The Order of the Dolphin: Origins and Future of SETI

An Honors Thesis Submitted in Partial Fulfillment of the Elon University Honors Program

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Introduction to Thesis Project

The body of my thesis contains four chapters of a popular science book entitled *The Order of the Dolphin: Origins and Future of SETI.* This project is not a conventional physics thesis, nor is it a typical English thesis. I classify the following book chapters as *popular science*, which is science communication that assumes an audience's interest in the topic, but not expertise (this broad definition leaves much room for interpretation, but scholars seem to have a difficult time pinning down a more precise description of the genre).[1] Through my own thesis writing experience, I have come to see popular science as a strange hybrid style that resides somewhere in the no man's land between creative nonfiction and scientific reporting. My work seeks to engage and entertain, while also informing the reader—translating the complex scientific ideas presented in jargon-filled journal articles into more accessible terms.

Writing a popular science piece about the search for extraterrestrial intelligence (SETI) is an immensely satisfying experience, not only because it allows me to combine my disparate academic interests, but also because popular science and SETI naturally feed off one another so well. According to astronomer Alan Penny, SETI is "a powerful forum for engaging with the public on the nature of scientific studies, using a subject in which the public is already interested."[2] In other words, SETI is prime fodder for popular science books. Meanwhile, popular science books are uniquely positioned to disseminate information to the public. SETI is a field that suffers from limited human and financial resources[3] (a certain Russian billionaire's recent hefty donation notwithstanding),[4] and science writing can play a pivotal role in fostering public support for these scientific endeavors.[5] Thus, popular science is the optimal genre for conveying research on the Order of the Dolphin and the history of SETI.

A Note on the Status of "John Lilly and the Cetacean Conversation"

I am coauthoring *The Order of the Dolphin: Origins and Future of SETI* with my thesis mentor, Dr. Anthony Crider. He will compose a fictional prelude for the John Lilly chapter, and the framework of that prelude will determine the trajectory for the latter half of the John Lilly chapter (which includes the description of interspecies communication research since John Lilly). Therefore, the "John Lilly and the Cetacean Conversation" section of this thesis constitutes an incomplete book chapter.

A Note on Citations

Authors of history of science books adhere to no standard citation style when crediting sources in their works. Some writers use footnotes,[6] some conclude with "Selected Further Reading and Notes" lists,[7] and others simply contain a bibliography[8] or list of references.[9] Popular science author Dava Sobel introduces the bibliography at the end of her book *Longitude* with the following explanation: "Because this book is intended as a popular account, not a scholarly study, I have avoided using footnotes or mentioning, in the body of the text, most of the names of the historians I have interviewed or the works I have read and relied on for my own writing."[10]

In my popular science chapters, I wanted to follow the example of authors like Sobel and avoid distracting the reader with parenthetical citations or footnotes. Thus, I use MLA style to list my sources in the "Works Cited" section and placed the citations that would normally appear in parenthesis throughout the text in endnote format. The final manuscript of *The Order of the Dolphin: Origins and Future of SETI* will only include the contents of my "Works Cited" section in the form of a reference list or bibliography, not the endnotes. However, because this thesis is part of a larger, ongoing project, I wanted to help readers (and myself) easily identify source materials for the information in each book chapter.

Book Proposal

I will continue writing the manuscript of *The Order of the Dolphin: Origins and Future of SETI* with Dr. Crider after graduating from Elon, and I plan to submit a book proposal that includes the following thesis chapters. Therefore, I have chosen to introduce my thesis in the style of a book proposal. The format I use here is modeled after the MIT Press proposal requirements.[11]

1. **A brief (1-2 paragraph) description of the work and its rationale/approach:**

In 1961, the National Academy of Sciences organized a meeting on the search for extraterrestrial intelligence (SETI) at the National Radio Astronomy Observatory in Green Bank, West Virginia. The ten scientists who attended, including future SETI icons such as Frank Drake and Carl Sagan, represented a variety of scientific fields. At the conclusion of the meeting, the attendees adopted the moniker "The Order of the Dolphin," in honor of participant John Lilly's work on interspecies communication. Since this seminal meeting, researchers in each of the Order members' fields have contributed in some way to the search for intelligent life.

There are many popular science books on SETI, but most make short mention of the Order of the Dolphin—if they mention the Green Bank meeting at all. This book will fill a gap in the literature by conducting an in-depth investigation into the circumstances surrounding each Order member's invitation to Green Bank and exploring SETI as the legacy of this meeting. Each chapter spotlights a different Order member and his field's contributions to SETI.

2. A description of any outstanding, distinctive, or unique features of the work:

One distinguishing feature of this book is that it frames each Order member's work as a potential way to find nonhuman intelligence. Each chapter begins with a fictional prelude, which illustrates a future where humans encounter nonhuman intelligence by some means related to that Order member's work. For example, Order member Otto Struve was one of the first scientists to suggest that many sunlike stars were surrounded by planetary systems, and he even suggested two methods for detecting these "exoplanets." Thus, the Struve prelude tells the tale of scientists discovering an inhabited exoplanet. Similarly, because Order member Philip Morrison was a particle physicist, the prelude to his chapter illustrates scientists finding an alien message in a stream of particles from outer space.

3. A description of how this book is similar to and different from other published books, in terms of style, topic, and depth (including specific mention of relevant titles).

Several books describe the search for extraterrestrial intelligence. The following lists comprise a sample of previously published SETI materials.

Books on extraterrestrial life:

- *Where Is Everybody? Fifty Solutions to the Fermi Paradox* by Stephen Webb
- *Deep Time: How Humanity Communicates Across the Millennia* by Gregory

Benford

- *Extraterrestrials: Science and Alien Intelligence* by Edward Regis
- *Murmurs of Earth: The Voyager Interstellar Record* by Carl Sagan
- *After Contact: The Human Response to Extra-terrestrial Life* by Albert Harrison
- *Sharing the Universe: Perspectives on Extraterrestrial Life* by Seth Shostak
- *Cosmic Company: The Search for Life in the Universe* by Seth Shostak
- *Social Implications of the Detection of an Extraterrestrial Civilization* by John Billingham
- *The Living Cosmos: Our Search for Life in the Universe* by Chris Impey

Books about the scientific search for extraterrestrials:

- *Signatures of Life: Science Searches the Universe* by Edward Ashpole
- *Five Billion Years of Solitude: The Search for Life Among the Stars* by Lee Billings
- *The Eerie Silence: Renewing Our Search for Alien Intelligence* by Paul Davies
- *Is Anyone Out There? The Scientific Search for Extraterrestrial Intelligence* by Frank Drake and Dava Sobel
- *Searching for Extraterrestrial Intelligence: SETI Past, Present, and Future* by H. Paul Shuch
- *Beyond Contact: A Guide to SETI and Communicating with Alien Civilizations* by Brian McConnell
- *SETI Pioneers* by David Swift
- *The Biological Universe: The 20th Century Extra-terrestrial Life Debate* by Steven Dick

The Order of the Dolphin: Origins and Future of SETI is unique primarily because it focuses on a topic that is only briefly mentioned in the majority of SETI books. *The Living Cosmos*, *The Eerie Silence*, and *The Biological Universe* dedicate, at most, a few pages to the Order of the Dolphin. In *Five Billion Years of Solitude*, Lee Billings spends merely a chapter describing the meeting. Frank Drake's first-hand account in *Is Anyone Out There?* is the most detailed description of the Order meeting currently available—but Drake still only spends about a chapter discussing the Order (moreover, archived correspondence leading up to the meeting demonstrates that Drake's account of the meeting planning process is historically inaccurate).

Because *The Order of the Dolphin* centers on a largely un-discussed conference, it will spotlight several key players in early SETI who are often skimmed over in the existing literature. The majority of books on extraterrestrial intelligence give much attention to big-name SETI scientists, such as Frank Drake and Carl Sagan, but some of SETI's other founding fathers, such as John Lilly and Otto Struve, have received significantly less attention. There will be some overlap between the spotlighted characters in *The Order of the Dolphin* and David Swift's 1990 book *SETI Pioneers*, but *SETI Pioneers* is a book of interviews and omits several Order members.

Popular science author Philip Plait uses fictional preludes to demonstrate scientific concepts and possibilities in his book *Death from the Skies*, but this technique has not yet been employed by any authors of popular SETI books. Therefore, the style of the chapters also sets *The Order of the Dolphin* apart from previously published materials.

4. **A description of the book's format (use of examples, problems, glossaries, bibliographies, appendices, supplementary materials, et cetera).**

This book is intended to be a popular science publication, so it will not include examples or problems typical of textbook-style publications. *The Order of the Dolphin* will include a bibliography. There will be no supplementary materials.

5. **An overview of the book's audience (readers' disciplines, prerequisites for understanding the book's material, assessment of the book's descriptive vs. quantitative style).**

The Order of the Dolphin is intended for anyone with an interest in the search for extraterrestrial intelligence or the history of science. The audience is not expected to have any background knowledge on the scientific fields discussed. The book will be largely descriptive, and will not include any mathematical expressions (barring the Drake Equation, which is not a real mathematical equation in the conventional sense).

The authors of this book hope to illustrate the complex nature of the search for extraterrestrial life; however, the book is not meant to be a rigorous crash course in several different scientific fields. Instead, a single read of any chapter should provide a non-expert audience with the general narrative of one Order member's research, as well as a better understanding of how multiple disciplines impact the search for aliens.

6. A status report on the manuscript (portion of material complete, expected date of completion, intended use of figures).

At the time of submitting this proposal, three chapters (the introduction and two Order member chapters) are complete. A third incomplete Order member chapter, "John Lilly and the Cetacean Conversation," is included among the enclosed sample chapters. The manuscript is expected to be finished within two years. The final manuscript may include figures or photographs, but none are included in these sample chapters.

7. A table of contents.

5) Otto Struve and the Hunt for Alien Worlds
6) Su-Shu Huang and the Goldilocks Zone
7) Carl Sagan and the Talking Fish
8) Melvin Calvin and the Hidden Biosphere
9) John Lilly and the Cetacean Conversation
10) Barney Oliver and the Calculator Universe

8. Sample chapters (ideally constituting at least one-fourth the length of the final work).

Please find enclosed four sample chapters (three complete and one partial) for *The Order of the Dolphin: Origins and Future of SETI*: “Introduction: J.P.T. Pearman and the Order of the Dolphin,” “Philip Morrison and the Backseat Bomb,” “Otto Struve and the Hunt for Alien Worlds,” and “John Lilly and the Cetacean Conversation.”

Introduction:
J.P.T. Pearman and the Order of the Dolphin

In retrospect, the whole affair looks like something straight out of a B-rated sci-fi movie: a secret meeting sponsored by the government, where a handful of the nation's top scientists convened at a remote location on All Hallows' Eve. The topic of discussion? Whether intelligent aliens exist, and if so, how we might contact them. The attendees dubbed themselves the Order of the Dolphin. No one recorded the meeting. No one photographed its participants.[12] To this day, the most prominent relic of the event is an equation contrived by Order member Frank Drake to calculate how many alien civilizations are broadcasting radio waves in the Milky Way galaxy.

This was not science fiction. Surreal as it seems, the Order of the Dolphin was a real group of scientists who met on Halloween, 1961, at the National Radio Astronomy Observatory in the tiny town of Green Bank, West Virginia. Tucked away in the Appalachian Mountains, where the only visible trappings of First World civilization were a sparse orchard of radio telescopes and a squat residence hall, ten scientists from a variety of fields—including big names like chemist Melvin Calvin and the not-yet-famous astrobiologist Carl Sagan—met to seriously talk about searching for aliens.

The search for extraterrestrial intelligence (SETI) has since been accepted by the scientific community as a legitimate, worthwhile endeavor. Back in 1961, though, the Order of the Dolphin members could almost be regarded as renegades, some of the first scientists who were openly excited about scouring the skies for other life among the stars. So why did a sector of the United States government see fit to handpick several scientists and send them off to Middle-of-Nowhere, West Virginia to talk about aliens? To understand that, we have to back up to 1947: the year of the UFO.

