狭帯域フィルターを用いた金属欠乏星探査

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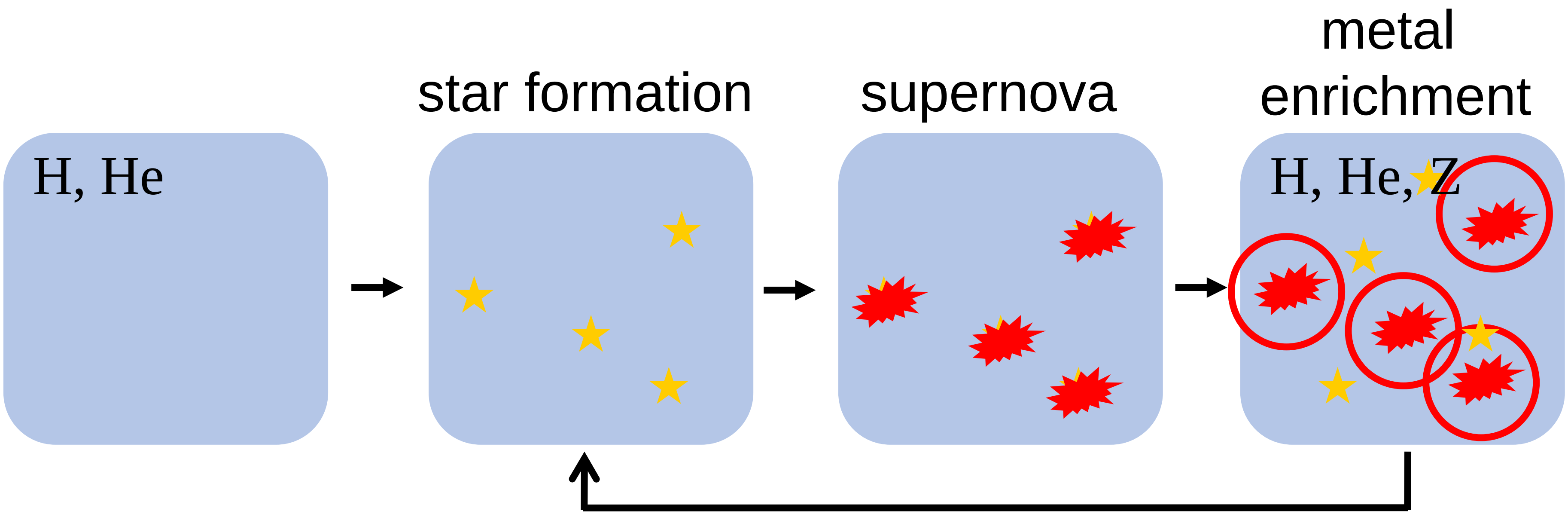
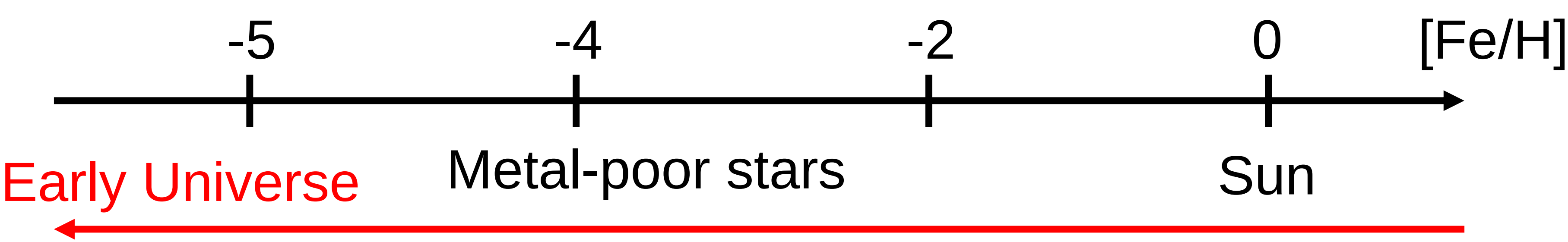
Metal-poor stars



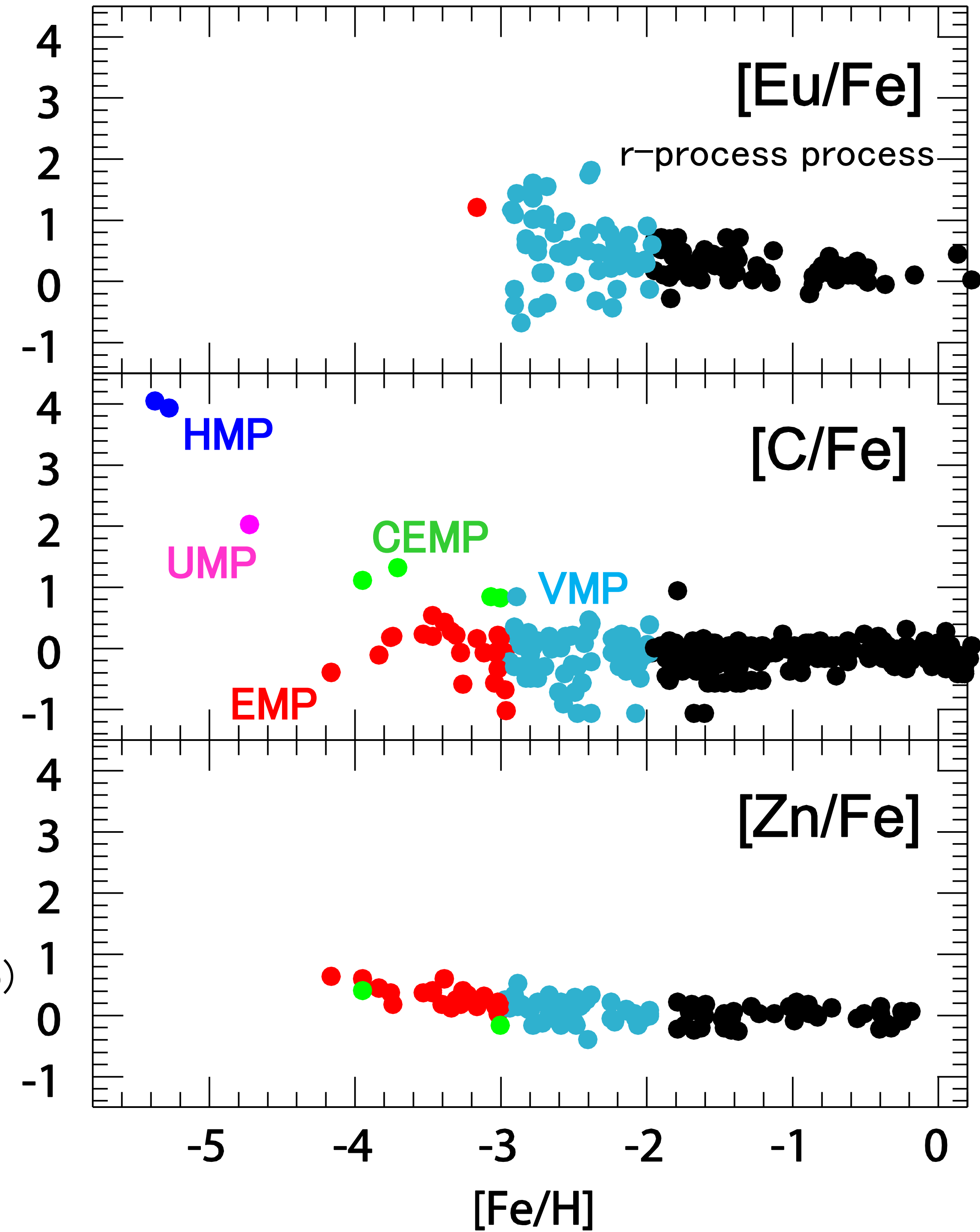
Metallicity increases with time

$[Fe/H] = \log(Fe/H) - \log(Fe/H)_{\odot}$



Metal-poor stars

(e.g., Cayrel + 04; Honda + 04)

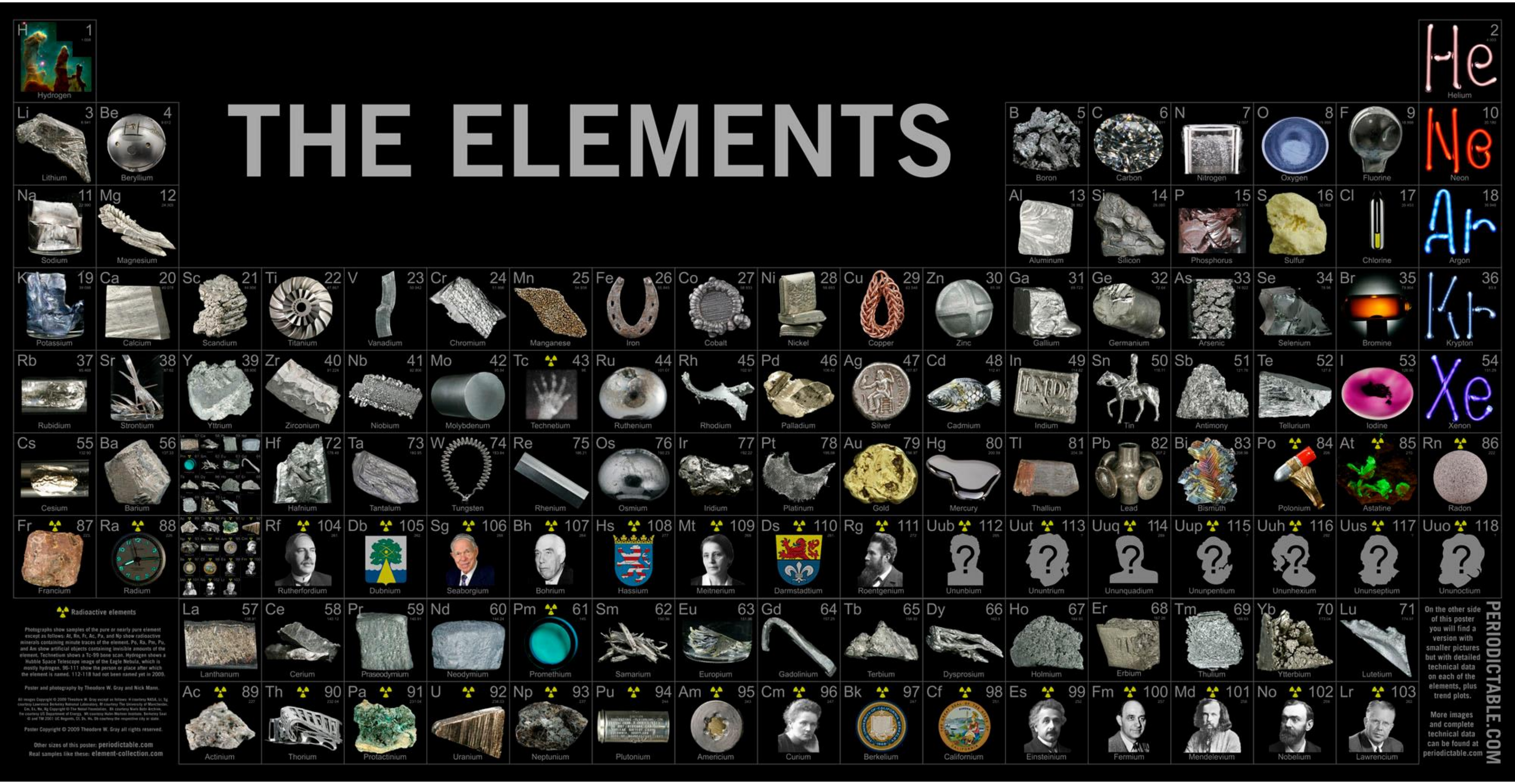


[Fe/H]<−5
Hyper Metal−Poor (HMP)
[Fe/H]<−4
Ultra Metal−Poor (UMP)
[Fe/H]<−3
Extremely Metal−Poor (EMP)
[Fe/H]<−2
Very Metal−poor (VMP)
(Beers & Christlieb 05)

