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Introduction

Are we alone in the universe? On a cold November day in 1961, in a quiet mountain town in West Virginia, an astrophysicist named Frank Drake wrote an equation on a blackboard and took our greatest step toward answering this profoundly human question. Dr. Drake was on a mission unlike any other: to conduct Earth's first attempt to meet our galactic neighbors. On that day, at what would become the Green Bank Radio Observatory, ten people were present. Today, there are thousands of people across the world working together to make the ultimate discovery.

Much like a remarkable little planet, the third one from its sun, the equation on the chalkboard would eventually take on a life of its own. It would be hotly contested, written and rewritten, declared the prescient future of humanity, asserted useless, obsolete. Gene Roddenberry would include it in his pitch for a new-fangled TV show called *Star Trek*. Physicists and philosophers alike would come to blows over what it meant, what it *could* mean. Today, it is our turn to learn about the Drake Equation:

$$N = R_* \cdot f_p \cdot n_e \cdot f_l \cdot f_i \cdot f_c \cdot L$$

2 INTRODUCTION

How many civilizations are out there in the Milky Way that we could talk to right now? The Drake Equation boldly contends that everything we need to conduct our galactic census can be neatly summarized in only seven numbers. But these seven numbers span a tremendous scale—from the birth of galaxies to the death of civilization.

R_* —the yearly rate at which new stars are born in the Milky Way

f_p —the fraction of stars that host planets

n_e —the number of planets per star that could potentially host life

f_l —the fraction of habitable planets on which life evolves

f_i —the fraction of life on a habitable planet that becomes intelligent

f_c —the fraction of intelligent life that develops interstellar communication methods

L —the average lifespan of a technological, communicating civilization

Multiply all those numbers together, and you will get N : the number of alien civilizations in our galaxy that might want to chat. The order of the seven variables is intentional—it progresses smoothly from “things scientists are pretty sure about” to “things we might be able to learn in the next few decades” to “things we will almost certainly never discover.”

In a 2009 interview, Dr. Drake laid out an optimistic vision. He calculated N to be 240,000, which works out to be one communicating civilization for every 4,167 stars. But over a decade has passed since then. A lot of progress has been made toward the earlier of the seven variables, such as the discovery of thousands of planets orbiting other stars. Somewhat less progress has been made in the nebulous middle variables

concerned with the part of life between “the primordial soup” and “the invention of the toaster oven.”

This book seeks not to answer the Drake Equation, although we’ll certainly take a crack at it, but to explain *why* it is so unknowable. Above all else, the equation is a vehicle in which we will take a remarkable journey through the science that’s really twenty sciences in a trenchcoat: *astrobiology*.

Beginning with the Big Bang, we will explore the lives and deaths of stars and their planets. We will ask what makes a planet suitable for life (it’s not just water!), and what life really needs to get going (not much!). We will learn about the kinds of big, catastrophic things life has survived, and the kinds of big, catastrophic things that are still on our horizon. Finally, we will tie it all together with a whirlwind tour of astrobiology’s present and future, and if you’re really feeling inspired—good news!—we’re going to talk about how *you* could become the person who gets to make first contact.

So join me on this expedition through space and time as we knit together the threads of the scientific method into the rich tapestry of our living, breathing world—together, we will peer through the lens of science at the endless creative potential of the cosmos, and draw ever nearer to answering the question asked by our distant ancestors and our present-day comrades alike: *Are we alone in the universe?*

The galaxy awaits—let’s go!

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