STELLAR ABUNDANCE SURVEYS AND GALACTIC CHEMICAL EVOLUTION

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EMMI-LEPP PRESENTATION
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THE UNIVERSITY OF CHICAGO

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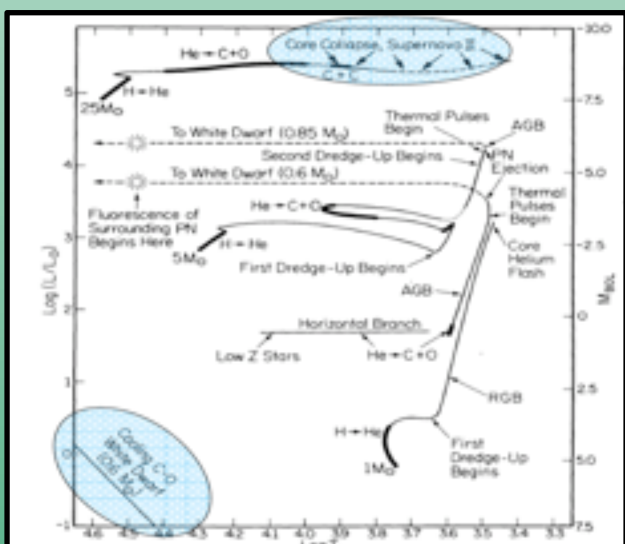
JINA

UTILITY OF STELLAR ABUNDANCES

STELLAR ABUNDANCES

STELLAR EVOLUTION

Life cycle of the star and associated stellar processes (e.g. thermal pulses)

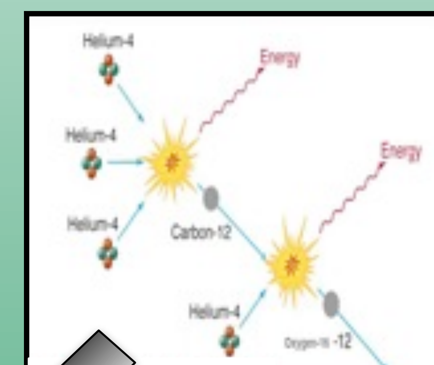


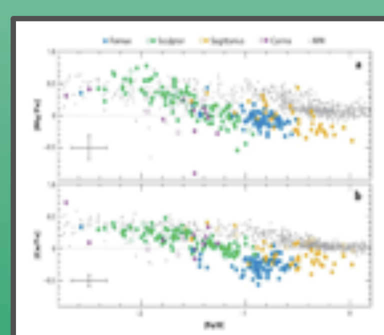
CHEMICAL EVOLUTION

Processing of elements in the ISM and incorporation into new stars

NUCLEOSYNTHESIS PROCESSES

Production of elements via coupled nuclear reactions in stars and other environments





STELLAR POPULATIONS AND ABUNDANCE PATTERNS

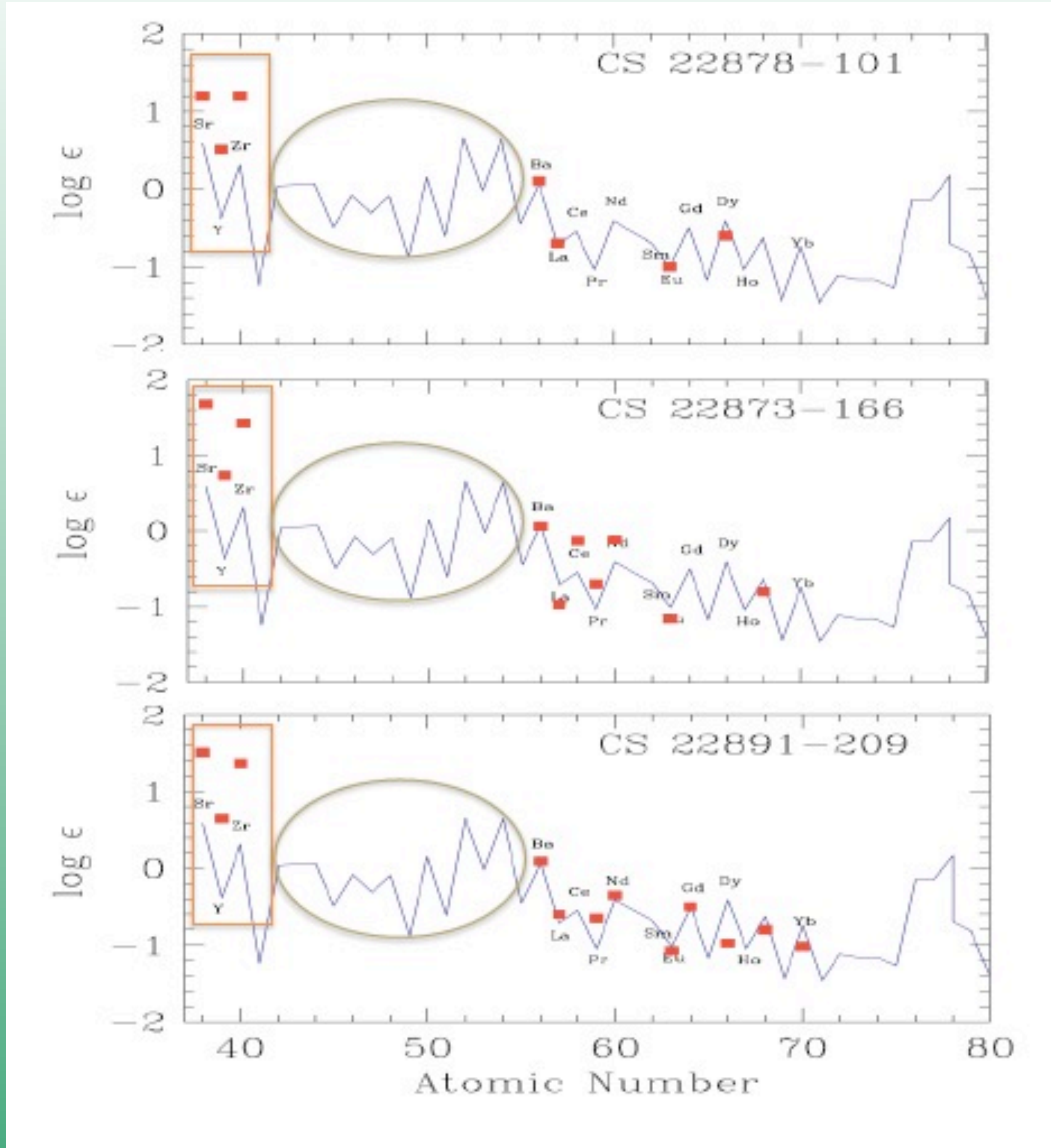
Observed abundance trends in various stellar populations combine both nucleosynthesis and chemical evolution

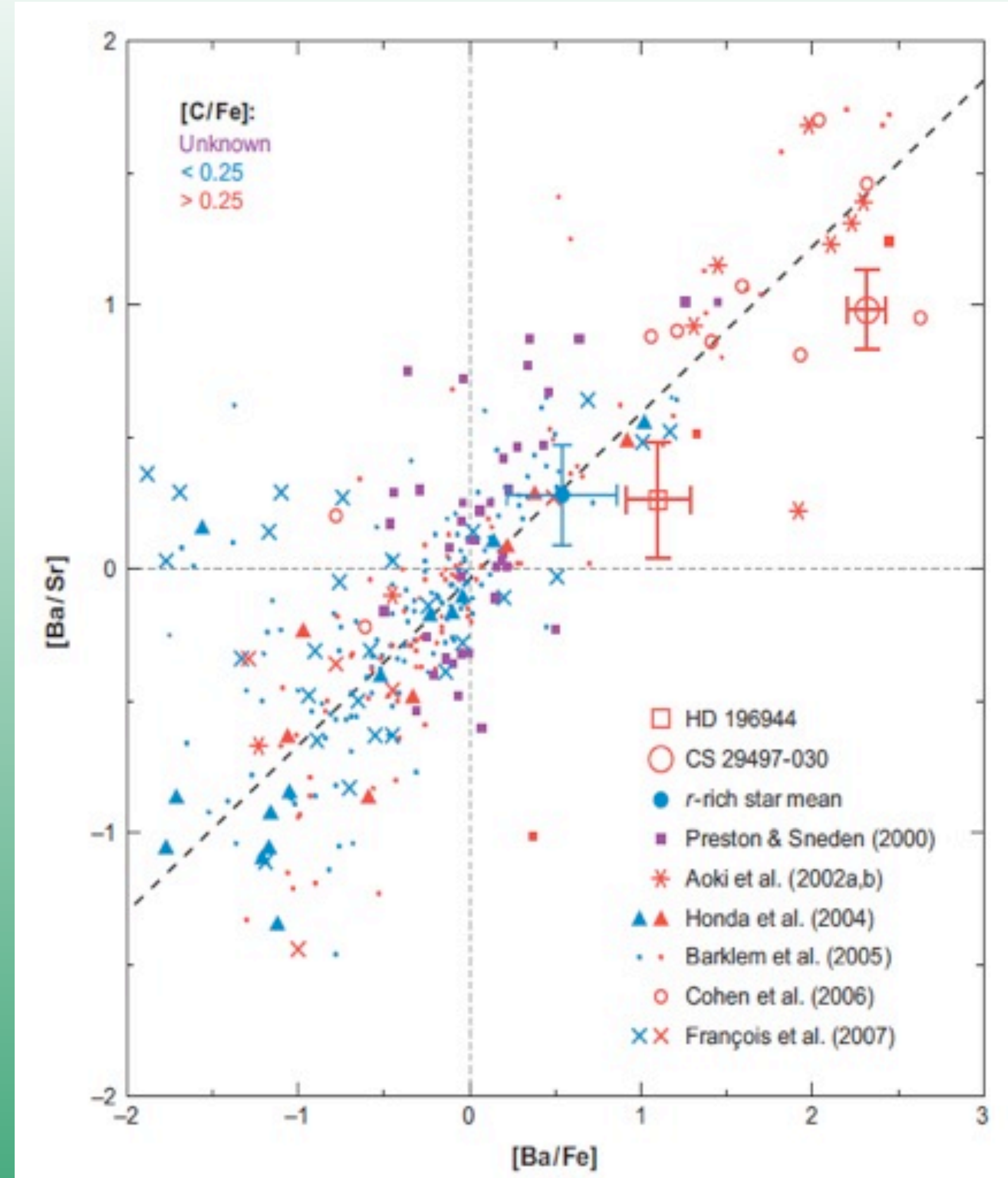
GALACTIC FORMATION AND ASSEMBLY

Abundance patterns and nucleosynthetic history of stellar populations, associations, and substructure reveal the formation and assembly history of the Galaxy

