Exoplanets and Astrotheology

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SEARCHING FOR ANOTHER EARTH: THE RECENT HISTORY OF THE DISCOVERY OF EXOPLANETS

by David Wilkinson

Abstract. The discovery of exoplanets is a small part of the array of scientific arguments for and against the existence of extraterrestrial intelligence. Yet the recent stunning achievement of this program of observational astronomy has had a significant effect on scientific opinion and public interest. It also raises some key theological questions. New observing techniques are leading to the discovery of extrasolar planets daily. Earth-like planets outside of our Solar System can now be identified and in future years explored for signs of life. This article maps the history of these discoveries and highlights some of the theological issues which are important to bring into dialogue with these scientific insights.

Keywords: exoplanets; search for extraterrestrial intelligence (SETI); theology

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The discovery of exoplanets is one of the fastest moving areas of science. When *Science, Religion and the Search for Extraterrestrial Intelligence* (Wilkinson 2013) was published, the author noted the difficulty that, unusually amongst works in theology, it would be quickly out of date. This is especially true for the chapter which dealt with the discovery of extrasolar planets, where the number and range of planets being discovered daily is extraordinary.

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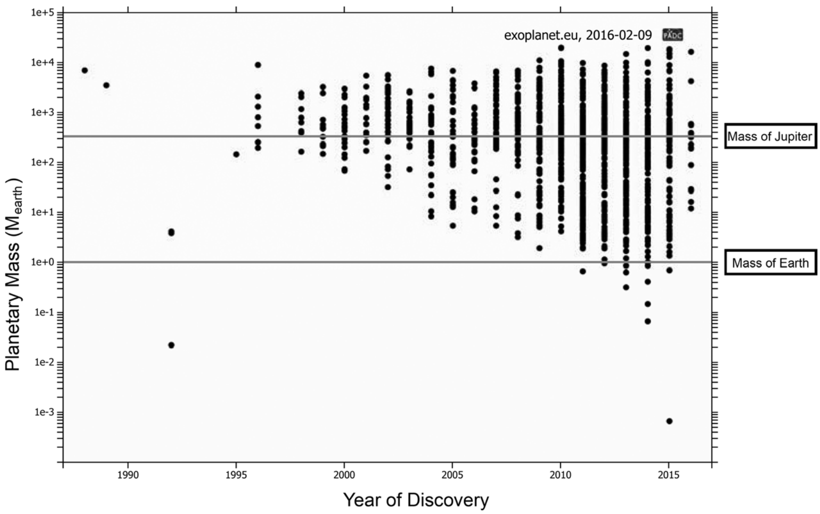

Figure 1. Extrasolar planets by year of discovery and their mass

At the time of writing this article, *The Extrasolar Planets Encyclopaedia* notes 2,069 planets and from its database we can see, as illustrated by Figure 1, how the number of planets discovered has increased in recent years.[1]

In this figure the year of discovery of a planet is plotted against a log ratio of its mass compared to the mass of the Earth. The dashed lines show the mass of the Earth and the mass of Jupiter. It shows very simply the rate of increase in the discovery of exoplanets and the growing diversity. Planets of a larger mass were discovered first but now planets of Earth-like mass are increasingly seen. This is due to new astronomical techniques and refining some of the early methods.

The planets are found in over 1,000 planetary systems and there are nearly 500 multiple planetary systems. In fact *The Exoplanet Data Explorer* adds another 4,000 candidates presently awaiting confirmation.[2]

This is a thrilling time for the search for extraterrestrial intelligence (SETI) and these discoveries have been a triumph of ingenuity in observational astronomy. The main difficulty in seeing other planets outside our own solar system is easy to understand. Stars emit a thousand million times more light than even the largest planets such as Jupiter. It is like picking out a light bulb beside a searchlight. Very few planets have been detected by direct imaging. So astronomy has had to be creative and subtle. Yet as Alan Boss makes clear the search for exoplanets is not straightforward and is continually negotiating the choppy waters of internal scientific disagreements and external considerations such as uncertain funding and media interest which can overhype or misrepresent the significance of observations (Boss

2009). So before rushing to discussions of the likelihood of little green men and women throughout the Galaxy, and its religious consequences, we must look at the variety of methods in this process of finding planets and also what kind of planets might be able to sustain the evolution of intelligent life. As with all science, there are insights and uncertainties.