Flying Saucers and Paradoxes

While flying a plane over the Cascade Mountains in late June of '47, pilot Kenneth Arnold supposedly spotted nine flying saucers hurtling through the sky. Arnold's account, understandably, generated a lot of media buzz. In the weeks that followed, hundreds of people from all walks of life and corners of the country came forward to weave their own tales of observing eerily maneuvering, strangely shaped aircraft. This first modern wave of UFO sightings,[13] which included a supposed UFO crash-landing on a ranch in Roswell, New Mexico,[14] crested a couple weeks later; if the UFO beholders were to be believed, it seemed early July was peak season for alien tourists. Even though these eyewitness testimonies were by no means conclusive evidence of alien visitation, they did captivate the public imagination. The UFO craze might have reached fever pitch in summer '47, but it stretched into the '50s.[15]

Flying saucer spectators weren't the only ones enthralled with the idea of extraterrestrial visitors. In the spring of 1950, *The New Yorker* published a cartoon that depicted aliens loading trash bins into their spacecraft—a jab at both a recent spike in UFO sightings and a mysterious string of public trashcan disappearances in New York City. The cartoon sparked a lunchtime conversation between a few post-war nuclear scientists at Los Alamos Scientific Laboratory. Their discussion centered on the question of whether or not intelligent aliens could achieve interstellar travel, and when humanity might do the same. One of the physicists, Enrico Fermi, (rather optimistically) predicted that humans had a one-in-ten chance of achieving faster-than-light travel by 1960.

Although the topic of the table's conversation gradually shifted away from interstellar voyages, Fermi's attention was snagged on the idea of aliens zipping through space at superluminal speed. He startled the rest of his colleagues when, apropos of apparently nothing, Fermi demanded of the table at large, "Where *is* everybody?"

What Fermi meant was, as far as he could calculate based on the size and age of our Milky Way, many alien civilizations should have already achieved interstellar travel and colonized the galaxy. If that were the case, then why wasn't the galaxy very obviously populated with extraterrestrial life? This quandary became known as the "Fermi Paradox," due to the contradiction between the number of star-hopping alien civilizations that Fermi thought *should* exist, and (dubious UFO sightings aside) the apparent absence of intelligent aliens.[16] Since that fateful lunchtime conversation, the Fermi Paradox has elicited potential solutions, spurred debates among scholars in a spectrum of fields, and become a cornerstone of SETI.

Fermi's prediction that humans would be sailing across interstellar space by 1960 was quite obviously incorrect. In fact, by 1960, the scientific community was only just starting to take a serious look at the question of extraterrestrial life for the first time. The 1950s had created a perfect storm of political entanglements, as well as biological and astronomical discoveries, that laid the foundation for the new field of astrobiology (then known as "exobiology"): the study of the living universe.[17]

Astrobiology: An Alliance of Sciences

In the 1950s, biologists were abuzz over several investigations into the origins of life on Earth. The most notable of these was the Miller-Urey experiment. In 1953, just three weeks after Watson and Crick published their famous paper on DNA's helical structure, Stanley Miller and Harold Urey published their own paradigm-altering study: they had forged the chemical building blocks of life in the lab. By filling a sealed vial with the gases thought to compose Earth's early atmosphere and then zapping the vial with a modest electrical current, Miller and Urey produced a "primordial soup"[18] of complex organic molecules. Their experiment lent credence to the idea that life could have easily arisen on early-Earth under similar conditions.[19]

Meanwhile, in the realm of space science, the so-called "nebular" hypothesis of planet formation was gaining popularity again, after several decades of the "rare collision" hypothesis dominating the field. As the name suggests, the rare collision hypothesis declares that planetary creation is a rare phenomenon. Extraterrestrial life must then also be exceedingly rare, if it exists at all. But by 1960, the nebular hypothesis, which says that planet formation is a common byproduct of star formation, was making a comeback. Paired with the results of the Miller-Urey experiment, the nebular hypothesis boded well for the possibility of life beyond Earth. Scientists figured that if it was "easy" for life to arise on an Earth-like planet, and Earth-like planets commonly formed around stars, then extraterrestrial life might not be so uncommon after all.[20]

What's more, in response to the Soviet Union's launch of Sputnik,[21] President Eisenhower signed the National Aeronautics and Space Administration (NASA) into existence in 1958.[22] A few prominent scientists, such as molecular biologist Josh Lederberg, persuaded the newly minted space organization to make life sciences research a priority. This was relatively easy, since the United States government was paranoid that the Soviets were on the brink of cooking up primitive life in their laboratories, and wanted American scientists to beat them to the punch.[23] Lederberg also pointed out that if

NASA were going to send spacecraft and human pioneers to other solar system bodies, then the administration needed to assess the risk of Earthly life forms contaminating extraterrestrial environments. As a result, the National Academy of Sciences established a Space Science Board to advise NASA on these matters—the same board that would eventually call the Order of the Dolphin to Green Bank. Lederberg was made head of the Space Science Board's sub-panel on extraterrestrial life, and he seized the opportunity to recruit several other astrobiology-interested scientists for the Space Science Board.[24]

A Triad of SETI Trailblazers

While the biologists and chemists were investigating the origins of life on Earth to suss out how it might arise elsewhere in the universe, astronomers were starting to consider how new technology could help them actively seek aliens.

In 1959, Cornell astrophysicists Giuseppe Cocconi and Philip Morrison coauthored a groundbreaking article that appeared in the premier science journal *Nature*, which suggested that radio telescopes were now sensitive enough to detect broadcasts from alien civilizations around nearby stars. They encouraged radio astronomers to search for alien signals in radio waves from outer space that had a very specific wavelength: 21 centimeters, the wavelength associated with radio emission from neutral hydrogen atoms. Cocconi and Morrison figured that aliens would probably use this "universal" wavelength of radio radiation to broadcast their messages because hydrogen is the most abundant element in the universe. Therefore, its emission characteristics should be familiar to any aliens who knew enough physics and astronomy to build radio telescopes.[25]

Unbeknownst to Cocconi and Morrison, a young staff member at the National Radio Astronomy Observatory (NRAO) named Frank Drake was already planning to conduct precisely the type of search they prescribed in their *Nature* paper. Drake nicknamed his revolutionary undertaking "Project Ozma,"[26] after the princess in L. Frank Baum's *Wizard of Oz* series.[27] In April of 1960, Drake pointed one of the NRAO's radio telescopes at two nearby sunlike stars and listened for alien broadcasts over the course of two hundred hours.[28] Nothing. Well, nothing but a couple of false alarms, courtesy of secret military operations.[29] Still, Project Ozma attracted significant attention among scientists and the general public. Dana Atchley, CEO of Microwave Associates Inc., donated equipment for the project, and Barney Oliver, Vice President of Research at Hewlett-Packard, personally visited Green Bank to see Drake's project in action.[30]

Giuseppe Cocconi, Philip Morrison, and Frank Drake were the first three SETI scientists. Even though a slew of studies in the space and life sciences in the 1950s set the stage for their research, these three distinguished themselves because they were not just examining the case of life on Earth to see how it might evolve elsewhere in the universe. They were advising astronomers to actively look—or were actually *doing* the looking—for evidence of alien life in outer space. They were establishing the *search* for extraterrestrial communication as a distinct branch of astrobiology. Moreover, Cocconi, Morrison, and Drake's collective work paved the way for the Green Bank meeting of 1961.

Enlisting the Order

The most well known account of SETI's origins comes from Frank Drake's book *Is Anyone Out There?*, wherein Drake relays his phone conversation with one James

Peter Pearman of the National Academy of Sciences Space Science Board. The story goes that the two didn't know each other when Pearman called Drake one summer afternoon in 1961. Apparently, Pearman had been closely following Project Ozma and was "trying to build support in the government for the possibility of discovering life on other worlds."[31] Pearman also thought it imperative to assemble a team of scientists who could examine the implications of Project Ozma. He was calling Drake because he wanted help in (a) figuring out who should be invited to such a symposium, and (b) securing permission from Drake's boss, NRAO Director Otto Struve, to hold the meeting at Green Bank.[32]

According to Drake, he and Pearman immediately started throwing out names to compile their exclusive guest list, which "had practically assembled itself over the course of Project Ozma."[33] Drake says that their impromptu brainstorm session generated ten names, including Pearman's and his own. Over the next few months, the two exchanged phone calls to thrash out the conference details,[34] with Pearman largely handling logistical oversight and Drake devising the meeting agenda.[35] The handpicked eight accepted their invitations and on Halloween, they all descended on the NRAO.

Drake's phone call story is a nice anecdote, but archived correspondence leading up to the meeting reveals that this isn't quite how the Order recruitment process unfolded. In fact, Josh Lederberg of the National Academy of Sciences Space Science Board was the first one to suggest holding a conference on extraterrestrial life—which hardly comes as a surprise, as he'd had a hand in so many other administrative aspects of astrobiology.

When the Space Science Board met in February of '61, Lederberg pointed out that since radio astronomers like Frank Drake now had the technological capability to actually look for alien signals, it might behoove the Space Science Board to commission a few experts to assess SETI's prospects—how best to conduct the search, if it was worth conducting at all.[36] Even though a meeting would probably not produce any firm conclusions about how to look for aliens, Lederberg felt it should evoke some new perspectives on the questions facing astrobiologists.[37] The other board members agreed, including Pearman. In mid-March, Pearman attended a talk that Drake gave to the Philosophical Society of Washington about SETI, and he approached Drake after the presentation to share the Space Science Board's conference idea. Pearman was pleased to learn that Drake, too, had been toying with the idea of organizing a SETI forum. They parted ways with the promise that they would be in touch to deliberate the meeting itinerary and invitees.[38] Perhaps a follow-up phone call after this encounter seeded the Order conscription story in Drake's book.

In any case, less than a week after the Philosophical Society meeting, Drake sent Pearman a letter confirming that Struve was on board with the idea of hosting a SETI conference at the NRAO. Drake capped the number of potential participants at thirty people—the maximum number of guests who could comfortably fit in the NRAO dormitory—and included a short list of names for Pearman's review.[39] Pearman passed Drake's correspondence on to a couple of other Space Science Board members including Lederberg, who of course also had some names to add, including his own.[40]

Just as the enlistment process was not as neat and tidy as Drake and his coauthor Dava Sobel would have their readers believe, orchestrating the Green Bank meeting was hardly as simple as setting a date and showing up. Originally, the conference was planned for May or June, but then got delayed to September, as the back-and-forth between Drake and the Space Science Board members dragged into the summer.

All the while, the list of potential invitees was in flux.[41][42] When members of the Space Science Board started sending out feelers in the scientific community to gauge who would be interested in the Green Bank conference, they received a lot of positive responses. This would have been great, if not for the fact that the Space Science Board was dead-set on restricting attendance to the few experts who would be able to contribute most substantially to the dialogue. This exclusivity would help the board keep the meeting out of the public eye. Enthusiasm in the scientific community for SETI aside, the National Academy of Sciences was hardly eager to handle the media attention it could draw by openly sponsoring a conference on aliens. As Drake said, "One could now broach the idea [of SETI] aloud, thanks to Project Ozma and the Cocconi-Morrison paper...but not without looking over one's shoulder to see who might be laughing."[43]

The ever-changing list of participants made it a little difficult to hammer out a meeting program. Drake and Pearman wanted the agenda to include presentations on SETI-related research, but the presentation lineup would hinge on which scientists attended the meeting in the first place.[44] [45] At the end of July, the Space Science Board Executive Director sent Struve a letter to formalize that last few months of Drake and Pearman's planning, outlining three goals for the discussion at Green Bank:

1. Estimate the probability that intelligent, civilized aliens had evolved elsewhere in the universe, as well as the likelihood that their radio broadcasts were detectable from Earth.

