Introduction

The scale of the universe cannot be fathomed with the human eye, but the night sky offers a start. If you live in or near a city, you only ever have seen a few stars. We need to travel away from built-up areas to see the heavens in their glory.[1] Someone with good eyesight (or glasses) would then be able to see around nine thousand stars, at least if she travelled to observe the sky first from one hemisphere of the Earth, then from the other. Binoculars would increase the tally of stars to maybe two hundred thousand, while even a cheap portable telescope would expand even that ten- or twentyfold. That, however, takes us only a tiny fraction of the way towards apprehending the whole. Our best scientific telescopes, pitched on mountains in Chile or Hawaii, or launched into space, allow us to estimate that there are around one hundred billion stars in our Milky Way galaxy: 100,000,000,000 stars.[2]

1 For suggestions about amateur astronomy and photographing the night sky, see Valerie Stimac, *Dark Skies: A Practical Guide to Astrotourism* (Carlton, Victoria: Lonely Planet, 2019); Sarah Barker and Maria Nilsson, *Fifty Things to See in the Sky*, illustrated by Maria Nilsson (London: HarperCollins, 2019); and Sten Odenwald's *Guide to Smartphone Astrophotography*, written for NASA and widely available online.

2 Jean-René Roy, Pierre-Yves Bely, and Carol Christian, *A Question and Answer Guide to Astronomy*, 2nd ed. (Cambridge: Cambridge University Press, 2017), 133; David H. Levy, *David Levy's Guide to the Night Sky* (Cambridge: Cambridge University Press, 2001). The Biblical image of a multitude, 'like the stars in the heavens', is well justified as meaning a great many. The other Biblical phrase for such a large quantity is sand upon the shore. The reader may be interested in a calculation of the number of grains of sand on Earth as around 7.5×10^{18}: around 2,700 stars in the observable universe for every grain of sand (although a lot of grains of sand for every star if we stick only to the Milky Way). The figure for sand comes from David Blatner, *Spectrums: Our Mind-Boggling Universe from Infinitesimal to Infinity* (New York: Bloomsbury, 2014).

Until we observed planets around other stars, we could not be sure that there were any. Planets could have been common, or extraordinarily rare. According to one theory for how solar systems form, planets would be routine, coalescing alongside stars from the same cloud of dust, or nebular.[3] The rival theory envisaged that planets are formed by the collision of one star with another, or of a star with a comet.[4] That would make planetary systems vanishingly rare, since the immense size of stars dwindles almost to nothing compared to the distance between them. Collisions would happen a great deal less often than the mid-air encounter of one ball with another on a golf course.[5] By the 1960s, the consensus among scientists was shifting towards the nebular hypothesis, but it took observation to settle the matter.[6] The epochal moment in recent science, which has done so much to provoke further research, was the announcement by Michel Mayor and Didier Queloz in 1995 they had uncovered a planet orbiting another star like our own sun. Since then, the number of these 'exoplanets' in our human catalogue has grown apace. On

[3] Immanuel Kant (1724–1804) was an early exponent in *Allgemeine Naturgeschichte und Theorie des Himmels* (Königsberg: Johann Friederich Petersen, 1755), translated as *Universal Natural History and Theory of the Heavens or an Essay on the Constitution and Mechanical Origin of the Whole Universe Treated According to Newton's Principles*, trans. W. Hastie (Ann Arbor: University of Michigan Press, 1969).

[4] Georges Louis Leclerc, Comte de Buffon (1707–1788), proposed collision of the sun with a comet in *Les Époques de la Nature*, published in *Histoire Naturelle: Générale et Particulière, Contenant Les Époques de La Nature* (Paris: de l'Imprimerie Royale, 1778).

[5] As Hannu Karttunen et al. have written, 'assuming a typical star density of 0.15 stars per cubic parsec and an average relative velocity of 20 km/s, only a few encounters would have taken place in the whole of the galaxy during the past 10^9 years'. On that view, 'the solar system could be a unique specimen' (*Fundamental Astronomy*, 6th ed. (Berlin: Springer, 2016), 168).

