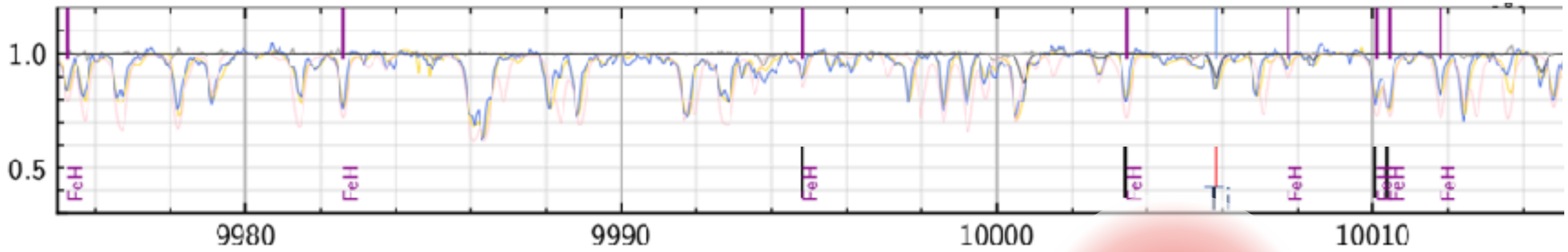
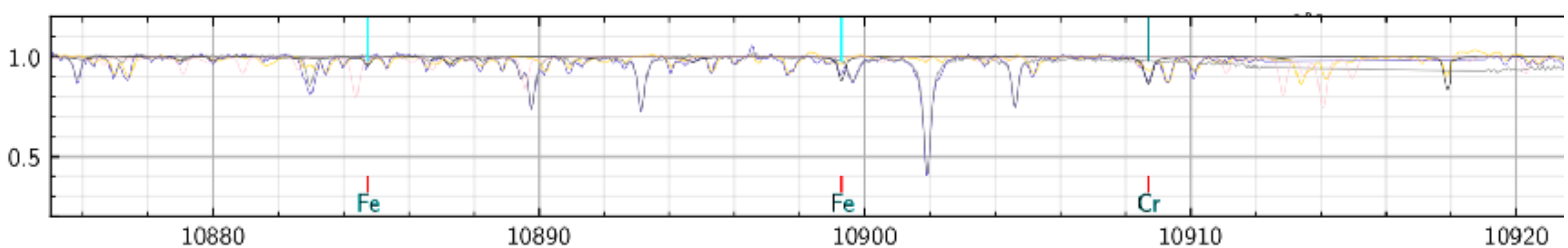


Detailed Chemical Analysis of M Dwarfs by High-Dispersion Near-Infrared Spectroscopy with IRD



Hiroyuki Tako ISHIKAWA (SOKENDAI/NAOJ)

W. Aoki, S. Hayashi (NAOJ), T. Kotani, M. Omiya, M. Kuzuhara (ABC)

Subaru Telescope 20th Anniversary @ Waikoloa Beach Marriott Resort and Spa on 19 November 2019

Motivation & Aim

to determine the individual chemical abundances of M dwarfs as planet-host stars

M dwarfs

T_{eff} ~ **2300 - 3900** K

$M = 0.08 - 0.6\ M_{\odot}$

$R = 0.08 - 0.6\ R_{\odot}$

> 70 % of nearby stars

T_{eff} ~ 5800 K

$M = 1\ M_{\odot}$

$R = 1\ R_{\odot}$

⇓

Popular target of planet search projects

IRD planet search

InfraRed Doppler instrument for the Subaru telescope (**8.2m**)

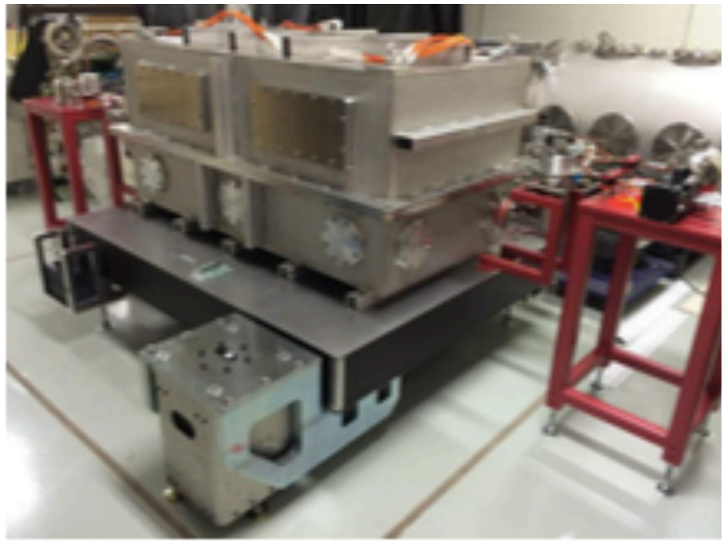
Radial velocity survey (February, 2019- (5 year))

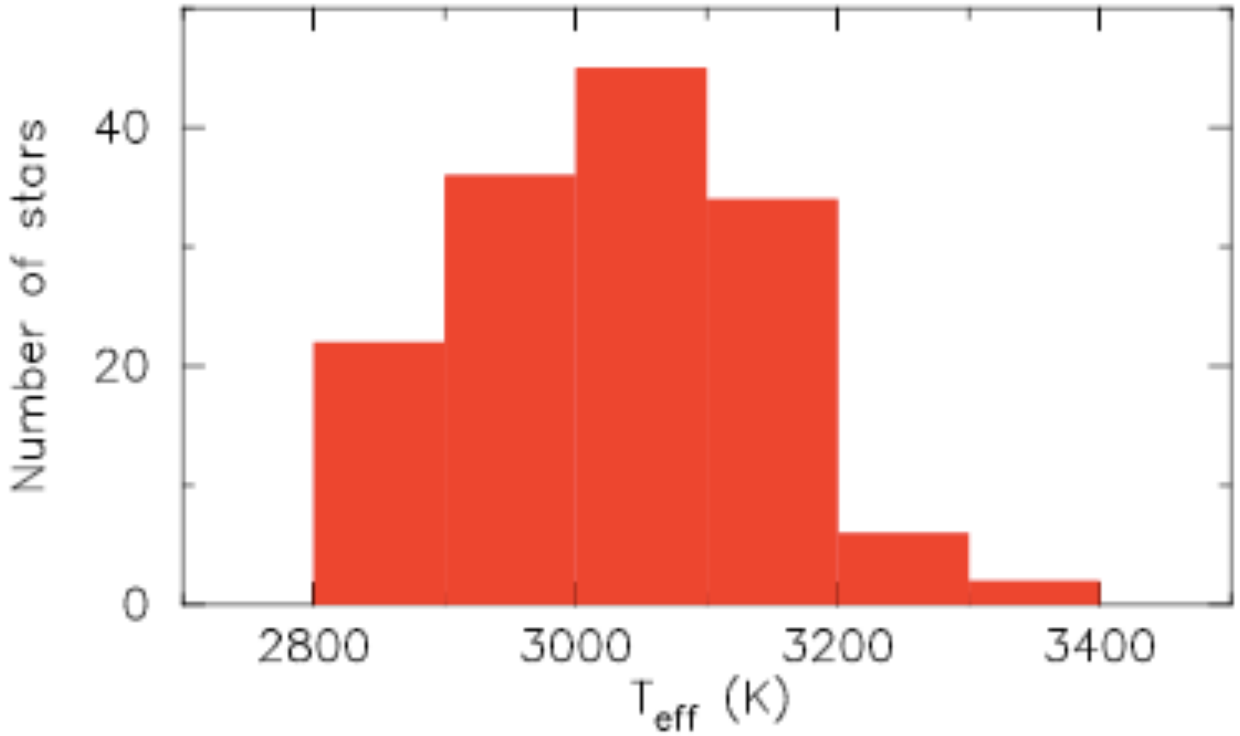
of nearby **mid-late M dwarfs** (0.1-0.2 M_{Sun})

for **Earth-mass planets**

$R = \frac{\lambda}{\Delta\lambda} \sim$ **70,000**

Y, J, H (**0.97-1.75**μm)





