Is it Aliens? The Most Interesting Star in the Galaxy

Professor Chris Lintott

29 April 2024

Is it aliens? One day could we see something in the sky - some sign or signal, some unexpected discovery - which would reveal the presence of intelligence waiting for us out there amongst the stars? Throughout this year's lectures I've mentioned discoveries, from the putative canals on Mars to Jocelyn Bell Burnell's pulsars, where some, at least, felt intelligence must be involved.

In truth, there is barely an astronomical discovery that someone hasn't attributed to alien life. My own favourite example is the brief fad, when high energy gamma-ray bursts were discovered in the 1980s, for considering that they might be the flashes produced by spacecraft accelerating faster than the speed of light. Closer to home, our interstellar visitor.,'Oumuamua, looked to some like a spacecraft as it sped through the Solar System. Even the third stage of the Apollo 12 rocket that carried astronauts to the Moon has been recently rediscovered and mistaken for an alien surveillance craft.

Many of these suggestions lie in a grey area between science and conspiracy, between scientific enquiry and pointless speculation. There is, though, a growing interest in the search for these 'technosignatures' - looking for the effects of intelligent life on the cosmos rather than for biological signatures of life themselves - as a way of dealing with the apparent lack of aliens turned up by fifty years or so of searching.

This absence of life is increasingly glaring given our success in the last thirty years in finding potential homes for life. We now know that the physics and chemistry that produced the diversity of worlds we see in our Solar System (described in lecture 2 of this series) has worked throughout the galaxy to produce a remarkable diversity of worlds, five thousand of which are now recorded in our catalogues.

Only a very few have been seen directly, not because such planets are intrinsically faint but because the glare from their parent star overwhelms them. Instruments known as coronagraphs can mimic the spectacular effect of a total solar eclipse, blocking out much of the stars light, and giving us images like those of the four-planet system around the star HR8799, but this technique only works well for faint dwarf stars.

Most of the planets we know about have been found by indirect means. One option is to watch for changes in spectra due to stars wobbling as the gravity of their planets pulls them towards and then away from us. This 'radial velocity' technique relies on spectroscopy of exquisite precision, capable of discerning a movement of less than a meter per second - planets are, after all, much smaller than their stars and thus their gravitational influence rather feeble.[1]

The problem with the radial velocity technique is that it is expensive, requiring a star to be monitored over a long period of time to establish the presence or otherwise of a planetary system. The transit technique, by contrast, allows many stars to be monitored at once, with the hope of spotting a dip in brightness caused

---

[1] In the next few years, data from the European Space Agency's *Gaia* satellite, our most accurate stellar cartographer, will enable us to find planets by literally watching the movement of stars on the sky, too

by the passage of a planet in front of them.

We have to be lucky for such an alignment to take place; it turns out, for example, that astronomers on one of the planets around nearby Teegarden's Star, which happen to orbit in a plane very close to that of our Solar System's planets, would see the Earth pass in front of the Sun once every year. The dip would be small - much less than one percent - but the repeated observation of transits would reveal the Earth's presence, its orbital period and its size. Cunning comparison between spectra obtained with the planet in transit and to one side can even reveal the nature of a planet's atmosphere.

Together, these techniques have revealed a diversity of planets that exceeds what many would have expected. Hot Jupiters are found closer to their stars than Mercury is to the Sun, completing an orbit every few days, and alongside them lava worlds, hot enough that any rocky surface must surely be molten. Further out, we have found the most common size planet - a superEarth, sitting between our planet and the ice giants, Uranus and Neptune - is a type lacking completely around the Sun.

From planets around double or triple stars, to worlds where sand falls as rain, to a planet with a ring system that puts Saturn's to shade, everything imagined by science fiction writers has turned out to be out there, waiting to be discovered. However, plot the properties of the population of planets we've found, and a pattern becomes apparent; we have found many more planets close to their stars than further away.

This is the result of an inherent bias in the technique: planets closer to their star make bigger transits, and their shorter orbital periods mean that we can collect more transits in a given period of observation. Most techniques for identifying transits in data which also includes changes of brightness due to stellar activity and changing observing conditions and instrumental performance look for repeated dips, missing out on the longest period planets.

For this reason, we have been taking data from NASA's planet hunting satellites, Kepler and then TESS, and asking volunteers on the PlanetHunters.org website to sort through them, keeping an eye out for single transits. This is remarkably effective, with the majority of long-period planet candidates found in TESS data coming via the efforts of these volunteers[2].

As with many of our citizen science projects[3], Planet Hunters volunteers have proved adept at finding things they weren't specifically looking for. Early in the project's life, attention was drawn to an otherwise unremarkable star known by the catalogue number KIC8462852. This was one of 200,000 stars studied by the Kepler satellite, engaged in a three year project to stare at a single patch of sky, on the border between the constellations of Cygnus and Lyra. KIC8462852 showed two dips early in this period of observation, but no third dip. As planets don't disappear, this ruled out a planetary origin for the events that had been seen, and no-one would have paid much more attention if the star hadn't, a year later, dimmed again, this time rapidly. For a period of around five days, the star was almost twenty percent fainter than normal, and still more unusually it then returned to its prior brightness and carried on shining like nothing had happened.

