Probing Chemical Evolution with Damped Lyman α Systems

What can DLAs do for you?

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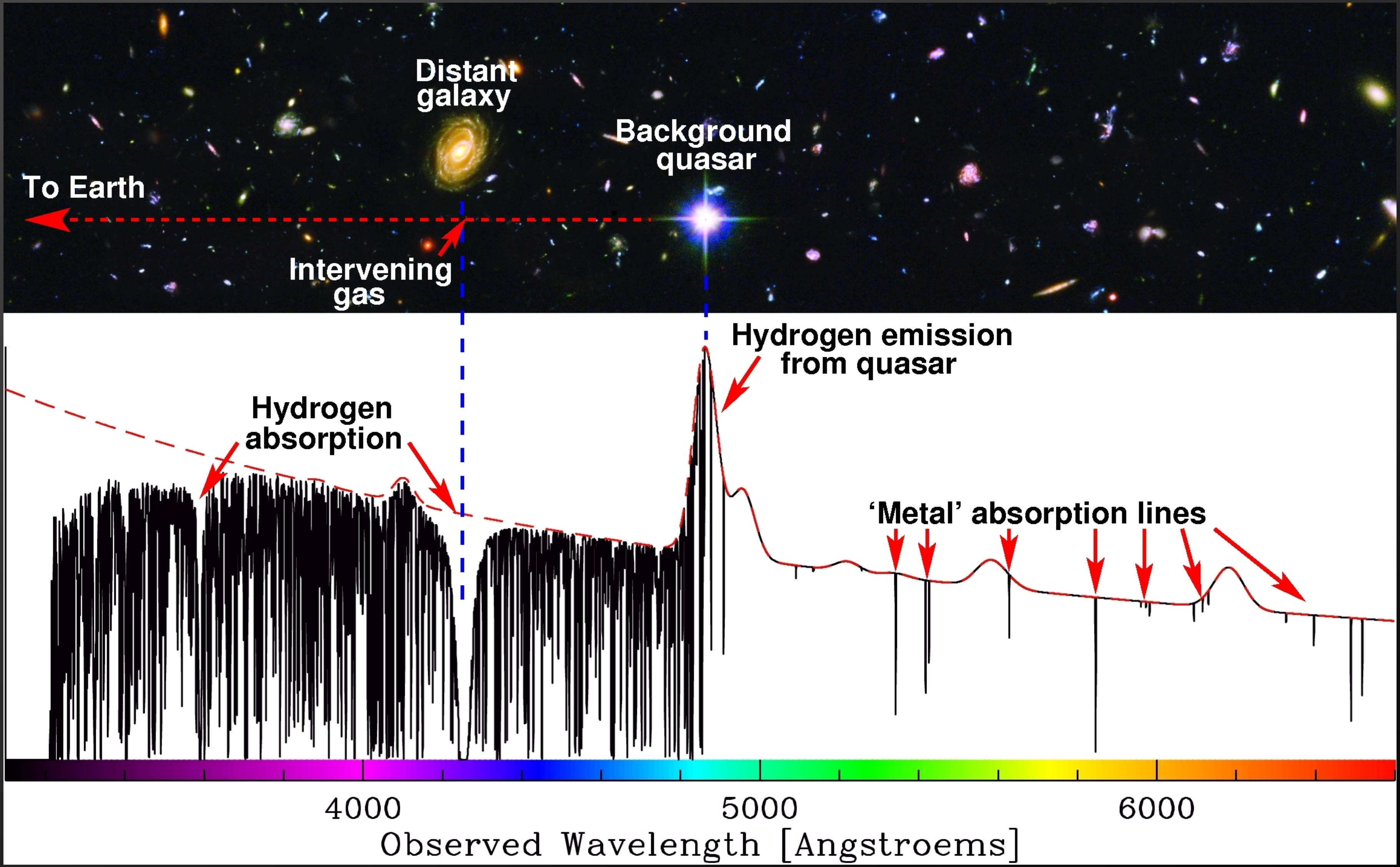
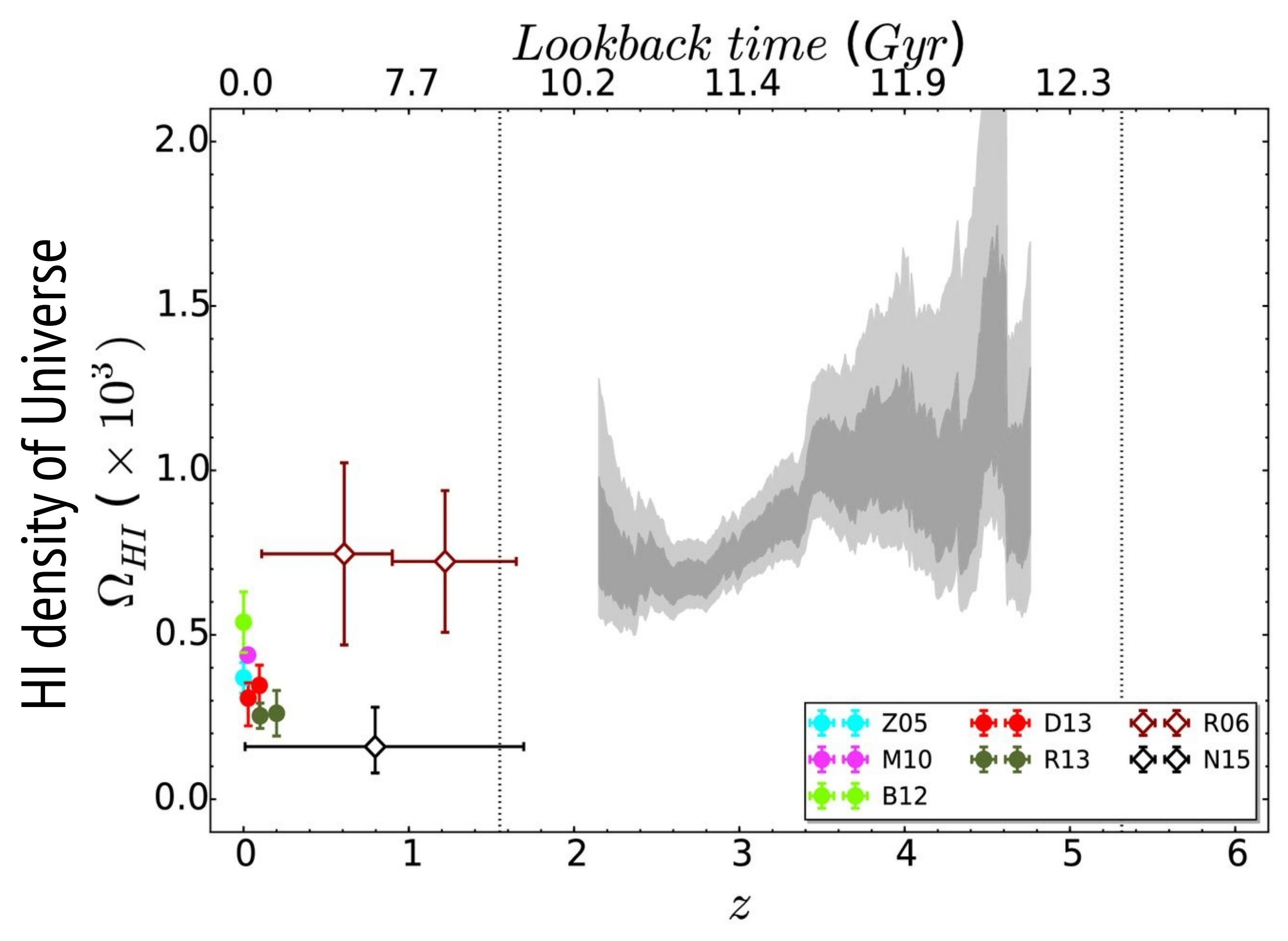
Quasar absorption line systems



