木曽シュミットシンポジウム2021
2021.10.5.

Tomo-e 狭帯域フィルター観測による北天の明るい金属欠乏星探査

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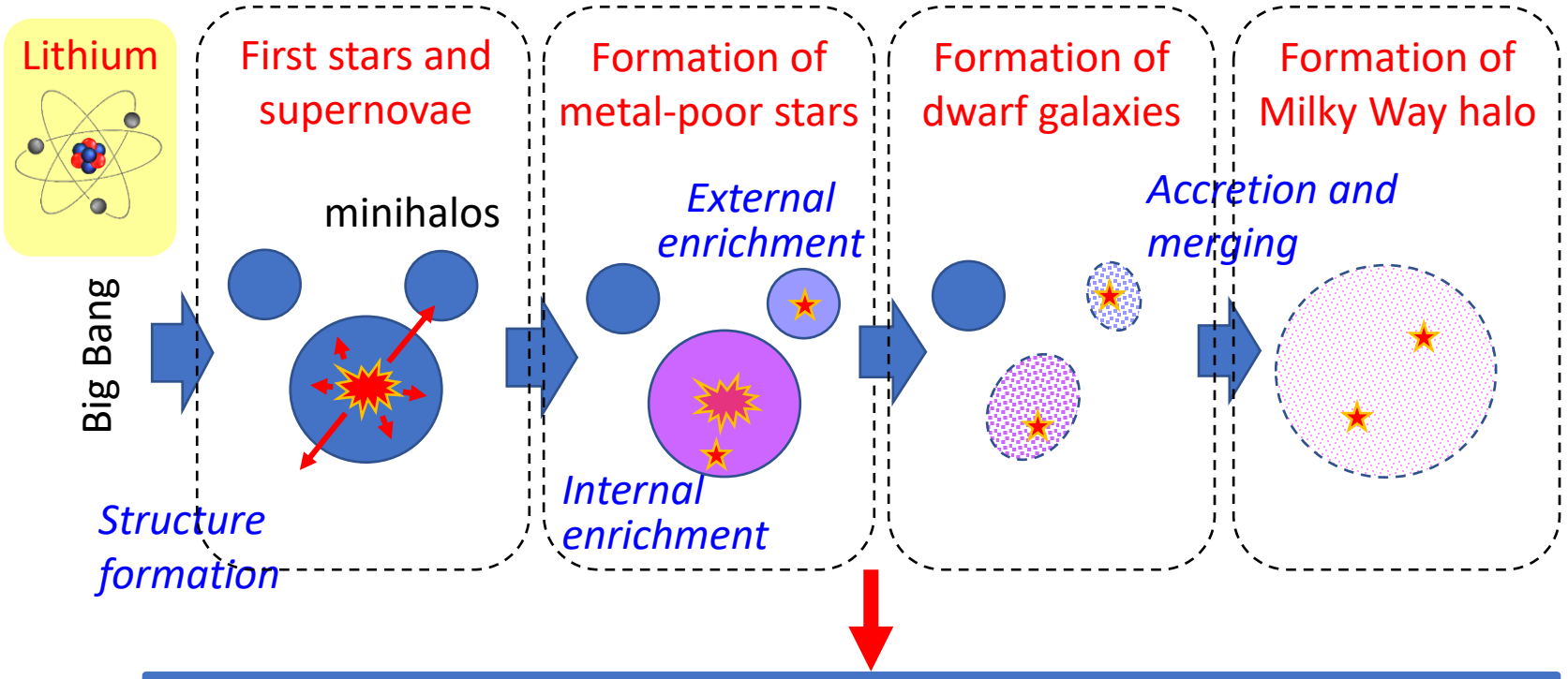
諸隈智貴（東京大学）

Large sample of metal-poor stars are useful for studying process from first stars to low-mass stars



Chemical abundances of extremely metal-poor stars
→ Nucleosynthesis of first stars/supernovae
→ Masses of progenitor stars
Understanding of evolution of metal-poor (low-mass) stars is needed.

Abundance pattern and abundance distribution

- Elemental abundance pattern of individual stars (or their averages) are compared with supernovae and other nucleosynthesis models
- Distributions of elemental abundance ratios are compared with chemical-evolution models

Tominaga et al. 2007

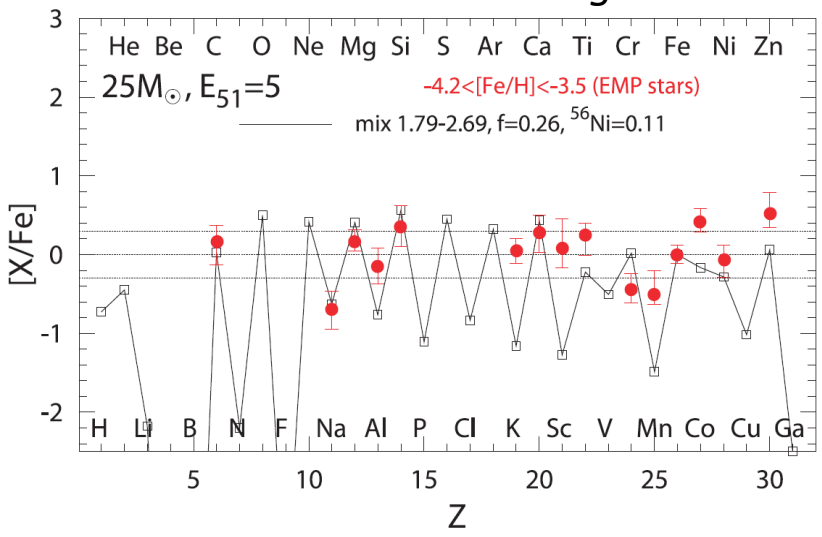
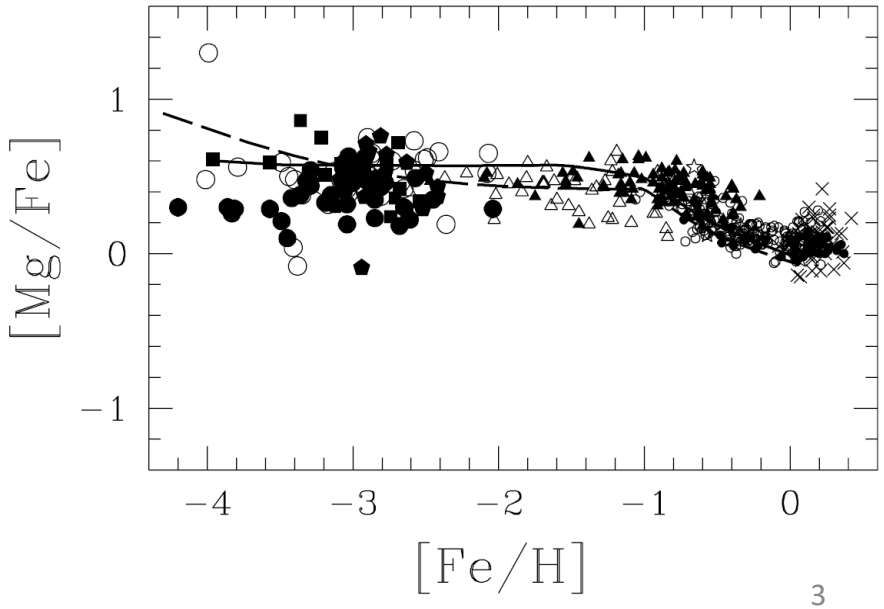


FIG. 7.—Same as Fig. 3, but for $M_{MS} = 25\ M_\odot$, $E_{51} = 5$.

