4MOST: Search for extremely metal-poor stars

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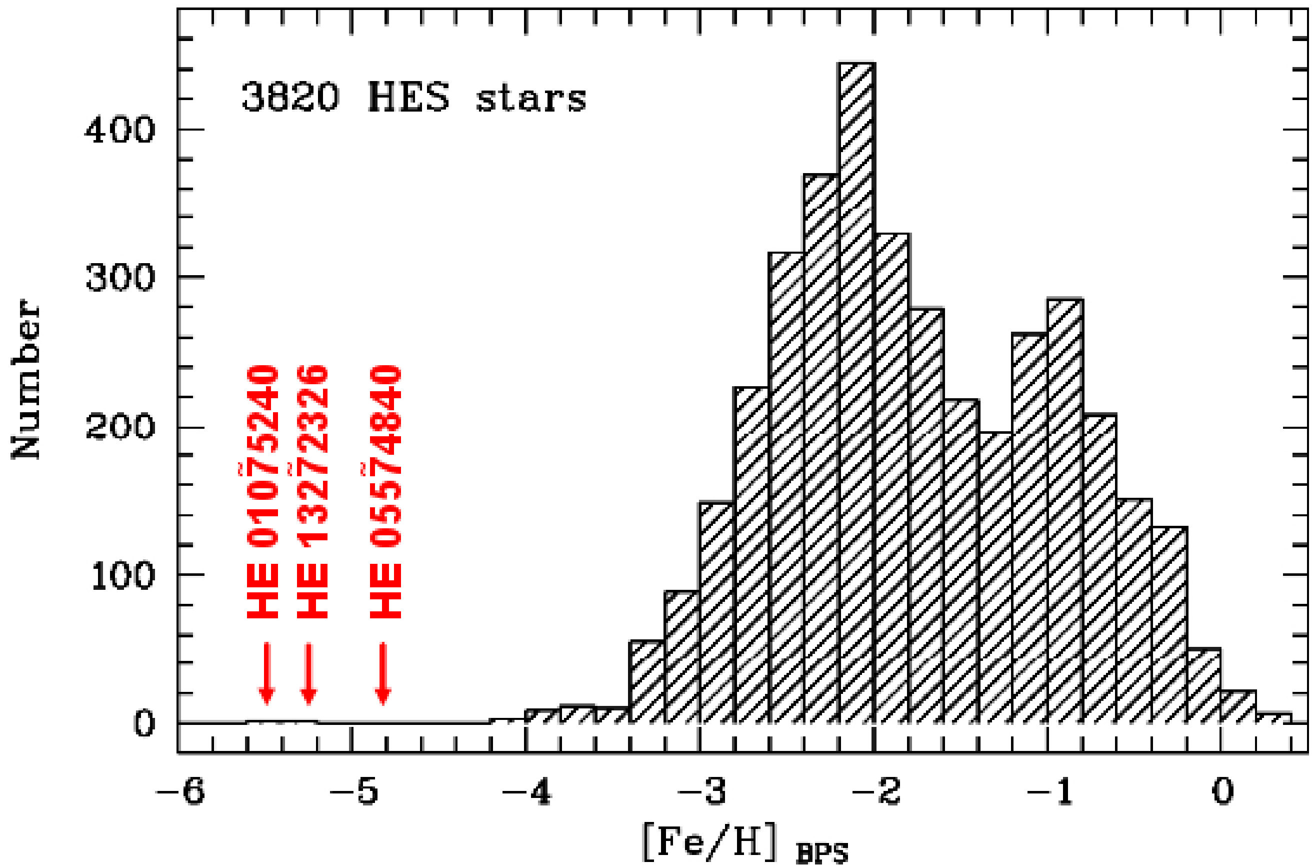
Extremely metal-poor (EMP) stars are rare



(N. Christlieb: metallicity distribution function from Hamburg-ESO Survey)

- Rule of thumb: number of EMP stars drops by factor 10 over one dex in metallicity currently known: ≈3000 at $[\mathrm{Fe/H}] < -2$
- Christlieb's/Frebel's/Norris' star, Caffau's star missing
- Mostly found in Halo (inner Halo peaks ≈ -1.7) $\rightarrow$ we usually look there

Why are EMP stars interesting?

