Assembling the Open Cluster Avengers of Galactic Evolution

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OCCAM

Open Cluster Chemical Abundance and Mapping

GALACTIC EVOLUTION

Over time gas inside a galaxy condenses, forming stars, these stars create heavier elements, and then they eventually die – throwing the elements they created into their surroundings. In galaxies, the region with the most star formation is the center, since gravity is pulling the gas inwards. This means that the center is also the place with the most heavy elements, or chemical enrichment, in the galaxy.

Top right: A summary of galactic evolution, plotted on the Milky Way's disk.

STAR CLUSTERS

Open star clusters are groups of stars all born at roughly the same time in the same gas cloud, this means that the stars in the cluster will all have the same distance, chemistry, and age. Moreover, we can calculate this age by looking at a cluster's Color-Magnitude Diagram (CMD). The CMD is a plot of the cluster's brightness as a function of its color, which is proportional to the star's temperature. Since stars which are very bright and very blue/hot live much shorter lives than their dimmer, redder/cooler, counterparts we can use this plot to derive an age. See **Figure 1** (below) for some example CMDs.

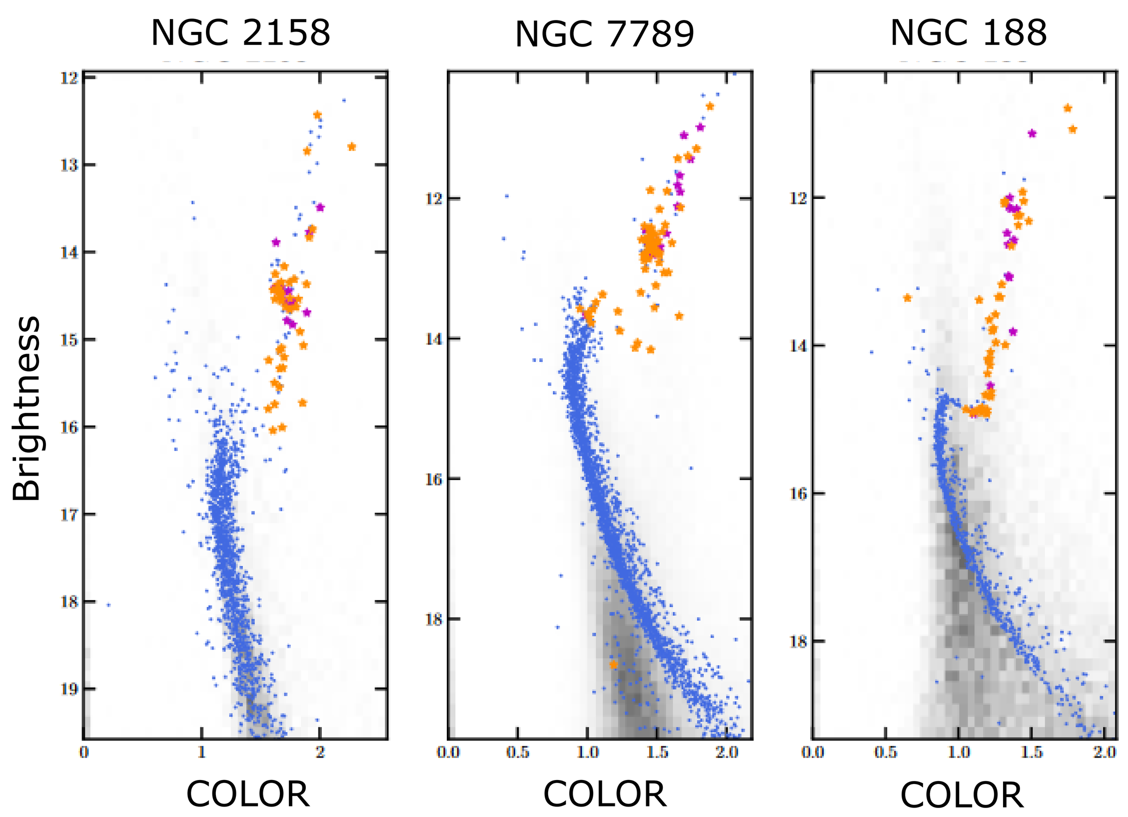
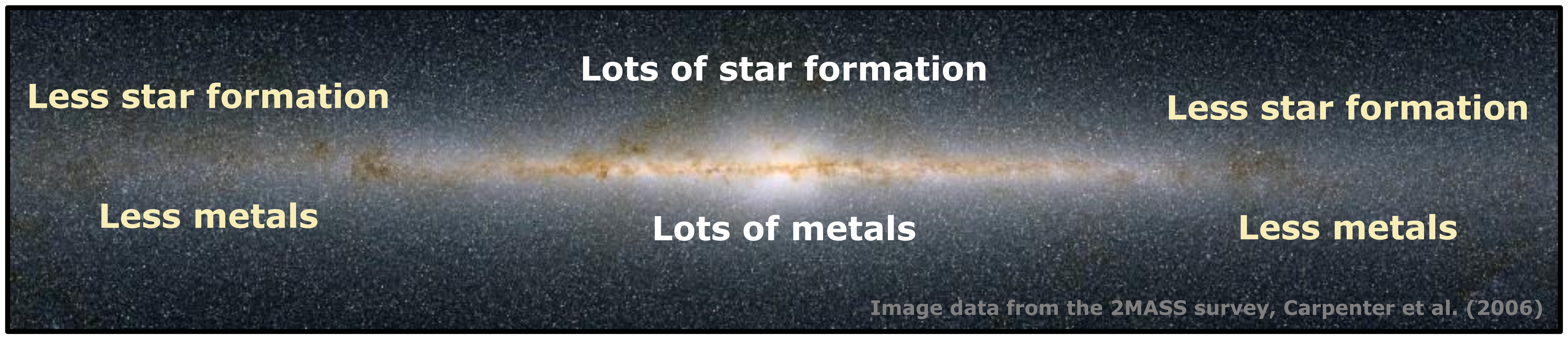