[6] This book is not the place for detailed exposition of how planets are found. Many recent books set out the science with admirable clarity. See Shawn D. Domagal-Goldman et al., 'The Astrobiology Primer v2.0', *Astrobiology* 16, no. 8 (August 2016): 561–653; David A. Rothery et al., eds., *An Introduction to Astrobiology*, 3rd ed. (Cambridge: Cambridge University Press, 2018); Wallace Arthur, *The Biological Universe: Life in the Milky Way and Beyond* (Cambridge: Cambridge University Press, 2020).

5 October 2021, *The Extrasolar Planets Encyclopaedia* listed 4,846 planets, in 3,582 planetary systems (with 798 of those solar systems known to possess more than one planet).[7] Those numbers are the provocation for this book, even more so once we extrapolate them to the galaxy as a whole, or even to the entire observable universe.[8]

The discovery of a first planet outside our solar system ranks among the most momentous feats of science, and a good deal has been written by theologians in response, chiefly with the prospect of extraterrestrial life in view. While theological interest has intensified, however, it would be a mistake to think that it is entirely new. As we will see, thinking in Christian theology about the implications of life elsewhere in the cosmos goes back almost six hundred years.

For a conservative estimate of habitable planets, we might concentrate only on the solar systems of sunlike stars. That can be defined in a few different ways, but we might end up classifying around 4 per cent of the stars in the Milky Way that way. That gives us 4 billion sunlike stars in our galaxy. Observations over the past twenty-five years suggest that most stars are encircled by planets, but many of those planets are not likely sites for life: some are composed of liquified or solid gas, like Jupiter, Saturn, Uranus, and Neptune; others are rocky but burnt to a crisp, like Mercury, or partly rocky but a very long way from the star, and cold, like Pluto (demoted to status of a 'dwarf planet' in 2006). To work out the proportion of stars with habitable planets, the two main criteria are a rocky composition (rather than gas), and a temperature at which any water present on the surface would be a liquid. Earlier

7 http://exoplanet.eu/catalog/. It is likely that many of these systems contain additional planets, that we are currently unable to detect.

8 We speak of the 'observable universe' as that which we could possibly observe. It marks out the distance that light could travel to date across the entire age of the cosmos. Since the universe is expanding, however, more would exist beyond that horizon. Indeed, on views of early cosmology that envisage an early period of unimaginably rapid inflation, one suggestion has the universe as a whole containing as many as 10^{100} stars (Tomonori Totani, 'Emergence of Life in an Inflationary Universe', *Scientific Reports* 10, no. 1 (December 2020): 1671).

estimates had about one in five sunlike stars with habitable Earth-like planets. Recently, that has been revised upwards, to between 0.37 and 0.60 such planets per sunlike star.[9] These figures will no doubt shift. For instance, we are beginning to make progress in understanding the capacity of a star to have several habitable planets in its orbit.[10] Habitable moons are also possible. However, if our estimate of the proportion of sunlike stars with Earth-like planets remained at about a half, that gives us two billion such planets in the Milky Way.

Two billion is an incomprehensibly large number, but even that is only a start. Our galaxy is not alone. In fact, by a strange coincidence, the number of galaxies in the observable universe seems to be about two hundred billion (200,000,000,000): almost identical to the number of stars in our galaxy.[11] If our galaxy is more or less average in terms of the number of stars it contains, that puts the number of stars in the observable universe at something like 2×10^{22}: twenty thousand billion billion stars, or two followed by twenty-two noughts. That in turn would suggest around 8×10^{20} sunlike stars, and perhaps 4×10^{20} rocky planets of the right temperature circling them: four hundred billion billion.

Of course, water will not be present on every rocky planet capable of harbouring it in liquid form, and all sorts of factors may be particularly conducive to the evolution of life, which may or may not apply to this or that planet. For instance, the presence of a moon may be significant, if life evolved in tidal pools, or underwater hydrothermal vents, if not. Other features may be significant for protecting any

9 Steve Bryson et al., 'The Occurrence of Rocky Habitable-Zone Planets around Solar-like Stars from Kepler Data', *Astronomical Journal* 161, no. 1 (22 December 2020): 36.