2. Determine whether it was worth conducting more SETI searches with existing technology; if the answer was no, predict SETI's prospects with more advanced equipment in the future, and determine what it would take to develop that technology.
3. Recommend a plan of action to the Space Science Board, regarding SETI efforts.[46]

Struve agreed to these terms and finally sent out the conference invitations in mid-September. Struve's invitations emphasized the discrete nature of the meeting and solicited papers for presentation. Struve hoped about twenty people would attend the conference, and he attempted to entice invitees with the promise that room and board would be covered by the NRAO...but admitted that, regrettably, the National Academy of Sciences would not cover travel expenses.[47]

By late October, only nine people, in addition to Drake and Pearman, had sent positive RSVPs to Struve's invitation: Lederberg was on the list, along with his mentee, Carl Sagan, the first scientist to christen himself an "exobiologist."[48] Struve also roped in an old mentee, Su-Shu Huang, who was a planetary scientist at Berkeley. Dana Atchley and Barney Oliver both got spots on the invite list because they had supported Drake's Project Ozma.[49] Coauthors of the world-famous *Nature* paper, Cocconi and Morrison were slotted to attend, as was Melvin Calvin, who had been researching the origins of life on Earth.[50] Last but certainly not least was John Lilly, who'd been conducting some controversial interspecies communication research with dolphins.[51]

A week before the meeting, Struve issued a tentative program to the intended participants with the pointed note that he'd had some difficulty getting people to submit papers for presentation, so the schedule was flexible. The official plan, however, was to begin by mid-morning on November 1 and wrap up the following afternoon.[52] Lederberg and Cocconi were both last-minute drop-outs, leaving ten men to attend the Green Bank conference: radio astronomer Frank Drake, biologist James Peter Pearman, observational astronomer Otto Struve, exobiologist Carl Sagan, planetary scientist Su-Shu Huang, astrophysicist Philip Morrison, electronics entrepreneur Dana Atchley, computational expert Barney Oliver, chemist Melvin Calvin, and neuroscientist John Lilly. On Halloween, this motley group of scholars flocked to Green Bank from all over the country.[53]

The Drake Equation

On the morning of Wednesday, November 1, the scientists who would become the Order of the Dolphin settled into the NRAO residence hall lounge, armed with some of the nation's best scientific minds (and hot coffee), ready to dive into a conversation on intelligent aliens.[54] After Struve made a few welcoming remarks, he sat back and let Drake take the lead. The gathered scientists watched in eager anticipation as Drake stepped up to the blackboard and started writing out an equation: $N = R^* f_p\, n_e\, f_l\, f_i\, f_c\, L$. Before he was halfway through, many of their party had begun to murmur.[55] *What* was Drake up to?

Drake had contrived this formula, which would come to be known as the Drake Equation, when he was trying to devise an agenda for the conference.[56] The Space Science Board Executive Director had explicitly requested that the Green Bank meeting produce an estimate for the probability that alien civilizations existed on other planets and that radio astronomers could tune into their broadcasts. But so many scientific issues came to bear on these questions. There were so many factors to juggle, so many angles to consider, that organizing and prioritizing them all proved no easy feat.

Ultimately, Drake decided to round up all of these SETI uncertainties into a single equation. The solution, *N*, signifies the number of radio-communicating civilizations in the galaxy. Each factor that influences the size of this number is written on the right side of the equation:

R^* = the number of sunlike stars born in the Milky Way each year
f_p = the fraction of those stars that host planetary systems
n_e = the number of planets in each solar system with environments that can support life
f_l = the fraction of habitable planets on which life actually appears
f_i = the fraction of life-bearing planets where *intelligent* life evolves
f_c = the fraction of planets with intelligent creatures, where those creatures develop methods of interstellar communication (namely, radio waves)
L = the length of time a civilization continues broadcasting (radio waves) into space[57]

The product of all of these factors is *N*. It's worth noting that the Drake Equation is underpinned by a couple of major assumptions. For instance, it presumes that life can only develop on planets around sunlike stars.[58] But Drake had to start somewhere.

Drake's equation provided a roadmap for the discussion at Green Bank. The factors of *N* range from questions of astrophysics, to planetary science, to evolutionary biology, to social science and technological trends. Unfortunately, no social scientists had even been invited to the meeting, so there were no experts present to weigh in on *L*. In fact, Pearman stated in his report to the Space Science Board that if a similar SETI assembly convened in the future, then the hard scientists should reach out people with an even wider range of expertise.[59]

As it was, Drake's equation guided conference discourse for the next two days, as participants postulated and debated the values for each factor of *N*. Subsequent chapters of this book include more detailed descriptions of each Order member's contributions to the conversation, but in the meantime, here is a brief summary of the Order's estimates for each factor value:

The only factor known with any reasonable certainty in 1961 was $R*$, the rate at which sunlike stars are born in the Milky Way. The participants at the Green Bank meeting quickly calculated this value by dividing the total number of sunlike stars in the galaxy (about ten billion stars) by the average lifetime of these stars (about ten billion years), which very neatly came out to approximately one star per year.[60]

The fraction of sunlike stars with planetary systems (f_p) was a bit hazier, since astronomers would not actually spot a planet outside our solar system for another thirty-plus years. But using indirect evidence based on observations of stars' rotation rates, the space scientists at Green Bank set f_p between 0.2 and 0.5.[61] They hoped that observations of planets around other stars would soon help narrow this range of possible values.[62]

The number of habitable worlds per planetary system (n_e) was also difficult to estimate, since astronomers had only our own solar system on which to base their conjectures about planetary systems throughout the rest of the galaxy. Even observations of just one other planetary system could improve their estimates by leaps and bounds.[63] Alas, the Green Bank attendees simply had to assume that the solar system's architecture was typical.[64] And since the solar system contains a richly diverse planetary population, they figured that at least *one* planet around each star would be suitable for sustaining life—perhaps more, based on the fact that Mars had probably once been habitable. Thus, the scientists at Green Bank granted n_e a value of one to five.[65]

If the aforementioned astrophysical factors of *N* seemed uncertain, determining the four biological, chemical, and sociocultural factors was almost guesswork. The Green Bank attendees agreed that based on current understanding of chemical evolution, life was probably an inescapable, or at least very common, step in planetary evolution (they didn't even touch the topic of life originating in non-planetary environments). Consequently, at the Green Bank meeting, the faction of habitable planets with life (f_l) was assigned a value of one.[66] It was anyone's guess as to how often alien creatures developed intelligence, but intelligence seemed to have indisputable value as a survival mechanism. Thus, they set the fraction of life-hosting planets with intelligent creatures (f_i) at one, too.[67]

When it came to determining the fraction of planets with intelligent species that would achieve interstellar communication (f_c), the scientists at Green Bank looked to the case of Earth as an example. They figured that of the handful of independent human civilizations that had cropped up across the globe (in China, the Americas, and the Middle East), a minimum of one of these had developed a means of interstellar communication: radio technology. Favoring a conservative estimate, the scientists decided that the fraction of planets with intelligent life that would develop interstellar communication was about 0.2. They realized that this prediction was extremely anthropocentric, but felt they had no other basis for contriving a reasonable value.[68]

The final factor of the Drake Equation, *L*, was the real clincher. At this point, the group had suggested values and ranges of values for the other factors of *N* that could, theoretically, average out to a number close to one.[69] This meant that, depending on whether *L* was very long or very short, *N* could be very large or very small. The galaxy could be teeming with intelligent life, or humanity could be alone.

Given that the Order convened in 1961, smack in the middle of the Cold War, the looming possibility of humanity's self-destruction weighed heavily on everyone's mind—especially Philip Morrison, who had been a leader in the Manhattan Project and seen the destruction of Hiroshima firsthand. In fact, the week leading up to the conference, American newspapers were streaked with headlines about the latest Soviet nuclear test.[70] Things certainly looked grim, where humanity's longevity was concerned. Accordingly, the scientists at Green Bank decided that either *L* must be exceedingly short, or exceedingly long. Species who were technologically capable of developing radio telescopes would inevitably develop a means of wiping themselves out; the question was whether or not they *would* self-destruct. If so, then their stint of radio communication would be quite short. On the other hand, if intelligent aliens figured out a way to control their dangerous technology and peacefully persist, they could broadcast radio waves for millions of years. In the end, the conference participants established two possible ranges for *L*: either less than a thousand years, or greater than a hundred million years.[71]

These alien enthusiasts, of course, hoped that *L* would be very, very large—both for the likelihood of finding alien peers, and the likelihood of humanity's own survival. At the end of the conference, Struve even made the toast: "To the value of *L*. May it prove to be a very large number."[72]

SETI Camaraderie and the Establishment of the Order

Even though most of the discourse at Green Bank centered on the Drake Equation, the attendees also deliberated SETI research logistics. They had all agreed that space was too vast for aliens to zip between stars in spaceships, even highly advanced ones, so the most efficient way to transmit messages was electromagnetic radiation, which travels at the speed of light—the fastest anything can pass through space.[73] In that case, which types of radiation should be searched (in addition to the 21-centimeter radio waves suggested by Cocconi, Morrison, and Drake)?[74] Was it better to devote a lot of time on a single telescope to SETI research, or a little time on many telescopes? What was the outlook for future SETI funding? (Not good, according to Pearman, since the United States government was hell-bent on sending a man to the moon by the end of the decade, and consequently much of the money in space science was being funneled toward manned space missions.)[75]

The Green Bank meeting was, as Drake succinctly put it, “a talk marathon.”[76] The group didn’t really break, even for meals; SETI-centric conversations followed the scientists into the dining room, back to the dormitory, and out into the rolling grounds of the NRAO.

The conversation wasn’t *all* serious, though. Around 4 a.m. on Thursday morning, the NRAO received a phone call from Sweden announcing that Melvin Calvin had been named a Nobel Laureate for his photosynthesis research.[77] Pearman, who’d heard rumor that Calvin was a shoe-in for the prize, had made certain that the NRAO was appropriately stocked for a celebration—which is how ten esteemed scientists wound up getting, as Carl Sagan put it, “smashed on champagne”[78] in the wee hours of Thursday morning.

At the end of their meeting, this assembly of SETI enthusiasts adopted the name "The Order of the Dolphin,"[79] a title inspired by John Lilly's interspecies communication research[80]...and perhaps by the alcohol and sleep deprivation resulting from Calvin's impromptu party. The Order of the Dolphin was never a scientific society in the traditional sense. The members didn't elect officers or hold regular meetings.[81] Once Pearman delivered his report on the Green Bank meeting to the Space Science Board in mid-November, the Order of the Dolphin had officially fulfilled its obligations to the National Academy of Sciences.[82]

Perhaps a few of the Order members thought or hoped that they would all reconvene in the future; after all, one has to imagine that a unique sort of relationship is forged between people who experience the combination of isolation, sleep-deprivation, intoxication, and SETI fervor that characterized the Green Bank meeting. What is abundantly clear, though, is that the members of the Order wanted to preserve the sense of SETI community they'd felt at Green Bank, whether they were in the same place or not. A few weeks after the conference, Calvin sent each Order member a silver pin, which depicted a leaping dolphin and had the Order member's name engraved on the back.[83] That winter, Drake sent a holiday card to his fellow Order members that, in the spirit of SETI, not only offered season's greetings, but also included a faux alien message for the recipients to decode.[84]

Various Order members also went on to induct honorary members in the months that followed the Green Bank meeting. A few days after the conference, Calvin, Lilly, and Atchley invited Harvard biophysicist A.K. Solomon and Doxie Woodward into the fold. The following spring, at an American Philosophical Society meeting, Calvin and Lilly swore Lilly's wife and one of his colleagues into the Order at the dinner table.[85]

The Green Bank meeting was more than just the seminal SETI conference. It was a unique, somewhat bizarre moment in history when ten scientists of assorted disciplines—friends, colleagues, mentors, and perfect strangers—gathered to indulge their mutual fascination with extraterrestrial life. Out of the few scholars from across the country who were even invited to this secret symposium, the ten Order members were the ones who travelled on their own dime out to the middle of nowhere, who discussed the Drake Equation for the first time ever, who helped lay the groundwork for the next half-century of SETI.