The Radial Velocity Method

It is often noted that the first exoplanet was discovered in 1992 by Alexander Wolszczan and Dale Frail (Wolszczan and Frail 1992). This is somewhat contentious, as this was a number of planets around a special type of stellar remnant, a pulsar PSR 1257+12, rather than a main sequence star. Further, as can be seen in Figure 1, later work has shown that tentative claims before this date did provide evidence for planets but needed more work to confirm that they were actually planets.

However, this discovery utilized an indirect technique which has become one of the ways to avoid the problems associated with direct observation. This technique, rather than looking at planets directly, attempts to look for the influence of planets on their parent stars. As a planet orbits around a star, the star should "wobble" in its position due to the gravitational pull of the planet. Trying to detect this wobble in position against the background stars is theoretically possible but is difficult to do with current technology.

Nevertheless, the wobble has another effect, and it was this that was utilized in October 1995 by Michel Mayor and Didier Queloz of the Geneva Observatory to detect a planet circling the star 51 Pegasi, which is 48 light years away in the constellation of Pegasus (Mayor and Queloz 1995). They used an effect on the light the star emits. The technique is called Doppler spectroscopy or the radial velocity method. The light from stars can be split into a spectrum of lines and when an emitting star is moving these lines are shifted across the spectrum compared to a stationary emitter. This Doppler shift is then used to measure the tug of planets on stars, as an unseen planet tugs the star back and forth. Light from the star shifts slightly to the red end of the spectrum as the star moves away from the observer, and then slightly to the blue as it moves toward the observer. This shift will be periodic because of the planet's orbit. From the radial velocity (which is the component of velocity along the observer's line of sight) and the period, and combining this with knowledge of the mass of the star (calculated from the brightness of the star), astronomers can then derive the radius of the orbit of the planet and a limit on the minimum mass of the planet.

Using the radial velocity method, astronomers can only estimate a minimum mass for a planet because the mass estimate also depends on the tilt of the orbital plane relative to the line of sight, which is unknown. From a statistical point of view, this minimum mass is however often close to the real mass of the planet. However, it is important to note that as this method does not observe the planet directly there is no information on the planet's composition. Also, if a planet's orbit is tilted 90 degrees to our line of sight, no Doppler shift will be seen in the star's spectrum no matter how massive the planet. As planets close to their stars complete a cycle around their stars faster and because massive planets tug harder on their stars and cause the biggest Doppler shifts, this technique tended first to see planets which were massive and located close to their stars.

So Mayor and Queloz estimated that their planet was about half the size of Jupiter but closer to its star than Mercury is to the Sun. It takes four days to orbit the star and could have a temperature of around 1,000 Kelvin. This was the first planet around a normal star and added to the sense that planets were widespread in the universe.

Over the intervening years the method has been refined and has yielded hundreds of exoplanets including a number of candidates that are much closer to the size, orbit, and temperature of the Earth. In 2011, a team led by Mayor announced a "rich haul" of more than fifty new exoplanets, including sixteen super-Earths (planets with a mass between one and ten times that of the Earth), one of which orbits at the edge of the habitable zone of its star. The group uses the HARPS spectrograph on the 3.6 meter telescope at ESO's La Silla Observatory in Chile. Observing 376 Sun-like stars, they have estimated how likely it is that a star like the Sun is host to low-mass planets (as opposed to gaseous giants). They suggest that about 40 percent of such stars have at least one planet less massive than Saturn. The majority of exoplanets of Neptune mass or less appear to be in systems with multiple planets. They also looked for rocky planets that could support life. They discovered five new planets with masses less than five times that of Earth. For example the planet HD 85512 b is estimated to be only 3.6 times the mass of the Earth and is located at a distance from its parent star where its temperature means that water could be in liquid form. The increasing precision of the new HARPS survey now allows the detection of planets under two Earth masses. So far, HARPS has found two super-Earths with reasonable estimated surface temperatures (Dumusque et al. 2011; Pepe et al. 2011; Figueira et al. 2012) and an Earth-sized planet with an Earth-like density (Dumusque et al 2012; Pepe et al. 2013).

