Small-scale chemical evolution in small-scale dwarf spheroidals

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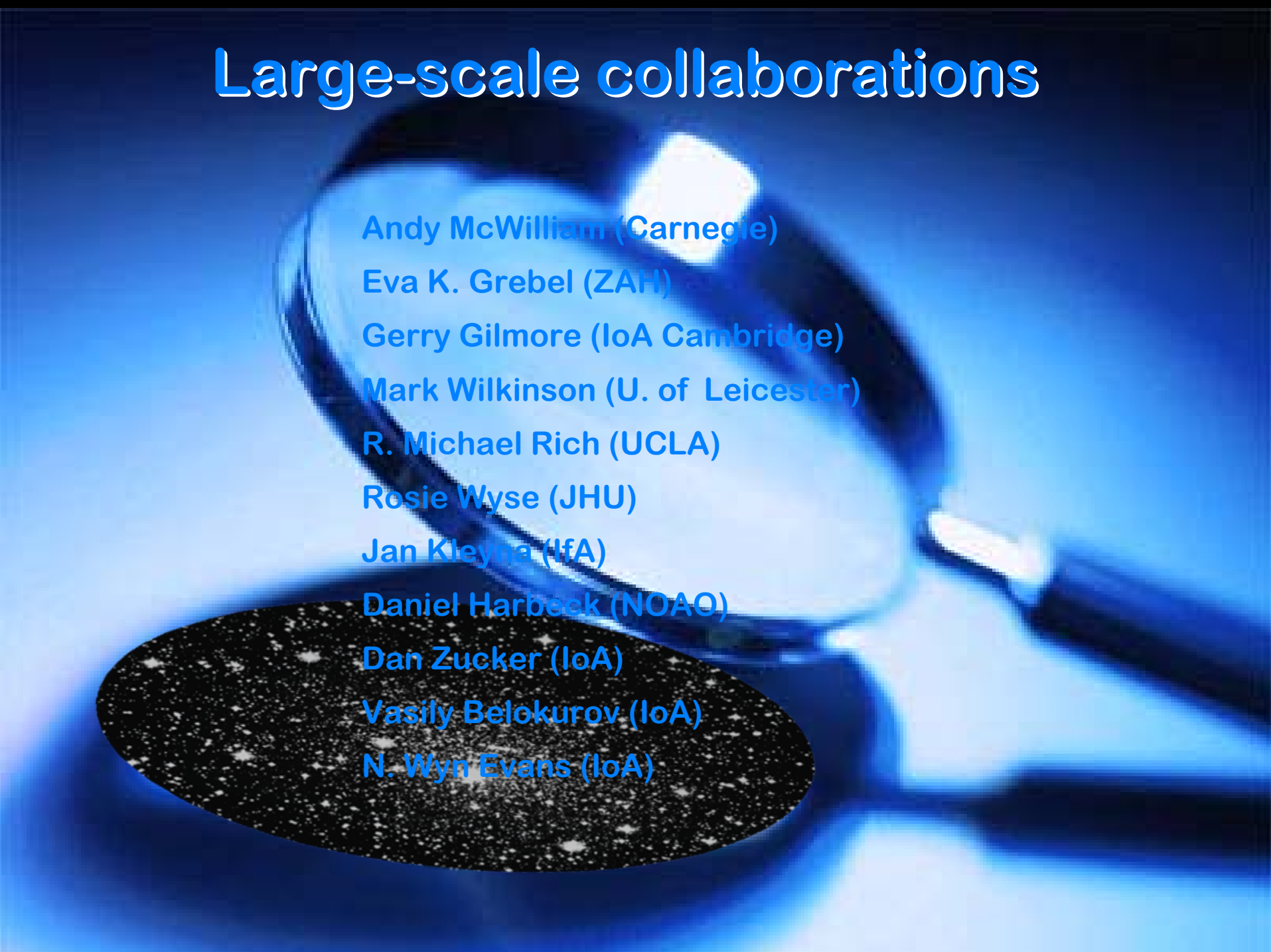
Back to the Galaxy II, KITP, Oct. 30, 2008

Large-scale collaborations



Andy McWilliam (Carnegie)

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Gerry Gilmore (IoA Cambridge)

Mark Wilkinson (U. of Leicester)

R. Michael Rich (UCLA)

Rosie Wyse (JHU)

Jan Kleyna (IfA)

Daniel Harbeck (NOAO)

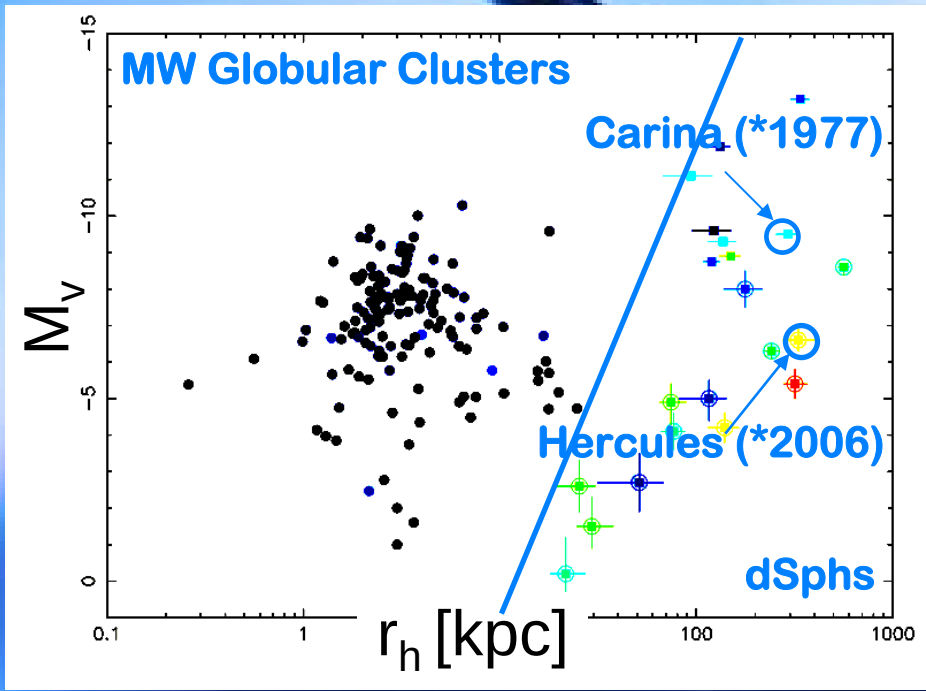
Dan Zucker (IoA)

Vasily Belokurov (IoA)

N. Wyn Evans (IoA)

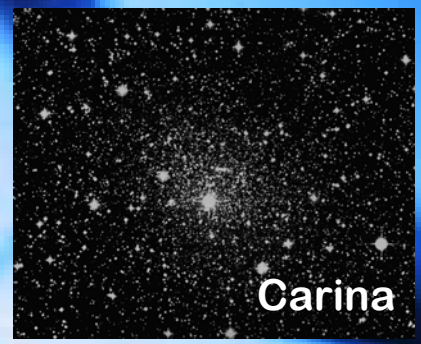
Smallest scales

- dSphs: long been known as *low* luminosity systems.
- Since ~2006: even *ultra*-faint dwarfs (Zucker et al. 2006; Belokurov et al. 2006,2007,2008; Walsh et al. 2007; Irwin et al. 2007).