Kobayashi et al. 2006



Searches for metal-poor stars

cf. *Beers & Christlieb (2005, ARAA)*
Roederer et al. (2014, AJ 147, 136)

- **Bond (1981) "Where is population III?"**
  Bond (1970, 1980) Curtis Schmidt (Michigan)
  Bidelman & MacConnel (1973) Curtis Schmidt (CTIO)

- **Catalogue:**
  -Henry Draper (HD) e.g. HD122563 Honda et al. (2006)
  -Bonner Durchmusterung (BD) e.g. BD+44 493 Ito et al. (2009,2013)
  -Córdoba Durchmusterung (CD) e.g. CD-38 245
  -Lowell Proper Motion survey (G) e.g. G64-12

Searches for metal-poor stars

- **HK survey (1980s-)**

  ***Beers et al. 1985, 1992*, etc.**

  -objective prism survey for Ca II H and K lines (R~800)

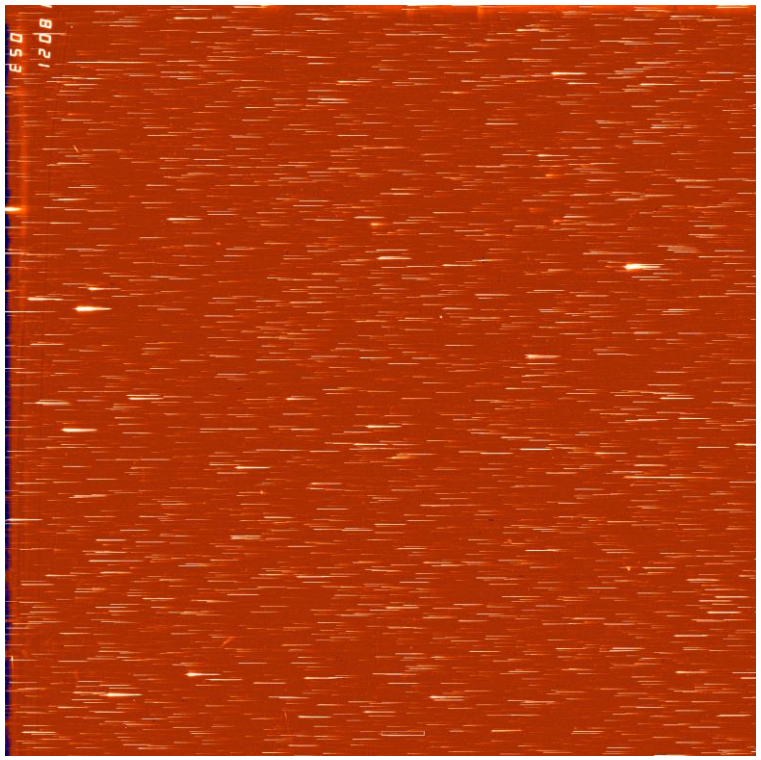
  -*B*~<15

Curtis Schemidt (CS) CTIO, e.g. BPS CS22892-052
Burell Schmidt (BS) KPNO, e.g. BPS BS16934-002

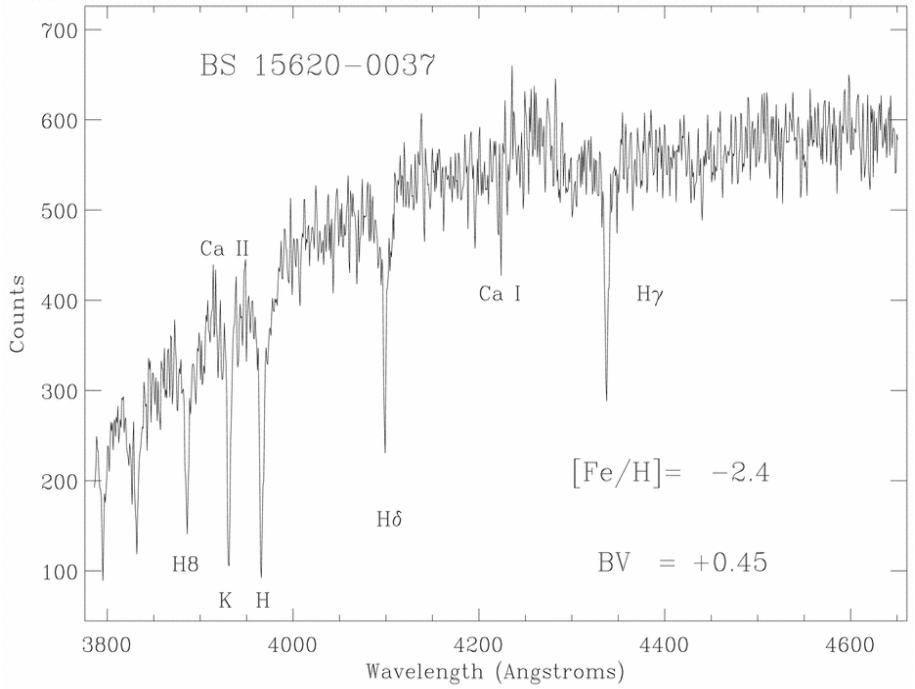
HK-II : re-analysis of the plates of HK survery

Objective prism survey of metal-poor stars (1980s～)

①wide-field spectroscopic survey



②follow-up medium resolution spectroscopy



Follow-up spectroscopy with Subaru/HDS for HK survey sample

- First Light of Subaru/HDS in 2000

Follow-up with Subaru/HDS (2000～)
Topics:
-r-process-enhanced stars (Honda et al. 2004)
-CEMP stars: s-process from CEMP-s, and establishing “CEMP-no” class (Aoki et al. 2002)

Searches for metal-poor stars

- **Hamburg/ESO survey (1990s-)**
  stellar content: *Christlieb et al. 2001* etc.
  → e.g. HE0107-5240 ([Fe/H]=-5.3, Christlieb et al. 2002)

Follow-up with Subaru/HDS (2003～)

Topics:

-most metal-poor stars (Frebel et al. 2005)

-CEMP stars (Aoki et al. 2007)

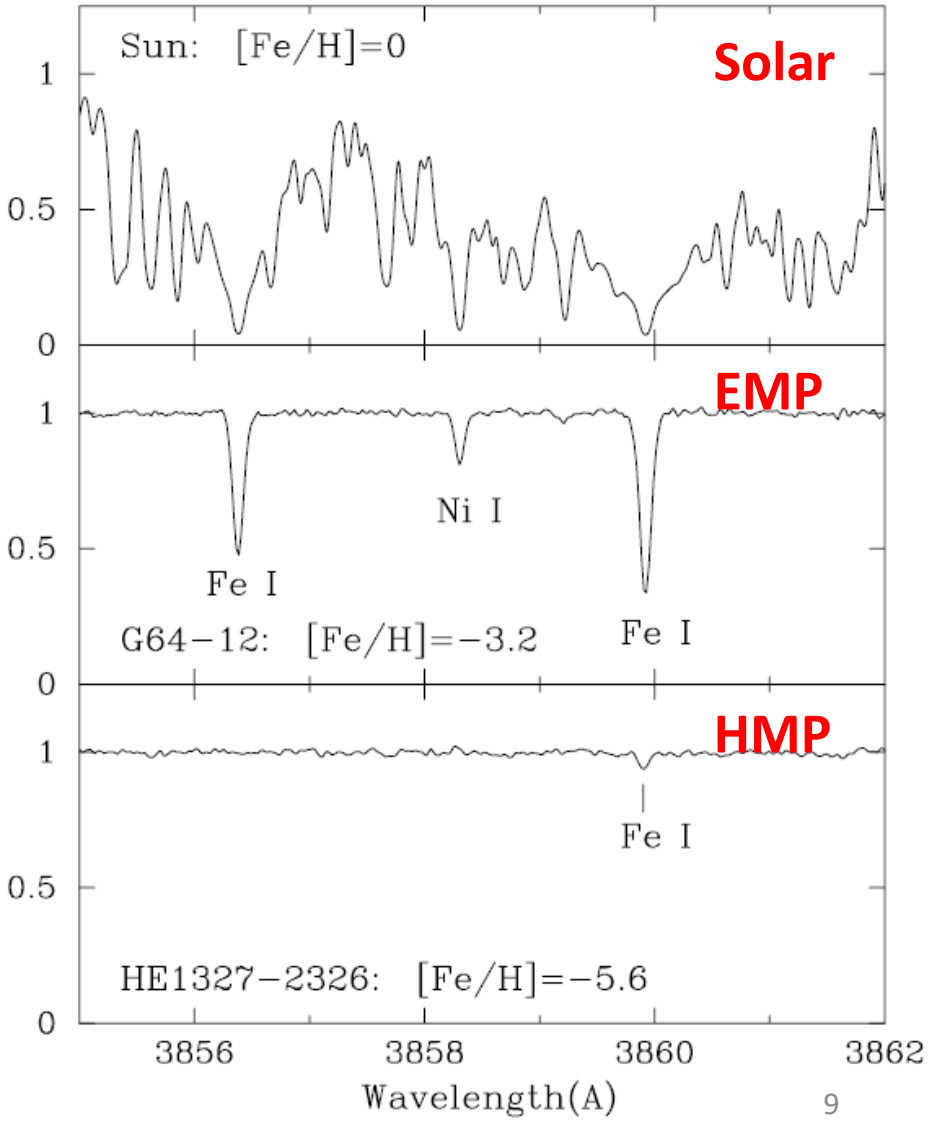
-Li (Aoki et al. 2009)