More recently, and combining this approach with the method to be described next, observers have been excited by the discovery of GJ 1132b, a rocky planet transiting a nearby low-mass star (Berta-Thompson et al. 2015). This may be the most important planet ever found outside the solar system, as it has a radius only 16 percent larger than Earth's and a matching density and is only forty light years from the Sun (Deming 2015). Although the planet is too hot to be habitable, it is cool enough to have a substantial atmosphere. In addition, its star is much smaller than the Sun and so less likely to swamp observations of the planet. This coupled with the fact that this system is relatively nearby means that it is possible that current and future planned telescopes will be able to observe the composition and dynamics of the planetary atmosphere.

The Transit Method

The transit method has become a very powerful alternative for detecting exoplanets, not least in looking for planets further away than the radial velocity method, and was first successfully used in 2003, in identifying a planet some 5,000 light years away. It is based on the simple premise that as a planet moves in front of its host star then the light from that star dims by a small amount. This is independent of the distance to the planetary system and only depends on the different radius of the planet compared to the star. Not only does it allow you to see planets; during an occultation, the atmosphere of a planet will absorb some of the radiation emitted by its companion star. Absorption lines may thus be detectable and indeed have led to the identification of carbon dioxide, methane, and water.

NASA's Kepler mission used this technique very successfully from its launch in March 2009 (Borucki et al. 2010). It used the transit method to search for planets around 150,000 stars using a specialized 0.95 meter diameter telescope to measure the small changes in brightness caused by these passing planets. To observe Earth-like planets transiting stars similar to our Sun, Kepler needed to see a dip in the star's visible light by only 84 parts per million. The mission was designed specifically to discover hundreds of Earth-sized and smaller planets and determine the fraction of the hundreds of billions of stars in our Galaxy that might have such planets.

The technique is extremely powerful for a number of reasons. First, it yields a great deal of information. Once a transiting planet is detected, its orbit can be calculated from its period and the mass of the star using Kepler's Third Law of planetary motion. The size of the planet is found from how much the brightness of the star drops and the size of the star. Then, from the orbit of the planet and the temperature of its star, the temperature of the planet is indicated. We thus have information to know whether the planet may be habitable. The Earth exists within a circumstellar habitable zone (HZ) which is sometimes defined as the range of distances from a star where liquid water can exist on a planetary surface. However, stars vary in their energy output over their lifetime and we also have to factor in the way that a planet's atmosphere both radiates heat energy away and locks energy in through greenhouse gases. Kasting et al. have calculated that for our own solar system the so-called continuous HZ (where liquid water is present on the surface on a planet for the majority of the life of the Sun) is 0.95 to 1.15 of the mean Earth–Sun distance (Kasting, Whitmire, and Reynolds 1993).

So we begin to see that we need to find a rocky planet, at a certain distance from its star and with a certain type of atmosphere if we are to start finding life anything like ours. However there are other considerations. The larger a star is, the shorter its lifetime. So stars have to be less than about 1.5 times the mass of the Sun to give enough stability for the development of complex life. Then over 50 percent of stars in our Galaxy are in binary or multiple systems which makes the HZ much more difficult, not least because one of the stars could use up its fuel quicker and then undergo a supernova explosion, becoming a neutron star or a black hole. The supernova explosion would send shock waves and intense electromagnetic radiation through the planetary system. If that was not sufficient to wipe out any living organisms, then the radiation from the remnant neutron star or black hole would finish off the job.

