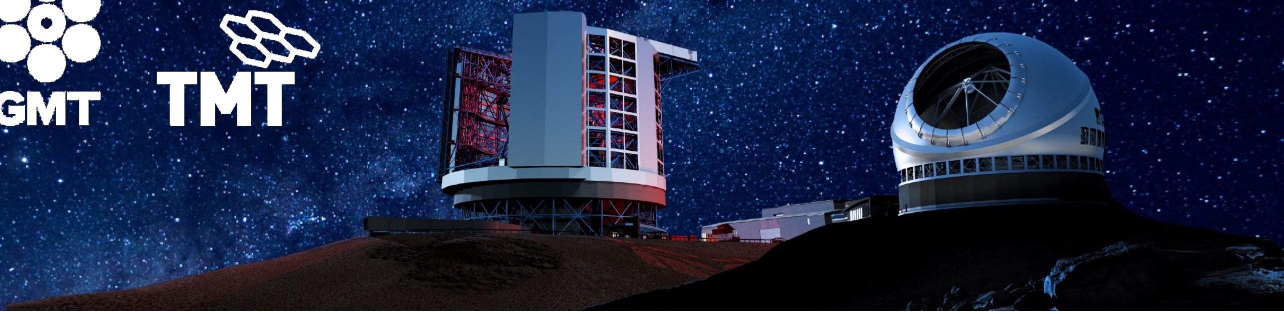


The First Stars and the Origin of the Elements

Derek Buzasi, Alex Ji, Gregory Mace, Vini Placco, Ian Roederer, Jennifer Sobeck

This KSP would use GMT/G-CLEF and TMT/HROS and would require ~24 nights.

The US-ELT program could detect and characterize the relics of the first stars.

Cosmological models predict that Pop III metal-free stars must have existed, but none have been found. This KSP will conduct a search for low-mass, long-lived Pop III stars, and should detect one (or more) or exclude their existence at 95% confidence.

It will also observe many second-generation (ultra metal-poor, UMP) stars to answer related questions:

— What was the IMF of the first stars that produced metals?
— By what mechanisms did the first stars explode as supernovae?
— What is the shape of the low-metallicity tail of the MDF?
— What metals did the first stars produce, and in what quantities?
— What role did environment play in shaping the first stars and earliest metal enrichment?

GMT/G-CLEF and TMT/HROS open new frontiers for high-resolution stellar spectroscopy.