10 Stephen R. Kane et al., 'Dynamical Packing in the Habitable Zone: The Case of Beta CVn', *The Astronomical Journal* 160, no. 2 (27 July 2020): 81.

11 Roy, Bely, and Christian, *Guide to Astronomy*, 177. Recent calculations may justify increasing this estimate by a factor of around ten, to about two trillion galaxies (Christopher J. Conselice et al., 'The Evolution of Galaxy Number Density at Z < 8 and Its Implications', *The Astrophysical Journal* 830, no. 2 (13 October 2016): 83).

life that does evolve: a giant neighbouring planet, like Jupiter, may be useful for hoovering up asteroids that would otherwise collide with an inhabited planet. Even lowering the figure of four hundred billion billion by several orders of magnitude, that still leaves us with an astonishing number of potential cradles for life, and that, to my mind, changes everything. The number of places where life could evolve and take hold seems to be extraordinarily large. Those calculations, moreover, say nothing about the billions of billions of habitable planets that may already have been and gone, or are yet to be.

The evolution of life is not impossible. I am sufficient evidence of that, as are you. Life can evolve, and there look to be billions of billions of planets where that might have happened. The emergence of life is a remarkable thing, and perhaps not at all common. But is it so uncommon as to happen only once in, say, four hundred billion billion opportunities? Extrapolation from one example is a perilous business, but we do have one more piece of information. Life got started on Earth surprisingly early: it stretches back maybe 3.8 billion years. The planet is 4.5 billion years old, and it spent around 0.5 billion years in the Hadean eon: the literally Hades-like first period, during which it was bombarded by meteorites, covered in volcanoes, and bathed in the radiation of elements with short half-lives. Life began only a short time later – 0.2 billion years later – and it has been going for 3.8 billion years since. That rapid arrival may offer one suggestion that life is not too difficult to get going.[12]

At present we are far more able to estimate whether a planet might be broadly habitable than we are at assessing whether it is

[12] Some recent work on the distinctive chemistry of this Hadean eon, however, has suggested that it was well placed for producing the sort of combination of molecules that might lie at the origins of life. On that view, it is not surprising that life got going in such seemingly inhospitable conditions: they would, in fact, be particularly productive (Bhavesh H. Patel et al., 'Common Origins of RNA, Protein and Lipid Precursors in a Cyanosulfidic Protometabolism', *Nature Chemistry* 7, no. 4 (April 2015): 301–7; John D. Sutherland, 'Opinion: Studies on the Origin of Life – the End of the Beginning', *Nature Reviews Chemistry* 1, no. 2 (February 2017): 12).

inhabited, but we stand at the cusp of a significant leap. Already to some extent, and soon with much greater accuracy, we will be able to analyse the atmospheric composition of planets around other suns. The James Webb space telescope is a significant addition here. Even the meagre absorption of a star's light by a planet's atmosphere (microscopic in comparison to the star) as the planet passes in front is enough to yield information as to which gases are present. If the combination of gases we see is thermodynamically anomalous – if the combination is not likely to form a stable mixture – that may serve as a sign of life. The Earth would appear anomalous in just this way if seen from elsewhere, since it contains a highly reactive combination of methane alongside oxygen.[13] This capacity to analyse atmospheres is set to change the stakes when it comes to detecting other life. Up to now, the emphasis has been on waiting for signs from an advanced civilisation (in radio transmissions, for instance, or by detecting the traces of how an advanced civilisation might engineer an entire solar system). Soon, however, we will be able to look for signs of life before it has reached an advanced state (if it ever does), given away simply by how it perturbs the chemistry of the planet it inhabits and shapes. That expands the range of living planets we could detect enormously. In terms of Earth, it would mean being able to detect life as it had been present for perhaps three billion years, not as it has been present for one hundred.