ORIGINAL PRESENTATION

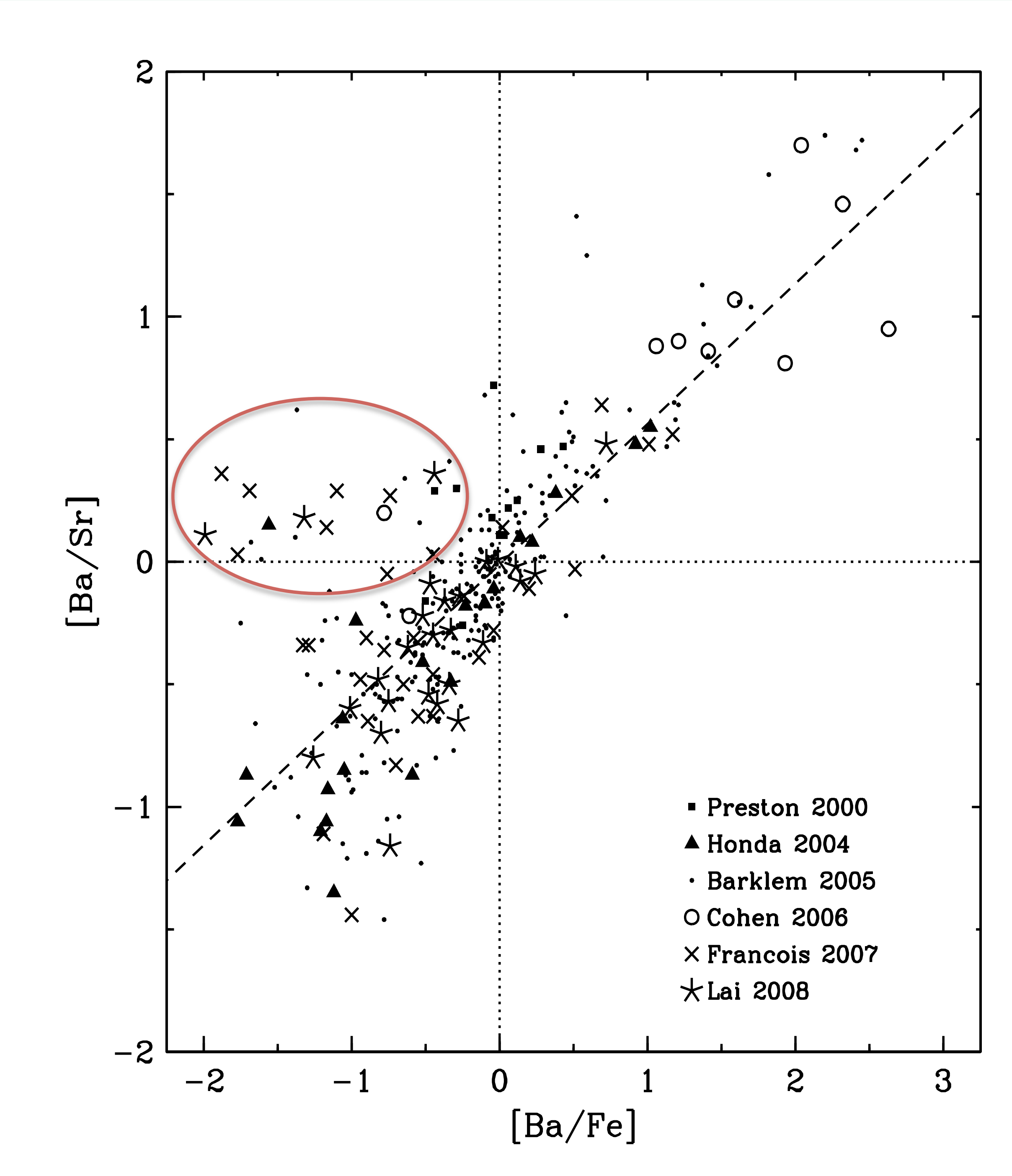
ABERRANT NEUTRON CAPTURE ABUNDANCE BEHAVIOR

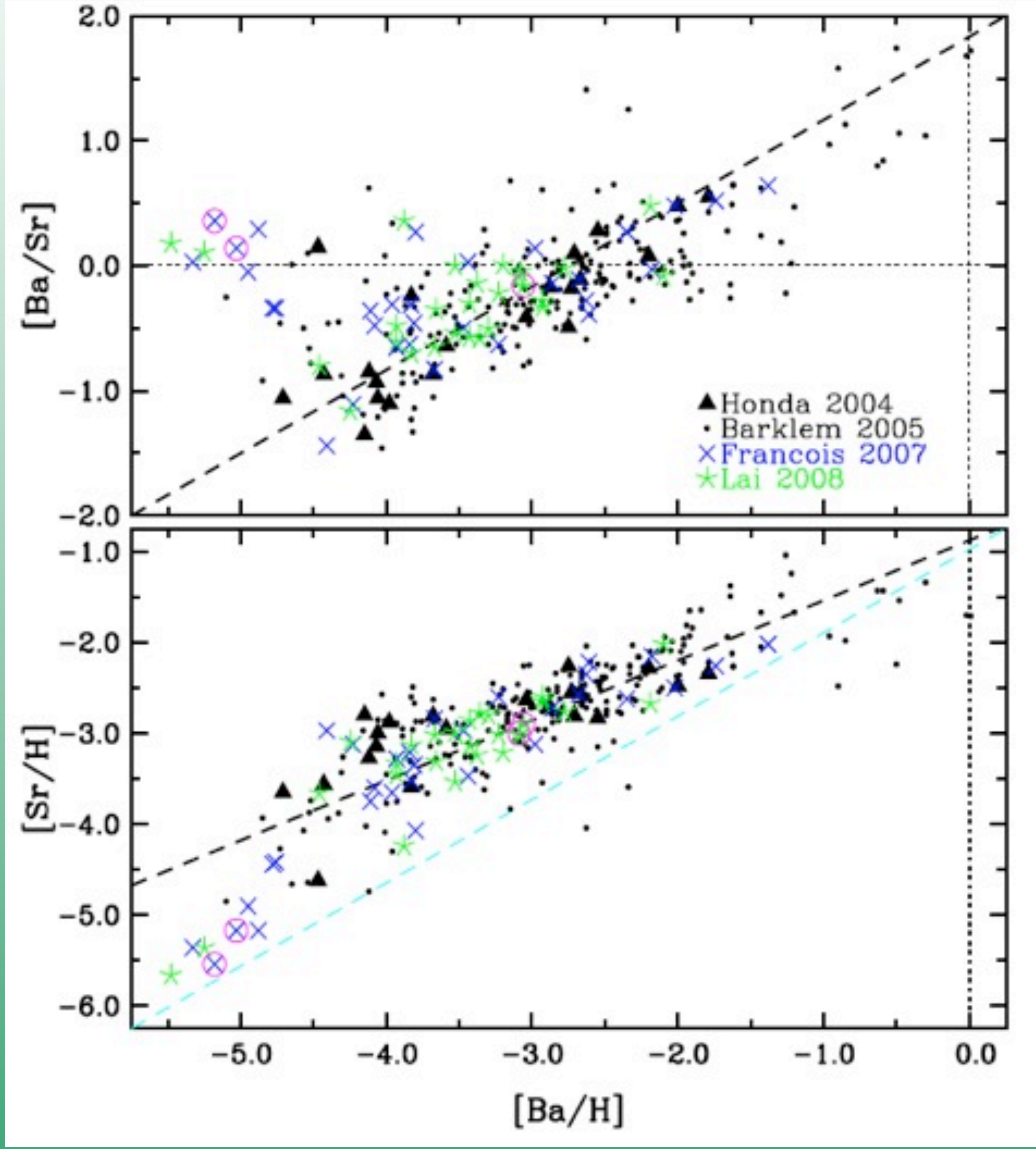




- LEFT PANEL: (First Stars Collaboration) Neutron capture abundances as a function of atomic number for three very metal-deficient ([Fe/H] < −2.5) stars.
- RIGHT PANEL: (Sneden, Cowan, & Gallino 2008) Evolution of [Ba/Sr] with [Ba/Fe] for a compilation of stars with low metallicity (note [Ba/Fe] is a “bulk” measure of neutron capture enhancement). Figure indicates also relative carbon enhancement in these metal-poor stars (labeled CEMP stars; note that subclasses of CEMP stars exist: CEMP-no s, CEMP-s, CEMP-r+s)

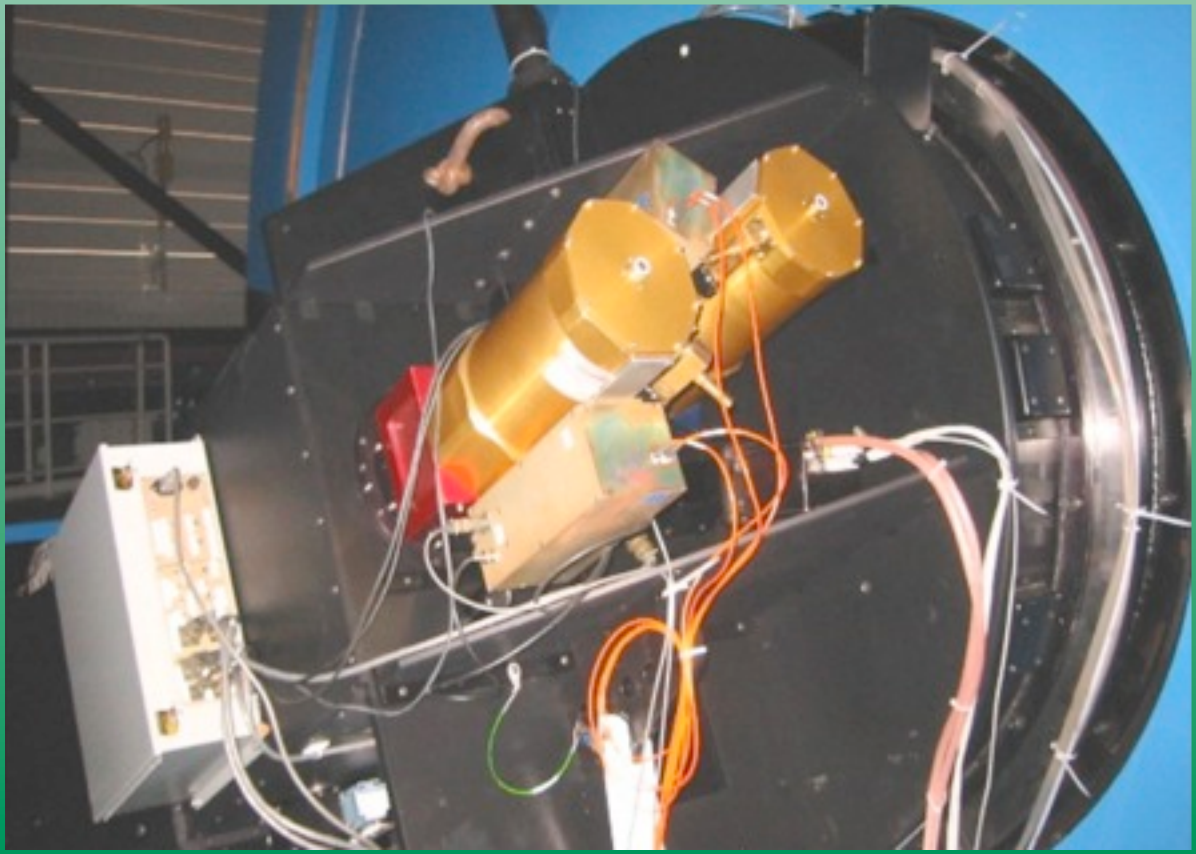
ABERRANT NEUTRON CAPTURE ABUNDANCE BEHAVIOR





– LEFT PANEL: Expanded Sneden, Cowan, & Gallino (2008) Sample. Effort to homogenize the sample and place all abundances on same solar reference scale.
– RIGHT PANEL: [Ba/Sr] and [Sr/H] as a function of [Ba/H]. Data now lacks dependency on Fe. Proposal target stars are encircled.

