Tracing the Chemistry of the Milky Way: Radial Variation and the Identification of Supernova Fingerprints

Natalie Myers[1], Peter Frinchaboy[1,2], John Donor[1], Taylor Spoo[1], Jonah Otto[1], Alessa Wiggins[1], Sarah Loebman[3], Jamie Tayar[4], Gail Zasowski[5], Katia Cunha[6,7], Adrian Price-Whelan[8], Steven Majewski[9], Amaya Sinha[5], Henrique Reggiani[10], Erika Holmbeck[10], Rachael Beaton[11], Julia O'Connell[1], Amy Ray[1,12]

(1)Texas Christian University (2) Canada-France-Hawaii Telescope (3) University of California Merced (4) University of Florida (5) University of Utah (6) Observatório Nacional (7) Steward Observatory, University of Arizona (8) Flatiron CCA (9) University of Virginia (10) Carnegie Observatories (11) STScI (12) University of Texas/HET

SDSS

APOGEE

TCU

BACKGROUND

For this work we primarily use open clusters, which are gravitationally bound groups of stars that were all born in the same gas cloud at the same time. From a single open cluster, we can derive relatively reliable distances, ages, and chemistry. Moreover, these open clusters are found throughout the Milky Way's disk (See Figure 1) and cover a wide range of chemistry -0.53 < [Fe/H] (dex) < 0.31) and age (0.02 < age (Gyr) < 9. This makes them ideal markers for Galactic chemical evolution.

The build-up of chemical abundances over time comes from various sources that can vary across the Milky Way. For example, Type II supernovae are rich in alpha elements, Type 1a are rich in iron-peak elements, Asymptotic Giant Branch stars create both alpha and s-process elements, and neutron star mergers create r-process.

OCCAM SURVEY

The goal of the Open Cluster Chemical Abundance and Mapping (OCCAM; Myers et al. 2022 and references therein, see QR Code) survey is to provide a high-quality catalog of open clusters to study the chemical enrichment history of the Milky Way. To determine open cluster membership, we utilize the abundances and radial velocities from SDSS/APOGEE DR17 (Abdurro'uf et al. 2022) and the 5D kinematic properties from *Gaia* EDR3 (Gaia Collaboration et al. 2021). With these data we apply a gaussian fitting routine to determine a membership probability. Finally, we adopt the distances and ages derived in Cantat-Gaudin et al. (2020), leaving us with a sample of 85 open clusters. This sample is shown in Figures 1, 2, and 3.

Myers et al. (2022)

Figure 2: The open cluster sample plotted as a function of radius and placed into four age bins. The youngest age bin is the top bin and the eldest clusters are in the bottom bin. The slopes as found in Myers et al. 2022 are shown in dark blue.