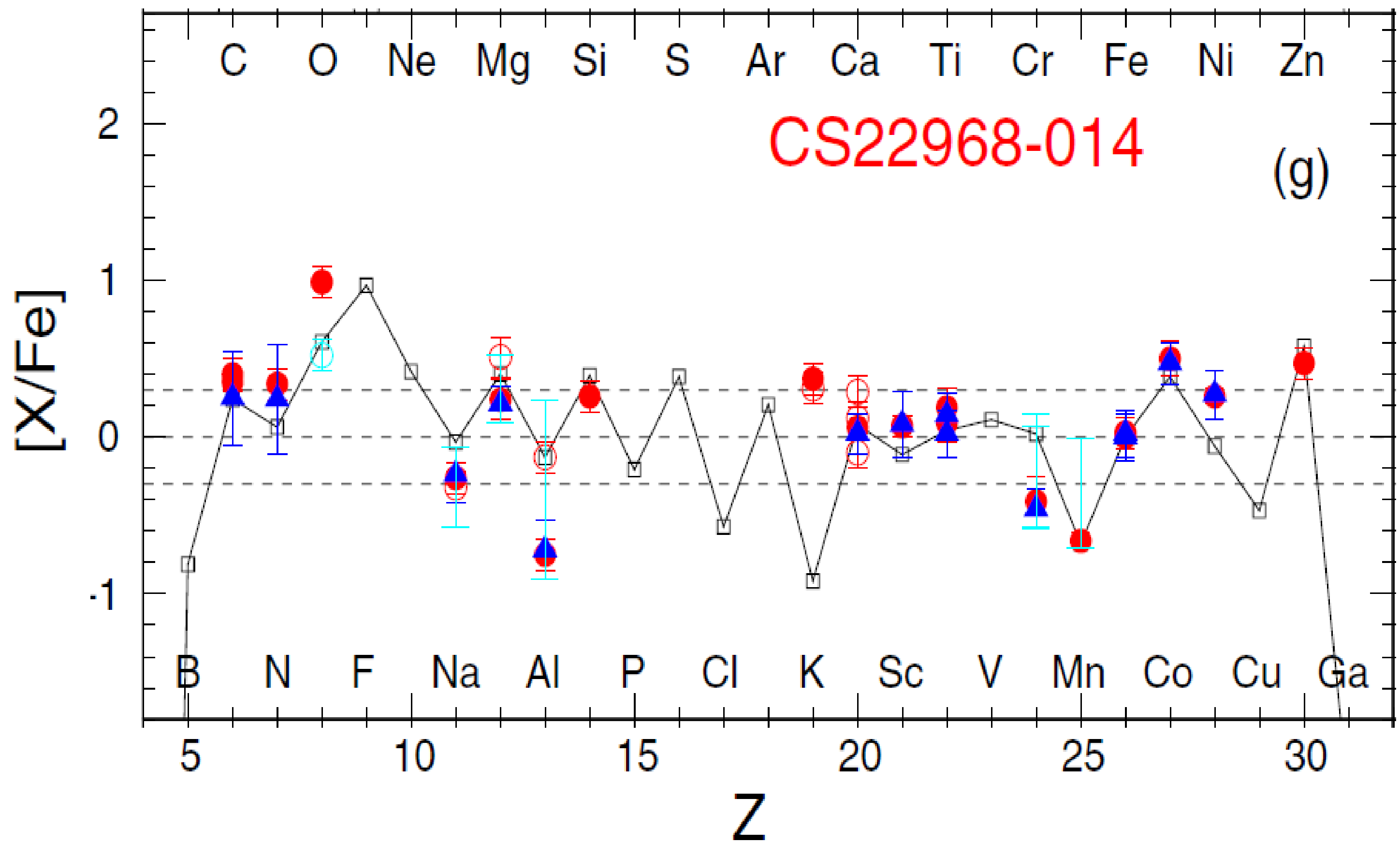
What we can learn from MP stars

- Origin of elements
- First supernovae
- First stars
- Chemical evolution
- Galaxy formation

Origin of elements



Abundance pattern of a MP star

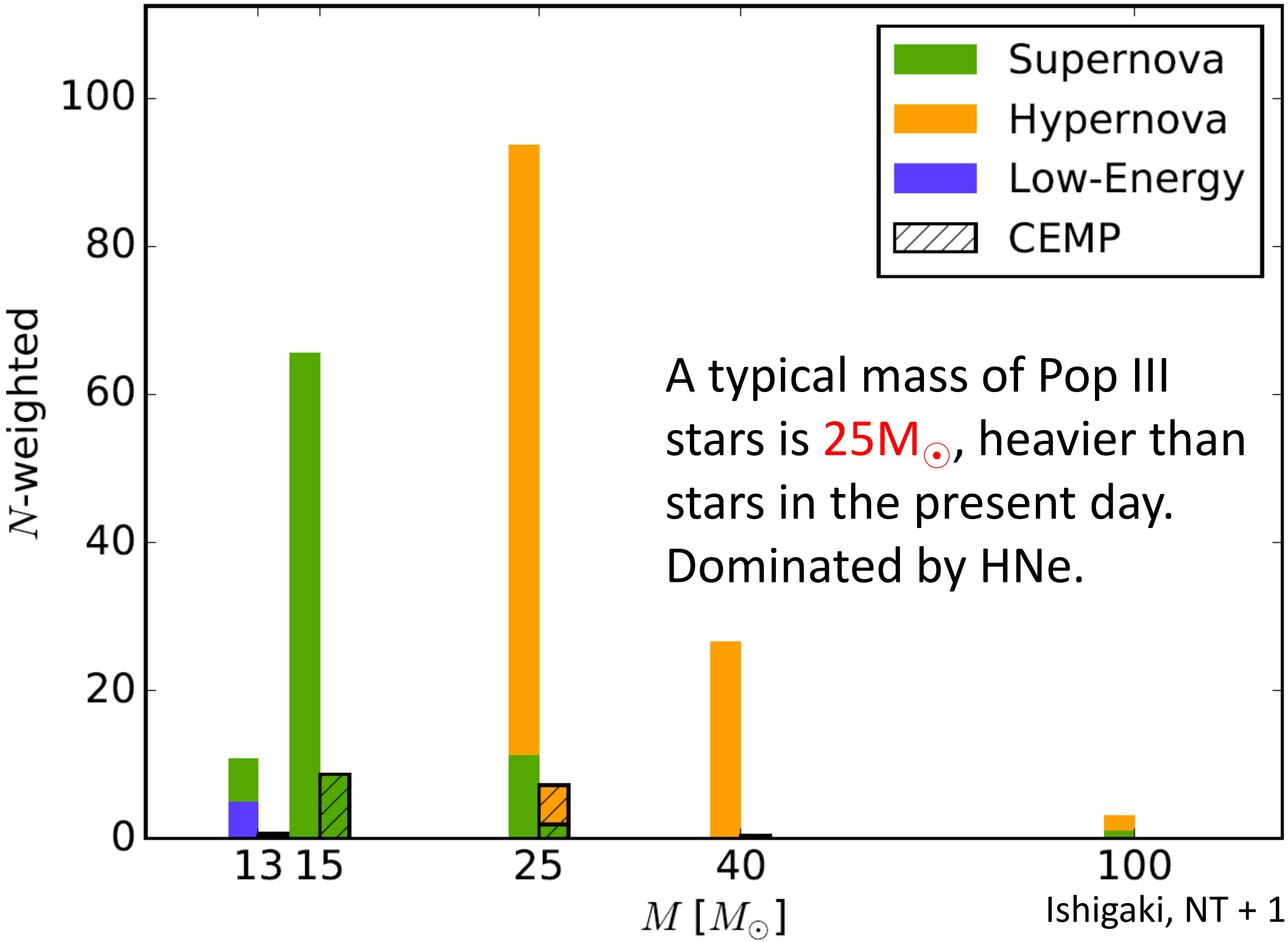


NT+14

- Main-sequence mass: 25Msun
- Explosion energy: 2×10^{52}ergs
- Ejected Fe mass: 8.61×10^{-2}Msun
- Remnant mass: 3.84Msun

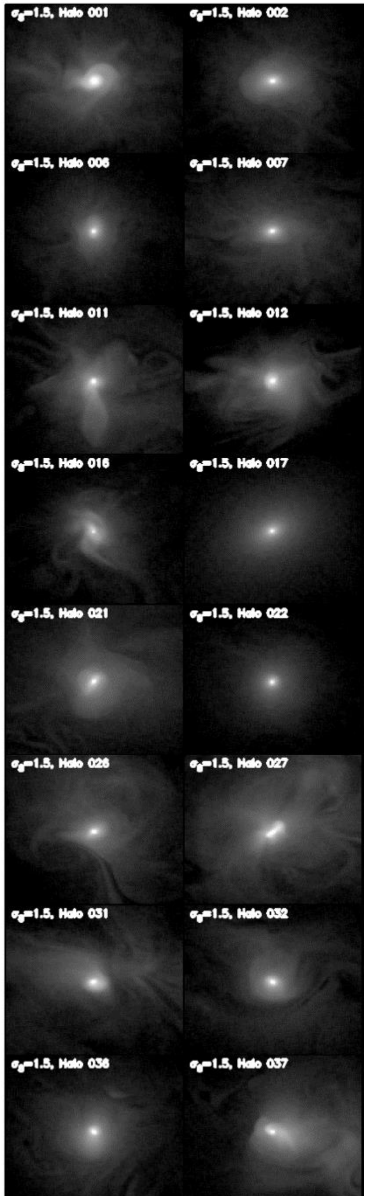
Initial mass function of Pop III stars

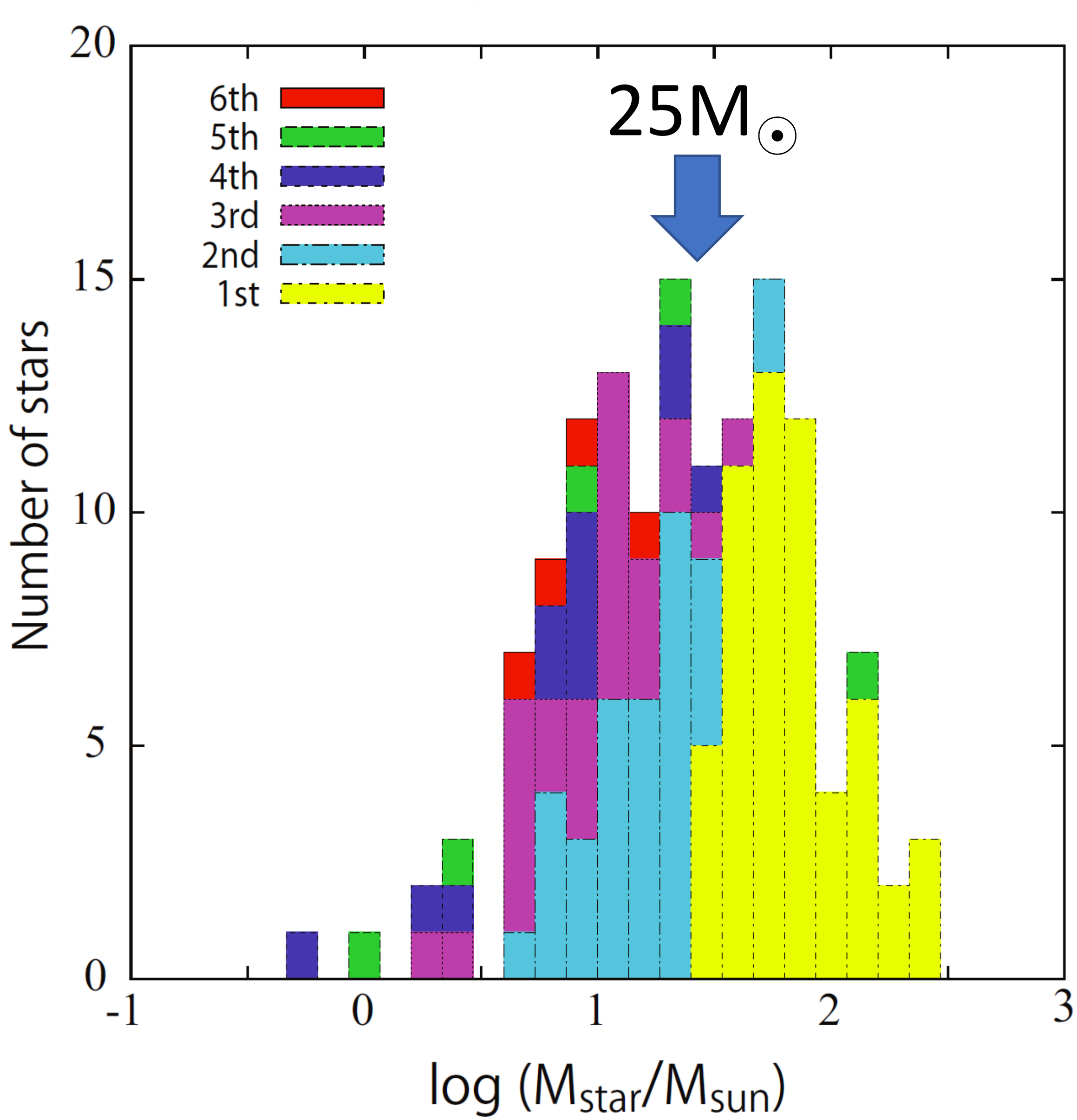
- χ^2 fitting of 218 stars with [Fe/H] < -3