Some Order members were already quite well known at the time of the meeting. Some had yet to be wrapped in the mantle of international fame. For a few of them, SETI became the focal point of their careers, while for others, SETI faded to the periphery of their lives. Their fields of expertise ran the gamut from radio astronomy to neuroscience, and each Order member's field has since contributed to the search for extraterrestrial intelligence in its own unique way. In that sense, SETI is truly the legacy of the Order of the Dolphin.

Philip Morrison and the Backseat Bomb

It all started with the song. No one, save the smattering of neutrino astronomers across the globe, would have ever paid attention to that particular corner of the cosmos—let alone sworn on their lives that it was home to intelligent aliens—if I hadn't posted the song.

I should back up a bit. Introduce myself, perhaps. Hello, my name is Nadia Peterson, but you probably know me as PhantomNeutrinoSeeker, the username under which I posted "Alien Anthem." When I'm not creating viral videos that attract cult followings, I'm a neutrino astronomer.

With all the recent hullaballoo over neutrinos from outer space, you may already know a little bit about these mysterious little particles. But for unfamiliar parties (or those who have fallen victim to the rampant misinformation about neutrinos in all the aforementioned hullaballoo), I'll provide a brief explanation. Neutrinos are the shy-guys of the subatomic universe. Despite being in the same family as well-known particles like electrons and constituting one of the most abundant types of particles out there, neutrinos hardly ever interact with other matter as they flit through space.[86]

Neutrinos' slippery quality is both a blessing and a curse for neutrino astronomers like me, who want to study the astronomical objects (i.e., stars) and phenomena (i.e., stellar explosions) that produce these ghostly particles.[87] *On the one hand, neutrinos' evasive nature allows them to reach our earthbound detectors from regions of the galaxy where obscuring material ensnares even particles of light. On the other hand, neutrinos' ninja-like stealth has made it extremely difficult for our detectors to, well, detect them. For a long time, neutrino physicists could only spot a tiny fraction* *of the neutrinos sweeping through their detectors, even with thousands of tons of incredibly sensitive machinery. What's more, neutrino detectors were, for the most part, only able to detect one of the three different "flavors" of neutrinos out there: electron neutrinos. Tau and muon neutrino detection was, for all intents and purposes, nonexistent.*

Basically, trying to get an accurate picture of the neutrino universe was like looking at a computer screen with only a handful of working pixels. Only a million times worse.

But neutrino detection technology inevitably advanced. With the help of the TRINITI (Tri-Neutrino Interception, Testing, and Identification) Network—a squad of neutrino detectors working in tandem to keep track of all three flavors of neutrinos generated by astronomical objects—we gradually gained a more comprehensive perspective of neutrino production and traffic in the galaxy. The Milky Way offers a plentitude of subjects for study, and we've been able to sketch out a rough picture of "normal" neutrino production for different types of objects and events in the galaxy. Except, we've gotten snagged on one region in particular, whose neutrino production is nothing short of baffling.

We haven't been able to determine which object, exactly, is responsible for the enigmatic neutrinos. We've got it narrowed down to a region several thousand light years away, amidst a collection of old stars and a nebula leftover from a star gone supernova. Whereas most objects pump out their neutrinos at a steady rate, or phenomena like supernovae flush a whole bunch of them into space at once, in this puzzling patch of sky, we've observed a rather peculiar pattern of neutrino production.

I'll spare you the nitty-gritty details here, but the gist of it is this: the number of *neutrinos TRINITI has detected from this region varies over time, but the change is not smooth or continuous. In fact, the transitions have a shockingly rigid, step-like quality. There are sudden changes—a veritable deluge of neutrinos suddenly gives way to a trickle, followed by a moderately populous stream, and so on. The intensity sometimes switches after a brief interval; other times, the flow continues at a steady intensity for a long while. Sometimes there are big jumps in intensity; sometimes there are smaller steps. There are slots of neutrino "silence" before the TRINITI detectors pick up on any neutrino output from the region again.*

The TRINITI team has measured six distinct "intensities" of neutrino generation from this region, and the variations in intensity are anything but random. They're rhythmic. Repetitious. The patterns double back on themselves and repeat. The interplay between the six intensity levels is exquisitely intricate.

Of course, the discovery of this weird neutrino outflow had the neutrino astronomy community collectively scratching our heads. Theorists nominated and debated explanations for TRINITI's anomalous observations. Could this be the result of some eccentric interplay between the supernova and its stellar surroundings? Could one of the stars in this region be a new type of star altogether—a "neutrino star," if you will?

Or maybe, as some started to speculate—first behind cupped palms and then (when no alternative solution quickly presented itself) out in the open—the neutrino outflow from this region was intelligently controlled. Maybe, one of my TRINITI colleagues suggested over lunch in the cafeteria one day, there was an inhabited planet around the star that went supernova, and the neutrino signal was the decimated civilization's epigraph. Its farewell to the universe. Its swan song.

I should have resisted the temptation. But the musician in me couldn't help herself and, I'll admit, I was intrigued by the possibility that the neutrino signal might be crafted by unseen little green men. I translated several months' worth of the peculiar neutrino output into a six-note musical piece, with the six neutrino intensity measurements played as C, D, E, F#, G#, and A#—the chilling combination of notes often combined to play dream sequences in films. It seemed fitting for a dying alien civilization's swan song. I made a recording of the song with some basic music-making software on my laptop, and paired that audio with a visual of the TRINITI logo to create a short video, which I posted under the title "Alien Anthem." One of my colleagues linked to the video on our lab's website, probably thinking it would provide good PR for TRINITI.

The theories flying around among the astronomical community, regarding the enigmatic neutrino signal's possible intelligent design, had gotten a bit of press coverage. But we were still so uncertain—and so many neutrino astronomers were clinging with a white-knuckle grip to the idea that this was merely some unexplained natural phenomenon—that the neutrino enigma was but a blip in science media coverage. Within a few weeks of my posting it, though, "Alien Anthem" racked up hundreds of millions of views. I understand why. Reading about strange particles spotted by a conglomerate of underground detectors is one thing. Hearing for yourself the eerie, sometimes lip-curling or eyebrow-raising melody of a potentially alien-composed "song" is something else entirely.

Neutrino astronomers have been working themselves ragged, scouring data and scanning the skies for other regions producing uncanny neutrino outflows. They're seeking another "neutrino star" to prove that step-like, rhythmic neutrino output is a *totally normal, natural thing in the galaxy. Yet, only one spot in space seems to be singing.*

I wouldn't put money on the little green men theory, but in the absence of evidence for another "neutrino star," I can't help hoping the signal is intelligently created. Of course I can't. Who doesn't want humanity to find ET? Not that I advertise this (perhaps childish) hope to my colleagues. I've been catching a lot of flak in the scientific community for inciting all the fanfare over "Alien Anthem." I understand that, too. Intrigued as I am by the prospect of extraterrestrial maestros, I'm a staunch devotee to the scientific method. More data must be collected before we definitively call "alien, ho!"

…Which is not the view taken by many of the most enthusiastic viewers of "Alien Anthem." I've seen footage of people on the news gathered in community centers or around bonfires to sing "Alien Anthem" like they would "Kumbaya," or some church hymn. I'm not sure what they think they're accomplishing, whether they're waiting for the Mother Ship or just plain rejoicing in the discovery of other intelligence across the galaxy. And no matter how loudly neutrino astronomers shout that the mystery of the strange signal isn't nearly solved yet, the people singing "Alien Anthem" sing louder. As far as a decent pocket of the public is concerned, this is it. We've found ET.

Philip Morrison lived two lives: one before Hiroshima, and one after Hiroshima. The latter half of Morrison's career found him pioneering new branches of astronomy, making a name for himself as a founder of SETI, and vehemently advocating for nuclear disarmament. As a high-energy astrophysicist at some of the most prestigious institutions in the country, Morrison tried to figure out what unimaginably small particles can reveal about the vast expanses of outer space and spent his free time trying to make sure that mankind didn't self-destruct. But before all that, before he'd born witness to the devastation wrought by atomic weaponry in 1945, nuclear physicist Philip Morrison was in the business of building the bombs.

Oppenheimer's Protégé

As a child, Philip Morrison was an avid builder and tinkerer. In the basement of his suburban Pittsburgh home, Morrison hoarded instruments like microscopes, chemistry sets, and a crystal radio, which he received as a fifth birthday present from his father.[88] Using this radio set, Morrison tuned into broadcasts by Pittsburgh's KDKA station, the first commercial radio station in the world. By age twelve, Morrison had his own ham radio operator's license and was chatting with people all over the world.[89] Little did he know that one day, he would suggest similar channels for making even more distant points of contact.

When Morrison wasn't occupied by his cellar-full of gadgets, he could usually be found reading books graciously provided by his Aunt Florie, who recognized Morrison's potential and wanted to foster his intellect. In addition to the nonfiction texts that provided Morrison a practically encyclopedic knowledge on various topics,[90] he devoured science fiction novels—especially those by H.G. Wells, though Morrison later denied that fantastical stories like *War of the Worlds* inspired his SETI pursuits.[91]

Morrison entered the Carnegie Institute of Technology (Carnegie Tech, for short) with the intent to major in radio engineering.[92] Despite Aunt Florie's obvious support of

Morrison's scholarly spirit, Morrison always suspected his parents were a bit "disturbed"[93] by his decision to go into science. Morrison's retail merchant father,[94] who had never even graduated high school, had hoped that his son would pursue a career like medicine, or law, or…some other profession that was at least a little bit familiar to him.[95] But Morrison's heart was set on the sciences. At Carnegie Tech, he continued to indulge his childhood passion for radio technology by spending his spare time building radios and establishing the Carnegie's first amateur radio station.[96]

Despite his radio fixation, Morrison ultimately graduated with a degree in physics, rather than radio engineering, because he preferred the kinds of people he met and the kinds of problems he got to solve in physics classes. In engineering, Morrison felt constrained by pre-laid designs for machines or processes, which could only be tweaked to increase efficiency. Morrison wanted to see the Big Picture—ask probing questions, stretch his imagination. He found that a physics education allowed him to dig deeper into the mysteries of the universe. Besides, Morrison thought, it was the 1930s. America was in the middle of the Great Depression. There were no jobs available, no matter which degree he earned.[97]

Fresh out of Carnegie Tech, Morrison made his way to the other side of the country for grad school. At the University of California, Berkeley, Morrison studied theoretical physics under Robert Oppenheimer,[98] the so-called "father of the atomic bomb."[99] But Morrison did not go straight into bomb building when he finished his doctoral dissertation in 1940.[100] In fact, despite being Oppenheimer's protégé, Morrison had difficulty landing *any* job. Apparently, during his time at Berkeley, Morrison had incurred the wrath of a physics faculty member named Leonard Loeb.[101] They got off on the wrong foot when Morrison, a brand new grad student at the time, accidentally blasted a set of speakers in the Berkeley student workshop on a Sunday night. Loeb came to see what all the racket was about and tore into Morrison.