Figure 1: Example color-magnitude diagrams for three well-studied clusters. Blue, pink, and orange dots represent stars that are a part of the cluster, while the background grey shades represent stars which are *not* a part of the cluster.

OCCAM SURVEY

The Open Cluster Chemical Abundance and Mapping (OCCAM) survey is a dataset of open clusters which has been assembled from two sources: SDSS/APOGEE and the *Gaia* Space Telescope. The APOGEE survey is a large-scale, high-resolution, infrared, spectroscopic survey which provides abundances of 16 different elements for over 657,000 stars in the Milky Way. *Gaia* provides information about the distances to stars, and their velocity for over a billion stars. With both of these surveys, we can create a dataset of uniformly taken data for star clusters in the Milky Way. With the OCCAM survey, we can not only investigate the change in chemistry across the Milky Way, but also through time.



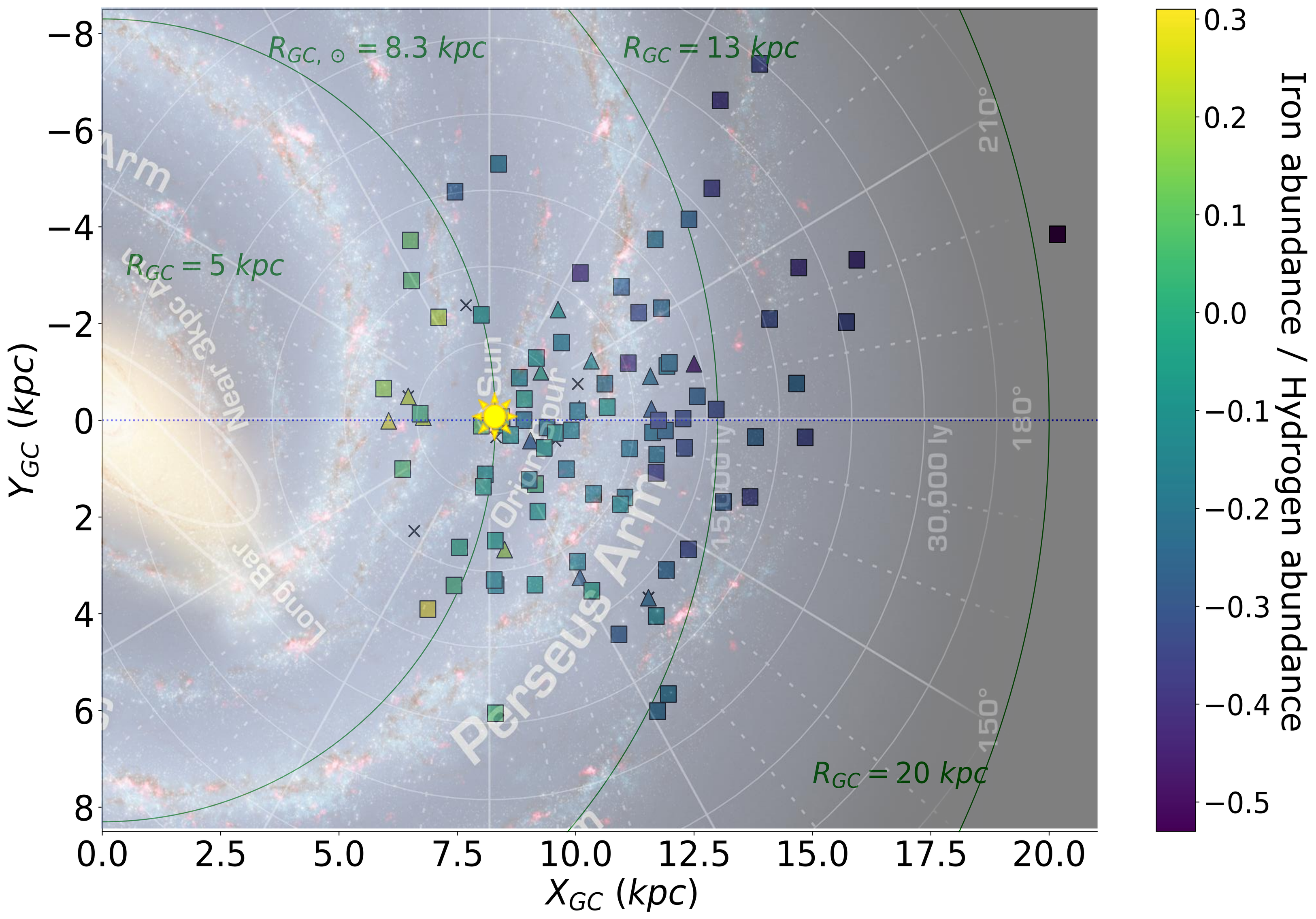


Figure 2: The entire OCCAM sample of open clusters plotted on the Milky Way plane. The points are colored by their metal content. "Metals" for astronomers are any elements heavier than hydrogen or helium.

