

Comparative characterization of extremely metal-poor and extremely metal-rich stars

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Abstract—Stellar evolution is the process by which gravitational forces change a star. As these forces act on stars, their characteristics change dramatically over the course of their existence. Stellar evolution is inevitable as stars deplete their initial fuel sources. The search for new fuel sources influences the properties of stars as they evolve. The timescales of stellar evolution depend on the mass of the star. The governing rule for stellar evolution is that the greater the mass, the faster the star evolves through the fuel-consuming stages. Another property that is directly related to a star's mass and evolution is its luminosity. It is now established that stars were and still are formed in a non-stationary environment where continuous evolution takes place. The spatial distribution of young stars and some specific stars, and their relationship to gas and dust concentrations, provide clues to the locations of star formation sites. Analysis of data processing of selected spherical galaxies (NGC 147 and NGC 185), the evolution of galaxies proceeds from right to left, and not against, whether this is a general property of spherical galaxies remains to be determined by future studies. The presented work also discusses metal-poor and metal-rich stars, a comparative description of how the ecological conditions of the galaxy change over time.

Keywords—Stars, heavy metal-poor stars, heavy metal-rich stars, galaxies, galaxy evolution.

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I. INTRODUCTION

EXTREMELY heavy metal-poor stars would have witnessed the early evolution of the galaxy, including information about the chemical characteristics of stars surviving today. It will answer many unanswered questions, including the explosion of the first generation of supernovae.

Our goal is to study stars that are as heavy metal-poor as possible and determine their chemical composition. This requires obtaining high-quality spectra and their complete analysis [1].

This issue is directly related to human life, because we are talking about the very chemical elements that we ourselves are made of, the planet is made of, the galaxy we live in and the objects around us are made up of many parts. Each of them evolves independently, but there are also certain interactions between them. The evolution of galaxies, the change in mass, shape, size, and composition of galaxies over time, there is a change in the content of various chemical elements in their stars and interstellar gas, starting from the early stages of their existence. Research methods [2].

There are three types of galaxies in the universe: spherical, spiral, and irregular. The evolution they have undergone can be:

- i. According to Hubble, all galaxies must transition from a spherical stage, first to a spiral stage, and then to an irregular stage;
- ii. But there is an opinion: On the contrary, all galaxies must go through the irregular, spiral, and elliptical stages in this order.
- iii. There is also a third opinion: an elliptical galaxy is always elliptical; a spiral galaxy is spiral. However, the substages within it undergo their own evolution. As for irregular galaxies, they are mainly formed by the merger of these two types of galaxies.

When Hubble first classified galaxies, he based his classification on the visible shapes of galaxies. This classification considers three main groups: a) elliptical galaxies -E; b) spiral galaxies -S; and c) irregular galaxies -I.

c galaxies are distinguished by their structure, stellar composition, and the motion of the objects within them; such galaxies are composed of a second type of population, mainly red and yellow giants and dwarfs, as well as partly low-luminosity white stars. No high-luminosity white and blue supergiants have been discovered among them yet, nor dust clouds and others. Line broadening is observed in the spectrum of elliptical galaxies; this should indicate that the stars in them are moving at high speeds in all directions, and it is necessary to estimate and

analyse these speeds.

In S-type galaxies, we see branches emanating from the central core, where, along with two or more main spiral branches, branching off from these branches are secondary branches of individual powerful star clouds, their thickness being on the order of several hundred parsecs. If such a galaxy is seen "from the side", it has the shape of a disk with a clearly defined band of Dark absorbing matter running down its entire length. Type I galaxies do not exhibit any symmetry or shape, as in the previous two cases, so they are considered separately and are called irregular.

The more widespread and accepted view today is that supernova explosions, in turn, enriched the primordial matter of the protogalactic cloud with heavy elements, from which stars with more familiar chemical compositions and masses subsequently emerged. Determining the Chemical Composition of Stars. The term "chemical composition of a star" is used in two different meanings. First, it is the percentage composition of hydrogen, helium, and all the heavy elements - X, Y, and Z. Second, it is the detailed chemical composition of the star's atmosphere, which is determined through high-resolution spectral observations. The composition of heavy elements in stars is often discussed based on the relative iron content in them, which is richest in absorption lines A-F-G-K in the visible range of the spectrum of stars [3].

Today, the detailed chemical compositions of many thousands of stars have been determined through the analysis of high-resolution spectra, and these data can be used for a statistical study of the above problems.

The main indicator of chemical composition is the relative logarithmic abundance:

$$[\text{Fe}/\text{H}] = (\text{N}_{\text{Fe}}/\text{N}_{\text{H}}) - (\text{N}_{\text{Fe}}/\text{N}_{\text{H}})_{\odot} \quad (1)$$

where $(\text{N}_{\text{Fe}}/\text{N}_{\text{H}})$ is the ratio of the number of iron atoms to the number of hydrogen atoms in the star's atmosphere, and $\lg(\text{N}_{\text{Fe}}/\text{N}_{\text{H}})_{\odot}$ is the (1) same ratio for the Sun [4], [5].