Martin et al. 2008

(2MASS)



(Kormendy)

(SDSS)

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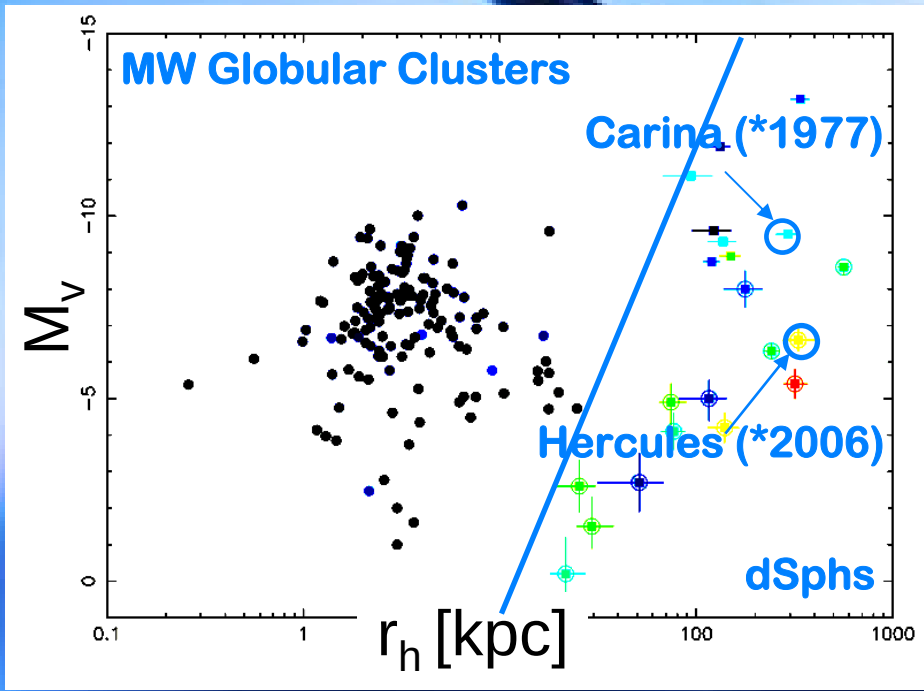
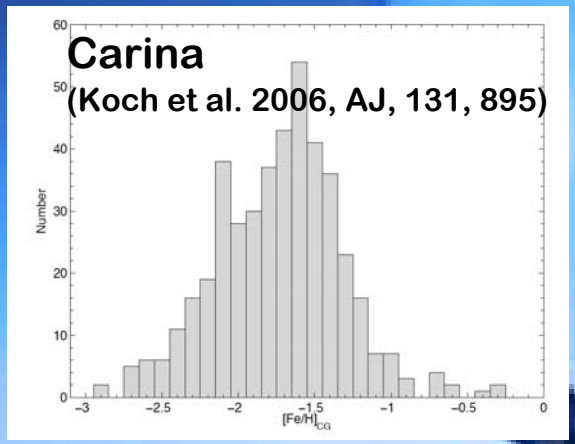


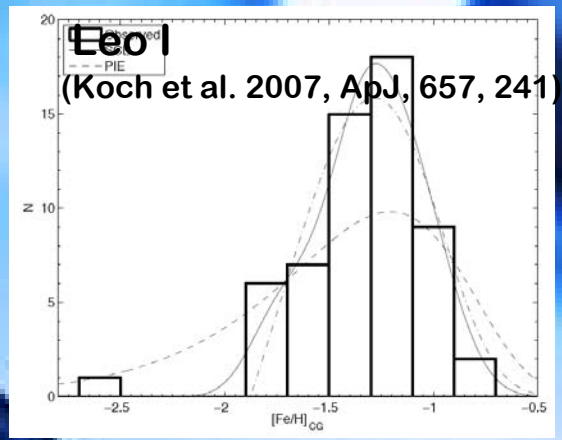
Martin et al. 2008

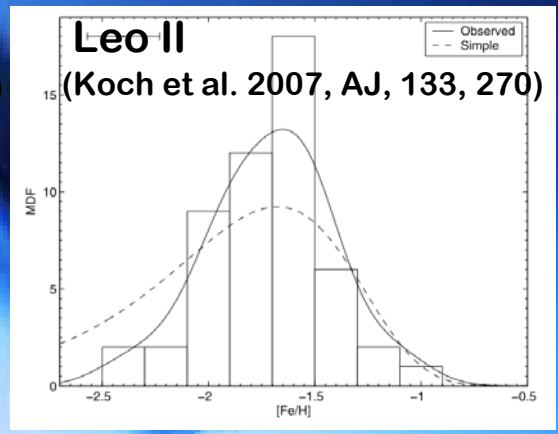
Distinct from GCs. Can study DM on smallest scales.

Small-scale building blocks of large scale halo(s) ?