Second, the Kepler instrument had a very large field of view, 105 square degrees, which enabled the mission to observe a very large number of stars. Since transits only last a fraction of a day, all the stars must be monitored continuously, that is, their brightness must be measured at least once every few hours. At least three transits are required to verify a signal as a planet. The Kepler science team then uses ground-based telescopes and the Spitzer Space Telescope to review observations on planet candidates the spacecraft finds. Then computer programs run simulations to help rule out other astrophysical phenomena masquerading as a planet.

All went well until 2013 with Kepler discovering thousands of candidates. Then the second of four reaction wheels, which are used to stabilize the spacecraft, failed and the Kepler mission seemed to be at an end. However, engineers were able to use pressure from sunlight as a "virtual reaction wheel" to help control the spacecraft. The resulting K2 mission promises to not only continue Kepler's planet hunt, but also to expand the search to bright nearby stars that harbor planets that can be studied in detail and better understand their composition. Since the K2 mission officially began in May 2014, it has observed more than 35,000 stars and collected data on star clusters, dense star-forming regions, and several planetary objects within our own solar system.

The power of this technique has given some stunning results. For example, it discovered three small planets orbiting the star KOI-961, all smaller than the Earth, the smallest being the size of Mars. Then in December 2011, Kepler 22b became the mission's first confirmed planet in the habitable zone of a Sun-like star: a planet 2.4 times the size of Earth. At the same time Kepler-20e and Kepler-20f became the first Earth-sized planets orbiting a Sun-like star outside our solar system. Kepler-20e is slightly smaller than Venus, measuring 0.87 times the radius of Earth. Kepler-20f is a bit larger than Earth, measuring 1.03 times its radius. Both planets reside in a five-planet system called Kepler-20, approximately 1,000 light-years away in the constellation Lyra (Fressin et al. 2012). While

Kepler-20e and Kepler-20f are Earth-sized, they are too close to their parent star to have liquid water on the surface.

Recent press excitement in July 2015 surrounded the discovery of Kepler-452b, a habitable super-Earth, about one and a half times more massive, that orbits a star similar to the Sun (Jenkins et al. 2015).

Another significant discovery was Kepler-16b, the first unambiguous detection of a circumbinary planet, that is, a planet orbiting two stars (Doyle et al. 2011). As a great number of stars exist in binary systems, this discovery signals that there may be more planets than we previously thought. This was quickly followed by the announcement of the discovery of the first transiting circumbinary multiplanet system Kepler-47 (Orosz et al. 2012). This system consists of two planets orbiting around a pair of stars. The discovery further shows that planetary systems can form and survive even in the bizarre environment around a binary star. Even more interesting, is that the outer planet, which is slightly larger than Uranus, orbits in the habitable zone.

It is worth noting that while the public announcement of such objects grabs great attention, each announcement is dependent on detailed work and a great deal of caution. Each of the objects has to be "validated." That is, it has to be ruled out that something other than the planet is responsible for the observed dips in brightness.

Nevertheless the technique has proved so powerful that NASA is investing in future developments in this area. The Transiting Exoplanet Survey Satellite (TESS) will be launched in 2017, to survey nearby regions to find the habitable transiting planets that are closest to Earth, and whose atmosphere can be studied in detail (Ricker et al. 2015). This will be followed by the much awaited James Webb Space Telescope which will focus on the most likely planets to determine their atmospheric properties (Beichman et al. 2014).

The Microlensing Method

Einstein's Theory of General Relativity predicts that the path of light can be bent by the presence of a gravitational field around a massive body such as a star or even a planet. This is called gravitational lensing. Astronomers, looking for planets, have used this principle in a technique called microlensing. This is where light from distance stars has a temporary brightening due to the presence of mass between the distant star and the observer.

In 2012, an international team using the technique of gravitational microlensing concluded that planets around stars are the rule rather than the exception—in fact some estimates say at least one planet on average per star (Cassan et al. 2012). Microlensing is not as sensitive as radial velocity or even transit methods to picking up potential planets that have to be massive or close to their star.

