Question 1:

Dear Cheap Astronomy – Is the Universe an e8 crystal?

Well… probably not, if only because most theoretical models rarely survive the journey to be genuine evidence-based theory without some major modifications along the way. e8 theory has some broad similarities with string theory, insofar as it is also a proposed theory of everything , aiming to unify standard model particle physics and general relativity – that is, Einstein's theory of gravity. But, just like string theory, it's probably not be appropriate to call e8 theory a theory, since its evidence basis is pretty-much non-existent. It's a hypothesis – and a largely untestable one, at least with any current technology.

Nonetheless, as with most theoretical models, you can't just dismiss it out of hand, since the Universe, that is everything, clearly exists, so there clearly must be an underlying theory of everything, although it's one that we are yet to formulate. So, that underlying theory of everything could be e8 theory or it could be string theory, or it could be some weird combination of the two, or it could be something totally different. And of course, by the time we do establish a theory of everything, we will probably have realised that what we thought was everything is actually only a small part of what everything actually is – and then we will commence a search for a theory of absolutely everything.

Anyhow, in asking whether the Universe is any kind of a crystal, what we're really asking whether it has an underlying organised structure of repeating patterns. You can have two dimensional crystals which are like a simple grid drawn out on a piece of paper and you can three dimensional crystals – like a cubed lattice or a dodecahedronal lattice – and such 3d crystals would include things like quartz, glass and diamonds – things that we usually think of as being crystals.

In fact, those animations that science communicators like to make, where you see spacetime drawn as a 2 dimensional grid that is then curved into hills and valleys due to the distribution of mass in the Universe, end up implying that the Universe is a crystal, in a technical sense, since that grid pattern is a repeating pattern that pervades the Universe. Indeed, any kind of field theory, which is based on any kind of matrix mathematics pretty-much implies that the Universe is a crystal, in a technical sense.

But to say the Universe is an e8 crystal requires accepting of a lot more weirdness than just that. Again, a bit like string theory, e8 theory tries to explain everything by appealing to the existence of extra dimensions – and not surprisingly e8 theory requires that there be 8 dimensions. A bit like hologram universe theories, e8 theory claims that the Universe we perceive as three spatial dimensions and time is really the projection of an eight dimensional crystal universe onto the four dimensions that we are able to see and experience. So, e8 theorists like to call our perceived Universe a quasi-crystal.

The real weirdness though, comes from e8 being an emergence theory, where it's implied that the projection of the e8 crystal onto our three spatial dimensions and time, self-organises itself from a random mess of lines and angles into the Universe of particles and forces that we are familiar with – indeed, the way that e8 theory deals with time means that self-organisation has an inevitability about it, so the past forms the future – and the future also forms the past. It's all about retro-causality time loops apparently.

If you aren't already cringing a little, it's also implied there's some kind of self-actualisation built into reality, which inevitably leads to the existence of self-aware beings, perhaps because it's their future awareness that drives the past to self-organise out of chaos. So, while the stuff about the 8 dimensional crystal universe projecting onto our 3d plus time dimensional universe is kind of interesting - in the same way that string theory's 10, 11 or 26 dimensional Universe is kind of interesting. But if the existence of the Universe depends on us as its self-actualising agents, then we position ourselves and maybe other and smarter aliens at a privileged non-Copernican position – notwithstanding that any Universe whose existence depends on our intelligence is in a bit of strife from the start.

Question 2:

Dear Cheap Astronomy – Can we directly image exoplanets and check for life signs.

Well, we can directly image them. There's an easily found list of directly imaged planets on Wikipedia. Of course, any such images are just small smudgy dots. There are limits on just how much you can magnify an image from light years away. For a start, to get high resolution images you'd need to ramp up your aperture diameter by orders of magnitude. But that's not the whole story. Even with ideal magnification, you'd obviously need to be above the Earth's atmosphere to avoid scattering and distortion effects, but even then there won't be a perfect vacuum between you and an exoplanet – and the further away it is, the further that problem will be compounded as more and more tiny gas and dust particles get in the way.

The second issue and possibly the biggest current barrier to exoplanet imaging is the exoplanet's star. Currently one of our best methods for finding exoplanets is by occultation, where the planet passes in front of its star and the star's light dims slightly as a consequence. However, trying to take an image of a planet that's in front of, and being backlit by, its blazingly-bright star is close to impossible. A star like the Sun is about a billion times as bright as the reflected light from any of the planets orbiting it.

Even imaging planet that's side lit by its star, with blackness of space behind it, is challenging. One option is to just to plonk an opaque disc in your field of view which will block out a star's light, but still allow you to collect photons from around its edges. Or you can try to isolate wavelengths of light that reflect off the planet but are not radiated by the star in those same wavelengths.

Given these limitations, it's not surprising that some of our best successes in direct exoplanet imaging to date have been exoplanets that orbit their star at a significant distance – which are probably well outside any kind of habitable zone.

Spectroscopic analysis of exoplanet atmospheres is at a similar state of early development. So, yes we've done it, but the resolution is low. For spectroscopy, it's actually good to have the planet occulting its star since you get a well-defined light source shining through the exoplanet's atmosphere back to Earth. We have so far detected sodium, water vapour, carbon monoxide, carbon dioxide, methane, hydrogen and helium in exoplanet atmospheres – and we've found indirect evidence of clouds, no clouds and even a stratosphere - although all these successful measurements come from less than twenty of the nearly 4,000 exoplanets that we currently know about. But, it's a start and, like direct imaging, we'll get better at this, probably a lot better.

If anyone finds definitive evidence of a biosignature on an exoplanet it'll be on the evening news, you won't need some cheap podcast to tell you about it. Nonetheless, the court is still out on what a definitive biosignature is. Finding water is encouraging, but just indicates potential habitability, not actual life. There are various geophysical processes that can put methane and even molecular oxygen in an atmosphere, although if you detected a 20% oxygen atmosphere you might start thinking there's got to be something else going on there. Probably the best biosignatures of all are also advanced civilisation signatures, like chlorofluorocarbons or nitrogen dioxide. Both are produced by industrial processes and not plausibly by any natural events. However, CFCs and nitrogen dioxide both arise from the particular mix of chemistries we have on Earth. Perhaps, one day we'll discover complex molecules that we know can't be produced naturally, but which we couldn't easily replicate on Earth, because they arise from an alien chemistry set.