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Letters to Nature

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A stellar relic from the early Milky Way

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FULL TEXT

- Previous | Next
- Table of contents

LETTER

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An extremely primitive star in the Galactic halo

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- Fossil record of creation and evolution of elements at the earliest times
  simplicity allows to derive strong constraints, e.g., on SN nucleosynthesis

Target counts

- Target counts derived from Galaxia model (Sharma et al. 2011) as provided by T. Pfiffl
- Restricted to sky accessible to 4MOST, $-70^\circ \leq \delta \leq +20^\circ$
- Number of halo sources is modest in terms of total number and density

Halo objects, everything V<20

abs(b)	N per deg^2			$N_{\rm tot}(10^3)$	halo	thin	thick	bulge
90 ... 80	255.8	$\pm$	27.9	84	1.00	0.00	0.00	0.00
80 ... 70	224.2	$\pm$	13.4	279	1.00	0.00	0.00	0.00
70 ... 60	270.8	$\pm$	11.2	588	1.00	0.00	0.00	0.00
60 ... 50	295.6	$\pm$	9.9	897	1.00	0.00	0.00	0.00
50 ... 40	319.7	$\pm$	9.5	1139	1.00	0.00	0.00	0.00
40 ... 30	410.3	$\pm$	10.7	1476	1.00	0.00	0.00	0.00
90 ... 30	320.2	$\pm$	4.8	4463	1.00	0.00	0.00	0.00
30 ... 15	532.0	$\pm$	9.5	3107	1.00	0.00	0.00	0.00
15 ... 0	471.1	$\pm$	8.5	3088	1.00	0.00	0.00	0.00

K-giants

Giants, V<20, B-V>0.6, abs(V)<2.5, no metallicity constraint

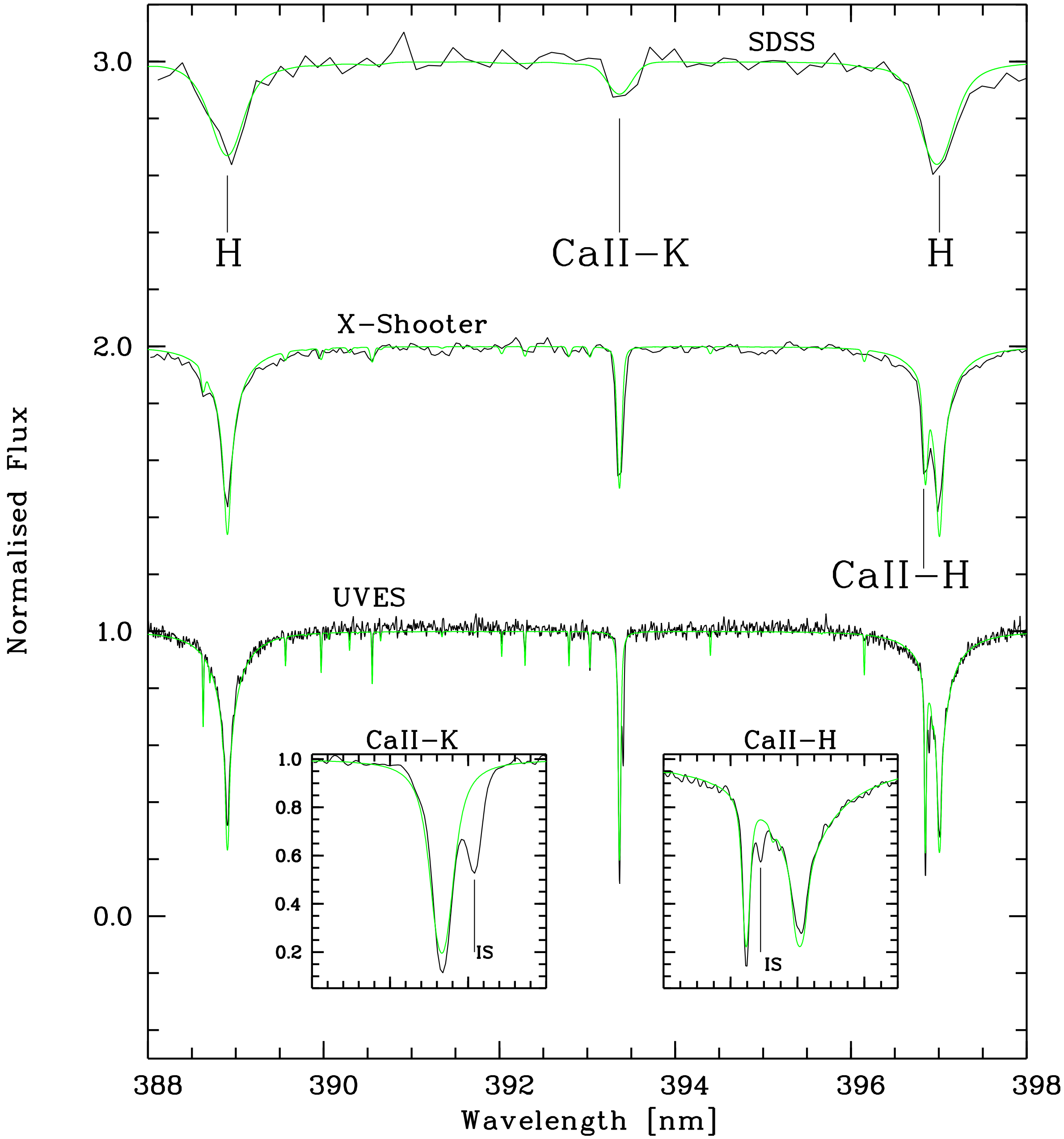
abs(b)	N per $\deg^2$	$N_{\rm tot}(10^3)$	halo	thin	thick	bulge
90. . . 30	84.2 ± 2.5	1174	0.56	0.03	0.41	0.00
30. . . 15	578.7 ± 10.0	3380	0.14	0.11	0.75	0.00
15. . . 0	10062.9 ± 39.2	65955	0.01	0.57	0.27	0.14