Over the course of Morrison's career at Berkeley, the antagonism continued, on account of Morrison's political persuasions.[102] He had joined the Young Communist League in 1936 and, like many of Oppenheimer's students and Oppenheimer himself, was very active in party affairs.[103] Loeb, on the other hand, was the kind of man who volunteered as a strikebreaker.[104] Morrison officially resigned from the Communist Party in 1942, but by then the damage had been done, where Loeb was concerned.[105] According to Morrison, Loeb sent letters to every institution where Morrison submitted job applications, warning employers that Morrison was a troublemaker. Morrison finally got a two-year teaching gig at San Francisco State College because a couple of his friends who worked there informed the department chair about Loeb's streak of sabotage.[106] Morrison spent two years in San Francisco before moving to the University of Illinois in Champaign-Urbana, where he was working when an old friend invited him to join the Manhattan Project. [107]

Building Bombs

Robert Christy was another one of Oppenheimer's students who had gotten his doctorate the same year as Morrison. Just before a Chicago Midwestern Meeting of the American Physical Society in 1942, Morrison received a cryptic phone call from Christy. The two hadn't seen each other since Berkeley.[108] "I know you're coming to Chicago for the [conference]," Christy said. "Don't leave Chicago without seeing me…This is urgent."[109]

Morrison was puzzled but intrigued. Upon arriving at Christy's office for their meeting, Morrison saw that the entrance to the physics department was flanked with armed guards. He realized that Christy must be involved in some highly classified government business. Sure enough, when Christy escorted Morrison past the guards and into his office, he revealed to Morrison his involvement in the Manhattan Project. What was more, he wanted Morrison to join.[110]

Morrison started out at the Metallurgical Lab in Chicago, where he replaced Christy as leader of the research group that had been established by Enrico Fermi, SETI's famous paradox proposer.[111] A year later, Morrison was transferred to Los Alamos Scientific Laboratory in New Mexico,[112] where he performed such a diverse range of tasks that it was generally agreed he knew more about making the plutonium bomb than anyone else.[113]

Morrison's Greatest Satisfaction

On a hot, blue-sky day in July of 1945,[114] a Dodge sedan trundled through the desert of New Mexico.[115] The type of plutonium bomb that would be dropped on Nagasaki in less than a month was about to get a trial run. The operation code name: Trinity. The place: White Sands Missile Range. The test bomb's plutonium core rode to White Sands in a special carrying case on the sedan's backseat next to Philip Morrison,[116] who checked the stability of the precious plutonium orb every hour or so. When they arrived at the test location, Morrison helped assemble the plutonium bomb and assumed his position about ten miles away from ground zero to witness the first ever explosion of a nuclear weapon.[117]

With less than a minute to go before the detonation, Morrison found himself lying belly-down, facing ground zero. He wore sunglasses and clutched a stopwatch in one hand, a piece of welding glass in the other. When the second hand of his watch marked t-minus five seconds, Morrison lowered his head into the sandbank and counted down in his head: four, three, two, one, zero—and looked up. He kept the right lens of his shades covered with the welding glass, the left lens covered by cardboard, and saw a brilliant violet glow that seemed to radiate from everywhere in his scope of vision—the ground, the sky, *everything* was alight. Then, a blinding flash of white.[118] After the initial flares, Morrison took off his sunglasses and watched as a turbulent column of flame and debris reared up from the flat face of the desert. Once the column had reached a few thousand feet, the top swelled into a mushroom head that loomed over the missile range.[119]

Morrison would later cite the detonation at White Sands as the most memorable, satisfying moment of his entire life. "It was a tremendous experience," he recalled.[120] Ironically, this was probably one of the last moments Morrison viewed his nuclear weapons work as a noble pursuit.

Little Boy and Fat Man

In August of 1945, Morrison was one of the few Manhattan Project physicists who travelled to Tinian Island to prepare two atomic bombs for delivery to Japan: the untested uranium bomb destined for Hiroshima, dubbed Little Boy, and its plutonium partner known as Fat Man, which would be dropped on Nagasaki.[121] Robert Serber, another one of Oppenheimer's students, had bestowed the bombs with these nicknames at Los Alamos in honor of their respective sizes and shapes.[122] Morrison assisted with the assembly of Little Boy at Tinian Island before it was dropped on Hiroshima on August 6. Three days later, Morrison helped arm Fat Man on the plane ride to Nagasaki.[123]

After Japan's surrender, Morrison participated in the U.S. Army mission that toured what remained of Hiroshima to examine the effects of the atomic bomb. He was overwhelmed with the destruction and despair amid the "rust-red rubble"[124] that was Hiroshima. A Japanese official guiding the American party through the city gestured to the wreckage and said, "All of this from one bomb; it is unendurable."[125] Philip Morrison found himself in grim agreement.

Many years later, when asked whether he regretted participating in the Manhattan Project, Morrison replied, "On the whole, no. At the time, we believed Germany was close to developing an atomic bomb… The regrettable bombings of Hiroshima and Nagasaki did bring that conflict to an end, and saved countless...lives on both sides."[126] But even if Morrison believed the deployment of Little Boy and Fat Man served a greater good, he was deeply troubled by the implications of nuclear weapons development for humanity's survival. "My only regret is the dark period that followed [the bombings]," he said. "The bomb opened a door to fear, expense, and danger rather than just end the war."[127]

Having walked the streets of Hiroshima, Philip Morrison understood the atomic bomb's impact better than almost any other American. "We saw the test shot [at White Sands]," he said, "and we pored over and calculated the damage that a city would suffer. But on the ground at Hiroshima and Nagasaki there lies the first convincing evidence of the damage done by the present atomic bomb."[128] And if nuclear weapons were ever used in warfare again, Morrison knew they would not be dropped in pairs. They would be detonated by the hundreds or thousands, each bomb packing enough power to flatten an entire metropolitan area.[129] "If the bomb gets out of hand, if we do not learn to live together so that science will be our help and not our hurt, there is only one sure future," Morrison said. "The cities of men on earth will perish."[130]

The pacifist attitude Morrison adopted after visiting Hiroshima colored the rest of his career and, indeed, the rest of his life. One day after the Second World War ended, Morrison became a founding member of the Association of Los Alamos Scientists, an organization that advocated for international constraints on the use of nuclear energy. He spent the winter of 1945 testifying before Congress, describing the horrors he had witnessed in Japan. He later led the Federation of American Scientists' (unsuccessful) opposition to the construction of the hydrogen bomb[131] and went on to publish several books that championed peace and nuclear arms control.[132]

Morrison stayed at Los Alamos until the summer of 1946, but with Hiroshima fresh on his mind, he was ready to put the nuclear weaponry chapter of his life behind him.[133] The University of California, Berkeley offered Morrison a job, but Morrison turned down the position at his alma mater in favor of a post at Cornell. "I was politically afraid because of my [history with the communist party] that the state of the University of California could soon be shaken down by some kind of legislative outburst," Morrison explained. By comparison, he saw Cornell as a place that "really didn't believe in firing people who had done nothing wrong just because a newspaper accused them of something."[134] The political climate at Cornell was not quite as tolerant as Morrison had hoped (he butted heads with two successive Cornell presidents because of his political affiliations and activism), but for SETI's sake it was fortunate that Morrison took the job at Cornell.[135] Here, Morrison would meet Giuseppe Cocconi, his coauthor on the famous *Nature* paper that helped launch modern SETI.

A More Peaceful Outlet for High-Energy Physics

Before Hiroshima, Philip Morrison would likely have described himself as a nuclear physicist, plain and simple. And although the first few papers he published at Cornell were still very much in the realm of nuclear physics, Morrison's interests shifted to high-energy astrophysics[136]—basically, instead of studying radio waves or visible light, Morrison was interested in studying the most energetic forms of radiation (like X-rays and gamma rays) to see what they could reveal about the universe. By the end of his career, Morrison was describing himself as a "high-energy astrophysical theorist."[137]

Morrison entered the field of astrophysics by studying the gamma rays and X-rays showering Earth from outer space—the same kind of high-energy radiation emitted from a nuclear weapon detonation. In fact, it was the U.S. Air Force's gamma ray and X-ray detecting satellites, which were launched to monitor atomic bomb explosions in outer space after the Nuclear Test Ban Treaty was signed, that detected an astrophysical event known as a "gamma-ray burst" for the first time.[138] So, in a way, high-energy astrophysics was merely another avenue for Morrison to study the kinds of particles that had fascinated him before Hiroshima.

Morrison was not merely a high-energy astrophysics convert. He was a high-energy astrophysics pioneer. The publication of Morrison's 1958 paper on astrophysical gamma rays[139] marked the birth of modern gamma ray astronomy.[140] In composing the paper, Morrison actually entertained the idea of searching for intelligent alien signals in gamma rays, but never gave it serious consideration—until a year later, that is.[141]

Searching for Interstellar Communications

Giuseppe Cocconi arrived at Cornell a couple of years after Morrison, and the two of them became close friends. Like Morrison, Cocconi was more interested in pondering the Big Picture questions of physics, rather than homing in on a single narrow research focus, and was involved in gamma ray research. While Morrison was busy thinking about gamma radiation from outer space, Cocconi was busy studying the gamma rays produced right here on Earth, by a machine at Cornell called an electron synchrotron. Cocconi wondered how far those manmade gamma rays might travel.[142]

One day, Cocconi approached Morrison with an idea. What if, Cocconi proposed, intelligent aliens *also* wielded the power to generate gamma rays and were using this kind of radiation to communicate across interstellar space? "We already make gamma ray beams," Cocconi reasoned. "Why not send them out across space to see if anyone out there can detect them?"[143]

Morrison was excited but cautious about considering Cocconi's proposal. He wasn't sure how well gamma rays would travel through the galaxy, or whether another type of radiation might be more efficient for transmitting signals. So Morrison suggested that they look at all different types of radiation, from gamma rays to radio waves, to see which might be best suited for carrying messages through the galaxy.[144]

Eventually, this impromptu investigation into alien signals brought Philip Morrison full circle, back to his childhood love: radio communication. Because planetary atmospheres like Earth's would absorb most types of radiation, the two physicists quickly narrowed the possibilities for communication channels to visible light, radio waves, and gamma rays.[145] Cocconi and Morrison ruled out visible light as a plausible means of communication, because any visible light that aliens produced would have to compete with the light from stars to be seen by terrestrial observers. In comparison, the galaxy is not very radio-bright (even the sun's radio signals would be minor compared to a concentrated radio beam transmitted from the Arecibo telescope). Therefore, intelligent extraterrestrials producing *radio* signals had much less chance of their broadcasts being washed out by background radiation. Cocconi and Morrison crossed gamma rays off the list of possible communication channels because gamma ray astronomy was still in its infancy.[146] That just left radio. Within a few days of Cocconi mentioning potential alien transmissions, Morrison calculated that the 250-foot-across radio telescope at the Jodrell Bank Radio Observatory in England, then the largest of its kind in the world, was just big enough to pick up on signals sent from the nearest stars.[147]

At first glance, Cocconi and Morrison made an odd pair of pioneers for radio SETI. They were theorists, and neither one had ever been involved in radio astronomy research. Morrison admitted that he and Cocconi were amateurs.[148] But in their "crude"[149] examination of all the kinds of radiation that aliens could use to transmit signals, Cocconi and Morrison concluded that the most reasonable was radio radiation—specifically, the types of radio waves produced by hydrogen atom emission. They decided to write a paper recommending that astronomers search this radio frequency for evidence of intelligent messages. They had no idea that Frank Drake was already trying to conduct that kind of search at the National Radio Astronomy Observatory.[150]

Cocconi and Morrison began working on the article while they were both at Cornell, but Cocconi left for sabbatical at CERN (the European Organization for Nuclear Research) in Geneva soon after. They finished composing the paper, titled "Searching for Interstellar Communications," when Morrison visited Switzerland the summer of 1959.[151] Prior to submitting the paper for publication, the pair sent it to Bernard Lovell, the Jodrell

Bank Radio Observatory director. They thought that Lovell might want to conduct a search for alien signals with his observatory's 250-foot telescope, as Morrison had imagined during his initial calculations. Unfortunately, Lovell was pessimistic about the possibility of detecting alien messages and responded negatively to the paper.[152] Not to be deterred, Cocconi and Morrison decided to submit the paper for publication anyway. "Searching for Extraterrestrial Intelligence" appeared in the 1959 September issue of *Nature*.[153]

The *Nature* paper garnered international fame. Morrison travelled extensively in the months following its publication and in every city he visited, reporters were falling over themselves to interview him. The idea that alien intelligence might exist was not a particularly novel one, but the idea that humans could empirically test whether such creatures existed (as opposed to passively waiting for them to arrive in flying saucers) was extremely tantalizing. Plus, the Cocconi-Morrison paper was not merely suggesting that *at some point down the road* humans would be able to look for aliens. The paper argued that with the Jodrell telescope and the soon-to-be Arecibo telescope, humanity *was* technologically capable of looking for aliens. The media's rabid attention eventually died down, but years later, even after Morrison thought the topic had "been beaten to death,"[154] he found himself fielding questions about the *Nature* paper and SETI.