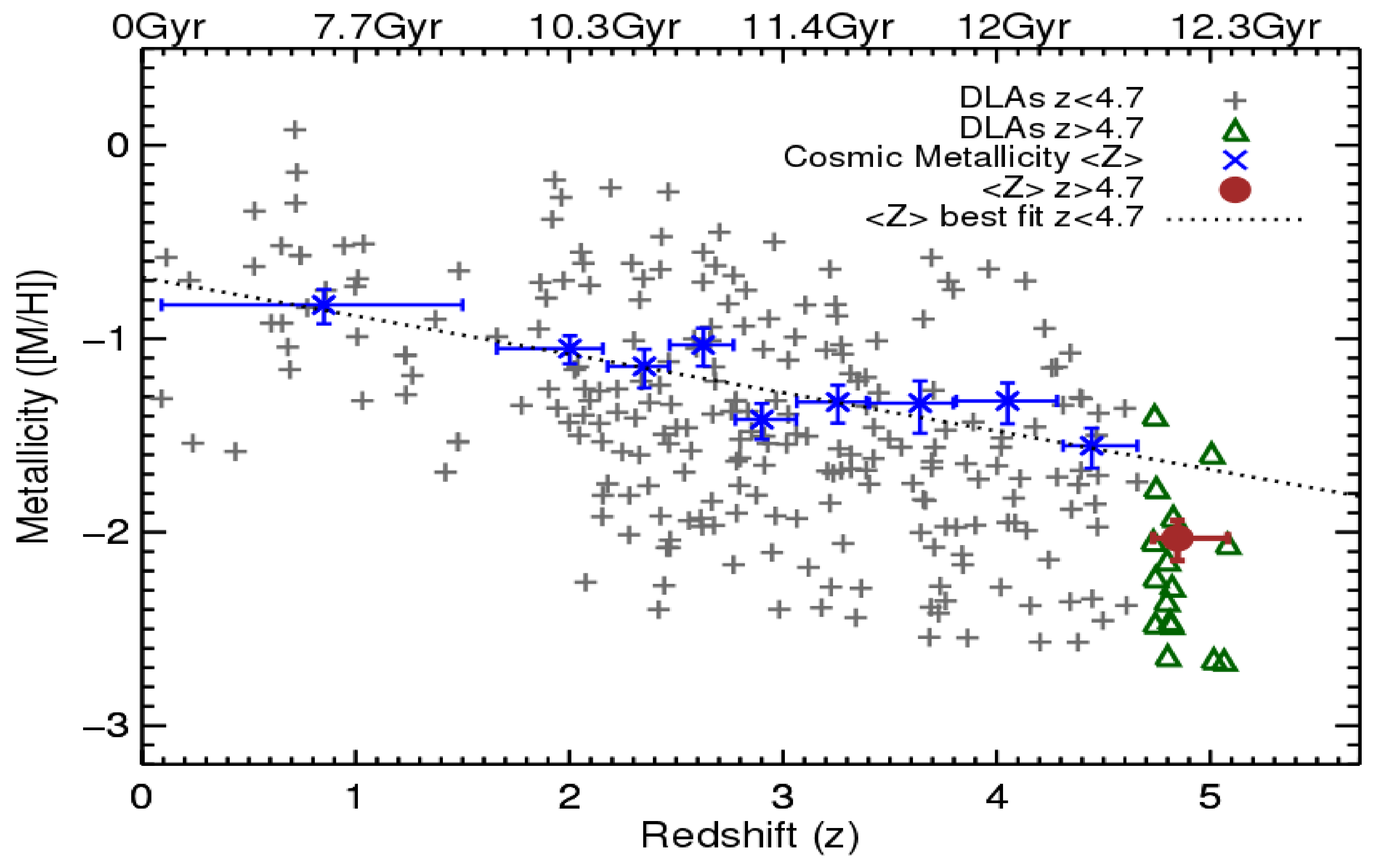
Damped Lyman α Systems (DLAs)

- Large HI column densities; logN(HI) ≥ 20.3
  - Galactic ISM columns
- Dominate HI content of Universe



Sanchez-Ramirez+ 2016

Damped Lyman α Systems (DLAs)



Rafelski+ 2014

Why use DLAs for chemical evolution?

Pros	Cons
• Probe evolution all the way back to $z\sim5$	

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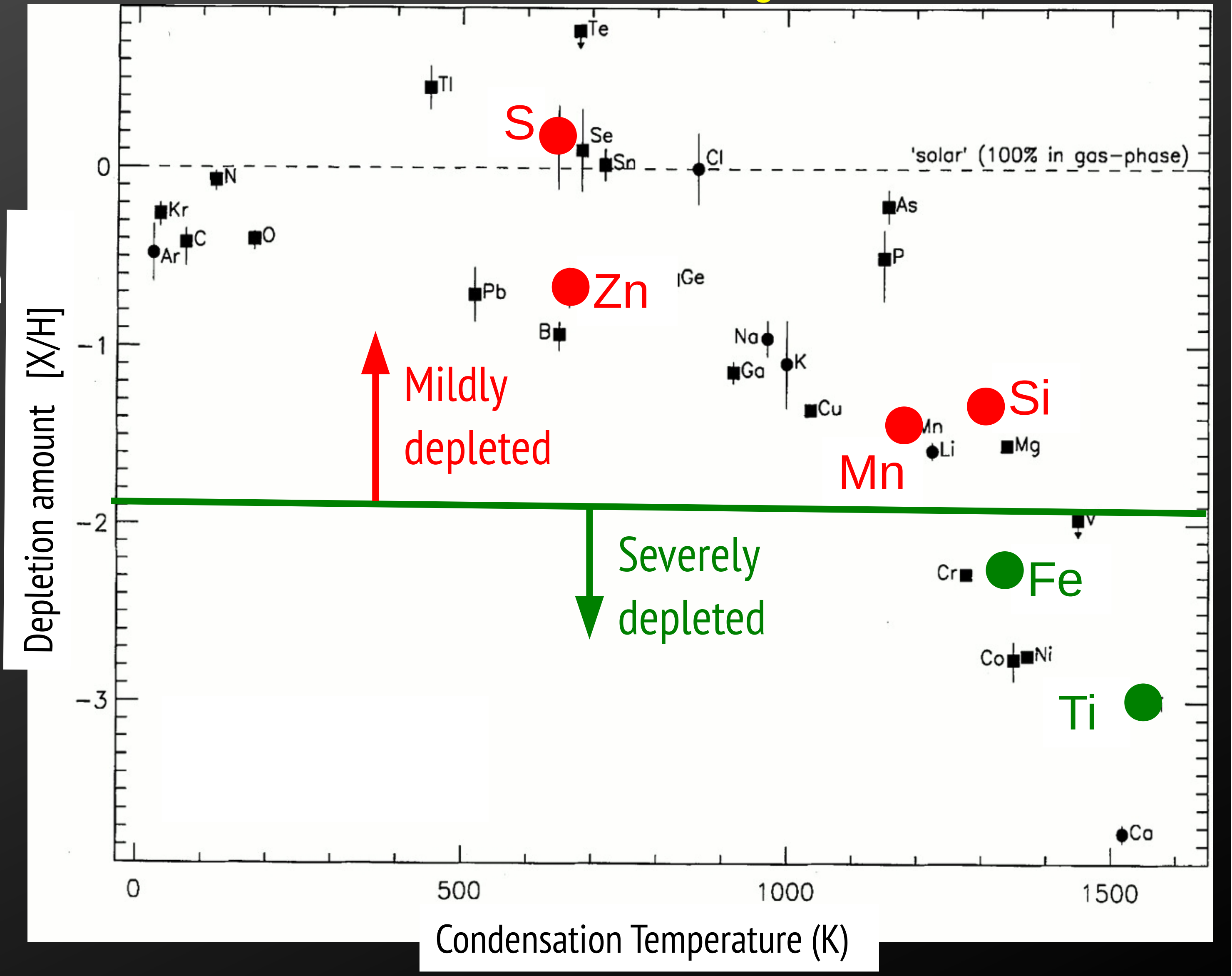
Pros	Cons
• Probe evolution all the way back to z~5	• Lack of galaxy properties without imaging
• Detailed abundances for systems other than Local Group	• Gas phase abundances – Dust depletion effects
• Magnitude and Morphology blind (require gas)	

