

# Elemental Abundances of M dwarfs

## Based on High-resolution Near-infrared Spectra

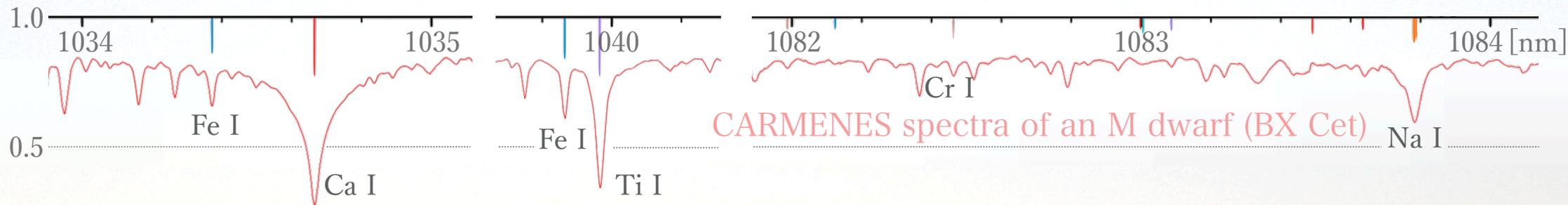


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Related publication: Ishikawa et al. submitted to PASJ

We show the feasibility and cautions of detailed chemical analysis of M dwarf stars using high-resolution ( $\lambda/\Delta\lambda \sim 80,000$ ) near-infrared (960–1710 nm) spectra of CARMENES.

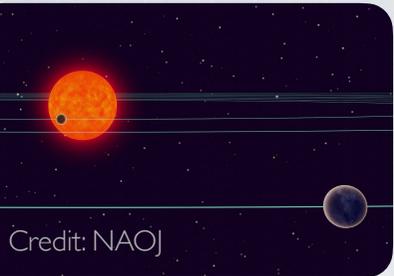


We determined the abundances of eight elements (**Na, Mg, K, Ca, Ti, Cr, Mn, and Fe**) of five M dwarf stars ( $T_{\text{eff}} \sim 3200\text{--}3800\text{ K}$ ), which form binary systems with G/K-type stars, and verified our analysis procedure.

By examining the effects of variations of elemental abundances assumed in the analysis on the resulting abundances, we demonstrate **the importance to determine the abundances of individual elements consistently.**

# Background & Motivation

## Why M dwarfs?



M dwarf is the smallest and coolest type of the main sequence star. Thanks to their small mass and size, and low luminosity, they have the advantage to detect planets using RV and transit methods, as well as to characterize small planets in the habitable zone.

M dwarfs have become prime targets of many exoplanet search projects recently.

e.g. **CARMENES** (Quirrenbach et al. 2014), **IRD** (Kotani et al. 2014), **HPF** (Mahadevan et al. 2012), **SPIRou** (Artigau et al. 2014) and more.

## Why elemental abundance\*?

The chemistry of host stars is crucial information indicating the planet formation scenario and the interior of planets.

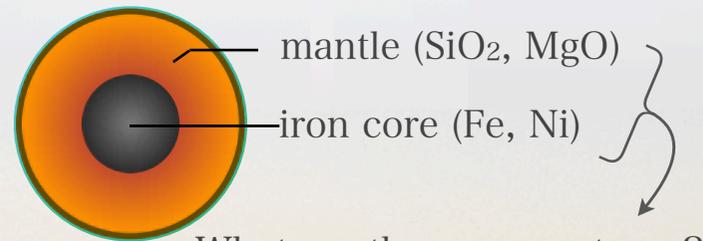
However, most previous studies only dealt with the overall metallicity using the empirical relations or template spectral fitting, and the attempts to determine the abundances of individual elements have been very limited (e.g. Souto et al., 2018).

The reliability of those metallicity determinations needs to be examined.