Chemical aspects of dSphs

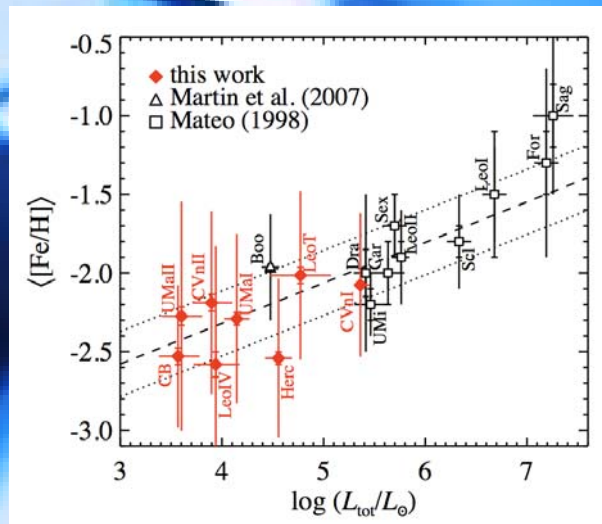






- metal poor
- very few stars with [Fe/H]<-3,
- broad abundance spreads

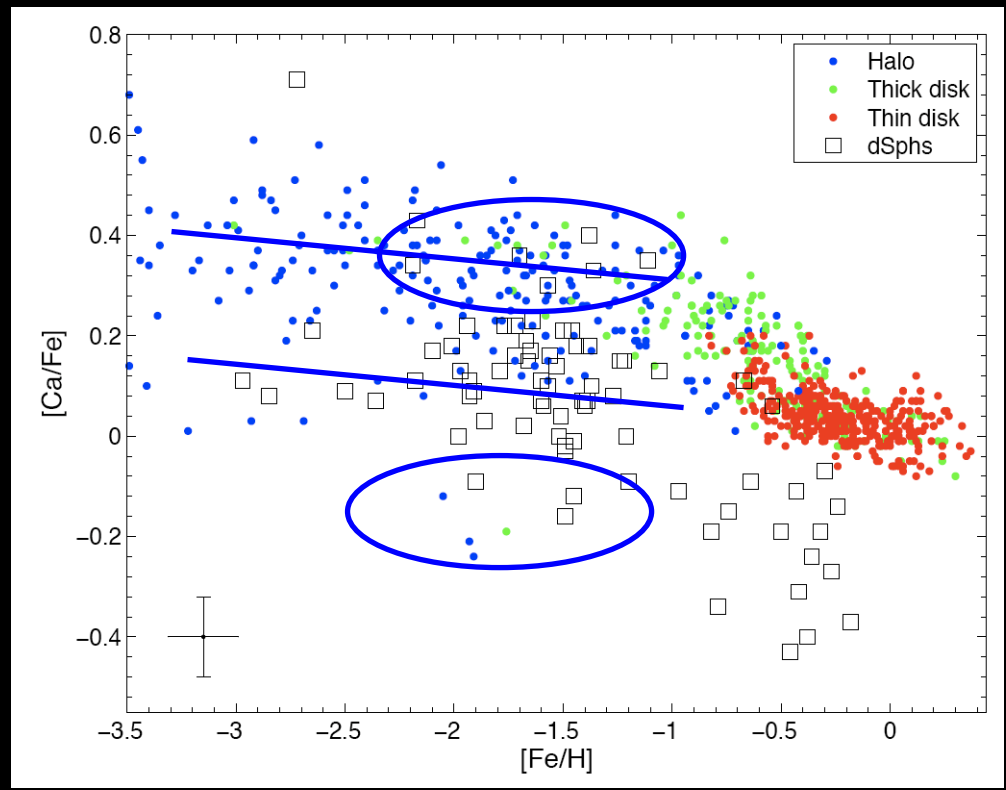
(Helmi et al. 2006;
Koch et al. 2006,2007a,b,2008)



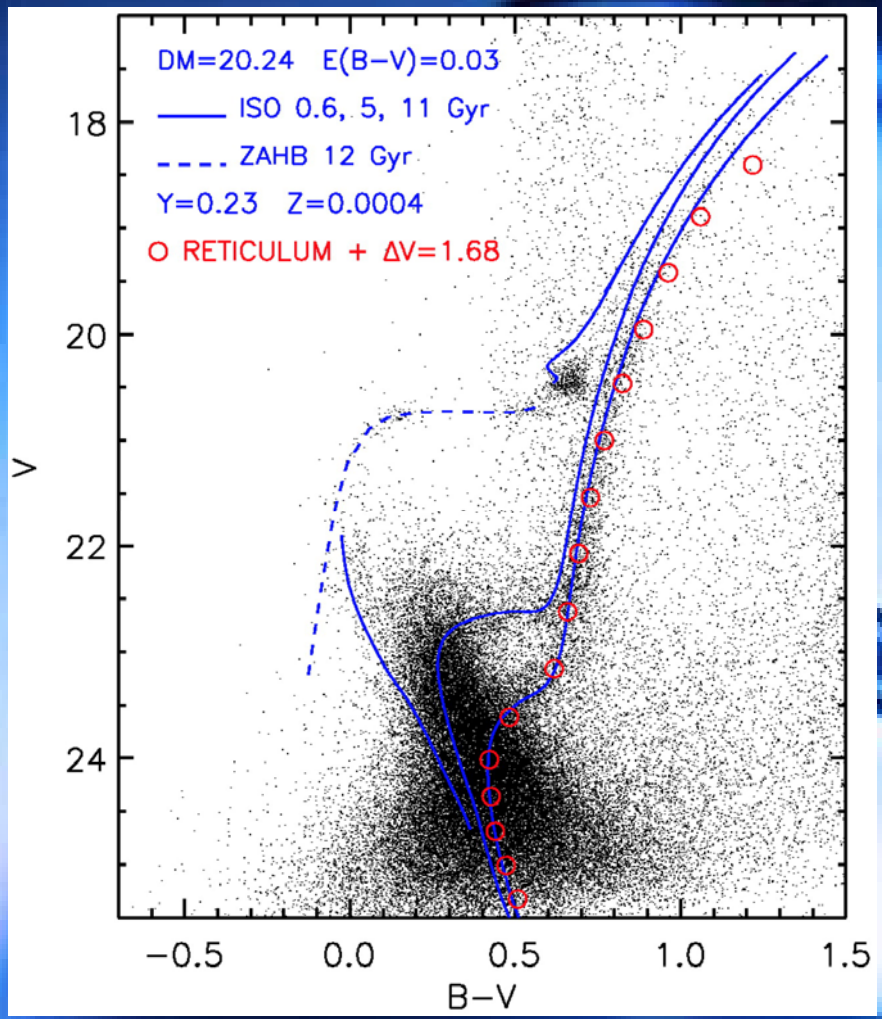
Kirby et al. 2008

α-elements and chemical evolution

- Formed on short time scales, thus good tracers of (rapid) SF (Tinsley 1979)
- systematically lower in the dSphs compared to Galactic halo (Shetrone et al. 2001, 2003; Geisler et al. 2007)
- slow CE in dSph vs. rapid halo formation (Unavane et al. 1996; Venn et al. 2004)
- partial overlap indicates fractional common origin

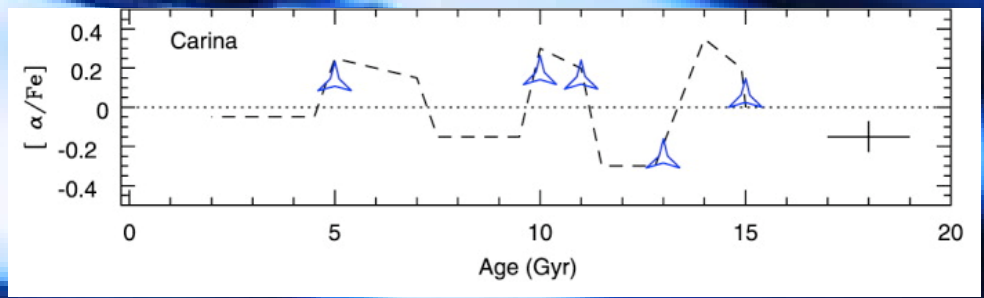


The Carina dwarf spheroidal



- complex evolution: at least 3 episodes of SF
- episodes and quiescent phases reflected in element ratios

(Shetrone et al. 2003; Tolstoy et al. 2003)



Monelli et al. (2003),
see also Smecker-Hane et al. (1994)