No other star in the Kepler dataset had ever done anything like this, and IC8462852 had not finished. A year later, there were nearly three months of dramatic change, with seemingly random variations in brightness causing the star to flash from observation to observation.

What was happening? The volunteers, including the experienced Darryl LaCourse, developed a model of a planet surrounded by a dust disk, dense and large enough to be capable of blocking out the light from the star. Such disks are seen around young stars, but KIC8462852, by this time referred to as the WTF star, is middle aged. Furthermore, the presence of enough dust to obscure the star should have meant that the

---

[2] Just last week, our sister project led by researchers in Belfast and using data from the ground-based Next Generation Transit Search announced the discovery of five new planet candidates, including what might be the lowest mass star to host a hot Jupiter, and another planet around what turns out to be a binary star.

[3] See Zooniverse.org for more than 100 projects you can get involved in.

system shines brightly in the infrared, but a check of the archives showed no infrared excess.

team led by Tabby Boyajian, now at Louisiana State University, started to check ever more obscure explanations. Neighbouring stars showed no sign of similar changes, and we event went so far as to check which pixel of the camera was involved in each measurement, in case some bizarre systematics were at work. Eventually, we had shown to our satisfaction that this really was the star misbehaving, and we published our results.

We did feel the need to have some explanation, and settled on blaming comets. These icy bodies swing in from the outer solar system, and occasionally break up. Biela's comet, for example, appeared in 1836, then again in 1832, before coming back as two pieces in 1846 and vanishing completely after its 1852 visit to our neighbourhood. Planet Hunters volunteers had already helped establish that exocomets existed around stars other than the Sun, so we invoked the break up of a massive comet around the WTF star. The idea was that this would have produced a string of comet pieces, each capable of causing a transit.

This idea had some merits; comets, being icy, do not glow brightly in the infrared and so we could 'hide' material to block the star without predicting an infrared excess. We could also, by rearranging our cometlets, predict any observed pattern of fluctuations the star cared to show (whether this makes it a better theory, or a less useful one, is perhaps an interesting question).

Unfortunately, we know quite a lot about comets. A typical comet, like 67P/Churyumov–Gerasimenko which was explored by ESA's Rosetta spacecraft, has a nucleus only a few kilometres across. Explaining the deep dips in brightness displayed by the WTF star would have required a much larger object, which must have broken up shortly before Kepler started observing it. Furthermore, as we see no other examples of such large transits around any other star, this comet must be nearly unique.

It was beginning to feel like too much of a coincidence. Others, calling the star Tabby's star, or Boyajian's star, started to propose their own solutions to the problem. Of them, the proposal from Jason Wright and co, published in the prestigious Astrophysical Journal[4] caught most attention. Their paper, entitled 'The Search for Extraterrestrial Civilizations with Large Energy Supplies. IV. The Signatures and Information Content of Transiting Megastructures' suggested that the light from the star was being blocked by the passage in front of it of fleets of orbiting solar panels, built by an intelligent but power-hungry civilization.

Such an idea, known as a Dyson sphere or swarm, is an old one, going back to Olaf Stapledon, the philosopher and science fiction writer I quoted in my first lecture, in the 1930s. His novel Star Maker inspired Freeman Dyson, the iconoclastic physicist, who considered how such structures might be detected. Now, Wright et al proposed, we may have found just such an object.

It's an interesting hypothesis, certainly, and it attracted plenty of attention. It suffers from the same flaw as our comet idea, in that any pattern of dips could be explained by invoking an arbitrary set of solar panels. It is also interesting to consider what the status of this claimed technosignature discovery from a SETI point of view; few would consider the changes in brightness alone sufficient evidence to claim the discovery of intelligence, but thinking about what to do next to test the idea was not straightforward.

In the meantime, people had been looking for more data on our favourite star. A particularly valuable intervention came from Harvard's library, where a multidecade effort had digitized the collection of astronomical photographic plates from the early twentieth century. Our star appeared on several, but they revealed a slow (we'd say 'secular') decline in brightness over the course of the century. What was one mystery - what was causing the sudden changes we observed - had just become two.

By now, Boyajian's star was known as the most interesting star in the galaxy, and an extensive monitoring campaign was underway. The primary Kepler mission had ended when a fault on board the spacecraft cost it its ability to point consistently at its target patch of sky, and so we used the LCOGT network of robotic

---

[4] Disclaimer: I'm one of the editors

telescopes to monitor the star. When it dipped, this time we were ready and telescopes around the world pointed at the star.

The crucial observations came from small telescopes in the Canary Islands and in Hawai'i. These showed that cameras with filters that allowed through blue and red light both saw dips in brightness, but the degree of fading was different in each. This means that, whatever is blocking the star, it can't be a solid object - no solar panel, but maybe something like a cloud of dust getting in the way.

