Automated Abundance Analyses with SME

Current limitations and future prospects

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Introduction

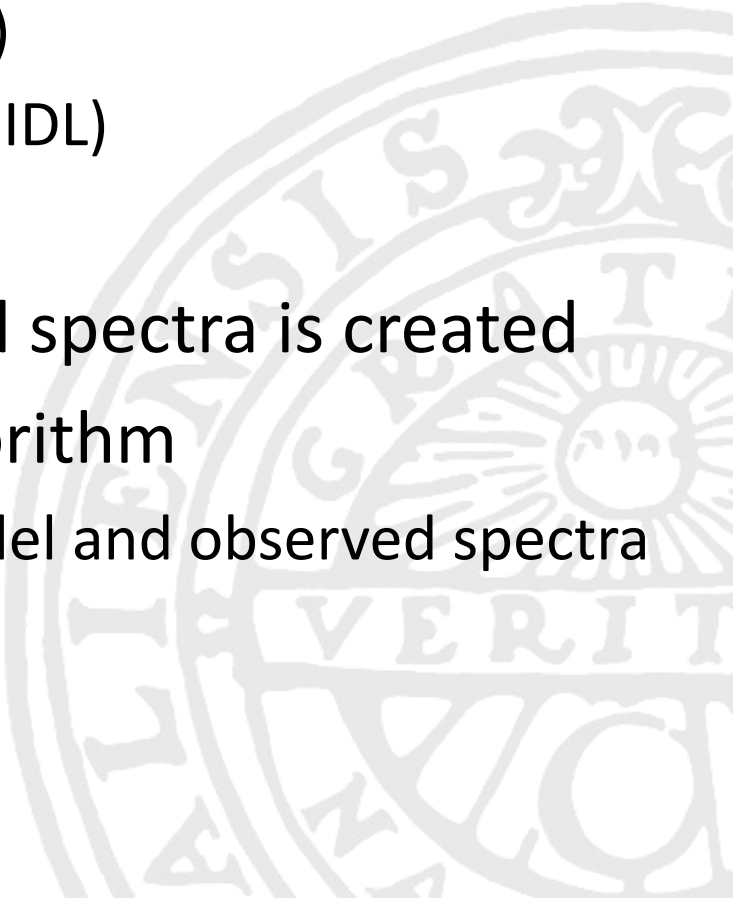
- Analysing high resolution spectra yields:
  - atmospheric properties of stars:
    - T_{eff}
    - log g
    - Chemical abundances ➠ Galactic chemical evolution
  - Insight in stellar structure, atmosphere and evolution
- Recent and future spectroscopic surveys result in thousands of spectra

  ⇒ **Automated spectrum analysis tools necessary**

SME

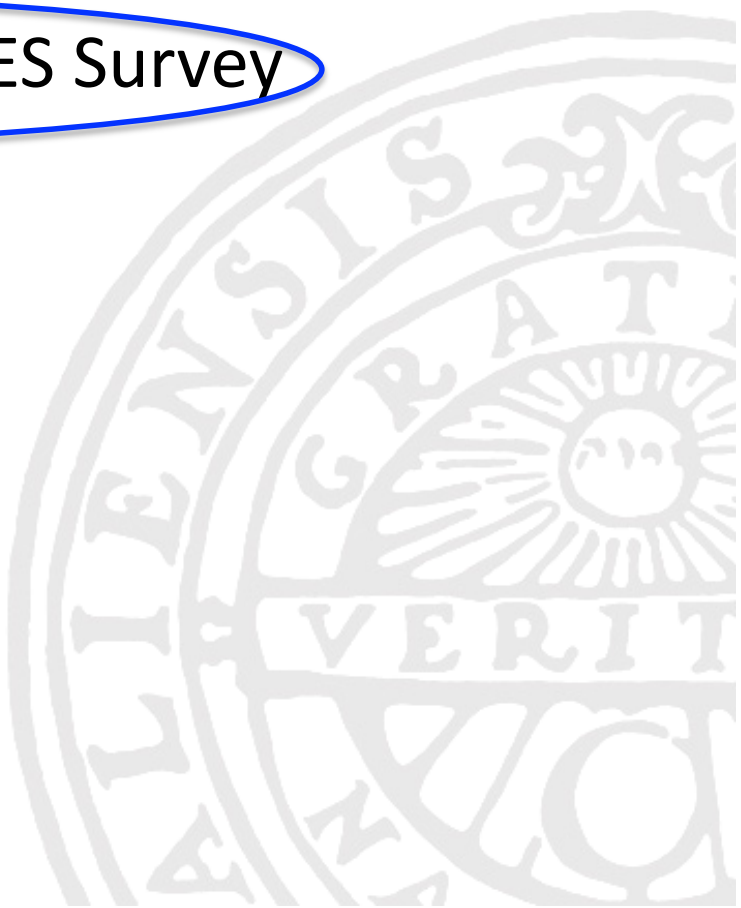
- Spectroscopy Made Easy (Valenti & Piskunov 1996,1998)
- Three components:
  - Spectrum synthesis component (C++)
  - Parameter optimisation component (IDL)
  - User interface (IDL)
- From input models, fit to observed spectra is created
- SME optimisation: Marquardt-algorithm