The problem with DLAs: Dust depletion

- Condensation onto dust grains
  - Underprediction of total column densities

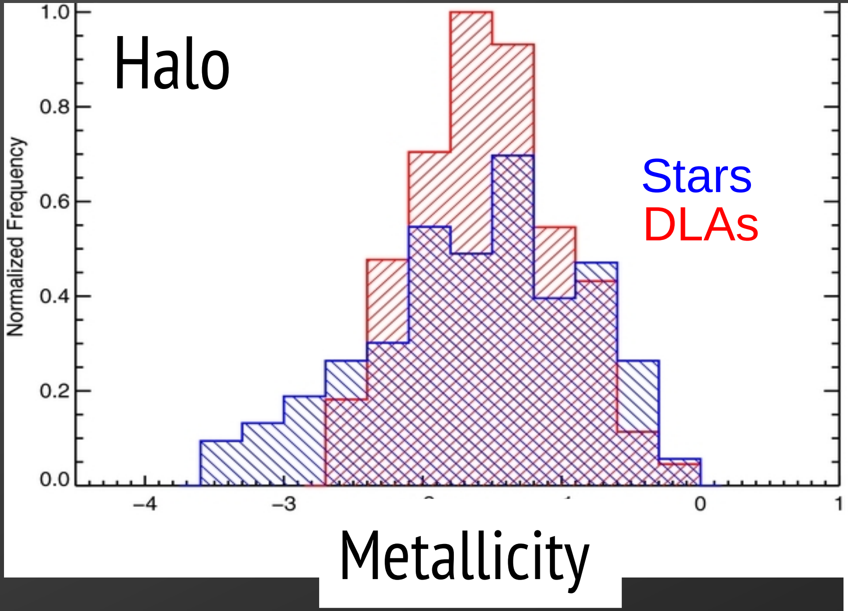


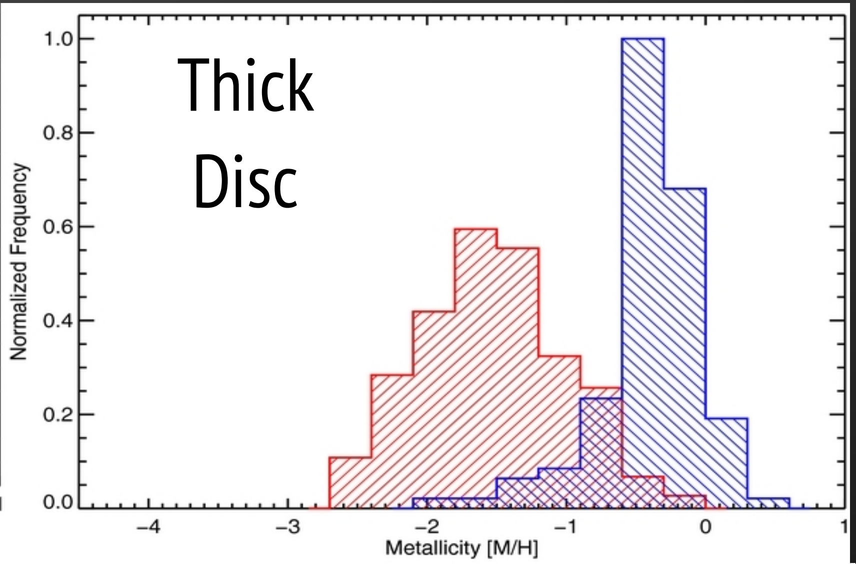
Savage and Sembach 1996

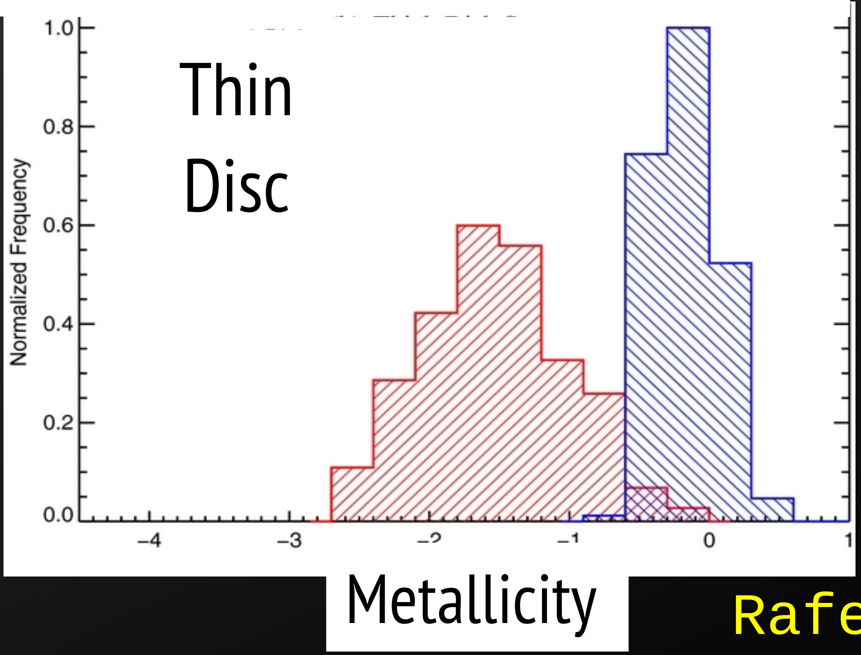
Goal of using abundances of DLAs

Can we use DLA chemistry to understand what environment DLAs arise whilst correcting for dust depletion?

