Perspective

Stellar metallicity is a key parameter for the search of Life in the Universe

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Abstract

The search for Life in the Universe generally assumes three basic life's needs: I) building block elements (*i.e.* CHNOPS), II) a solvent to life's reactions (generally, liquid water) and III) a thermodynamic disequilibrium. It is assumed that similar requirements might be universal in the Cosmos. On our planet, life is able to harvest energy from a wide array of thermodynamic disequilibria, generally in the form of redox disequilibrium. The amount of different redox couples used by living systems has been estimated to be in the range of several thousands of reactions. Each of these reactions has a specific midpoint redox potential accessible thanks to specialised proteins called oxidoreductases, that constitute life's engines. These proteins have one or more metal cofactors acting as catalytic centres to exchange electrons. These metals are de facto the key component of the engines that life uses to tap into the thermodynamic disequilibria needed to fuel metabolism. The availability of these transition metals is not uniform in the Universe, and it is a function of the distribution (in time and space) of the supernovae explosions and complex galaxy dynamics. Despite this, Life's need for specific metals to access thermodynamic disequilibria has been so far completely overlooked in identifying astrobiological targets. We argue that the availability of at least some transition elements appears to be an essential feature of habitability, and should be considered a primary requisite in selecting exoplanetary targets in the search for life.

Keywords: habitability, trace elements, search for life, star metallicity, astrobiology, exoplanets

Main

The notion of habitability plays a key role in the search for Life in the Universe (see Box 1 for definitions of some of the terms used in this perspective). In astrobiology, habitability is usually defined as "the ability of an environment to support the activity of at least one known organism"[1]. The notion of habitability is given by the set of known physical and chemical conditions necessary for the emergence and the evolution of life as we know it. However, the knowledge of these conditions is still approximative. We have a primitive knowledge of Life as a natural phenomenon in the Universe, and the true limits of life on Earth are still largely undefined[2]. Hence, beside a universal definition of habitability[3], we need a conceptual tool which might guide the selection of the most promising targets[4]. Pre-selection of targets is unavoidable, as the astronomical searches for biosignatures are very expensive in terms of telescope time and data analysis effort. As both resources are strongly limited, an effective strategy in searching for life needs a reliable selection of targets, among the ever increasing number of known exoplanets.

The current notion of habitability is based on our present-day knowledge of the basic needs for the existence of life on Earth. In particular, the search for Life in the Universe generally assumes the three following requirements: a) building block elements, *i.e.* molecules composed of the so-called CHNOPS elements (Carbon, Hydrogen, Nitrogen, Oxygen, Phosphorus and Sulphur, the major macromolecules building elements used by life); b) a source of free energy which can sustain thermodynamic disequilibria[5] and c) liquid water, acting as a universal solvent to life's reactions[6]. There is no lack of the first two ingredients in the cosmos[7,8], and recent data suggest that water might be also abundant[9,10]. Here, we argue that the availability of transition metals is a strong constraint on the distribution of Life in the Universe, and should be systematically considered while selecting the most promising candidates for the search for extraterrestrial life.

Current data suggests that CHNOPS elements are present in a large number of organic chemical species in the interstellar medium, in the star-forming regions and in the planet-forming gas and solids in protoplanetary disks[7,11–13], making the basic building blocks of life a non limiting factor in the emergence and evolution of Life in the cosmos. The energy needed for biomass synthesis is also abundant in the Universe. Stars are a long-lasting and abundant source of free energy sustaining dynamic planetary atmospheres and the (eventual) biospheres. For instance, free energy flux is not a limiting factor for production of biomass by means of (hypothetical) oxygenic photosynthesis on exoplanets around main-sequence stars hotter than 3000 K (see, *e.g.*,[14]). Additionally, exoplanets and planetary bodies with an active geology supported by radioactive decay or tidal forcing might sustain life through geochemical and thermal disequilibria, as currently happening on Earth at deep-sea hydrothermal vents[15] and in other chemosynthetic dominated extreme environments[2,16]. Similar geological-derived thermodynamic disequilibrium supported by hydrothermal circulation is currently at play on the astrobiological targets Enceladus, Europa and Titan[17]. Hence, the first two necessary ingredients for life, CHNOPS building blocks and thermodynamic disequilibria, appear to be abundant on the cosmic scene and potentially in all planetary systems. For a long time, the limiting factor has been considered to be the presence of liquid water, and much attention has been devoted to the search for water, both in the Solar system and beyond[18]. However, recent observational data and theoretical studies suggest that the presence of water, and potentially subsurface liquid water, might be more abundant in the cosmos than previously estimated[19,20].