\* Abundance of element X is commonly reported as:

$$[X/H] = \log_{10} (N_X/N_H)_* - \log_{10} (N_X/N_H)_\odot$$

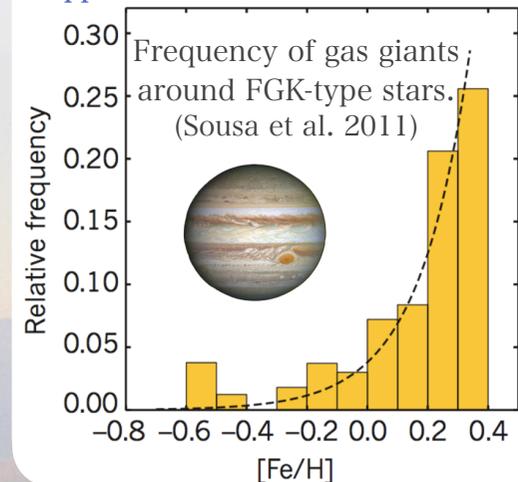
e.g.) Internal structure of rocky planets



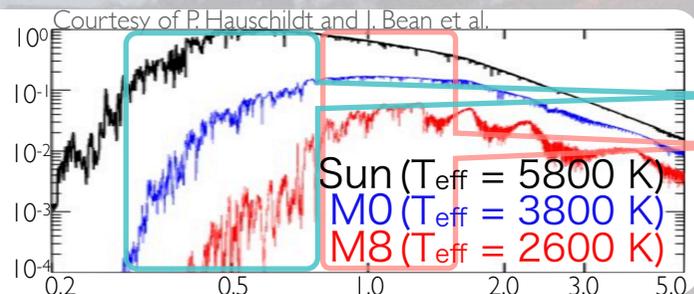
What are these percentages?  
How is the mineralogy?

(e.g. Unterborn & Panero, 2017)

e.g.) The planet-metallicity correlation supports the core accretion scenario.



## Why high-resolution near-infrared spectra?

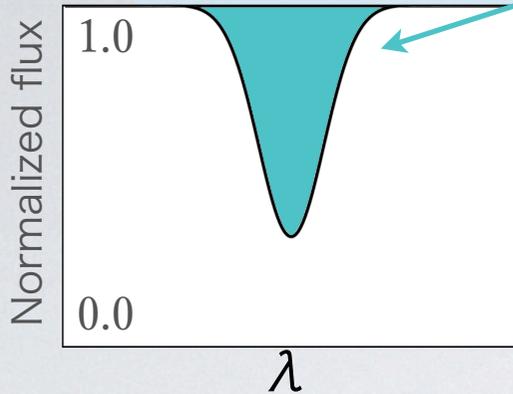


The main limitations are their faintness and the complicated molecular absorption, especially in their optical spectra of M dwarfs.

The near-infrared wavelength has the flux peak of M dwarfs and relatively free from problematic molecular absorption.

The high-resolution is needed for line-by-line analysis.

