The First Deep Chemical Study of NGC 2298

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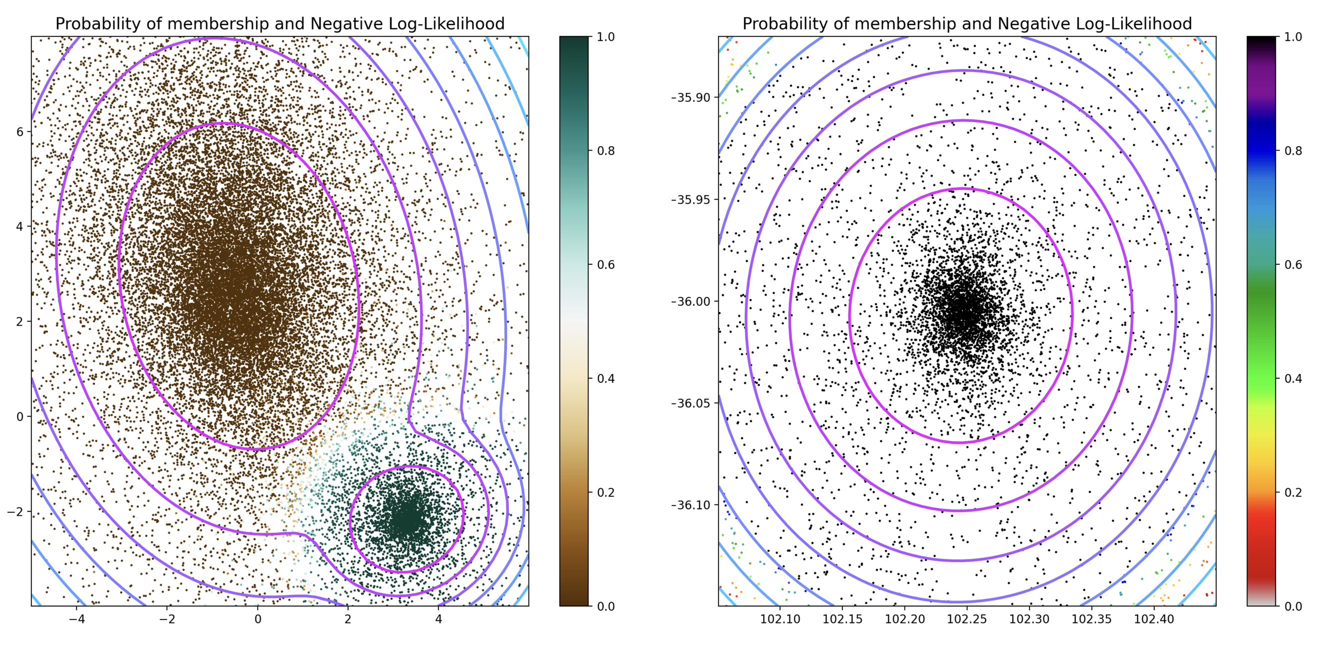
1. Abstract

We present **the first detailed elemental abundances of stars in the metal-poor globular cluster NGC 2298**. Based on near-infrared high-resolution (R $\sim$ 22,500) spectra of 12 members obtained during the second phase of the **Apache Point Observatory Galactic Evolution Experiment (APOGEE)** at Las Campanas Observatory as part of the seventeenth Data Release (DR 17) of the Sloan Digital Sky Survey IV. We employed the **Brussels Automatic Code for Characterizing High accuracy Spectra (BACCHUS)**.

We find a mean and median metallicity [Fe/H]= -1.76 and -1.75, respectively, with a star-to-star spread of 0.14 dex, which is compatible with the internal measurement errors. we don't find any evidence for an intrinsic [Fe/H] abundance spread. The typical α-element enrichment in NGC 2298 is overabundant relative to the Sun, and it follows the trend of other metal-poor GCs. We confirm the existence of an Al-enhanced population in this cluster, which is clearly anti-correlated with Mg, **indicating the prevalence of the multiple-population phenomenon in NGC 2298**.