  $\Rightarrow$ Minimise χ^2 statistic comparing model and observed spectra



SME in the literature

- Examples of SME use:
  - Valenti & Fischer (2005): 1040 FGK stars
  - Barklem et al. (2005): The HERES Survey

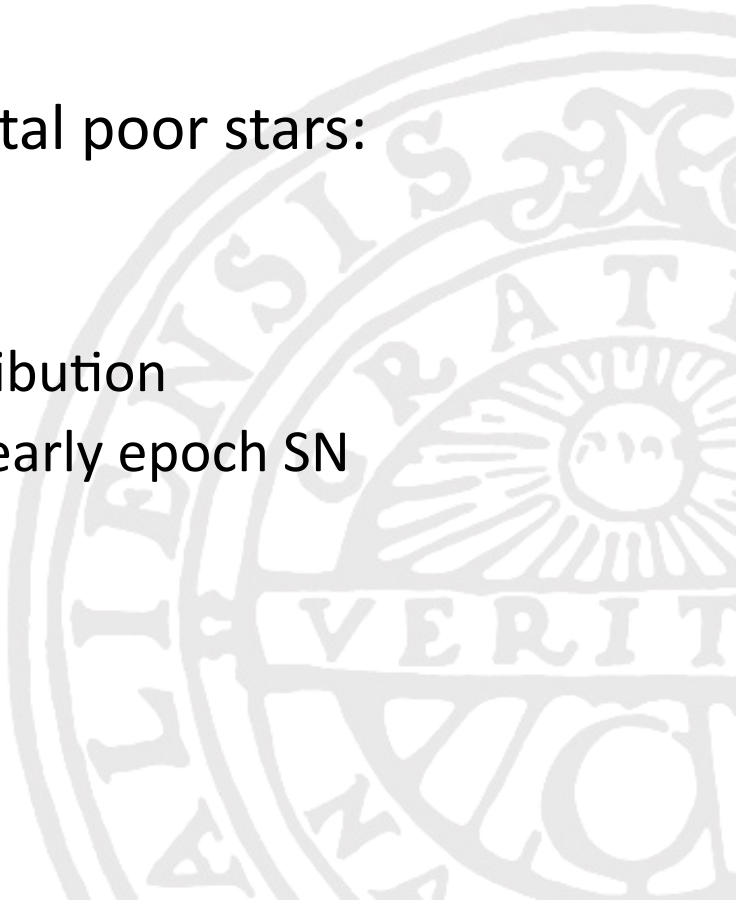


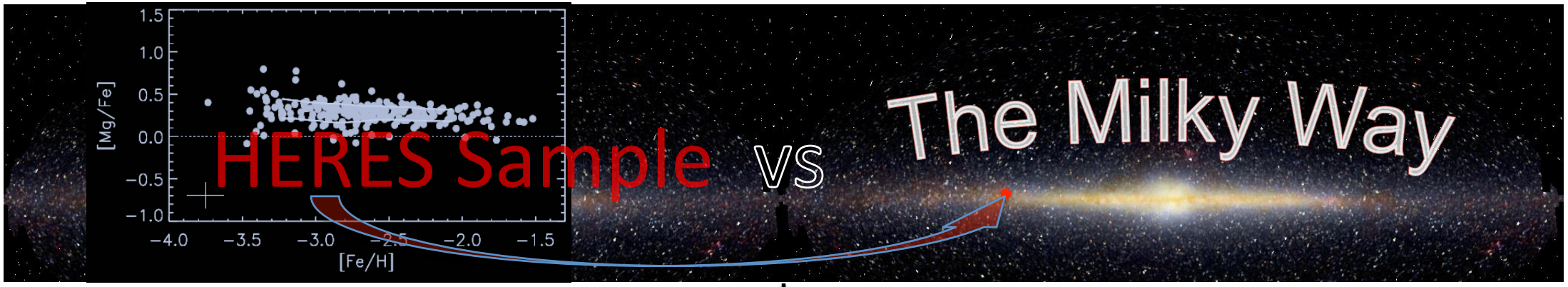
HERES

- Hamburg/ESO R-process Enhanced Star survey
  (Chriestlieb et al. 2004, Barklem et al. 2005)
  - VLT/UVES sample of 373 spectra of metal poor stars:
    - S/N ~ 50, R ~ 20000, λ = 3760 - 4980Å
  - Low quality for abundance analysis

    $\Rightarrow$ Investigate scatter in abundance distribution

    $\Rightarrow$ Insight in mixing and diversity of early epoch SN