With this formulation, stars with higher metallicities than the Sun have a positive common logarithm, while those more dominated by hydrogen have a corresponding negative value. For example, stars with a magnitude of +1 have a metallicity 10 times that of the Sun (10^{+1}); conversely, stars with a magnitude of -1 have $1/10$, while stars with a magnitude of 0 have the same metallicity as the Sun, and so on. Young Population I stars have a significantly higher iron-to-hydrogen ratio than older Population II stars. The metallicity of protostars of Population III is likely to be less than -6, which is a millionth of the iron abundance in the Sun [6]-[8].

Knowing from detailed spectral analysis the total composition of all heavy elements in the solar atmosphere ($\approx 1.7\%$), we can easily calculate the ratio $[\text{Fe}/\text{H}]$. That is, we can translate metallicity into the total composition of heavy elements in the atmosphere of the star under study. Relative abundances of oxygen and some other elements 2-3 times higher than in the Sun are observed in old, iron-deficient stars, which belong to the halo and thick disk of our galaxy.

Fred Hoyle proposed in 1946 that the chemical elements present[3] in the universe today originated from hydrogen and helium in nuclear fusion reactions in the cores of stars. And then they were thrown into the universe as a result of supernova explosions. From the interstellar medium enriched with heavy elements, stars again arose, and so on. Because the contribution of type Ia supernovae to the formation of iron-group elements is significantly greater than that to the formation of α -elements (O, Mg, Si, S, Ca, Ti), the $[\alpha/\text{Fe}]$ ratio in our galaxy will decrease over time.

As a result of the explosion of these supernovae and the ejection of stellar debris by them. Thus, by the time the $[\alpha/\text{Fe}]$ value starts to decrease, it is about 1 billion years since the start of star formation. Therefore, younger stars have a lower relative composition of α -elementson average.

Studies of the chemical composition of stars in our galaxy[3] have shown that it varies from star to star: Early stars and halo stars contain much fewer heavy elements than young stars and stars born in a disk. Also, the metallicity of the interstellar gas decreases with distance from the galactic center. This review[3] focuses on the chemical evolution of gas in galaxies. It should be noted that the metallicity of the interstellar medium is usually characterized by the relative oxygen content $[(\text{O}/\text{H})]$, while the metallicity of stars is characterized by the relative iron content $[(\text{Fe}/\text{H})]$.

A thorough discussion of the main scientific goals of studying metal-poor stars is given in several articles [9],[10].

II. OBSERVED MATERIAL AND ITS ANALYSIS

The Poorest Stars in Terms of Metals

Analysis of the observed material showed that an extremely heavy metal-poor star was found among the observed ones with $[\text{Fe}/\text{H}] = -6.1$ [10], for which the content of lithium, magnesium, and calcium in them was measured. They were unable to detect iron lines in the spectrum directly, but $[\text{Fe}/\text{H}] < -6.1$ was obtained from CaII resonance lines; we assume $[\text{Ca}/\text{Fe}] > 0.40$. The chemical abundance pattern of J0023+0307, with very low $[\text{Fe}/\text{Mg}]$ and $[\text{Ca}/\text{Mg}]$ abundance ratios, but relatively high absolute Mg and Si abundances, indicates that J0023+0307 is a second-generation star that formed from a molecular cloud contaminated by a single supernova,

in which a backup mechanism played a role [10], [11].

They [10], [11] measured a carbon abundance of $A(C) = 6.2$. This places J0023+0307 in the lower band on the $A(C)$ – $[Fe/H]$ diagram, indicating that there is no contamination by a binary companion. This star is also unique because it has a lithium abundance of $A(Li) = 2.02 \pm 0.08$, which is close to the lithium plateau level. Or from the upper limits in all other extremely iron-poor stars. The upper shell of lithium abundance in immature stars whose metallicity spans more than three orders of magnitude ($-6 < [Fe/H] < -2.5$). When the synthesis of helium in the central region of the star ends, the formation of nuclei composed of heavier elements begins, which occurs at a faster rate and takes less time. The physicochemical evolution of galaxies is the history of the accumulation in the galaxy of atoms of all those chemical elements that appear as a result of one or another process Fig. 1) [10].