In recent decades, scientific study in the area of this book has shifted in the direction of thinking about the universe as a whole as a place where life can evolve and flourish. We see this in a shift

[13] The combination of carbon dioxide with methane, in the absence of carbon monoxide, is another marker, if seen from afar, that would have suggested the presence of life on Earth during some earlier periods (Joshua Krissansen-Totton, Stephanie Olson, and David C. Catling, 'Disequilibrium Biosignatures over Earth History and Implications for Detecting Exoplanet Life', *Science Advances* 4, no. 1 (January 2018): eaao5747; David C. Catling and Kevin J. Zahnle, 'The Archean Atmosphere', *Science Advances* 6, no. 9 (February 2020): eaax1420).

of terminology. For a period, the language of 'exobiology' predominated, as the name for scientific speculation about life beyond ('exo') Earth (or on 'exoplanets'). Today we more often talk of 'astrobiology', which is the scientific study of the place of life in the cosmos. The shift is from concentrating on life other than terrestrial life (of which, as yet, we know none) to thinking about place of life in the cosmos *per se*, of which terrestrial life is part. That goes hand-in-hand with the integration of 'planetary science' (previously seen as being about other planets) with 'Earth science', with each discipline enriching the other. In this book I will use 'exobiology' when addressing other life, and 'astrobiology' when I am thinking about the place of life in the universe.

Astrobiology and Christian Doctrine

Little in recent science outshines the discovery of planets around other stars. Results pouring in since the mid-1990s have transformed our understanding of the universe, which turns out to be strewn with planets, a fair proportion of them potentially habitable. That makes astrobiology – the scientific study of life as a phenomenon of the cosmos as a whole – a discipline *de jour*. Renewed theological discussion of other worlds, and life elsewhere, has followed, although as a topic for Christian theology *per se*, that is not new. Theologians have been writing about the theological implications of biological life beyond Earth since the mid-fifteenth century.[14] The attitude of those early Renaissance theologians was typical of much that would follow: they were unphased by the prospect of other life, but also brisk in their discussions, leaving us only a paragraph at most on the topic. They acknowledged the possibility of life elsewhere, thought that it posed no particular problem

[14] For further discussion of Ray, Wilkins, and Trollope, with quotations and citations, see Chapter 1.

for Christian belief, and moved on to some other topic. Examples of this sort of response into Early Modernity could be multiplied at length. We see it, for instance, in John Ray's classic combination of biological survey and theological wonderment, in which he throws off, more or less in passing, a single, unthreatened mention of life on other planets in relation to God. In this period, theology often features in works approaching life beyond Earth from a scientific perspective (such as one from John Wilkins, Bishop of Chester).[15] Again, however, those theological comments tend to be as notably brief as they are unruffled.

Christian rumination on other life remained a significant topic in the centuries that followed, even if it was not explored in any detail. When Anthony Trollope, for instance, wanted to depict a group of characters talking about a modish topic of the day in *Barchester Towers* (1857), he had them talking about life elsewhere in the solar system, and its theological implications. In 1920, Frank Weston (1871–1924), Bishop of Zanzibar, saw his contribution on the topic as joining an already lively scene, in which 'it is *often* argued that if other planets are dwelling-places of rational beings the incarnation with its atoning work cannot be true'. (He found this conclusion 'unwarranted'.)[16]

A succession of familiar theological names commented on extraterrestrial life in the twentieth century, if only in passing, among them Yves Congar, Hans Küng, Eric Mascall, Wolfhart Pannenberg, Karl Rahner, and Paul Tillich. Some of that writing expanded the bundle of theological discussions of the theme, but they still rarely exceeded a few paragraphs in length. Towards the end of the century, and into the twenty-first, chapter-length surveys of themes in theology and astrobiology became common, and were published

[15] John Wilkins, *The Discovery of a World in the Moone. Or, A Discovrse Tending to Prove, That 'tis Probable There May Be Another Habitable World in the Moon*, 5th ed. (London: J. Rawlins for John Gellibrand, 1684).

[16] Frank Weston, *The Revelation of Eternal Love: Christianity Stated in Terms of Love* (London: A. R Mowbray and Co., 1920), 128, emphasis added.

in multidisciplinary edited collections.[17] That genre allows only a limited scope, however, and writing for a non-theological audience tends to restrict the author's capacity to go into detail. Nonetheless, these contributions are witness to the enduring place of theology among the arts and humanities, and to recognition of the role that religion plays for many in interpreting the world, not least if life elsewhere were to be confirmed.