The 2nd HMP star HE1327-2326

Frebel et al. (2005, Nature 434, 871)

very weak Fe lines
→[Fe/H]=-5.4

detection of CH molecular bands
→excess of carbon



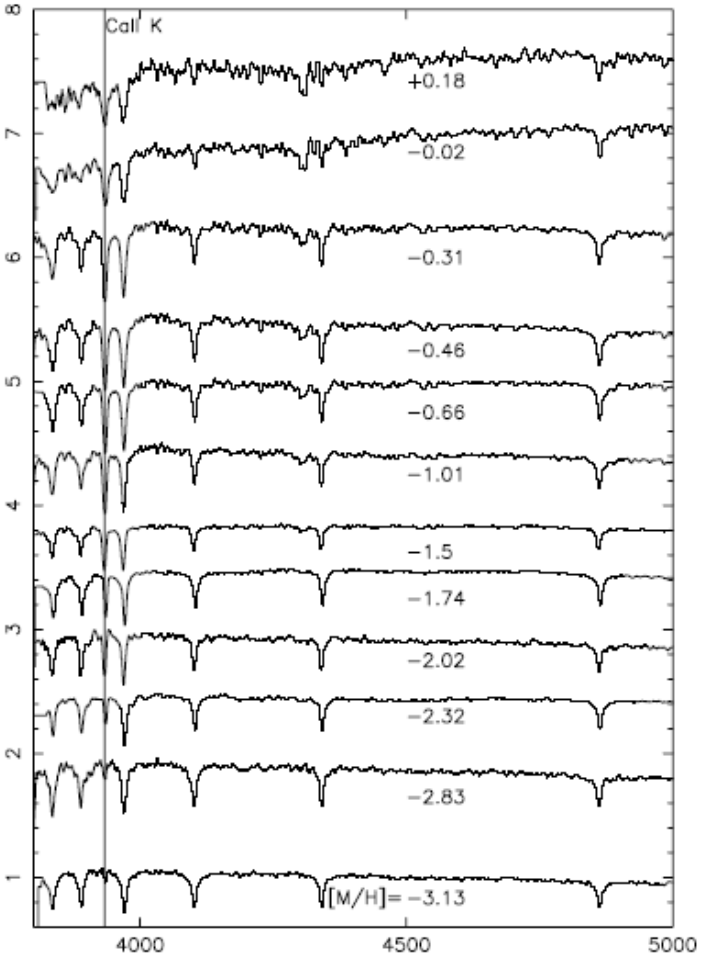
SDSS/SEGUE

Searches for very/extremely metal-poor stars by SDSS/SEGUE

The 2.5m telescope at Apache Point Observatory

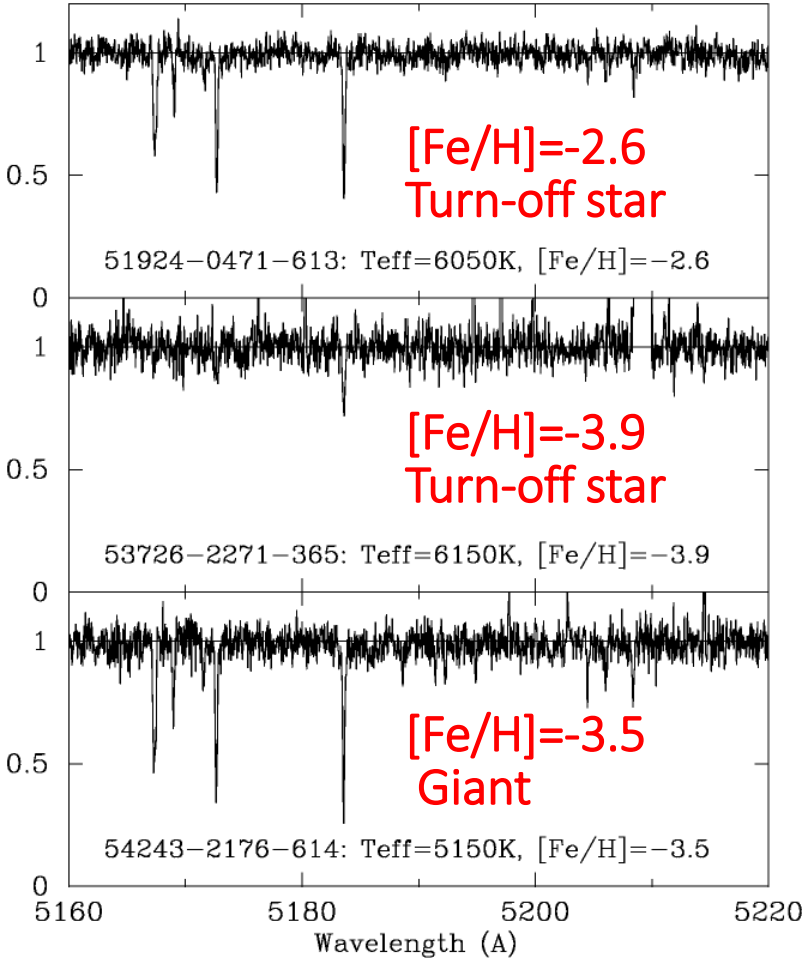
- Imaging/spectroscopic surveys
- <u>Surveys of Galactic stars 240,000</u>

R~2000



Follow-up high resolution spectroscopy with Subaru for selected SDSS objects

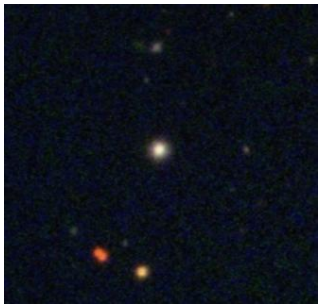
Follow-up with Subaru/HDS for 150 objects (2008-2009)
Topics:
-chemical compositions of 137 very/extremely metal-poor stars
-binary frequency



SDSS/SEGUE

Discovery of a low-mass star with peculiar chemical composition

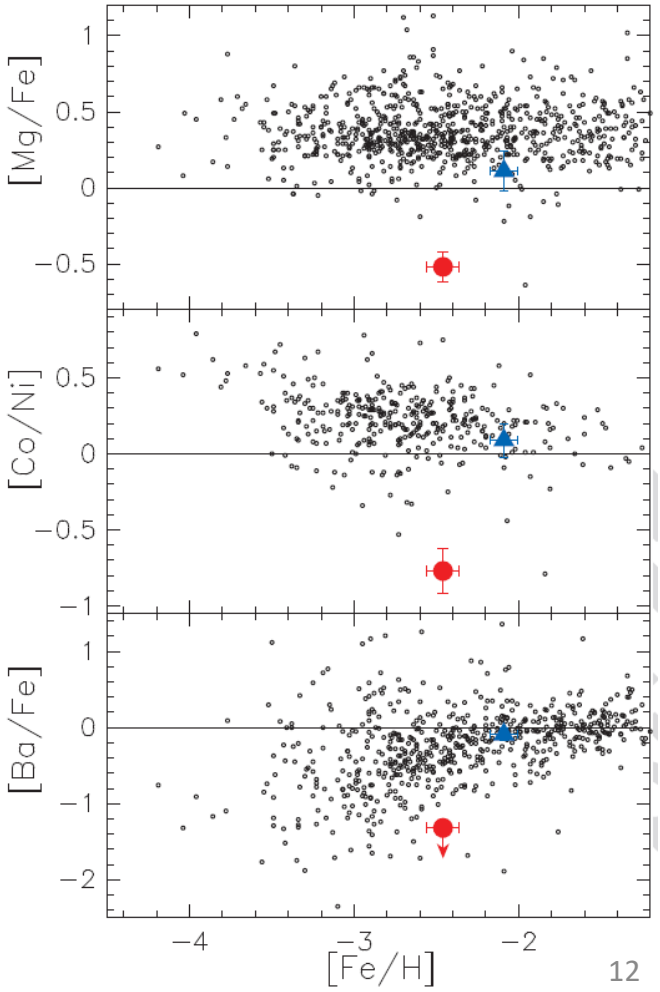
SDSS J001820.51-093939.2



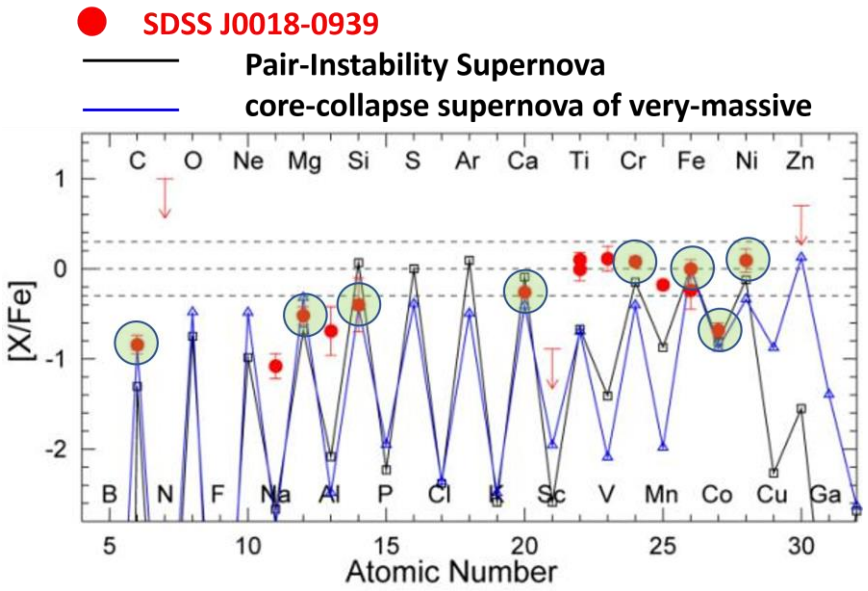
Taken from SDSS

- [Fe/H]=-2.5
- Low C, Mg, Co, Ba etc. abundances
  → excess of Fe
- A low-mass main-sequence star

Aoki, Tominaga, Beers, Honda, Lee (2014, Science)



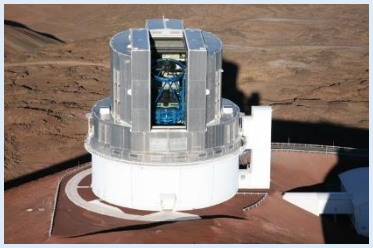
Recording yields of a very-massive star?