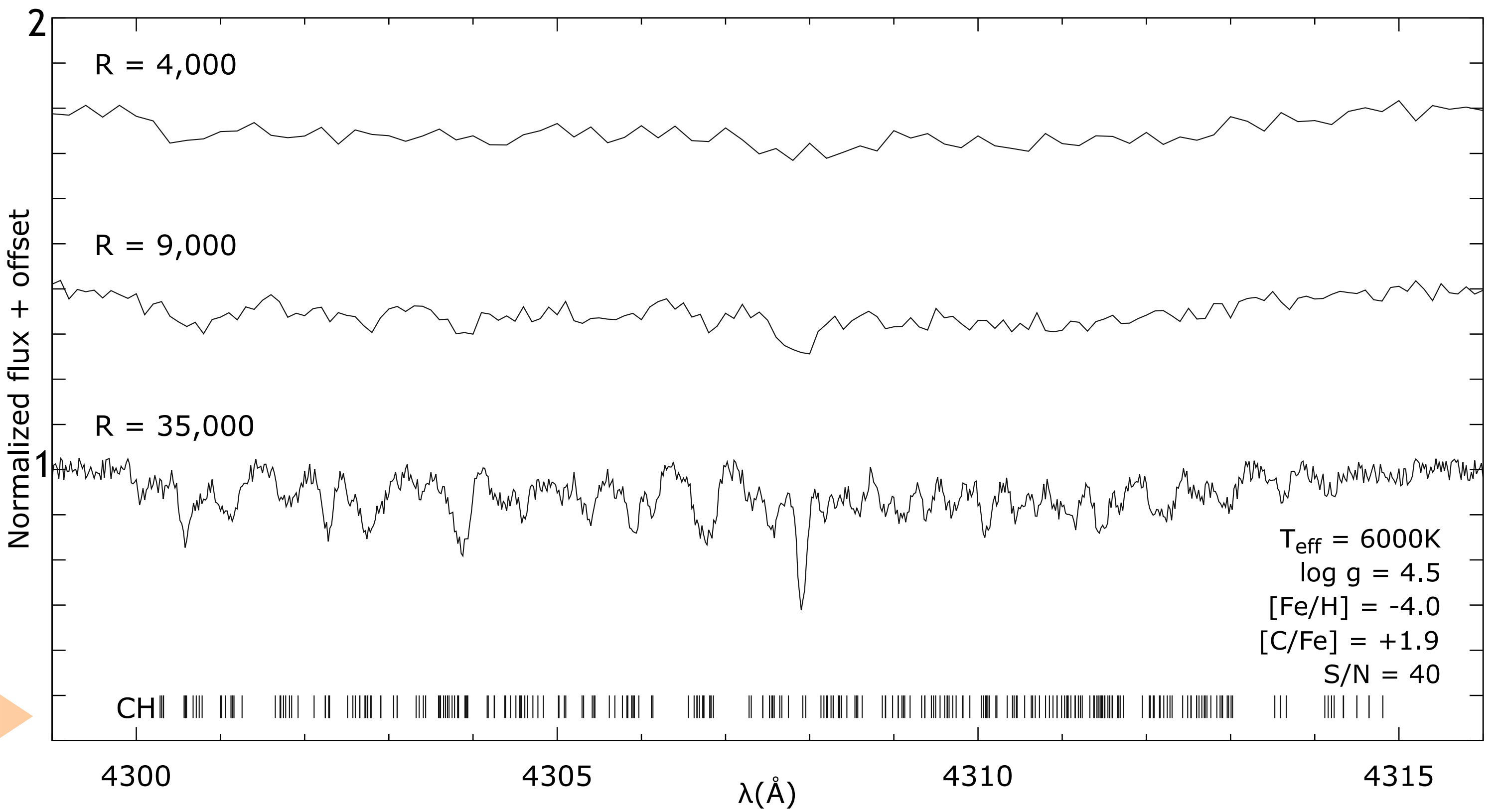
Challenge today:

- only ~30 UMP ([Fe/H] < −4) stars known
- many more candidates from SDSS, SkyMapper, LAMOST, J-PLUS, Pristine, LSST, … are too faint for high-res spectroscopy on 6-10m class telescopes

Experimental design: collect spectra of ~400 UMP late-type (FGK) stars with GMT/G-CLEF and TMT/HROS

- high-resolution (R = 35,000)
- high-S/N (S/N = 50 at 5000 Å)
- optical wavelengths (3500-9000 Å)