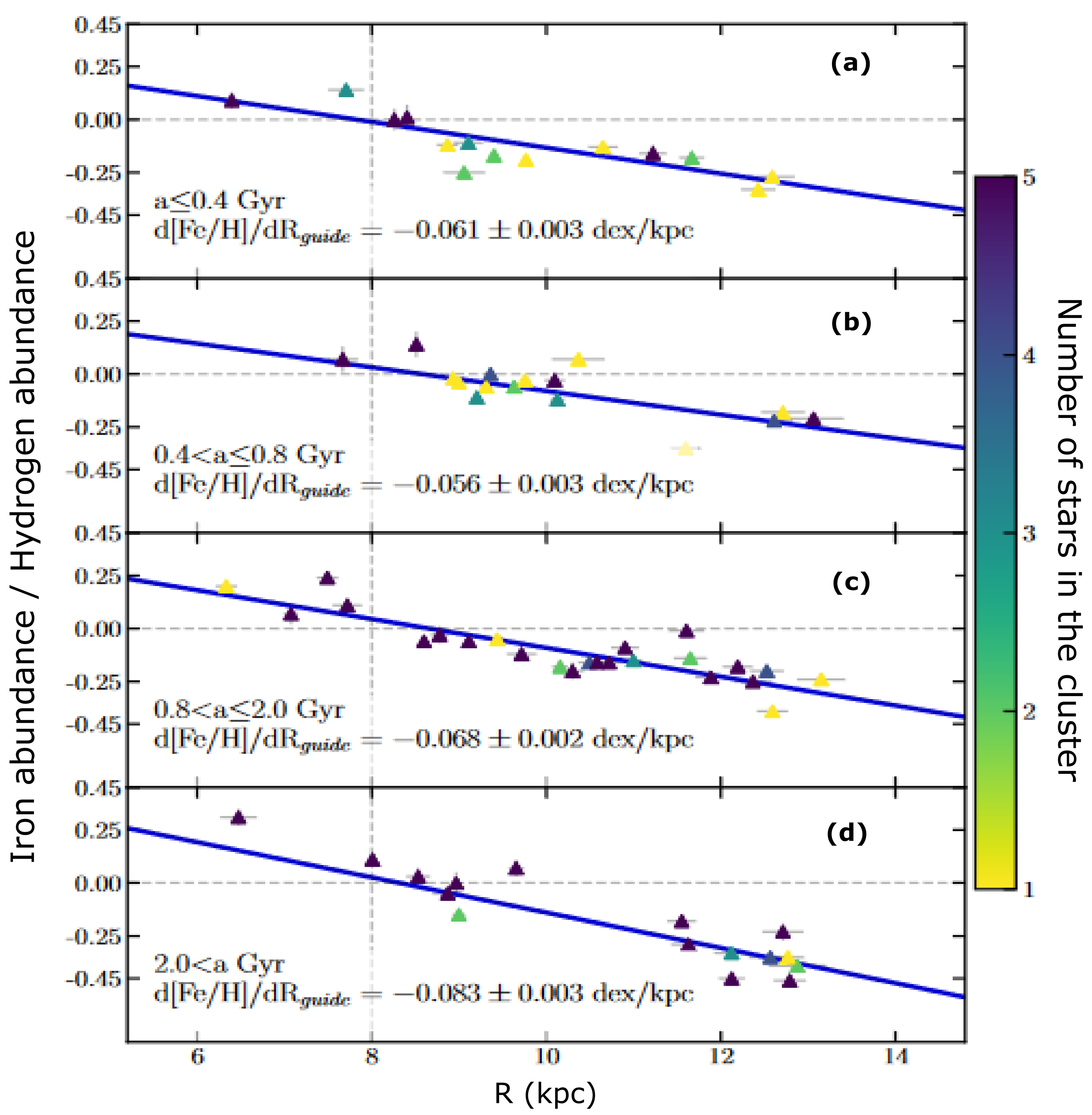


Figure 3: The open cluster sample now plotted with the iron abundance vs. radius, in four age bins. Each cluster is color-coded by the number of stars we have chemistry for.

ABUNDANCE GRADIENTS

Once we have assembled the chemistry and the distances for each cluster, we can investigate the variation of these elements throughout the Milky Way.

Figure 3 shows the cluster sample divided into four age bins and plotted as the abundance of iron vs. radius. Iron can be used as a proxy for the abundance of all elements heavier than helium. The age bins cover ages less than 400 million years (a), 400 million years – 800 million years (b), 800 million years – 2 billion years (c), and all clusters older than 2 billion years (d). From Figure 3 we can see that the abundance of iron in the center of the Milky Way is larger than in the outer regions – creating the gradient in each age bin. We can also compare the slopes of the gradients in each age bin to see that in older groups of clusters the slope gets steeper.

SciCom

Let's Talk Science

Stars are the chemists of the Milky Way. Over time stars will create and then throw elements heavier than helium into their surroundings. Therefore, to understand how the Milky Way has evolved over time, we not only need ages and distances of stars, but we also need to know their chemistry. Open clusters are ideal tools for this because we can derive accurate distances, chemical abundances, AND ages for each one. This project assembles all stars which are members of open clusters to investigate the variation of chemistry throughout the Milky Way both spatially and through time.

FUTURE WORK

MORE CHEMISTRY! Currently our sample of open clusters has chemistry for 16 different elements on the periodic table, almost all of which are lighter than iron. By going to observatories and collecting our own spectra of these cluster members, we can add more heavy elements to our sample!

MORE CLUSTERS! With new data coming in from SDSS V, we'll be able to add over 1000 more clusters to our current sample of open clusters. This will allow us to better sample the Milky Way's chemistry over different time-scales and in different regions.

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