Microlensing can detect planets over a wide range of mass and those that lie much further from their stars. The gravitational field of their host stars, combined with that of the possible planets, acts like a lens, magnifying the light of a background star. If the star that acts as a lens has a planet in orbit around it, the planet can make a detectable contribution to the brightening effect on the background star. However, you need the right alignment of a background and lensing star, plus the planet if microlensing is going to be seen.

Six years' worth of microlensing data was used and yielded three exoplanets. This may not seem a lot, but the fact that planets and stars have to be in the right alignment means that either the astronomers were incredibly lucky or planets are so abundant in the Milky Way that it was almost inevitable. The conclusion was that one in six of the stars studied hosts a planet of similar mass to Jupiter, half have Neptune-mass planets, and two thirds have super-Earths.

A Diverse Collection of Planets

The data concerning exoplanets gives a view of the diversity of stars in the universe, the majority of which have diverse planetary systems. Early discoveries were gas giants comparable in size to Jupiter or larger because they were most easily detected. Now we know there are a range of masses, densities, and radii from their star. Unlike our Solar System, gas giants are not inevitably far from their star, some being very close and very hot. There are rocky planets much bigger than the Earth such as Kepler 10c, ice giants such as Kepler 101b which is three times the size of Neptune but more than 60 percent heavy elements (Bonomo et al. 2014) and low-mass low-density planets which could be ocean planets, hot planets with a steam atmosphere, or mini-Neptunes.

Perhaps more significant is that recent results from a variety of these methods suggest Earth-sized planets in great numbers in our Galaxy (Dressing & Charbonneau 2013, 2015; Petigura, Howard, and Marcy 2013; Morton and Swift 2014). If 25 percent of Sun-like stars have an Earth-sized planet in a habitable zone then there could be over 10 billion potentially habitable Earths in our Galaxy.

The discoveries of the last twenty years should not be underestimated in their public impact, their contribution to SETI research, or indeed their theological significance.

Exoplanets Energizing SETI

Recent exoplanet discoveries have energized SETI. Subject to uncertain public funding and often in the past having to be funded by private individuals (Garber 1999), the large amount of data coming in on exoplanets and the likelihood of Earth-like planets and the real possibility of studying in detail the atmospheres of these planets has transformed the scientific and political scene. The Committee on Science, Space and Technology of the U.S. Congress held specific hearings on the search for exoplanets in May 2013, December 2013, and May 2014. Its chairman, Lamar Smith, commented, "The unknown and unexplored areas of space spark human curiosity. . . . Finding other sentient life in the universe would be the most significant discovery in human history."[3] After decades of trying to find alien radio signals, exoplanet research seems a more likely route to begin to answer the question of whether we are alone in the universe.

As has been argued previously, confidence in SETI as a research program is very sensitive to certain scientific insights as well as theological beliefs (Wilkinson 2013). In the nineteenth century there was a growing movement against the plurality of inhabited worlds (see the papers by Dunér and Crowe in this volume). It was clear that the other planets and moons in our Solar System seemed to be unable to support life. Evolution began to be seen as a very special process with a high degree of sensitivity to the circumstances. Life had developed here on Earth because of very special circumstances. In addition, the possibility of planets around other stars began to have problems. Astronomers had begun to think about how planets formed. One option, the nebular hypothesis, suggested that planets formed as the stellar nebular (the gas cloud out of which stars form) collapsed and formed a star. If this was the case then the vast majority of stars would have planets associated with them. This had been proposed in 1734 by Emanuel Swedenborg and developed by Kant and Laplace. As the nebula contracted, it flattened and shed rings of material, which later collapsed into the planets. This model, dominant in the nineteenth century, began to run into difficulties to do with the distribution of angular momentum between the Sun and planets. This resulted in a concerted move away from such a model and a search for alternatives. One alternative was that planets were formed from material dragged out of one star by the close encounter of another star. This would mean that the number of planets would be very small indeed, as these close encounters are particularly rare. Although this alternative never became dominant, the undermining of the nebula hypothesis had a negative effect for SETI. Theoretical modeling in the twentieth century restored the dominance of the nebula hypothesis, but the discovery of exoplanets in such large numbers has closed the argument. The discovery of so many planets in such a short time should not be underestimated. Planets of different sizes including Earth-like planets, multiplanet solar systems, planets around binary stars, and planets within habitable zones have transformed our understanding of planetary formation and our estimates of how many planets there may be in the universe.

