For life to form on a planet it needs to orbit the right kind of star

December 2 2014, by Belinda Nicholson, Brad Carter And Jonti Horner

Artists conception of the a star with two Saturn-mass planets discovered by the Kepler satellite. NASA/Ames/JPL-Caltech

In the search for life-sustaining planets we must first choose the right host star.

There are many factors that would make a star system too hostile for life to even get started, let alone survive for any period long enough to evolve.

So what sort of star provides the perfect conditions for a habitable planet elsewhere in the universe?

Not too young

The earliest known evidence of life on Earth is from around 3.5 billion years ago, about one billion years after the formation of our planet.

Life may have existed before this, but we can use that date as a first estimate of the amount of time needed for life to become so established that we can detect its signature across interstellar distances.

This immediately gives us a criterion by which we can whittle away otherwise promising targets for the search for life. If a planet's host star is too young – even if that planet seems otherwise perfect for hosting life – it won't have had the time for life to become established.

Not too big

The biggest, brightest stars are like the rock-stars of the galaxy. They live fast but die young.

The lifetime of a star is roughly inversely proportional to its mass cubed. This isn't a perfect relation (things are actually a bit more complicated), but it isn't too far off.

So a star ten times more massive than our sun would live for just 1/1000th as long. We expect our sun to have a life in excess of 10 billion years, so a superstar with ten times our sun's mass would live just 10 million years. That's far too short for life to develop and thrive on any of its planets.

So the most massive stars will live and die far too quickly to be good targets in the search for life. It turns out that the most massive star that would have a life-span long enough for life to become established is just one and a half times the mass of our sun. This sets an upper limit on the mass of our targets.

Not too small

The smaller a star, the less hot and luminous it is. To illustrate this, consider the sun's closest stellar neighbour, Proxima Centauri. Proxima is about one eighth the mass of our sun. Despite its proximity, it remains a factor of a hundred times too faint to see with the unaided eye.

The low luminosity of these dim dwarfs means that their planets must orbit closer in order to be habitable. However, if you move a planet sufficiently close to its host star it will become trapped – knows as tidally locked – keeping one face perpetually turned towards its host, just like our moon and the Earth.

Proxima Centauri lies in the constellation of Centaurus (The Centaur), just over four light-years from Earth. Credit: ESA/Hubble & NASA

Whether life could develop and thrive on a tidally locked planet is still the subject of debate. We can certainly not rule out life in such an environment, particularly since there are scenarios that allow a planet to keep rotating with respect to its host (Mercury is trapped in our solar system, spinning just three times on its axis for every two laps around the sun).

Such scenarios would help ensure the planet does not get too hot on one side verses the other, but are certainly less ideal than the best target would be. So given this difficulty, a rough lower limit on the mass of a perfect host star is about half the mass of our sun.

Not too violent

Like our sun, stars have been observed to have magnetic activity – displayed through spots and flares – and emit a continual wind of plasma particles into their surroundings (like the solar wind).

While our sun can be quite active with solar flares that can overload power-grids and telecommunications systems, it is relatively well-behaved and reserved compared to the activity observed on other stars.

The smallest stars are often seen to be quite violent, with some showing massive flare activity. This reinforces our conclusion that small stars are not the ideal first place to look for habitable planets.

Beyond this, it is well known that younger stars are typically much more active than older ones, irradiating the planets that orbit them with strong stellar winds. This, again, may well not prove conducive to the development of life, as violent winds could strip a planet of its atmosphere, and the high energy radiation contained in stellar flares can damage or extinguish any newly formed life.