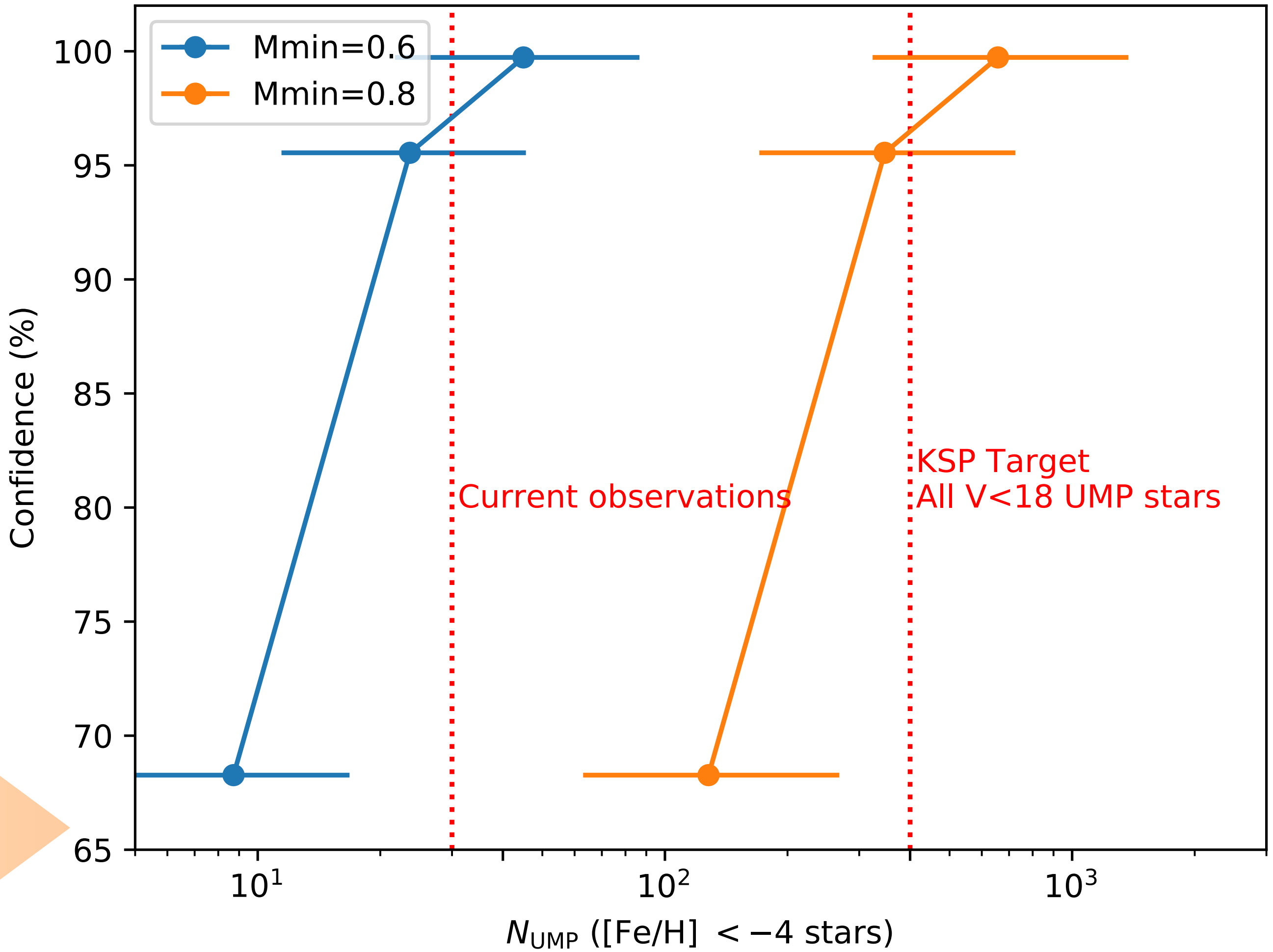
Model spectrum of the CH *G* band in a warm, F-type UMP star. Lines are not detectable in low- or medium-res spectra, but they are in high-res spectra.



Unique advantages of the US-ELT program (1 of 2): access to both hemispheres

Extrapolating from current surveys, one needs to go as faint as V = 18 to find ~400 UMP stars. Expecting 1 UMP star per 100 deg^2 requires 40,000 deg^2, so access to both hemispheres is required (unless going much fainter in one hemisphere with many more nights).

