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CTA Proposal: SEGUE 1: An Unevolved Fossil Galaxy from the Early Universe

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1. TOPIC BACKGROUND

When studying the early universe scientists commonly seek out stars with low metal content. Locked inside these stars is information about the physical and chemical conditions that led to the formation of the star. The low metallicity of these stars, specifically low [Fe/H] values and high [α/Fe] values, indicate that the stars were formed in the early universe. By comparing the quantity of α-elements, iron, and hydrogen we can map the timescales of nucleosynthesis to the timescales of different types of supernovae. The α-elements are carbon, oxygen, neon, magnesium, silicon, sulfur, argon, and calcium.

The earliest supernovae events in the universe were core-collapse supernovae of Massive stars. Massive stars produce large amounts of α-elements during their stellar evolution and core-collapse explosion. Massive stars have short lifetimes of less than 10 million years. Heavy metals, such as iron, appeared later in the astronomical timeline as a byproduct of Type Ia supernovae. Type Ia supernovae originate from binary star systems containing a white dwarf stars. These binary systems have much longer lifetimes, on the order of 10^8 years, before collapsing into a supernova. These substantially different timelines allow scientists to approximately date the relative timing of nucleosynthesis in early stars.

For decades scientists looked at low metal stars in the halo of the Milky Way to study the early universe. In the past decade efforts such as the Sloan Digital Sky Survey (SDSS) have uncovered a plethora of very dim dwarf spheroidal (dSph) galaxies and ultra faint dwarfs with total luminosities in the range of $10^5 L_\odot \lesssim L \lesssim 10^7 L_\odot$ and $L \lesssim 10^5 L_\odot$, respectively. Within this pool of dSph and ultra faint dwarf galaxies scientists discovered a small handful of ultra faint dwarf galaxies that showed extremely low [Fe/H] values. In this small handful one galaxy, SEGUE 1 stood out from the rest. SEGUE 1 stood out since it's stars show increasing metallicity but do not exhibit decreasing [α/Fe] ratios. This would indicate that SEGUE 1 dates back to the very early universe predating Type Ia supernovae events.

2. NOVELTY

The authors of this paper made new spectrography measurements of six stars within SEGUE 1 using the MIKE spectrograph focusing on the chemical enrichment process to better understand star formation in the very early universe. The six stars that were chosen were the brightest stars in SEGUE 1 which allowed for high resolution spectrography.

3. RESULTS, DISCUSSION, AND FUTURE WORK

Using the MIKE spectrograph the authors collected data on the abundance of iron (Fe I and Fe II), carbon, α-elements, neutron-capture elements, and other lighter elements. The authors then compared this data to stars found in classical dSph galaxies and the Milky Way halo and concluded that SEGUE 1 is a surviving first galaxy with only one round of star formation. In the three lowest metallicity stars, out of the six observed stars, the abundance of iron (both Fe I and Fe II) indistinguishable from the noise in the measurements. In the 3 stars with observable amounts of iron there was no correlation between increasing metallicity and increasing iron abundance. This indicated that there was only one Type Ia supernova that enriched SEGUE. This contrasts the trend found in galaxies from later where there would be a clear trend in increasing metallicity and increasing iron abundance as they evolve alongside energetic supernovae events. Other indications of the age of SEGUE include enhanced [α/Fe] values found in all it's stars that

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are consistent with their birth cloud, and the low abundance of neutron-capture elements. The consistent [α/Fe] values in SEGUE 1 stars suggest that there were no energetic supernovae events that enriched the birth gas cloud during the star formation events. The low abundance of neutron-capture elements in SEGUE's non-binary stars, which total to less than $\sim 10^{-7} M_{\odot}$ for each element, indicate that there were no neutron-capture element producing process, which produce $\sim 10^{-4} M_{\odot}$ of neutron-capture elements per event, that occurred during the star formation phase.

Future research points to observing a larger portion of SEGUE 1 stars. The six stars that were observed in this paper were deemed to be the brightest in the ultra faint dwarf galaxy and only allowed for a moderate S/N values between 20 and 46. In order to observe the other, dimmer, stars in SEGUE 1 we would require better telescopes to overcome the noise.

REFERENCES

Frebel, A., Simon, J. D., & Kirby, E. N. 2014, The Astrophysical Journal, 786, 74, doi: 10.1088/0004-637x/786/1/74