While the public response to the Cocconi-Morrison paper was largely positive and enthusiastic, Morrison's colleagues at Cornell expressed a variety of reactions. Most thought SETI was a silly idea that was not worthy of much serious discussion. Others were intrigued—not convinced, but willing to at least consider SETI's potential.[155] Fortunately, some condescension from his coworkers was the most severe professional ramification that Morrison suffered for the *Nature* paper. "Once you get to be an elderly professor, nobody pays much attention or cares what you do anymore," Morrison dismissed. "As long as I published papers of some consequence, my colleagues couldn't very well complain."[156] Perhaps a younger scientist would have a harder time publishing such a speculative paper and maintaining a serious scientific reputation. As it was, one brief article about looking for aliens was hardly enough to taint the reputation of someone as accomplished and well-respected as Philip Morrison.

The Order of the Dolphin

According to Frank Drake, Cocconi and Morrison were the first two people that he and Pearman thought to enlist in the Order of the Dolphin. Drake in particular was excited about the prospect of having Morrison at the meeting. As an undergrad at Cornell, Drake had attended several of Morrison's lectures and was apparently a bit of a fan. "You couldn't be a science student at Cornell and *not* go to Morrison's lectures," Drake gushed. "Once behind a lectern he became a majestic figure."[157]

Morrison flew to West Virginia from New York and arrived at the NRAO to be greeted by an enthusiastic Frank Drake.[158] Many years later, even when Morrison's memory of the meeting was "rather blurred,"[159] he recalled how pleased he was to be surrounded by so many other SETI enthusiasts at Green Bank.

During the Order's discussion of the Drake Equation, Morrison weighed in on a few different factors. In the debate over f_p (the fraction of stars that host planetary systems), Morrison went head-to-head with Struve, who believed that half of all sunlike stars must be girded by planets. Morrison proffered a more conservative estimate—about twenty percent—to account for the possibility that debris surrounding baby stars might form asteroids instead of planets, which do not provide suitable habitats for life.[160]

In regards to f_i (the fraction of life-hosting planets that evolve intelligent species), Morrison favored a more generous prediction. He was taken with the research of John Lilly, who was studying interspecies communication between humans and dolphins. According to Lilly, dolphins were intelligent creatures with their own language and possibly their own underwater society. If Lilly were correct, then Morrison believed that the evolution and cohabitation of humans and dolphins on Earth demonstrated the potential for multiple intelligent species to evolve on any planet.[161] The most disappointing thing about the whole Order of the Dolphin, Morrison would later say, was the fact that Lilly's research turned out to be a dead-end.[162]

When it came to discussing *L,* the length of time an intelligent civilization broadcasts signals into space, Morrison had a rather dismal outlook. He might have shed his identity as an atomic bomb builder many years before the Order of the Dolphin meeting, but memories of Hiroshima still colored his perspective. Morrison's viewpoint on humanity's longevity might have been especially dire the week of the Green Bank meeting, due to all the American media attention on the latest Soviet nuclear test.[163] He pointed out to his fellow Order members that if a civilization only lasted a decade or two after it invented nuclear weaponry (roughly the amount of time that had passed since Morrison walked the ruined streets of Hiroshima), then there would only be one broadcasting civilization in the whole galaxy at any given time.[164]

Over the next several decades, Morrison's World War II work continued to have an indirect influence on other SETI speculators' estimates of *L*. Many scientists during the Cold War believed that alien civilizations advanced enough to transmit interstellar signals would inevitably discover the power of uranium, use it to construct weapons like Fat Man, and self-annihilate after only a very short *L*.[165] Soviet SETI icon Iosif Shklovsky, who authored a book on extraterrestrial life that was later translated and expanded by Order of the Dolphin member Carl Sagan,[166] was one such pessimist.[167] Although Shklovsky once had a very optimistic outlook on SETI, he became depressed by the Cold War and felt that a nuclear holocaust was inescapable. If humanity was destined to destroy the Earth, it seemed to Shklovsky that this fate was likely shared by other intelligent creatures in the galaxy. Scientists might as well give up on SETI.[168] Regrettably, Shklovsky did not live to see the end of the Cold War, which might have revitalized his faith in SETI's eventual success.[169]

SETI Insights and Involvement

Unlike a few of his fellow Order members, whose direct SETI involvement began and ended with the Green Bank meeting of 1961, Morrison remained a prominent figure in the SETI community for the rest of his career. Even though the *Nature* paper was his one and only research article on the search for extraterrestrial intelligence, Morrison was frequently called upon in subsequent years to participate in SETI efforts or simply offer his thoughts on alien communication.

One question Morrison frequently fielded was what he imagined intelligent aliens to be like. The majority of his responses could be summarized in three words: it didn't matter. Ever a pragmatist, Morrison thought it was a waste of time to wonder about the characteristics of alien life forms and their societies. He thought that even supposedly informed guesses based on observations of Earthly life were largely useless. "Our experience, our history, is not yet rich enough to allow sound generalization," he said.[170]

What really mattered, Morrison argued, was that scientists now had a real, feasible way to check for alien signals: using radio telescopes. Instead of dawdling around, conjecturing about the qualities (or even the probability of the existence) of aliens, Morrison thought it was much more prudent to just start looking for their messages. "We owe the issue [of SETI] more than mere theorizing," he said.[171]

Although getting Morrison to reveal his personal visions of extraterrestrial intelligence was about as easy as drawing blood from a stone, Morrison was more than happy to address the question of how to look for alien signals. And on that point, he never budged: radio, radio, radio.[172]

In 1964, Morrison left Cornell to take a position at MIT.[173] SETI was never a major component of Morrison's research at MIT, but he still attended and facilitated SETI meetings. In 1971, when most SETI work was being done in the Soviet Union, Morrison attended the first international meeting on extraterrestrial communication at the Byurakan Astrophysical Observatory in Soviet Armenia.[174] Soviet astronomer Nikolai Kardashev and Carl Sagan pulled together the meeting, which turned out to be a pseudo-sequel of the Green Bank Meeting, with Philip Morrison, Carl Sagan, Frank Drake, and Barney Oliver all in attendance.[175]

In 1975-1976, Morrison chaired the Science Workshops on Interstellar Communication, now known simply as the "Morrison Workshops," as part of a NASA feasibility study on SETI. The Morrison Workshops produced a document that offered thoughts on several aspects of SETI, such as the significance of finding a signal, humanity's obligation to reply to any alien correspondence, and how to deal with false alarms.[176] Unsurprisingly, the report also reaffirmed that radio waves were the most likely medium of alien messages.[177]

The year after the Morrison Workshops, NASA launched the twin Voyager probes, each one loaded with a "Golden Record" that carried images and sounds of Earth. Carl Sagan, who led the NASA team that designed the message, dialed up Morrison to ask his opinion on the Records. Morrison was supportive, and even suggested a few ideas for what to put on the Records, like a depiction of all the continents and an image of a satellite in orbit. He also encouraged the designers to represent a diverse human population on the Records.[178]

Even when he was not directly involved with SETI work, Philip Morrison showed his support for the effort by contributing both time and money to the SETI League.[179] "I have a long connection with [SETI]," Morrison explained. "So I have certain obligations to try to have it prosper as much as possible."[180]

As much as he cared about the search for aliens, Morrison estimated that his involvement with SETI had only consumed about 2% of his career.[181] At MIT, Morrison gave seminars on quantum electrodynamics, biophysics, and astrophysics. When he arrived in 1964, X-ray astronomy was still in its infancy. True to form, Morrison became one of the earliest investigators in this branch of high-energy astronomy: he acted as the principal theoretical expert for two experimental X-ray astronomy research groups[182] and published one of the first review articles on X-ray astronomy.[183]

Morrison's stalwart insistence that aliens would use radio particles to communicate was rather ironic, given that he devoted the astrophysical era of his career to studying gamma ray and X-ray particles instead. However, not everyone approached SETI with the same set of blinders that Morrison did. Other scientists proposed examining non-radio types of electromagnetic particles, like visible light, for evidence of extraterrestrial intelligence. And still other scientists have suggested that non-electromagnetic particles, like neutrinos, might be the medium of choice for aliens' interstellar messages.

OSETI

While Cocconi, Morrison, and Drake were pondering the potential of radio, Robert Schwartz and Charles Townes were contemplating the signaling potential of visible light. At first glance, optical light particles might not seem like promising carriers of alien communication, because even though optical light obviously has no trouble penetrating Earth's atmosphere—and therefore such signals could be detected even by ground-bound observers—lots of astronomical objects (i.e., stars and interstellar gas) emit optical light particles. However, high-power lasers might give alien civilizations the chance to send signals with optical light particles that can be observed even amidst all the light emanating from stars or gas.

In 1961, Schwartz and Townes published the seminal optical SETI (also known as OSETI) paper in *Nature*, suggesting that advanced civilizations might communicate with optical lasers. Schwartz and Townes (inventor of the precursor to the laser, the maser, in the 1950s)[184] argued that although radio astronomy had so far dominated SETI, humans were near the point of constructing lasers that could send detectable signals across interstellar space.[185] The first laser had only been developed the previous year,[186] but Schwartz and Townes thought SETI researchers should expand their focus from radio waves to include optical radiation—especially because, the way Schwartz and Townes saw it, only "historical accident"[187] had allowed radio astronomy to develop before laser technology. An alien civilization might very well have developed lasers first, and become adept at using them for interstellar communication.

In their *Nature* paper, Schwartz and Townes determined that aliens within a few tens of light years, who were about as technologically advanced as humans, could broadcast optical signals detectable by telescopes and spectrographs on Earth.[188] But not everyone was convinced of OSETI's viability. The following year, Order of the Dolphin member Barney Oliver published a paper arguing that there needed to be a huge increase in laser power before lasers could compete with radio waves as the ideal form of communication across interstellar distances.

Despite Oliver's skepticism about the potential of OSETI compared to radio SETI[189]—which was echoed a year later by Morrison[190]—both the SETI Institute and The Planetary Society now support searching for optical signals,[191] and several major OSETI searches have been conducted. When astronomers undertake OSETI searches, they look for signals in the form of very brief, high-intensity pulses of optical light, which are discernible from the continuous radiation of stars.[192] Such pulses require a lot less power to produce than continuous streams of light particles, so even though pulses are more difficult to detect—because an observer must be looking at precisely the right place at precisely the right time to see them—they are much easier to transmit.[193] And because lasers are tightly collimated streams of light that don't spread out much as they travel through space, they can traverse long distances without losing much power. The downside is that each laser signal can only be transmitted along one particular direction, effectively targeting one particular star system. Moreover, unlike radio waves, optical light particles are easily scattered and absorbed by dust, so regions of the galaxy thick with obscuring material could block optical transmissions.[194]

A handful of astronomers conducted independent OSETI searches in the decades that followed Schwartz and Townes' paper, such as Stuart Kingsley, who privately owned and operated the Columbus OSETI Observatory beginning in the early 1990s.[195] In 1993, Kingsley organized the first OSETI conference,[196] but it was not until a few years later that large-scale OSETI got underway. Between 1997 and 1999, the SETI Institute held a series of workshops, wherein the members of the SETI Science and Technology Working Group (which included both Frank Drake and Charles Townes) debated which strategies SETI scientists should invoke over the next two decades.[197] These workshops spawned the ideas for OSETI projects both at the University of California, Berkeley and the Harvard-Smithsonian Center for Astrophysics.[198]

In 1997, Dan Werthimer started directing an OSETI search at UC Berkeley's Leuschner Observatory: The Optical SETI Pulse Search. Wertheimer's team used a 30-inch telescope to observe 2,500 nearby stars for bright pulses as brief as a billionth of a second. Another OSETI program at Berkeley searched for continuous laser signals originating from planets around other stars (exoplanets). Famed exoplanet astronomer Geoff Marcy led this thousand-star search, primarily using data that he and his research partner, Paul Butler, had collected during their exoplanet-hunting days.[199]

Similarly, at Harvard-Smithsonian's Oak Ridge lab, SETI Science and Technology Working Group member Paul Horowitz started directing an OSETI research group in 1998. The OSETI team looked for intense laser pulses from alien civilizations by "piggybacking" on a 61-inch telescope's exoplanet observations[200]—meaning that Horowitz's group used data collected for exoplanet research to conduct its OSETI searches, rather than allotting telescope time to collect its own, independent observations.