Environments probed by DLAs







Lack of high-metallicity DLAs to probe thin disc (and dSphs)

Rafelski+ 2012

“Metal Rich” DLAs

- Probe galaxies that:
  - Study thin-disk and dSphs environments at z~2 (ISM of stars today?)
  - May contain rarely detected elements (Mn, B, Pb; Prochaska+ 2003)

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  - Study thin-disk and dSphs environments at z~2 (ISM of stars today?)
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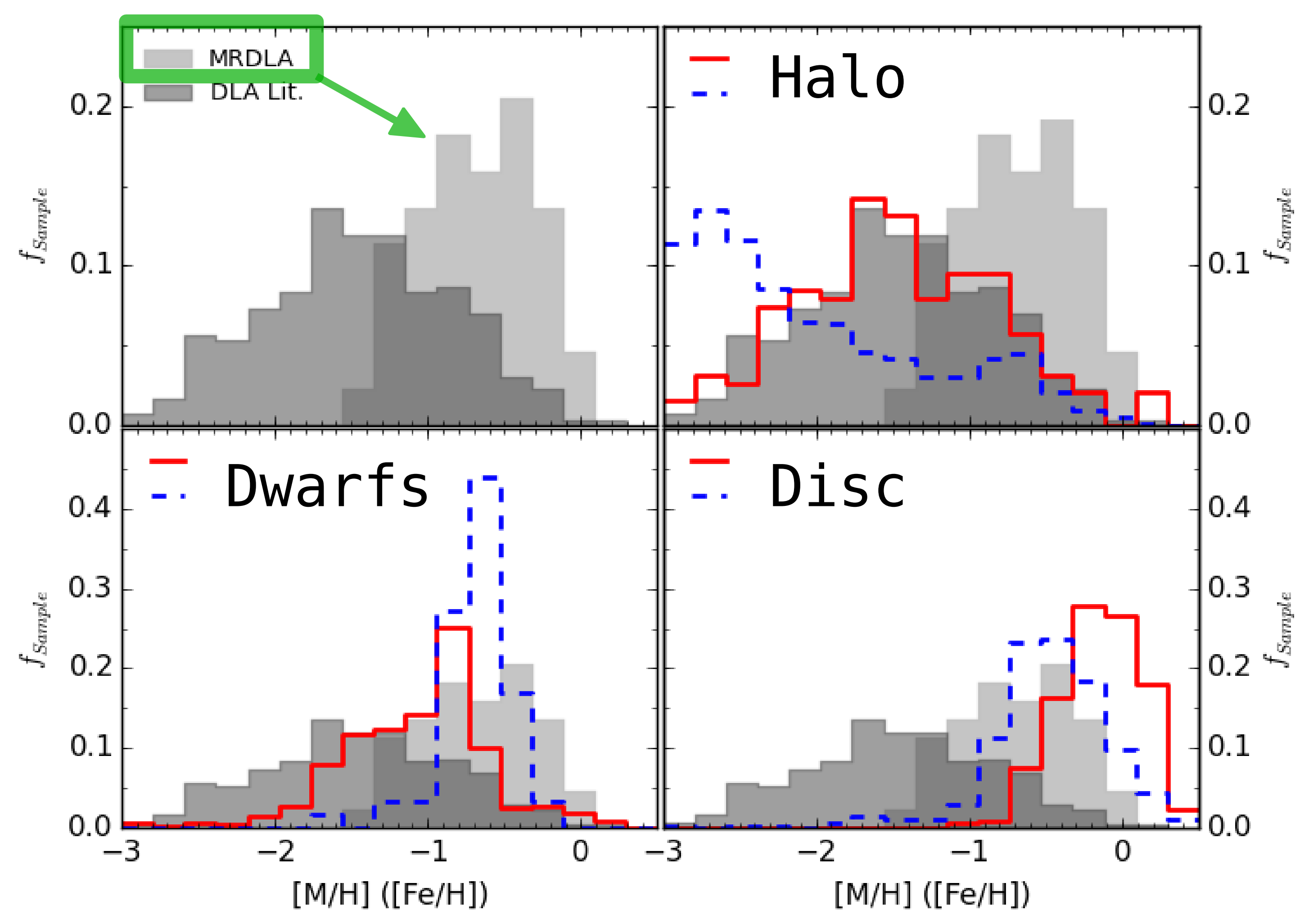
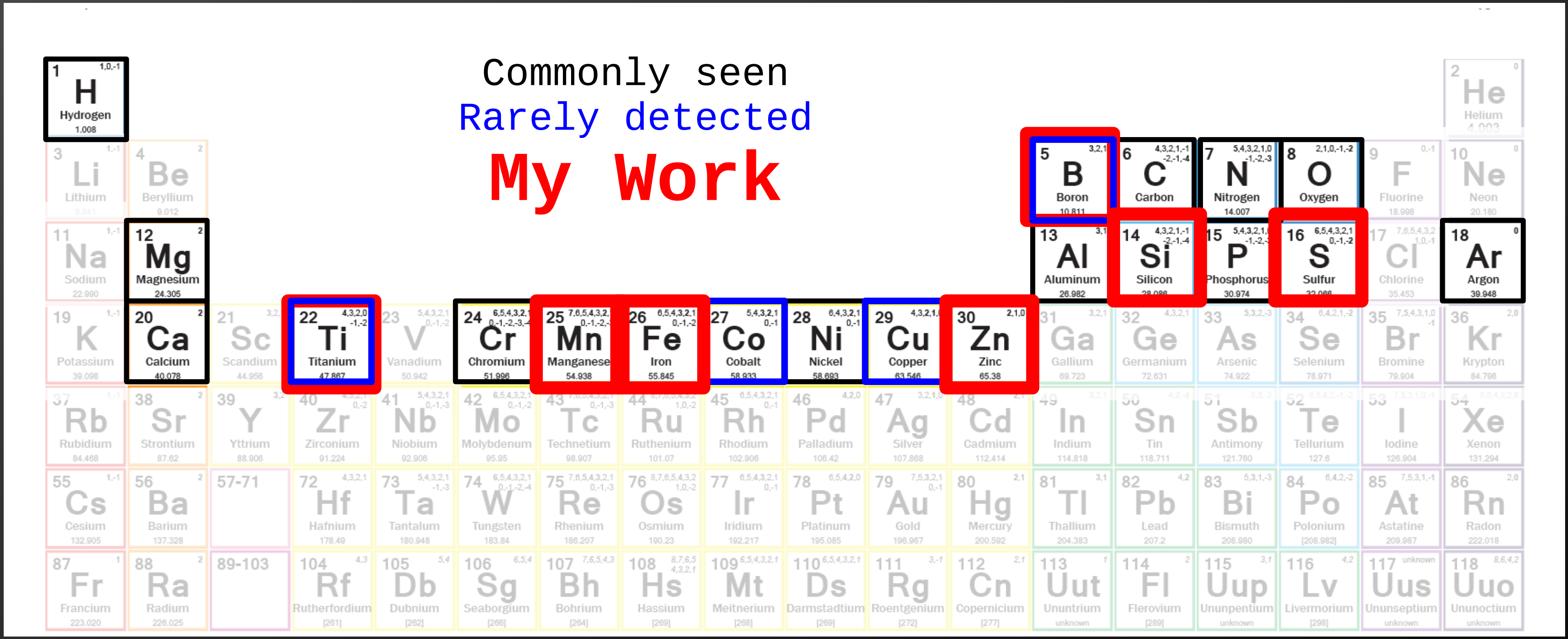
- 45 metal-rich DLAs with 100+ hours of Keck/HIRES (Berg et al. 2015; Paper I)