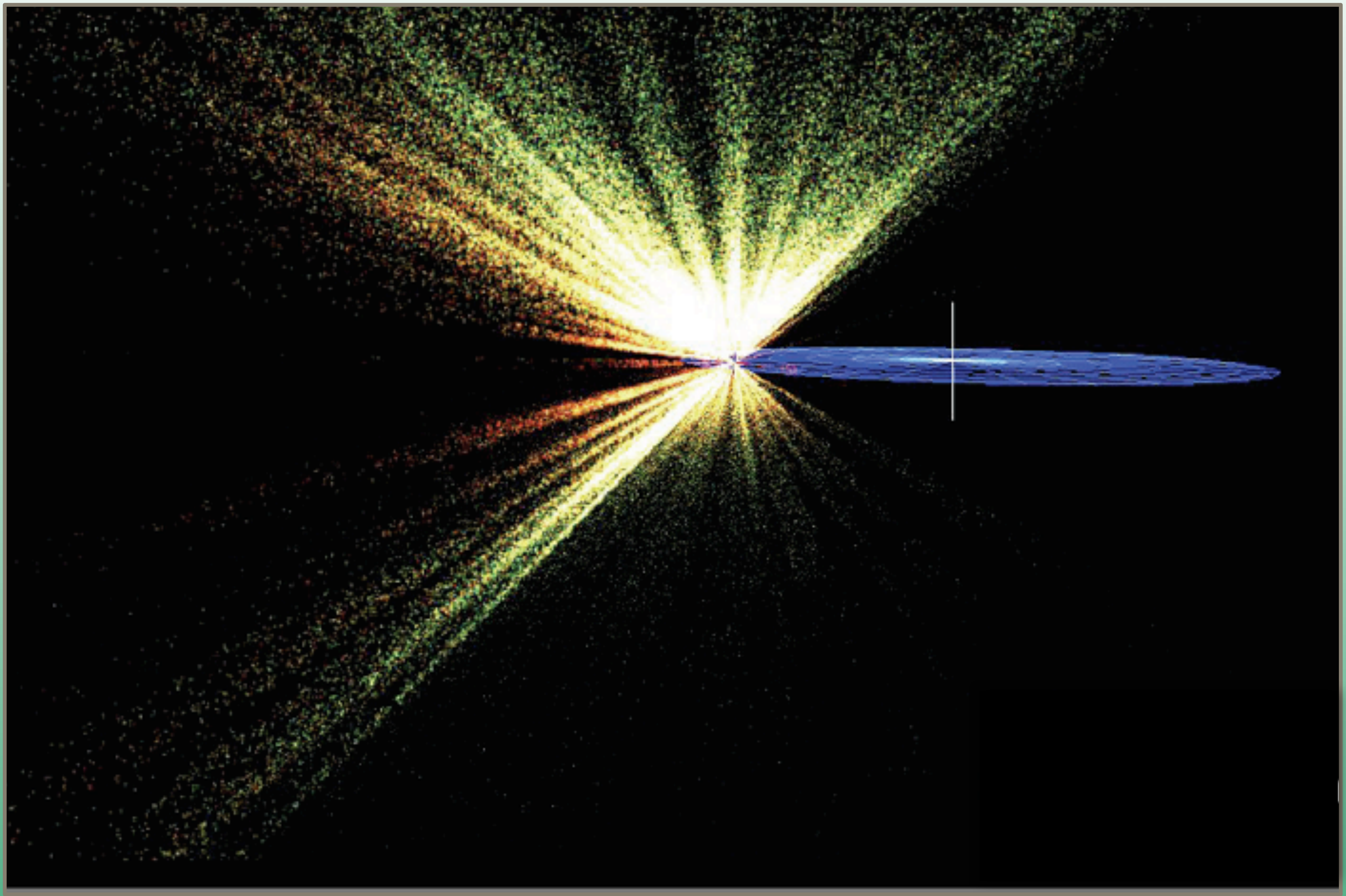
ABERRANT NEUTRON CAPTURE ABUNDANCE BEHAVIOR

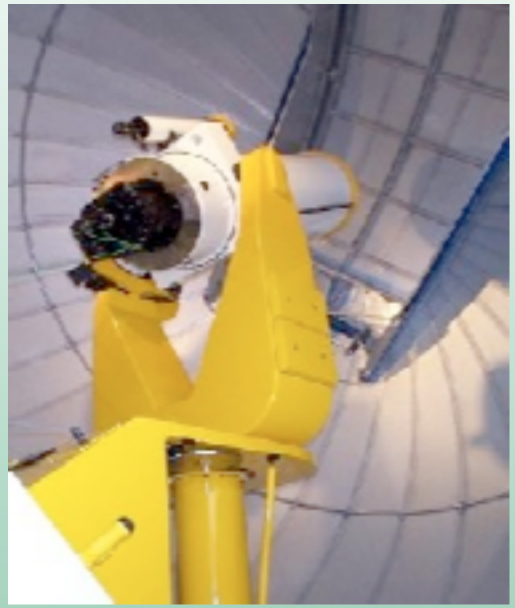


- Data acquisition transpired April 2011
- Magellan-Clay 6.5 m Telescope
- Resolution = 40,000
- Wavelength Coverage Range (3200-9000 Å)
- Spectra acquired for Four Targets
- Data reduction completed (with both the IDL and Python pipelines)
- Abundance analysis underway
- Preliminary findings confirm Ba and Sr abundance data; based on snapshot abundances, two targets do possess high Ba and Sr
- Intend to extract abundances for Ag, Pd, Yb, etc.

LARGE SCALE SURVEYS: SEGUE AND APOGEE

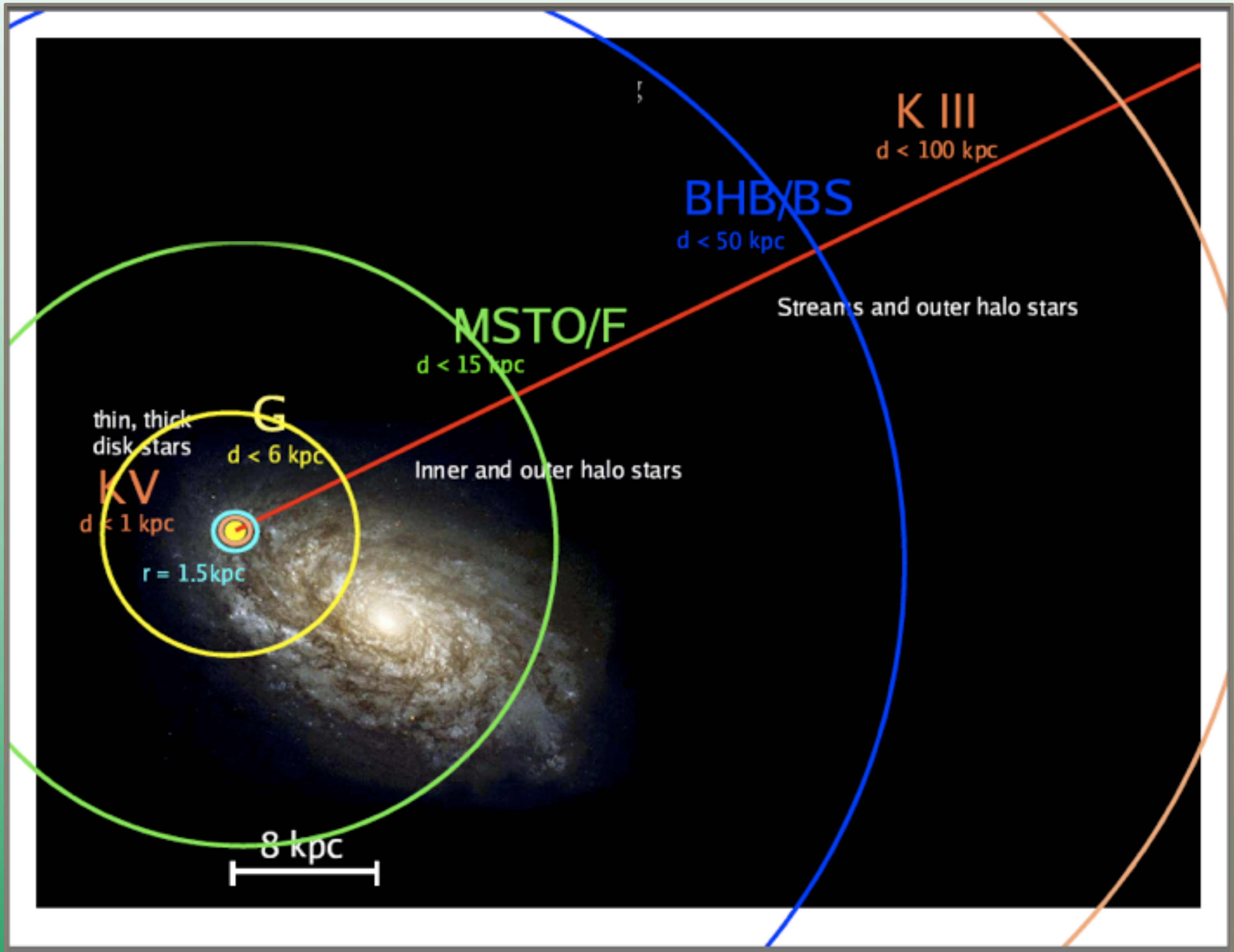
LARGE SCALE SURVEYS: SEGUE





- **SEGUE-1 AND SEGUE-2:** Sloan Extension for Galactic Understanding and Exploration (SEGUE)
- **TOTAL SAMPLE:** 500,000 stellar spectra (roughly 400,000 of which have available atmospheric params (T_{eff}, log g, [Fe/H]) from the SSPP, SEGUE Stellar Parameter Pipeline)
- **SAMPLE CHARACTERISTICS:** R~2000; λ = 3850-9000 Å