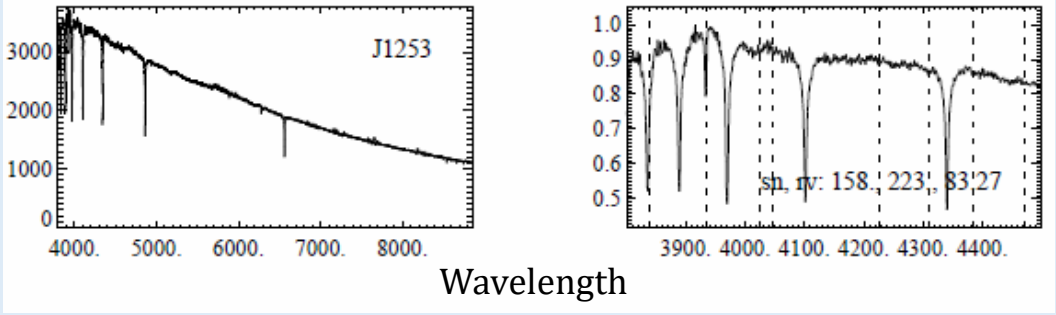
Ongoing studies for large samples of metal-poor stars with LAMOST and Subaru

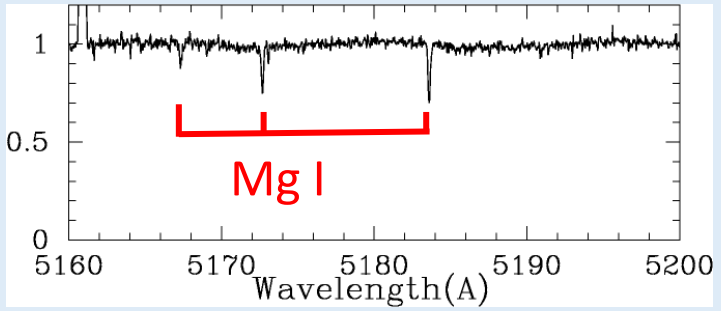
Aoki et al. / Li et al. (in prep.)

LAMOST
R=1800
4000 fibers



Subaru
R=36,000
386 stars





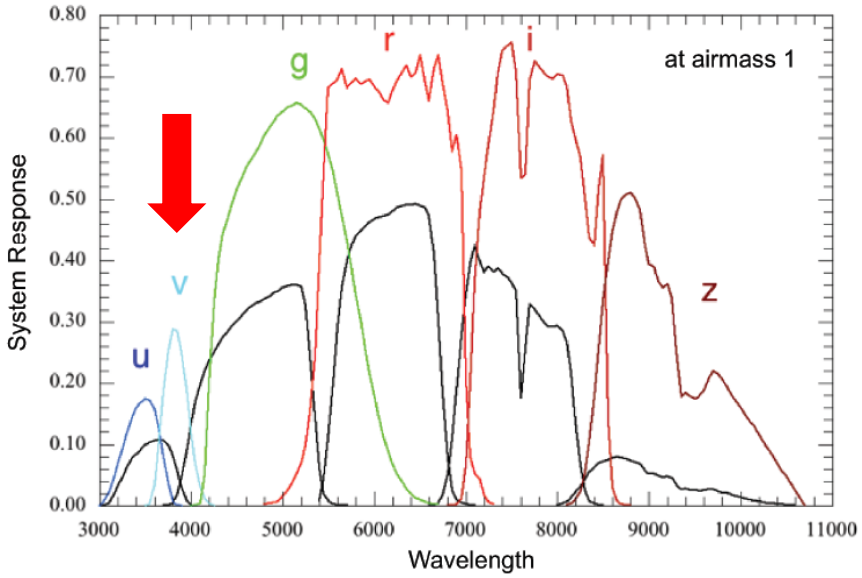
LAMOST covers relatively bright stars (V<14) that are very useful for high-resolution follow-up observations

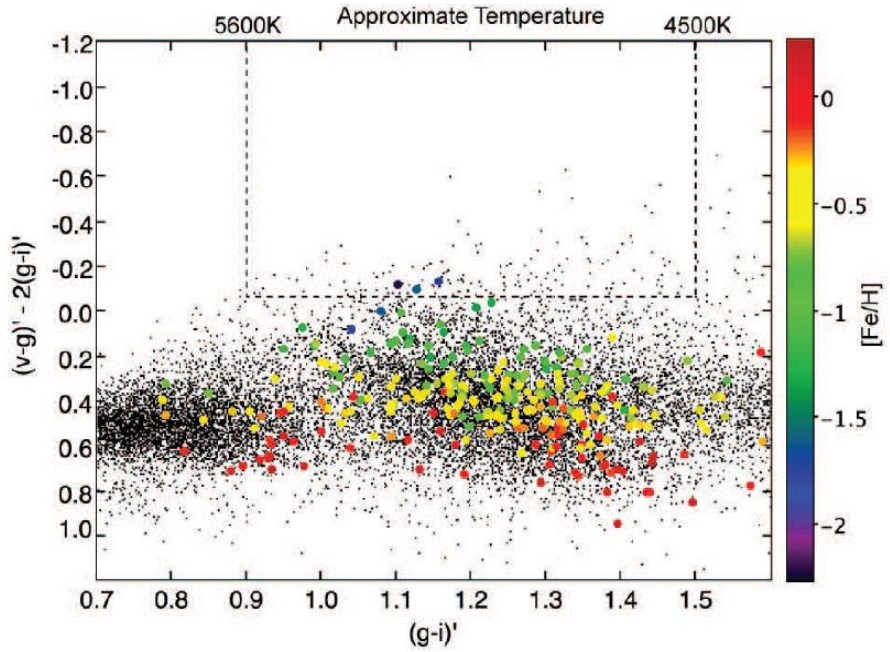
Photometric survey of metal-poor stars and follow-up high-resolution observations

Skymapper
narrow-band filters
to measure
strengths of Ca HK
and other lines

High-resolution spectra
Magellan, Keck, ESO 2.2m
R=28,000-48,000
150 stars
Yong et al. (2021)

Norris et al. 2013, Jacobson et al. 2015, Marino et al. 2019



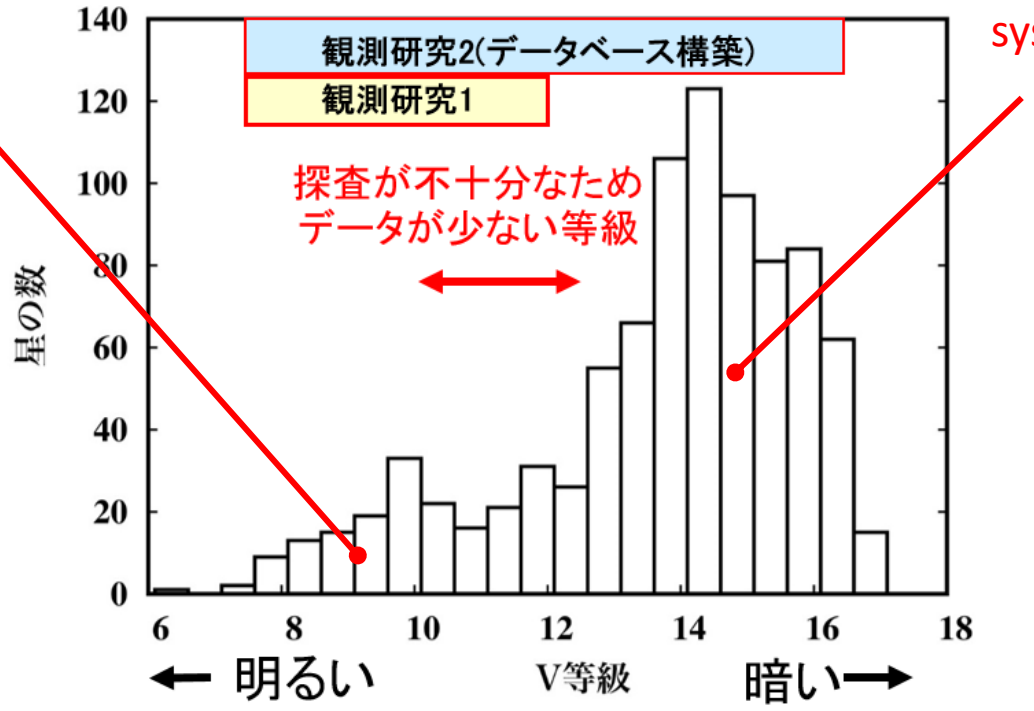


Magnitude distribution of metal-poor stars studied based on high-resolution spectra

Survey of *bright* metal-poor stars is still insufficient!