Considering all of the above, astronomers define the “habitable zone” as the circumstellar region where a rocky planet with an Earth-like atmosphere could have liquid water on its surface[1]. It is also currently accepted that the definition of habitability can be extended by specific planetary conditions that might support the presence of liquid water and temperatures conducive for life existence. For example, the presence of subsurface oceans on Enceladus, Europa and elsewhere in the Solar System makes icy moons promising targets[21], while the rocky subsurface of planets might be considered habitable if the vast subsurface ecosystems present on Earth[22] is taken into account This set of conditions includes a large number of possible astronomical targets that exceed our current observational capacity by several orders of magnitudes, and at the same time are based on a coarse understanding of Life’s requirements.

The role of stellar metallicity in habitability

Considerations on the availability of heavy elements in the context of habitability have focused so far almost exclusively on their role in providing the “bricks” for the formation and composition of planetary systems. In the currently accepted theoretical scenario for planet formation, planets form via a bottom-up process[23], the accretion of solid material in the protoplanetary disks around very young stars, from dust grains (scale of the order of 10^{-3} cm) up to planetesimals (order of 10^{6} m), where finally gravity kicks in dominating the formation process. Elements heavier than hydrogen and helium are essential in this process: indeed, the very first generation of stars after the Big Bang probably could not produce planets as we observe today, as most of the heavier elements have been formed through nucleosynthesis processes connected with star evolution[24].

Star metallicity (commonly measured as the ratio of iron to hydrogen and indicated with $Z_{\odot}$) appears to be correlated to the presence of giant planets[25], probably because the prestellar enrichment of heavier elements in the interstellar matter is necessary for the formation of the giant planets’ rocky cores (see[26] and references therein). Statistical analyses of known exoplanets show no trend between rocky planets occurrence and host-star metallicity[27], albeit this might change in the future as more exoplanets are discovered. Indeed, a low metal content in protoplanetary disk is expected to inhibit the fast accretion of rocky bodies massive enough to start aggregating the gas in the circumstellar disk before this is swept away by the strong winds of the star forming sun. Despite the lower metallicity threshold necessary for rocky planet formation is still unknown, theoretical models suggest that the first Earth-like planets might have formed from protoplanetary disks with metallicities $Z \gtrsim 0.1\, Z_{\odot}$[28].

Given the importance of metals in the formation of planets, it is not surprising that the relationship between star metallicity and habitability has been investigated in the past, focusing on the role of heavy metals on important characteristics of rocky planets. For instance, several authors have considered the role of heavy elements for planet formation and long-lasting geological activity[29], the duration of the habitable (temperate) zone[30] and the frequency of rocky planets in the habitable zone as a function of the metallicity[31,32]. However, it appears that the connection between availability of heavy metals, and specifically transition elements, and Life has been so far neglected in the astronomical literature.

The ever growing list of exoplanets host-stars measurements hints at a widely varying metal-enrichments at a given stellar mass[33–35], and at a diverse C/Fe ratio between stars with low-mass planets and stars without planets[36]. This suggests a possible relationship between CHNOPS distribution and metal availability that has yet not been explored in detail. Despite the importance of stellar metallicity in controlling planet formation, the availability of selected trans-iron transition elements might be fundamental in enabling the emergence and evolution of Life.