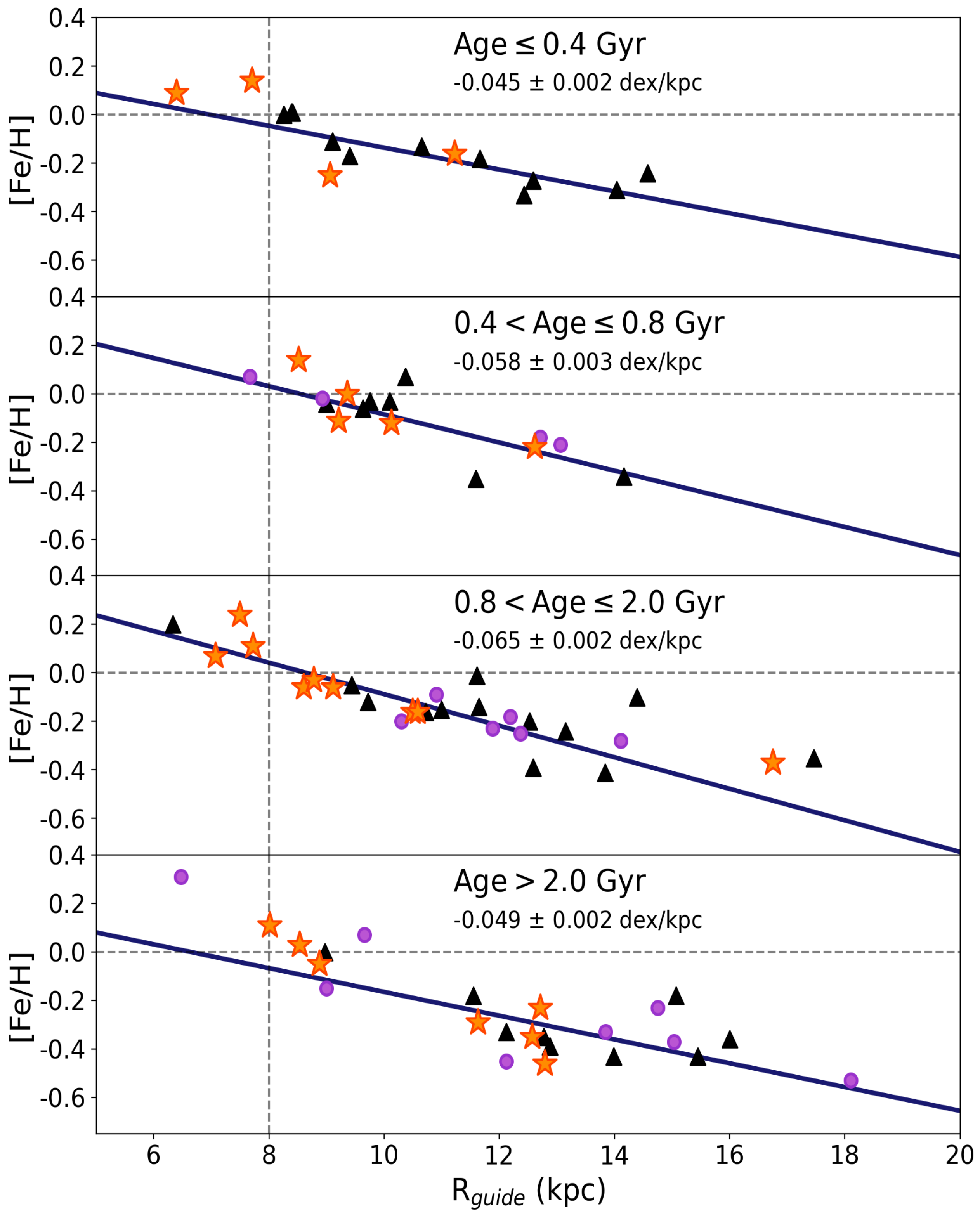