Bright stars in conventional catalogues

Stars searched for by systematic surveys

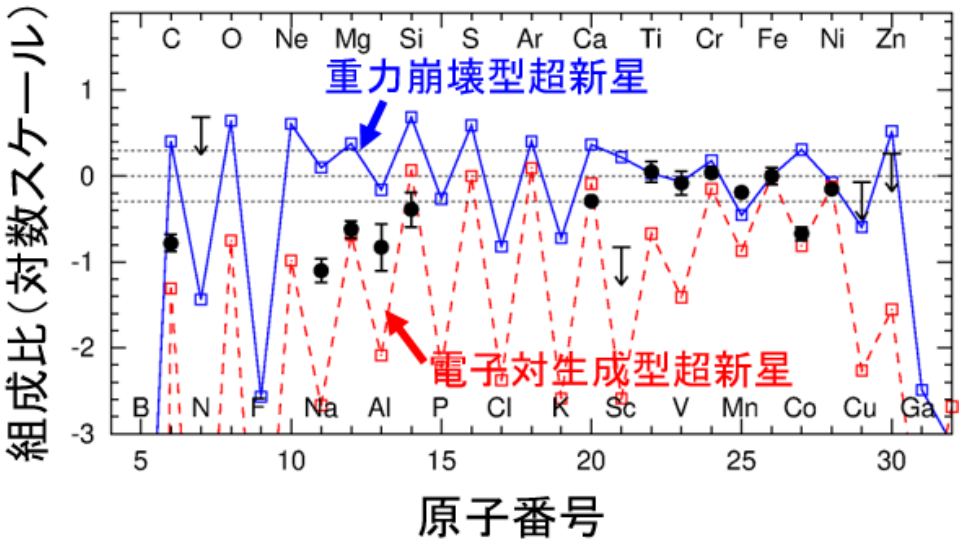


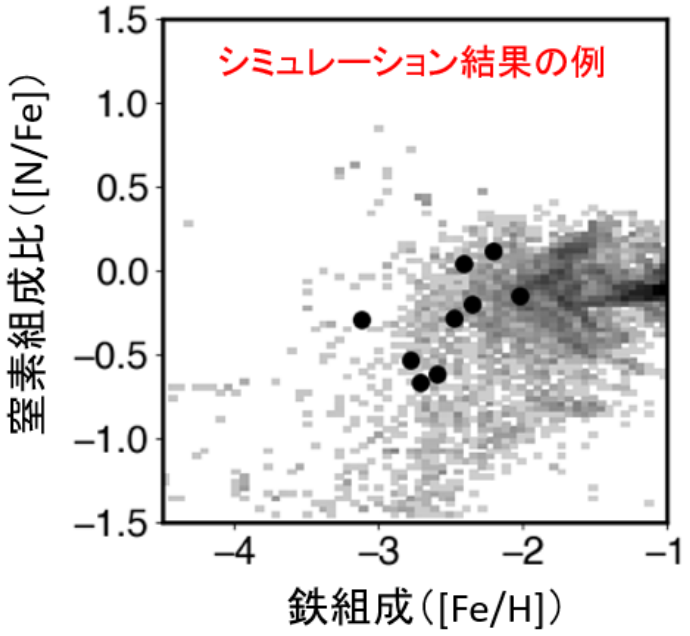
based on SAGA database

Chemical abundance studies expected for *bright* metal-poor stars

Detailed chemical abundance ratios can be determined for bright metal-poor stars by follow-up observations with very high quality.

ex.) Zinc: weak spectral lines in the optical range
Nitrogen: NH lines in the UV range (336nm)