Metal availability as a key control on Life emergence and evolution

All life as we know it uses thermodynamic disequilibria to access energy used to drive energy- consuming chemical reactions. The “simple” act of converting an inorganic carbon molecule (most often in the form of CO_2) into a reduced organic carbon (like the one performed during photosynthesis to form glucose) requires accessing energy to drive an otherwise thermodynamically unfavourable reaction. The necessary energy is usually harnessed from available thermodynamic disequilibria in the environment, coupling electron donors and acceptors in biologically-mediated redox reactions (*e.g.*, hydrogen and carbon dioxide, commonly used as energy and carbon sources by methanogens in the reaction $4H_2+CO_2 \rightarrow CH_4+2H_2O$ are a common and probably old redox couple used by life). Sometimes complex energy sources are used to drive redox reactions, such as in oxygenic photosynthesis, in which photons are used to extract electrons from water. Life is thus capable of collecting the necessary energy using a complex molecular machinery that drives redox reactions in a controlled and precise way[37]. These nanoengines (see[38]) are proteins (specifically, catalytic proteins known as enzymes, Box 1) capable of catalysing redox reactions called oxidoreductases.

These enzymes are evolutionarily tuned to be able to transfer electrons to and from target molecules in a controlled way[38], allowing life to take advantage of the energy associated with the reaction and to perform chemical (and often physical) work (Box 2). Since redox reactions require the flow of electrons, oxidoreductases reaction centres need to be finely tuned in their midpoint electron potential to accept and donate electrons without dissipating unnecessary energy. The vast majority of known oxidoreductases uses a diverse set of metal containing cofactors. to achieve this[37]. For example, the vast majority of oxidoreductases utilised to extract high energy electrons from hydrogen (a common electron donor in microbial redox reactions) contain a nickel-iron metal cofactor[39,40], while many enzymes acting on oxygen (a strong electron acceptor respired by a large number of organisms) use instead copper containing cofactors to be able to gently pass electron to the strongly electronegative O_2 molecule[40,41]. While most known enzymes use one or more first or second row transition metals (see Figure 1), the list of biologically important metal cofactors is growing[42]. Only recently we have identified enzymes that catalyse the first step of methane oxidation (an important biosignature and greenhouse gas) using the rare earth elements lanthanum and cerium. The exact composition of the metal cofactors used by life is still unknown, however the majority of known oxidoreductases involved in key energy conserving reactions contain transition metals that include Fe, Cu, Mo, V, W, Co, Ni, Mg, Mn among others (see Figure 1). These biometals (*sensu*[42]) are *de facto* the key component of the engines that life uses to tap into the thermodynamic disequilibria needed to fuel metabolism.

Life on Earth is entirely dependent on the environmental availability of biometals in order to sustain its growth. For example, primary productivity in the oceans can be severely limited by the availability of iron[43], and similar controls might be exerted by diverse metals in other ecosystems[42]. Metal availability might also have played a key role in influencing the evolution of Life[44,45], as the availability of biometals has significantly changed over time as a results of key planetary transitions, such as the onset of plate tectonics[46,47], changes in volcanism[46,48] and the great oxidation event[49]. Given the tight link between the necessity to extract energy from thermodynamic disequilibria and the ubiquitous use of metals as key cofactor in accomplishing this, the role of metals in Life might be more fundamental than previously recognized[50], and should be considered as a key requirement to harness energy provided by the star or the geology of the planet.

Stellar metallicity as a key parameter in the search for Life

While we search our solar system and the Universe for targets of astrobiological interest, we argue that the availability of transition metals necessary to access a diverse array of thermodynamic disequilibria is an essential feature of habitability. Chemical elements heavier than helium (including all biometals) have been produced in detectable amounts relatively late in cosmic history[51] (Figure 1). According to the Hot Big Bang scenario, hydrogen and helium have been produced in the early primordial nucleosynthesis (when the universe was about 10 to 20 minutes old), while synthesis of heavier chemical elements could be possible in significant quantities only during several stages of stellar evolution, with the first generation of stars (the so-called Population III) appearing on the cosmic scene when the Universe was not younger than about 100-200 million years old[52]. While details are still highly debated, this scenario is strongly supported by the measured chemical abundances in the oldest stars in the Galaxy and the molecular clouds where new stars are formed[53].