However, caution is still needed. It is easy to move from exoplanets too quickly to speculating about intelligent life. Back in 1996, on the basis of just a handful of discovered exoplanets, Michael D. Lemonick wrote in *Time:*

> Perhaps most important of all, the discovery of planets around relatively nearby sun-like stars implies that our galaxy, the Milky Way, 100 billion stars strong, must be bursting with other worlds and that there is life out there somewhere.(Lemonick 1996, 47)

Both in the popular press and in the scientific literature, the headlines are "A Home from Home" or "Earth's Twin." But they often make the mistake of equating Earth-like planets to habitable Earth-like planets and then to inhabited Earth-like planets and then to inhabited by intelligent beings Earth-like planets.

However, a lot more things need to be examined before such a conclusion is drawn. It is clear that far more observations are needed, to both see other planets and, more importantly, study their atmosphere and composition. Certainly the next generation of telescopes are beginning to detect atmospheric composition through spectroscopy (Konopacky et al. 2013). The question is then: what should we be looking for that would indicate life?

One of the standard answers is the detection of ozone and methane. Oxygen is difficult to see in the infrared, but UV radiation from a star gives rise to ozone from the oxygen. Ozone is therefore a strong indicator of the presence of oxygen produced by photosynthesis. When coupled with evidence for methane, which is produced both by microbes and large organisms, you can be confident of a biosphere on the planet. Again we need to stress that data needs to be interpreted and we cannot immediately jump to a conclusion that by observing an atmosphere's spectrum we can be sure of the existence or nonexistence of life. For example, if the observations do not show ozone what might that tell us? It could be that we have a habitable world which is not inhabited. Or it could be that it is inhabited but there are other reasons why there may be oxygen which does not manifest itself in the form of ozone. There might not be enough UV from the star to produce ozone from oxygen. Or it may be that the biosphere is at an early stage of development and that photosynthesis has not built up enough oxygen, or the biosphere may be deep below the surface of the planet.

There is then the need to balance discoveries of a biosphere against arguments about the development of intelligent life—it is a long way from an amoeba to an accountant. Indeed with the large number of potential Earth-like planets in the Galaxy this may in fact strengthen the Fermi paradox of "if they existed they would be here." If there were so many potential sites of life and if intelligent life easily developed then why in the 10 billion year history of the Galaxy have we not seen evidence for alien colonization? (Jones 1985; Webb 2002; Kerr 2004).

It is important to review all of these scientific arguments carefully rather than to rush too quickly to the religious implications. Faith communities do themselves great disservice by not taking time to understand the science involved. This is even more important in an area where science is overlaid by the myths and narratives of science fiction.

Nevertheless, as a Christian theologian I welcome the way that exoplanet discoveries have energized the SETI program in scientific, media, and political circles. This is in large part because I stand in the tradition of those such as Galileo, Kepler, Huygens, and Bentley who on the basis of their Christian conviction believed that God was the free creator of the universe and was not bound by human reason. Thus, the only way to discover the nature of the universe was to observe it rather than simply to derive it from logical considerations. Therefore SETI is a program which should have theological support in the sense that only by searching the creation will we be able to understand the richness of it. At the same time I want to be open to the challenges and opportunities that these discoveries might have for theology.

Energizing Theological Reflection

It is tempting to go straight from exoplanets to alien life and focus theological reflection on incarnation, sin and redemption (Tillich 1953; Mascall 1956; Pittenger 1959; Peacocke 2000; Worthing 2002; Peters 2003, 2009, 2011; O'Meara 2012). Some of this will be discussed in the other papers in this volume. Exoplanet discoveries may be a spur to this kind of discussion within Christian theology but there are a few other theological points that often get missed.

