Hi this is Steve Nerlich from Cheap Astronomy www.cheapastro.com and this is *Alien biology - The case for water.*

This the first of two podcasts on the possibilities of life and extraterrestrial intelligence.

It's a mighty big universe with a current estimate of 100 billion galaxies with an average of 300 billion stars each – which means around 30 sextillion stars in all. And in a universe this big, if something can happen once – it seems almost inevitable that it is going to happen more than once, at least somewhere in this vast expanse. So since terrestrial intelligence has happened – you'd think you could comfortably put money on it happening extra-terrestrially.

You have probably heard of the Drake equation which seeks to define the likelihood of us finding extraterrestrial intelligence within our galaxy. Essentially the equation states that from a large population of stars, a certain number will have planets and a certain number of those will capable of supporting life. Then it's a question of what proportion of planets that can support life actually do - and then what proportion of those ecosystems might support the development of an intelligent species. From there, it's just a question of what proportion of those intelligent species either accidentally or deliberately broadcast a detectable signal - with the consideration of whether such a signal arrives in the period in which we are capable of detecting it.

The last point is important since we know the Milky Way galaxy is quite old, at least 12 billion years old - and our 5 billion year old Solar System has appeared well into the second half. Could we have missed all the action already? Has the United Federation of Planets already been and gone and everyone's since left through a wormhole into a younger parallel universe - just when we had started banging the rocks together down on our little bluey green planet here. Or if all the aliens haven't already left is everyone just holding back to see what these crazy humans are really like before they strike up a conversation?

But on the other hand, we might be one the first intelligences to emerge. You need a few generations of star formation and supernovae to create heavier elements necessary for the development of a complex ecosystem. After all, we know it took us at least 3.5 billion years to get from photosynthesis to landing on the Moon. So maybe it does take 12 billion years for any intelligence to emerge in a new galaxy.

But we do need to come up with explanation for an apparent rarity of extra-terrestrial intelligence – since like the Fermi paradox says – if they are out here, why can't we hear them? The best answers to this seem to be:

1) Perhaps we shouldn't assume that broadcasting is a natural consequence of intelligence – after all the Earth is becoming increasingly radio-quiet as we move to cable and fibre based communication.
2) Perhaps we are one of the first to emerge – or otherwise the signals of other recently emerged intelligences haven't yet crossed the light year distances necessary to reach us.
3) They're aliens – with a thoroughly alien perspective on life, the universe and everything. This perspective might not include a desire to communicate with other aliens, like us.

Anyhow – let’s assume they’re out there and we just haven’t found them yet.

It may seem a little Earth-centric to assume that alien biochemistries probably require liquid water, but they probably do. Given the chemical possibilities available from the most abundant elements in the universe, even an alien scientist with some other exotic biochemistry would still agree that a water-based biochemistry would be the most likely type to emerge in our universe – and that alien would probably also agree that water would be the most likely foundation for a complex ecosystem from which intelligent life could emerge.

Based on what we know of life and biochemistry, it seems likely that an alien biochemistry will need a solvent (like water) and one or more elemental units for its structure and function (like carbon). Solvents are important to enable chemical reactions, as well as physically transporting materials – and in both contexts, having that solvent in its liquid phase seems a necessity.

We can expect that any common biochemically useful solvents are most likely to form from the most common elements in the universe – which are, in order: hydrogen, helium, oxygen, neon, nitrogen, carbon, silicon, magnesium, iron and sulfur.

You can probably forget about helium and neon – being noble gases, they are largely chemically inert and only rarely form chemical compounds, none of which obviously have the properties of a solvent. Looking at what’s left, the polar solvents you could make are firstly water (H_2O), then ammonia (NH_3) and hydrogen sulfide (H_2S) and various non-polar solvents can also be formed, notably methane (CH_4). Broadly speaking, polar solvents have a weak electric charge and can dissolve most things that are water-soluble, while non-polar solvents have no charge and are more like the industrial solvents we make on Earth, for example turpentine.

Isaac Asimov, who when he wasn't writing science fiction was a biochemist, proposed a hypothetical biochemistry where poly-lipids (essentially chains of fat molecules) could substitute for proteins in a methane (or other non-polar) solvent. It has been suggested that such a biochemistry could be supported on Saturn’s cold moon Titan.

But nonetheless, water looks to be by far the best candidate to support a complex ecosystem elsewhere in the universe. After all, it is likely to be the most universally abundant solvent around – and it occurs in its liquid phase at a higher temperature range than any other solvent. A biochemistry should be more dynamic in a warmer environment which has more energy available to drive biochemical reactions. And in such a dynamic environment organisms can grow and reproduce (and hence evolve) that much faster. Water also has some useful chemical properties going for it:

1). A strong surface tension (three times that of liquid ammonia) – which would encourage organic compounds to collect together and perhaps encourage the development of membranes;
2). Being a polar solvent means it can form weak electrostatic bonds – which, supports the 3d structure of proteins in Earth biochemistry; and

3). It can engage in electron transport reactions, the key method of energy production, by donating a hydrogen ion and its corresponding electron.

Now, it is the case that on Earth that hydrogen sulfide gas is used in electron transport reactions by some Earth-based chemosynthetic bacteria – but as a fluid hydrogen sulfide only exists in a temperature range of -90 ^{o}C to -60 ^{o}C at 1 atmosphere of pressure.

And while we are on the subject, ammonia is only a liquid between -80 ^{o}C to -30 ^{o}C and methane is only a liquid between -180 ^{o}C and -160 ^{o}C, at least at 1 atmosphere of pressure.

These points at least make a strong case for liquid water being the most statistically likely basis for the development of complex ecosystems in warm environments elsewhere in the universe. Although other biochemistries based on other solvents are quite possible – it seems likely they will be limited to cold, low energy environments where the rate of development of biological diversity and evolution may be very slow. The only exception to this rule might be high pressure environments which can sustain those other solvents in their fluid phase at higher temperatures - where they would otherwise be a gas at a pressure of 1 atmosphere, the air pressure at sea-level on Earth.

Thanks for listening. This is Steve Nerlich from Cheap Astronomy www.cheapastro.com. Cheap Astronomy offers an educational website putting the chemistry back in astronomy podcasting. No ads, no profit, just good science. Bye.