All biometals lighter than iron are the outcomes of fusion nuclear reactions in the core of massive stars (*i.e.*, with a mass larger than about 2 solar masses)[24]. As iron is the most tightly bound nucleus (with binding energy 8.8 MeV per nucleon), it marks a separation between lighter elements that can be synthesised by the fusion of nuclei and heavier elements that are produced via nuclear fission processes. For instance, most of the heavy elements up to bismuth are produced in this way in type-II supernovae explosions[53]. Supernovae explosions have also a key role in diffusing the nuclear ashes in the interstellar medium enriching molecular clouds. As a consequence, the chemical compositions of molecular clouds and stars is a complex function of the position in the Galaxy, as a consequence of the star-formation history and supernovae explosions rate (which determine the production rate of heavy elements) and the Galactic dynamics and random merging events with smaller galactic systems (that affect the global mixing of chemical species in the disk).

Given that the distribution of elements above iron in the cosmos is a function of the distribution (in time and space) of the supernovae explosions and complex galaxy dynamics, the availability of these elements is not uniform in the Universe. Measurements of stellar metallicity are increasingly available for elements heavier than iron, allowing for the investigation of metal distribution in the host stars of distant planetary systems. In particular, the Apache Point Observatory Galactic Evolution Experiment (APOGEE[54]) has completed an homogeneous, high-resolution and high signal-to-noise spectroscopic survey of the stellar populations of the Milky Way, allowing to obtain a detailed chemical composition for about 146,000 stars. While the bulk planetary composition is controlled by the metal composition of the parent star[55], the crustal abundance of metals on a planetary scale is controlled by a large number of local factors. Processes like core formation, crustal differentiation, active geology and redox conditions of the planetary surface all influence the distribution and availability of CHNOPS elements and metals,[8,44] controlling their ultimate availability for Life. Despite this, first order estimates of bulk planetary composition might be enough to determine a first order approximation of the metal availability for life.

Current and future missions will rely heavily on our knowledge of the possible mechanisms leading to atmospheric biosignatures in order to determine the presence of Life. Among the most promising possible biosignatures, far from equilibrium atmospheric gases are considered particularly promising[56]. Compounds such as hydrogen and methane, detected concomitantly with oxidising gases like oxygen or nitrous oxide, suggest the presence of processes sustaining their recycling over time. These gases play a key role in the metabolism of life on Earth. Hydrogen is the most important electron donor in microbial metabolism, and the ability to utilise hydrogen in redox reaction is ubiquitous and probably evolved very early. Similarly methane is a key metabolic by-product of life, and recently the ability to produce methane from a variety of different chemical reactions has been discovered in all known domains of life[57,58]. Oxygen and nitrous oxide are both considered strong biosignatures as on Earth they are exclusively produced through life-controlled reactions (although, molecular oxygen in detectable traces could be due also to abiotic planetary processes, see, *e.g.*,[59]). The enzymes used by life to interact with these gases (either through their production or utilisation) use a diverse set of metals that are uniquely bound to these metabolisms (Figure 2). For example, hydrogen production and utilisation is possible thanks to NiFe containing enzymes, methane production is nickel and cobalt dependent while oxygen and nitrous oxide utilisation enzymes are dominated by the use of copper containing cofactors.

Therefore, the measurement of biometals abundance in exoplanets host-stars will allow a more reliable ranking of the most promising targets in the search for life, but also a thoughtful and more robust evaluation of the potential biosignatures. The concomitant presence of potential biosignatures and the correlated biometals (according to what we observe on Earth) would strongly support the interpretation of the discovery of a Life instance elsewhere in the Galaxy. In the case of the detection of far from equilibrium atmospheric gases with a *null* detection of the related biometals, we could not conclude to have found another living planet, or we should consider the option of a life-instance very different from what we already know, with quite different approaches to accessing thermodynamic disequilibria.

Given that the distribution of elements in the Galaxy is non-uniform (Figure 3), any target depleted in these metals might be discarded *a priori*, as the likelihood to be able to harness or transform energy through these processes might be limited. Clearly, under different environmental conditions other metals might be able to handle the electron flow required to interact with molecules, but overall the ability of metals to mediate redox reactions is a fundamental property of matter, and thus not expected to change even if the instance of life might change significantly in its composition or form. Akin to the requirement for thermodynamic disequilibria, we argue that the necessity to control redox chemistry is a fundamental property of Life itself, thus implying the use of metals in one form or the other.