LARGE SCALE SURVEYS: STELLAR PROBE TYPES IN SEGUE

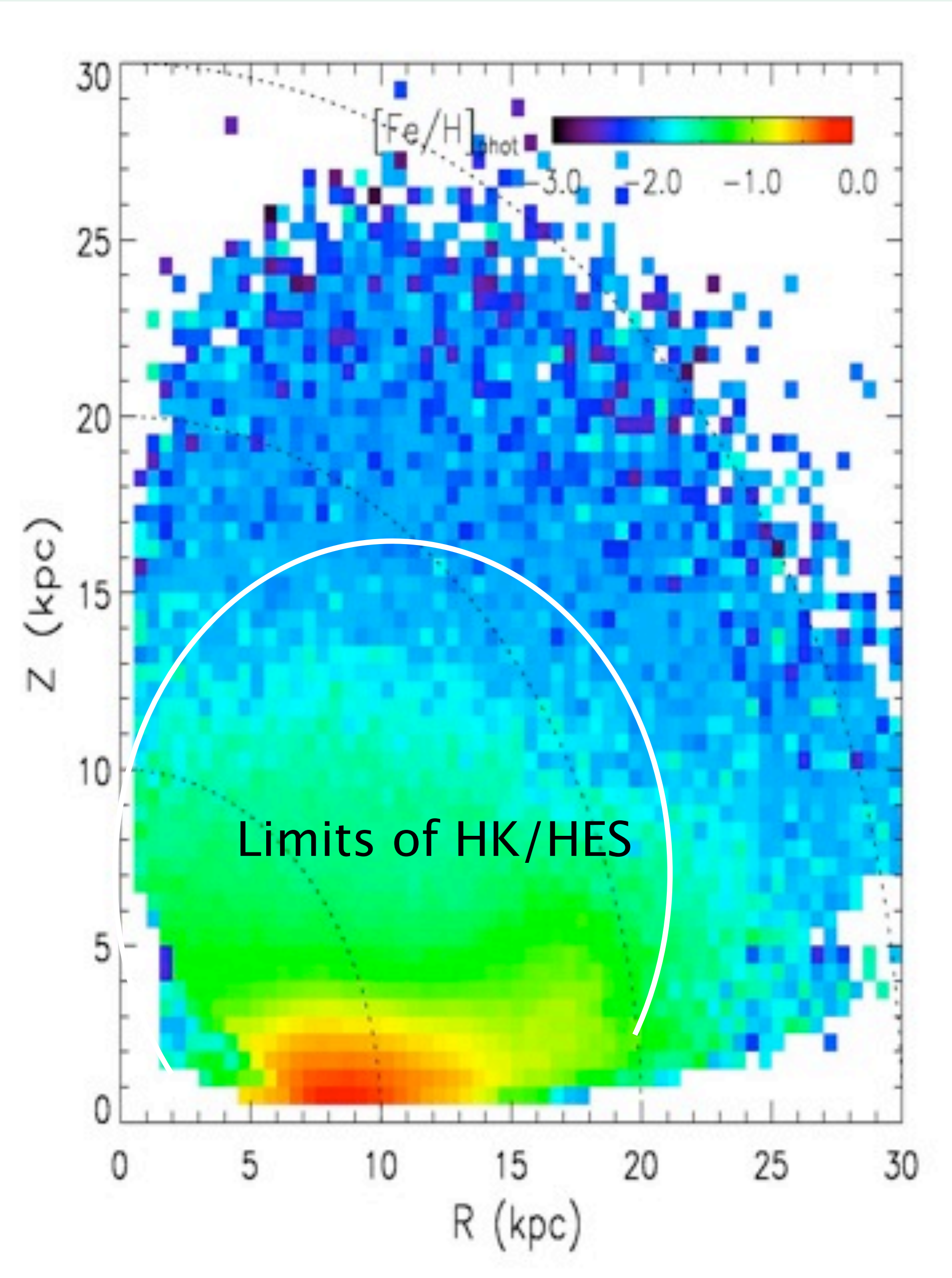


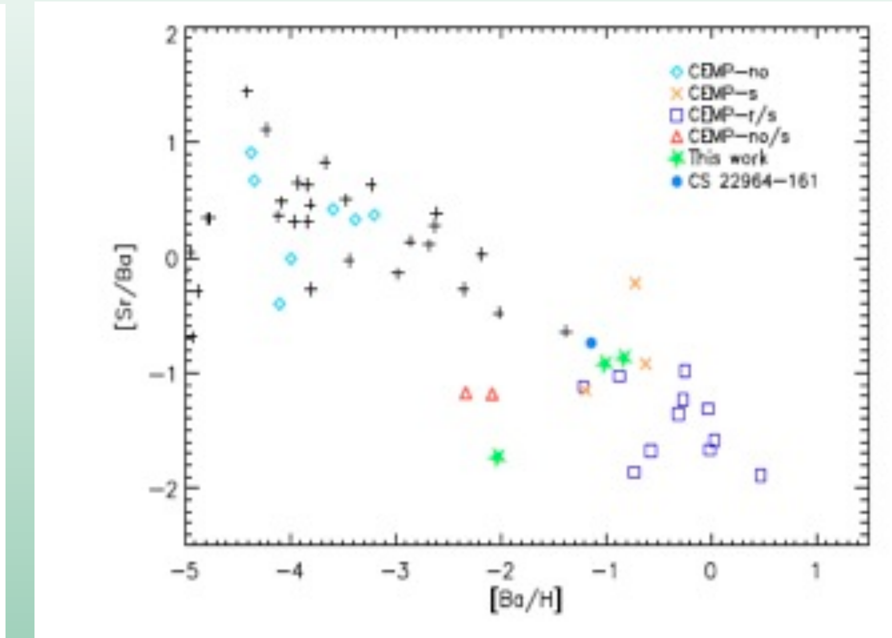
– THERE EXIST DIFFERENT TYPES OF STELLAR PROBES THAT EXHIBIT INCREASING LEVELS OF ABSOLUTE BRIGHTNESS THAT ALLOW FOR THE EXAMINATION OF GREATER AND GREATER DISTANCES IN THE DISK, THICK DISK, AND MILKY WAY HALO.

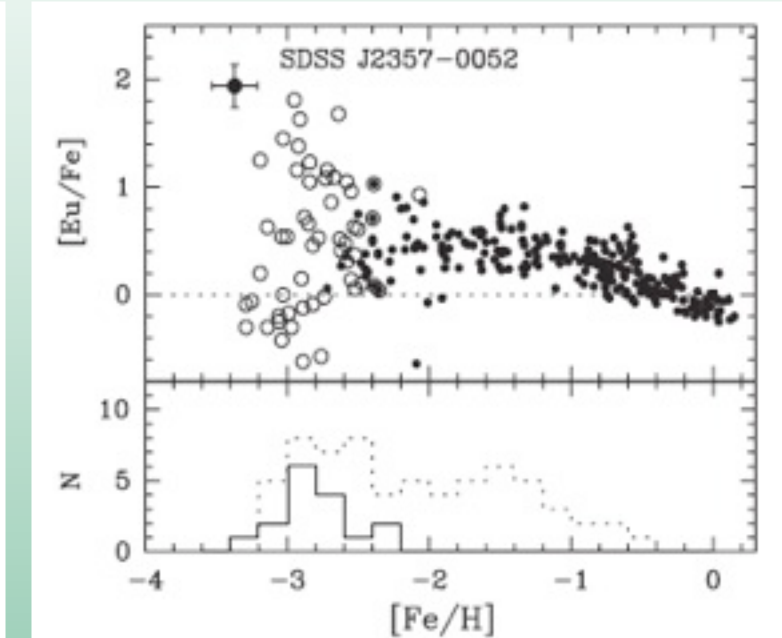
LARGE SCALE SURVEYS: METAL–POOR STARS OF SEGUE

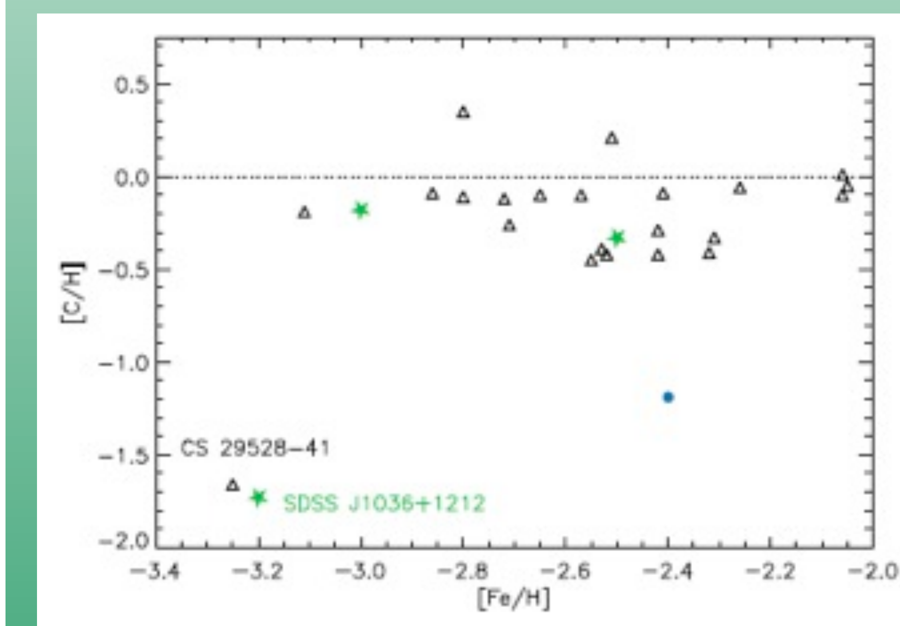
Classification	Metallicity	Pre-SEGUE	Post-SEGUE
Metal-Poor	[Fe/H] < -1.0	15,000	150,000+
Very Metal-Poor	[Fe/H] < -2.0	3,000	30,000+
Extremely Metal-Poor	[Fe/H] < -3.0	400	1000+
Ultra Metal-Poor	[Fe/H] < -4.0	5	5
Hyper Metal-Poor	[Fe/H] < -5.0	2	2
Mega Metal-Poor	[Fe/H] < -6.0	0	0

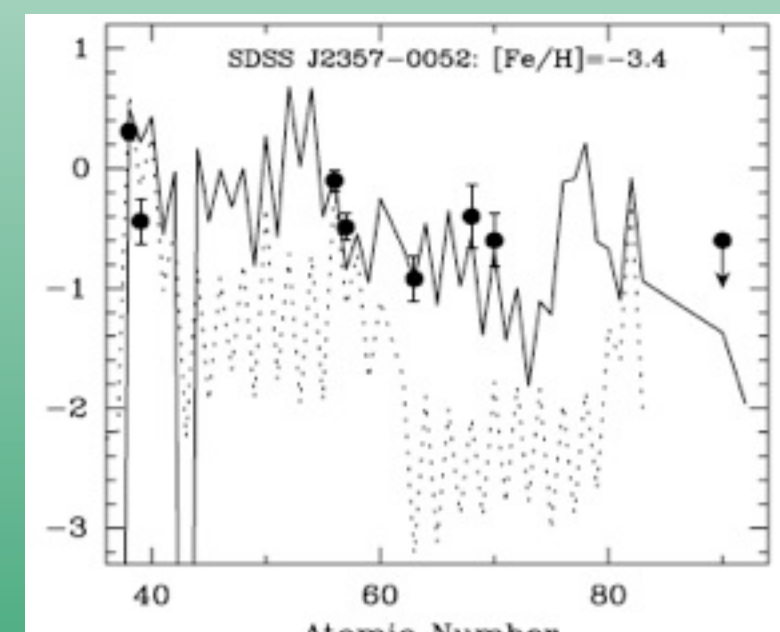
LARGE SCALE SURVEYS: RECENT RESULTS FROM SEGUE









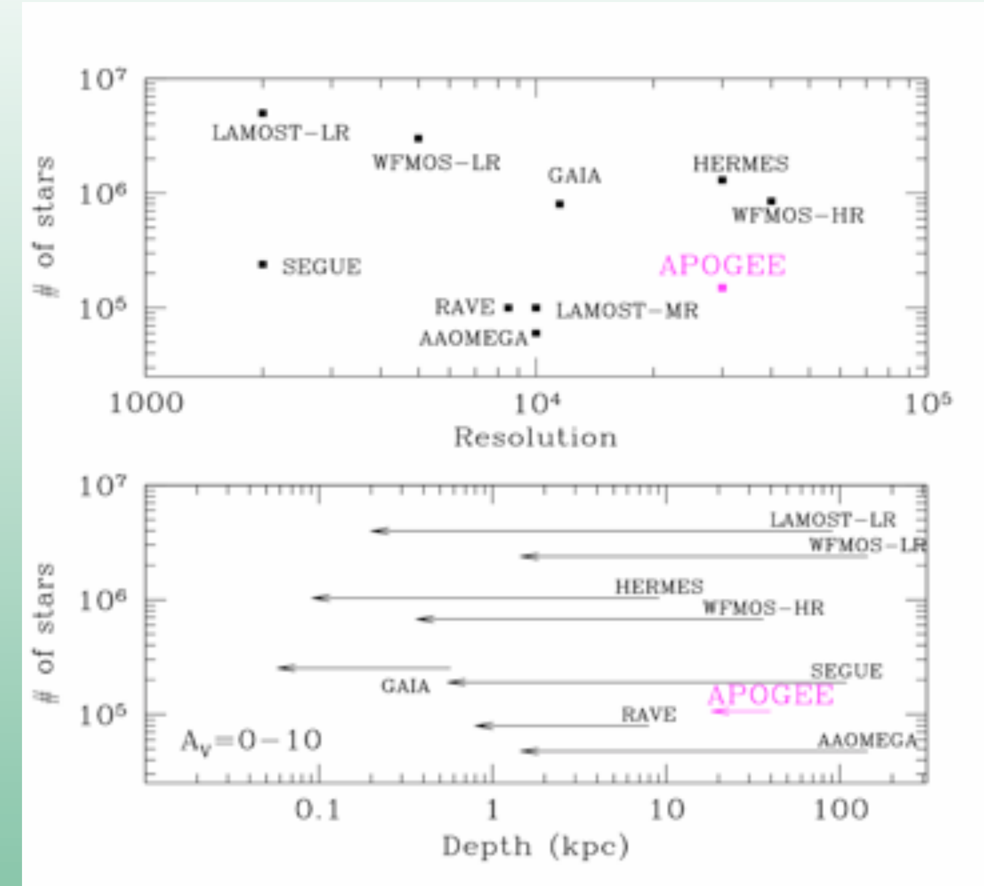


Current Metallicity Map (Beers et al.)