- 373 Metal-poor stars:
  $-3.8 < [Fe/H] < -1.5$
- Cool MS stars:
  $4200K < T_{eff} < 6780K$
- Spectroscopic binaries and fast rotators removed
- Stars with strong molecular C-features discarded
- All stars have adequate photometric data
- Total analysed sample
  = 253 Stars

- $-5.5 < [Fe/H] < +0.5$
- $2800\ K < T_{eff}(MS) < 40000\ K$
- < 50% are binaries
- About 20% of the [Fe/H] < – 2 stars are C-rich
- We are getting there …
- But still a long way to go!

Automating SME

- SME: new interface

  ⇒ Automated and homogeneous analysis of spectra

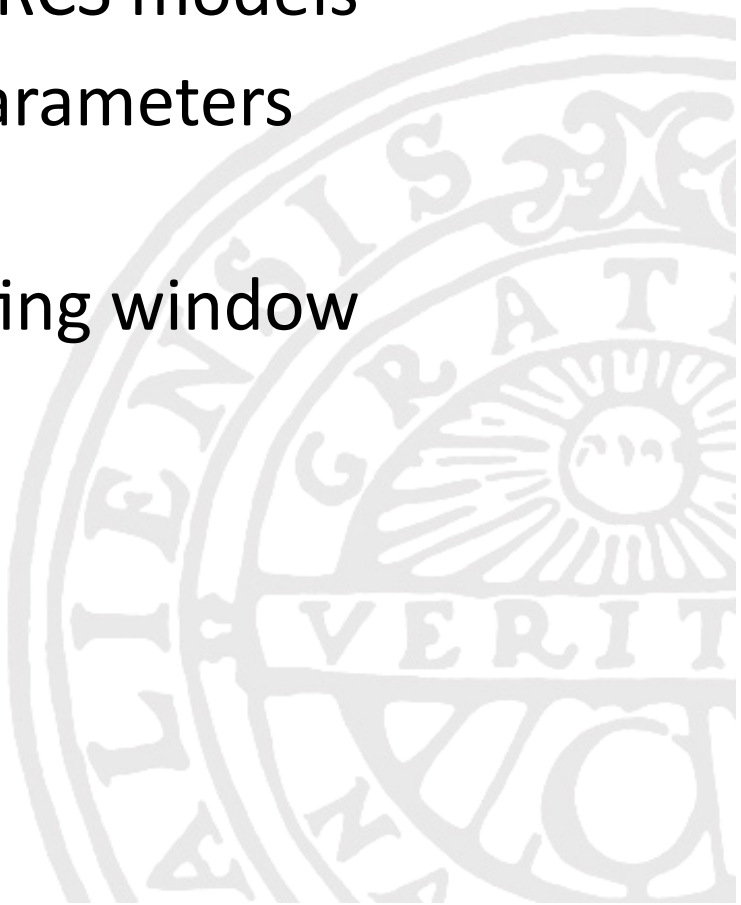
The new interface takes care of:

- Extracting relevant spectral regions appropriate for the line list from spectral windows
- Identifying continuum points and normalise spectra
- Rejecting pixels hit by cosmic rays

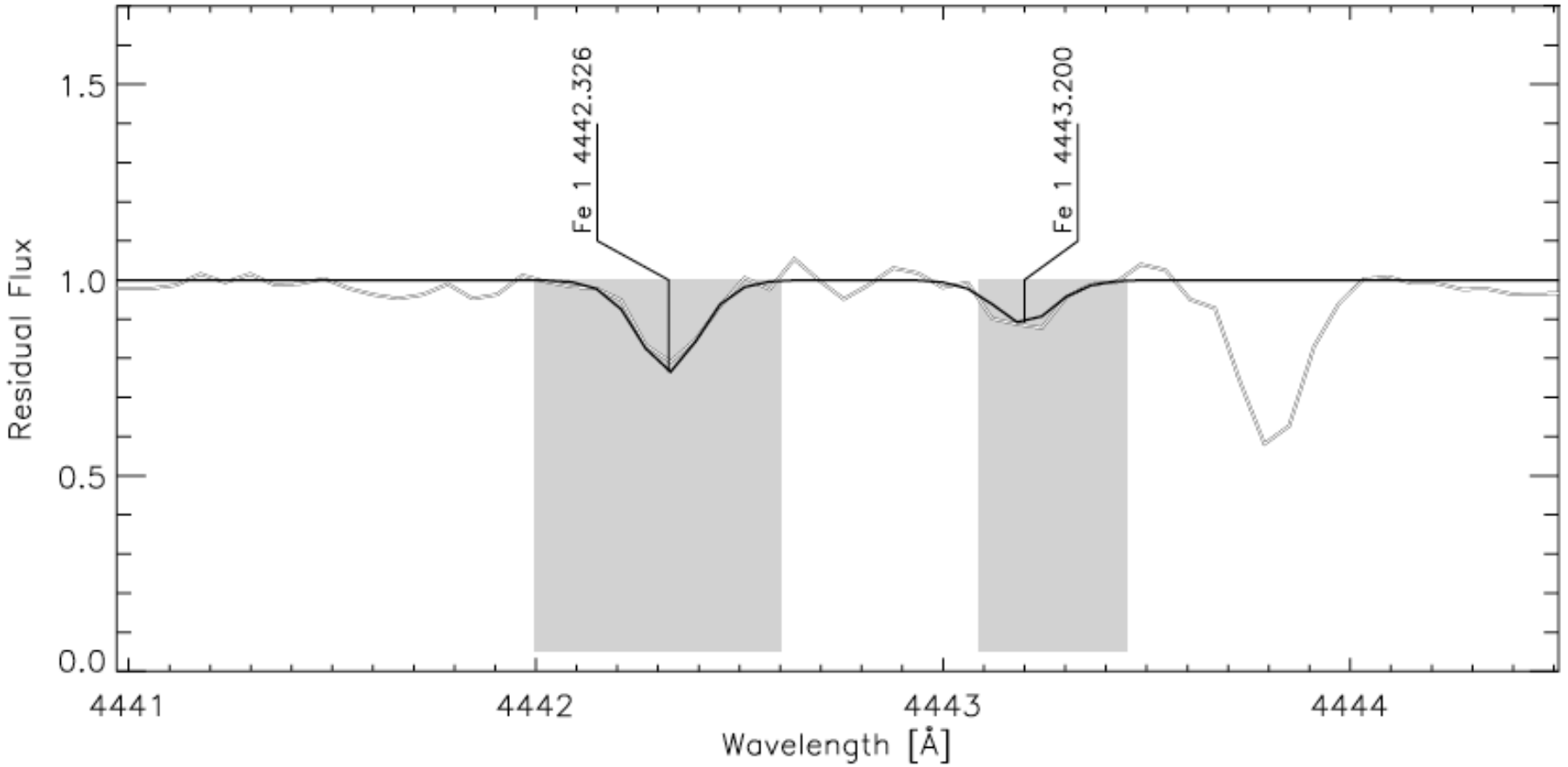
⇒ **All in a completely automated fashion**