Conclusions

It is necessary to move towards a new framework of discussion around the identification of current and future habitability targets. Several authors argue that in order to search for Life in the Solar System and beyond, a conceptually tight proof definition of life and, hence, of habitability, are essential[60]. However, we believe that such a definition could be only obtained at the end of our inquiry. In this early stage of our exploration, we need above all a robust and yet pragmatic definition of habitability which can serve us as a guide in selecting and prioritising promising targets. We argued that any notion of habitability must include the requirement of transition elements for life's metabolism. This is strongly supported by the role played by *all* biometals in life's metabolism on Earth. Even a null result of this search would have a deep scientific and cultural impact. But assessing a null result requires that our search is based on robust *a priori* probabilities for the existence of life as we know it and a rigorous target selection (as telescope time will always be limited). Effectively reducing the space of possibilities for Life requires a well-thought systematic astronomical search. In the near future, the ESA mission PLATO[61] will find hundreds of candidate rocky planets in the temperate zone of Sun-like stars. Companion follow-up spectroscopic observations will confirm the exoplanetary interpretation of the transit signals and to determine their mass and bulk density (via Doppler shift technique). A high-resolution (R ~ a few tens of thousands) spectroscopic follow-up aimed at measuring the presence of CHNOPS *and* biometals in the host-stars will be a valuable addition. This will allow the selection of the most promising exoplanet candidates for atmosphere characterization via transmission spectroscopy with the James Webb Space Telescope and the future space missions Ariel and Pandora. Ariel and Pandora are the first space missions entirely dedicated to the study of exoplanetary atmospheres, and will likely provide within a decade a census of astrophysical biosignature in nearby exoplanetary systems. In this search, there is the risk of incurring in a large number of false positives[62]. Coupling gas atmospheric disequilibria measurements with information regarding the availability of key metal cofactors (required for their production or utilisation) will provide an additional constraint on the identification of true biosignatures. Future studies regarding the influence of the availability of key metals in controlling the emergence and evolution of specific metabolic pathways on Earth and their role in generating abiotic biosignatures will be required. In this regard, a systematic high-resolution spectroscopic survey of nearby stars and of all the planetary systems host-stars will be a cornerstone in the search for Life in the Galaxy.

Data Availability

No new data was produced for this work.

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Competing interests

The authors declare no competing interests.

Contributions

This perspective was conceived and written equally by G.C. and D.G.

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Boxes

BOX 1. Key definitions at the interface between astronomy and biology

Life vs life. In this perspective we will refer to Life (with capital L) as a natural phenomenon in its entirety, while we will use life (all lower case) when referring to specific instances of the phenomenon, for example life on Earth.

Habitable Zone. Traditionally, the habitable zone is defined as the circumstellar region where a planet with an Earth-like atmosphere will have surface liquid water. This term can be misleading, as the presence of liquid water and the potential to host life only loosely overlap[63]. The so-called "habitable zone" is just a first order approximation of the effective habitability of a planet. More nuanced definitions have been proposed for the habitable zone[4], and the region where surface liquid water can be present is more appropriately termed "temperate zone." For instance, Shapley[64] already wrote about this proper concept in his work, and referred to it just as the "liquid water belt." In order to build a robust measure of exoplanets' potential to support life, a more comprehensive definition of habitability is needed.

Trace elements. Trace elements are operationally defined as the elements present in small quantities (a "trace amount"). This definition effectively changes the list of trace elements depending on the frame of reference. For example, in biology these are typically defined as all the elements necessary for the growth of organisms excluding the main building blocks elements CHNOPS, while in geology they are defined with respect to rock forming elements.

Metals. In astronomy, metals are broadly defined as all elements with atomic numbers larger than larger than 2. In chemistry, metals are elements that readily form cations in solution, are good heat and electricity conductors and form metallic bonds. Metals are further divided in alkali metals, alkaline metals, lanthanides, actinides, transition metals and metalloids.