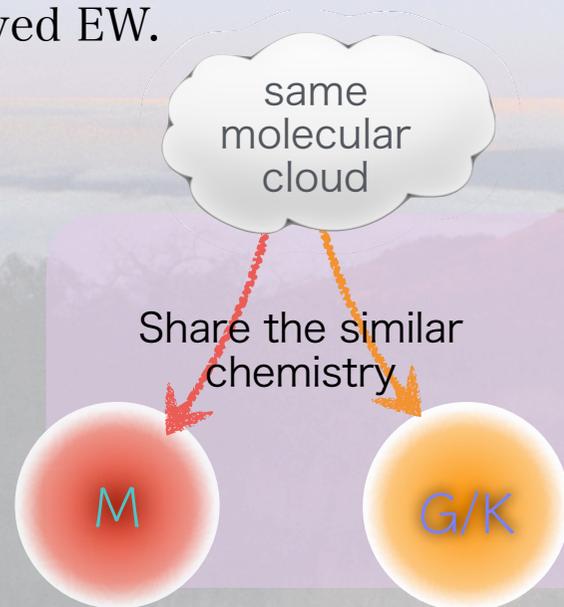
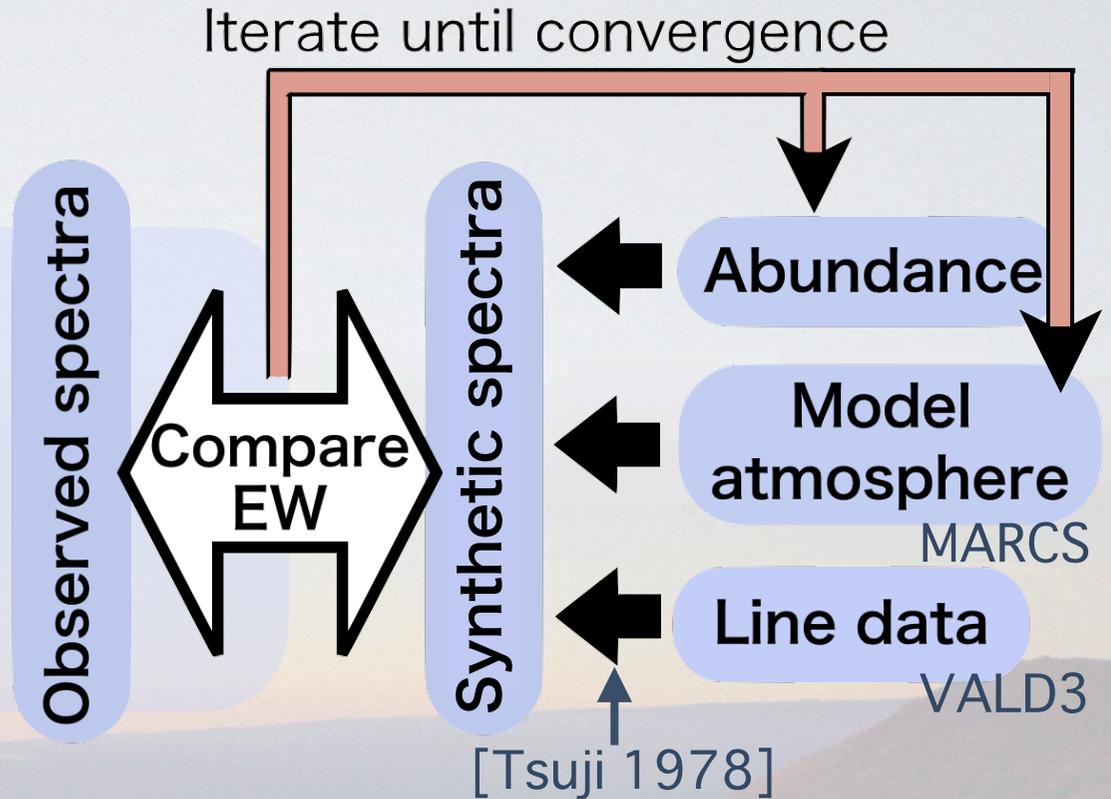
# Method



We measure the equivalent widths (EW; the area shown left) of the selected (isolated & sensitive to abundance) atomic lines by fitting the Gaussian or Voigt profile.

We compare the EW with the theoretical one from the synthetic spectra calculated assuming stellar parameters.

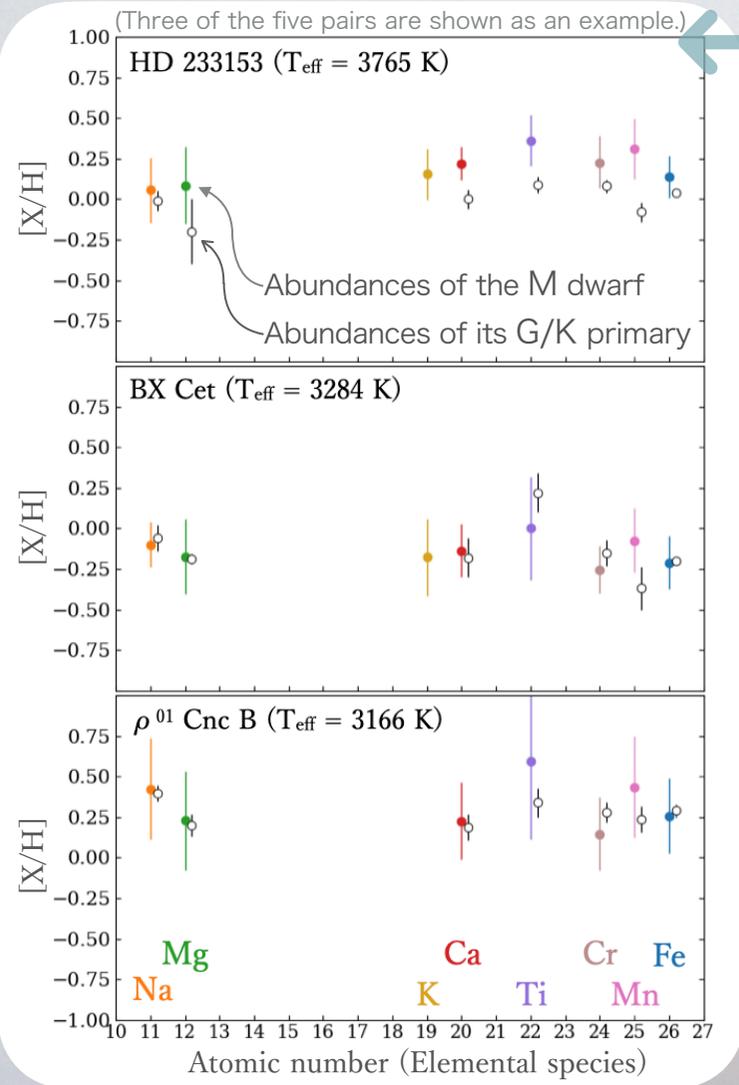
Elemental abundance is searched iteratively so that the theoretical EW matches the observed EW.