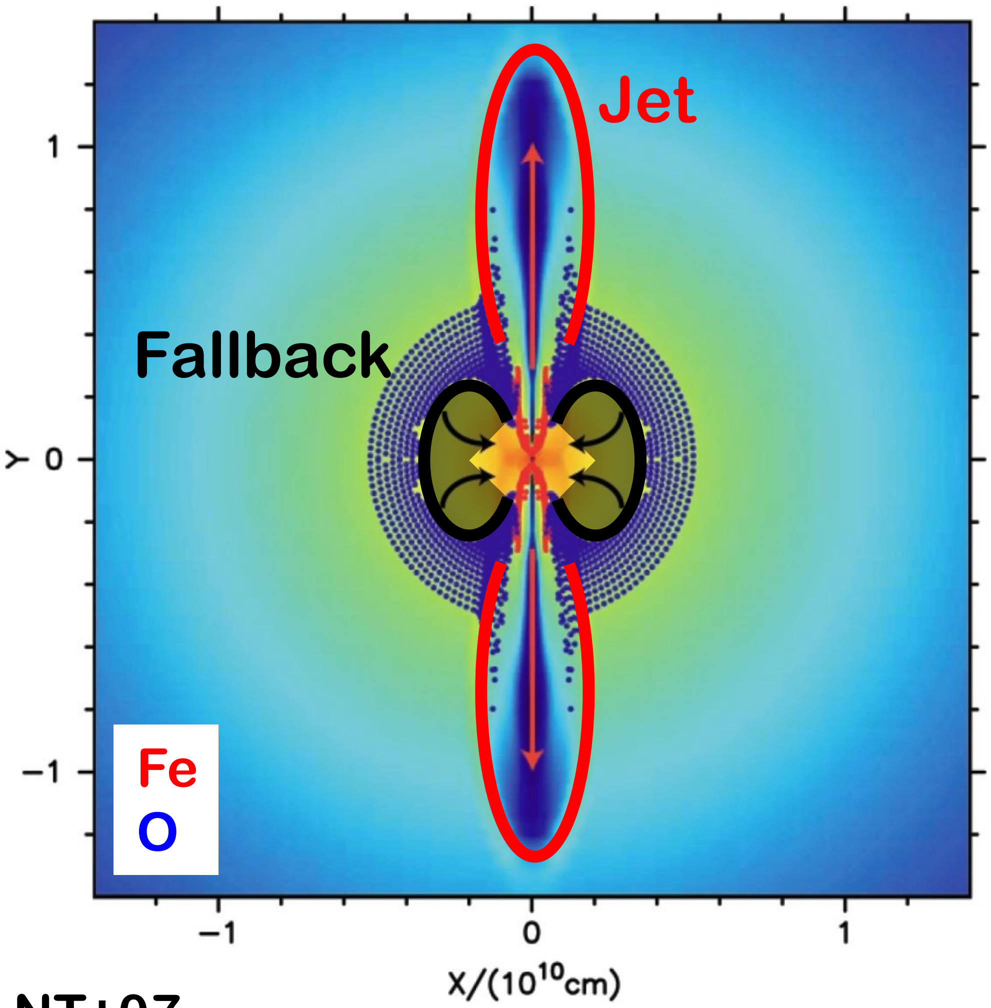
Ishigaki, NT + 18

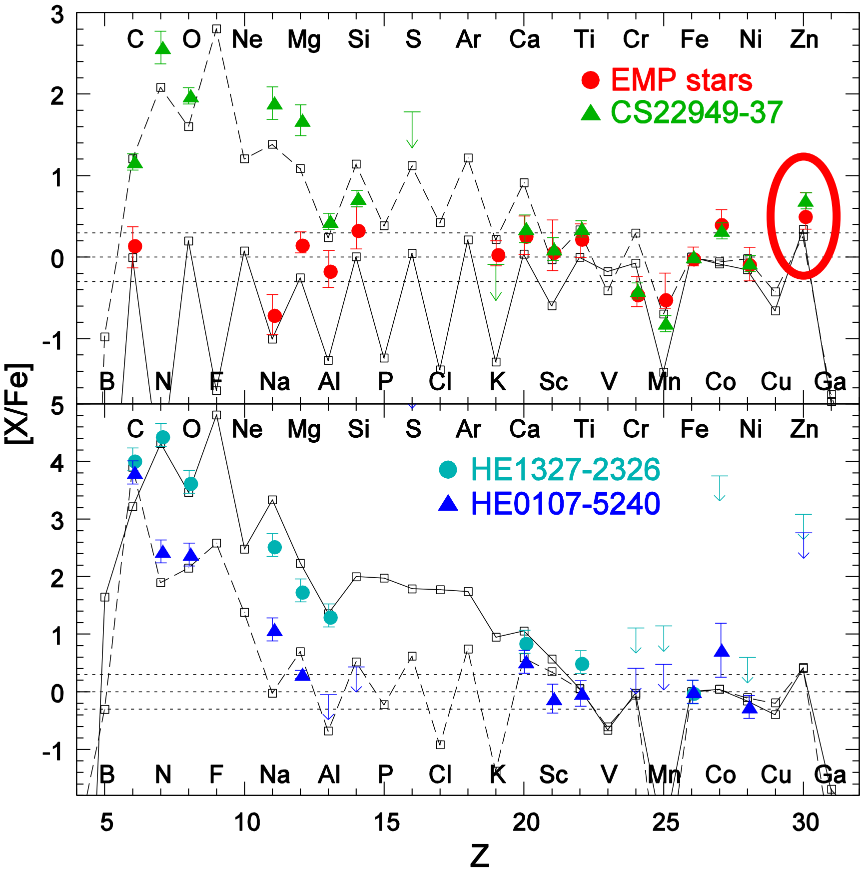
IMF from cosmological simulation





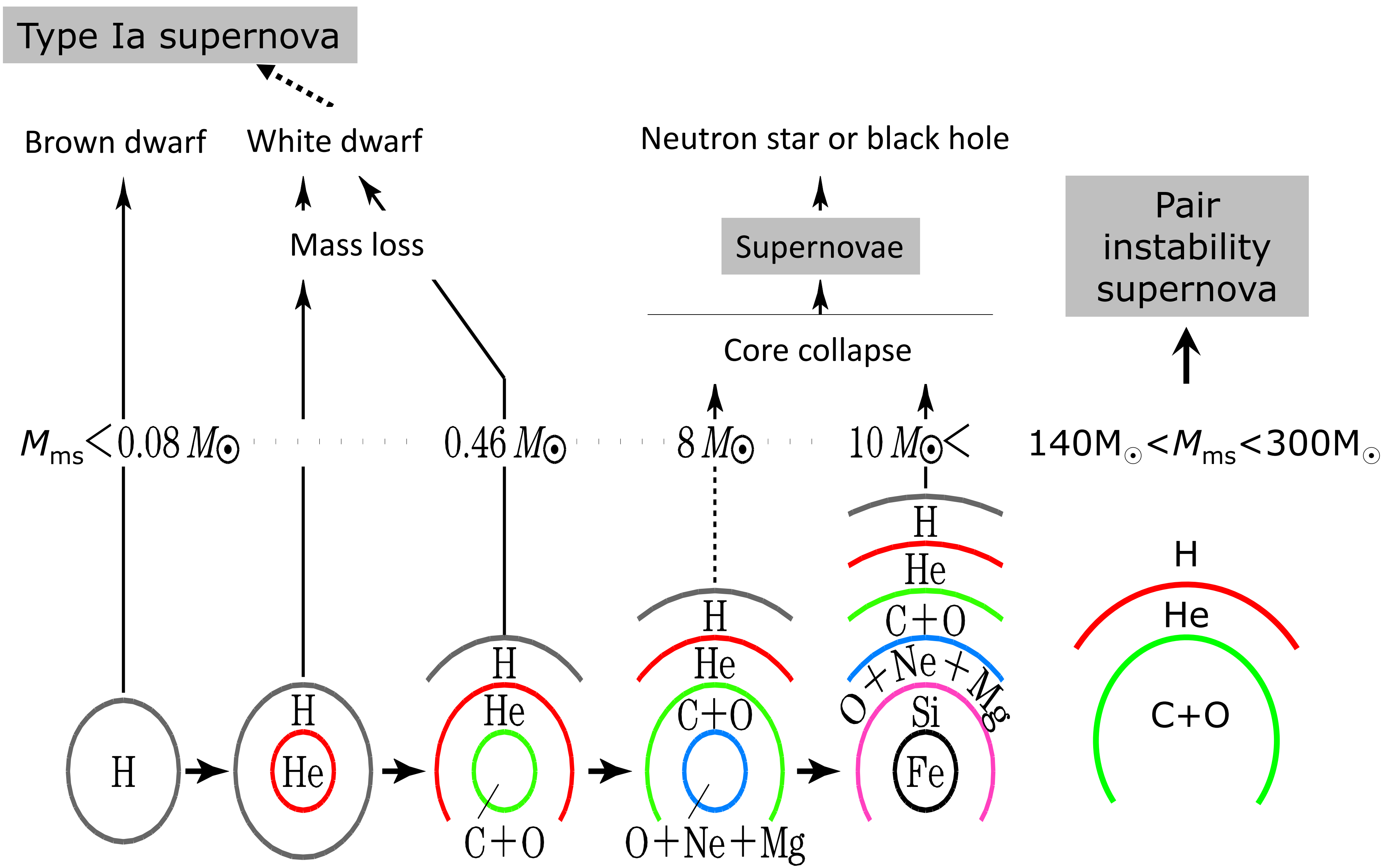
Aspherical supernova explosion





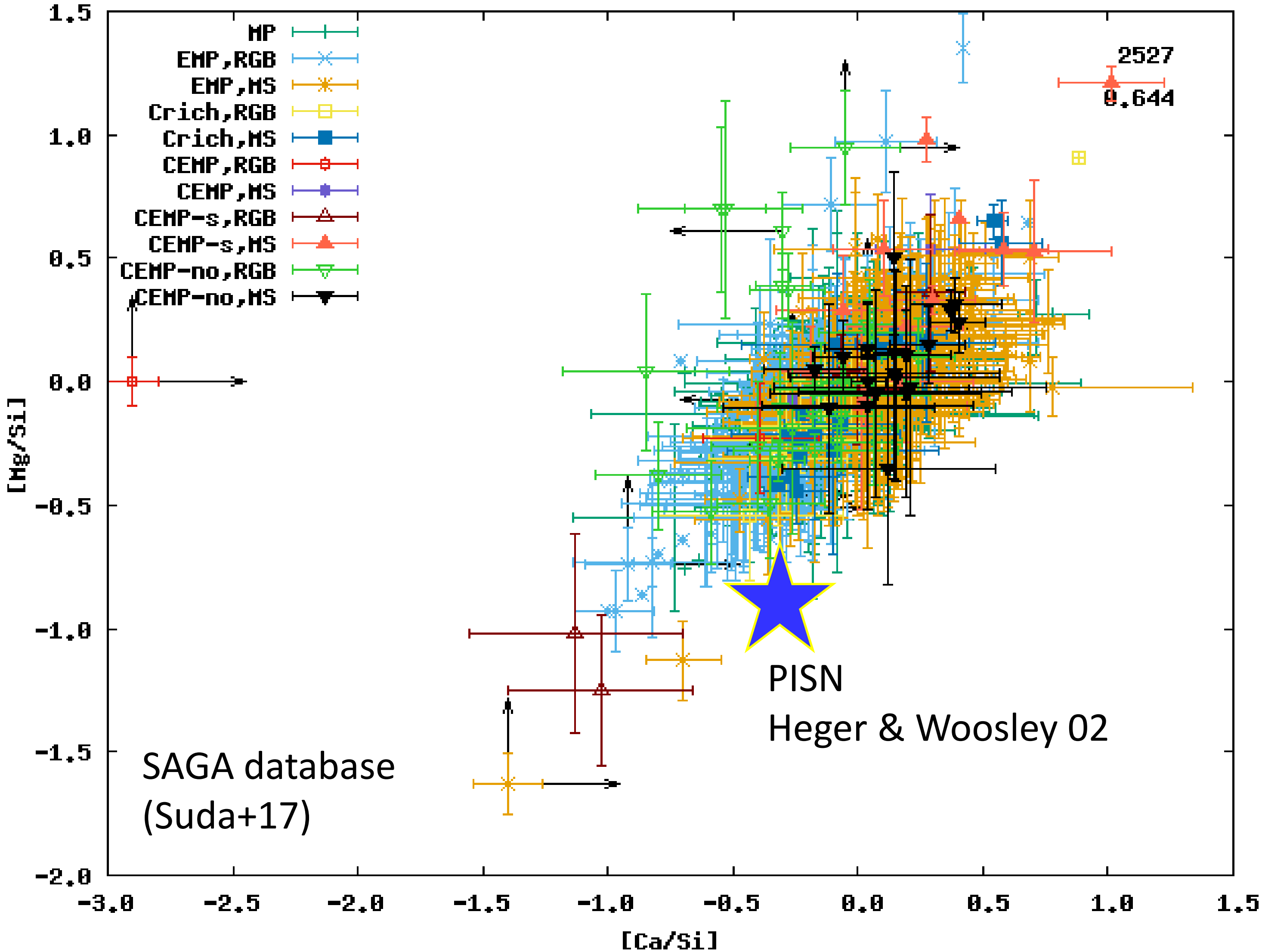
NT+07

Stellar fates depend on their masses



元素はいかにつくられたか(野本憲一編)