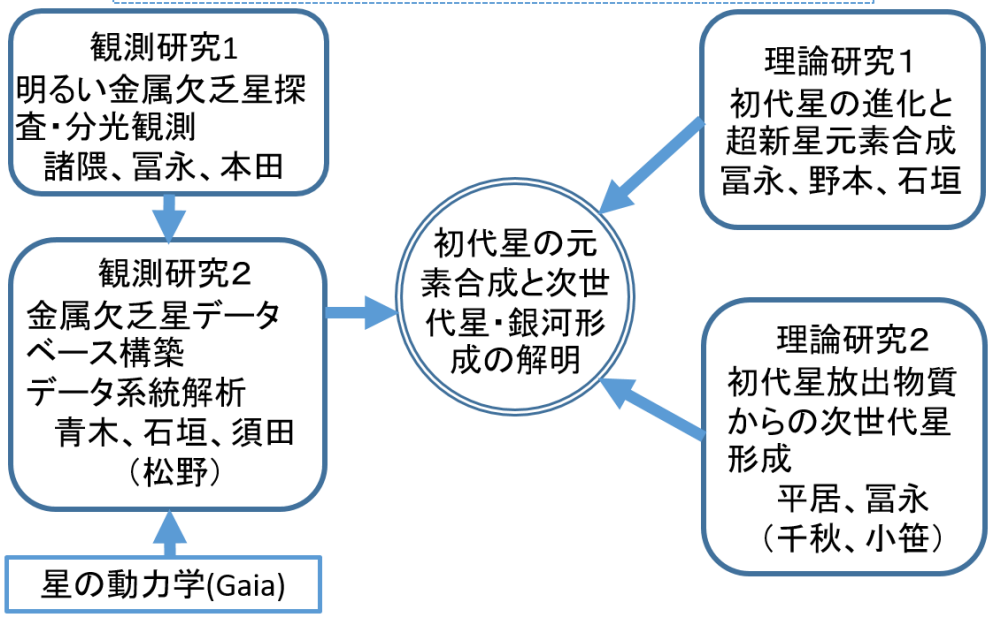
基盤研究A（2021～2024年度）

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

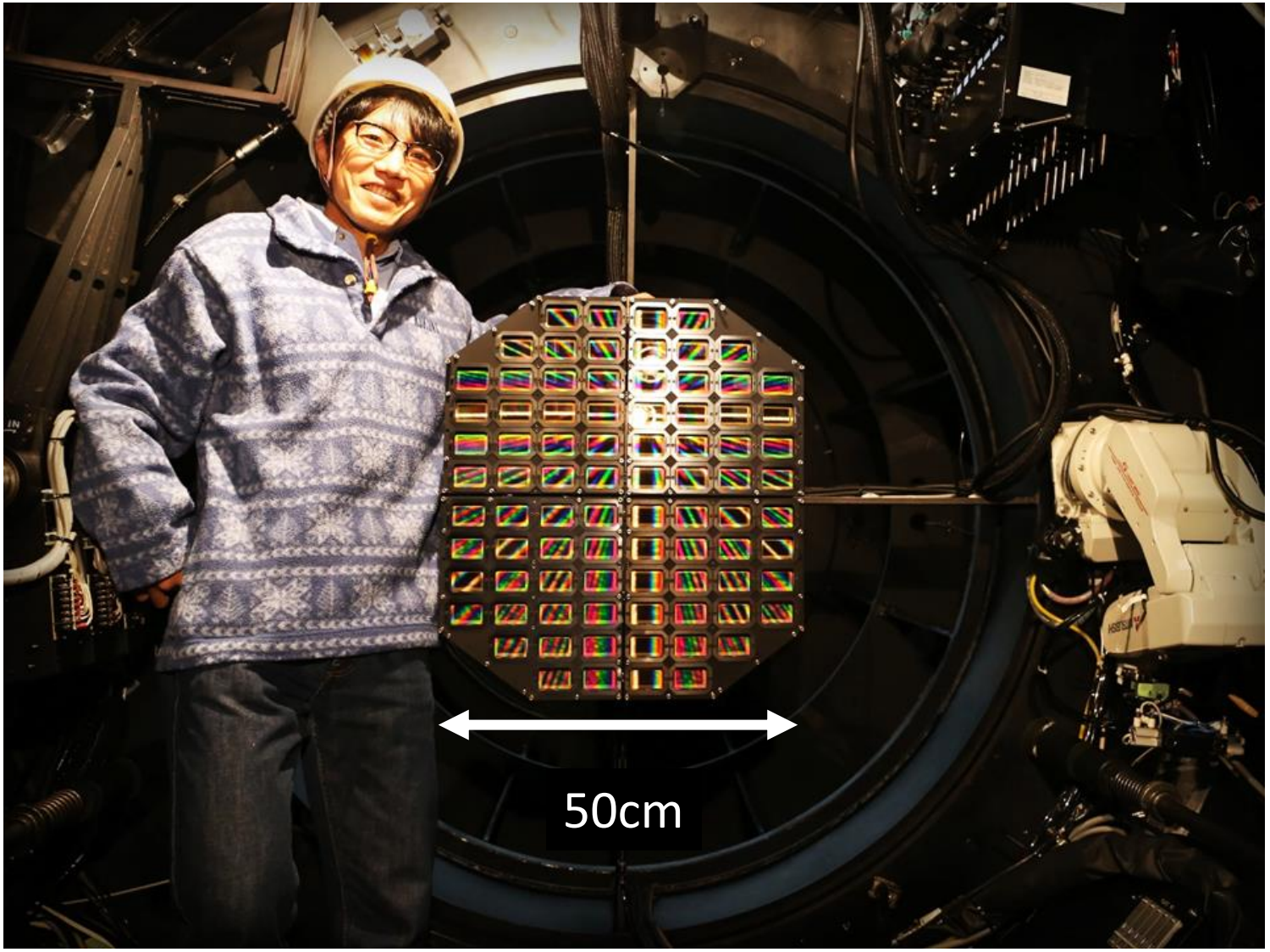
「北半球から観測可能な明るい金属欠乏星を網羅的に探査」

図2

- 研究代表者：青木和光
- 研究分担者：冨永望、本田敏志、諸隈智貴、石垣美歩、平居悠、須田拓馬、野本憲一
- 研究協力者：千秋元、小笹隆司、松野允郁

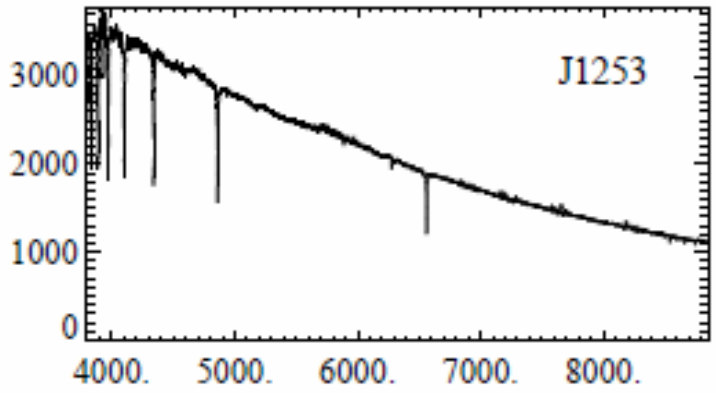


Northern sky photometric survey with Tomo-e Gozen Camera

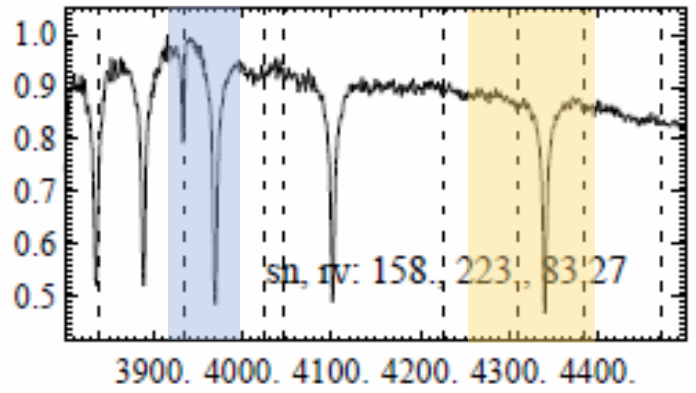