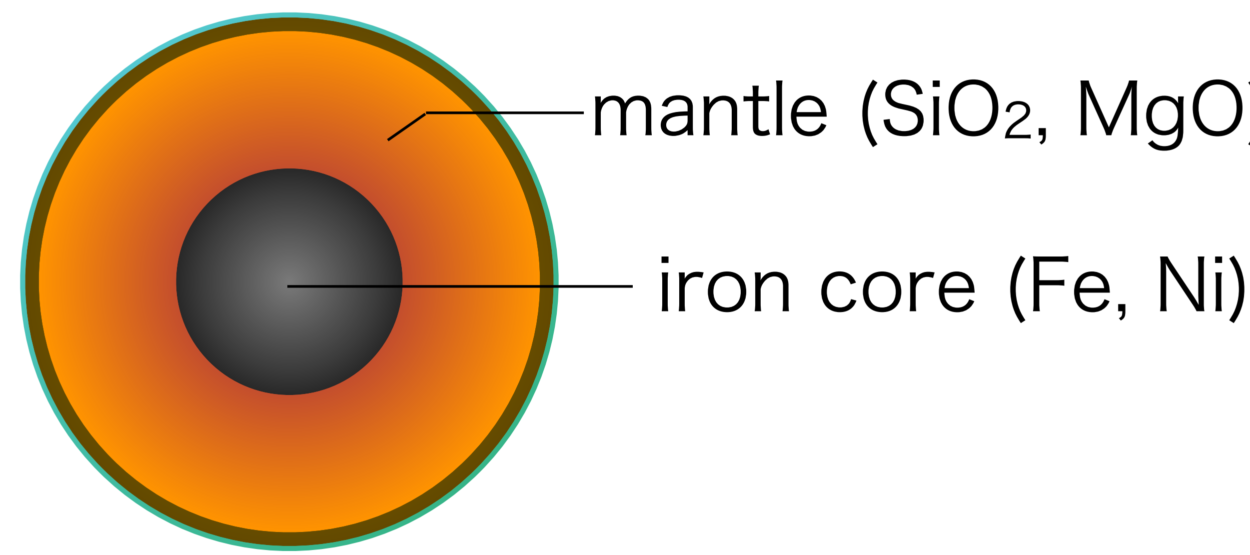
c.f.) Omiya-san's poster (P31)

Chemical Analysis

The **individual chemical abundances** of host stars are critical to constrain the **internal structure** or the **formation processes** of planets.

mass & radius
of rocky planets
↓
mean density

degeneracy ➡



Fe, Mg, Si govern the internal structure of rocky planets.

(e.g. Unterborn & Panero, 2017; Dorn et al. 2017)

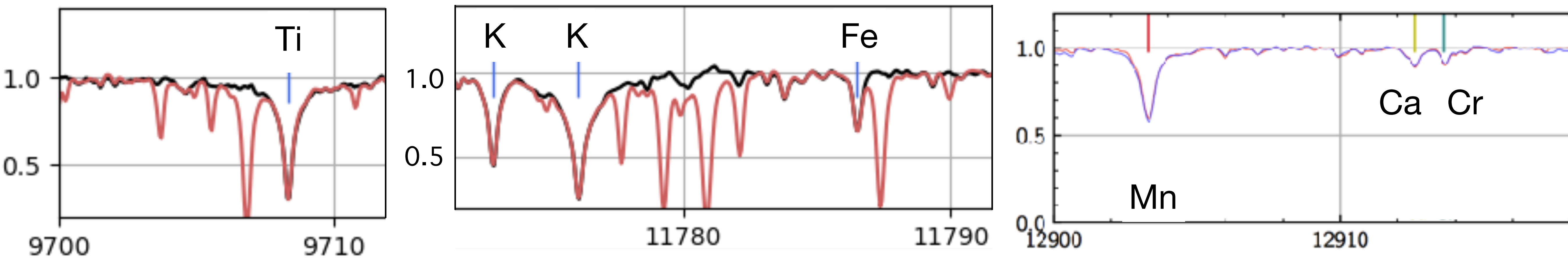
⇒ **Importance of individual abundances NOT the overall solar-scaled"metallicity"**

Analysis

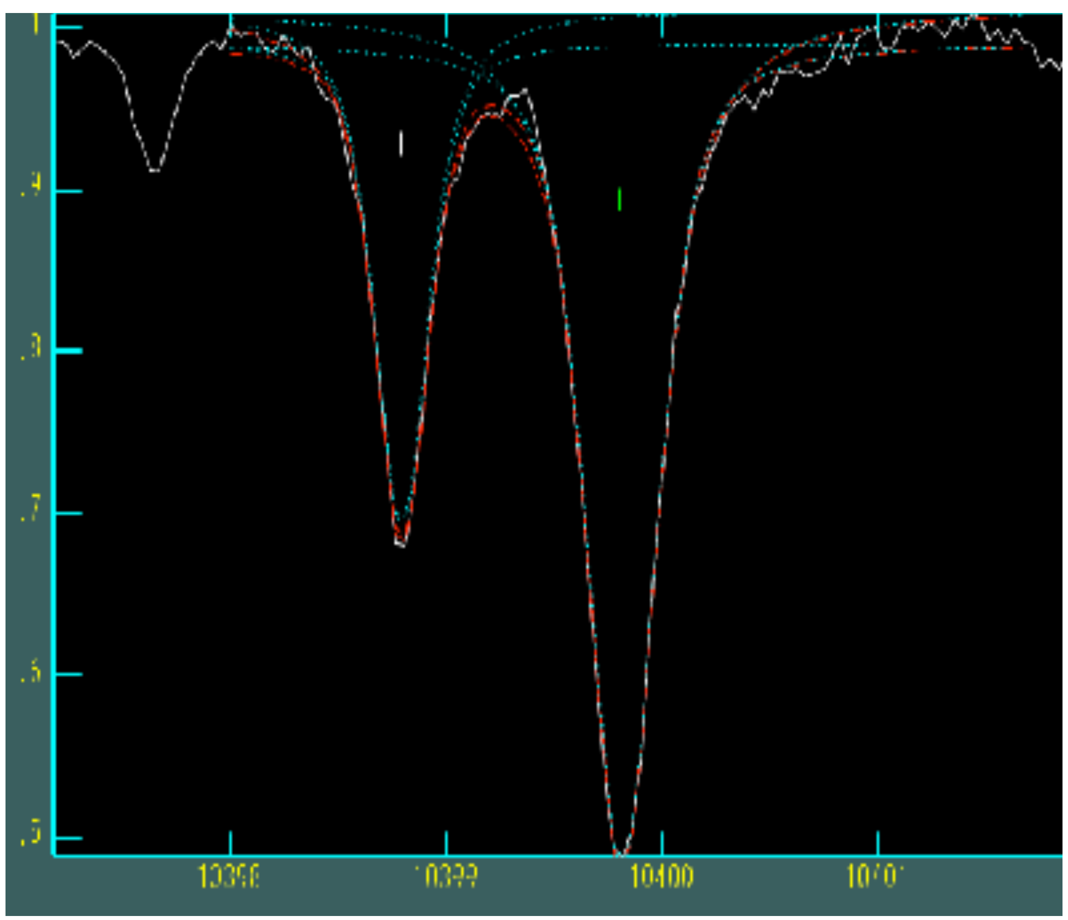
- model comparison of equivalent widths
- assessment of the results using binary systems