Carina within Large Programs

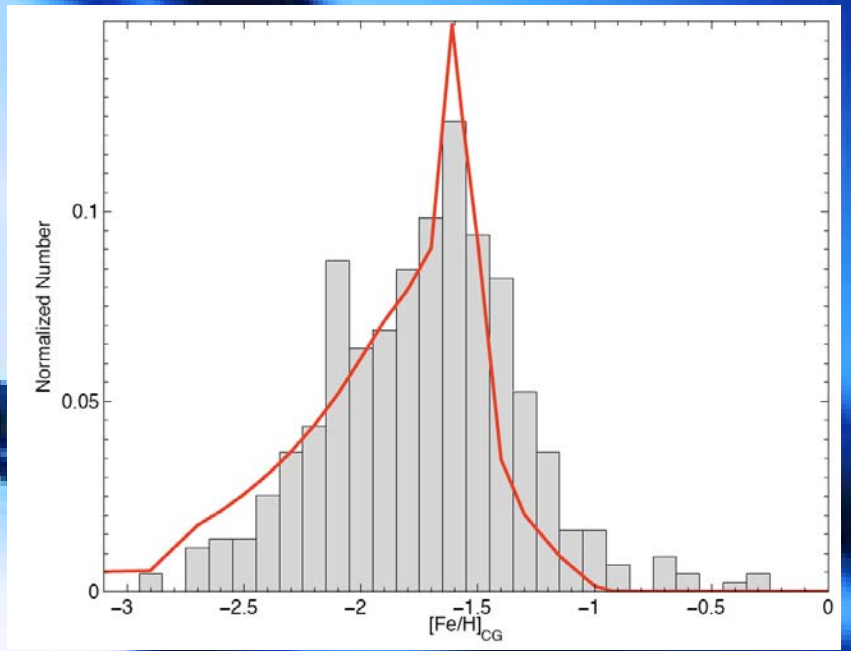
(Koch et al. 2006, 2007a,b, 2008)

- **Multi-object Spectroscopic Programs**
  (450 stars w/ VLT/FLAMES, 10 w/ VLT/UVES,
  30 w/ Magellan/MOE)

Low-resolution data (calcium triplet) are good indicators for MDF.

Mean $[Fe/H]_{CaT}$ = -1.7; (slow chemical evolution)

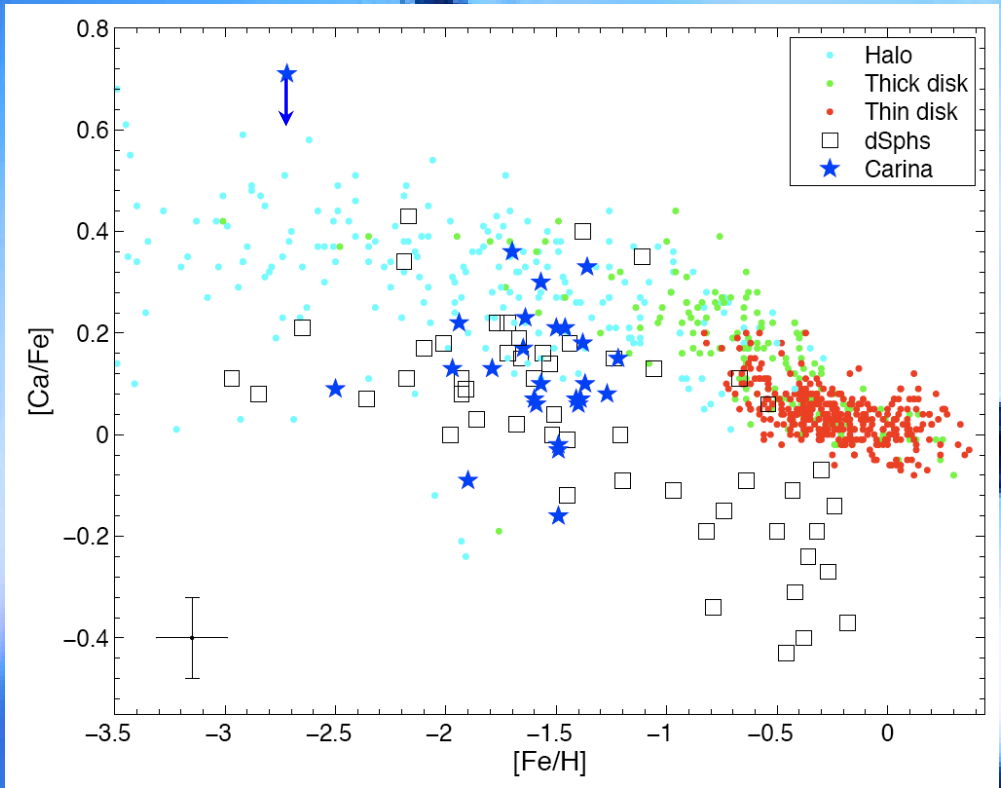
Shape of MDF governed by strong winds; K-giant problem



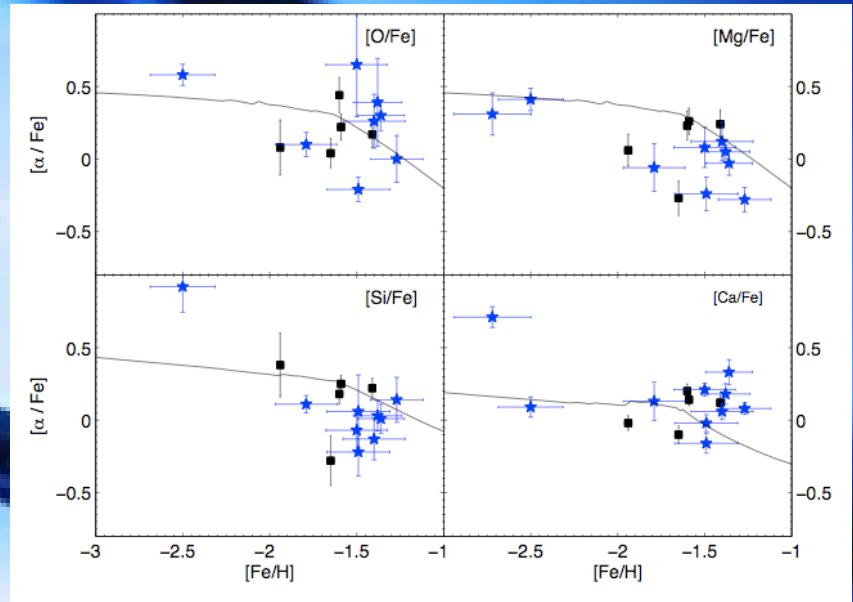
Koch et al. (2006; AJ, 131, 895)
Lanfranchi et al. (2004,2006,2008)

High-resolution results - α-elements

- Also Carina is depleted w.r.t. Galactic halo, i.e., slow evolution compared to rapid halo formation.