2. Likely Members, Gaia DR3



Probability of Membership through proper motion and spatial position respectively, also are shown the Log-Likelihood contour levels

To characterize the cluster We might start identifying their members, to perform this We used a common approach of Gaussian Mixture Model, We define the probability of each source as follows $Prob_C(i) = \frac{\Phi_C(i)}{\Phi(i)}$ with $\Phi(i) = \Phi_C(i) + \Phi_F(i)$

For the vector point diagram We use 2 components of 2-D Gaussian's (one for the field stars and the other for the Cluster)

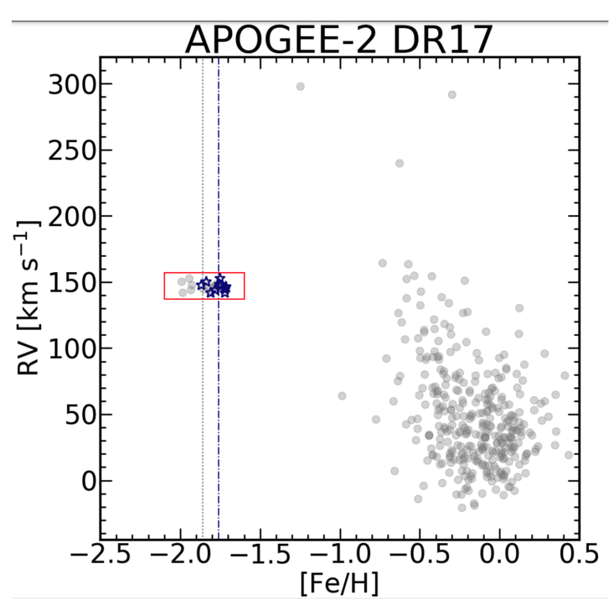
$$\mathcal{N}(\vec{X}|\vec{\mu}, \Sigma) = \frac{1}{(2\pi)^{1/2}} \frac{1}{|\Sigma|^{1/2}} exp\{-\frac{1}{2}(\vec{X} - \vec{\mu})^T \Sigma^{-1} (\vec{X} - \vec{\mu})\}$$

For the spatial distribution We employ a single component for the cluster and and a flat distribution for the field $\Phi_F^r = \frac{1}{\pi r_{max}^2}$

The covariance's matrix and vector centers were obtained through machine learning (python package [1])

3. Likely Members, APOGEE Stars

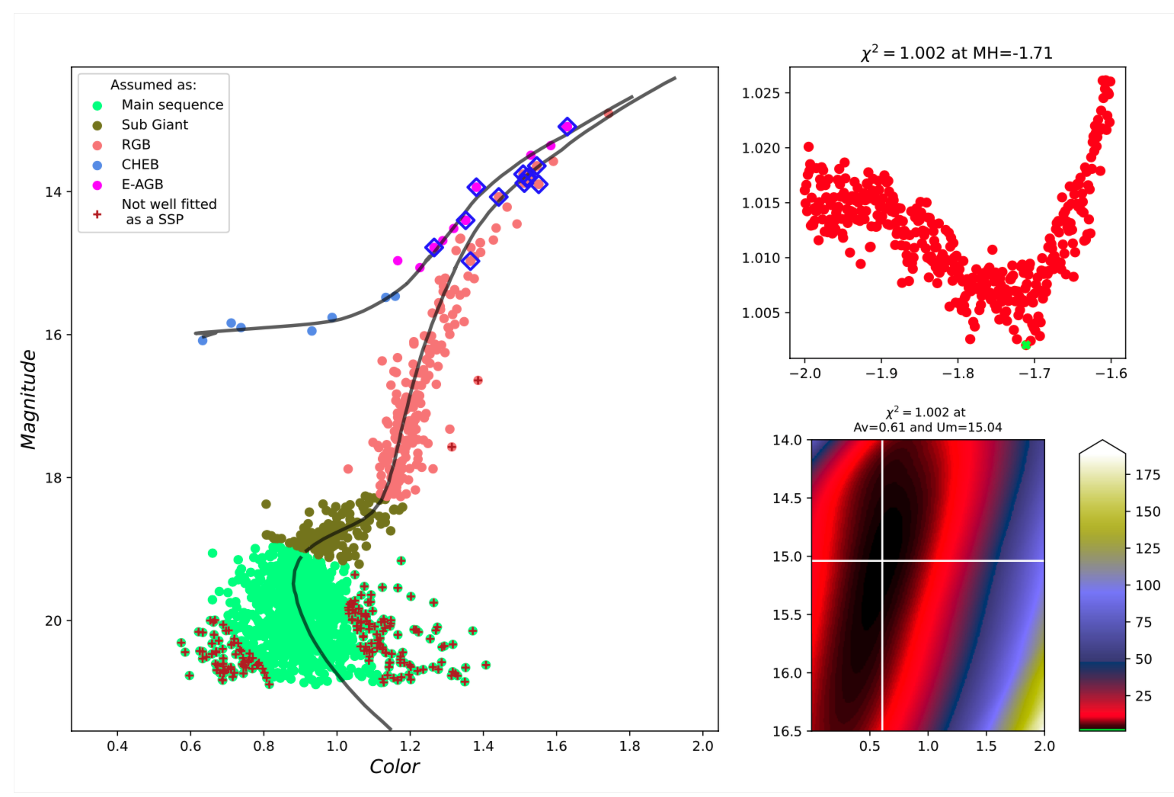
The gray dotted and navy blue dash-dotted lines mark the average [Fe/H] of the 12 NGC 2298 stars analyzed in this work , in gray the preliminary values of ASCAP and in navy our results



Once We got our High probability members We used to determinate which stars that were in the sample of APOGEE were likely part of the Cluster, We got 12 stars that are in the innermost part of the cluster and are within the range of proper motion.