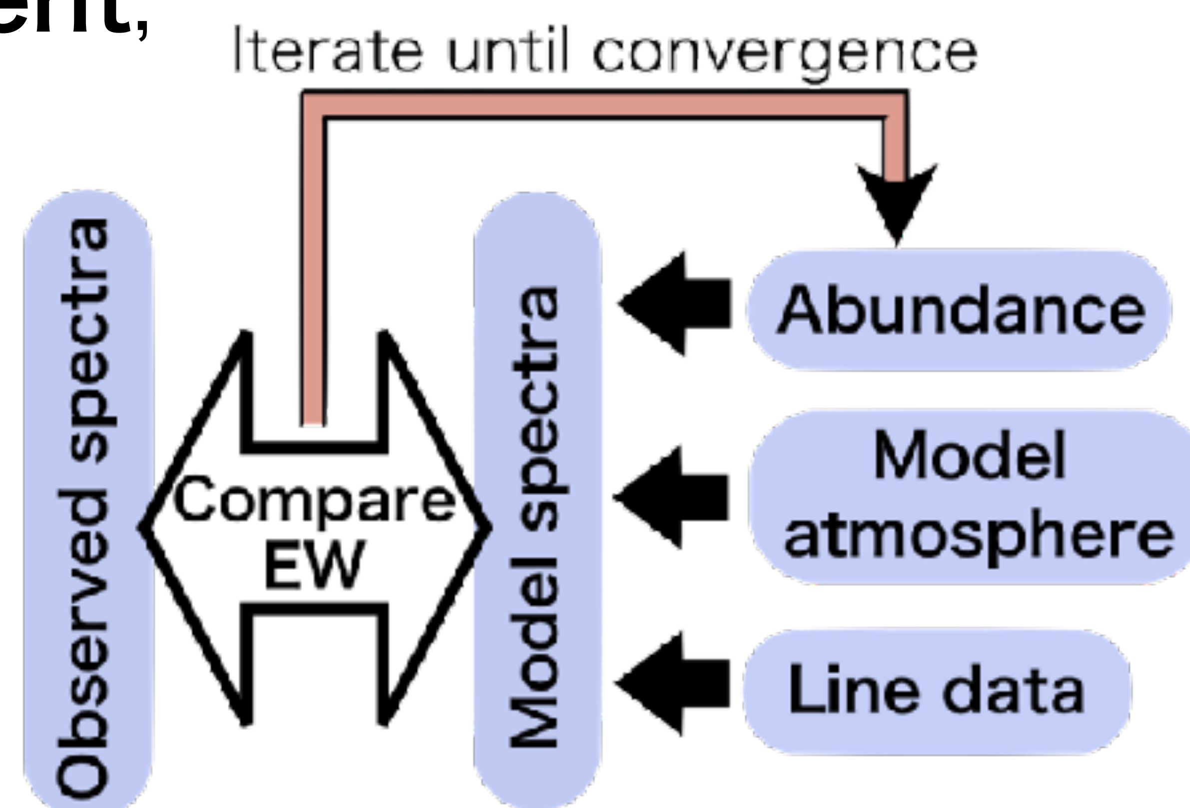
Chemical Analysis

Line identification,



Equivalent width measurement,

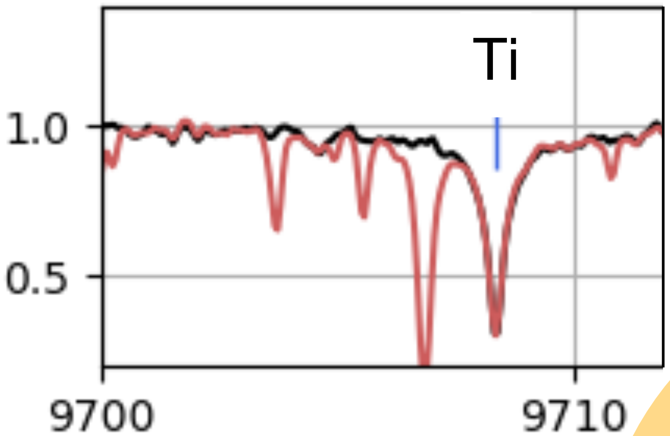


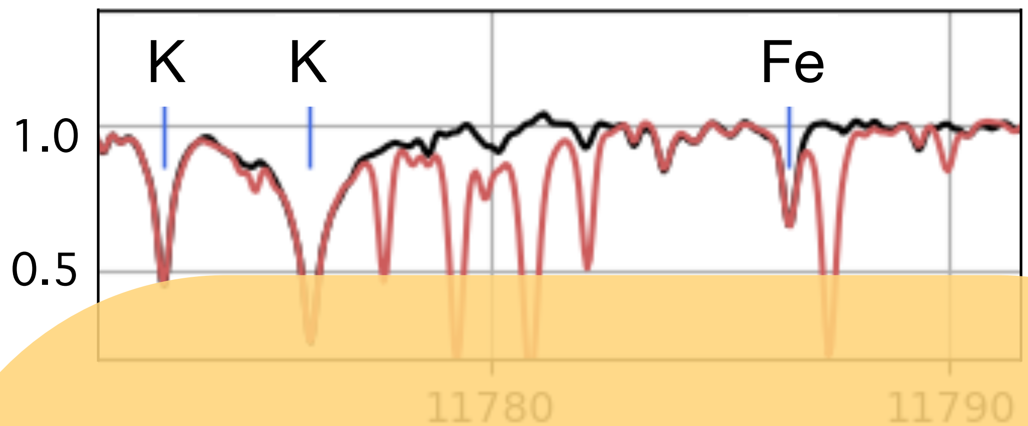


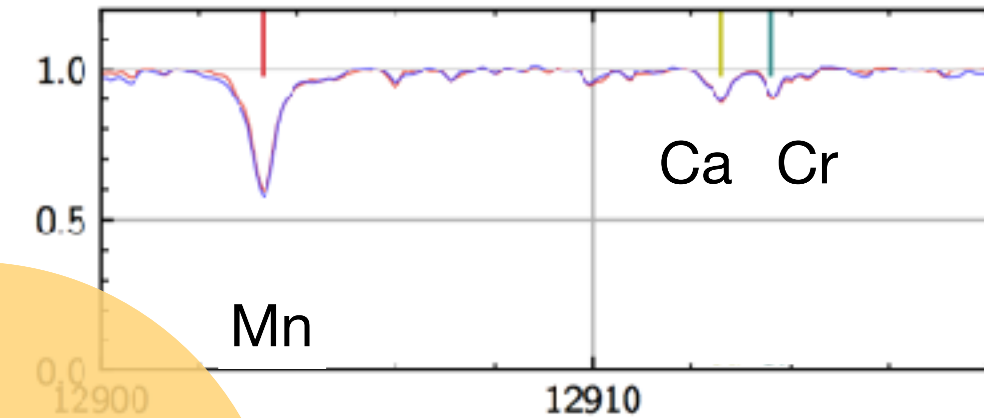
Translate EW into abundances.

