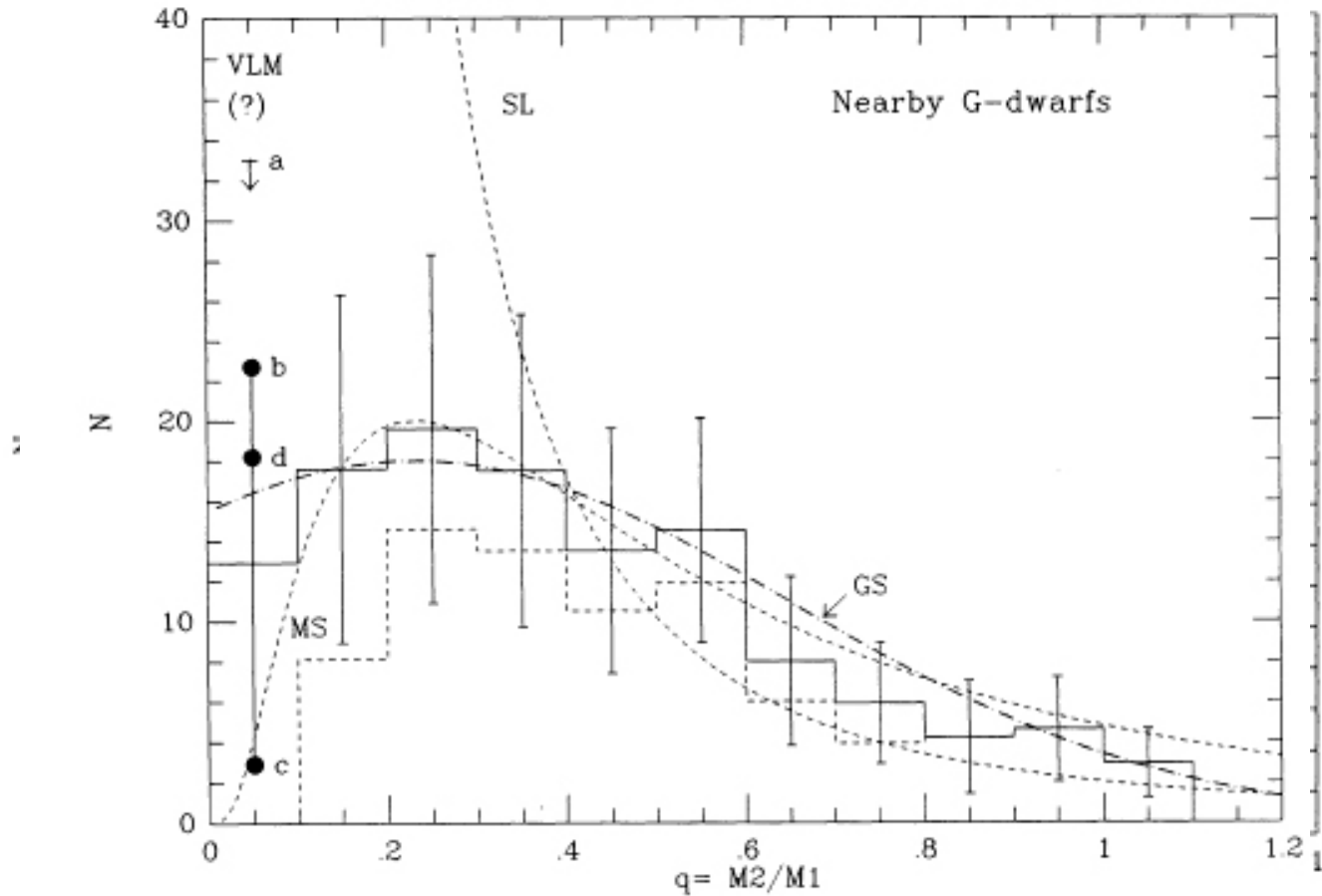
Provide constraints on Pop III SF

IMF?

Binaries at low Z