Over the past two decades, edited collections have appeared, devoted to theological discussions of other life in the universe, plus a few single-author volumes.[18] Nonetheless, room remains for development in several directions, to which I hope this book will be a contribution. One would be to move writing further from commentary upon what I described above as the 'bundle of theological discussions', accumulated from historical sources. However distinguished those authors might be thought to be, their insights are typically sparse and offered – as I have said – for the most part

[17] Examples include chapters by Ernan McMullin, Celia Deane-Drummond, Cynthia Crysdale, Richard Randolph, and Francisca Cho, in *Exploring the Origin, Extent, and Future of Life: Philosophical, Ethical, and Theological Perspectives*, ed. Constance M. Bertka (Cambridge: Cambridge University Press, 2009), and essays by Robin Lovin and Guy Consolmagno, in *The Impact of Discovering Life beyond Earth*, ed. Steven J. Dick (Cambridge: Cambridge University Press, 2015).

[18] Steven J. Dick, ed., *Many Worlds: The New Universe, Extraterrestrial Life, and the Theological Implications* (Philadelphia: Templeton Foundation Press, 2000); Ted Peters et al., eds., *Astrotheology: Science and Theology Meet Extraterrestrial Life* (Eugene, OR: Cascade, 2018); Kenneth J. Delano, *Many Worlds, One God* (Hicksville, NY: Exposition Press, 1977); Marie George, *Christianity and Extraterrestrials?: A Catholic Perspective* (Bloomington, IN: iUniverse, 2005); Thomas O'Meara, *Vast Universe: Extraterrestrials and Christian Revelation* (Collegeville, MN: Liturgical Press, 2012); Keith Ward, *Christ and the Cosmos: A Reformulation of Trinitarian Doctrine* (Cambridge: Cambridge University Press, 2015); Jacques Arnould, *Turbulences Dans l'univers: Dieu, Les Extraterrestres et Nous* (Paris: Albin Michel, 2017); Olli-Pekka Vainio, *Cosmology in Theological Perspective: Understanding Our Place in the Universe* (Grand Rapids, MI: Baker Academic, 2018). David Wilkinson's *Science, Religion, and the Search for Extraterrestrial Intelligence* (Oxford: Oxford University Press, 2013) contains two theological chapters. Giuseppe Tanzella-Nitti's encyclopaedia article 'Extraterrestrial Life' remains an ideal introduction to topics of theological importance, accessed 1 February 2018, https://inters.org/extraterrestrial-life.

in passing. Far more valuable is attention to existing theological writing that bears upon questions raised by astrobiology, for all the implications for other life would have been entirely absent from the author's mind. Chapter 14 of this book provides an example. Down Christian history we find discussion about what difference (if any) the Incarnation has upon the relation of the Word to the rest of creation. In the Reformation, and debates stemming from it, this typically had to do with Christ's presence in the Lord's Supper. There is obviously much in that material that bears upon the question of multiple Incarnations elsewhere in the universe, even though that topic was not historically in view. In this fashion, a central task for theological consideration of life elsewhere in the universe is to expand the range of the historical material, such as this, that can be brought to bear on the topic.

Another expansion would address the range of doctrinal topics under discussion, whether in turning to topics previously little considered at all (such as eschatology), or in bringing topics together that have otherwise mainly been treated separately, with the hope of cross-fertilisation. Alongside such expansions of breadth, there will also be value in an increase in academic depth or focus. Much that has been written theologically about life elsewhere in the universe, historically and to some extent today, has been conceived with a wide or popular religious readership in mind. The motivations for that are often admirable, but a degree of technical precision can be lost as a result. That is particularly to be seen in discussions of Christology. For instance, where the idea of more than one Incarnation has been denied, what is meant by 'Incarnation' is often difficult to pin down, or else set out very much at variance with the sort of formulations of Christological thinking that are foundational to Catholic, Orthodox, Anglican, and Protestant traditions. Any attempt to engage astrobiology with greater theological precision will likely also entail a deeper grounding of our discussions in a specific theological tradition: Augustinian, Bonaventurian, Calvinist, Thomist, or whatever.