Chemical Analysis

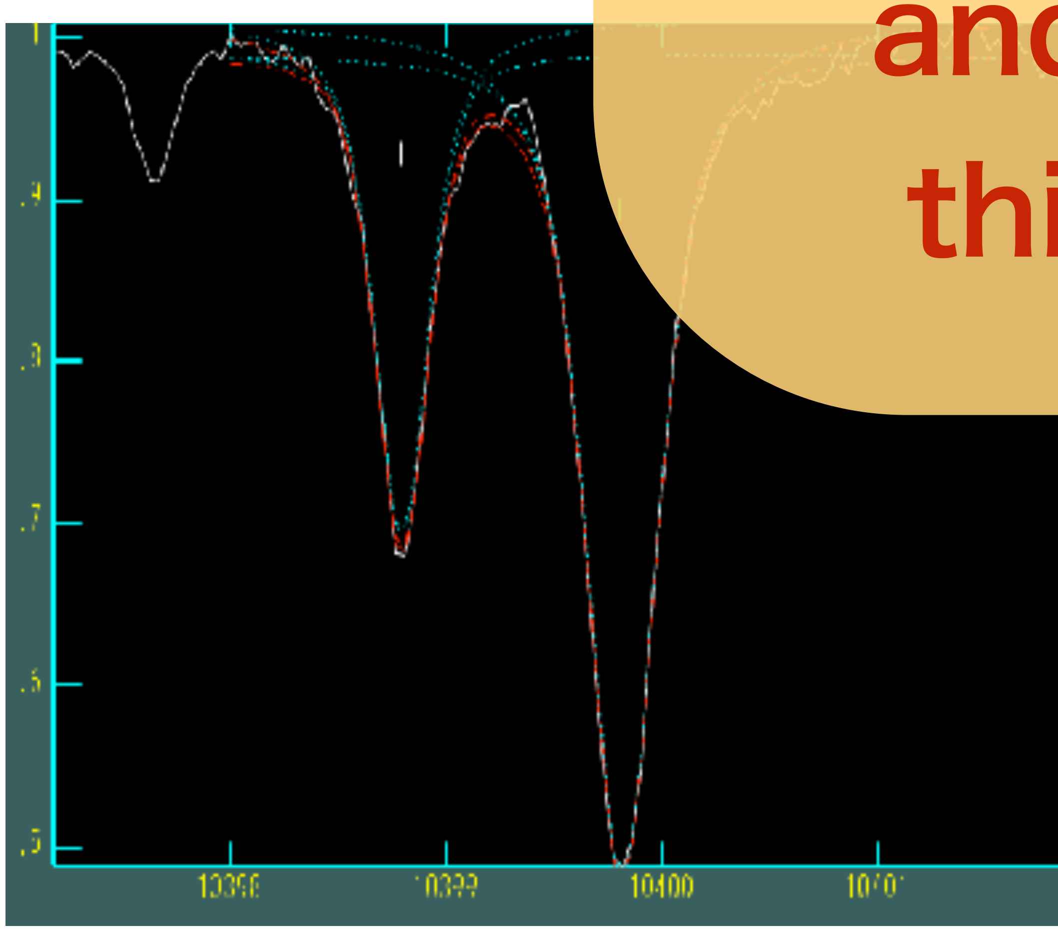
Line identification,

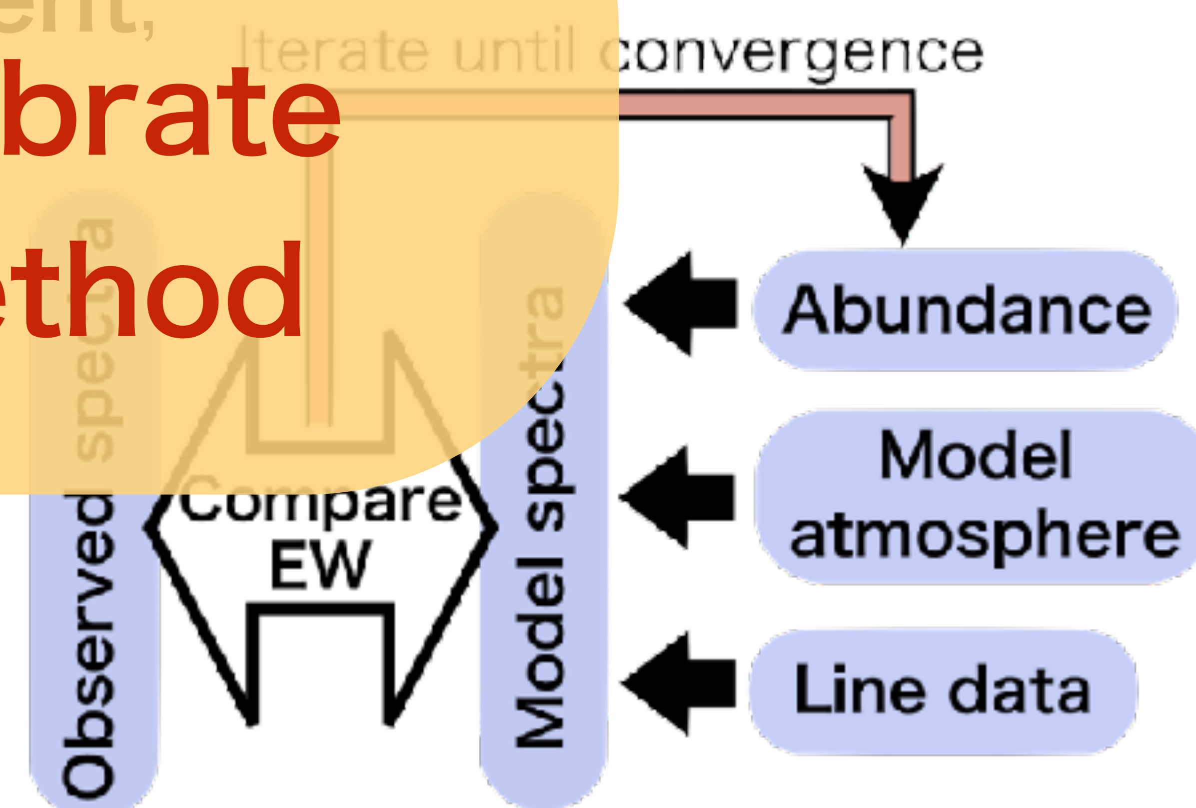






Equivalent width measurement,

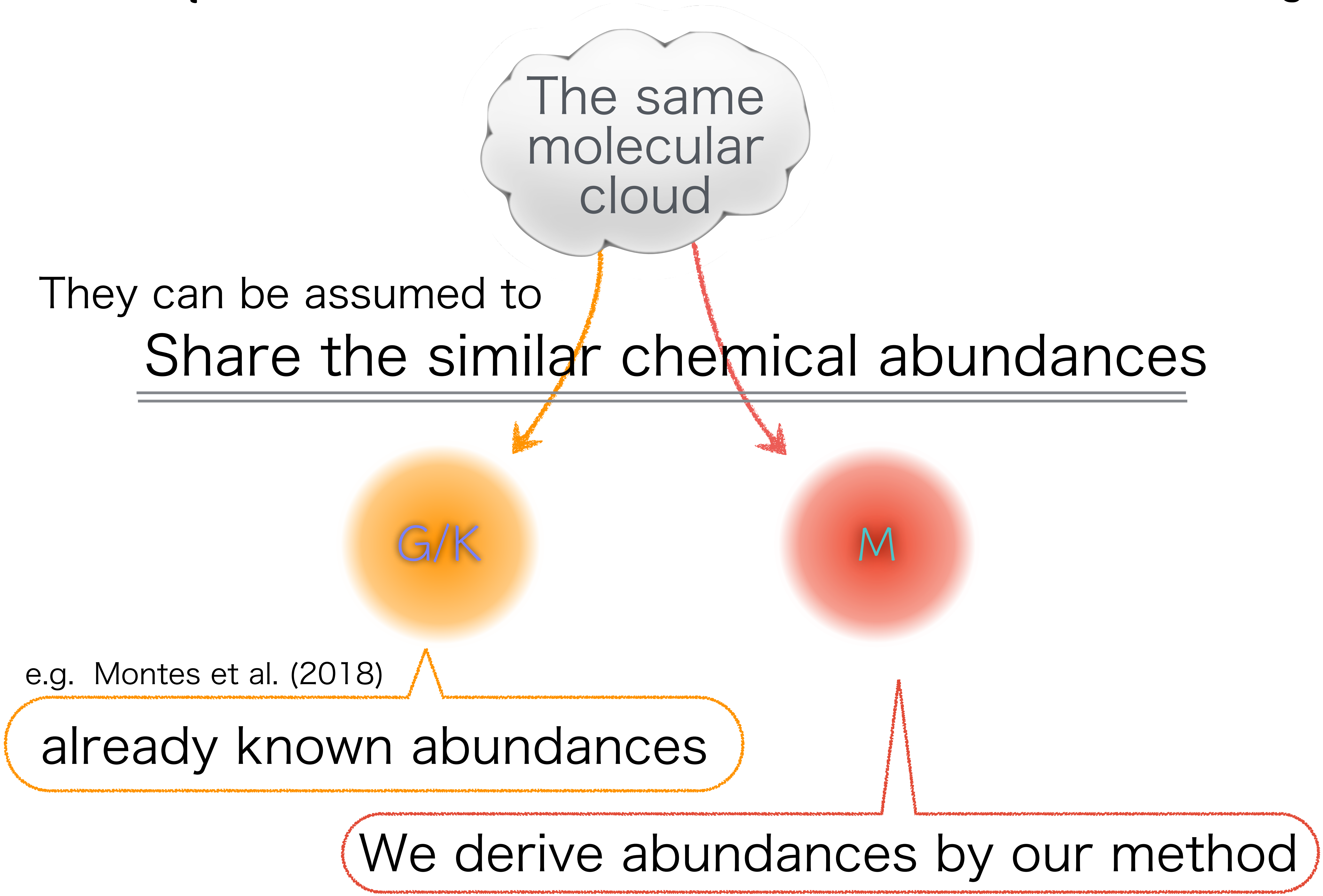




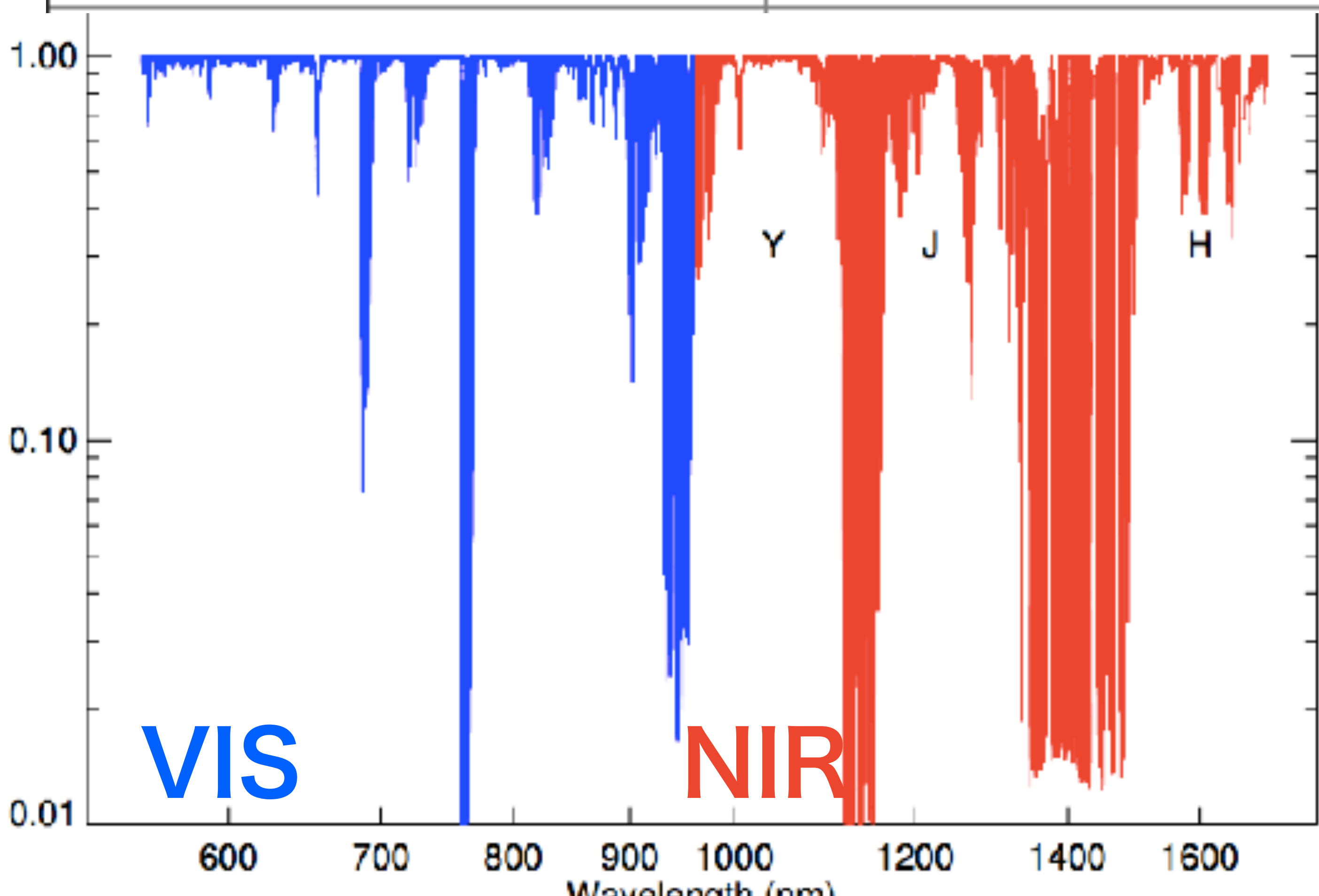
We need to assess and calibrate this method

Translate EW into abundances.