First, there is *the extravagance of a Creator God in such a creation*. Alongside traditional Christian images of lawgiver, king, builder, and architect, exoplanets may strengthen the image of the great artist in creation. The account of Genesis 1 stresses creativity and diversity in abundance. The Earth was formless and empty (v2), a phrase that could be translated as "total chaos'" or "waste and void." This formless Earth could signify either nothingness or disorder. The word is often used in describing the experience of being lost in a desert without tracks or distinguishing features to guide you (Job 6:18). It is into this monotony, disorder, and darkness that God brings differentiation, contrast, structure, and order. The acts of separation in Genesis 1 give a sense of structure and also show God as giving diversity to the created order. Then into this structure comes light and life. Once again, here is diversity and creativity, with perhaps its high point being the great understatement, "He also made the stars" (Genesis 1:16)!

Christian astronomers such as Richard Bentley, Christiaan Huygens, and the nineteenth century observer Temple Chevallier were struck by the vastness of creation as they encountered the power of telescopes to see myriads of stars and galaxies. This led to a sense of the power of God in creation reflecting especially Psalm 19:1, "the heavens declare the glory of God" (Wilkinson 2015). For some, the discovery of exoplanets may do the same thing.

But the insight goes deeper. Not all exoplanets will have intelligent life and indeed not all exoplanets will have life of any kind. So why so many stars and so many planets, many of which human beings will never see? For Bentley and Huygens this became an argument for alien life. After all, they speculated, there must be other intelligent life elsewhere in the universe who could see the glory of God that would never be seen by humans! However, a better argument is surely simply to see the billions of exoplanets as a challenge to any anthropocentric view of creation. The Oxford cosmologist E. A. Milne wrote:

> Is it irreverent to suggest that an infinite God could scarcely find the opportunities to enjoy himself, to exercise His godhead, if a single planet were the seat of His activities? (Milne 1952, 152)

I would want to extend this. Milne was thinking of other inhabited worlds. But this Creator God can "enjoy himself" with the diversity of many uninhabited worlds. This develops a view of the creator as extravagant artist. The sense of awe in the scale and diversity of exoplanets may even encourage a sense of worship.

Carl Sagan once challenged faith communities with the words:

> How is it that hardly any major religion has looked at science and concluded, "This is better than we thought! The Universe is much bigger than our prophets said, grander, more subtle, more elegant"? Instead they say, "No, no, no! My god is a little god, and I want him to stay that way." A religion, old or new, that stressed the magnificence of the Universe as revealed by modern science might be able to draw forth reserves of reverence and awe hardly tapped by the conventional faiths. (Sagan 1995, 50)

It seems to me that this is at times a fair criticism of some expressions of Christian faith. Exoplanets may be a small part of subverting such a view. Certainly in a rediscovery of God as artist the Abrahamic faiths have the theological framework to address it. Lucas Mix develops these themes in this volume (Mix 2016).

Second, *recognizing that this diversity is God-given means that it is to be respected and cared for as gift*. The biblical accounts of creation taken together critique an arrogance which sees human beings as the center and exploiter of the rest of creation. It is striking that the Genesis 1 narrative reaches fulfilment not in the creation of Adam and Eve but in the Sabbath day on which "the whole creation glorifies its maker"(Fergusson 1998, 17).

This provides a perspective on the distinctive role of humans within the created order as that of priests giving voice to creation's praise.

It may seem odd to raise this in connection with exoplanets, but the exploration of these planets in searching for life raises ethical questions. The fact that there are a number of possible habitable planets not too far away compared to galactic distances raises the real scenario of visiting those planets. Indeed, in the exploration of Mars we see the first wave of that kind of visit. Further, habitable exoplanets raise the possibility of decamping human beings from a planet which is running out of resources and being polluted by human activity. Might there be ethical issues that have to be brought into conversation with scientific possibilities?