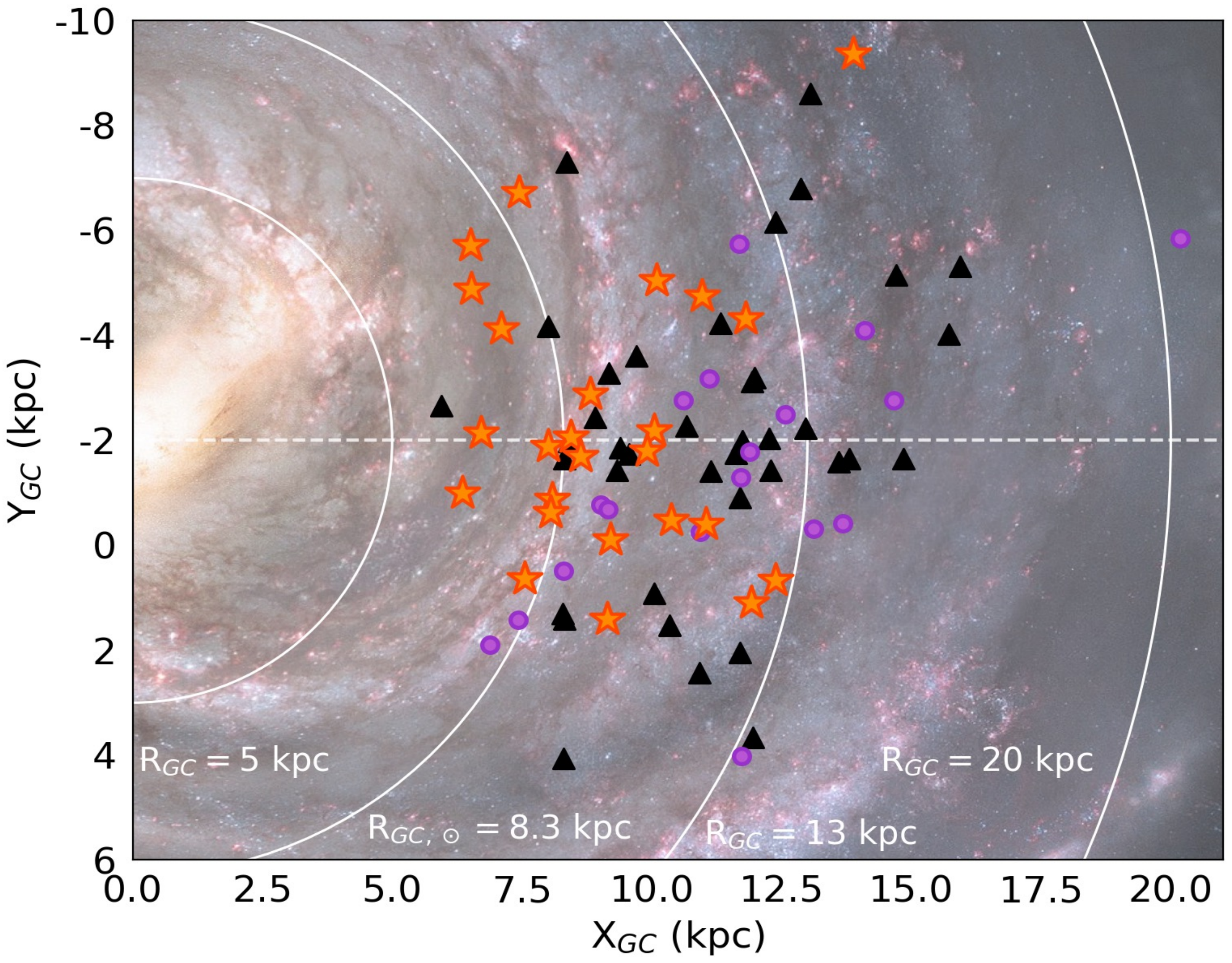