Compare Abundances in Binary



	VIS channel	NIR channel
Wavelength coverage, Δλ*	520-960 nm ([V]RIZ)	960-1710 nm (YJH)
Spectral resolution, R	94,600	80,400



Comparable to IRD

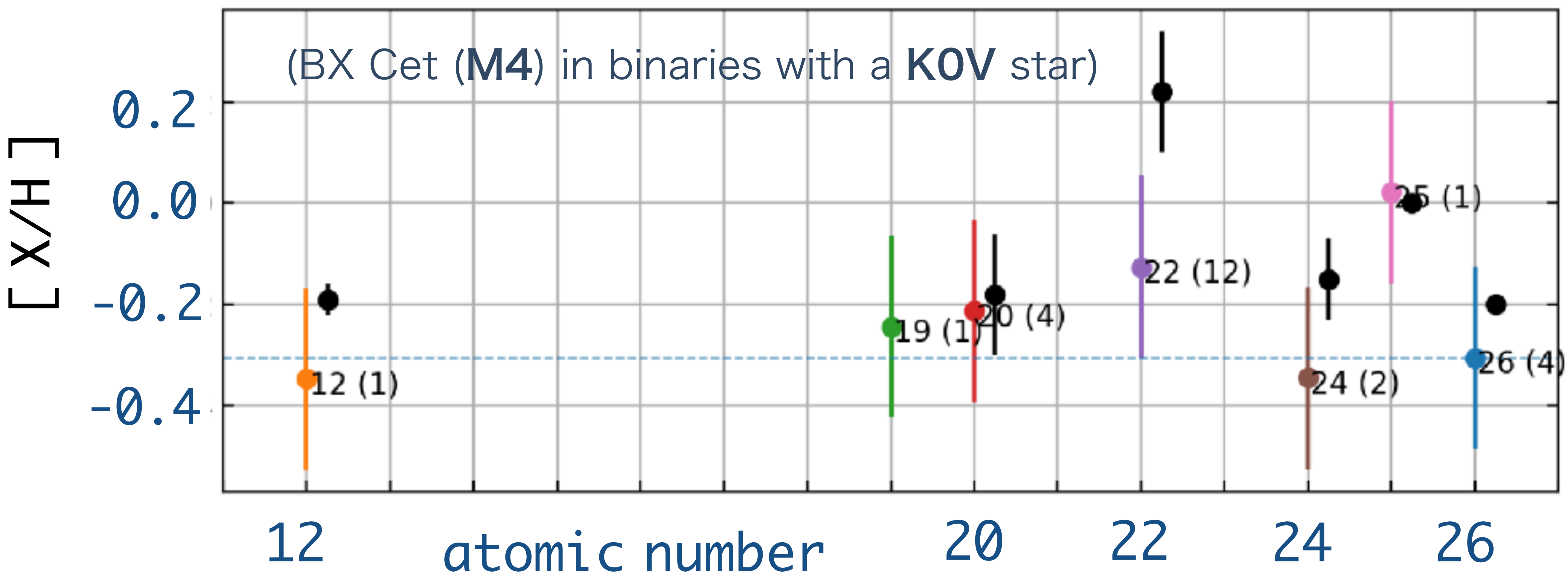
planet search around mainly **early-mid** M dwarfs (c.f. IRD: mid-late)

Results

Result of individual abundances

Black markers refer to the abundances for the **primary star**

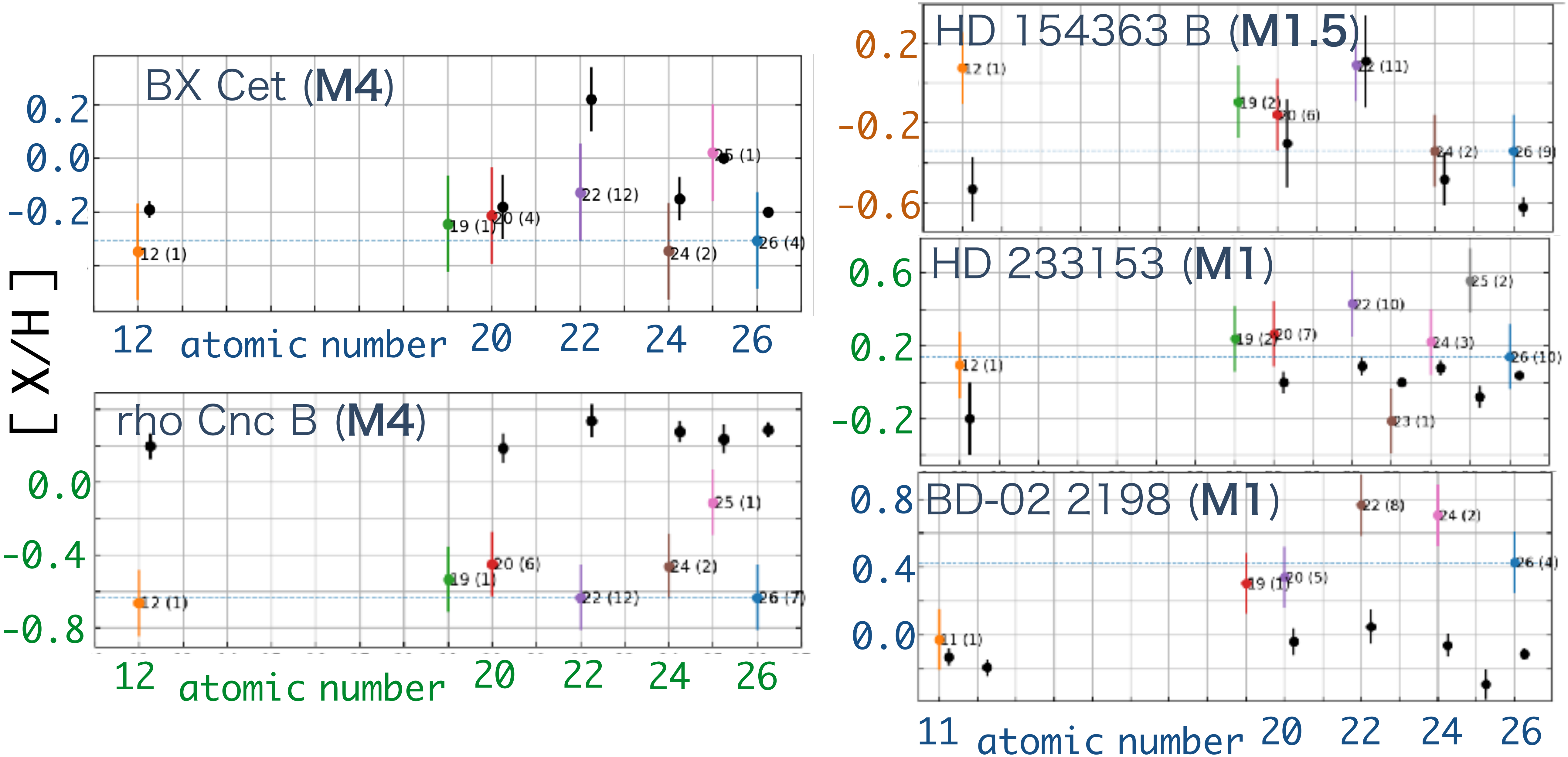
(Montes+2018)



Our results for several elements **agree** with the abundances of its primary star (K0V)