Koch et al. (2008, AJ, 135, 1580)

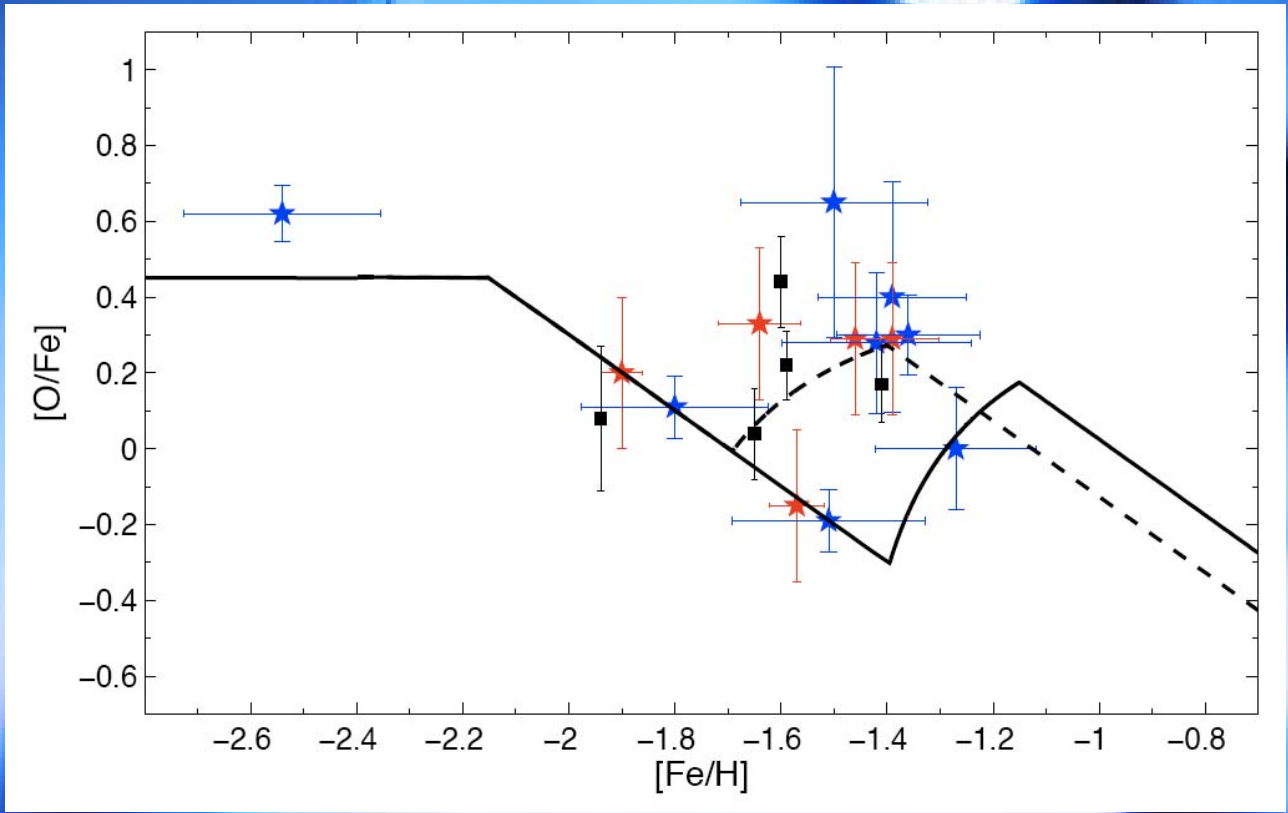


Koch et al. 2008; Shetrone et al. 2003; models by Lanfranchi et al. 2006

Large scatter in the α-elements

Carina's chemical evolution

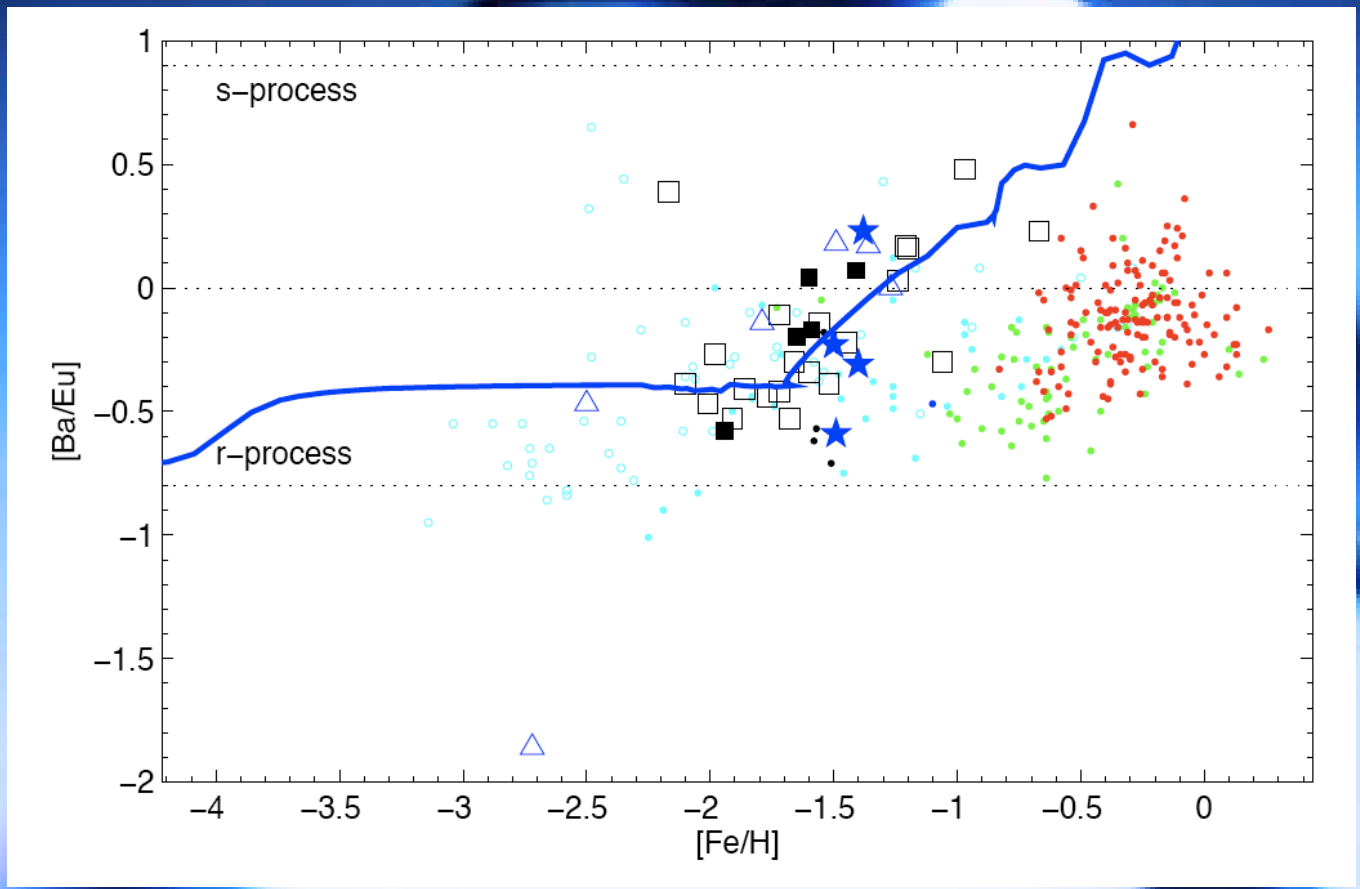
- Models with bursts, at least two episodes