Environments probed by DLAs



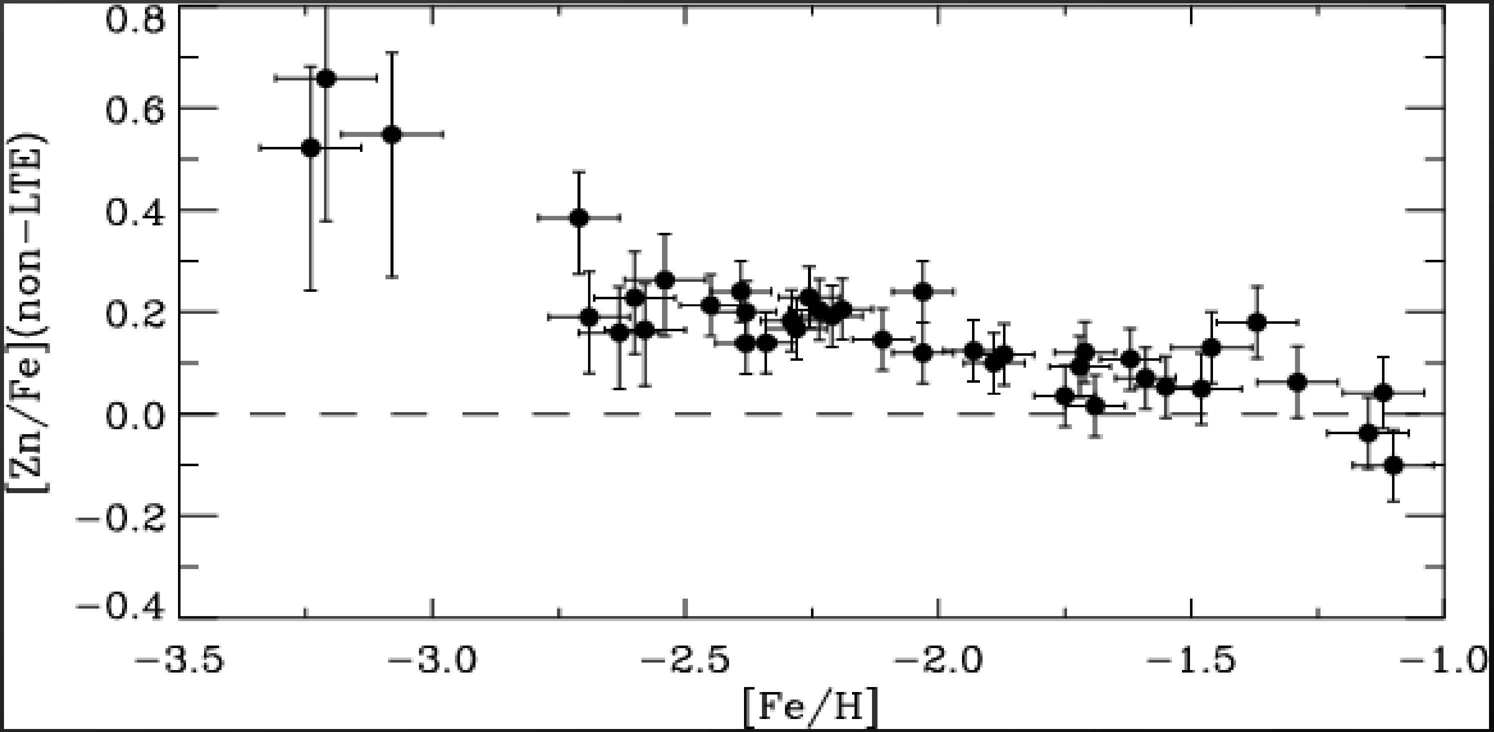
Berg+ 2015 (Paper II)

Detailed Chemistry

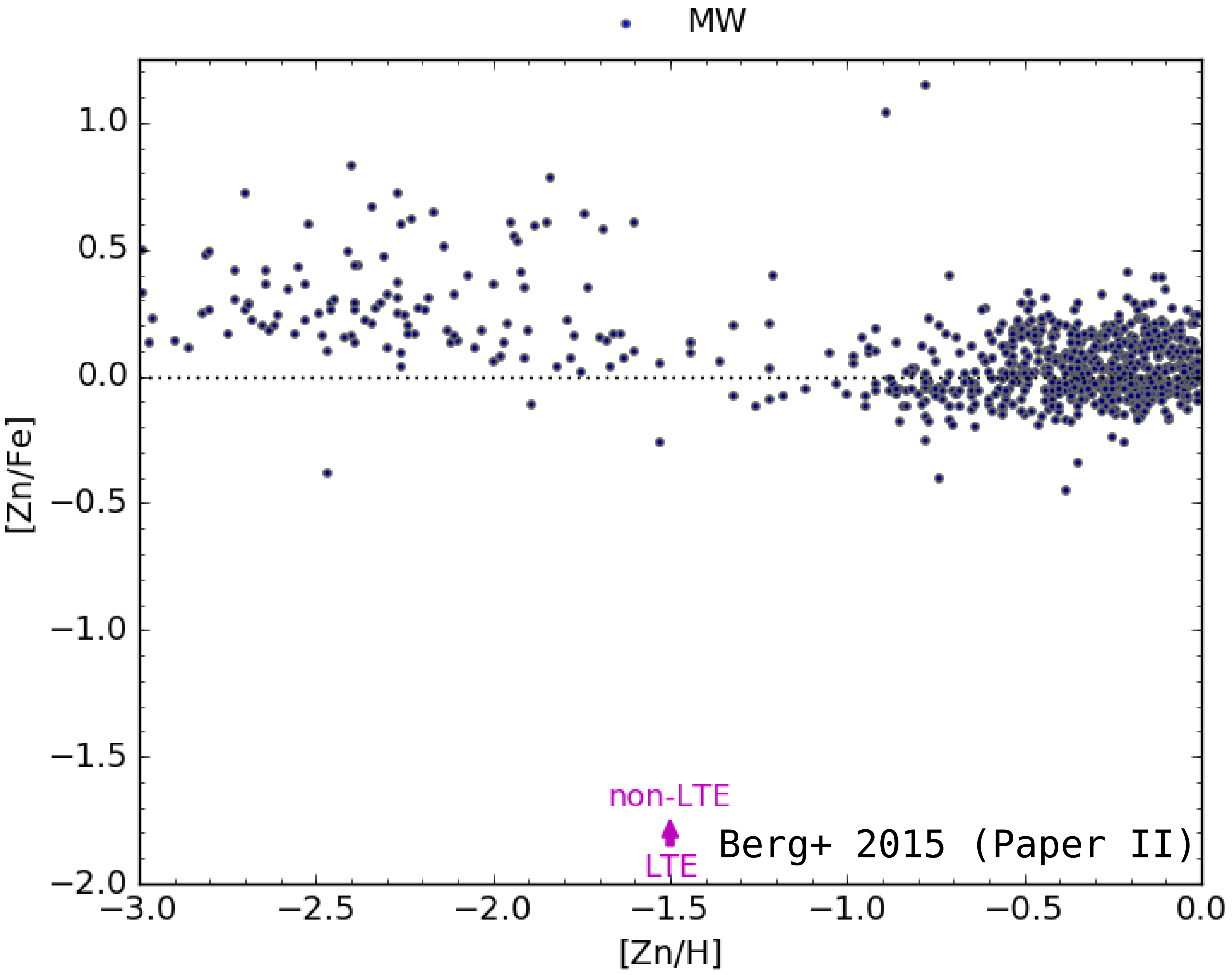


[Zn/Fe] – dust tracer or nucleosynthetic probe?