Result of individual abundances

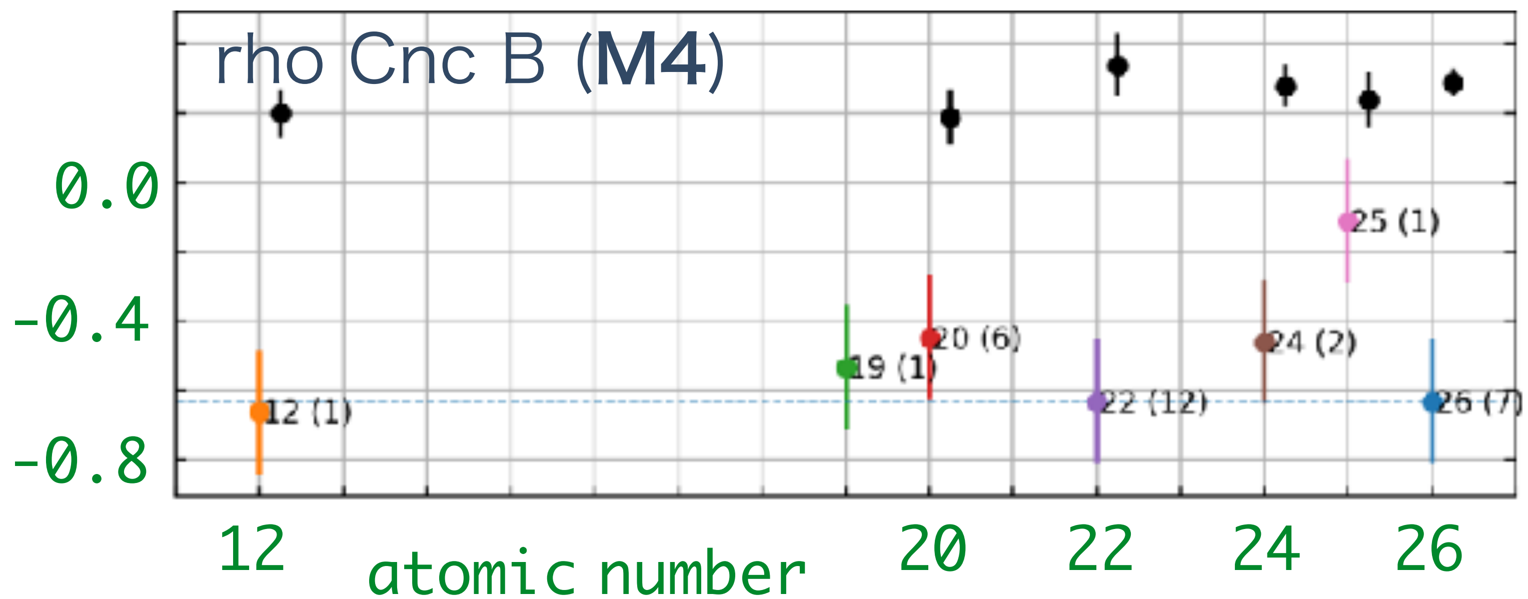
Black markers refer to the abundances for the **primary star** (Montes+2018)



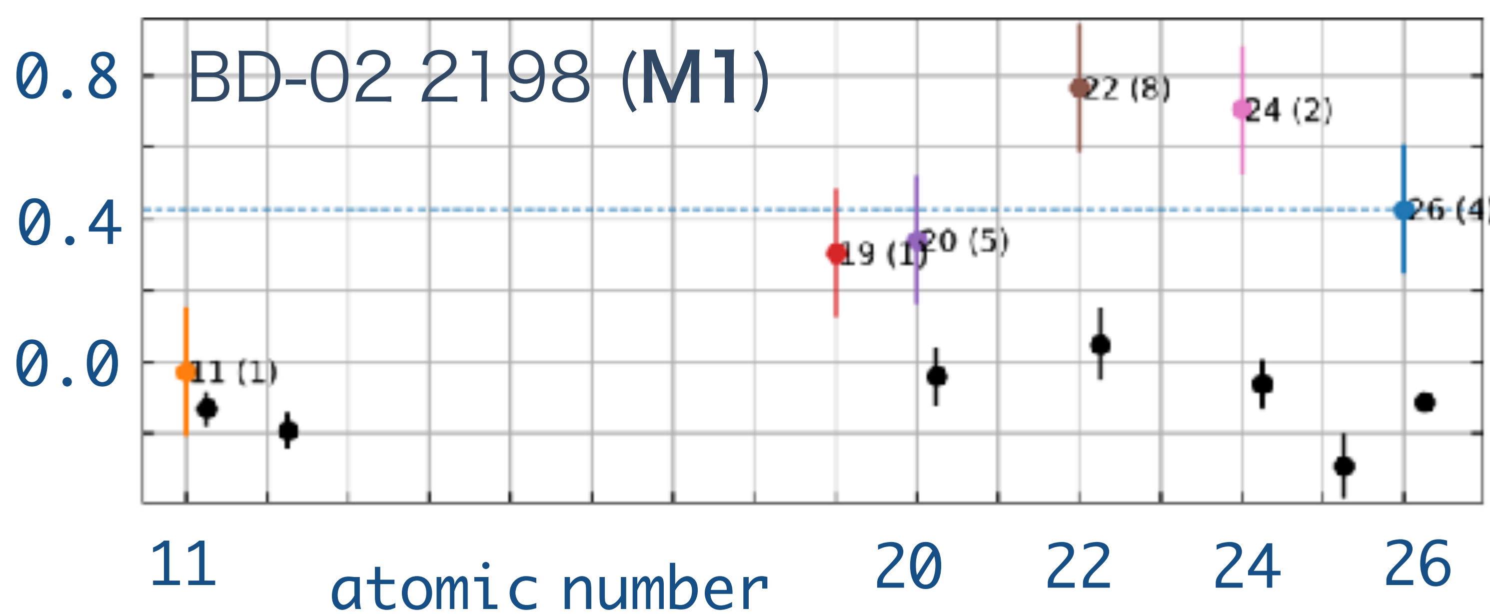
Our results for 3 objects roughly **agree** with the abundances of their primaries… but 2 objects do **not**.

Result of individual abundances

Black markers refer to the abundances for the **primary star** (Montes+2018)



generally **too low** abundances for one object and

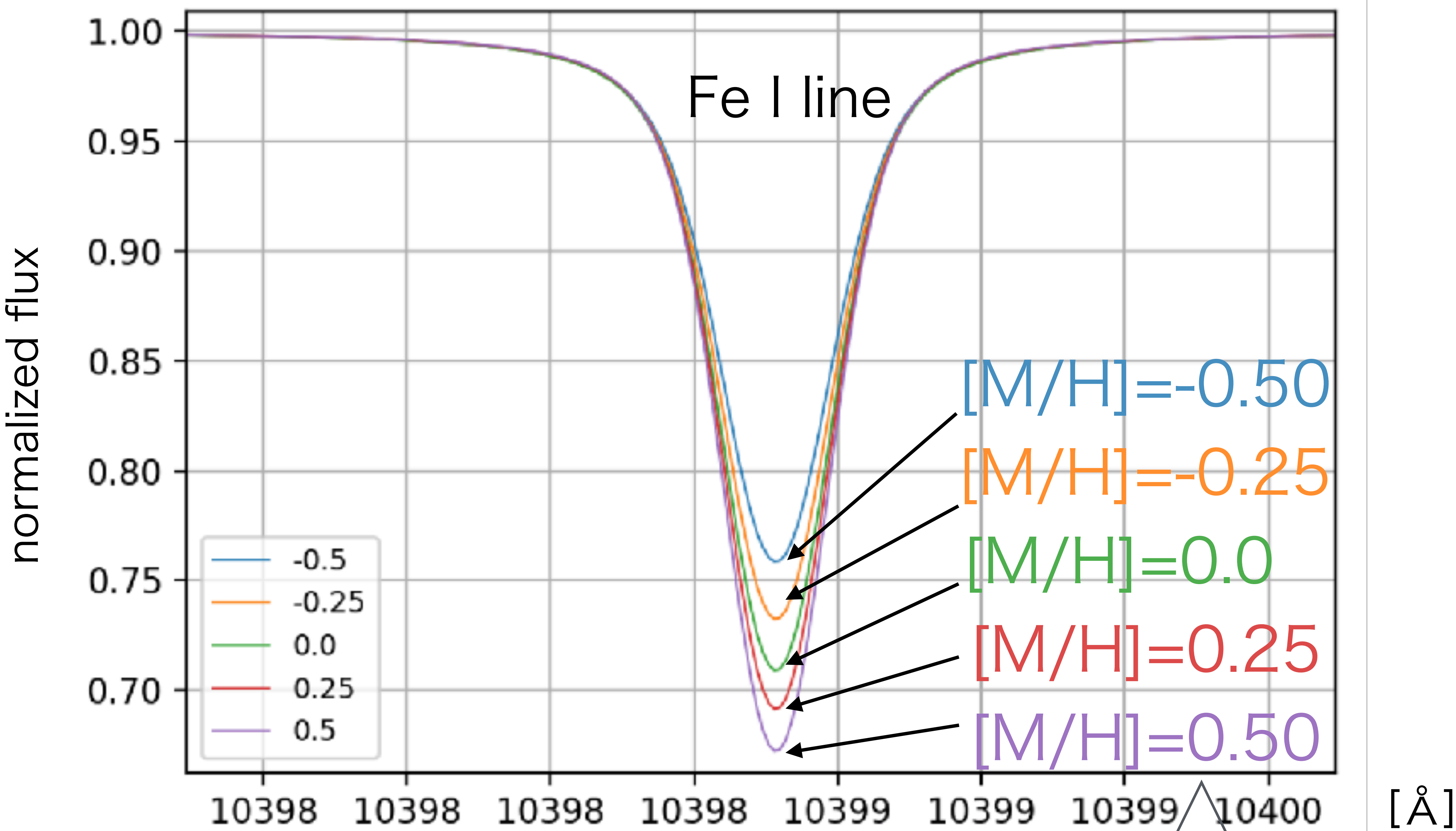


generally **too high** abundances for another.