Also consistently with our guesses the initial results of ASCAP (the pipeline of APOGEE) shows 12 stars with a significant difference in metallicity and that shows a clustering in their radial velocities.

4. Inferred Parameters



HR-Diagram of our high probability members and our best fit of isochrone through a χ^2 test with 3 free parameters, the absorption, distance modulus and metallicity.

(Age (13.15[Gyr]) taken from [2]

The atmospheric parameters of our sample such as $\log(G)$ and T_{eff} could be directly been inferred through an interpolation of the isochrone (PARSEC isochrone [3]), since our data and fit allows Us distinguish between AGB and RGB stars

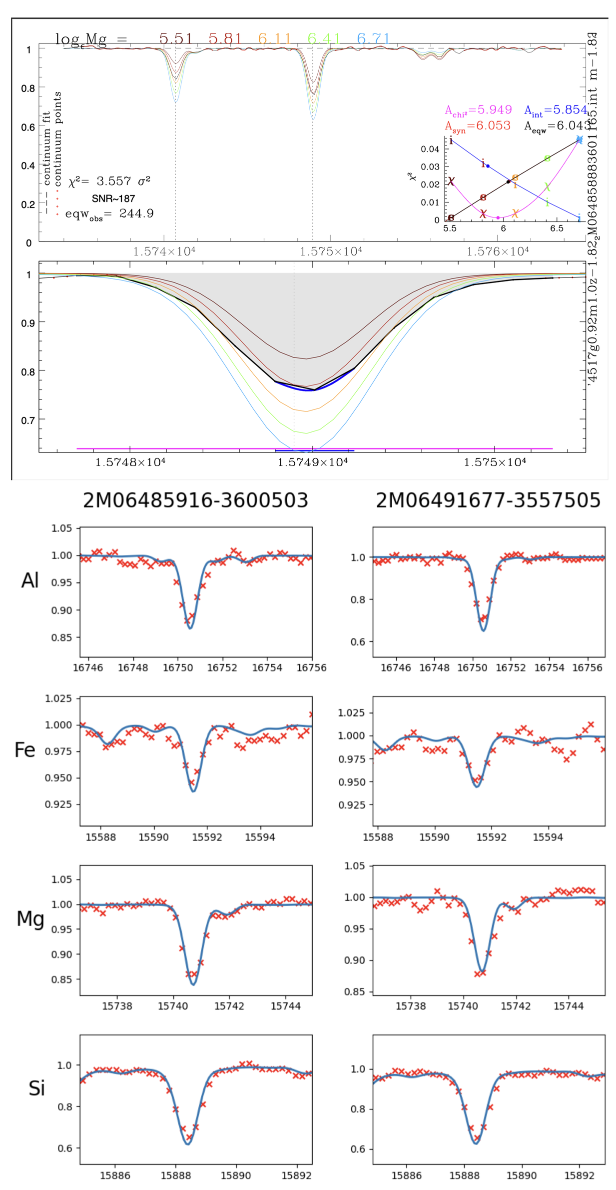
The micro turbulence was obtained through

$$\xi_{micro} = 0.998 + 3.16 \times 10^{-4} \cdot X - 0.253 \cdot Y - 2.86 \times 10^{-4} \cdot X \cdot Y + 0.165 \cdot Y^2$$

with $X = T_{eff} - 5500$ [K] and $Y = \log(g) - 4.0$ (Equation taken from [4])