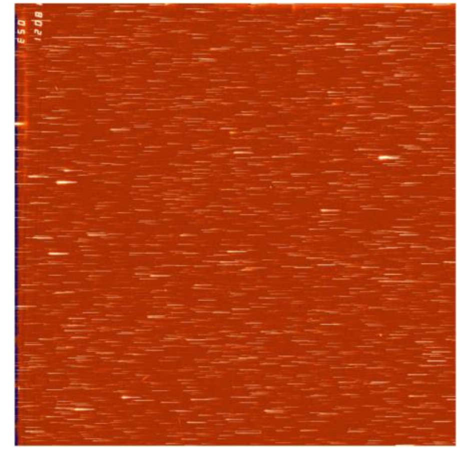
[Ca/Si] vs. [Mg/Si]

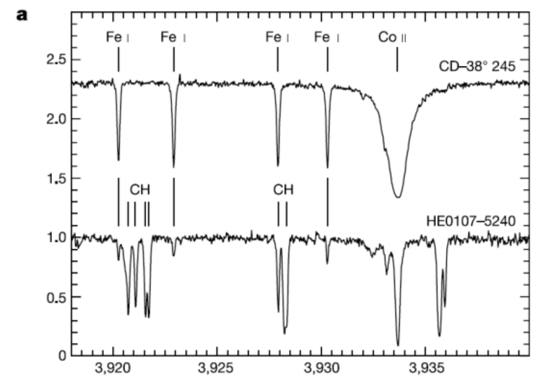


MP
EMP,RGB
EMP,MS
Crich,RGB
Crich,MS
CEMP,RGB
CEMP,MS
CEMP-s,RGB
CEMP-s,MS
CEMP-no,RGB
CEMP-no,MS
2527
0.644
[Mg/Si]
[Ca/Si]
1.5
1.0
0.5
0.0
-0.5
-1.0
-1.5
-2.0
-3.0
-2.5
-2.0
-1.5
-1.0
-0.5
0.0
0.5
1.0
1.5
PISN
Heger & Woosley 02
SAGA database
(Suda+17)

Past surveys

- Objective prism survey
  - HK survey (Beers+)
  - Hamburg/ESO survey (Christlieb+)

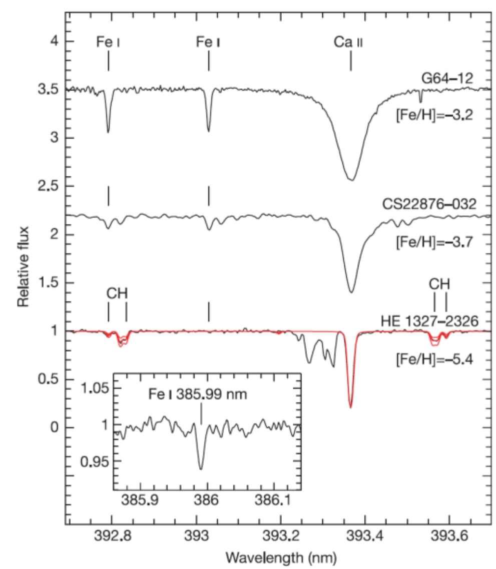




[Fe/H] ~ -5.2

A stellar relic from the early Milky Way

N. Christlieb*†, M. S. Bessell‡, T. C. Beers§, B. Gustafsson*, A. Korn||, P. S. Barklem*, T. Karlsson*, M. Mizuno-Wiedner* & S. Rossi¶



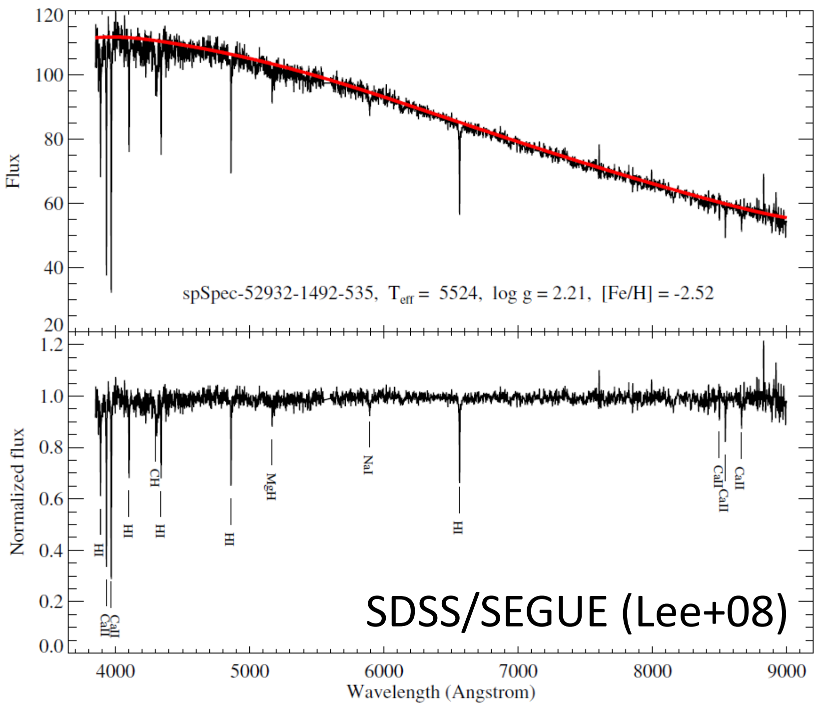
[Fe/H] ~ -5.4

Nucleosynthetic signatures of the first stars

Anna Frebel[1], Wako Aoki[2], Norbert Christlieb[2,3], Hiroyasu Ando[2], Martin Asplund[1], Paul S. Barklem[4], Timothy C. Beers[5], Kjell Eriksson[4], Cora Fechner[3], Masayuki Y. Fujimoto[6], Satoshi Honda[2], Toshitaka Kajino[2], Takeo Minezaki[7], Ken'ichi Nomoto[8], John E. Norris[1], Sean G. Ryan[9], Masahide Takada-Hidai[10], Stelios Tsangarides[9] & Yuzuru Yoshii[7]

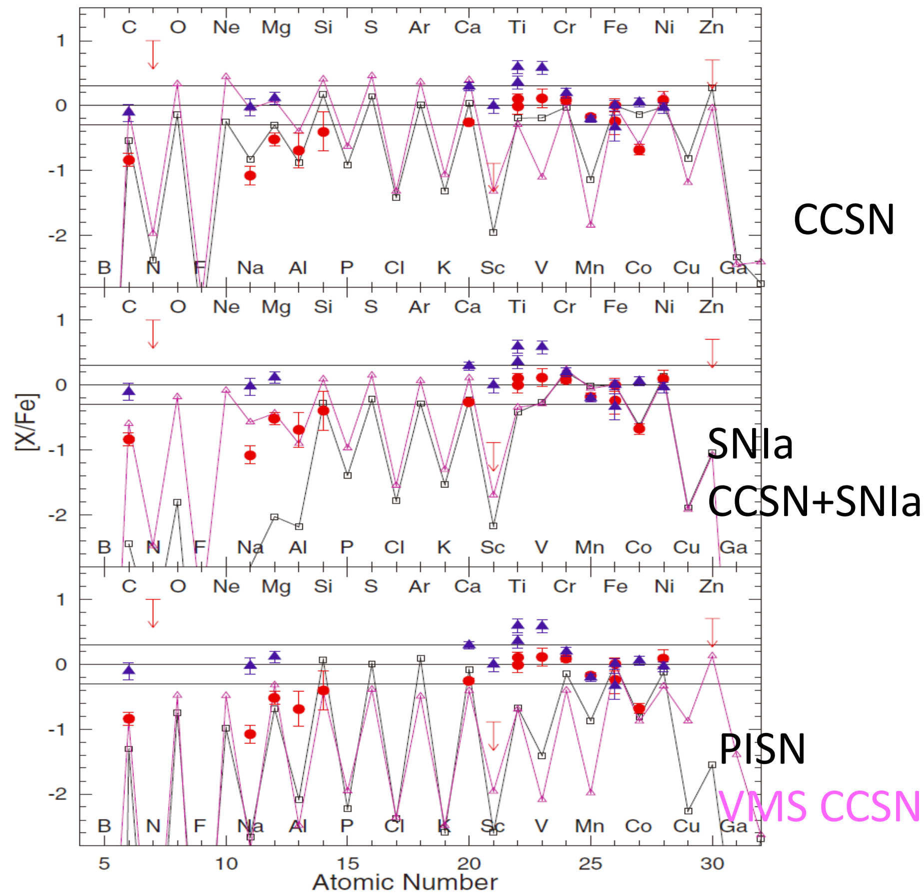
Past surveys

- Low-resolution multi-object spectroscopic survey



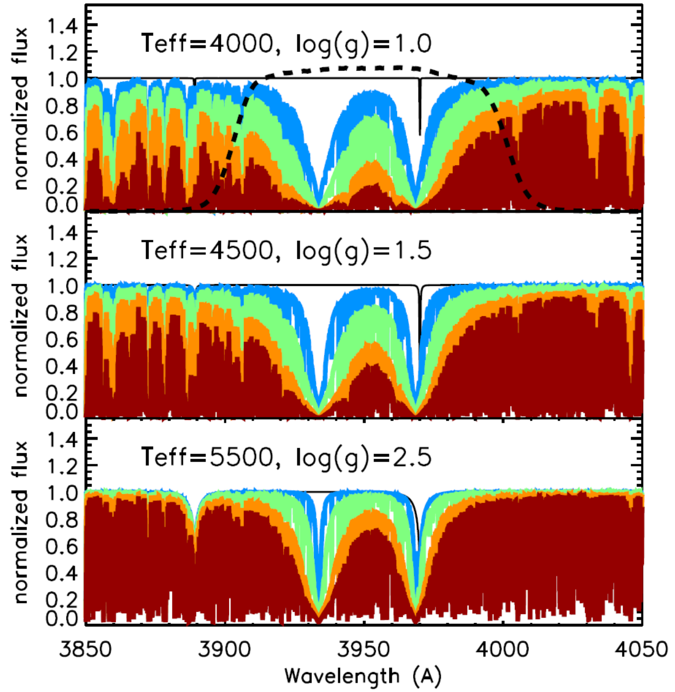
A chemical signature of first-generation very massive stars

W. Aoki,[1,2*] N. Tominaga,[3,4] T. C. Beers,[5,6] S. Honda,[7] Y. S. Lee[8]



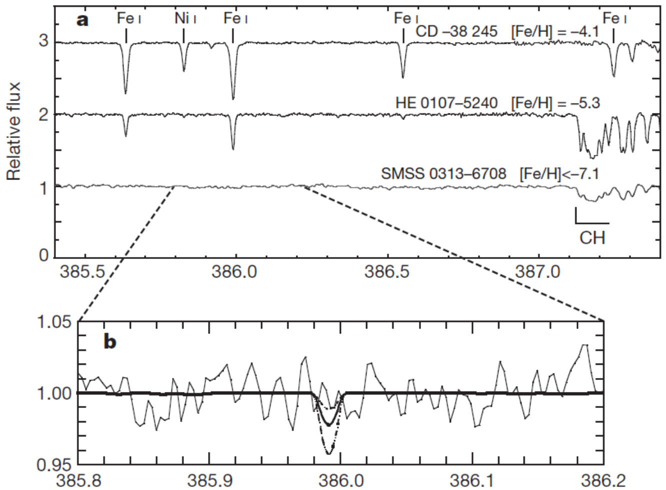
Past surveys

- Narrow-band photometric survey
  - Skymapper survey (Keller+)
  - Pristine survey (Starkenburg+)
    - 26 papers in 5 years
  - ZERO survey (Chiba+)