Narrow-band filters for Kiso/Tomo-e metal-poor star survey

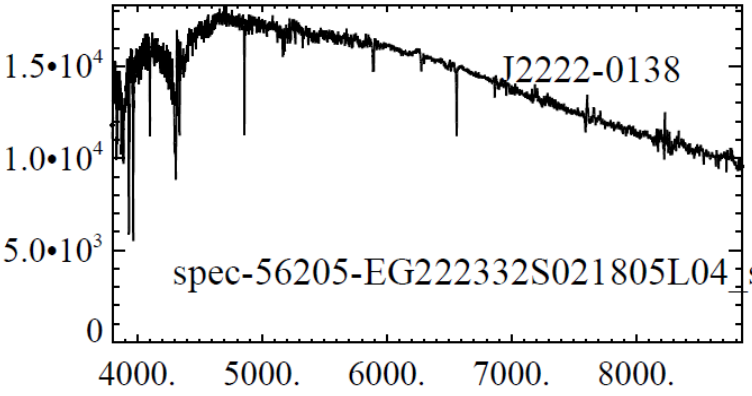
Metal-poor dwarf star

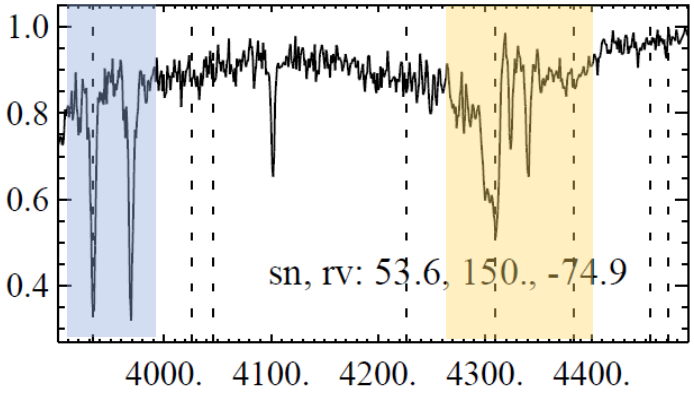


Ca K+H (+balmer) CH + Hγ

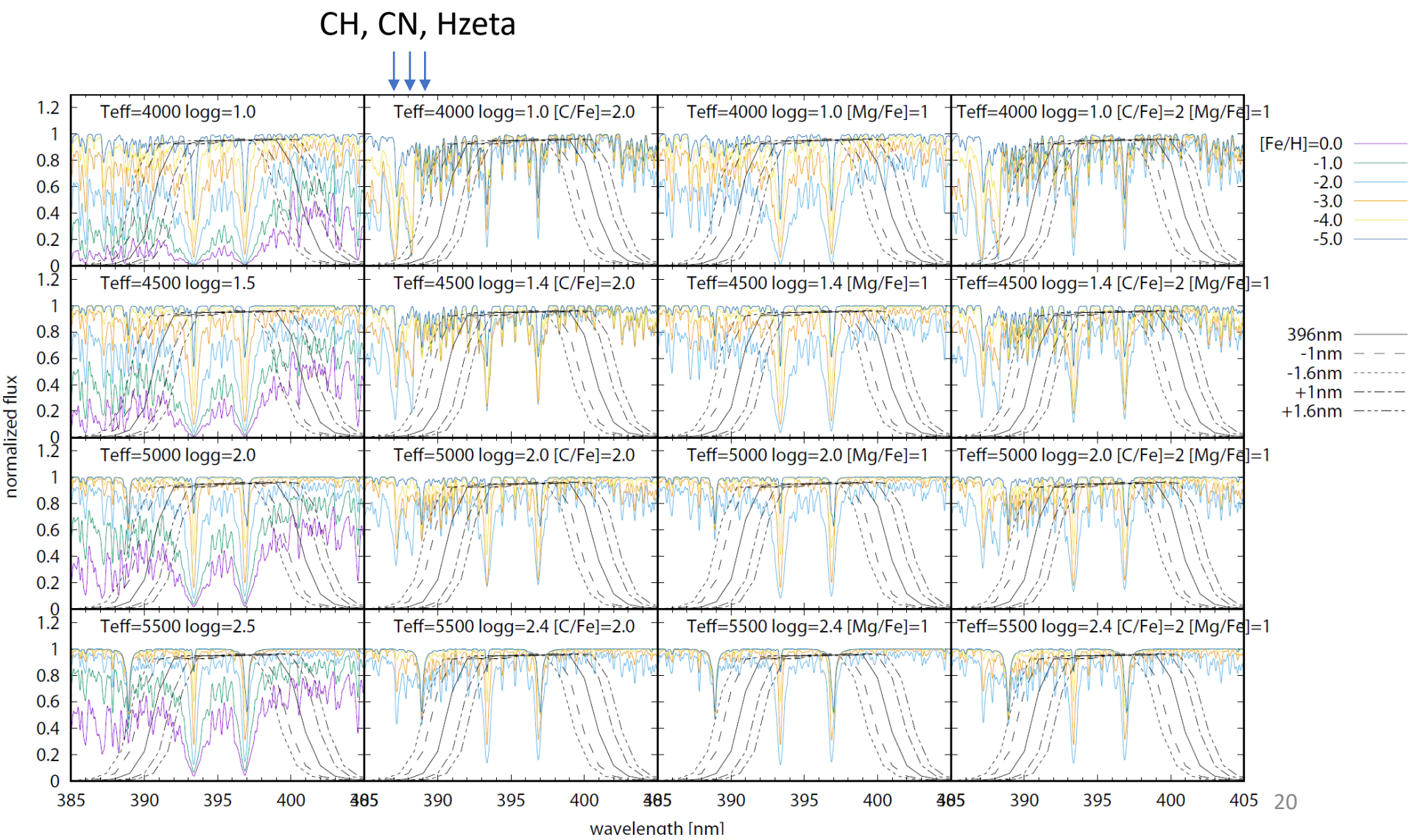


Carbon-enhanced metal-poor star

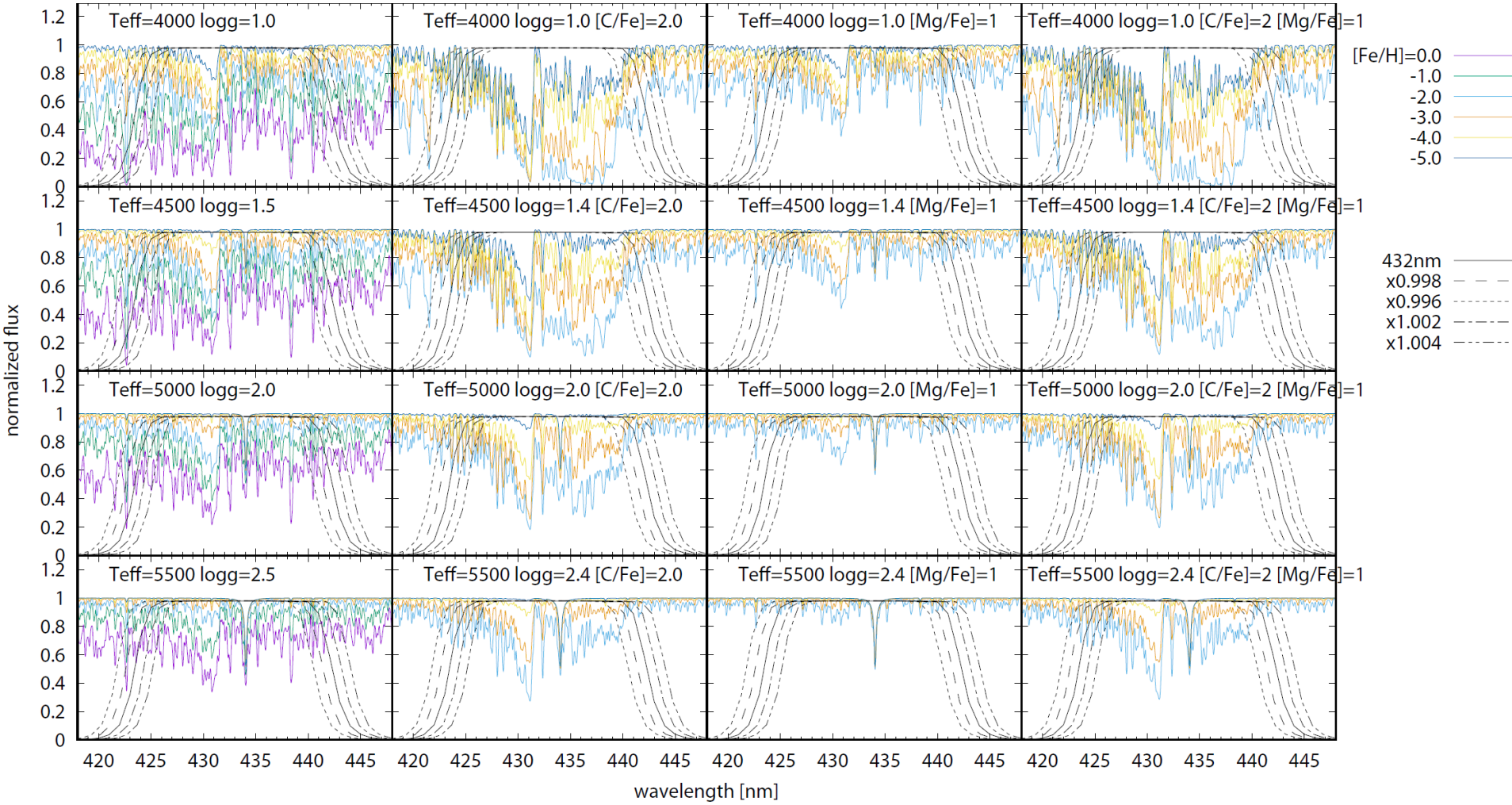




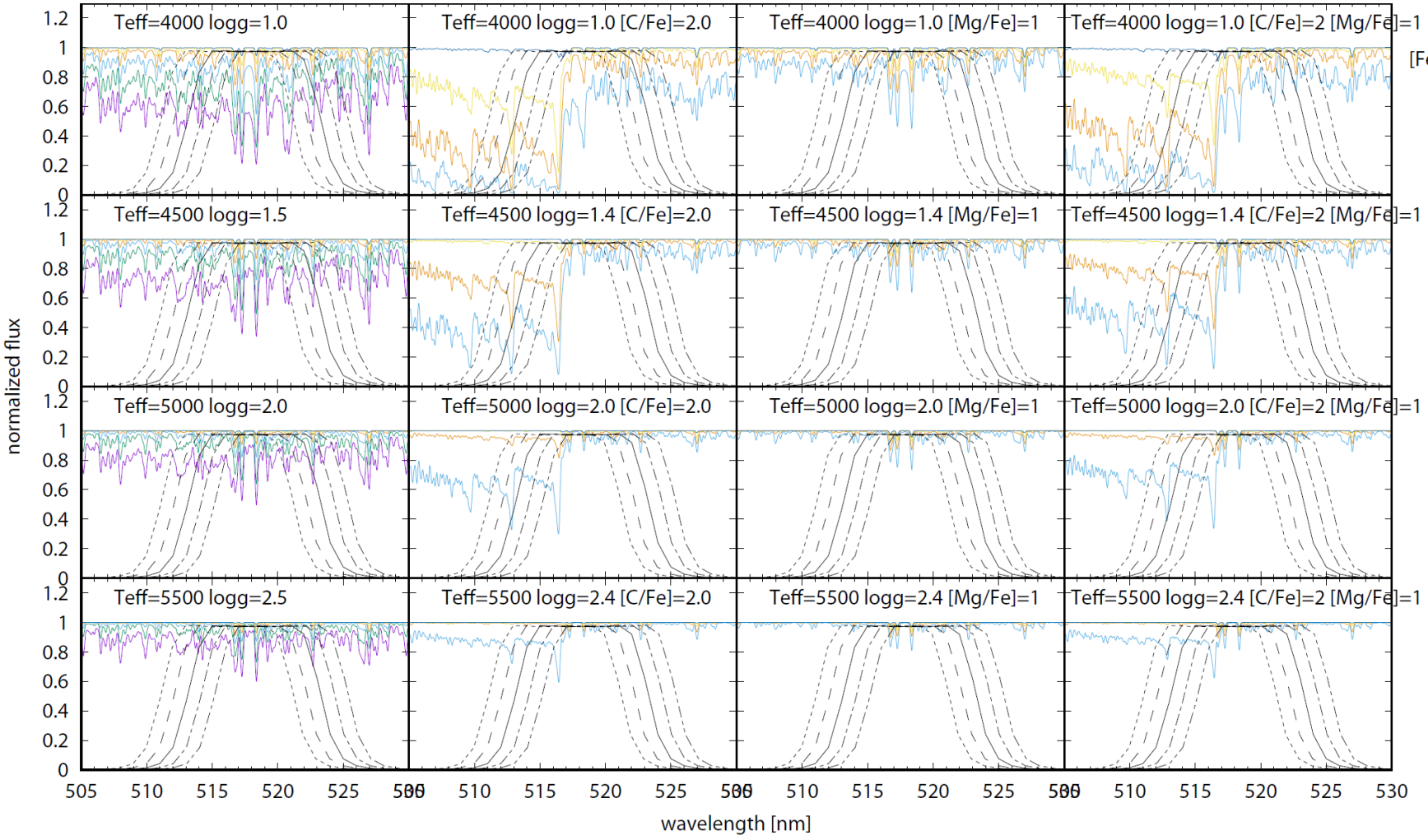
Narrow-band for CaHK (395nm)