Giants, V<20, B-V>0.6, abs(V)<2.5, $[\rm Fe/H] < -2$

abs(b)	N per $\deg^2$	$N_{\rm tot}(10^3)$	halo	thin	thick	bulge
90. . . 30	14.3 ± 1.0	200	1.00	0.00	0.00	0.00
30. . . 15	23.1 ± 2.0	135	1.00	0.00	0.00	0.00
15. . . 0	35.4 ± 2.3	232	0.97	0.03	0.00	0.00

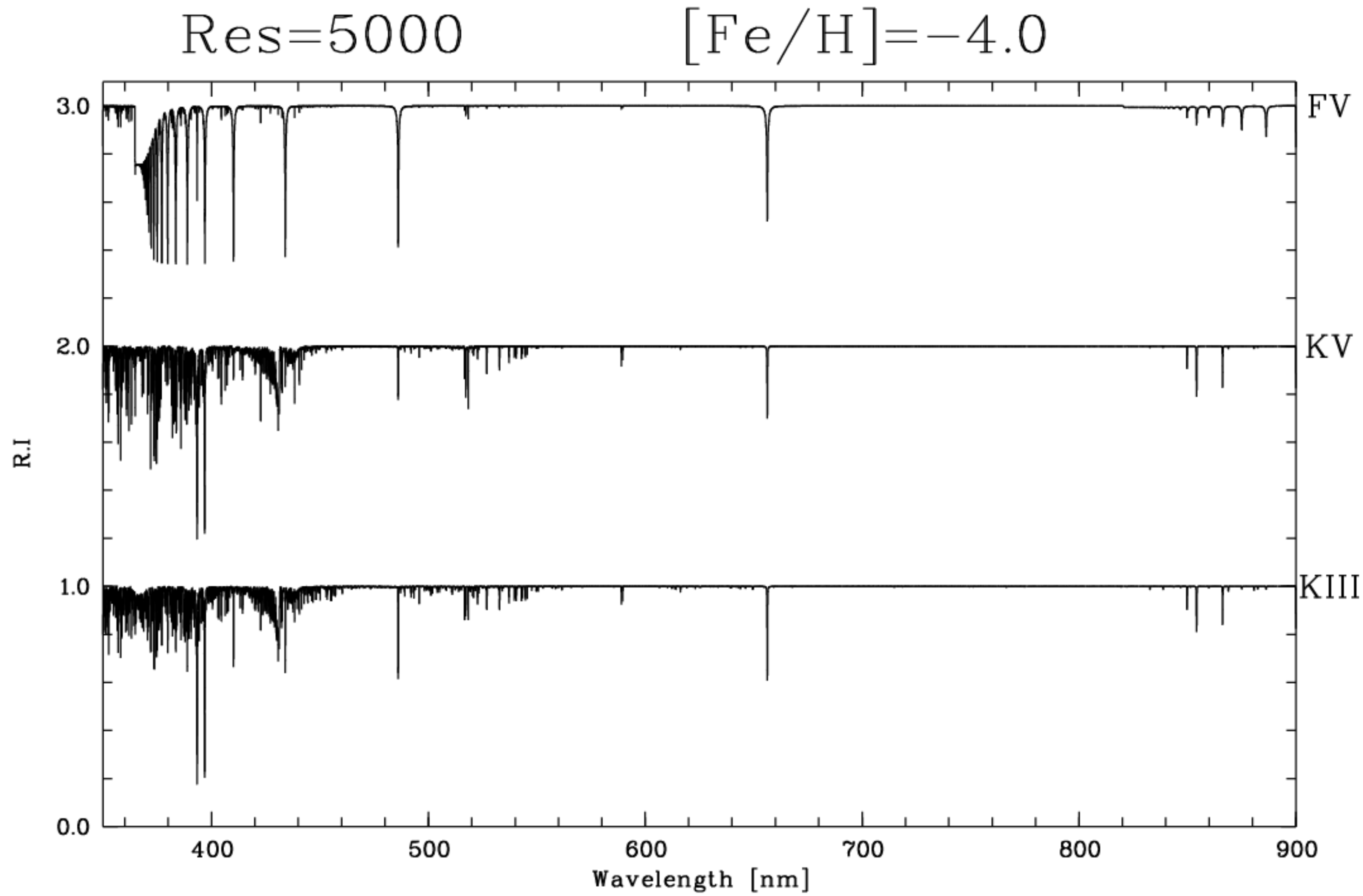
- Halo DRSs: LR 2.6×10^6 K-giants at abs(b)>20, HR 1×10^5 at abs(b)>30
- Many of these distant sources are Halo giants $\rightarrow$ low metallicity
- May provide several 10 hyper metal-poor (HMP) stars $[\rm Fe/H] < -5$
- Caveat: LR Halo case asks for typical S/N≈10 per Å, sufficient to more than just identify HMP stars? If V≈19 limiting magnitude number drops by factor 7