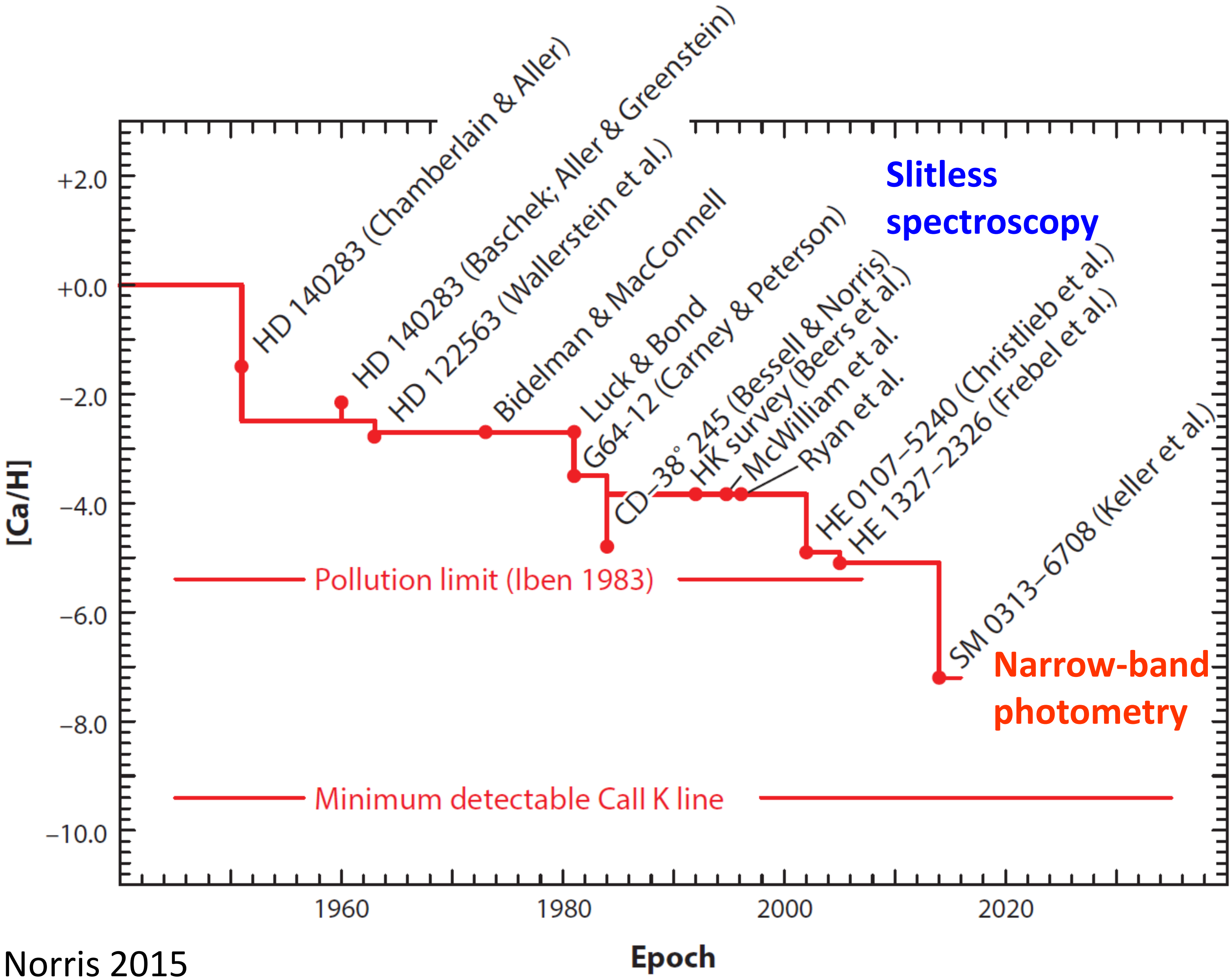


A single low-energy, iron-poor supernova as the source of metals in the star SMSS J031300.36−670839.3

S. C. Keller[1], M. S. Bessell[1], A. Frebel[2], A. R. Casey[1], M. Asplund[1], H. R. Jacobson[2], K. Lind[3], J. E. Norris[1], D. Yong[1], A. Heger[4], Z. Magic[1,5], G. S. Da Costa[1], B. P. Schmidt[1] & P. Tisserand[1]