Behara et al. 2010: Detection of a CEMP-no s star SDSS J1036+1212

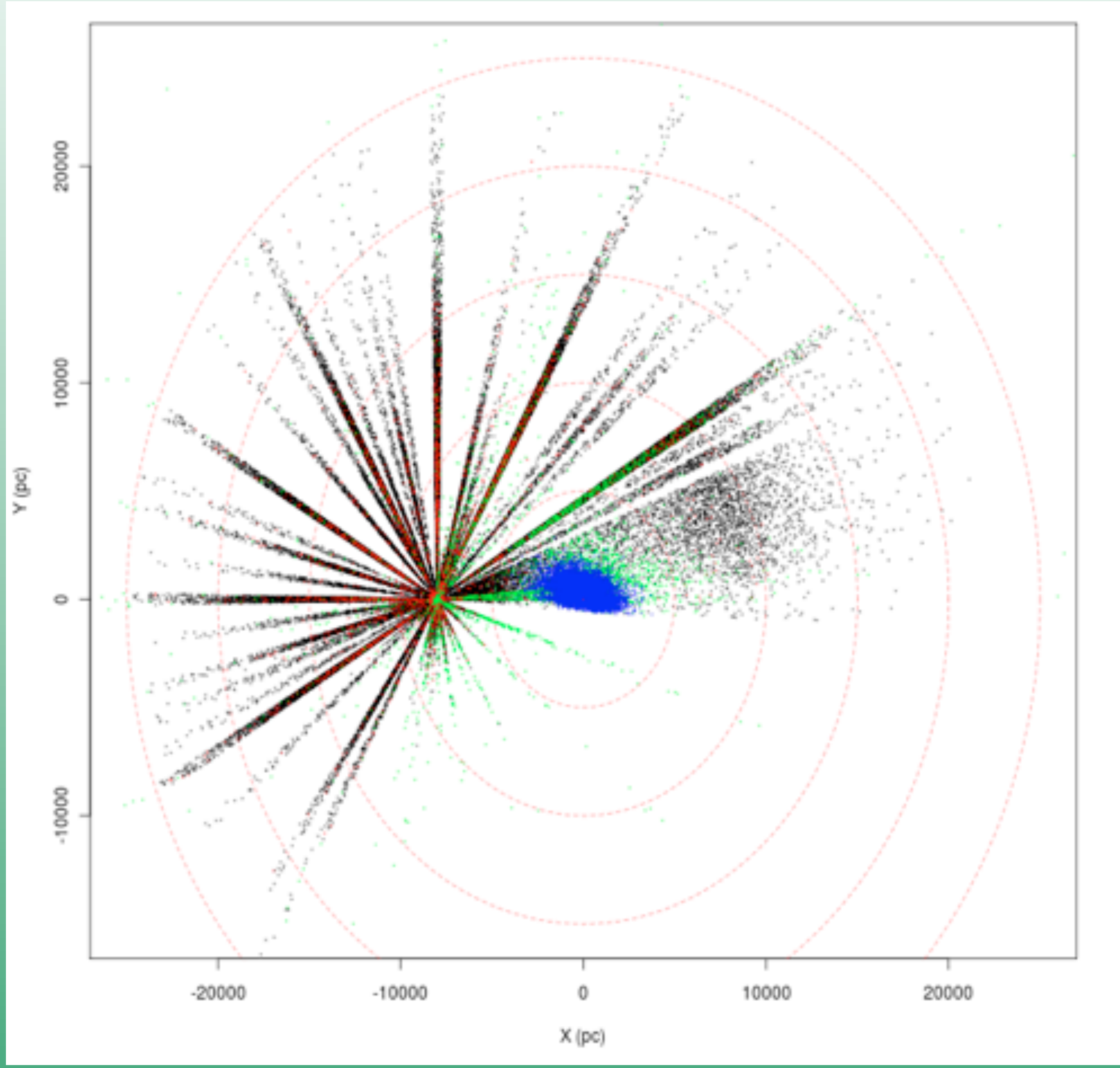
Aoki et al. 2010: Observation of an extremely r-process enhanced, metal-deficient main sequence star

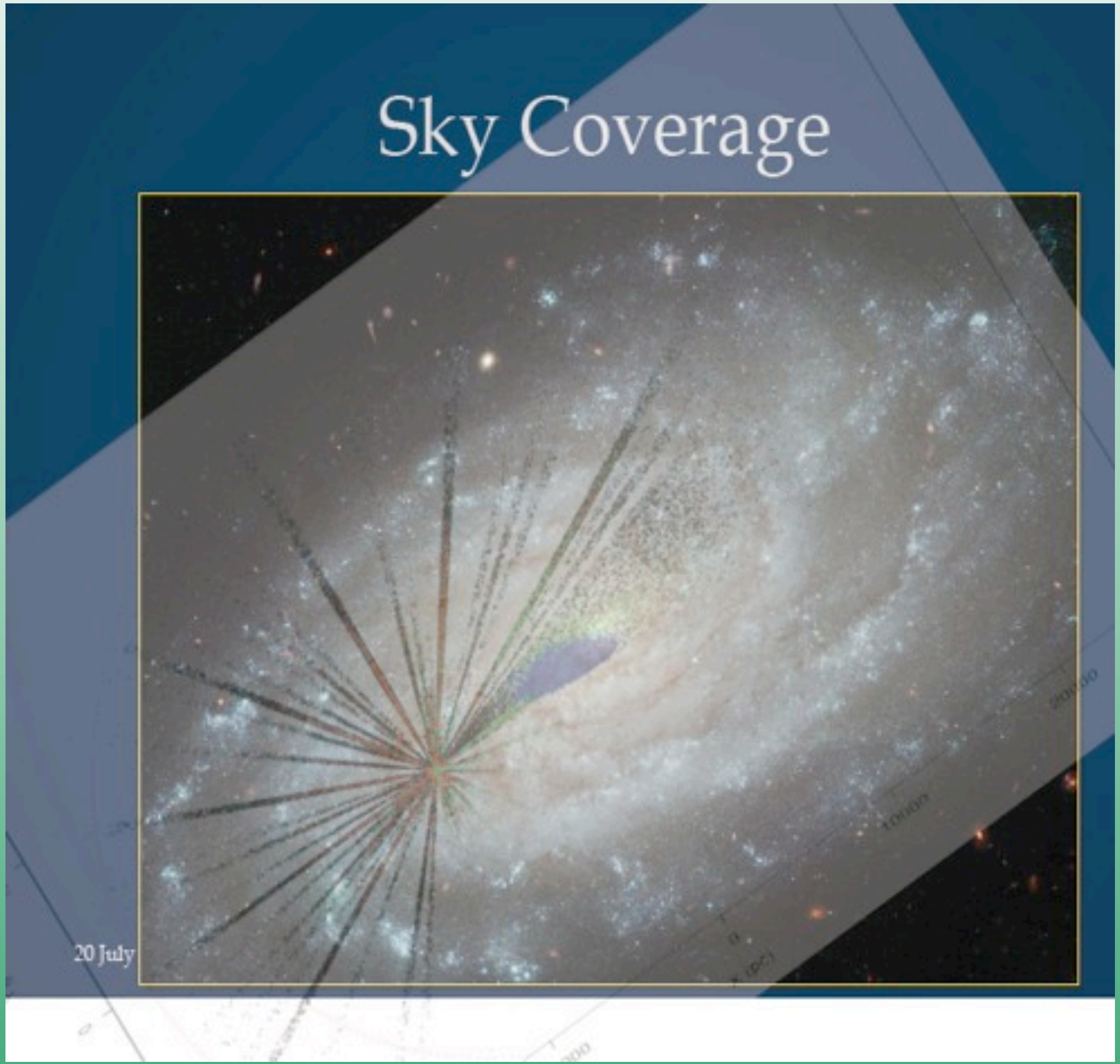
LARGE SCALE SURVEYS: APOGEE OVERVIEW



- **Apache Point Observatory Galactic Evolution Experiment (APOGEE)**
- The 4th (and final) SDSS-III project (2011 - 2014)
- A high-resolution (R~29,000), high signal-to-noise spectroscopic survey (S/N = 100/pixel)
- Operates in the near-infrared (H band): 1.51-1.68 μm
- Will target ~10^5 RGB stars sampling the bulge, disk(s), and halo(es)
- Stellar parameters and abundances for ~15 elements
- 300 fibers at a time
- RV precision: < 0.5 km/s
- Abundance precision: <0.1 dex

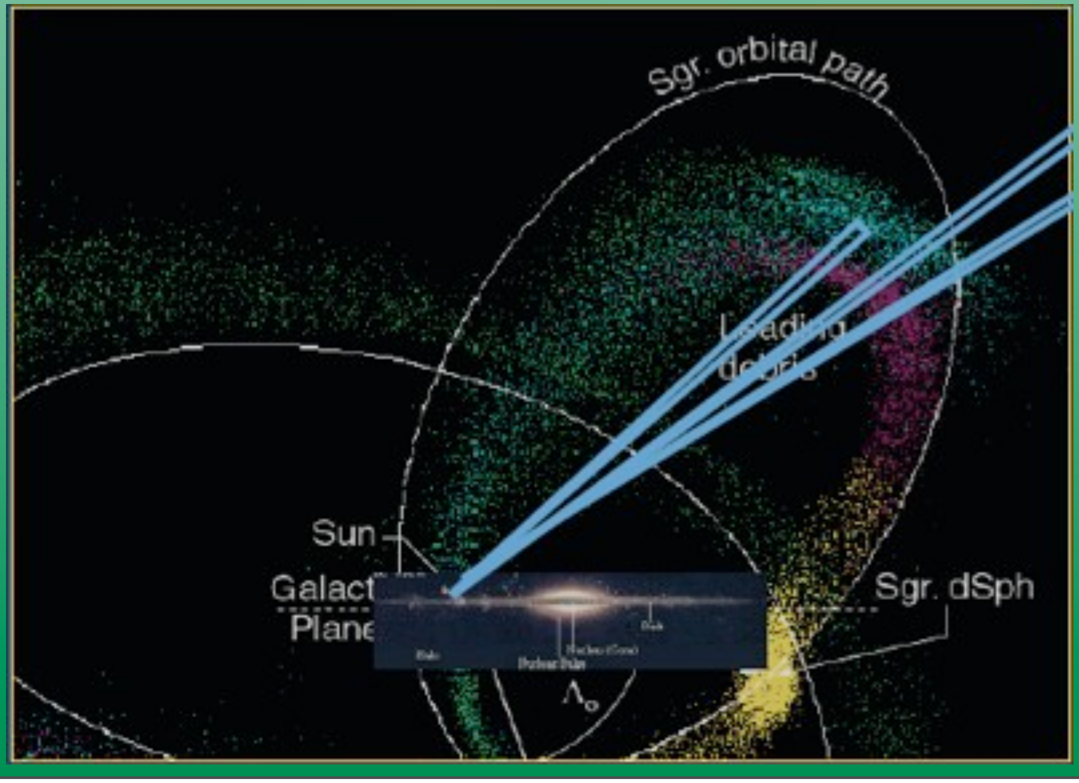
LARGE SCALE SURVEYS: APOGEE COVERAGE MAPS