Biometals. Biometals are defined as a subgroup of metals that have specific biological roles as cofactors with regard to protein structure and function.

Cofactors. Cofactors are organic or inorganic molecules that interact with the enzyme to activate or speed up (*i.e.*, catalyse), a chemical reaction.

Enzymes. A protein, or protein complex, capable of catalysing a set of specific chemical reactions.

Oxidoreductases. A specific group of enzymes involved in oxido-reduction reactions.

Biomass. The total mass of organisms in a given area or volume, often expressed in terms of amount of carbon. Biomass is created through metabolic processes that are fueled either by the breakdown of organic carbon compounds (heterotropy) or the synthesis of organic compounds from inorganic precursors (autotrophy).

BOX 2. Redox chemistry and energy in living systems

Life uses a large number of chemical elements to build up its biomass. The main macromolecules composing life biomass are lipids, proteins, carbohydrates and nucleic acids. All these macromolecules are composed for the vast majority by a small number of elements known as life's building blocks. These elements, namely carbon, hydrogen, nitrogen, oxygen, phosphorus and sulphur (often referred to as the CHNOPS elements from their chemical formula) on average constitute up to 98.9 % of an organism's dry weight. The availability of these elements is considered essential for the emergence of Life, and their availability across time and space can limit the amount of biomass produced. In addition to CHNOPS elements, living organisms need a large number of other elements that appear in minor abundance (trace elements) within molecules and organic and inorganic cofactors[65]. This is due to the crucial role that trace elements have in chemical reactions that Life uses to obtain energy and build up biomass.

Life on our planet is able to harvest energy from a diverse array of thermodynamic disequilibria, generally in the form of redox chemistry. This is generally accomplished by diverting ions (mainly as protons) and electrons through different paths in the cell, ultimately allowing to build up electrochemical potential used to store energy and carry out work. The amount of different redox couples that life is able to utilise has been estimated to be in the range of several thousands of reactions, to which we need to add the ability of life to extract high-energy electrons using light from a broad wavelength range (*i.e.*, phototrophy). Each of these reactions has a specific midpoint redox potential that life on Earth is able to access thanks to specialised proteins called oxidoreductases, that constitute life's engines. These proteins, generally, have one or more metal cofactors that directly act as catalytic centres for exchanging electrons. The exact range of redox potential available to each oxidoreductase is controlled in a variety of different ways, starting with the use of a diverse array of transition metals that include Fe, Cu, Mo, V, W, Co, Ni, Mg, Mn among others (Figure 1). Recently the role of trace elements in controlling metabolisms has come into focus (see[42] for a review), and diverse initiatives are honing on the role of trace elements in controlling life emergence and evolution.