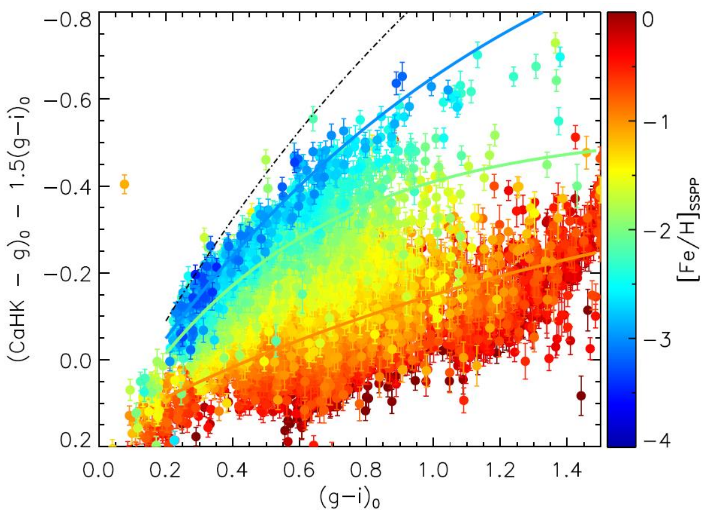


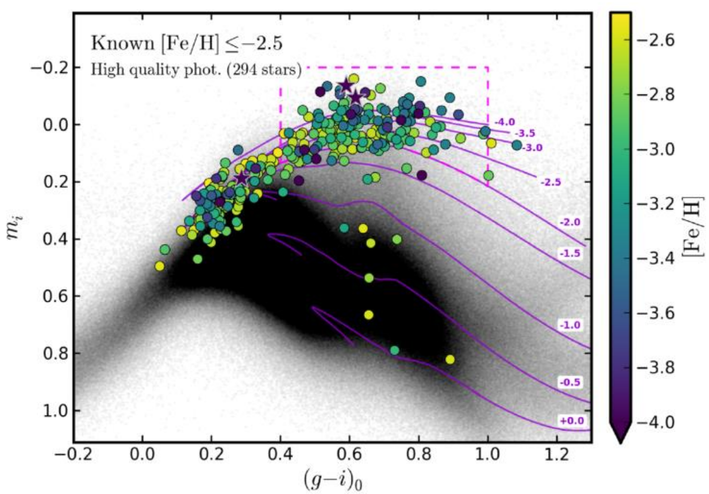
Ca abundance of Fe-poor stars

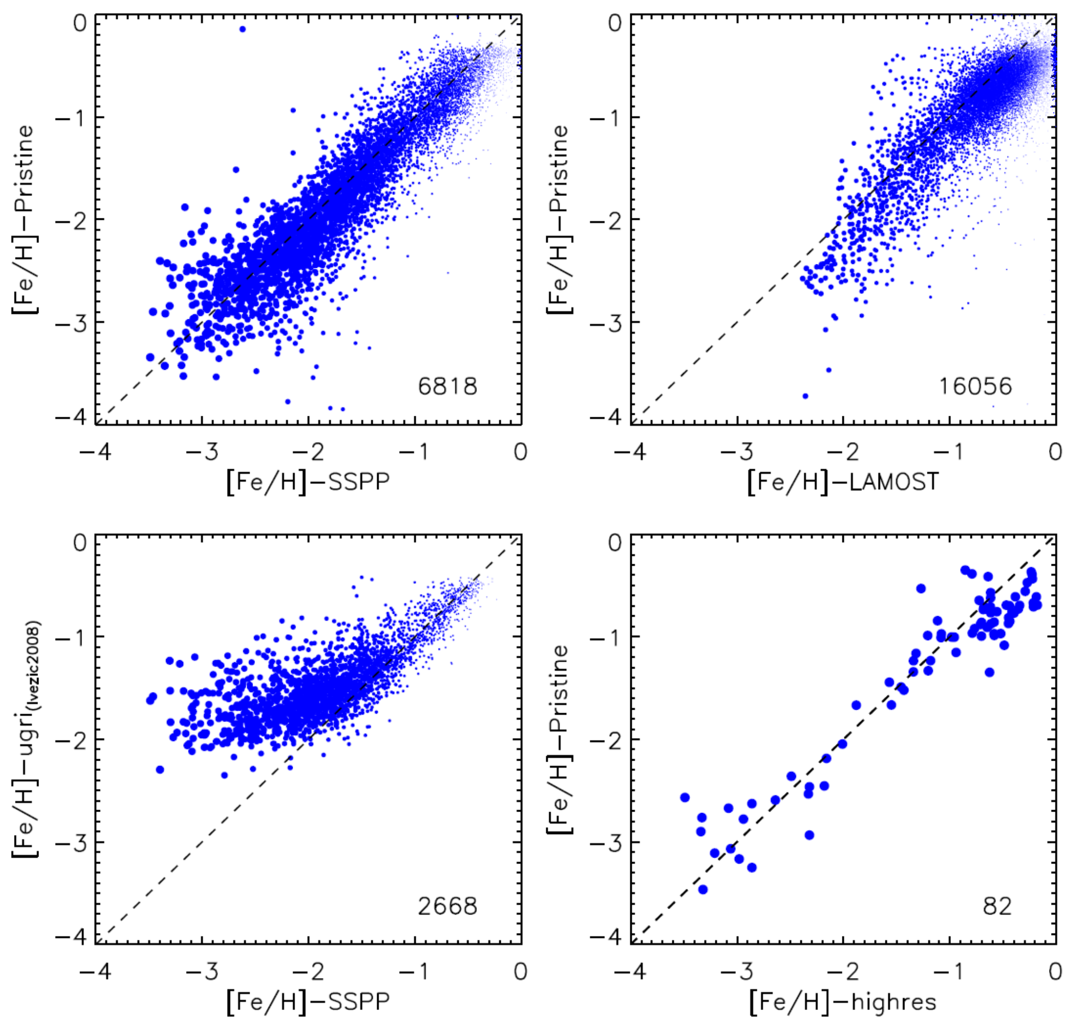


Frebel & Norris 2015

Narrow band surveys
Pristine survey & Skymapper survey

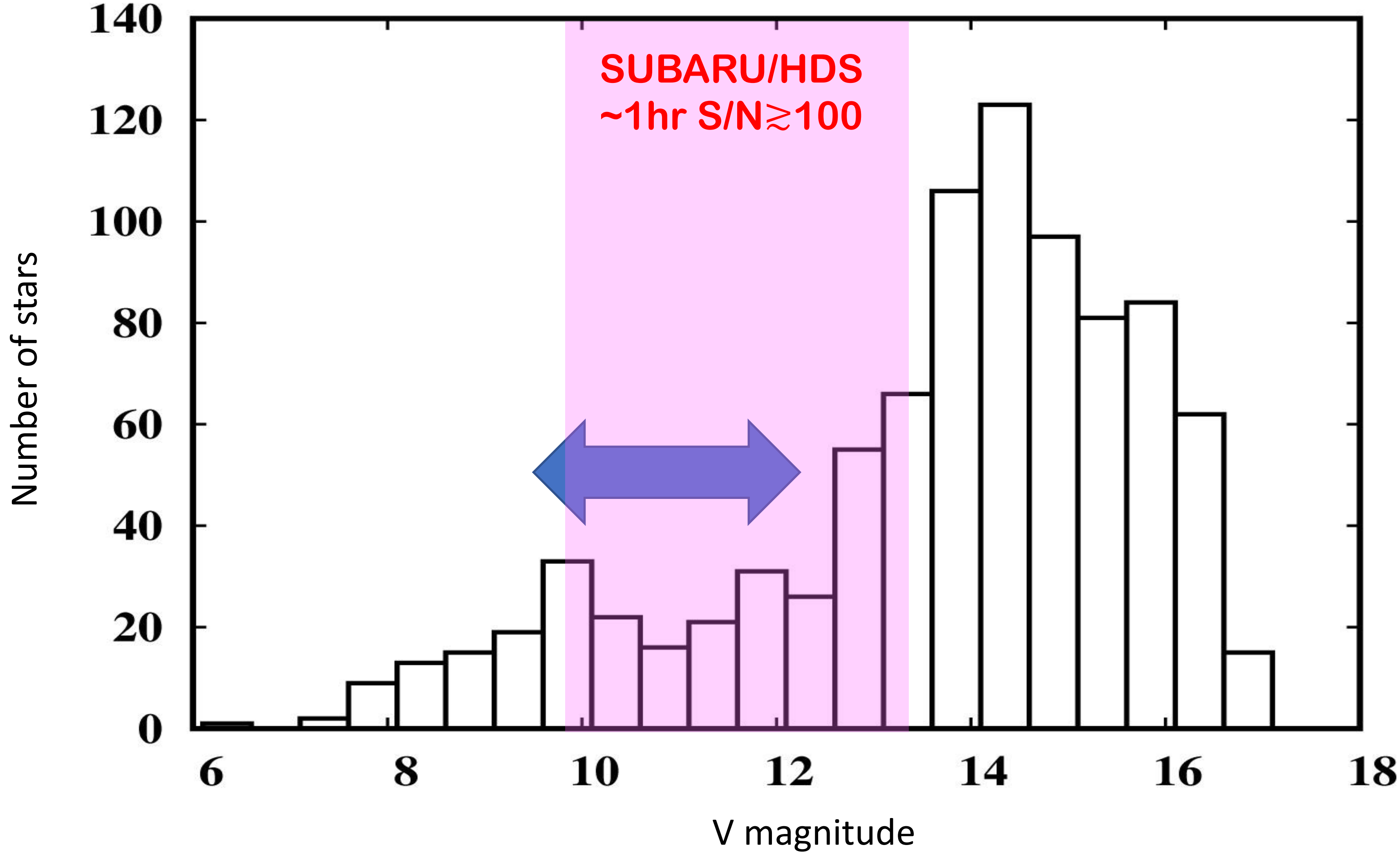






Starkenburg+17; Da Costa+19

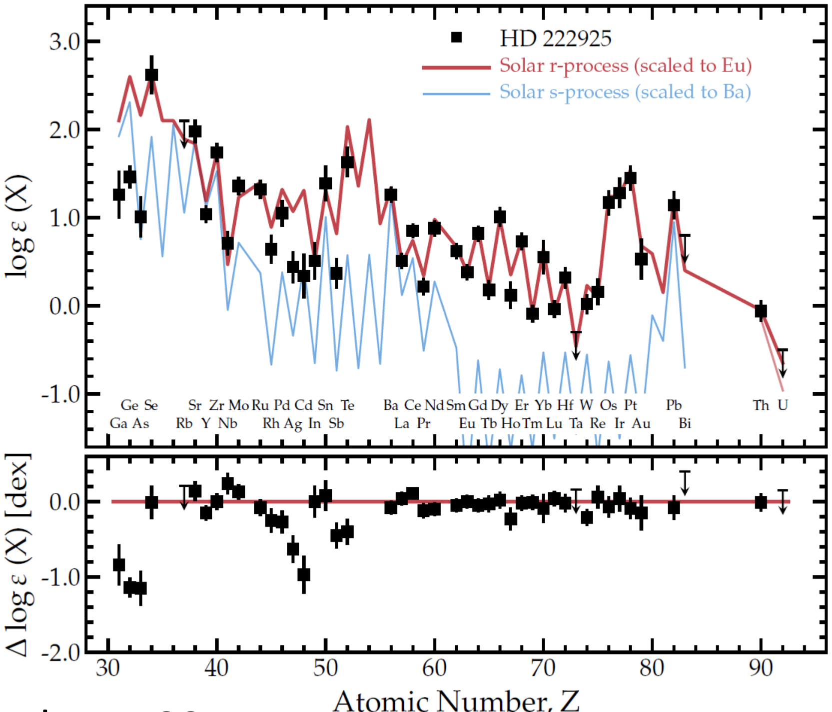
Number of metal-poor stars with [Fe/H]<-2



Profits from bright metal-poor stars

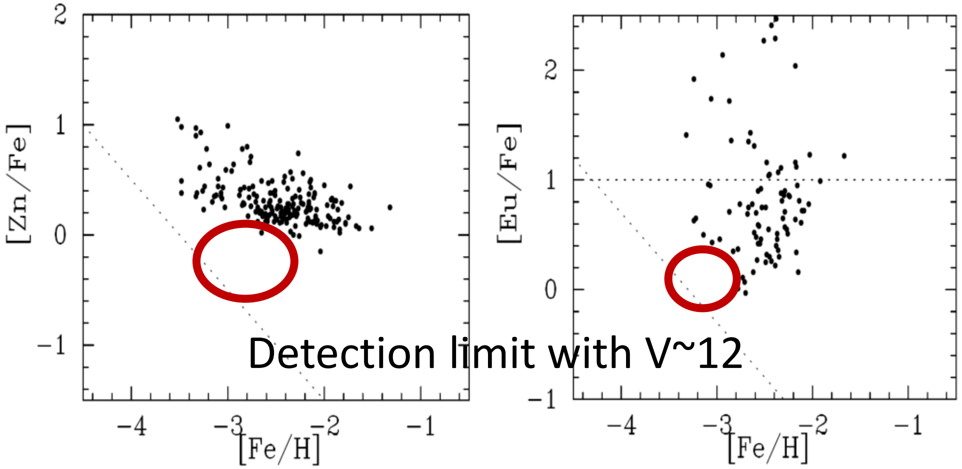
- Measurement of rare elements

UV spectroscopy



Roederer+22

- Measurement of low abundance or stringent upper limit



基盤研究A（2021～2024年度）

明るい金属欠乏星の全北天域探査による初代星元素合成と初期銀河系形成の解明

既製品フィルターを用いたパイロット観測+追観測の結果 -> 岡田さん（甲南大）

「北半球から観測可能な明るい金属欠乏星を網羅的に探査」

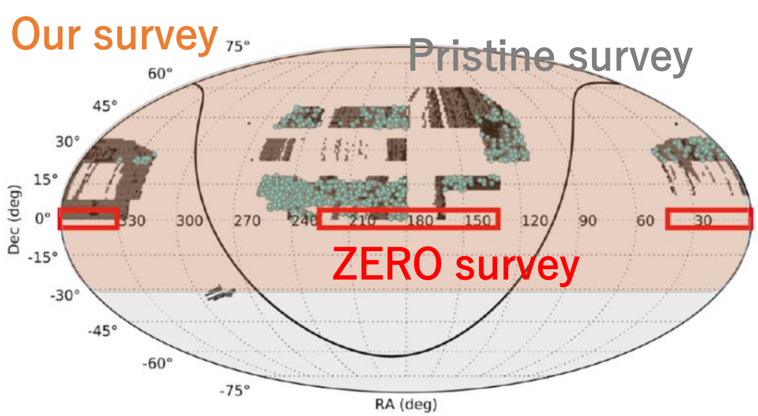
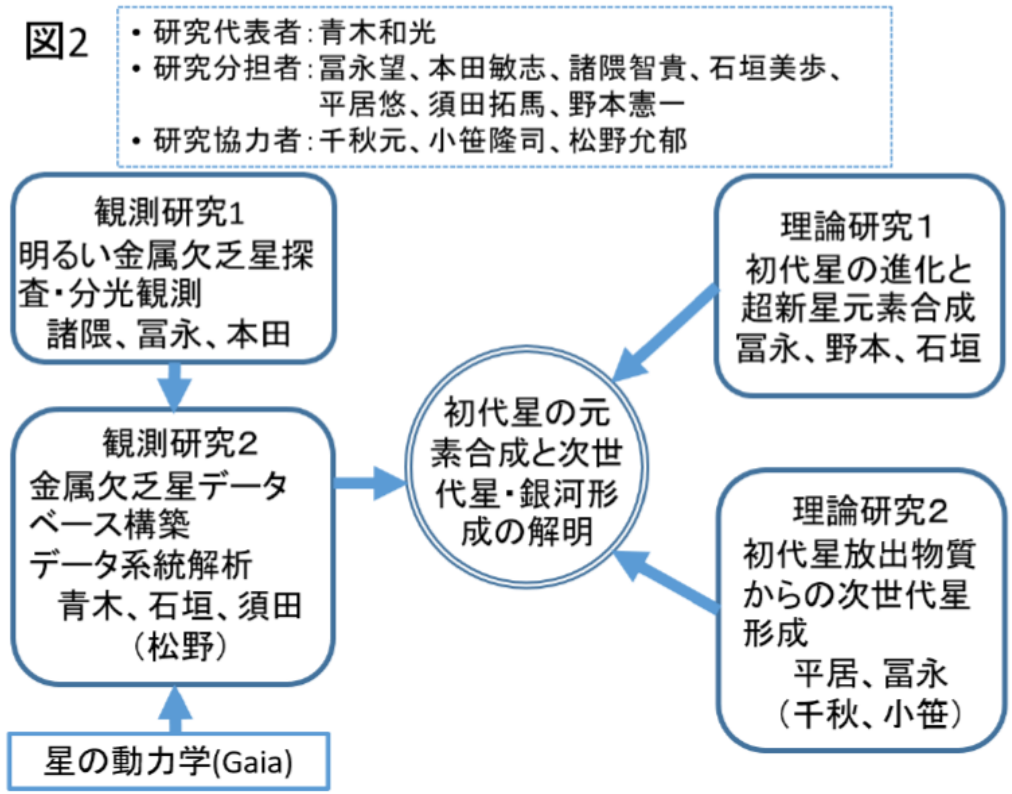
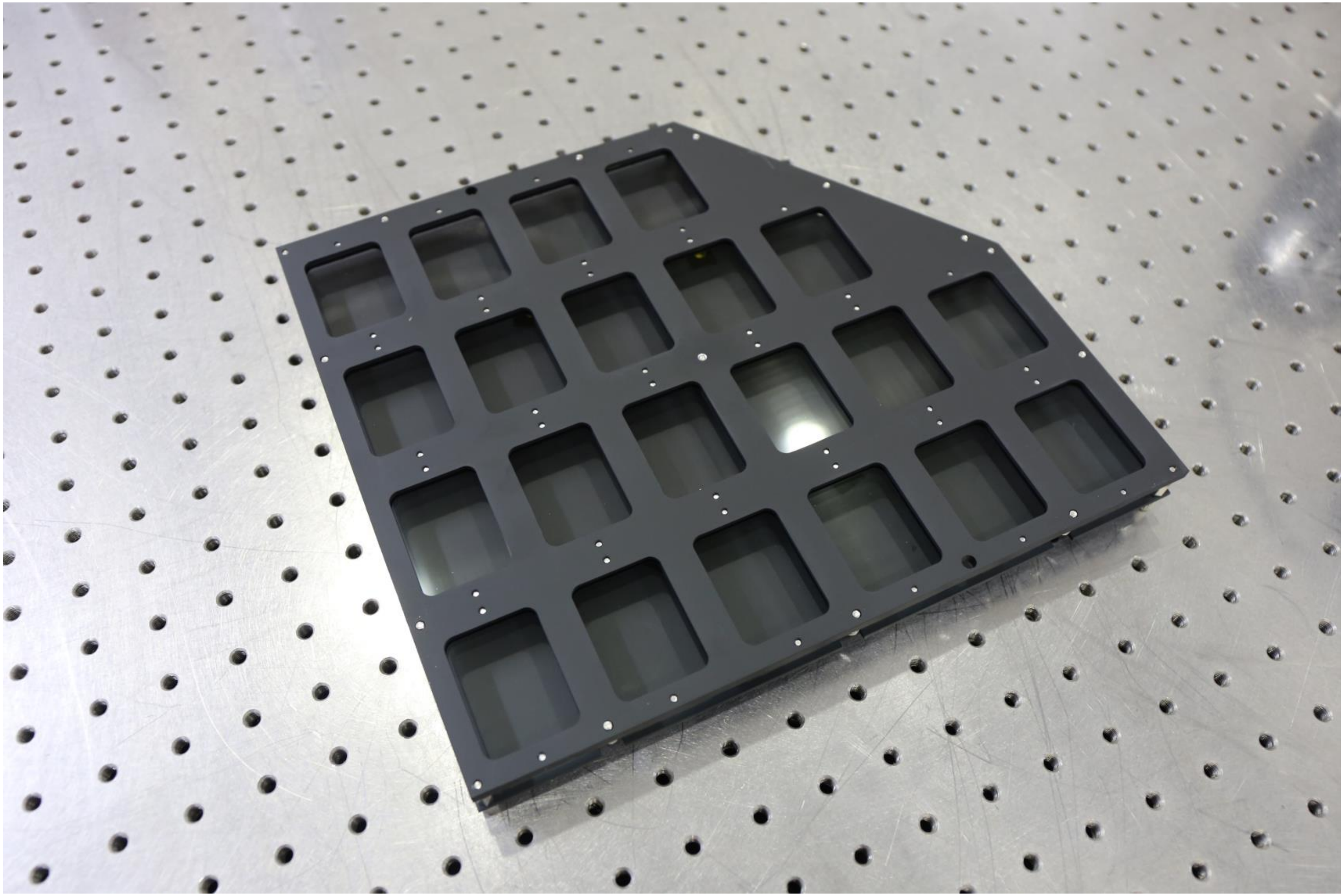