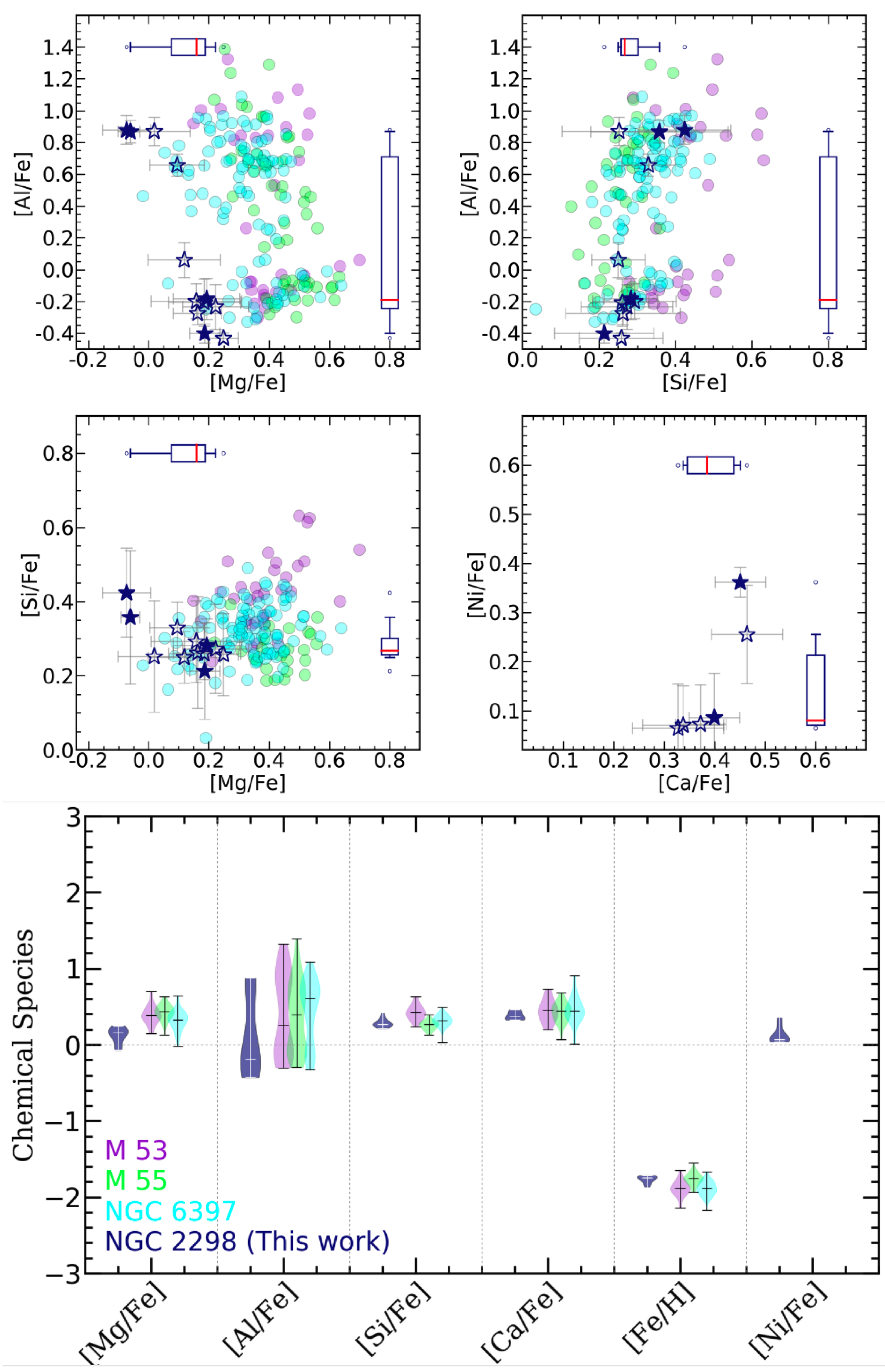
5. BACCHUS

With these parameters We are able to compute the abundances for a variety of chemical species



A typical output of BACCHUS Software and some of the convoluted synthetic spectra for different chemical species of two stars in our sample

6. Results



Our Abundance results are summarized diferentially and globally respectively and are compared with other cluster in the same range of metallicity (clusters stars measures taken from [5]

7. References

[1] F. e. a. Pedregosa, "Scikit-learn: Machine learning in Python," *Journal of Machine Learning Research*, vol. 12, pp. 2825–2830, 2011.

[2] S. e. Monty, "A Pilot Study of the Stellar Populations in NGC 2298 and NGC 3201," *apj*, vol. 865, p. 160, Oct. 2018.

[3] A. e. Bressan, "PARSEC: stellar tracks and isochrones with the PAdova and TRieste Stellar Evolution Code," *mnras*, vol. 427, pp. 127–145, Nov. 2012.

[4] A. e. Mott, "Improving spectroscopic lithium abundances. Fitting functions for 3D non-LTE corrections in FGK stars of different metallicity," *aap*, vol. 638, p. A58, June 2020.

[5] S. e. Mészáros, "Homogeneous analysis of globular clusters from the APOGEE survey with the BACCHUS code - II.," *mnras*, vol. 492, pp. 1641–1670, Feb. 2020.