Discussion & Remaining Issues

absorption line strength is affected by
the abundance of **not only** the corresponding species

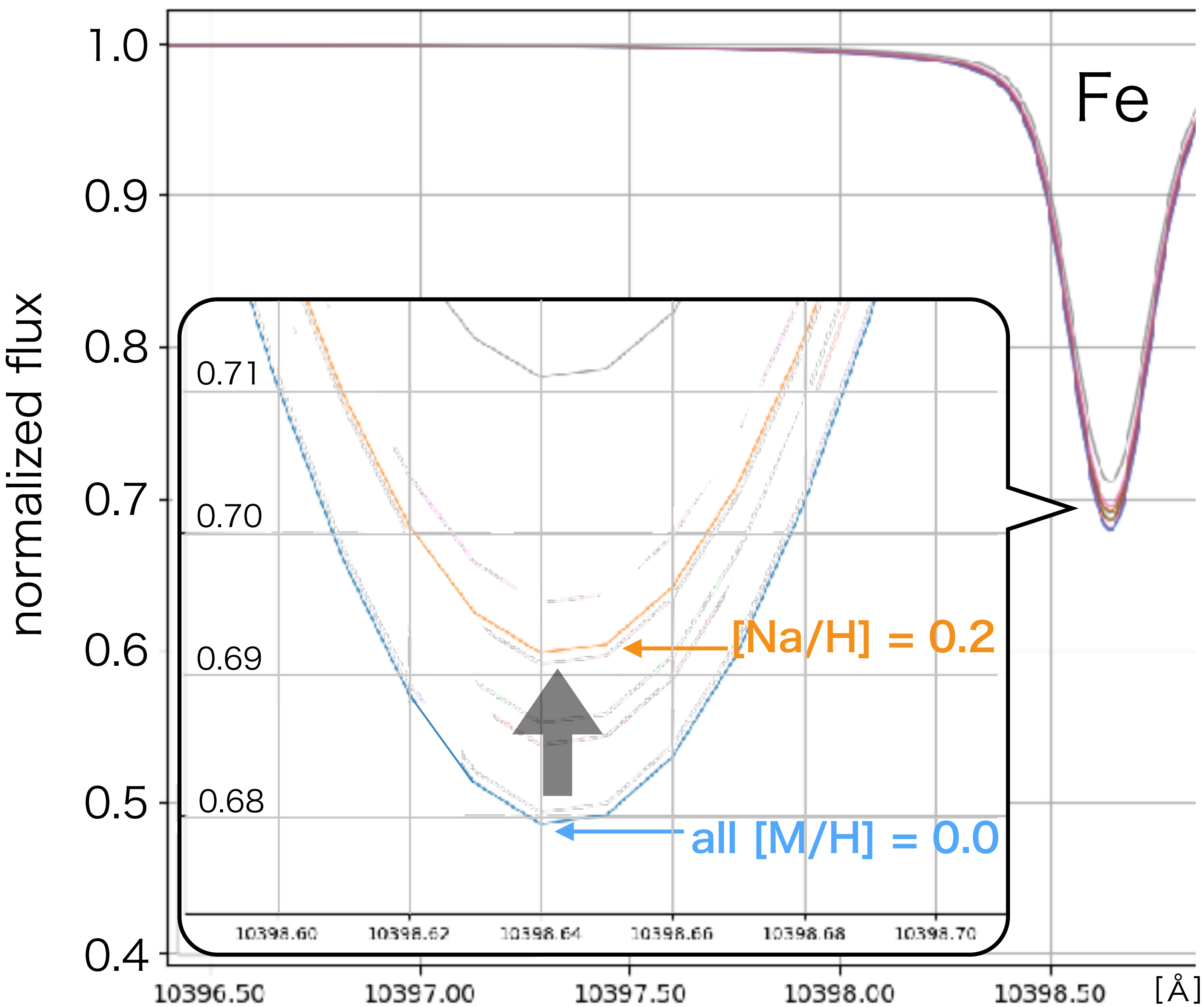
Insensitive depth to metallicity



less than 1 % per 0.1 dex change of [M/H]

Strength of the Fe lines is NOT adequately sensitive to [M/H]