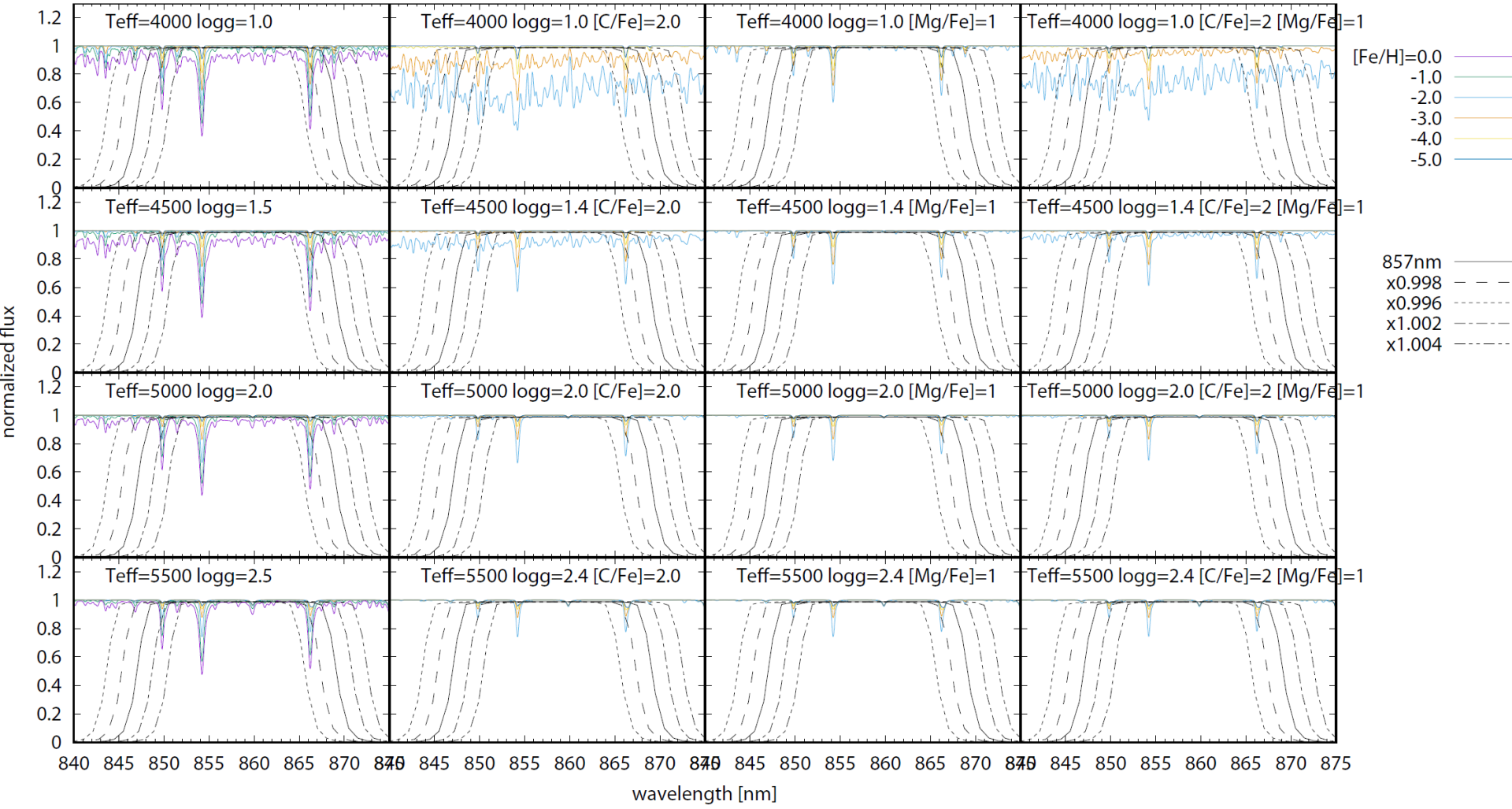
CH 432nm (fwhm=20nm)



Mgb 518nm (fwhm=10nm)

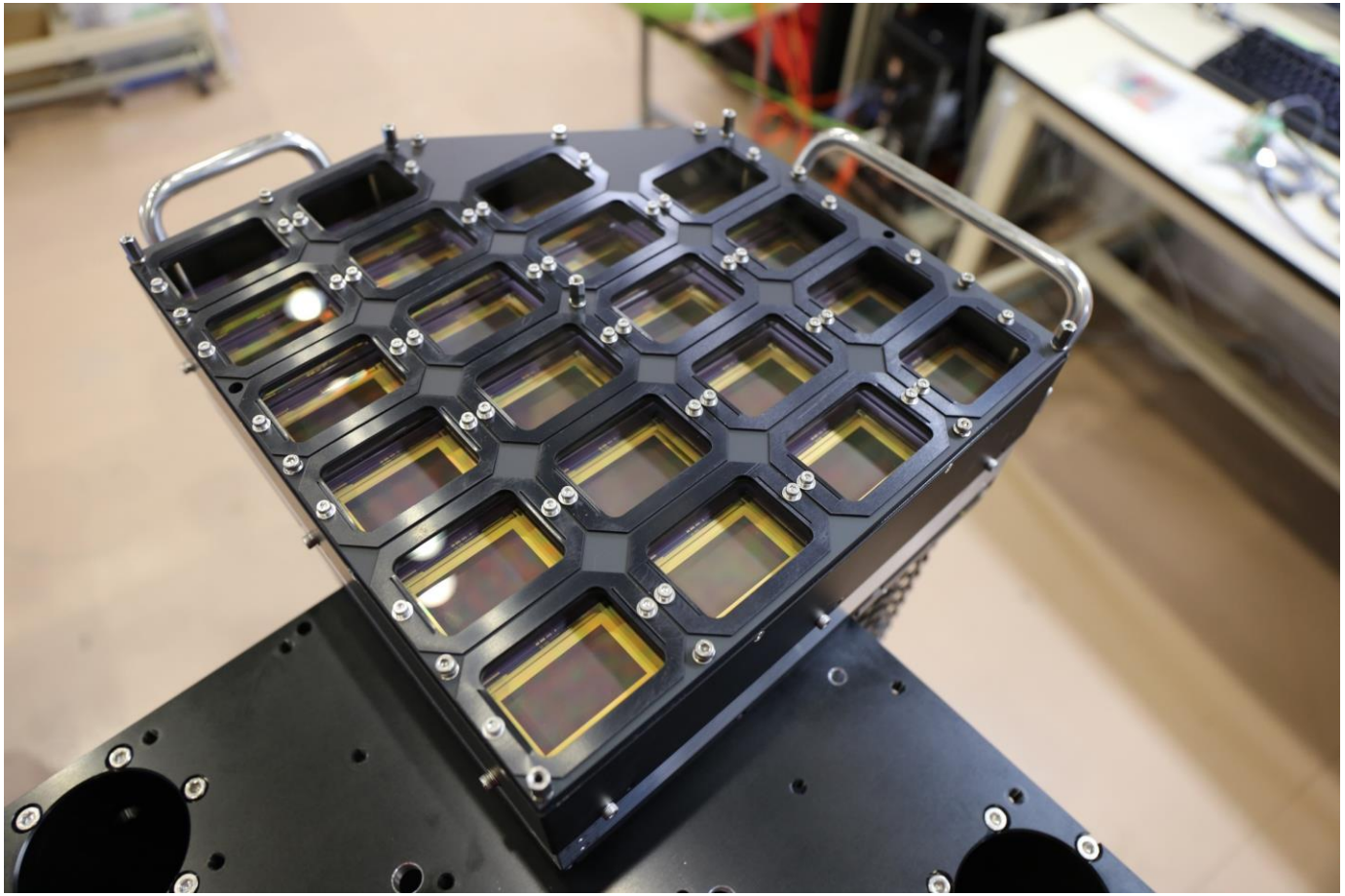


CaIR 857nm (fwhm=23nm)



New filter holder is required for narrow-band filters

Tomo-e Gozen Q1



Plan of the survey project for bright metal-poor stars with Tomo-e Gozen

- Designing and fabrication of filter holders for Tomo-e Gozen by tight collaboration with NAOJ ATC (approved as an open-use program)
- Fabrications of narrow-band filters
  - 395nm x 21 (or 42)
  - 432nm x 21 (or 42)
  - 518nm ?
  - 857nm ?
- 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?

Survey plan

- Required number of nights:
  - Narrow-band filter survey (NB395, 10nm width)
  - Magnitude at 395nm: <15 mag (cool red giants)
  - Efficiency at 395nm: x 0.5
  - Two narrow-band filters

  1 night for no filter survey for 12,000 deg^2 for <17.5mag
  → 10 clear nights (?) x 2 to cover whole northern sky
  …need to correct overhead.

- Observing plans:

  Observations are not time critical
  Need to avoid GW O4 (August 2022- ?)
  - Test: before August 2022?
  - Main survey: after GW O4, before the end of FY2023?