Koch et al. 2008, AJ, 135, 1580;
Koch et al. 2007, AN, 328, 652;
models by Gilmore & Wyse 1991

- These SF events can account for scatter!
- May even predict location of bursts

Heavy elements in Carina



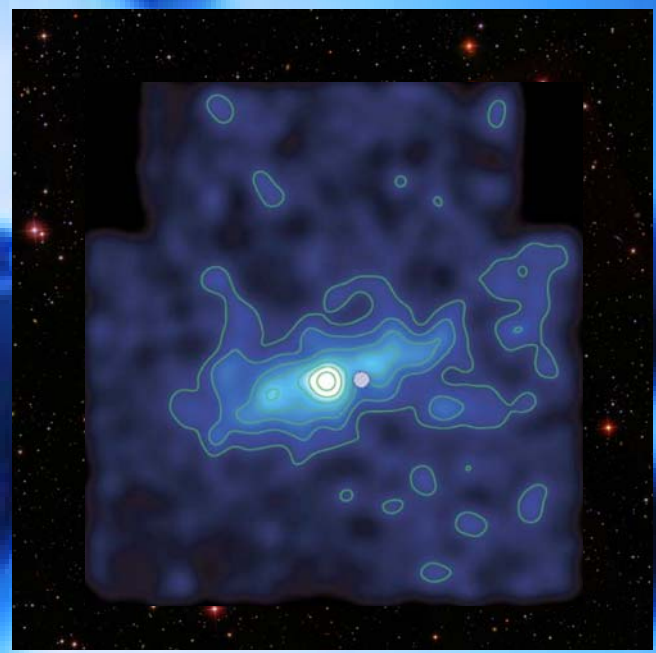
Koch et al. in prep.,
models by
Lanfranchi et al. (2006, 2008)

- r-process (SNe II) dominated early on, rise towards s-contributions later ([Fe/H]~-1.7)

Hercules

- Ultrafaint dSph, discovered within SDSS (Belokurov et al. 2007); M_V=-6.6; d=140 kpc
- presumably low-mass, metal-poor, elongated (one of the most elliptical LG dSphs)
  (Coleman et a. 2007, Martin et al. 2008; de Jong et al. 2008; Kirby et al. 2008)
- multiple populations and kinematical substructure?

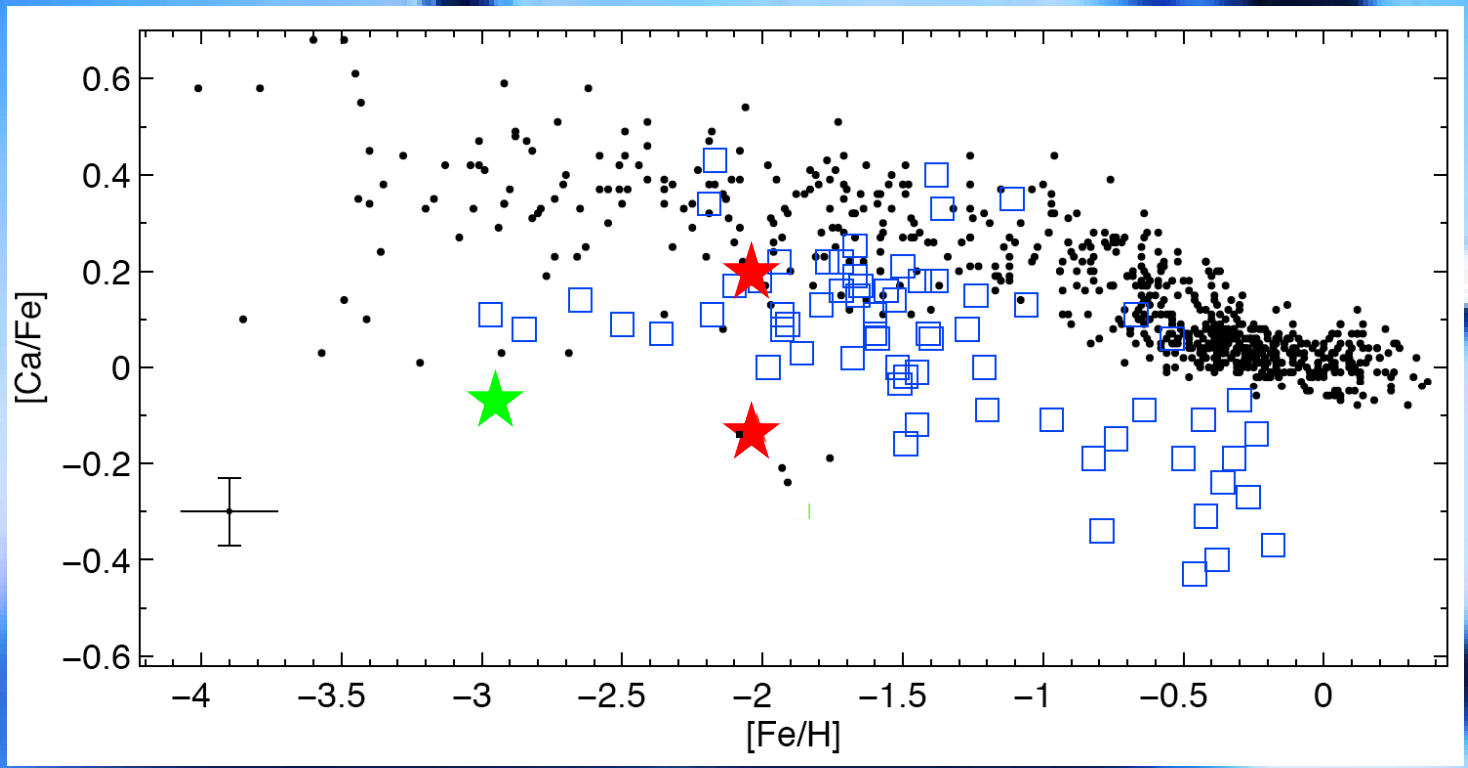
The first high-resolution spectra of red giants in Her.
(MIKE@Magellan;
R=20,000; 4000-9000 Å)



SDSS DR6; 30'x30' (ca. 4xr_h)

Hercules - heavy elements

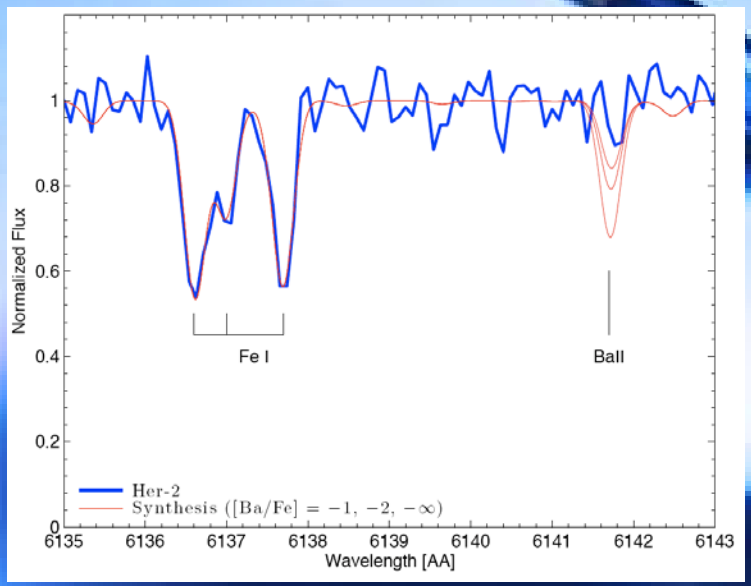
Depletion in [Ca/Fe] compared to the Galactic halo, similar to the more luminous dSphs.