SME: input

- Pipeline reduced count spectrum
  with corresponding measurement error spectrum
- Grid of 1D, plane-parallel, LTE MARCS models
- Initial guess stellar atmosphere parameters
  and abundance
- Atomic and molecular line list: fitting window

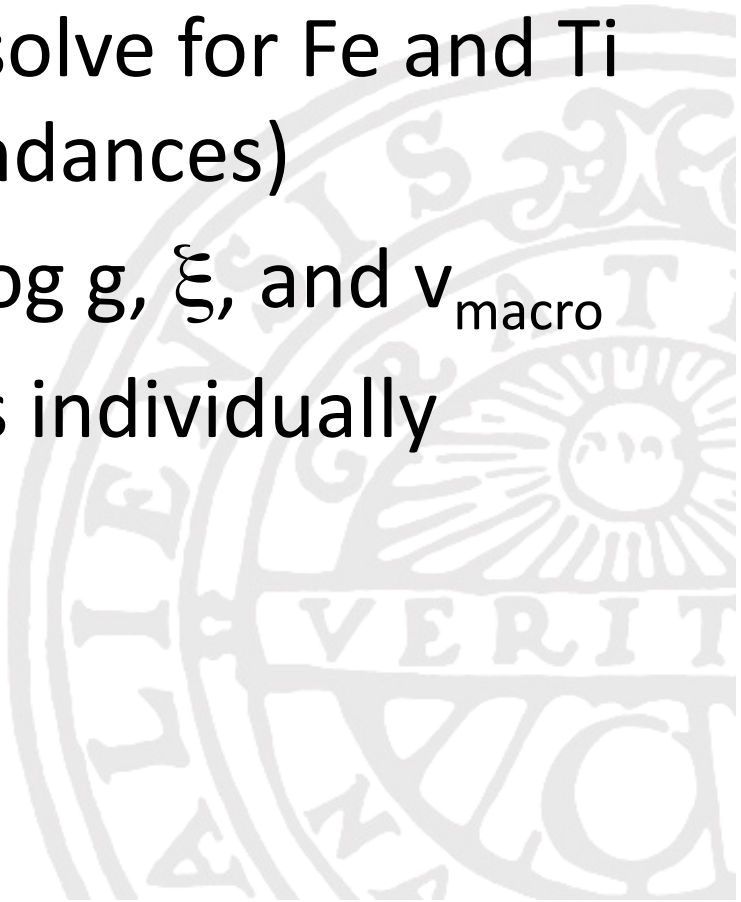


SME: input


Fe 1 4442.326
Fe 1 4443.200
Residual Flux
1.5
1.0
0.5
0.0
4441
4442
4443
4444
Wavelength [Å]

