Planets Outside Our Solar System: Looking for Signs of Life by **Professor Alan Aylward**
of University College London, a talk given by Zoom on 16-10-20

There are about 400 bn stars in our galaxy, many of which will have exoplanets ('exo' denoting outside the solar system). Our galaxy is about 120,000 light-years (LY) across; the Sun about 27,000 LY from the centre. About 170 bn galaxies have been observed.

Voyager 2, at its exit speed from the Solar system, would take 86,000 years to reach the nearest star.

Liquid water is necessary for life on Earth, and presumably beyond. Mars had oceans, there is water in the gas giant planets and some of their moons: Enceladus, orbiting Saturn, emits plumes of water; Jupiter's Europa has an icy crust over a subsurface ocean possibly over a mineral 'soup'.

The Kepler probe looked at about 160,000 stars and found 4175 confirmed exoplanets in a patch of sky in Cygnus - the number is now 4334. To be seen an exoplanet's orbit must be closely aligned with Earth. If perpendicular it would escape detection, implying several times as many exist than have been observed. Another, European, probe, Gaia, is making repeated observations of many more stars, the results of which should indicate vastly more exoplanets.

Gliese 581 is a red dwarf star about 20 LY away from the Sun in the Libra constellation. Its estimated mass is about a third of that of the Sun, and its luminosity about 1%. It has several exoplanets, a large one with a 'year' measured in days, causing a regular dimming as it crosses in front of its star. The rotation of the star & exoplanet is about a common centre, so light from the star is Doppler shifted. Both the dimming (perhaps only by 0.1 to 1%) and the Doppler shift can be measured. Measurements by both methods enable a better characterisation of an exoplanet.

HD 80606 is a star which UCL have studied with a telescope with a 35cm mirror. It is 190 LY away, and is accompanied by several moons; one a hot gas giant moon, with a mass 4 times greater though it is slightly smaller than Jupiter. Its density is slightly less than Earth's. It has an extremely eccentric orbit, similar to Halley's comet, with an orbit taking it very close to its star and then very far out every 111 days.

There are some distant stars which have been observed by *microlensing*. A *lens*, which can be a massive star or galaxy, in the path of light from the star, blocks the line of sight but through gravitational attraction produces displaced, magnified images of the star. Such alignments are rare, but if maintained for a reasonable (by human standards) length of time, yield evidence of other phenomena as well as exoplanets.

One surprise was to find Jupiter-like exoplanets orbiting close to their stars. A simulated model of Jupiter was placed in an orbit close to the Sun – and found to be stable despite the more intense radiation.

It has also been found that the Solar planetary system is not typical of exoplanet systems around other stars; indeed none has yet been found that even approximately matches it. There are exoplanets which orbit more than one star; giants close in and rocky farther out… In astronomical timespans exoplanets can do a dance - and it is now thought that our planets had a quite energetic dance as the solar system evolved.

The exoplanets found so far range in size from 1/3 the size of Earth to 10,000 as big, but their numbers peak at between one to two times the size of Earth.

Exoplanetary atmospheres: can something be inferred about their atmospheric composition?

As an exoplanet crosses in front of its star certain wavelengths, corresponding to the absorption spectra of the components of the exoplanet's atmosphere, will cause a dip in the normal characteristic. Seeing dips requires the use of a highly sensitive interferometer, with the bright centre of the star masked out, as dips can be as small as 0.01%, with readings often affected by single pixels. To study such details about an exoplanet, there is an effective limit of 14 LY from Earth, and the exoplanet has to be large and orbit close to its star. Many orbits are measured and averaged to get a result.

The dips in a star's ultra-violet spectrum can be related to elements or small molecules in its atmosphere. Infra-red dips, seen when the exoplanet goes behind the star, can give information about the exoplanet's surface. However, if the exoplanet is not at an Earth-like temperature, one needs to know the spectra of said elements or small molecules from a few to thousands of degrees Kelvin – which are seldom available.

Life: In the Solar system the habitable zone extends from Venus to Mars. Professor Aylward put up a table:

Mean temp, ^{O}C	Without Greenhouse Gasses	On The Surface	With Greenhouse gasses
Venus	-43	470	513
Earth	-17	15	32
Mars	-55	-50	5

Proxima Centauri, a red dwarf about 4.2 LY from the Sun has an exoplanet, Proxima Centauri b, which orbits the star in 11 (Earth) days. It is in the star's habitable zone, as the star is cooler than the Sun.

The star's spectrum has been measured as Proxima Centauri b orbits, and the difference from the shape of the normal output is mostly due to the presence of water and methane molecules in its atmosphere. This hints that Proxima Centauri b may have the possibility of life. Small organic molecules also have their spectra, but unless present in high concentrations would be virtually impossible to detect.

See: Discovering Earthlike Planets by Dr Anglada-Escudé on 18 May 2018

Telescopes – To extend the range at which exoplanets can be studied there are several factors that have to be taken into account. Having the telescope in space gets the best signal. But an accompanying spectroscope is too heavy, at 40 tons, to put up there too. On the Earth's surface atmospheric effects have to be corrected, but much larger diameter telescopes are being planned. A telescope on the back of the Moon (away from light from Earth) ?