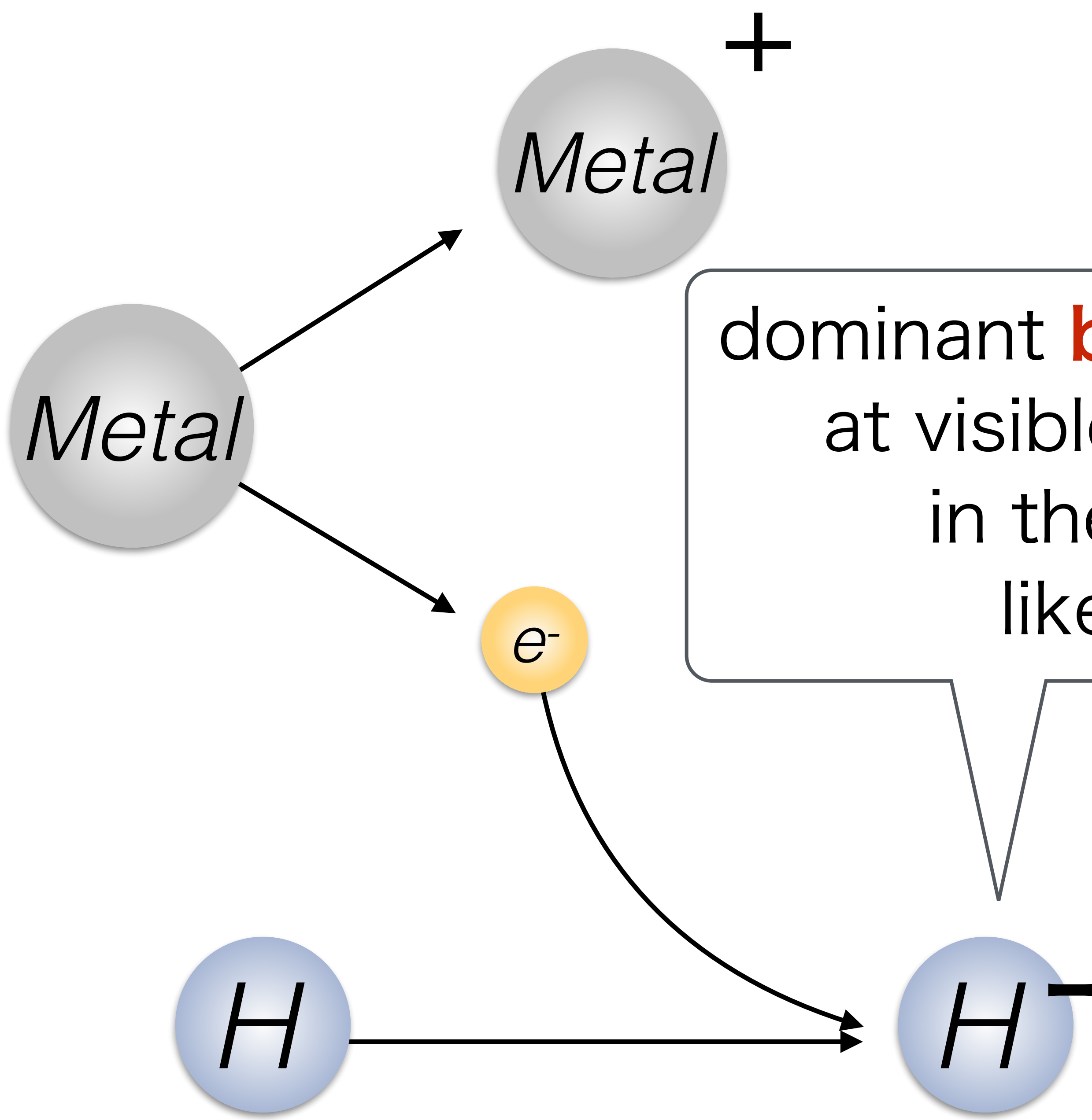
Insensitive depth to metallicity



For example,
0.2 dex rise
of [Na/H]
made a Fe I line
weaker more than 1%

Strength of the Fe lines is sensitive to other elements

Negative Hydrogen Ion



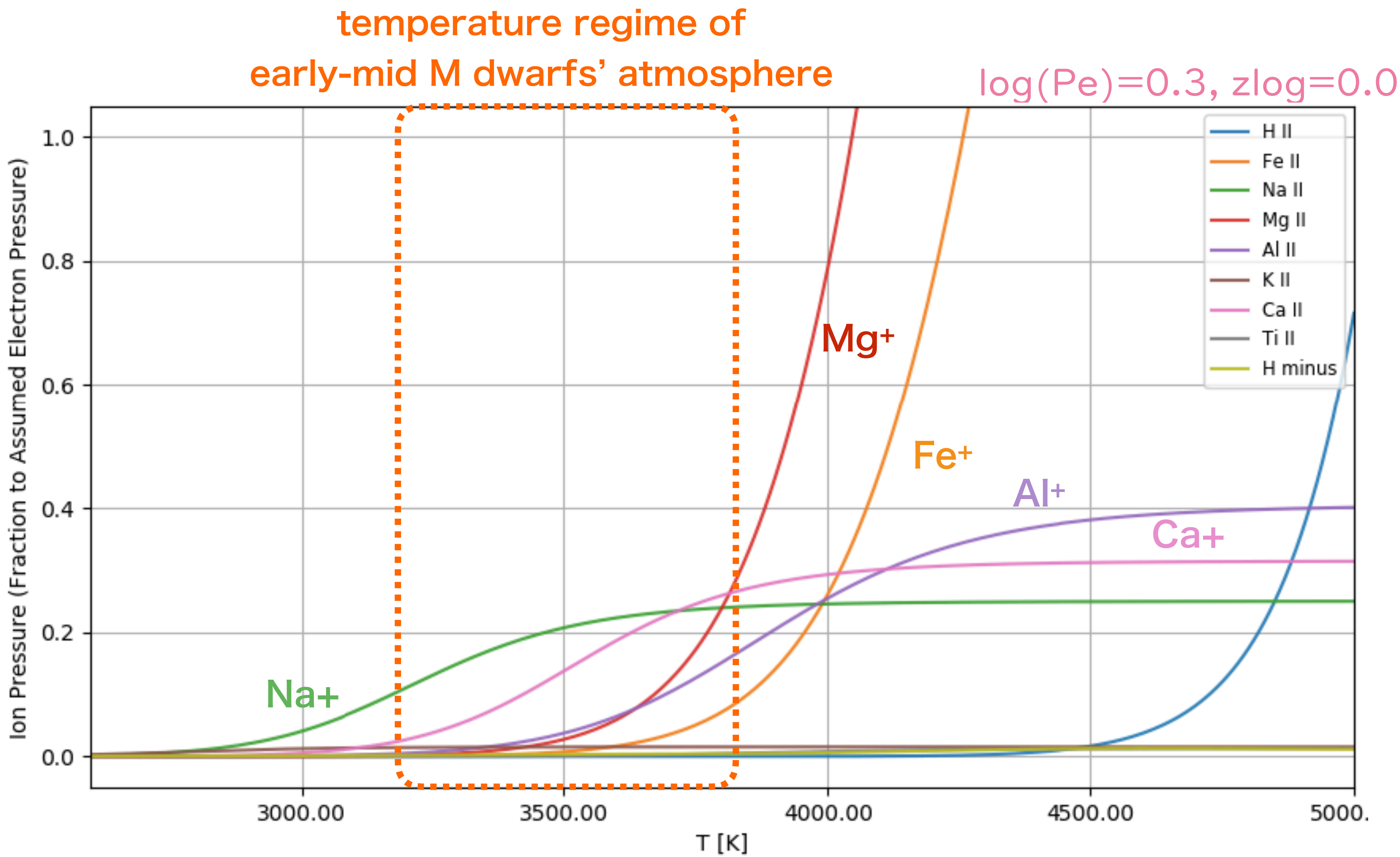
dominant **bound-free opacity source** at visible and near-IR wavelengths in the atmospheres of stars like the Sun and cooler

[e.g. Mihalas 1978]

normalized depth of Fe I lines gets smaller

Negative Hydrogen (increased with the electron emitted by metals) makes the Fe I lines get weaker

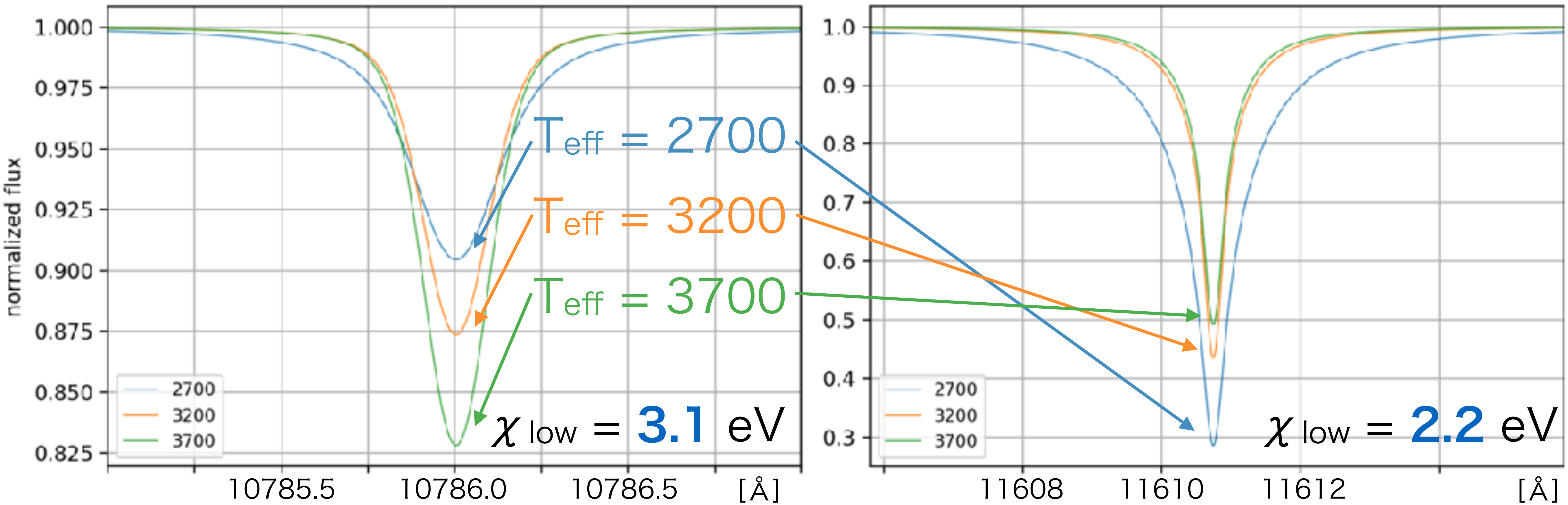
Electron donor elements



Na, Ca, Al & Mg have large contribution to the electron increase

Effect of atmospheric temperature

As metals increase,
the temperature of a certain depth of atmosphere rises



The metallicity-sensitivity of each line is also affected by the **temperature-sensitivity**, which is **specific to each line** (lower excitation potential)

Factors to determine line strength

Abundance of Fe itself

metal increase -> Fe line gets **stronger**

Abundance of electron donor (Na, Ca, Mg…etc)

metal increase -> H^- increase -> Fe line gets **weaker**

Atmospheric Temperature

metal increase -> atmosphere get hotter ->

Fe line gets **stronger** or **weaker** depending on χ_{low} / T_{eff}

Abundance-sensitivity of each line differs depending on the line and temperature range

Conclusion

We succeeded to determine the **individual chemical abundances of early-mid M dwarfs** (T_{eff} ~ 3200-3800) by line-by-line analysis on the high-R near-IR spectra.

We assessed our results using the FGK+M binaries and found an unexplored issue: Fe I line strength is determined by not only the Fe abundance but also abundance of other metals (as electron donor), temperature or excitation potential of the line transition. That makes **some absorption lines insensitive to abundances**.

We argue that it is **needed to strictly choose the useful lines** (depending on T_{eff}) and properly **determine individual metal abundances** in order to constrain the chemical composition of M dwarfs.

Once we establish our method, we **will apply it to the IRD survey target stars** to understand the distribution of individual chemical abundances of nearby M dwarfs and its correlation with planets around them.