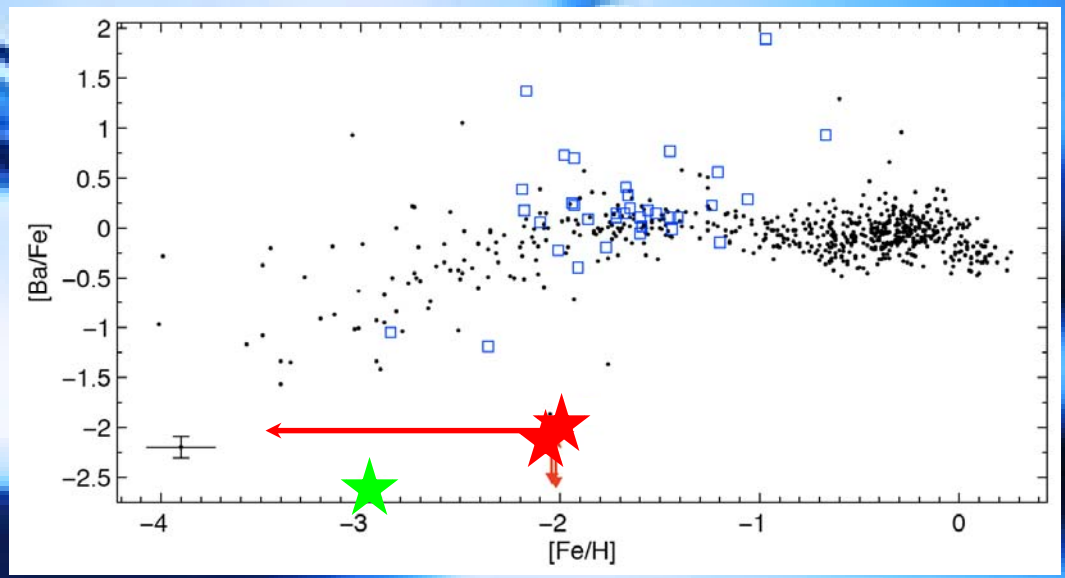


Koch, McWilliam & Wilkinson (2008)

Hercules - n-capture elements

- Her stars are strongly depleted in Ba, Sr, Eu; These elements are ***not detected***
- So far only seen in a few halo stars and Dra 119 -- but only at lower metallicity ([Fe/H]=-2.95; Fulbright et al. 2004)

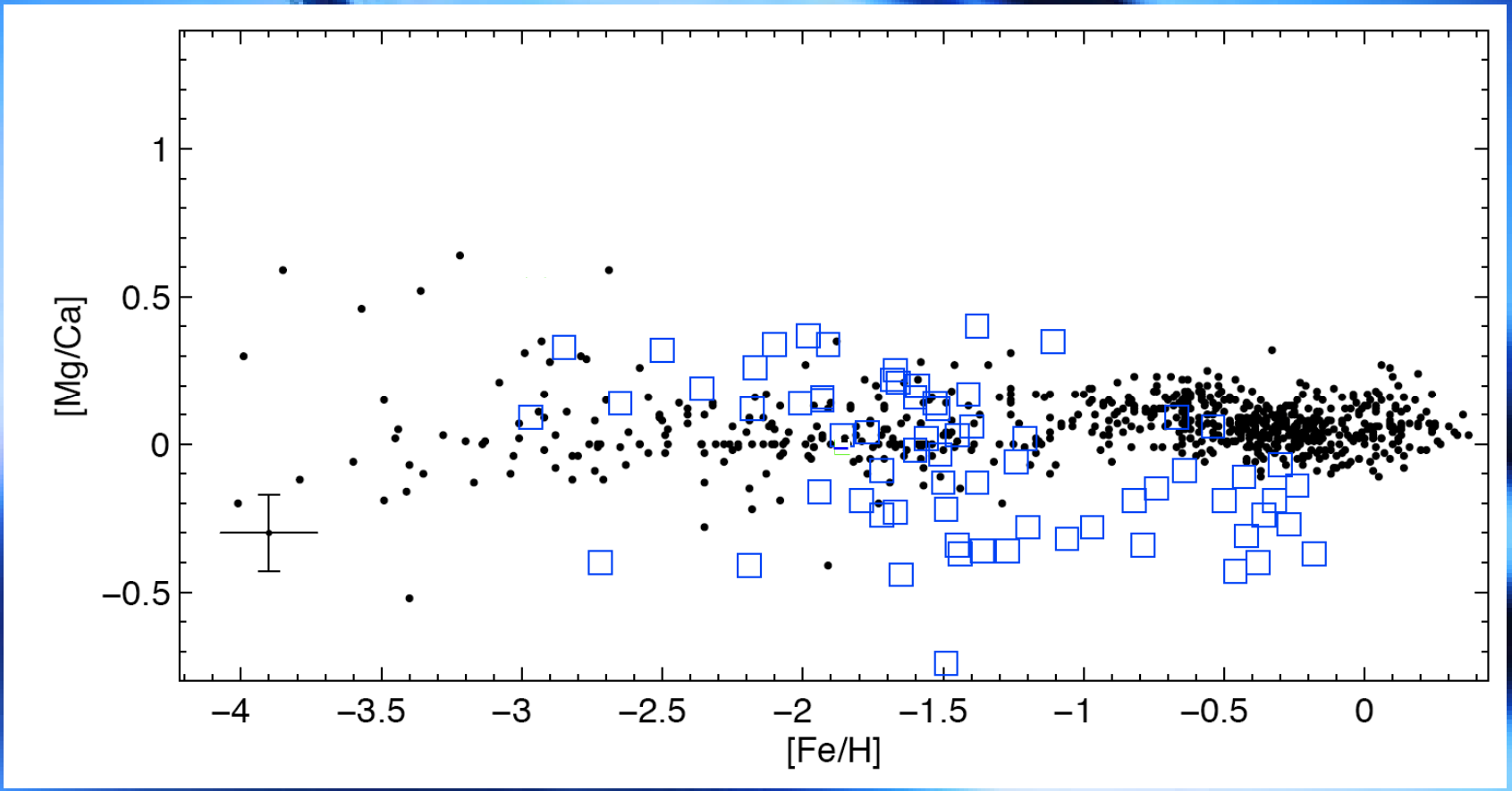




Koch et al. 2008, ApJL, in press

Hercules - a small-scale hero?!