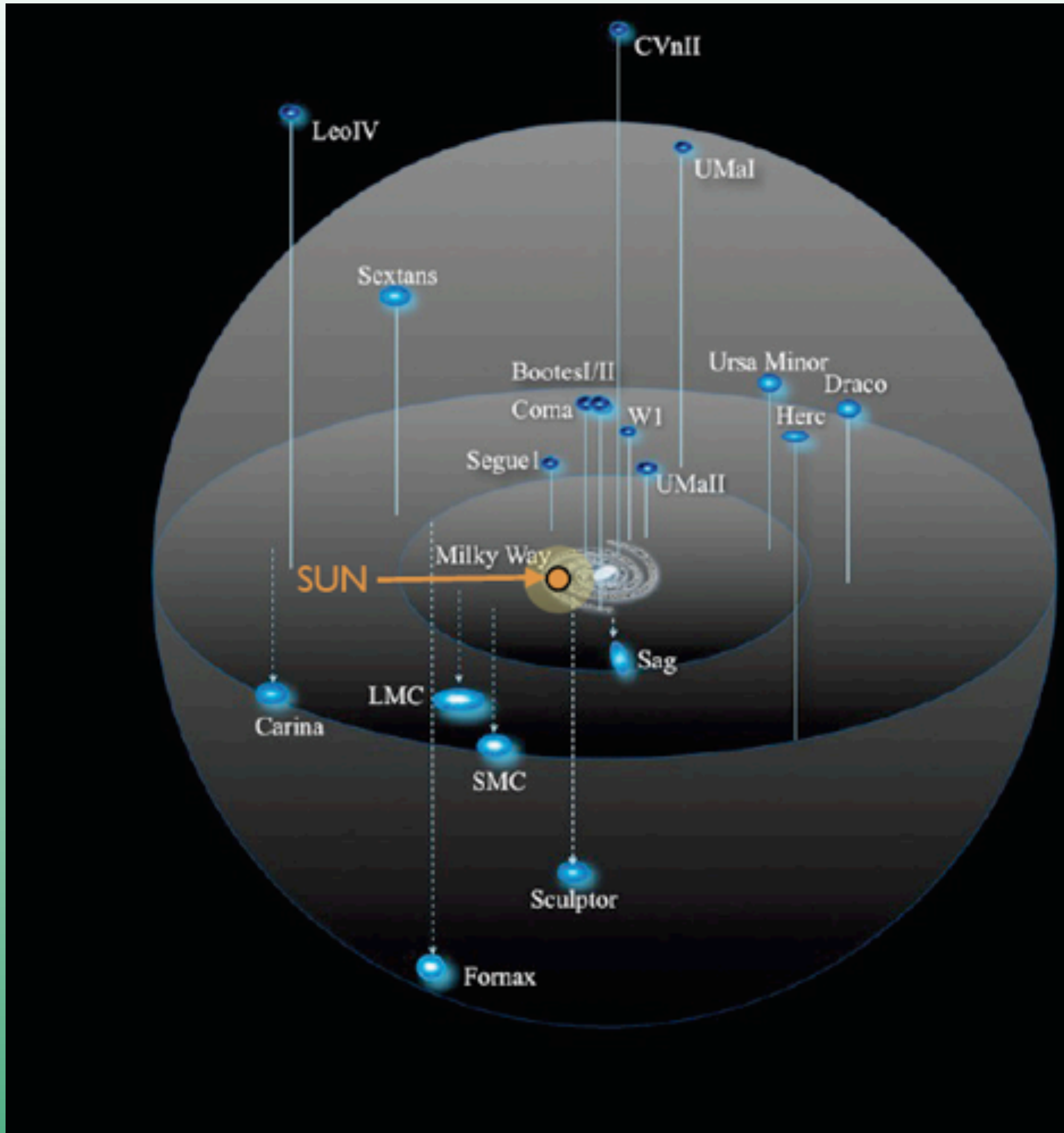
LARGE SCALE SURVEYS: APOGEE SCIENTIFIC MOTIVATIONS

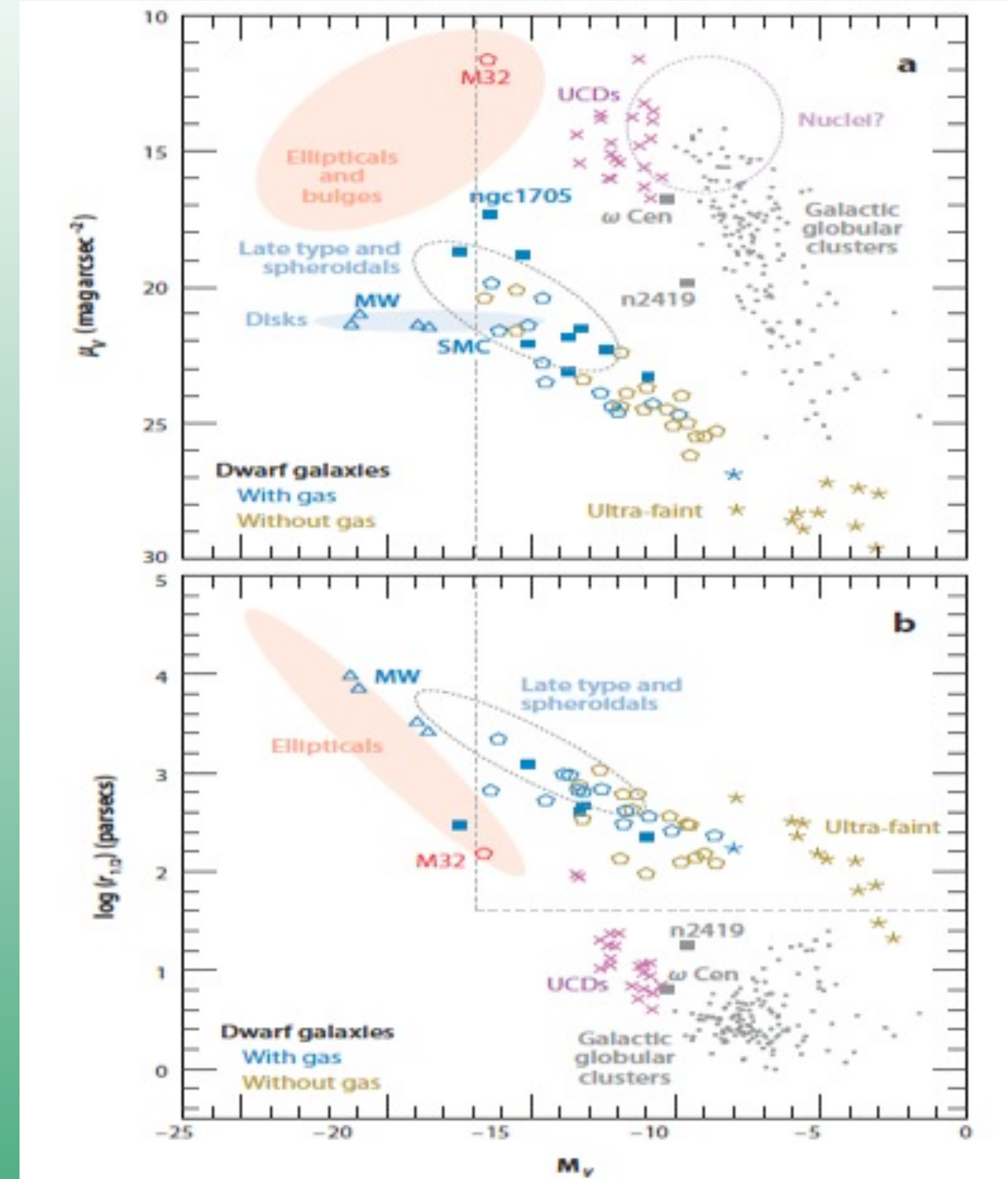
- First large-scale, systematic, uniform Galactic stellar survey
- Access to regions highly obscured by dust (thus typically avoided!)
- High-precision abundances for many types of elements: Fe, CNO, α-elements, odd-Z, iron peak, possibly even neutron capture (sensitive to SFH and IMF)
- Precise RVs to map kinematics and substructure
- Dataset 2-3 orders of magnitude larger than any other high-R Galactic chemistry survey!



DWARF GALAXIES

DWARF GALAXIES: UNIQUE STELLAR POPULATIONS



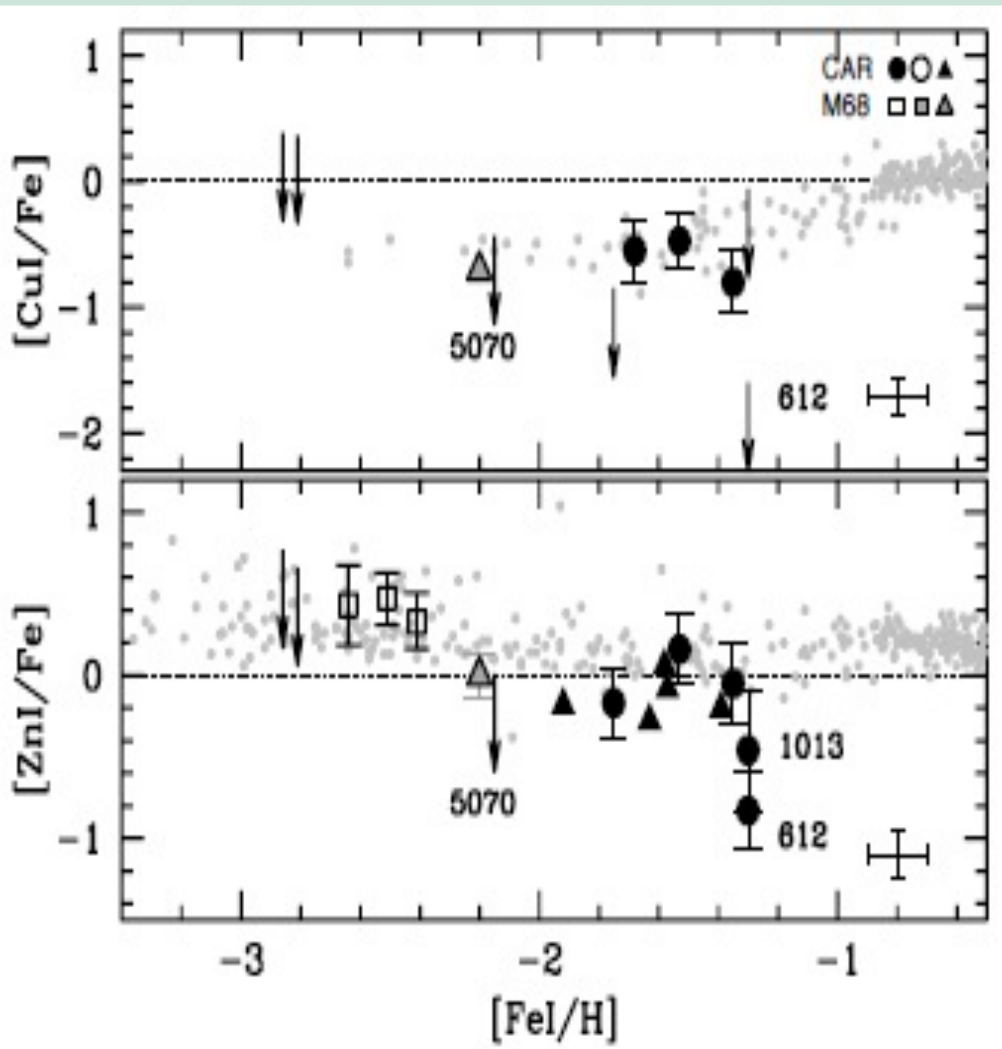


-Dwarf Spheroidal Galaxies (dSph), Ultra Faint Dwarf Systems (UFD), Dwarf Irregular Galaxies (dIrr), Blue Compact Dwarfs (BCD)

-RIGHT PANEL: Central Brightness (μ_V) and Half-Light Radius ($\log r_{1/2}$) as a function of Absolute Magnitude (M_V). Note the absence of apparent discontinuities.

DWARF GALAXY AND MILKY WAY ABUNDANCE COMPARISON

Abundance analysis of 9 bright giants of the Carina dwarf spheroidal galaxy from **Venn, Shetrone**, et al. (in press); data acquired at the VLT and Magellan Telescope Facilities; stars have a metallicity range of $-2.9 < [Fe/H] < -1.3$