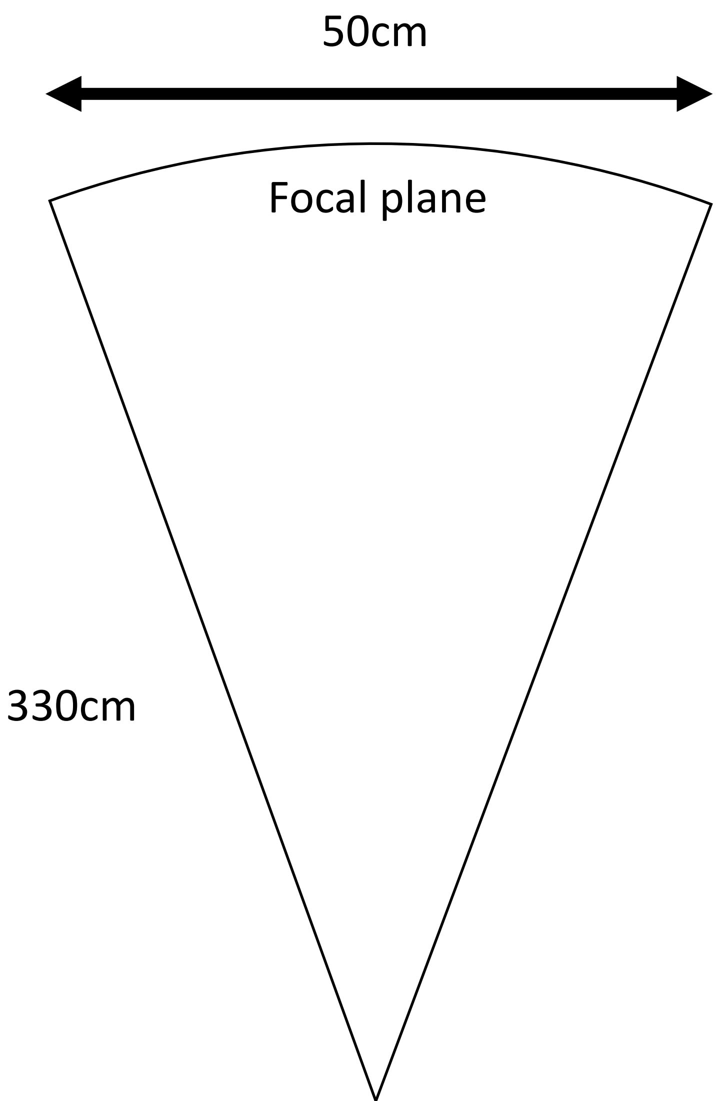
図2



Current filter holder



Tomo-e Gozen Camera



$$\lambda = \lambda_0 \sqrt{1 - \left(\frac{\sin\theta_0}{n^*}\right)^2}$$

https://www.thorlabs.co.jp/NewGroupPage9_PF.cfm?Guide=10&Category_ID=134&ObjectGroup_ID=3880

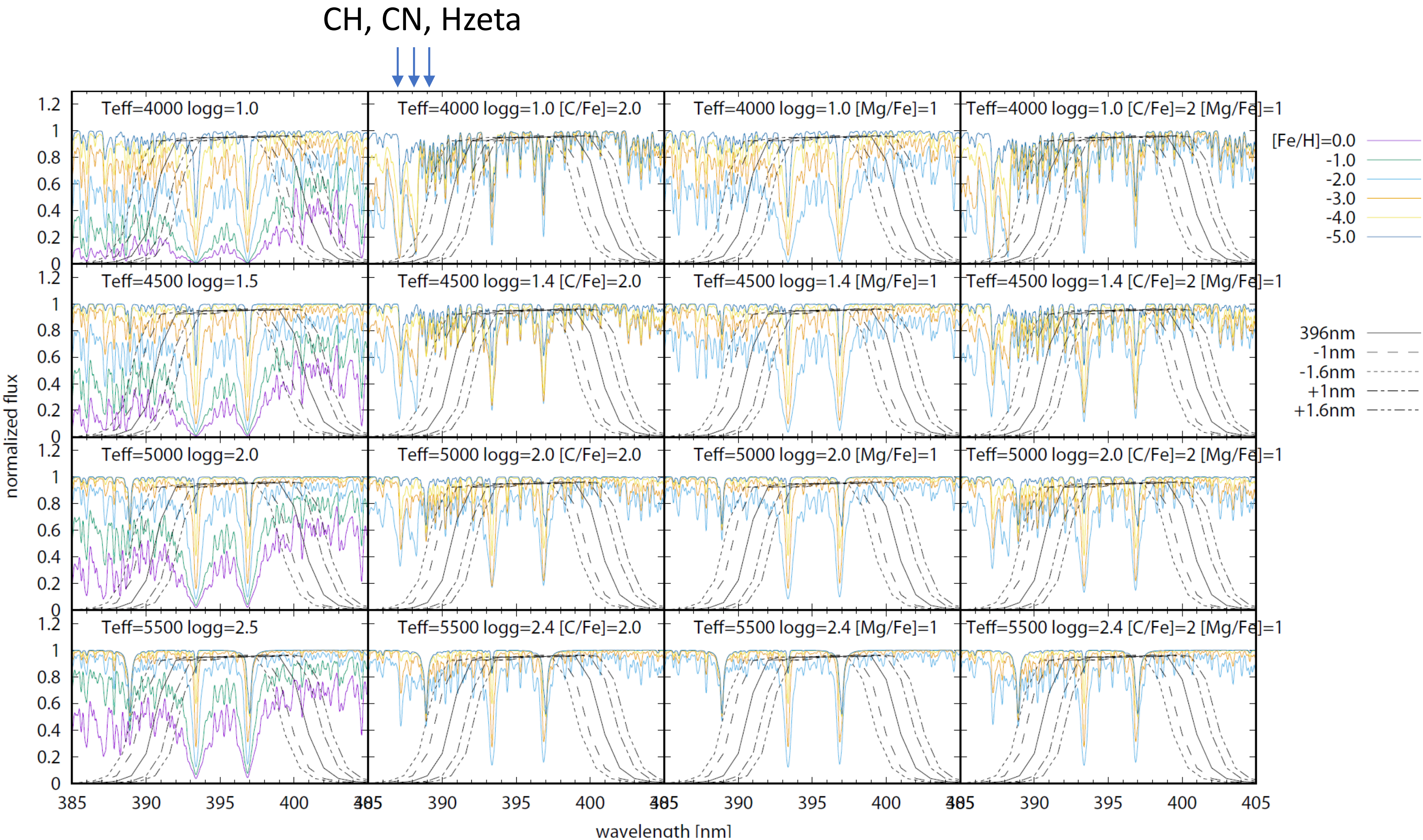
$\sin\theta = 0 – 0.076$

$\lambda/\lambda_0 = 1 – 0.9971$ ($n^*=1$)

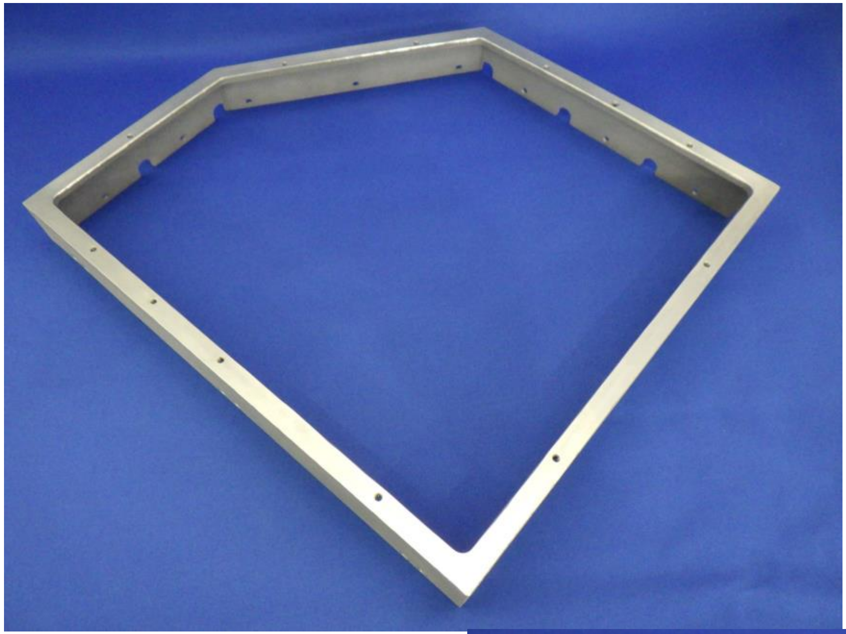
Fused silica $n^*=1.46\text{-}1.47$

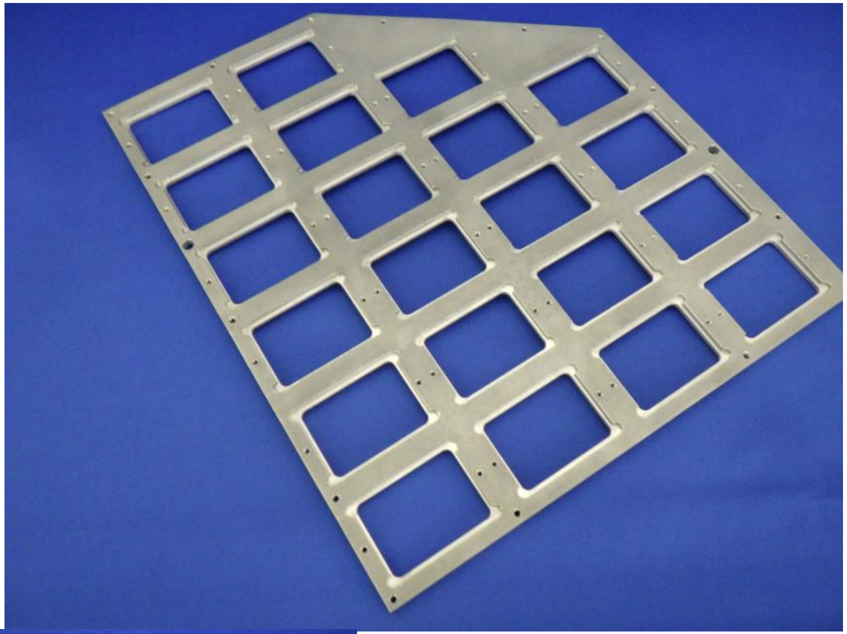
$\Delta\lambda = \pm 0.6$nm ($\lambda_0=400$nm)

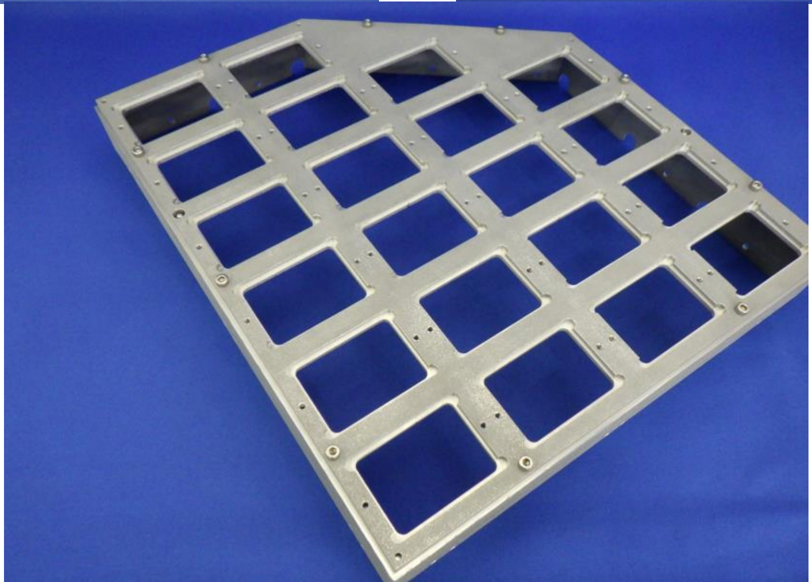
Narrow-band for CaHK (395nm)