Caffau's star, g=16.9, $[\mathrm{Fe/H}] \approx -5.0$



- X-shooter spectrum
  $R = 7900$
  1 h exposure time
  8 m telescope
  4.1 pixels per FWHM
  observed with IFU
  S/N=230 per Å
- 4MOST LR requirement
  S/N=10 per Å (or pixel?)
- TOPOS
  ESO Large Programme:
  V=19
  4 h exposure time
- 16 h 4MOST at same efficiency of spectrograph

Turn-off stars, giants, and cooler dwarfs



(Normalized noiseless spectra, F-dwarf, K-dwarf, K-giant)

- Spectral information content of K-dwarfs competitive with giants
  . . . but intrinsically faint
- Additional nucleosynthetic signatures, e.g., Mg isotopic ratios

EMP dwarfs and subgiants

Hot dwarfs + subgiants, 7000 K>$T_{\rm eff}$>5500 K, V<19, no metallicity constraint

abs(b)	N per deg^2	$N_{\rm tot}(10^3)$	halo	thin	thick	bulge
90 . . . 30	929.9 ± 8.2	12961	0.10	0.23	0.67	0.00
30 . . . 15	4892.3 ± 28.9	28574	0.03	0.33	0.64	0.00
15 . . . 0	17329.2 ± 51.4	113580	0.00	0.73	0.24	0.03

Hot dwarfs + subgiants, 7000 K>$T_{\rm eff}$>5500 K, V<, $[{\rm Fe/H}] < -2$

abs(b)	N per deg^2	$N_{\rm tot}(10^3)$	halo	thin	thick	bulge
90 . . . 30	28.6 ± 1.4	398	1.00	0.00	0.00	0.00
30 . . . 15	43.1 ± 2.7	252	1.00	0.00	0.00	0.00
15 . . . 0	27.8 ± 2.1	182	1.00	0.00	0.00	0.00

Cool dwarfs + subgiants, 5500 K>$T_{\rm eff}$>4000 K, V<19, $[{\rm Fe/H}] < -2$

abs(b)	N per deg^2	$N_{\rm tot}(10^3)$	halo	thin	thick	bulge
90 . . . 30	2.1 ± 0.4	29	1.00	0.00	0.00	0.00
30 . . . 15	0.9 ± 0.4	5	1.00	0.00	0.00	0.00
15 . . . 0	1.4 ± 0.5	9	1.00	0.00	0.00	0.00