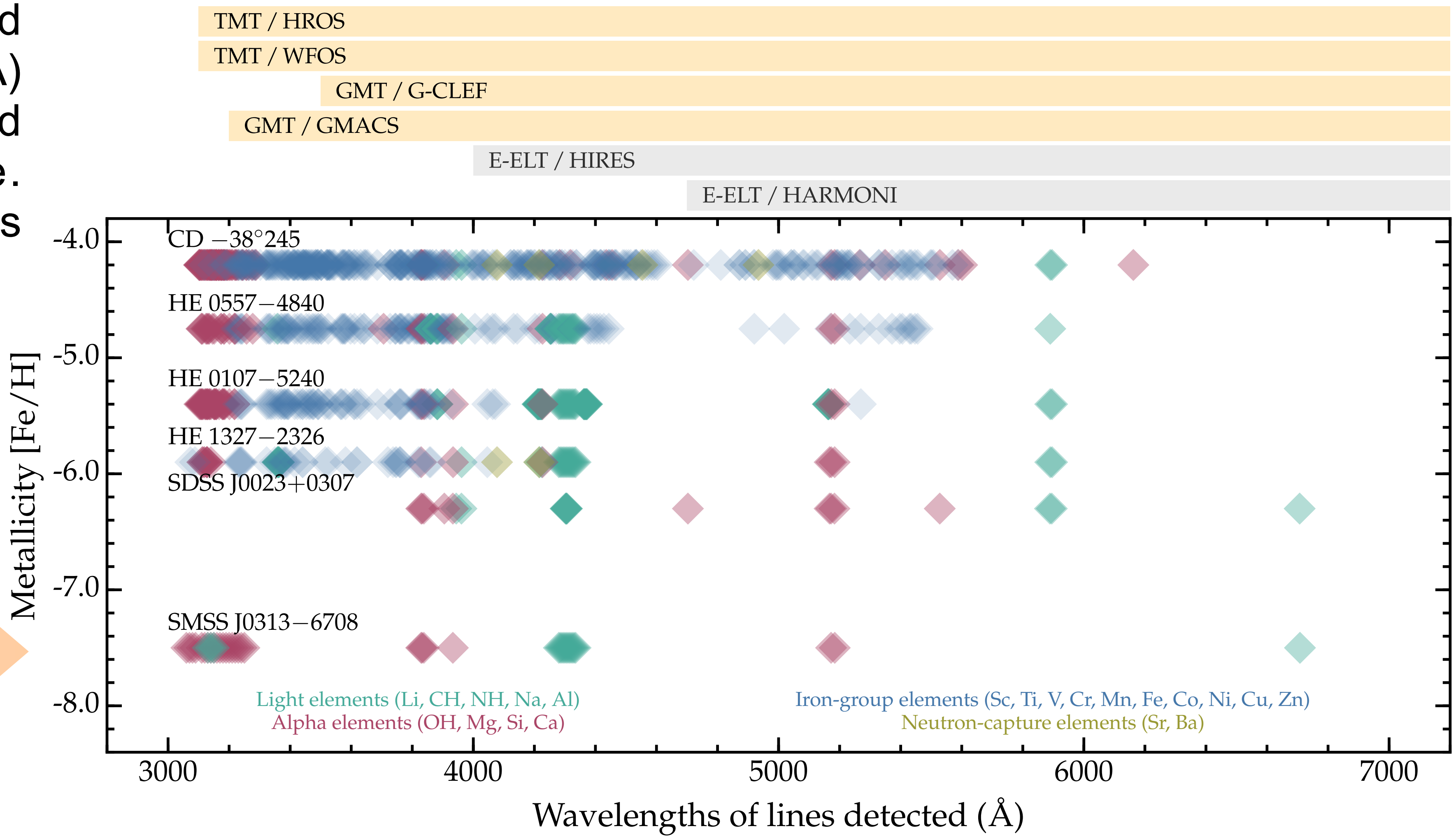
Number of UMP stars that need to be observed to reach various confidence levels that metal-free stars of mass 0.6 M$_\odot$ (blue) and 0.8 M$_\odot$ (orange) did not form. (Figure adapted from Hartwig et al., 2015, MNRAS, 447, 3892)



Unique advantages of the US-ELT program (2 of 2): blue wavelength coverage

Most lines of interest are found at blue wavelengths (< 4000 Å) where only TMT/HROS and GMT/G-CLEF are sensitive. The E-ELT/HIRES design does not cover these wavelengths.

Wavelengths of metal lines detected in known UMP stars. The wavelength coverage of moderate- and high-res spectrographs on TMT, GMT, and E-ELT is shown.



Summary

- The US-ELT program would uniquely enable a comprehensive search for the remnants of the first stars in the Milky Way.
- Need both GMT and TMT working as a system to cover the full sky
  (one hemisphere is insufficient)
- Only the GMT/G-CLEF and TMT/HROS designs cover the blue spectral range
  (E-ELT/HIRES design does not)
- Requires high S/N and high spectral resolution optical spectra
- This project could be completed in ~24 nights with GMT+TMT
  (could be distributed over several years)