Figure 1: The entire DR17 OCCAM sample of open clusters plotted on the Milky Way plane. The different points are discussed in "Observations".



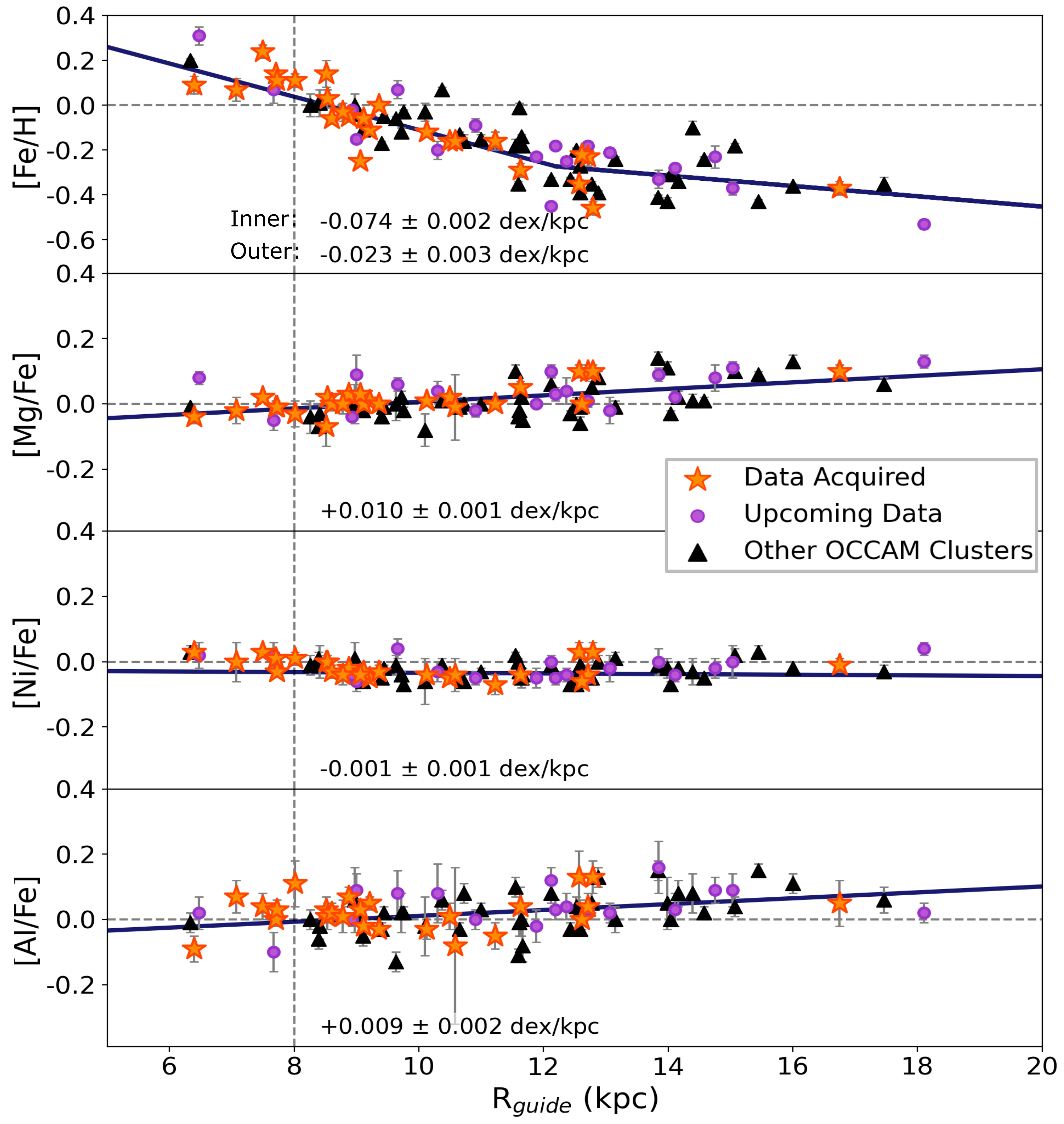


Figure 3: The open cluster sample plotted as a function of radius and placed into three separate age bins. Orange stars designate clusters with data actively being reduced/analyzed, purple circles indicate clusters we have proposed to get, black triangles designate other OCCAM clusters.

ABUNDANCE GRADIENTS

The trends of different elements can be used to explore the enrichment history of the Milky Way. Figures 2 and 3 showcase the open cluster sample as a function of radius, where each fit reported in Myers et al. is shown as a blue line and the slope is reported on the plot. In Figure 3 we show the general metallicity gradient, as well as three other gradients from a representative alpha element ([Mg/Fe]), Iron-peak element ([Ni/Fe]), and odd-z element ([Al/Fe]). Since we are using open clusters, we can split this sample into age bins, shown in Figure 2. Minus the eldest age bin, we see a trend of steadily increasing slopes through each age bin. For simplicity we only show the [Fe/H] gradient in age-bins. For the behavior of other abundance gradients available in APOGEE, see Myers et al. (2022).

N-CAPTURE ELEMENTS

APOGEE provides abundances for numerous alpha ([O, Mg, Si, S, Ca, Ti]), iron-peak ([Ni, Co, Mn, Cr, V]), odd-z ([K, Al, Na]), and light elements ([C, N]). However, abundances for heavier elements are less reliable and available. These elements, often called neutron capture elements, are those created through the slow (s-) or rapid (r-) neutron capture processes, which happen in regions with a large neutron flux (e.g., AGB stars, supernovae, and neutron-neutron star mergers).

By acquiring r- and s-process elements for the OCCAM sample, we aim to build a reliable, age-datable, sample of all major element groups. We will use this sample to better characterize the radial gradients, calibrate chemical clocks, and constrain models of Galactic chemical evolution.