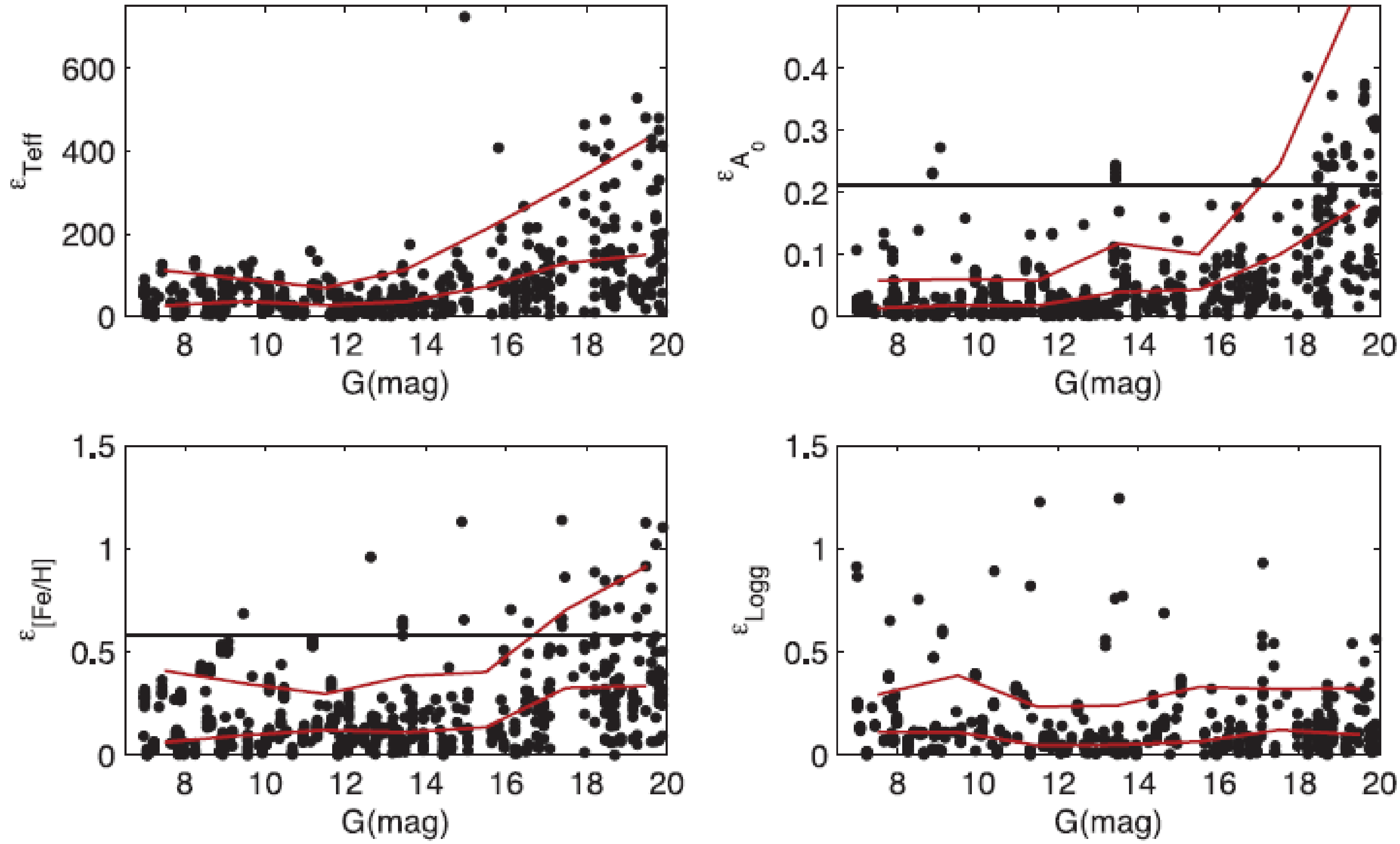
EMP dwarfs and subgiants

- Dwarfs and subgiants add significantly to the pool of EMP candidates
- Effective pre-selection in terms of metallicity vital
- Target densities demand for combination with other observing programmes