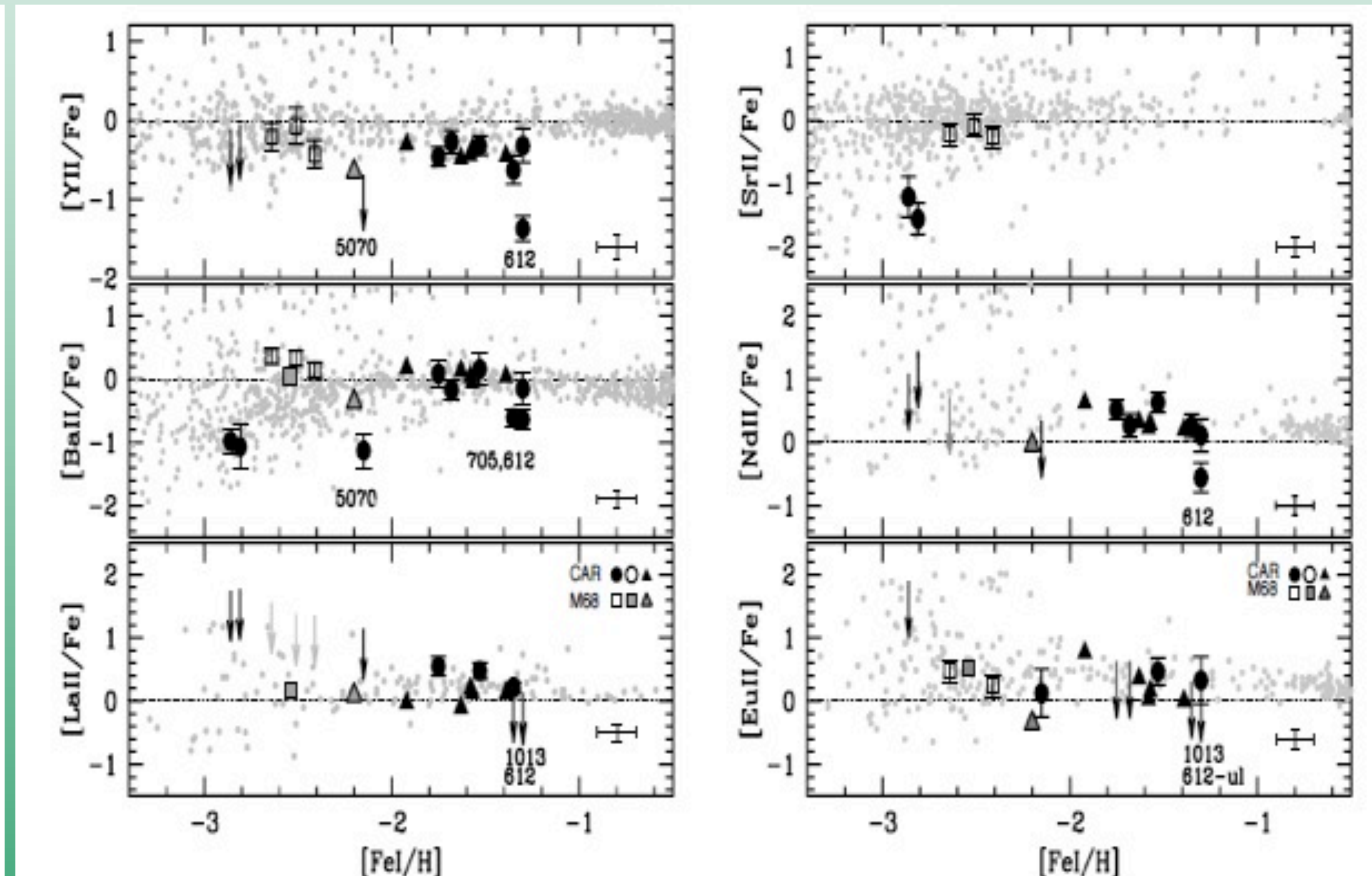


FIGURE: The LTE copper and zinc abundances in the Carina stars. The Cu and Zn abundances in Car-612 are remarkably low. M68 data are taken from Lee et al. (2005) and Shetrone et al. (2003).

FIGURE: The LTE abundances for the heavy elements Y, Ba, La, Sr, Nd, and Eu in Carina and M68, compared to the Galactic distribution. The Y abundance in Car-612 is remarkably low, but verified. The Galactic star abundances for La are from the critically examined compilation by Roederer et al. (2010). Additional data for Carina are taken from Koch et al (2008) and Shetrone et al. (2003).

DWARF GALAXY AND MILKY WAY ABUNDANCE COMPARISON

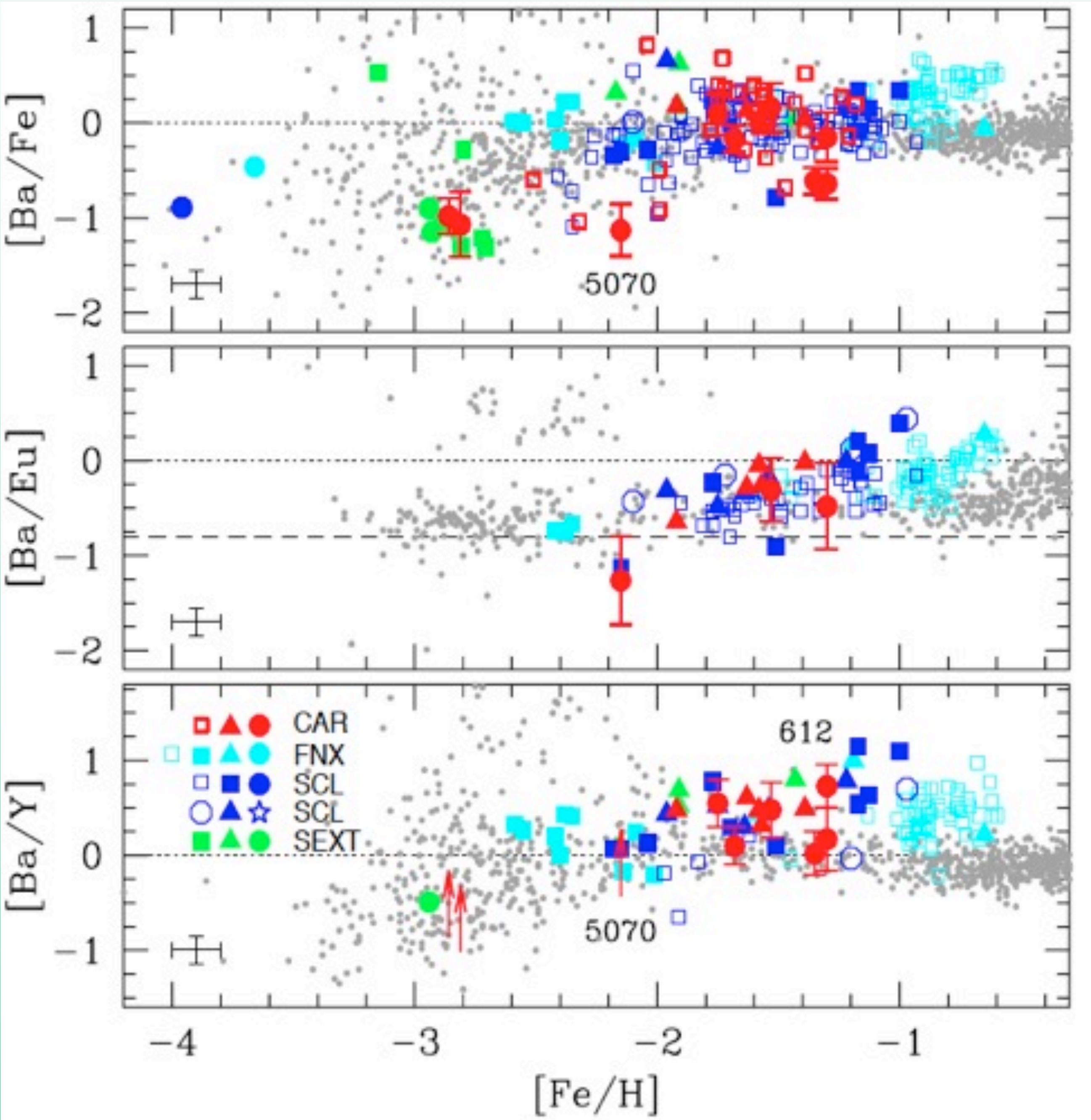


FIGURE: [Ba/Fe], [Ba/Eu], and [Ba/Y] for stars in Carina (red), Sculptor (blue), Fornax (cyan), and Sextans (green). Fornax values from Letarte et al. 2010 are corrected values from Letarte & Hill, priv. communication. Representative error bars of Δ[Fe/H] = ±0.1 and Δ[Ba/Fe,Eu,Y] = ±0.15 are shown.

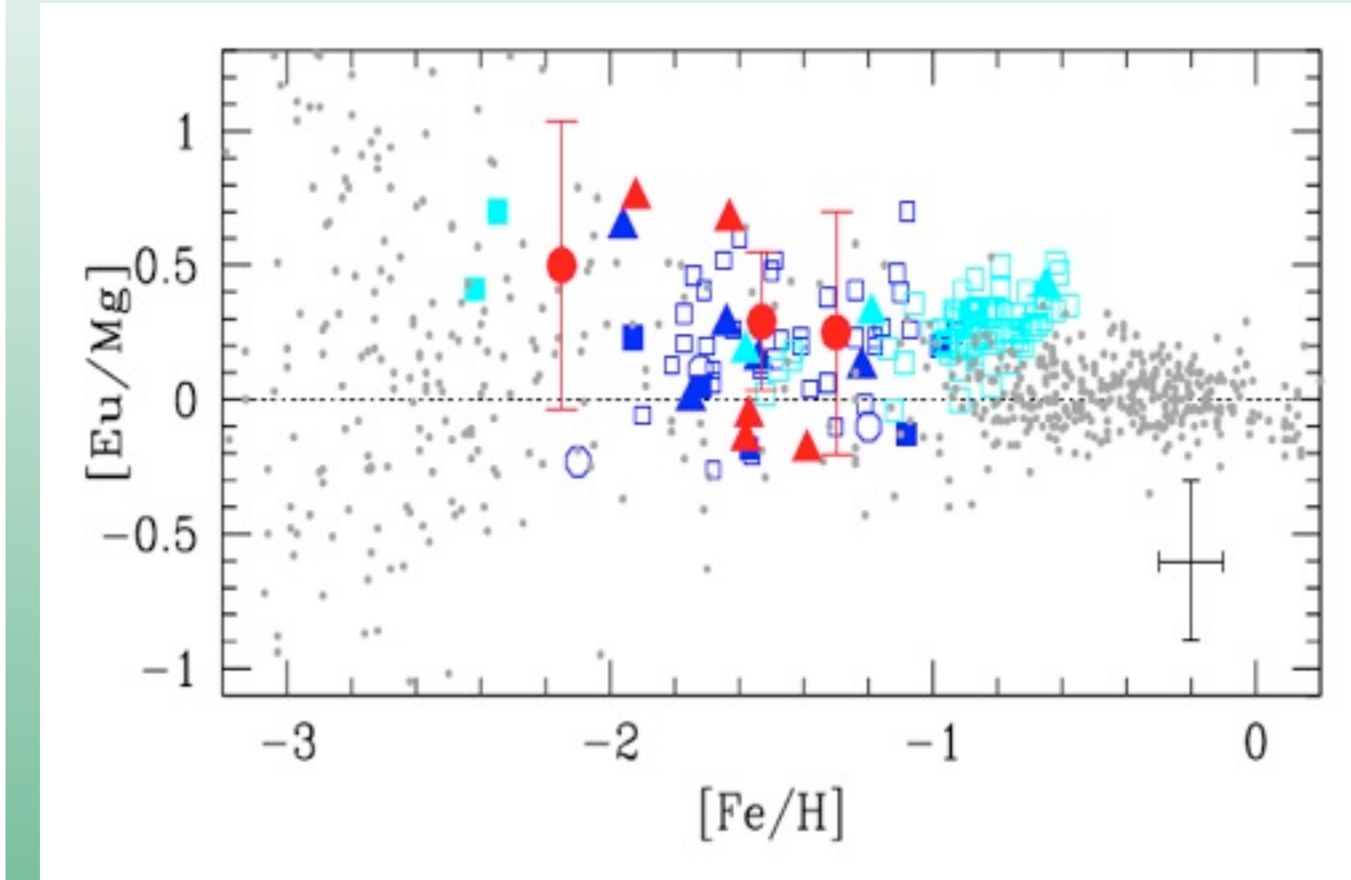


FIGURE: Examination of [Eu/α] in dSphs. The plot is nearly identical whether we use Mg or Ca for α. Representative error bars of Δ[Fe/H] = ±0.1 and Δ[Ba/Fe,Eu,Y] = ±0.3 are shown.