- Forms in lockstep with Fe at solar metallicities
  - DLA dust tracer (e.g. Pettini+ 1994)?
- Different contribution at low metallicities (hypernovae?)



Nissen+ 2007



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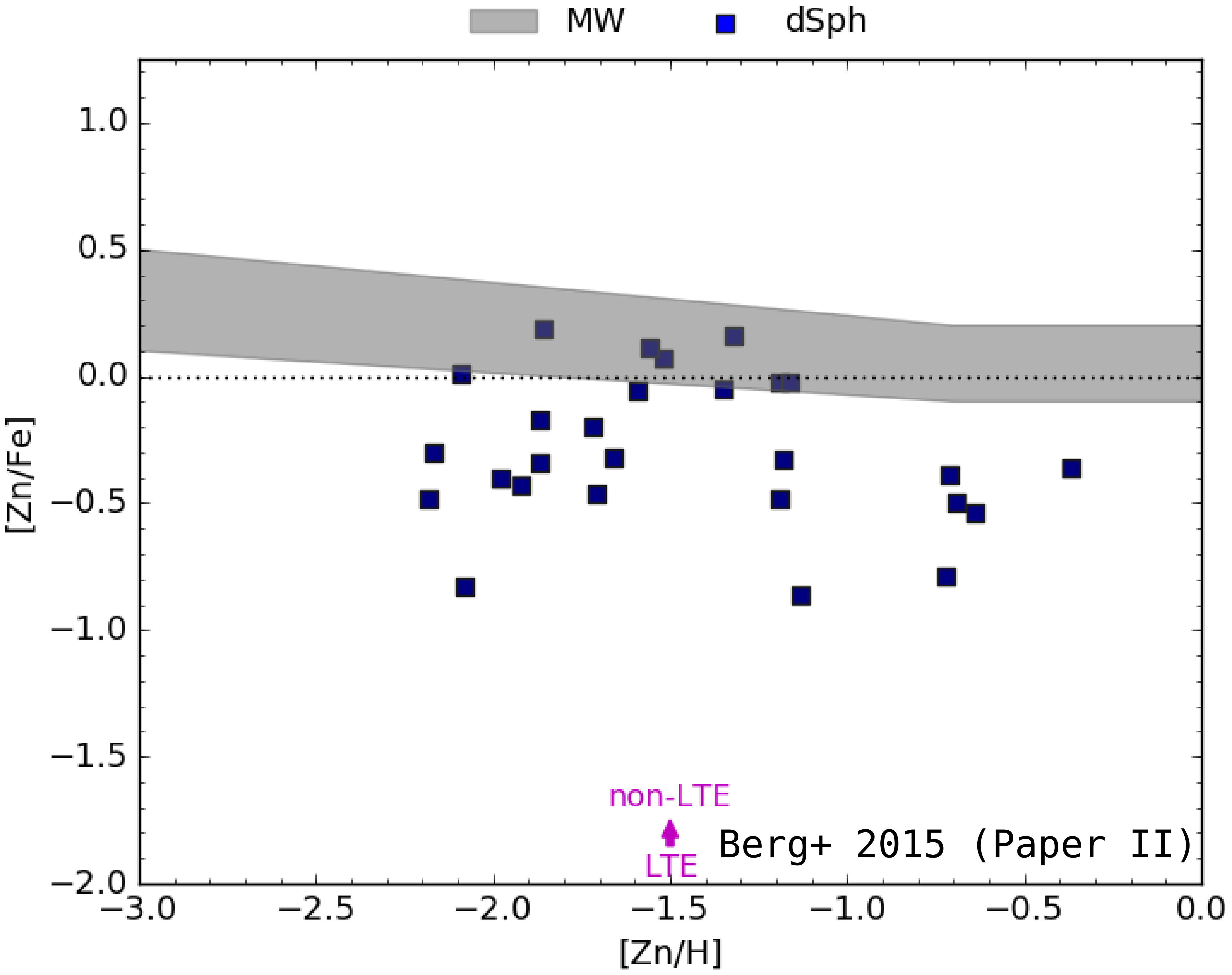