Where did the dust come from? That's still not clear, but I have a favourite theory, first suggested by Brian Metzger and colleagues. They believe that Boyajian's star, sometime in the last thousand years, has consumed a planet. The addition of debris from such a meal to the star's upper atmosphere would, we think, cause the star to heat up and brighten, fading slowly as the remains of the planet were mixed into the bulk of the star. The sudden dips could then be caused by rubble left over from the planet's pre-prandial destruction, or more dramatically, by a queue of similarly doomed smaller objects in similar orbits, on their way to destruction.

This is a neat idea, explaining both parts of the puzzle in one go. It also has interesting implications, implying a perhaps unsettling degree of instability. How common is it for stars to be consumed by planets? A study earlier this year looked at double stars, which formed together, and which should therefore have the same composition; one in twelve, though, differed from their companions, with the mix of extra heavy elements suspiciously like what one would expect from planet consumption.

If one in a dozen solar systems around Sun-like stars are unstable enough to lead to planets plunging into their stars, then perhaps we have found a solution to the apparent absence of aliens - a stable solar system is just hard to come by. But there may be a catch; the use of double stars makes this experiment possible, but wide doubles are also influenced by the galaxy in a way that single stars are not, with galactic tides often altering the orbits of the two stars around each other. This might be the cause of the instability that sends planets to their doom, and it might suggest - and we really need to check this - that Boyajian's star should be a double.

Whatever its status, it encouraged people to look for similar behaviours in other stars. The most infamous is HD 139139, observed by Kepler during its first mission, which seems to show common, deep dips in brightness at random times, at some periods as often as once every few days. Could it be a large population of planets? A comet or a planet disintegrating? Or, perhaps, an alien megastructure?

Andrew Vanderburg, who led the study of the object, should have the last word: 'In astronomy we have a long history of not understanding something, thinking it’s aliens, and later finding out it’s something else,” he says. “The odds are pretty good that it’s going to be another one of those.” In the meantime, we're having to be patient, as recent observations with ESA's Cheops spacecraft showed no transits at all. Has its behaviour changed? All we can do is keep looking.

I said earlier that Boyajian's star had inspired new enthusiasm in the search for technosignatures. Such thinking goes back at least to Dyson, who suggested looking for his eponymous swarms of solar panels by seeking their infrared signature; several systematic sources for surprisingly bright infrared sources have been carried out over the last few decades. Optical SETI programs have looked for flashes of laser light being used for communication, the colours of asteroids in our Solar System have been examined to see if any look surprisingly metallic, and we have even surveyed nearby star systems to hunt for the debris caused by alien mining efforts. Some (optimistic?) researchers have even looked at the light coming from whole galaxies to see if there are signs of a full scale technological boom underway.

The upcoming Vera Rubin Observatory, a survey telescope equipped with a 8 meter mirror and the world's largest digital camera, will produce mountains of data worth filleting for the unusual and unexpected. At a recent workshop thinking about how to make use of this data, ideas from the sensible - looking for alien signals broadcast in response to significant cosmic events, such as nearby supernovae - to the more outlandish, like wondering if a sufficiently advanced civilisation would find it amusing or aesthetically pleasing to make stars in distant regions of the galaxy flash in unison. We may soon have the dataset we need to check.

This is, I think, the real lesson from Boyajian's star. It may not have turned out to be aliens this time, but thinking about its behaviour allows us to meet the challenge posed by the remarkable diversity of planets we see in the galaxy by thinking about a remarkable range of behaviours. Thinking creatively might be key to finding our neighbours in this vast cosmos.

Further reading

Many of these topics are explored at greater length in my new book: *Our Accidental Universe*, Trova, 2024. Available now!

Up-to-date statistics and details of exoplanet discoveries are always available at https://exoplanetarchive.ipac.caltech.edu/

You can help us try to find planets at www.planethunters.org.

The new Planet Hunters NGTS discovery is described in O'Brien et al, Astronomical Journal, 167, 5, 238: https://iopscience.iop.org/article/10.3847/1538-3881/ad32c8. Previous Planet Hunters discoveries are listed at Zooniverse.org/publications.

Our original paper on Boyajian's Star is 'Planet Hunters IX. KIC 8462852 - where's the flux?', Boyajian et al, 2016 Monthly Notices of the Royal Astronomical Society (MNRAS), 457, 4 https://ui.adsabs.harvard.edu/abs/2016MNRAS.457.3988B/abstract

The alien suggestion was made by 'The G^ Search for Extraterrestrial Civilizations with Large Energy Supplies. IV. The Signatures and Information Content of Transiting Megastructures ', Wright et al, 2016 Astrophysical Journal (ApJ), 816, 1, 17 https://ui.adsabs.harvard.edu/abs/2016ApJ...816...17W/abstract

See also:

'Secular Dimming on KIC 8462852 following its consumption of a planet', Metzger, Shen & Stone, 2017, MNRAS, 468, 4, 4399 https://ui.adsabs.harvard.edu/abs/2017MNRAS.468.4399M/abstract

'The First Post-Kepler Brightness Dips of KIC 8462852', Boyajian et al. 2018, ApJ Letters, 853, L8 https://ui.adsabs.harvard.edu/abs/2018ApJ...853L...8B/abstract

For a summary of recent thinking on technosignature searches see Lazio et al: https://arxiv.org/abs/2308.15518