The resulting abundances are evaluated by comparing with the abundances of the G/K primary stars.

Stars in a binary system form together from the same molecular cloud, thus their chemical abundances can be expected to be almost identical ( $\sim 0.02$  dex; e.g. Hawkins et al. 2020).

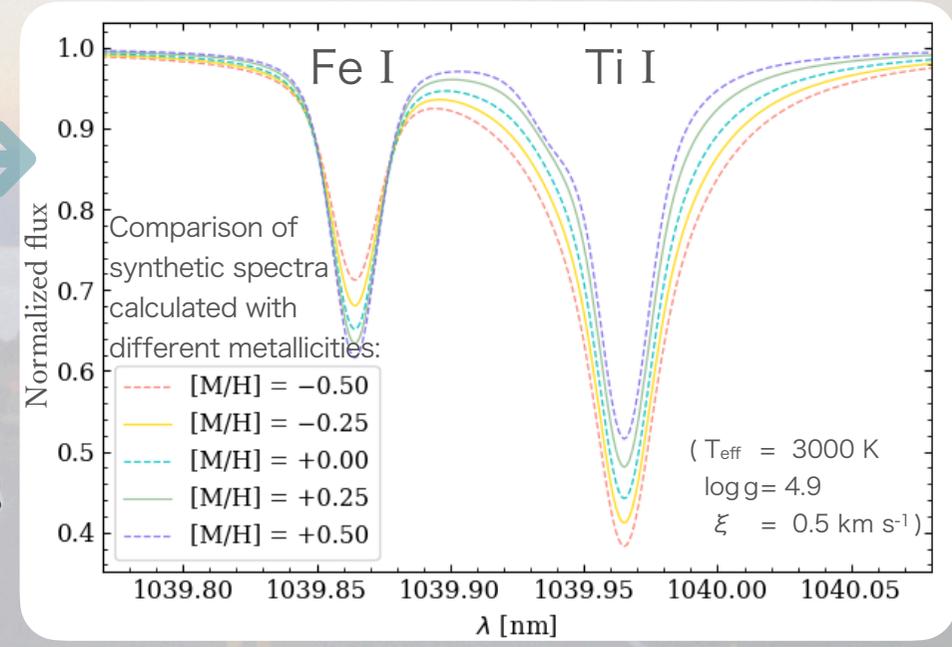
# Results & Discussion



The abundances of **eight elements** are determined. They show **the agreement with those of the primary stars** derived by Montes et al. (2018) from the high-resolution visible spectra within measurement errors of  $\sim 0.2$  dex.

+ We found:

- Most absorption lines are sensitive to the abundance changes not only of the corresponding elements but also **of other elements, especially the dominant electron donors such as Na and Ca.**
- The strength of Ti I lines show **a negative correlation with the overall metallicity** in  $T_{\text{eff}} < 3400 \text{ K}$  due to the consumption of neutral titanium by forming TiO molecules.



To correctly estimate the abundance of any element, we need to determine the abundances of other individual elements consistently.