Then, in 2006, the world's first large telescope specifically dedicated to OSETI research was unveiled at Oak Ridge. Using this telescope, OSETI researchers began the Harvard All-Sky Optical SETI Survey, which would scan not just a few thousand targeted stars, but the entire dome of sky visible from Oak Ridge. Since the newly constructed 72-inch telescope would examine tens of millions of stars, rather than just a few thousand, the new OSETI sky survey project marked a 100,000-times improvement over the previous piggyback search.[201]

Neutrino Communication

In addition to considering non-radio electromagnetic particles, like optical light, as potential carriers of alien signals, some scientists have speculated about using neutrinos to transmit interstellar messages. Even Morrison considered neutrinos' message-carrying potential when he was working on the Cocconi-Morrison paper.[202] Neutrinos are some of the most abundant particles in the universe (second only to electromagnetic particles).[203] They're nearly massless, electrically neutral, fundamental particles that rarely interact with the other matter in the universe; in fact, trillions of them are passing through your body every second.[204]

Because neutrinos interact so feebly with other material as they flit through the universe, they can penetrate regions of the galaxy that would intercept radio waves or optical light. This quality makes them attractive candidates for aliens' particle messengers. Unfortunately, neutrinos' elusive quality also makes them extremely difficult to spot; neutrinos were entirely hypothetical until 1956, because there were no machines sensitive enough to detect them. Even now, for every one neutrino a detector registers, trillions more sweep past Earth unnoticed. Nonetheless, as neutrino detectors become more acutely sensitive, neutrino SETI might gain a foothold as its own distinct branch of astrobiology in the not-too-distant future. Perhaps one day, a bizarre pattern of neutrino production from some otherwise unassuming region of space might prove metaphorical music to SETI scientists' ears.

The ever-increasing possibilities for particle carriers of interstellar messages—be they electromagnetic particles like radio, infrared, and optical, or other types of particles like neutrinos—can be unnerving. As Schwartz and Townes wondered in their *Nature* paper, "What other methods are we overlooking which might appear natural to some other civilization? …The rapid progress of science implies that another civilization, more advanced than ourselves by only a few thousand years, might possess capabilities we now rule out."[205] On the other hand, it is rather exciting that the advancement of technology is continually opening entirely new channels for receiving alien correspondence—whether Philip Morrison would recommend tuning into them or not.

Otto Struve and the Hunt for Alien Worlds

In some ways it's worse, I think, knowing that intelligent aliens exist but having no way to converse with them. No way to know whether they'll ever interpret the deluge of radio signals that astronomers have been streaming their way since news of their existence broke mere months ago. No way to travel across the vast expanse of space that separates our worlds—an expanse that light itself apparently requires a whopping three centuries to traverse.

"Three hundred light years," said an astrophysicist whose talk-show interview I watched last week, "is a veritable hop, skip, and jump away, on the cosmic scale."

And yet.

So close yet so far away doesn't even begin to cover it.

(Now that the radio DJs who play my morning commute have started interspersing their usual lineup of '90s smash hits with updates on the alien story, my daily coffee comes with a side-serving of existential crisis.)

The paradigm-altering discovery of alien intelligence is equal parts exciting and frustrating. It's amazing to have found any extraterrestrial life—let alone technologically advanced creatures. And if there were any means of communicating with our alien peers, we might find them not so unlike ourselves. I've spent a fair bit of time reading up on their planet during slow days at the office, and as far as finding a twin Earth goes, it seems to fit the bill to a tee: a rocky orb roughly half the size of our own world, wheeling around a sunlike star in the constellation Lyra.

What's funny, the newscasters say, is that technically scientists have known about the existence of their world for almost seven years. Since its discovery, this planet's official catalogue name has been buried among thousands upon thousands of others in the ever-expanding list of planets around other stars, otherwise known as "exoplanets." But even nowadays, hardly anyone would recognize the planet by this long string of letters and numbers. Most people know the planet by the moniker "Gem." Depending on who you choose to believe, "Gem" either stems from the Latin word "gemina," meaning "twin," or signifies that the discovery of this planet is the crowning jewel of scientific achievement (well, human *scientific achievement).*

After getting caught up on the story of Gem's discovery, I prefer to think the name has a diamond-in-the-rough sort of significance to it.

Gem was first plucked from exoplanet obscurity when a team of astronomers from Sweden carefully scrutinized the light emanating from its atmosphere and discerned the presence of an ozone layer—a "telltale sign of biological action on the planet's surface," according to the talk-show astrophysicist interviewee. Gem really hit the headlines when a separate group detected the imprints of non-naturally-occurring pollutants in the atmosphere. The first hints of alien industry.

Amidst all the fanfare and prophecies of alien invasion, scientists plugged the same message over and over again in the media: evidence of ozone plus some other strange atmospheric ingredients does not an extraterrestrial civilization prove.

The real clincher came with astronomers' realization that Gem shouldn't have an atmosphere at all. The planet was too small, and therefore had too weak a gravitational tug to have trapped such an extensive envelope of gas above its surface. Something was *distinctly* off *about the whole business. Astronomers made more careful observations of Gem passing in front of its sun and inspected Gem's gravitational effects on the star more closely to make absolutely certain that they hadn't overestimated the extent of Gem's atmosphere or miscalculated its mass. But for all the exoplanet experts could tell, Gem and its inexplicable atmosphere unapologetically defied the known laws of atmospheric physics.*

Impossible? Some certainly thought so. But that left the planetary scientists in a bind. Did they now have to reevaluate their entire understanding of planetary atmospheres, a body of knowledge founded upon thousands of other observations over decades of work, for the sake of Gem?

Or perhaps the answer was much simpler. Perhaps this one particular case, this one blip on the radar, as it were, truly did *indicate the presence of some intelligent interference. Perhaps an industrious species, far more advanced than even our own, had touched down on Gem (for what reason, it was anyone's guess) and molded the planet to fit their own biological needs. Perhaps they were continually generating their own life-preserving capsule of breathable air, which would explain why Gem had an atmosphere even though it was not naturally able to hold onto one.*

If this were the case, then the discovery of industrial aliens raised a fair few more questions than it answered. But the alternative—that scientists would have to start back at square one and craft a whole new model of planetary and atmospheric formation to incorporate Gem—seemed downright abhorrent to the planetary scientists who publically commented on the matter.

And so, here we are. Humanity is standing on the brink of accepting that it is not alone after all. Most of the people I've talked to about Gem and its potential inhabitants feel a kind of kinship toward these unknown alien comrades. I can't say I disagree. To me, the experience feels something like stumbling upon the photo of a long-lost sibling in the old family album. There are obviously recognizable pieces of humanity in these aliens, in their planet and in their industry. I find myself wondering whether they, too, are looking out at the stars, speculating about our existence. Are they searching for us? As our astronomers gaze out at them across interstellar space, are they staring right back?

Because life as we know it is a strictly planetary phenomenon, the discovery of planets around other stars is of special importance in the search for extraterrestrial life. For hundreds of years, scientists and philosophers speculated that other stars might host planetary systems like our own. Sixteenth century Italian philosopher Giordano Bruno famously stated that in infinite space there must be "an infinity of worlds of the same kind as our own," and was famously executed for that view.[206]

The latter half of the twentieth century was riddled with claims of exoplanet discovery,[207] but no one would definitively find a planet orbiting another sunlike star until 1995, using a method suggested by legendary optical astronomer and Order of the Dolphin member Otto Struve.

Otto *who*?

After Otto Struve's death, innumerable articles praised his "immense and illustrious services to astronomy"[208] and lamented the fact that the astronomical community was "not likely to see another Struve."[209] At first glance, it's natural to suspect that these authors had succumbed to some degree of hyperbole. After all, these days “Struve” is hardly a household name like “Einstein” or “Sagan” or even “Schrodinger” (although the latter probably owes most of his fame to a hypothetical feline). But in Struve’s time, the astronomical community was generally of the opinion that he was the world’s greatest observational astronomer. The author of Struve’s obituary in the *Irish Astrophysical Journal* didn’t even try to summarize his accomplishments, claiming “it would take…too long to list here all his affiliations and honors.”[210] Clearly, though his name has largely faded into obscurity outside small pockets of amateur and professional astronomers, Otto Struve was a central character in astronomy during the first half of the twentieth century.

The Struve Dynasty

Inasmuch as anyone is “destined” to pursue a particular line of work, Otto Lyudvigovich Struve was destined to become an astronomer. By the time Otto was born, three generations of Struves had made names for themselves as founders and directors of Russian observatories.[211] Otto’s great-grandfather, grandfather, and uncle were all recipients of a Gold Medal of the Royal Astronomical Society of London.[212] The Struve men were practically royals in the astronomical community—and, in fact, are often referred to as the “Struve Dynasty.”[213] Needless to say, Struve’s forefathers left him some pretty big shoes to fill, but Otto rose to the occasion. Eventually.

The young Otto Struve’s academic career was interrupted twice by war. In 1916, he abandoned his studies at the University of Kharkov to fight in the Imperial Russian army.[214] After returning to finish his degree in 1919 and spending a brief stint as an instructor in the university’s astronomy department,[215] he enlisted in the White Army.

When the White Army surrendered to the Soviets, Struve was among the refugees who fled to Constantinople. The heir to the prestigious Struve Dynasty spent the following months working odd jobs and living in uncomfortably close quarters with his fellow Russian ex-officers.[216] These accommodations were something of a step down from the comforts of upper class society that Struve had enjoyed on his family's estate during childhood.[217]

Luckily, Struve hadn't left everything of value behind in Russia. He still had his family name, which was all it took to save him from destitution in Constantinople. The man who succeeded Struve's uncle as director of Berlin-Babelsberg Observatory heard about Struve's unfortunate situation and promptly wrote to Edwin Frost of the Yerkes Observatory in Wisconsin. Frost was more than happy to hire Struve on his name alone. After some short correspondence (rather stilted, since Otto didn't read English and had to get a local YMCA employee to translate letters for him), Struve set out for America.[218]

Rise to Fame

One has to wonder whether Frost briefly regretted his blind hiring policy when Struve arrived at Yerkes Observatory in October, 1921, decked out in the orange shoes, purple trousers, and green jacket he'd purchased at a flea market in New York while en route to Wisconsin.[219] Despite his somewhat dubious fashion sense, Struve lived up to his family name, and then some, by throwing himself wholeheartedly into astrophysical research. After earning his doctorate from the University of Chicago in 1923, Struve rose quickly through the ranks at Yerkes, succeeding Frost as director just nine years later.[220]

During his directorship, Struve transformed Yerkes into one of the nation's major astronomical research centers.[221] He assembled a superstar staff that included future famed astronomers, such as Gerard Kuiper and Subrahmanyan Chandrasekhar, and churned out many of his own research papers.[222] Most accounts of Struve's career distill his work down to bare-bones summaries,[223] which is what happens to scientists who publish nearly a thousand articles, not to mention several books. To give some sense of the breadth of Struve's expertise, a few of the primary topics recurring in his work included: binary stars, stellar atmospheres, interstellar gas clouds, and other diffuse matter permeating the galaxy.[224] In 1919, astronomer Henry Norris Russell had published a paper arguing that the "central problem of astronomy"[225] was the need to develop a theory of stellar evolution. Struve seems to have taken Russell's statement as a personal challenge, as most of his research—especially in regards to binary stars—worked toward solving that "central problem."