Christian theology will want to push the ethical considerations of respect and conservation to all other planets in the universe, whether inhabited or not. This resonates with some of the thinking coming from SETI scientists themselves. Christopher McKay comments that the discovery of alien life, if alive or revivable, will pose fundamentally new questions in environmental ethics (McKay 2011). He suggests that, while life is not the only source of value in the natural world, it is unique in that it is something of value that can be preserved, but it can also be spread without limit. If life has value then humans can create value and spread value as they spread life. However, human action can also cause damage, for example in biological contamination associated with exploration of potentially biological worlds like Mars. He proposes that we must explore Mars in a way that is biologically reversible (McKay 2009, 2011).

In addition, the engineering of planetary atmospheres for human habitation is already being discussed (Zubrin and Wagner 1997; McKay 2000). Rees sees the importance of this "terraforming" as giving the human race a safeguard against possible disasters affecting the Earth (Rees 2003). But how should this be done in a way that stops other planets and other life-forms simply being exploited for human gain? Christian theology's emphasis on the whole universe as gift to be used sensibly and wisely has a contribution here.

Third, *Christian theology will resist any attempt to resurrect any design argument on the basis of exoplanet discoveries*. It is interesting that the last few decades have seen a re-emergence of this kind of argument in cosmology, based on anthropic balances and intelligibility, although framed in terms of pointers to God rather than proofs (Wilkinson 2008). Going a step further, Paul Davies has argued that there are as yet undiscovered principles of complexity, organization, and information flow consistent with the laws of physics but not reducible to them and that these principles lead to life and indeed intelligent life. He comments, "If life is widespread in the universe, it gives us more, not less, reason to believe in cosmic design"(Davies 2000, 15).

The discovery of exoplanets does not in itself help in this type of argument. In fact, not even the discovery of life helps in this type of argument. This is ably illustrated by C. S. Lewis, who with characteristic wit commented on atheists' attempts to use both sides of the ETI debate to attack Christian faith:

> If we discover other bodies, they must be habitable or uninhabitable: and the odd thing is that both these hypotheses are used as grounds for rejecting Christianity. If the universe is teeming with life, this, we are told, reduces to absurdity the Christian claim—or what is thought to be the Christian claim—that man is unique, and the Christian doctrine that to this one planet God came down and was incarnate for us men and our salvation. If, on the other hand, the earth is really unique, then that proves that life is only an accidental by-product in the universe, and so again disproves our religion. Really, we are hard to please. (Lewis 1990, 14)

As Kant and Hume pointed out a long time ago, the design argument is "hard to please." Arguing that the Earth alone is a "goldilocks planet" or that many inhabited worlds are evidence of a bigger plan of design still suffer the classic critiques of the argument. Perhaps the discovery of the range of exoplanets may energize the "wow" factor of a sense of awe in the universe and the deeper question of the place and identity of human beings.

Pascal wrote,

> When I consider the short duration of my life, swallowed up in the eternity before and after, the little space which I fill, and even can see, engulfed in the infinite immensity of spaces of which I am ignorant, and which know me not, I am frightened, and am astonished at being here rather than there; for there is no reason why here rather than there, why now rather than then. Who has put me here? By whose order and direction have this place and time been allotted to me? . . . The eternal silence of those infinite spaces frightens me. (Pascal 1958, 61)

Exoplanets renew the question of "when I look at the heavens . . . what are human beings?" (Psalm 8). And it is here that Christian theology responds not with arguments of design, but in the claim of a God who reveals truth in many and various ways but supremely in incarnation. That of course does not answer all of the questions but contributes to the conversation about SETI. Other papers in this issue press these questions further, in particular what the discovery of life may mean for theology. However, even if intelligent life on other planets is never encountered, the discovery of exoplanets will continue to press future theological conversation on diversity and extravagance in creation.

Notes

1. Schneider, J. "Interactive Extra-solar Planets Catalog". *The Extrasolar Planets Encyclopedia*. Available at http://exoplanet.eu/, accessed February 9, 2016.
2. Available at http://exoplanets.org/, accessed November 23, 2015.
3. Available at https://science.house.gov/news/press-releases/committee-examines-advances-astrobiology-research, accessed November 23, 2015.

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