Metal-poor stars

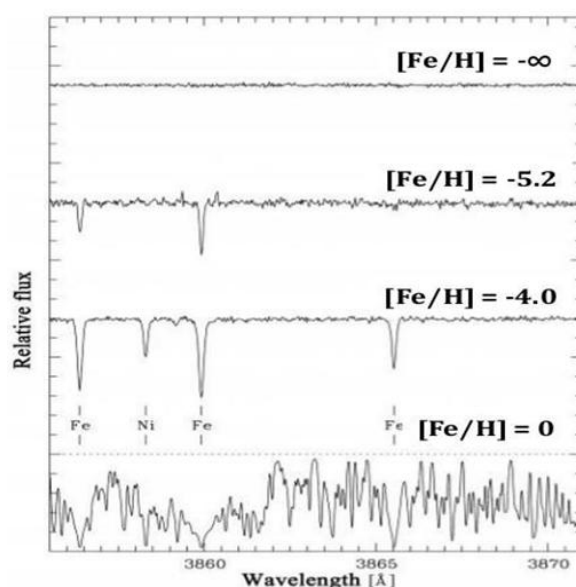


Fig. 1 Modern understanding of metal-poor stars [10]

Less massive galaxies retain gas weakly and lose heavy elements produced by stars, along with matter exiting the galaxy. Irregular galaxies also exhibit a lack of oxygen compared to spiral galaxies. The abundance of oxygen in spiral galaxies is correlated with macroscopic environmental parameters such as luminosity and rotation rate. Studies of the chemical composition of stars in our galaxy have shown the following differences: early and halo stars contain much less heavy elements than young stars and stars born in the disk the authors considered [12]. Galaxies NGC 147 and NGC 185 are the two most massive satellites of the Andromeda Galaxy. Even though they are close to each other in the sky and have the same mass, luminosity and morphological type, they have distinct star formation history (SFH), different amounts of interstellar gas and tidal distortion. Pulsating asymptotic giant branches (AGB) are thought to be appropriate probes to determine the dust production of these two galaxies. Galaxies NGC 147(E5) and NGC 185(E3) (in the sky towards Cassiopeia), four new clusters were observed in galaxies NGC 147 and NGC 185. Three of these are associated with NGC 147 and one with NGC 185. Despite their initial similarities, they exhibit some differences. NGC 147 is a typical E, consisting mainly of early stars and dust, and is free of gas [12].

However, NGC 185 has a significant number of intermediate-aged stars, as well as gas and dust. Table I gives the $[Fe/H]$ values for the clusters: NGC 147 and NGC 185.

TABLE I
[Fe/H] VALUES FOR THE STAR CLUSTERS UNDER CONSIDERATION

Object	[Fe/H]
N147-	$-1.9 \pm$
1	0.4
N147-	$-2.0 \pm$
2	0.4
N147-	$-2.1 \pm$

3	0.3
N 185-	-1.1 ±
1	0.2

Based on the analysis of the galaxy spectra and the data in Table I, we conclude that the evolution of the selected spherical galaxies occurred from right to left, and not vice versa, as is the case in the Hubble model [12].

Metal-Rich Stars

The most common elements in the universe were and are hydrogen and helium, and the heavy elements were most likely created by thermosynthesis at some stage.

It is an observed fact that, in the example of our galaxy, stars that were formed earlier are metal-poor stars, while relatively newly formed stars are metal-rich stars. Also, the gravitational factor, along with the chemical factor, also affects the evolution of stars [13], [14].

Of the stars studied, the star HD 19994 was found to contain the most metallicity, with a metallicity index of + 1.15 (this means that it contains $10^{1.15}$ times more metallic substances than the Sun), and the star J0023+0307, whose metallicity index is - 6.1 (this means that it contains $10^{-6.1}$ times less metallic matter than the Sun), turned out to be the poorest among the studied stars. It appears that the ecological state of our galaxy is currently at least 18 million times ($10^{1.15}/10^{-6.1} = 10^{7.25} \sim 18.10^6$) more polluted with metals in some parts of the galaxy than it was at the beginning of the birth of the second generation of stars.

III. CONCLUSIONS

We reviewed the evolution of celestial objects, stars, stellar environments, star clusters, and galaxies. The matter that makes up a star existed before it was conceived and will continue to exist after its "death", but, in the course of continuous evolution, it is only for a certain period of time in the state and type in which it represents a star. These stars also have masses larger than the Sun.

The further down the main sequence we go, the more the luminosity, masses, and effective temperatures decrease, reaching minimum values in the lower right corner of the diagram(Fig.1). A characteristic of young open clusters is that their faint stars have not yet reached the initial main sequence and, unlike other stars, they form a special grouping.

Regarding the evolution of selected spherical galaxies, it was shown on the examples of galaxies NGC 147(E5) and NGC 185(E3) that the evolution occurred from right to left, and not vice versa.

The paper also presents the poorest and richest stars in metals, their comparative characterization, and the changing ecological conditions in the universe in general.

Extremely metal-poor stars are rare in our galaxy, they are characterized by their carbon content and most likely formed after the first generation of stars.

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