New filter holder produced by ATC



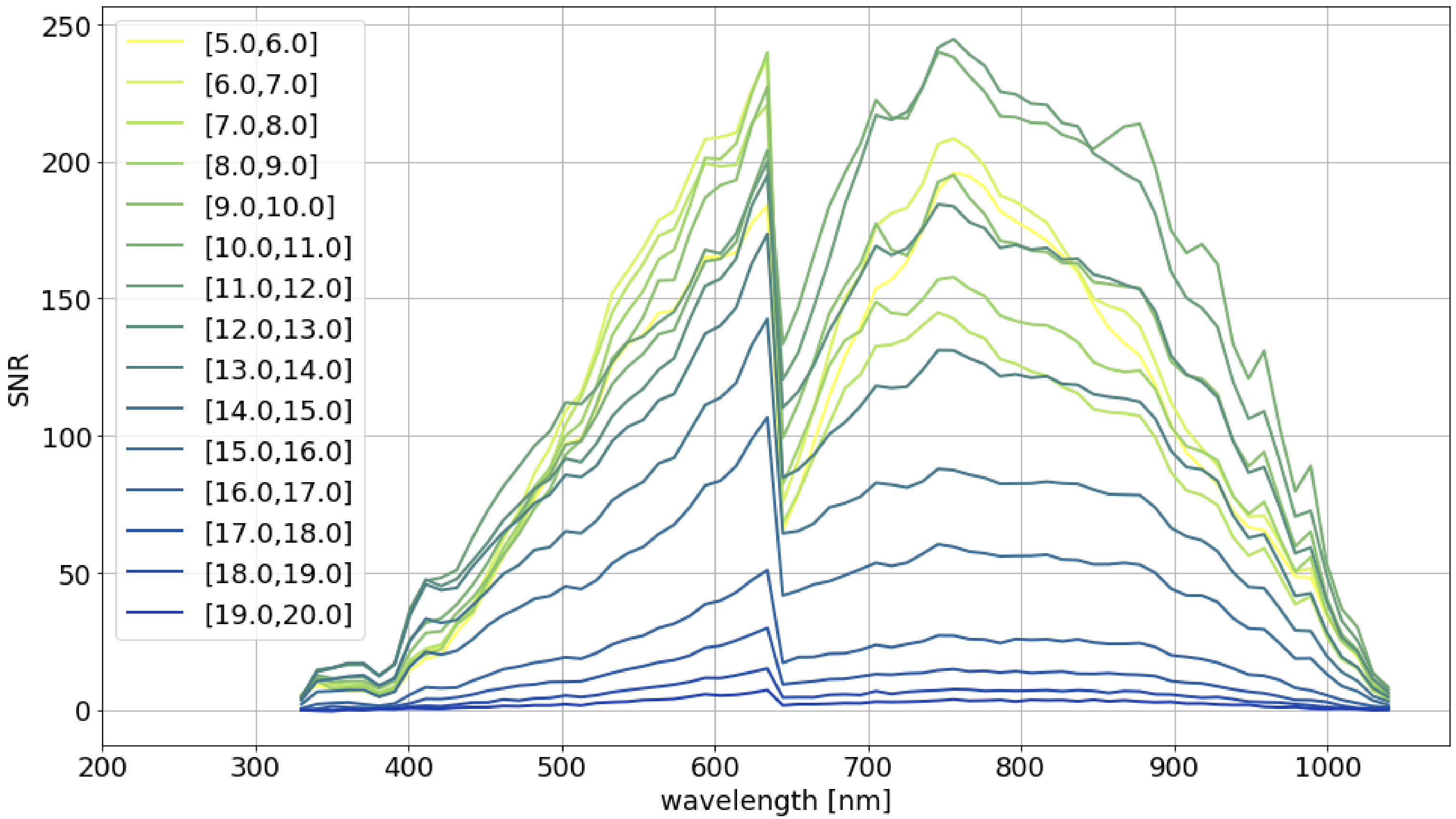




Gaia DR3

- Astrophysical parameters (Teff, logg, [M/H], AG, distance, etc.) from BP/RP spectra for 470 million objects
- Astrophysical parameters (Teff, logg, [M/H], [X/M] for 12 elements, etc.) from RVS spectra for 5.5 million objects
- Mean BP/RP spectra for 219 million sources, most of them with $G < 17.6$ mag
- Mean RVS spectra for 1 million well-behaved objects

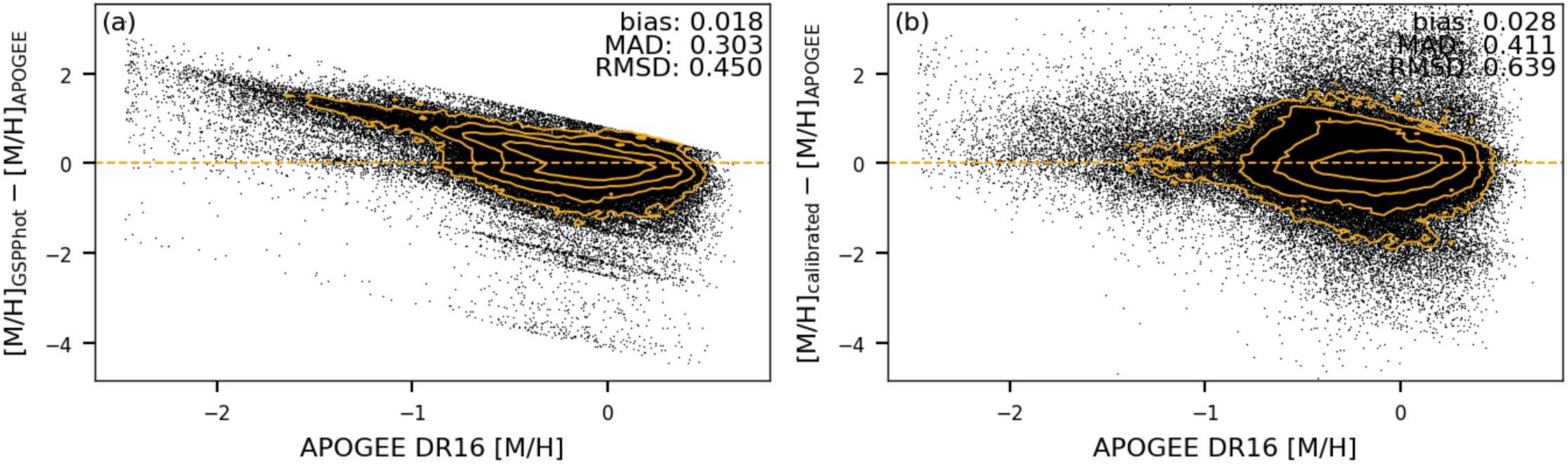
Gaia DR3 BP/RP Mean Spectra



Metallicity estimates exhibit substantial biases compared to literature values and are only useful at a qualitative level. However, we provide an empirical calibration of our metallicity estimates that largely removes these biases.

Andrae+22

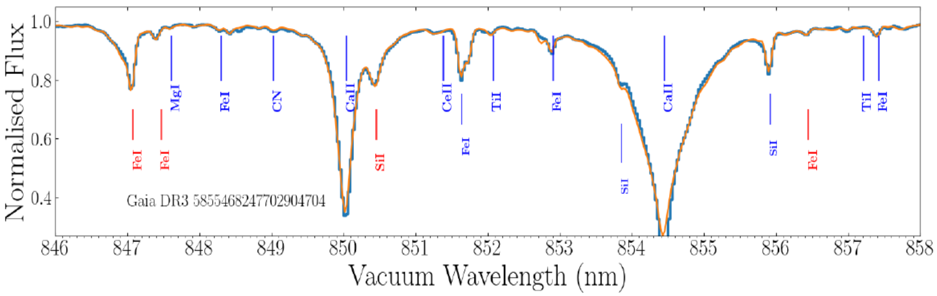
Metallicity estimate with BP/RP spectra

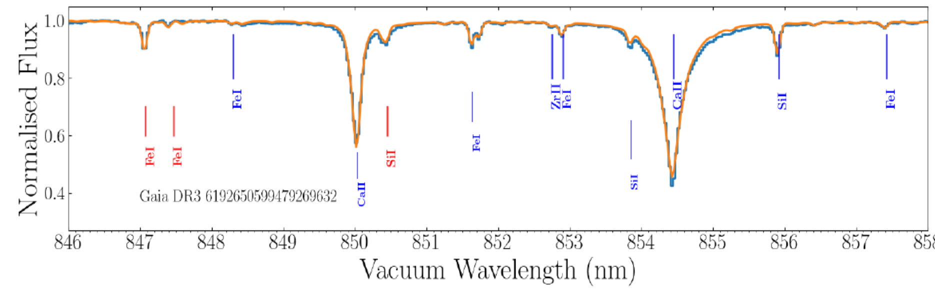


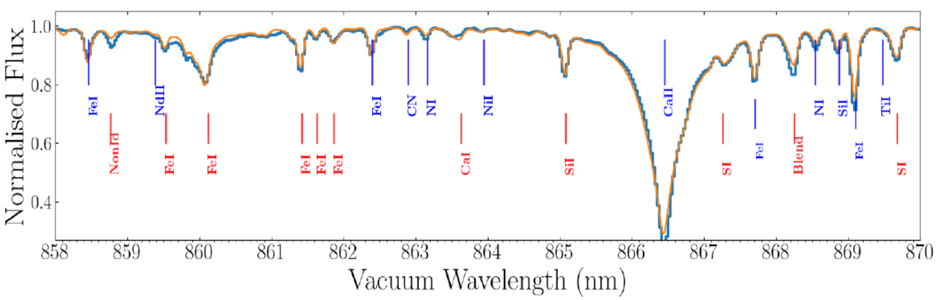
Metallicity estimates from GSP-Phot are generally very poor, being ~0.1 dex too low and exhibiting additional strong systematics. Therefore, we do not recommend to use the [M/H] estimates from GSP-Phot. However, GSP-Phot [M/H] estimates can be calibrated empirically, e.g. using LAMOST data.

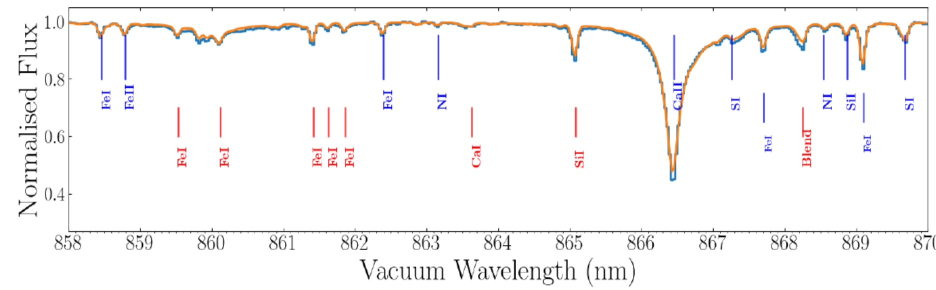
https://gea.esac.esa.int/archive/documentation/GDR3/Data_analysis/chap_cu8par/sec_cu8par_apsis/ssec_cu8par_apsis_gspphot.html

Gaia DR3 RVS spectra









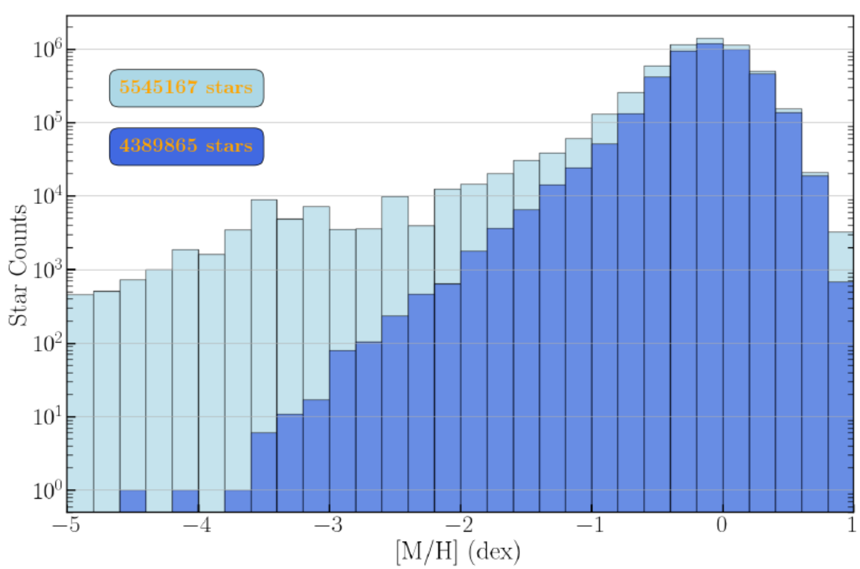


Fig. 26. Metallicity distributions for the MatisseGauguin parametrised stars. The light-blue histogram refers to the whole sample without any filtering. The medium-blue histogram presents a very strict filtering selecting stars with the best derived metallicities (see associated text for more details).

Recio-Blanco+22

Requirements and survey plan

- Two narrow band filters (NB395, 10nm width, NB433 20nm width, NB518?, NB857x)
  - Magnitude at 395nm: <15 mag @ 395nm (cool red)
  - Efficiency at 395nm: x 0.5
  - Signal-to-noise ratio: **>20-50?**
- Required number of nights:

  1 night for no filter survey for 12,000 deg2 for ~<18mag (5sigma)

  → **??** clear nights x 2 to cover whole northern sky
- Observing plans:
  - Observations are not time critical
  - (probably) need to avoid GW O4 (Mar 2023-)
  - Test observation: (hopefully) **Sep 2022?**
  - Main survey: during breaks of GW O4?, after GW O4?, before the end of FY2023?
- Follow-up spectroscopy
  - With Nishi-Harima, Subaru, etc.
  - Collaboration with US team to study r-process-enhanced stars (RPA: R-Process Alliance) through IReNA
- Byproducts
  - Searches for stellar activities using Ca H-K lines
  - Others?