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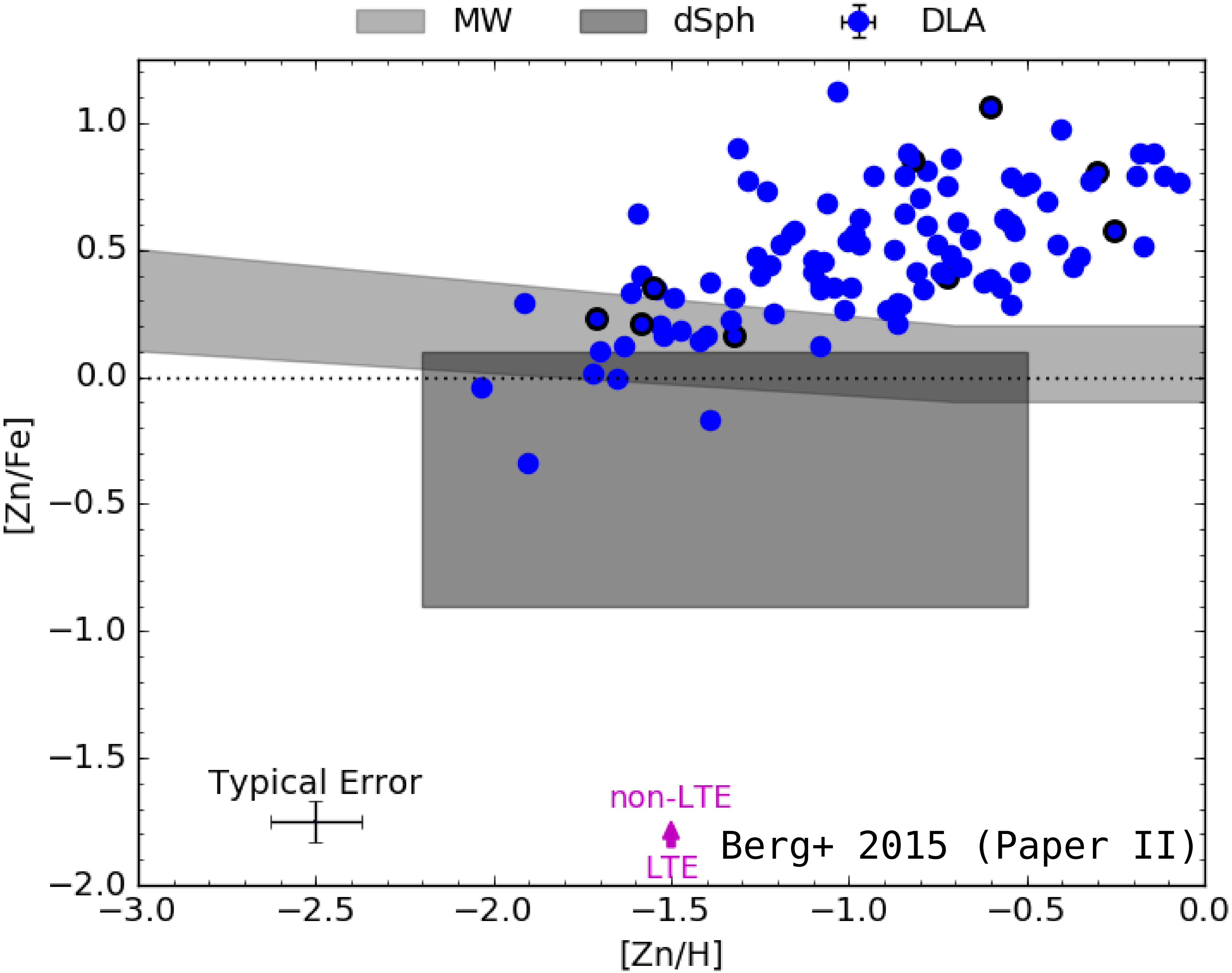
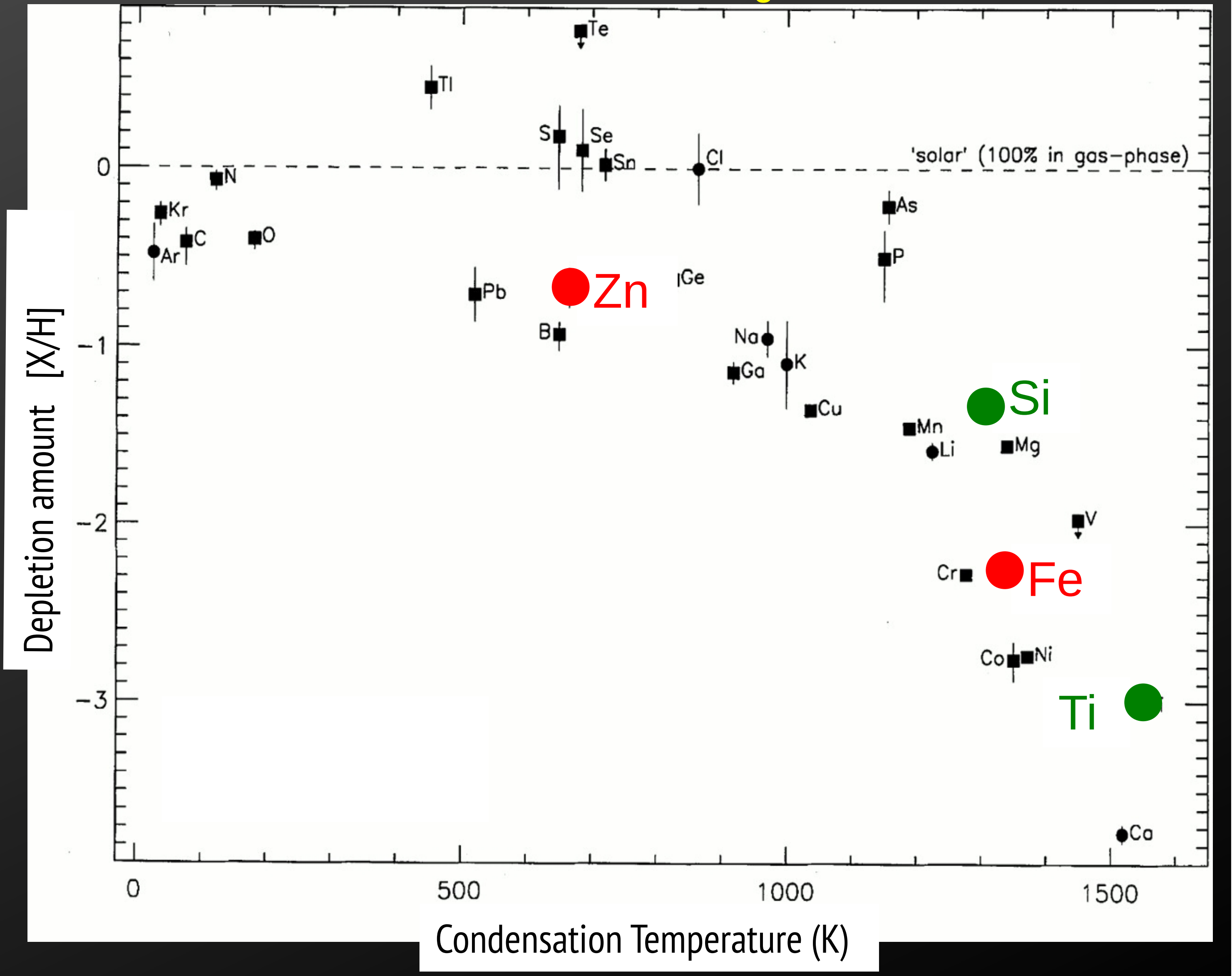

MW
dSph
DLA
1.0
0.5
0.0
−0.5
−1.0
−1.5
−2.0
[Zn/Fe]
−3.0
−2.5
−2.0
−1.5
−1.0
−0.5
0.0
[Zn/H]
Typical Error
non-LTE
LTE
Berg+ 2015 (Paper II)

The problem with DLAs: Dust depletion

- Relative depletion patterns should scale from galaxy to galaxy
  - Elements with similar nucleosynthetic origin should give dust scaling