SME: Spectrum Synthesis procedure

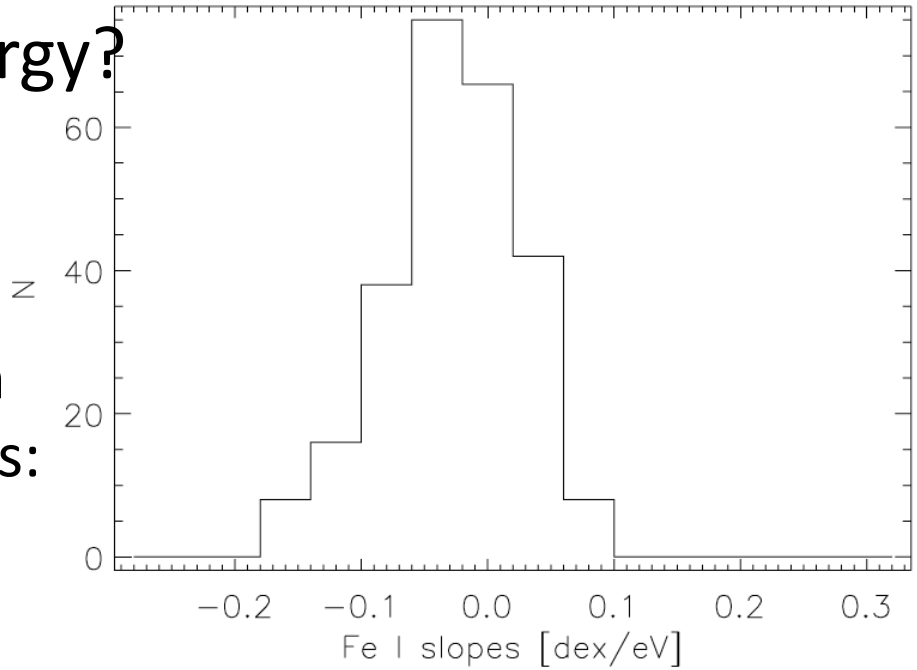
- Initial estimates of T_{eff}, log g, [Fe/H], ξ, v_{macro}, and abundances are used to solve for Fe and Ti abundance (Scaled solar abundances)
- Repeat step 1 but with free log g, ξ, and v_{macro}
- Solve for remaining elements individually



SME: Result checking

- Check line to line abundance variations in Fe and Ti

  $\Rightarrow$ Trends in excitation energy?



- Error analysis:
  - Solve for all abundances with fixed offset stellar parameters: T_{eff} + 100K; log g + 0.3 dex; ξ + 0.2 km s^{-1}
- Computing time: 2-3 CPU hours

SME: Elemental Errors

- Abundance scatter analysis

  ⇒ **Accurate error estimates vital!**

- Absolute vs relative errors:

  ⇒ Errors in gf and some part of modelling errors (LTE & 1D) cancel

- Error estimate includes contributions from uncertainties in:

Observations	Stellar parameters
Atomic and molecular line list	Model atmospheres
Continuum fitting	Inherent assumptions