Target pre-selection

- Indiscriminate search for EMP stars very inefficient $\rightarrow$ target pre-selection
- Photometric pre-selection
  - GAIA photometry
  - Southern Sky Survey (if available)
- Kinematics from GAIA
  - Halo kinematics $\rightarrow$ high speed $\rightarrow$ (statistically) high proper motion
  - reduced proper motions
- Beware of selection biases

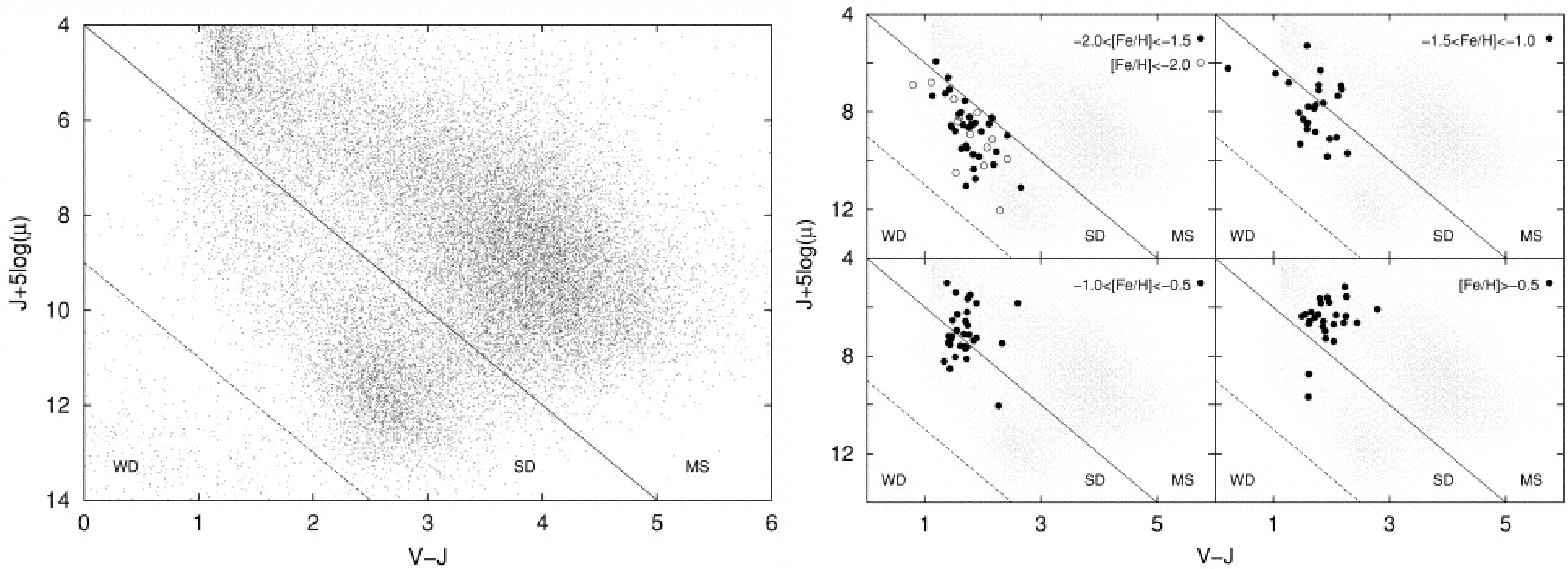
Gaia photometric system performance



(Liu et al. 2012, SVM algorithm, red lines give 50% and 90% percentile)

- Obs: here preferentially stars of "normal" metallicity
  - nevertheless: uncertainty about 1 dex at G=20 (by 2019?)

Adding GAIA proper motions?



(Yong & Lambert 2003, MS main-sequence stars, SD sub-dwarfs, WD white dwarfs)

- Example: cool sub-dwarfs from New Luyten Two-Tenth catalog ($\mu > 0''.18\,\mathrm{yr}^{-1}$), photometry from 2MASS and USNO-A
- Reduced proper motion: apparent magnitude plus (log) proper motion
- Enhances discrimination but may add unwanted selection bias

Summary

- From Halo DRSs already a significant number of EMP to HMP stars can be expected
  - DRS S/N sufficient to characterize HMP stars?
  - additional exposures for increasing S/N?
- Dwarfs and subgiants potentially add a significant number of candidates
  - allow for further investigations: isotopes, lithium abundance
- Efficient preselection essential
  - best procedure here?
  - interplay with disk/bulge LR DRS?
- Generally low target densities demand for combination with other programmes "science in parallel"