Figures

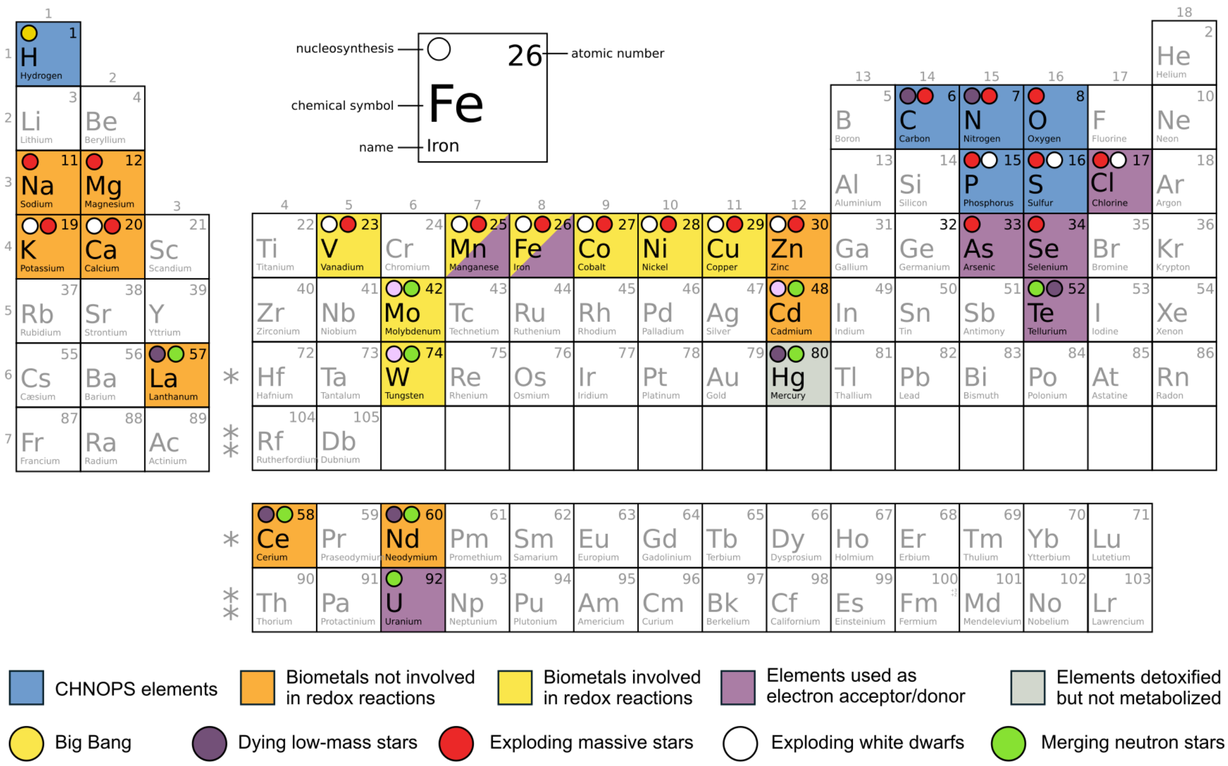

Figure 1. Periodic table of elements and their nucleosynthesis. Biological utilisation of the elements and biometals (in orange and yellow) and their nucleosynthesis processes in the Universe. CHNOPS elements and elements used as electron donors/acceptors by biology are also reported. Iron and Manganese are the only biometals that not only serve as cofactors, but might be used as metabolic substrates for redox reactions.

