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The violent youth of solar proxies steer course of genesis of life

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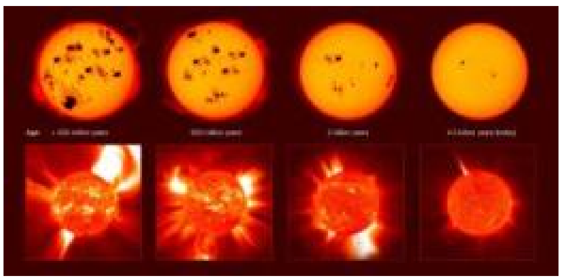

Stars similar to our Sun -- "solar proxies" -- enable scientists to look through a window in time to see the harsh conditions prevailing in the early or future Solar System, as well as in planetary systems around other stars. These studies could lead to profound insights into the origin of life on Earth and reveal how likely (or unlikely) the rise of life is elsewhere in the cosmos. This work has revealed that the Sun rotated more than ten times faster in its youth (over four billion years ago) than today generating a stronger magnetic field and stronger activity. This also meant that the young Sun emitted X-rays and ultraviolet radiation up to several hundred times stronger than the Sun does today. Credit: IAU/E. Guinan

Just how rare life is in the Universe is one of the key questions in the natural sciences today. By pulling in multidisciplinary expertise from biology, geology, physics and astronomy, astrobiologists are addressing different facets of this very profound question, and notably how the conditions around different types of stars in an early stage of development might help or hinder the emergence of life in a solar system. Several scientists at the forefront of this research have just concluded IAU Symposium 264 on "Solar and Stellar Variability -- impact on Earth and Planets".

The Sun is awe-inspiring and fearsome — a superheated ball about 300,000 times as heavy as the Earth, radiating immense amounts of energy and hurling great globs of hot plasma millions of kilometres out into space. The intense radiation from this giant powerhouse would be fatal close to the Sun, but for a planet like Earth, orbiting at a safe distance from these violent outbursts, and bathed by a gentler radiation, the Sun can provide the steady energy supply needed to sustain life. Now sedate and middle-aged, at around 4.5 billion years old, the Sun's wild youth is behind it.

Edward Guinan, a professor of astronomy and astrophysics at Villanova University in the USA, and his "Sun-in-Time" project team have studied stars that are analogues of the Sun at both early and late stages of its lifecycle. These "solar proxies" enable scientists to look through a window in time to see the harsh conditions prevailing in the early or future Solar System, as well as in planetary systems around other stars. These studies could lead to profound insights into the origin of life on Earth and reveal how likely (or unlikely) the rise of life is elsewhere in the cosmos. This work has revealed that the Sun rotated more than ten times faster in its youth (over four billion years ago) than today. The faster a star rotates, the harder the magnetic dynamo at its core works, generating a stronger magnetic field, so the young Sun emitted X-rays and ultraviolet radiation up to several hundred times stronger than the Sun today.

A team led by Jean-Mathias Grießmeier from ASTRON in the Netherlands looked at another type of magnetic fields — that around planets. They found that the presence of planetary magnetic fields plays a major role in determining the potential for life on other planets as they can protect against the effects of both short-lived intense particle storms when the star ejects mass from its corona and the persistent onslaught of particles from the stellar wind. Grießmeier says: "Planetary magnetic fields are important for two reasons: they protect the planet against the incoming charged particles, thus preventing the planetary atmosphere from being blown away, and also act as a shield against high energy cosmic rays. The lack of an intrinsic magnetic field may be the reason why today Mars does not have an atmosphere".

Guinan explains a surprising realisation that emerged from their work: "The Sun does not seem like the perfect star for a system where life might arise. Although it is hard to argue with the Sun's 'success' as it so far is the only star known to host a planet with life, our studies indicate that the ideal stars to support planets suitable for life for tens of billions of years may be a smaller slower burning 'orange dwarf' with a longer lifetime than the Sun — about 20-40 billion years. These stars, also called K stars, are stable stars with a habitable zone that remains in the same place for tens of billions of years. They are 10 times more numerous than the Sun, and may provide the best potential habitat for life in the long run". He continues: "On the more speculative side we have also found indications that planets like Earth are also not necessarily the best suited for life to thrive. Planets two to three times more massive than the Earth, with a higher gravity, can retain the atmosphere better. They may have a larger liquid iron core giving a stronger magnetic field that protects against the early onslaught of cosmic rays. Furthermore, a larger planet cools more slowly and maintains its magnetic protection. This kind of planet may be more likely to harbour life. I would not trade though — you can't argue with success".

Manfred Cuntz, an associate professor of physics at the University of Texas at Arlington, USA, and his collaborators have examined both the damaging and the favourable effects of ultraviolet radiation from stars on DNA molecules. This allows them to study the effect on other potential carbon-based extraterrestrial life forms in the habitable zones around other stars. Cuntz says: "The most significant damage associated with ultraviolet light occurs from UV-C, which is produced in enormous quantities in the photosphere of hotter F-type stars and further out, in the chromospheres, of cooler orange K-type and red M-type stars. Our Sun is an intermediate, yellow G-type star. The ultraviolet and cosmic ray environment around a star may very well have 'chosen' what type of life could arise around it".

Rocco Mancinelli, an astrobiologist with the Search for Extraterrestrial Life (SETI) Institute in the USA, observes that as life arose on Earth at least 3.5 billion years ago, it must have withstood a barrage of intense solar ultraviolet radiation for a billion years before the oxygen released by these life forms formed the protective ozone layer. Mancinelli studies DNA to delve into some of the ultraviolet protection strategies that evolved in early life forms and still persist in a recognisable form today. As any life in other planetary systems must also contend with radiation from their host stars, these methods for repairing and protecting organisms from ultraviolet damage serve as models for life beyond Earth. Mancinelli says "We also see ultraviolet radiation as a kind of selection mechanism. All three domains of life that exist today have common ultraviolet protection strategies such as a DNA repair mechanism and sheltering in water or in rocks. Those that did not were likely wiped out early on".

The scientists agree that we do yet know how ubiquitous or how fragile life is, but as Guinan concludes: "The Earth's period of habitability is nearly over — on a cosmological timescale. In a half to one billion years the Sun will start to be too luminous and warm for water to exist in liquid form on Earth, leading to a runaway greenhouse effect in less than 2 billion years".

Source: International Astronomical Union