OBSERVATIONS

To derive abundances for r- and s- process elements, we need to data from the optical wavelength regime. Therefore, we are working to observe and analyze our own optical data for stellar members in the open clusters of OCCAM. As of this conference, we have 20 nights of data and 6 more upcoming nights. Figures 1, 2, and 3 all have open clusters denoted one of three ways: orange stars (at least 1 stars worth of data has been collected), purple circles (we plan on observing these clusters soon), and black triangles (the rest of the OCCAM sample).

LICK OBSERVATORY

SUBARU TELESCOPE

McDonald Observatory
The University of Texas at Austin

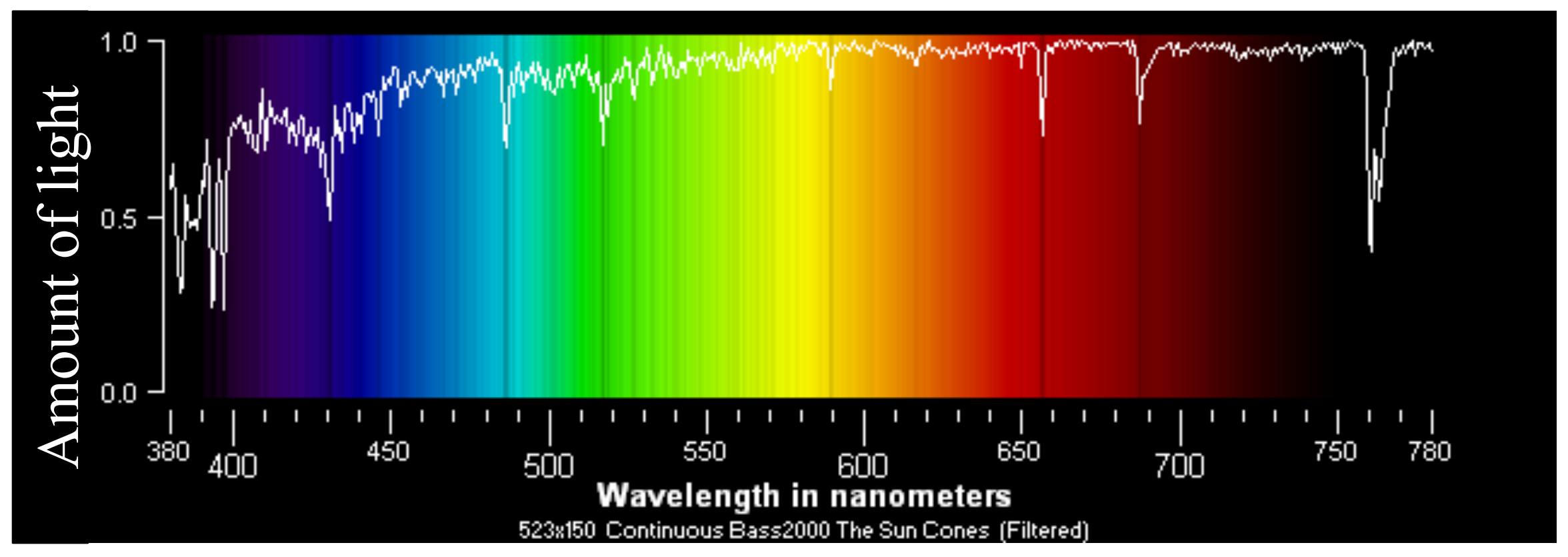
CARNEGIE SCIENCE | LCO

W. M. KECK OBSERVATORY
On the summit of Mauna Kea, Island of Hawai'i

DATA ANALYSIS

For the reductions of the data, we will be using the standard data reduction processes within the IRAF software. To determine the abundances, we will be using a the Turbospec software.

To determine the abundance of some element in a star, we must look at its spectrum (example, below). The spectrum is all the light from the star spread out into its individual energies (or colors). However, different elements can steal some of the light at very specific energies, thus creating "lines" in the spectrum. To find the number of atoms of an element in the spectrum we can measure how much light has been stolen from that energy.



Works Cited:

Abdurro'uf, 2022. doi:10.3847/1538-4365/ac4414.

Gaia Collaboration, 2021. doi:10.1051/0004-6361/202039657.

Myers, N., 2022, doi:10.3847/1538-3881/ac7ce5.

Image Credit: Nick Risinger

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