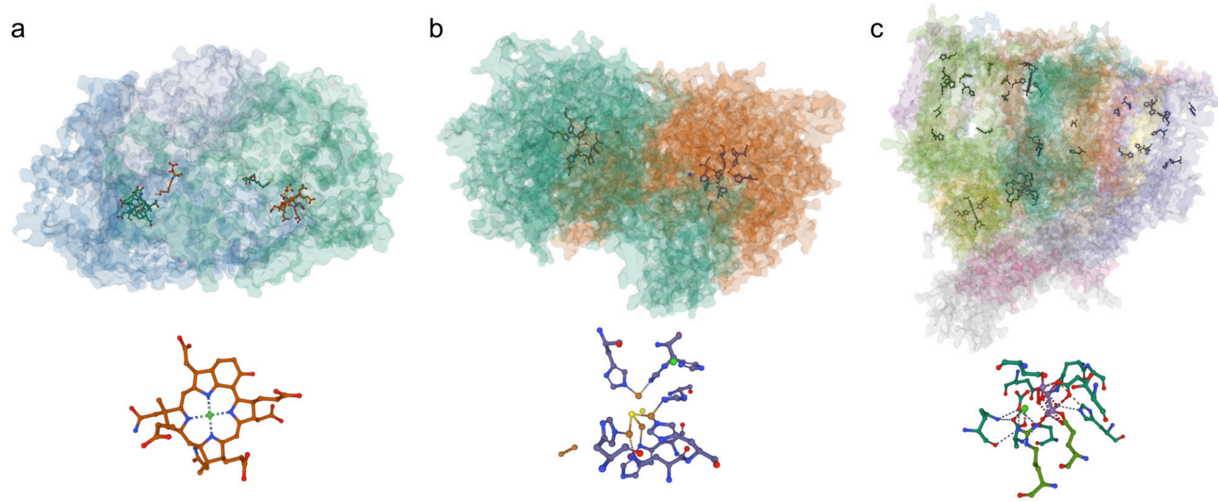

Figure 2. Example of metal containing enzymes involved in the production or utilisation of possible biosignature gases such as CH_4, N_2O and O_2. The three dimensional structure of the protein is showed as a continuous molecular surface (with significant transparency applied for visualisation purpose) colored according to the different amino acid chains, while the cofactors are shown using a ball and stick model within the enzyme and on their own colored according to the type of atoms. **a**, The key enzyme for methanogenesis, the Methyl-coenzyme M reductase from the archaea *Methanopyrus kandleri* (McrA, Protein Data Bank accession number 1E6V. Structures can be visualised and inspected at https://www.rcsb.org/). The nickel containing F430 cofactors are visible within the enzyme in two copies, together with other small ligands. The structure of the nickel (Ni^{2+}) containing F430-cofactor (the nickel atom is colored in green) responsible for the last reduction step required for methane production is visible below the enzyme. **b**, The enzyme responsible for the production of nitrous oxide, Nitrous oxide reductase from the bacterium Pseudomonas stutzeri (NosZ, PDB 3SBR) with the two copper containing cofactor visible within the enzyme. The structure of the copper sulphide cofactor (Cu_4S_2) and the dinuclear copper is visible below the enzyme. Copper atoms are colored in orange while sulphur atoms are in yellow. **c**, The complex multimeric structure of the Photosystem II from the cyanobacterium *Thermosynechococcus elongatus* (PSII, PDB 1S5L), where the oxygen evolving complex responsible for the splitting of water in oxygenic photosynthesis is located. All the chlorophyll and pigments have been removed for visualisation purposes. The structure of the oxygen evolving complex $CaMn_4O_4$ cofactor, the site of water splitting and oxygen generation is visible below the enzyme. Calcium is colored in green, while manganese and oxygen are colored in purple and red respectively.

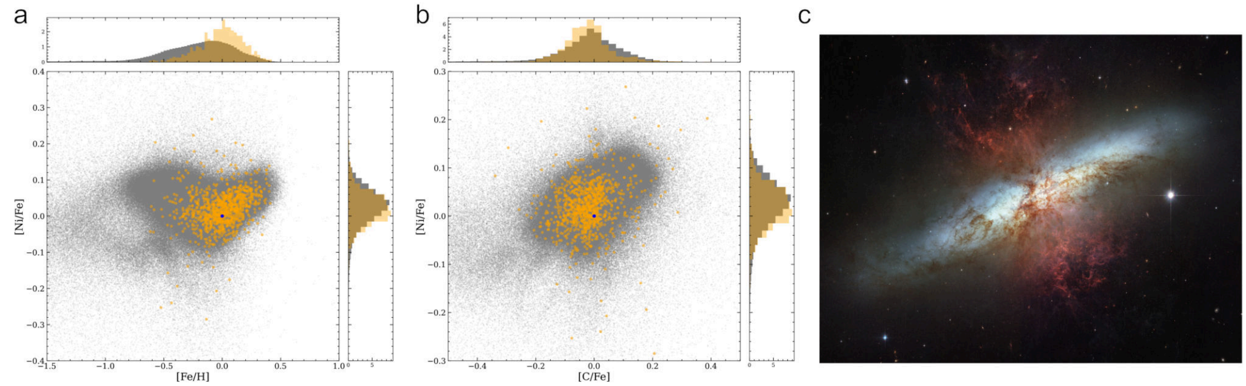

Figure 3. Examples of the distribution of key biometals in the APOGEE star catalogue. Stars with known planets are colored in orange. The Sun is colored blue. **a**, Ni/Fe composition as a function of star metallicity measured as Fe/H. **b**, Ni/Fe distribution as a function of star carbon abundance expressed as C/Fe. **c**, Messier 82, also known as the Cigar Galaxy, a starburst galaxy approximately 12 million light-years away in the constellation Ursa Major, imaged by the Hubble Space Telescope (435 nm, 555 nm, 658 nm and 814 nm) showing the plumes of glowing hydrogen blasting out from its centre and spreading supernova materials light years away (credits: ESA/Hubble). Similar events fertilise the cosmic neighbour of the biometals necessary for life to emerge and evolve.