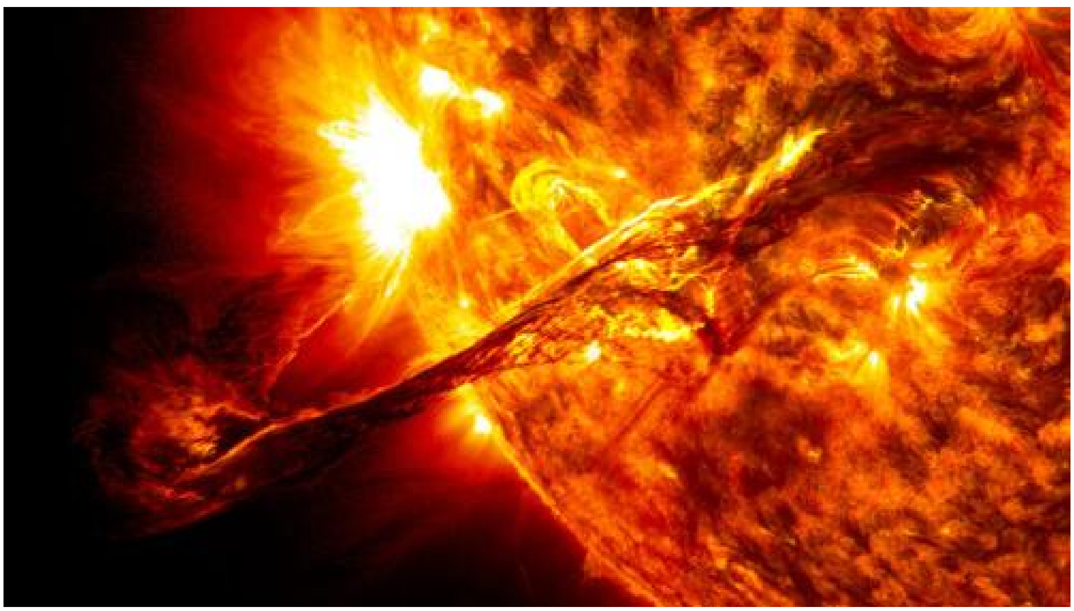
Not too rich and not too poor

The elemental composition of a star – what astronomers call its metallicity – determines what types of rocky planets, if any, will form around it.

The big bang, from which all matter in the universe originates, produced vast amounts of hydrogen and helium, but vanishingly small amounts of all other elements. Everything else - the carbon, nitrogen and oxygen that make up our bodies, was produced in the furnaces at the heart of the first generations of stars.

Each star and the planets around it are made from the same material. Depending on where and when the stars formed, they can have vastly different quantities of the heavy elements that are so crucial for the development of life.

If a star has a low metallicity – too element-poor – then it seems unlikely that it will have enough heavy elements to form rocky, earth-like planets in the first place.



A large prominence erupting from the surface of the sun, captured by NASA's Solar Dynamics Observatory. Credit: NASA/SDO/AIA/Goddard Space Flight Center

If a star has a high metallicity - is far richer in heavy elements than is our sun – then the planet formation process might well proceed along a far different path than that which resulted in our own solar system.

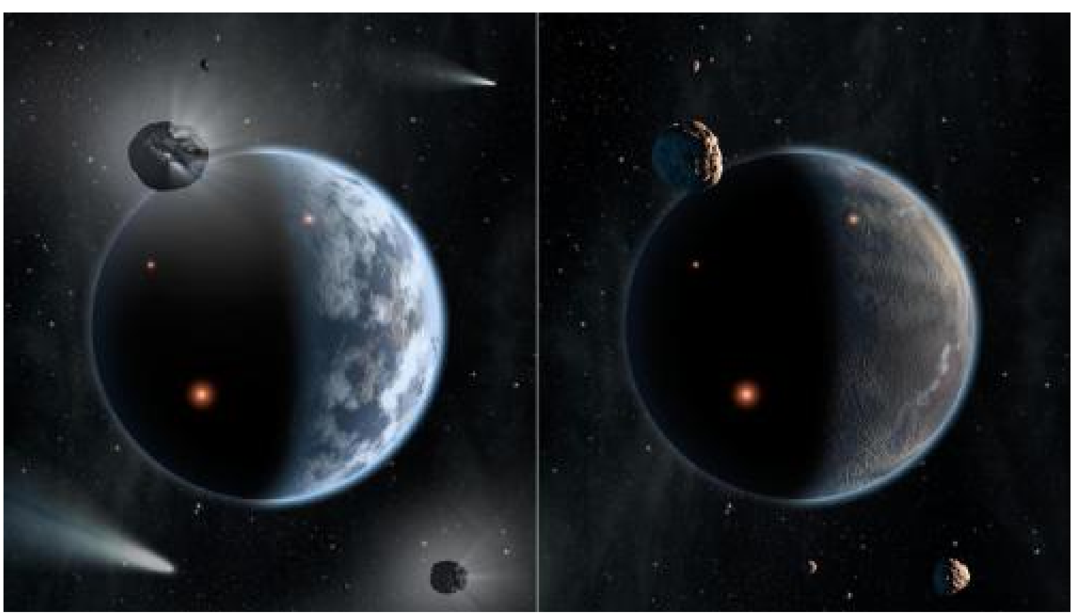
A number of recent studies have considered the chemistry of the planets that would form around high metallicity stars. Their findings are remarkable. Rocky planets that form around stars significantly more metal rich than our sun may well be "diamond planets", rather than the silicate-based worlds we see in our solar system.

Whether such planets could host life is an open question – we have no examples to study up close and so have little to no understanding of how they would evolve with time. But planets that are so different to our own are not the first place we'd look, should we wish to maximise our chances of a successful discovery.

Not too crowded

The ideal host star for a habitable planet is probably one that is solitary, without a binary companion and not surrounded by too many other stars in a cluster.

Other stars complicate the picture and would make a planet in such a system markedly different to our own Earth.



Credit: NASA/JPL-Caltech

In recent years, a number of planets have been discovered moving on stable orbits in binary star systems, either orbiting one star in a widely separated binary, or around both in a close binary.

It is clearly possible that life could develop and thrive on such worlds. But, again, their situation is so different from the Earth-like system it appears this is not the first place we should look for habitable planets.

This recipe isn't complete

When searching for life beyond the solar system, it is clear that the nature of an exoplanet's parent star will play a critical role in choosing the best targets to study.

But the story doesn't end there. Even after whittling down our list of promising targets in this manner, we will doubtless be left with tens, if not hundreds, of promising worlds.

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