Hi this is Steve Nerlich from Cheap Astronomy www.cheapastro.com and this is *Habitable zones*.

A so-called habitable zone is a narrow circumstellar region within which the surface conditions of celestial bodies will allow liquid water to form. We tend to think think that liquid water probably offers the best environment in the Universe for sustaining and evolving life, since it is probably the Universe's most abundant chemical solvent. In the absence of a solvent, atoms and molecules will tend to just sit there. But in a solvent, the can move around and they can interact. In a solvent, you get what we call chemistry.

Of course if life needs water to get started, it's also going to need water to keep going, something you can readily learn for yourself by camping out in the desert for a few days. So for a habitable zone to be really habitable, not only do you need to have water in a liquid phase, you also need it to stay that way. Indeed, if you want a rich ecosystem from which intelligence might feasibly arise, you may need liquid water to persist for billions of years.

So if you want habitability, you should start by looking for a celestial body that is orbiting its star in just the right temperature zone. A planet is an obvious candidate, but it is possible you could also have a habitable moons. Indeed, in the cases of the Solar System moons Europa and Enceladus, it turns out that their distance from the Sun is almost irrelevant, since their subsurface water reservoirs are kept heated by geothermal activity.

Nonetheless, a planet in a stable orbit around a stable star is more likely to offer a habitable environment that can remain stable over billion-year timeframes. But it's not just the temperature zone that's important, you also need the right sort of planet. You need a planet with a solid surface, a lowish albedo and an atmosphere that can absorb and retain heat. In fact, an atmosphere is crucial – not only to retain heat, but also create pressure. Even at ambient temperatures, water will quickly evaporate into its gas phase if exposed to a vacuum. You need the right temperature and an atmospheric pressure exceeding that temperature's vapour pressure if you want to retain water as a liquid.

And, even then, it's not just about the planet. The type of star that a planet orbits is also a key consideration. With hot, massive and short-lived O,B or A class stars you can probably forget about habitability. These stars pump out so much stellar wind that any planets around them, even if they are in the right temperature zone, could not hope to hang onto an atmosphere, let alone an ocean.

But fortunately, these big short-lived stars represent a relatively small proportion of all the stars in the Universe. In fact, most stars in the Universe are at the other extreme, being small and long-lived red dwarves. We have already found several technically habitable-zone planets orbiting red dwarfs. However, because red dwarves have lower temperature outputs than higher stellar-class stars, their habitable-zone planets have to orbit much closer to the star, indeed so much closer that they may become tidally-locked.

Once a planet isn't spinning, it loses any chance of having a magnetic field, which is generated by the motion of a molten inner-core. The absence of a magnetic field is problematic for red dwarf planets, since red dwarves tend to be highly-erratic variable stars. A planet orbiting in close proximity would be exposed to unpredictable outbursts of x-rays and high-energy stellar wind particles. It's unclear if habitable zone red dwarf planets could hang onto an atmosphere under these conditions. So while red dwarf planets in habitable zones may be common, it remains to be seen if they really are all that habitable.

For these reasons we are forced to the admittedly-parochial conclusion that the most likely habitable locations in the Universe will be Earth-like planets orbiting Sun-like stars. This assumption may be proved wrong the moment we achieve First Contact, but until then it's the best working hypothesis we've got.

Earth-like planets around Sun-like stars can stay warm while orbiting further out from the star, since a Sun-like star is both hotter and more massive than a red dwarf. Such stars may only maintain habitable conditions for 5 to 10 billion years. But heck, if your ecosystem can't produce technology-wielding space colonists over those timescales, you're just not trying.

One of the closest Sun-like stars is Tau Ceti, which, like the Sun, is also a solitary G type star, although it's only 78% of the mass of the Sun. Tau Ceti has a lower metallicity, which means it probably formed earlier – maybe a billion years earlier. Tau Ceti has an unconfirmed exoplanet in its habitable zone, Tau Ceti e, which is 1.8 Earth masses, but it is increasingly thought to be a bit too close-in and hence a bit too Venus-like for genuine habitability.

The first exoplanet found, that might conceivably support an ocean of water, was Gleise 581d, which is a so-called super-Earth and may be up to 7 Earth masses – or as Wikipedia likes to describe it, half a Uranus. However Gleise 581 is a red dwarf and 581d's precise position in or out of that star's habitable temperature zone remains the subject of some heated debate. Small astronomy joke there.

To try and better grapple with the complexities of habitability, which needs to consider the complexities of temperature, planetary characteristics and also stellar spectral classes, people have developed the Earth Similarity Index – which you can find by looking for the "List of Potential Habitable Exoplanets" on Wikipedia.

Top of the list is KOI-1686.01, although KOI stands for Kepler Object of Interest meaning it was detected by the Kepler space observatory, but its features still remain to be confirmed by secondary ground-based observations. Kepler's preliminary observations put KOI-1686.01 in the habitable zone around a star that is about half a solar mass, while the planet is about 1.3 Earth masses. On that basis, the exoplanet has an Earth similarity index of 0.89, where Earth has an Earth similarity index of 1.0. In other words, KOI-1686.01 is about 89% similar to Earth.

The highest *confirmed* exoplanet on the List of Potential Habitable Exoplanets is Kepler-62e (currently ranked No. 3), which is about 83% similar to Earth. It was also discovered by the Kepler observatory, but has since been confirmed by ground-based observations. It is estimated to be 1.6 Earth masses and orbits a star, of about 0.7 solar masses, every 122 Earth days.

The next confirmed exoplanet down the list is Gliese 667 Cc – being a planet orbiting the star Gliese 667 C. This exoplanet is 82% like Earth, although it is over 4 Earth masses. Its star is a member of a trinary system, meaning its sunsets would put the binary sunsets on Tatooine to shame. Gleise 667Cc is worth particular mention here since its only 23 light years away, while KOI-1686.01 and Kepler-62e are both over 1,000 light years away.

But once again, Kepler 667C is one of those pesky red dwarves.

If we decide instead that our search for habitability should focus on finding the right kind of stars, then the nearest solar analogue (that is, a star like the Sun) is Delta Pavonis. Delta Pavonis is a solitary star of 0.99 solar masses and it's only 20 light years away. Delta Pavonis was not in the Kepler observatory's search region and to date ground-based observations have not found any radial velocity shifts.

But, whether or not it has planets, time is running out for Delta Pavonis, which is several billion years older than the Sun. Because it is nearly the same mass as the Sun, Delta Pavonis is nearly ready to turn into a red giant. Let's hope that if anyone is in orbit, they can get out of there in time. To date, the SETI institute reports no radio source of technological origin from Delta Pavonis – but then that's the same result for every other extrasolar system in the Universe that SETI has scanned so far.

Finding out whether habitable worlds are actually habitated is the next big challenge – and what an astronomical challenge it is.

Who knows what, or who, is out there.

Thanks for listening. This is Steve Nerlich from Cheap Astronomy, www.cheapastro.com. Cheap Astronomy offers an educational website that keeps you in the zone. No ads, no profit, just good science. Bye.

Pronunciation guide:

Tau Ceti – Tau rhymes with Mao (as in Chairman Mao); Ceti -Settie.

KOI – Kay Oh I, not Koy

Numbers in star names – read as digits (i.e. Five Eight One, not Five hundred and eighty one)

Gleise – Glee-sah

Pavonis – Pav (lova), on (not off), is (this without th)

SETI – Settie (don't spell out the letters).