DWARF GALAXY AND MILKY WAY ABUNDANCE COMPARISON

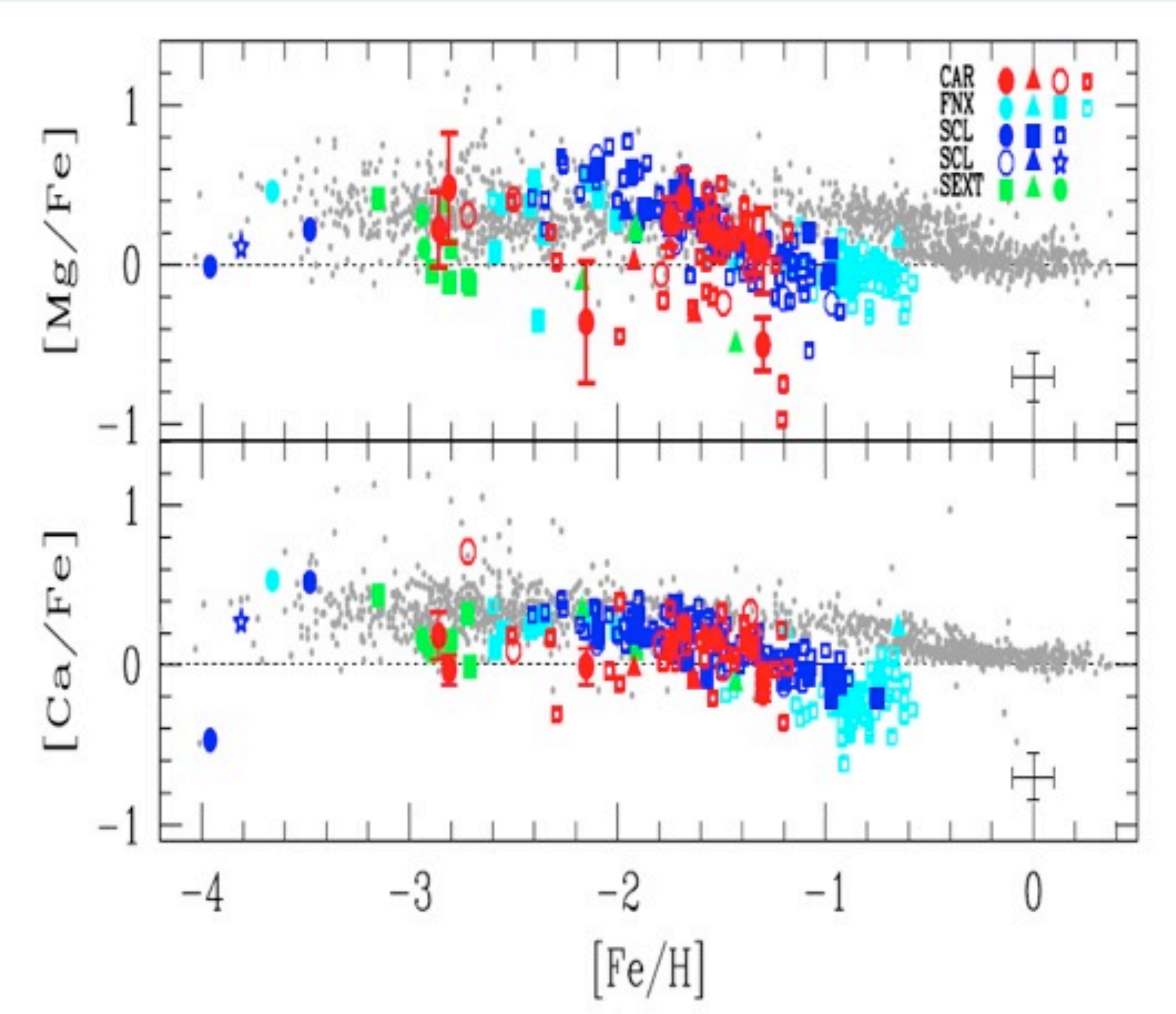


FIGURE: [Mg/Fe] and [Ca/Fe] in the most metal poor stars in the Galaxy, dwarf spheroidals, and ultra faint dwarfgalaxies. Black symbols represent the UFDs: solid/empty circles are for Bootes from Feltzing et al. (2009)/Norris et al. (2010), solid triangles for Ursa Major II from Frebel et al. (2010a), solid diamonds for Com Ber from Frebel et al. (2010a), plus signs forHercules from Koch et al. (2008b), and asterisk for one star in Leo IV by Simon et al. (2010).

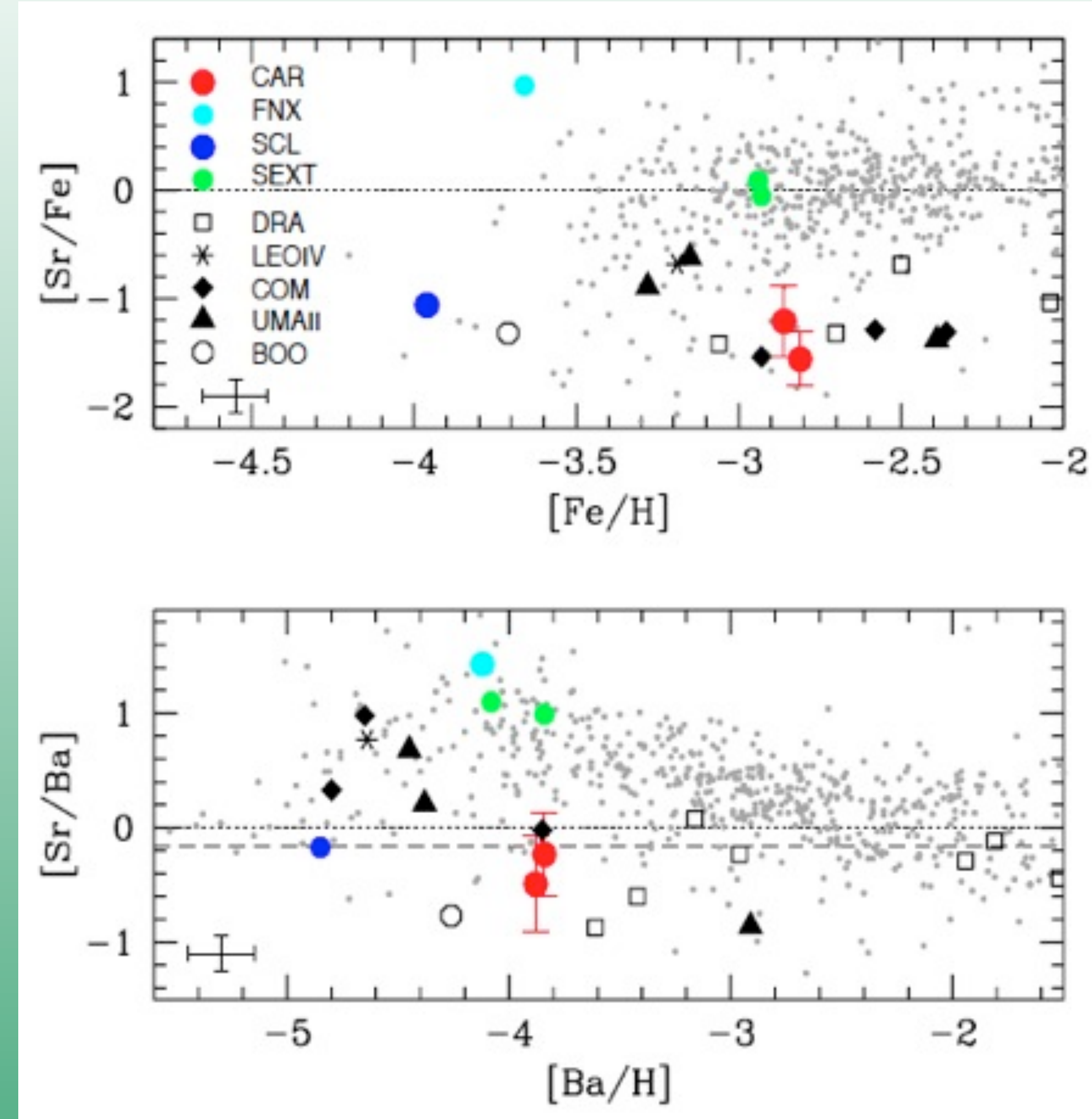
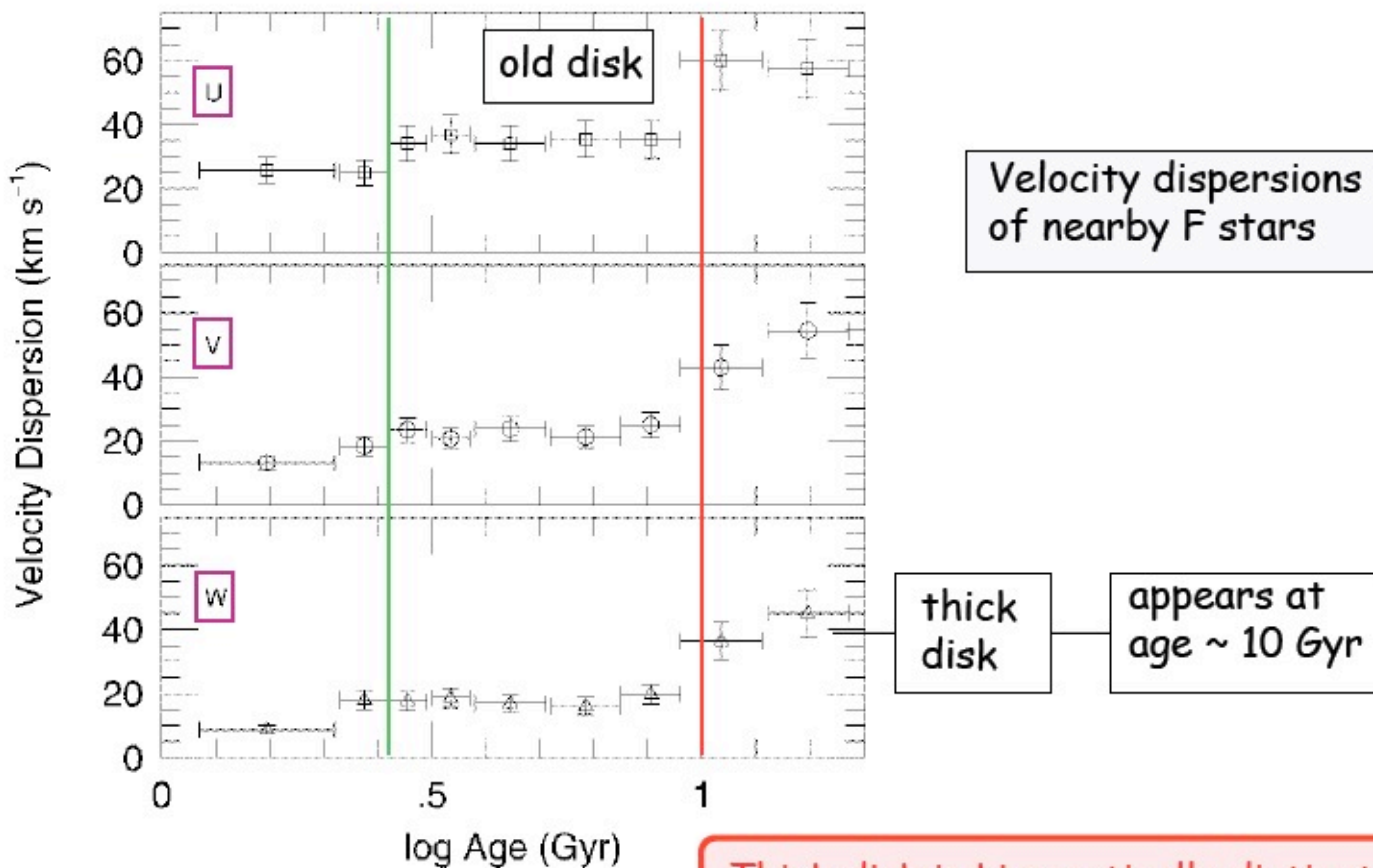


FIGURE: Examination of Sr in low metallicity stars. The [Sr/Fe] ratio is lower than in most other systems, Galactic and dSph galaxies, but has similarities with some UFDs (Draco, Com Ber in particular).The [Sr/Ba] ratio is enhanced in metal poor stars in the Galaxy and many dSph and UFD stars. However, it is not enhanced in Carina, nor Draco.

A NOD TO CHRIS SNEDEN...

THE OLD DISK (AND OLD TERMINOLOGY)



Thick disk is kinematically distinct

Freeman 1991; Edvardsson et al 1993; Quillen & Garnett 2000