Models for high-mass SNe II predict noteably high Mg yields w.r.t. Ca - in fact observed in Her. (These do not seem to produce n-capture elements.)



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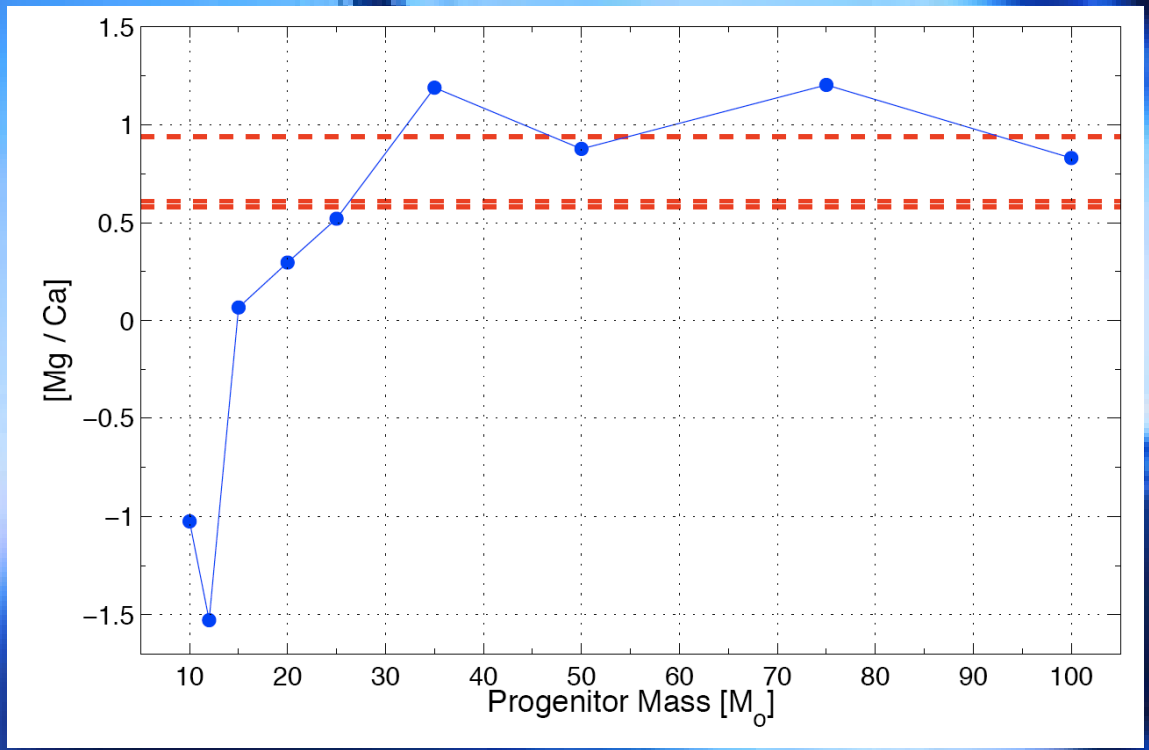


Her-2

Her-3, Dra 119

(Heger & Woosley 2008)

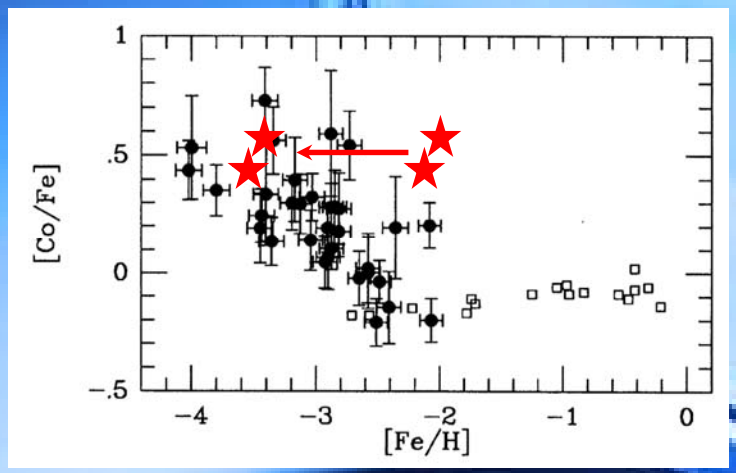
Our high [O, Mg, Si / Ca, Ti] implies M_{prog} ~ 35-50 $M_\odot$

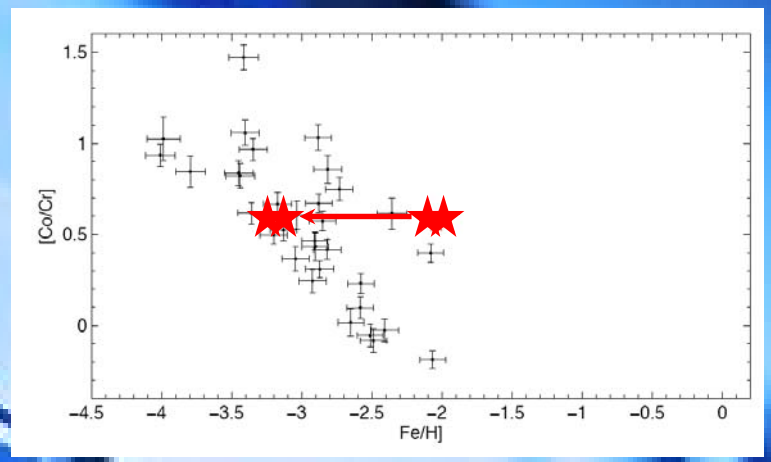
Stochastical Star Formation

- $M_{tot} = 7 \times 10^6 M_\odot$ and M/L = 330 implies $M_* \sim 40000 M_\odot$ (see also Martin et al. 2008)
- Incomplete sampling of high-mass end of IMF: stochastical SF tests imply that **no more than 10**, perhaps **only 1-3** massive SNe II influenced the Her stars (high [Mg/Ca])
- Inhomogeneous pollution & incomplete mixing ("SNe pockets") (Marcolini et al. 2008, MNRAS, 386, 2173)

Stochastical Star Formation

Low [Ba/Fe], high [Co/Fe], low [Cr/Fe] similar to Galactic halo stars at [Fe/H] < -3.





Koch et al. 2008; McWilliam et al. 1995

Why at "high" [Fe/H] ?

- A few SN ejecta diluted with much less (30x) primordial gas than in halo.
- primordial **Population III** ejecta dilute standard-composition gas.

Summary & Conclusions

- Traditional picture: dSphs are metal poor; huge metallicity spreads; [α/Fe]-depletion
- *ultra*faint dSphs: More metal poor; also huge [Fe/H] spread; some [M/Fe] patterns as luminous dSphs
- peculiar halo stars may originate in ultrafaint dSph-like systems. There ***is*** overlap of halo and dSphs abundances
- Very different from GCs and luminous dSphs. Study (DM) properties on smallest scales.
- Earliest enrichment phases and different modes of SF: **incomplete sampling** of high-mass (>30 $M_{\odot}$) end of IMF due to extremely low stellar masses.
- The ultrafaints are sites of the **first stars**?!