SME tested

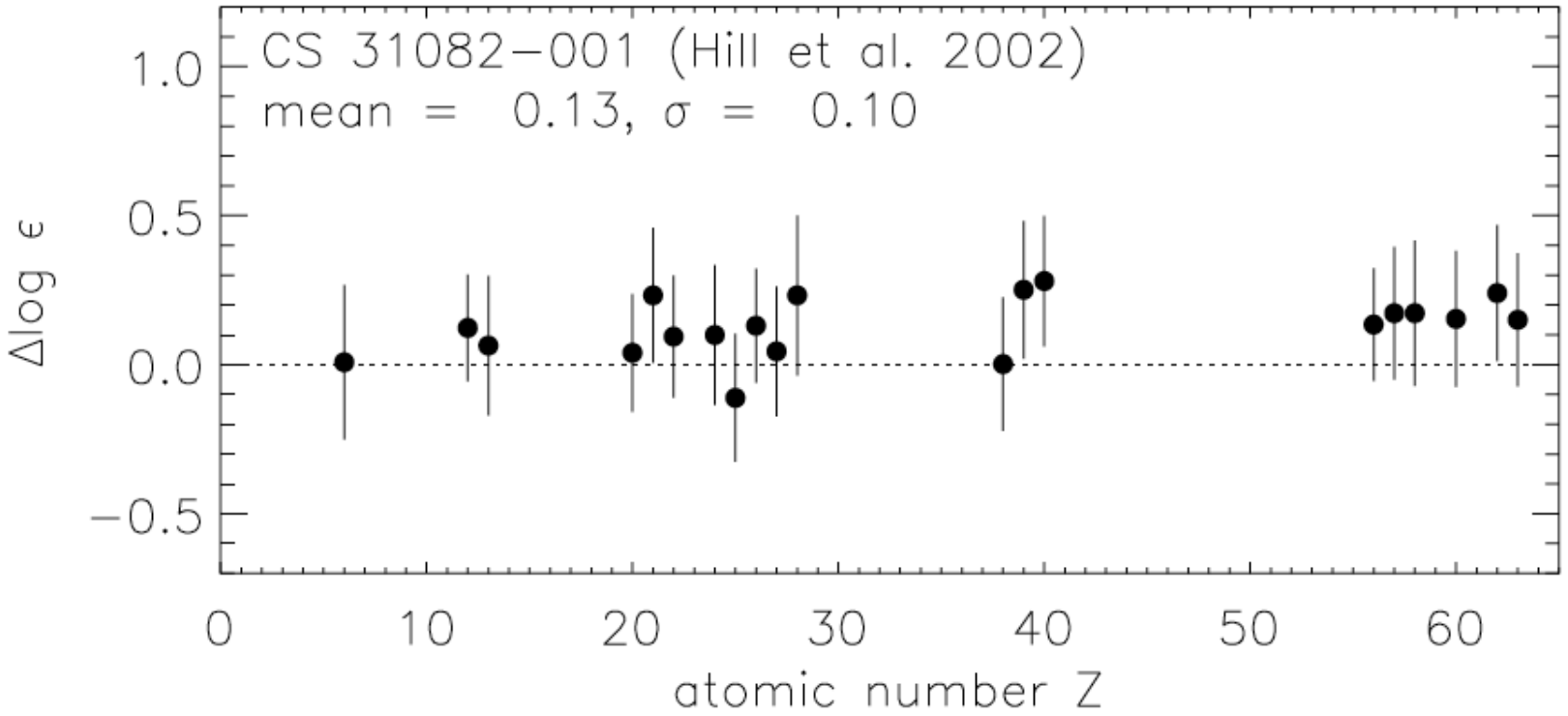
- 5 comparison stars from literature
  - Adopted T_{eff} systematically warmer ~100K
    - ⇒ Higher log g: +100K → +0.2 dex
    - ⇒ Higher metallicity: +100K → +0.1 dex
  - No significant systematic effect in bluer lines due to blending or continuum placements
  - No significant trends with line strenght

⇒ Accuracy on relative abundance patterns

~ 0.15 dex

SME tested

- 5 comparison stars from literature



⇒ Accuracy on relative abundance patterns

~ 0.15 dex

SME: Robustness at low S/N

Parameter	Δ Parameter			
	S/N = 30	20	15	10
log ϵ(C)	−0.02 (0.20)	−0.10 (0.20)	−0.07 (0.20)	−0.19 (0.22)
log ϵ(Mg)	−0.04 (0.12)	−0.06 (0.12)	−0.02 (0.12)	−0.02 (0.13)
log ϵ(Al)	−0.19 (0.19)	−0.14 (0.30)	—	—
log ϵ(Ca)	−0.02 (0.12)	−0.04 (0.12)	−0.06 (0.11)	−0.06 (0.14)
log ϵ(Sc)	−0.02 (0.17)	0.00 (0.18)	−0.09 (0.19)	—
log ϵ(Ti)	−0.03 (0.16)	−0.02 (0.16)	−0.04 (0.16)	—
log ϵ(V)	—	—	—	—
log ϵ(Cr)	−0.06 (0.17)	−0.09 (0.19)	—	—
log ϵ(Mn)	−0.07 (0.16)	−0.11 (0.18)	−0.03 (0.19)	—
log ϵ(Fe)	−0.02 (0.13)	0.00 (0.12)	−0.02 (0.13)	0.00 (0.15)

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Conclusions and Remarks

- Our technique gives results in agreement with literature
- Our technique is quite robust even down to S/N = 15
- The technique shows fair precision:
  - Relative errors ~ 0.15 dex
  - Absolute errors ~ 0.25 dex
- Technique does not deal with CH strong content

  ⇒ Check autoMOOG (Marsteller er al. 2009)
- Photometric data of observed stars is necessary

  ⇒ SME without photometric data: Valenti & Fischer (2005)
- Future: Analyses of GC and Gaia-ESO survey?