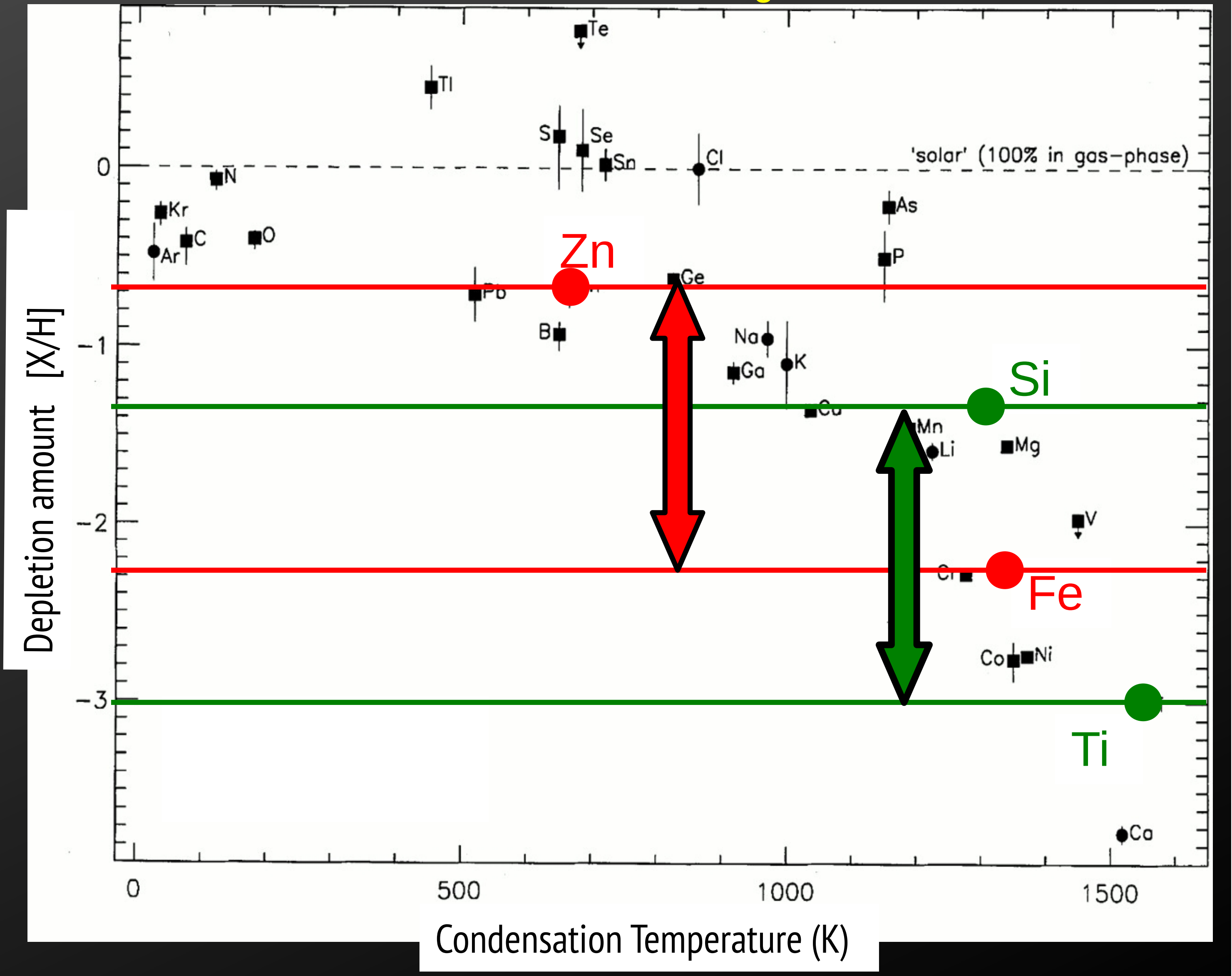
Savage and Sembach 1996

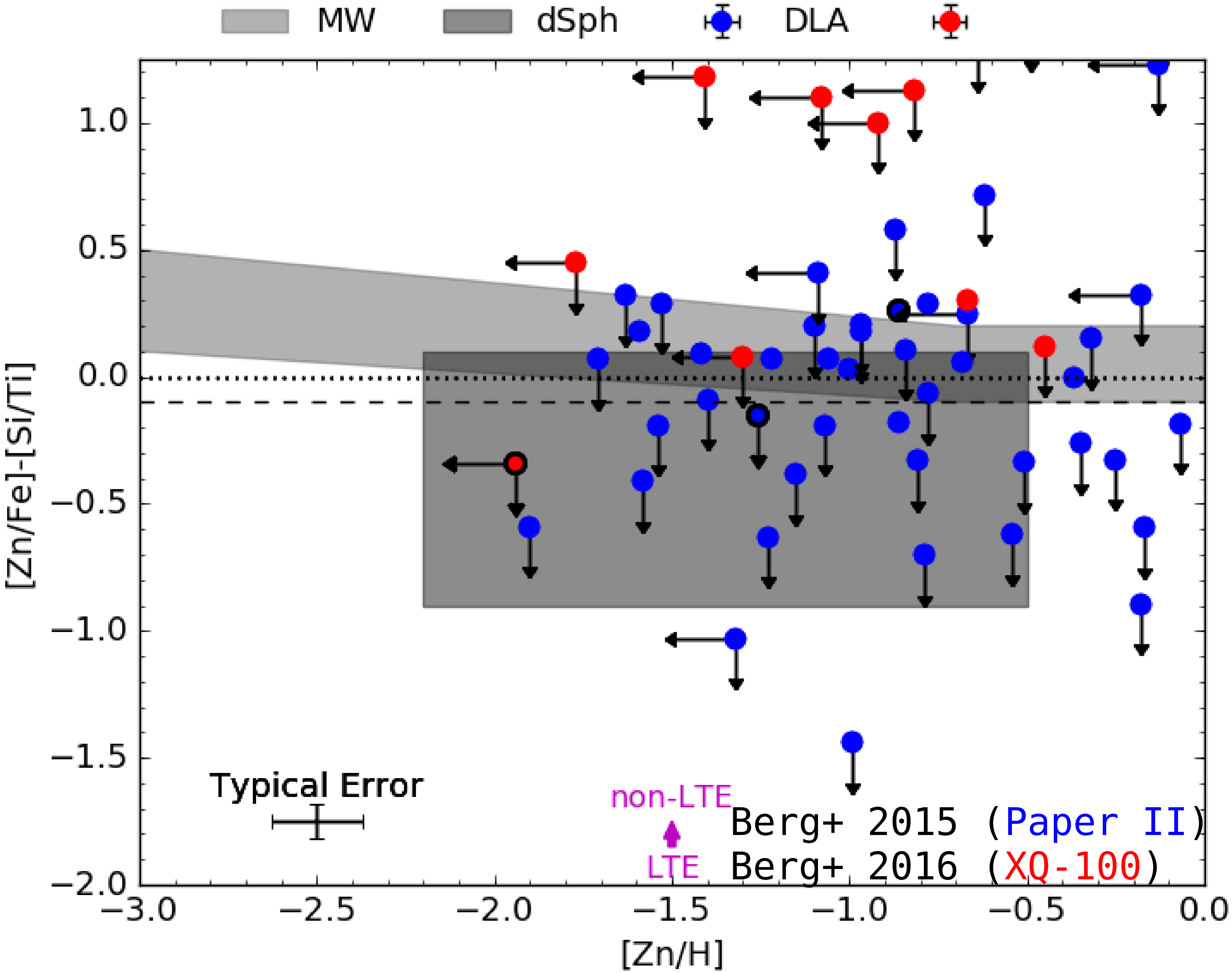


The problem with DLAs: Dust depletion

- Si and Ti both alpha-elements; same relative depletion as Zn-Fe
- [Zn/Fe] – [Si/Ti] will give the nucleosynthetic contribution of [Zn/Fe]

Savage and Sembach 1996




MW
dSph
DLA
[Zn/Fe]-[Si/Ti]
[Zn/H]
1.0
0.5
0.0
−0.5
−1.0
−1.5
−2.0
−3.0
−2.5
−2.0
−1.5
−1.0
−0.5
0.0
Typical Error
non-LTE
LTE
Berg+ 2015 (Paper II)
Berg+ 2016 (XQ-100)

Zn an Fe-peak tracer?

- Zn is not an Fe-peak tracer for ALL galaxies
- Some DLAs are similar to dSph [Zn/Fe] values
  - Others are consistent with both MW and dwarfs
- Need *accurate* Zn abundances in different environments!

DLA chemistry summary

- DLAs offer probe of observing chemical evolution across cosmic time
- MRDLAs can probe regime where differences in chemistry are seen in Local Group environments
  - [Zn/Fe] – Consistent with MW and dSphs
  - [α/Zn] – Low α in DLAs
  - [Mn/Fe] – Like dSphs (at high metallicities)
- Require handle on odd-Z and Zn in various environments