Struve was not a theoretician, and he often published his astronomical observations without explanation, waiting for some other scientist to interpret his data.[226] However, in every realm of astronomy he investigated, Struve contributed heaps of observations and cultivated a flock of students to pick up the proverbial baton when he inevitably switched research focus again.[227] Thus, Struve gradually established himself as a figurehead in the American astronomical community, which ultimately led to him playing host at the Green Bank meeting of 1961.

Otto: the Token Struve?

Struve's résumé is beyond impressive. Any reasonable reader might wonder how much Struve actually contributed to those thousand research papers. After all, Struve was living as a vagabond in Constantinople when Edwin Frost flew him to America to work at Yerkes, simply because the Struve name carried so much weight.[228] Is it possible that other astronomers listed Struve as an author on their publications just to get that extra boost of credibility? Did Struve have hordes of graduate students tacking on his name onto their own published research? Was Otto simply a "token Struve," used by other scientists to give their work name recognition and prestige?

It might be easy to think so. After all, even on their best, most caffeinated days, reading about Otto Struve today might make most people feel about as productive as a stump. Believe it or not, though, it seems that Otto Struve *really was* just that good. Struve was the lead or single author on most papers published under his name. Family fame might have helped Struve get his foot in the door, but his astonishingly prolific career truly was a mark of his relentless work ethic. As his great-grandfather Wilhelm Struve once said, "Struves cannot live happily without unceasing work, since from the earliest youth we have been persuaded that it is the most useful and best seasoning of human life."[229] Wilhelm would know, having published nearly 300 articles and fathering 18 children over the course of his own career.[230]

Struve was often the first to arrive in the observatory in the morning and one of the last to leave in the evening, if he left at all. He spent many overnight observing sessions at Yerkes, but his remarkable attention to detail was apparently unhindered by keeping such ridiculous hours.[231] "It is usually easy to recognize the characteristic Struve touch," recalled famed British physicist E.A. Milne. "The individual stars, with their individual peculiarities, were [Struve's] personal friends."[232]

This description of Struve's relationship to the stars gives the impression that he was a recluse whose only companions were balls of gas light years away, which might have explained why he was such a productive astronomer. True, it could hardly be said that Struve maintained a healthy balance between work and personal life. But he did have a happy marriage to Mary Martha Lanning, with whom he used to ice skate on Lake Geneva and sing romantic Russian songs. To be fair, Otto met Mary when she was working as a secretary at Yerkes, so perhaps there was no facet of Struve's life untouched by his work.[233]

Still, Struve's colleague Gerard Kuiper recalled that Struve "was often overworked, and suffered from insomnia, which caused him sometimes to be in somewhat of a daze following two or three hours of sleep."[234] During the final few years of his Yerkes directorship, Struve's relationships with his faculty were strained. Many of the colleagues Struve had hired when they were up-and-coming young astronomers, like Kuiper and Chandrasekhar, had earned their own name recognition and began to resist Struve's strict control over observatory operations. In 1947, Struve relinquished the Yerkes directorship to Kuiper and moved out to California, where he became Department of Astronomy chairman at the University of California, Berkeley, and the director of Leuschner Observatory. Although Struve took his observational research as seriously as ever, Kuiper said Struve was a changed man after the move. He was able to devote more time to his graduate students at Berkeley and ended up working closely with fellow Order of the Dolphin member Su-Shu Huang on studying the "habitable zones" for planets around other stars.[235]

Someone of such academic prowess must have been intimidating to his colleagues and Berkley students. Larger than life, even. In fact, The National Academy of Sciences' biography of Struve explicitly specifies his height and weight to dispel rumors that Struve was a man of *very* great size —which, the biography remarks, was not actually "all *that* great." Still, Struve was very serious man who had little patience for those who lacked his dedication to astronomy.[236] He cut an imposing figure with his perpetual formal attire and military bearing,[237] and Frank Drake later said that Struve's one lazy eye made it difficult to know where to look when addressing him.[238]

Bringing Astronomers Together

Severe first impressions notwithstanding, Struve was a kind and even funny man in close company.[239] He did not *try* to intimidate his colleagues.[240] On the contrary, he was exceedingly dedicated to assisting his students and other budding astronomers in any way possible.[241] Struve's fellow scientists were attracted to his observational mastery and his reputation for fair-mindedness, and Struve was exceptionally good at using his reputation to advance the field of astronomy.[242] As director of Yerkes, Struve coordinated inter-institutional projects like the construction of McDonald Observatory (jointly operated with the University of Texas),[243] which was the first telescope shared between two universities. He also served as the president of the American Astronomical Society (AAS) and the International Astronomical Union (IAU),[244] and editor of the *Astrophysical Journal*.[245] As leader of the IAU, Struve played a crucial role in facilitating collaboration between astronomers in different countries—especially the Soviets and Americans. *Soviet Astronomy* applauded Struve as "a man who had never forgotten the country in which he was born…the country which he knew well, whose scientific achievements he actively publicized, and with whose representatives he invariably maintained the most cordial relations."[246] (The article conveniently neglects to mention Struve's affiliation in the Russian Civil War.) Given his affinity for unifying dissimilar persons for the sake of science, Struve was just the man for the job of hosting the Green Bank meeting in 1961.

Struve and Stellar Rotation

The seeds for Struve's participation in the Order of the Dolphin were planted long before he arrived at the National Radio Astronomy Observatory. At the meeting, most of Struve's contribution to the dialogue was based on his radical belief that half of all sunlike stars were surrounded by planetary systems,[247] and that some of these probably hosted life.[248] He arrived at this conclusion by studying how quickly different types of stars rotated. Struve had been working on problems related to the intrinsic spinning of stars as early as his thesis in 1923, when he invoked stellar rotation to explain the widths of stars' spectral lines.[249] Spectra are the rainbow patterns produced when starlight is passed through a prism. These rainbows are marred with dark bars called *absorption lines*, and the positions of absorption lines present in a particular star's spectrum depend on the chemical makeup of that star. Struve realized that the rotation of stars smudges these dark lines on their spectra: the faster the star is spinning, the wider its spectral absorption lines are.

Pinning down the relationship between spectral lines and stellar spinning was probably the first big splash Struve made in the field of astronomy. Almost half a century earlier, another astronomer had suggested that scientists might discern the spin rates of stars by scrutinizing the widths of their spectral lines,[250] but it was not until Struve and his Yerkes collaborators actually measured the revolution rates of individual stars that stellar rotation was accepted as a common phenomenon.[251]

But, as often happens in the progress of science, settling one astronomical question opened up a whole new can of worms. In 1930, Struve noticed an oddity in his measurements of stellar rotations: large, blue stars spun at breakneck speed compared to their smaller, sunlike counterparts.[252] This discovery perplexed Struve, because according to the nebular theory of star formation, every star is forged in the collapse of a rotating cloud of gas. The laws of physics demand that spinning objects (like gas clouds) must *keep* spinning, or else transfer their tendency to spin to other objects. That is, their *angular momentum* must be conserved. So, from the moment of birth, stars spin with the angular momentum they inherited from their parent gas clouds. But why should there be such a sharp cut-off between very rapidly rotating stars, and those revolving at a much more leisurely pace?[253]

Suspecting Alien Worlds

Struve did not immediately realize that the strange drop off in stellar rotation rates might be due to the presence of planetary systems around sunlike stars.[254] It was not until nearly two decades later, when other astronomical and geochemical research had turned the tide to favor the existence of planetary systems, that Struve would dare suggest that slower-spinning, sunlike stars had had their angular momentum stolen by unseen planets orbiting them.

Struve's conversion to the belief in exoplanets was a slow process. In 1949, at the very end of a presentation to the National Academy of Sciences on binary stars, Struve suggested (almost as an afterthought) that perhaps planetary systems caused the abrupt break in stellar rotation rates.[255] Struve was still on the fence when he published his famous book *Stellar Evolution* in 1950, allowing that planetary systems *might* surround other stars, but assuring his audiences that there were other ways to account for stellar rotation observations.[256] It wasn't until the following year that Struve finally endorsed the idea that planets orbit other stars—rather enthusiastically. In a short piece he authored for the Astronomical Society of the Pacific, Struve declared that "indirect reasoning leads unmistakenly to the conclusion that our planetary system is but one among billions!"[257]

That same autumn, Struve unknowingly validated the extraterrestrial interests of undergraduate Frank Drake. Struve presented a three-part lecture series at Cornell, which was attended by a significantly star-struck Drake, who was evidently just as spellbound by Struve as he was by Morrison. In Struve's third and final lecture, he announced that his findings on stellar rotation indicated that the galaxy was rife with planetary systems around sunlike stars, and proclaimed that such an abundance of planets clearly demonstrated the possibility of life throughout the cosmos. Drake, who had never once shared his speculations about alien life with his peers or professors for fear of sounding childish, was floored.[258] Scientists had speculated about life on Mars long before Struve even arrived in America, but suggesting the possibility of life around *other* stars? It was unheard of. Drake wanted nothing more than to talk to Struve about their mutual interest in aliens, but it would be almost a decade before he had the opportunity to do so.[259]

Struve's Self-demotion

Given that Struve was one of the most prolific researchers and prominent science administrators of the twentieth century, he undoubtedly raised more than a few eyebrows over the course of his career. But perhaps Struve's most surprising act of all was his decision to leave UC Berkeley and become the director of the National Radio Astronomy Observatory (NRAO) in 1959. By then, Struve was suffering health problems related to the hepatitis he had contracted in Turkey, and he was the age at which most of his colleagues would retire.[260] Moreover, this new directorship was something of a demotion from his position at Berkeley, since radio astronomy was a relatively new field that most scientists considered on the fringes of "real" astronomy.[261] Needless to say, Struve's choice baffled many of his colleagues, and his true motives for moving to the NRAO are still a bit muddled.

In his 1992 biography of Struve, astronomer Kevin Krisciunas wrote that Struve became convinced of the importance of radio astronomy while he was working at Berkeley. Struve was even on the search committee to find a director for the newly founded NRAO, and when the committee failed to find a suitable candidate, Struve stoutly volunteered to fill the post himself.[262] Astronomer Leo Goldberg gave a similar impression of Struve's hire at the NRAO. According to Goldberg, several conversations with Grote Reber, one of the pioneers of radio astronomy, sparked Struve's interest in the field. "I can testify from personal observation," Goldberg professed, "that no observatory director ever had a more intensely loyal and devoted group of young scientists under his direction than Struve during his short term of service at [the NRAO]."[263]

But perhaps the three-decade lapse since Struve's death permitted Krisciunas to romanticize the past, and Goldberg was simply intent on portraying his late colleague, and personal inspiration, in a complementary light. In any case, Frank Drake, who was a young staff member at the NRAO when Struve arrived, painted a different, harsher picture of Struve's appointment. Drake and his colleagues were understandably shocked by the unveiling of their new superior, since Struve had never demonstrated the slightest bit of interest in their field.[264] According to Drake, Lloyd Berkner cajoled Struve into the position by appealing to his unconditional love of science. “Do it for the sake of astronomy,”[265] Berkner said, and Struve did.

At first glance, Drake’s story might seem a bit dubious. Really, would someone leave his prestigious position in California to join a new profession that absolutely disinterested him, which required relocating to a mostly undeveloped nook of West Virginia …all for the sake of science? Maybe, if that person were Otto Struve, who had spent most of the waking hours of the last four decades devoted to astronomical discovery. He was practically the poster boy for scientific martyrdom.

Struve may initially have had some interest in the NRAO because of its intended role as a national laboratory where many permanent staff, as well as visiting scientists, could conduct and discuss their research. After all, Struve was all about bringing astronomers together. However, Struve soon found that the NRAO was too isolated, underfunded, and ill equipped to serve its intended role as an astronomy hub.[266] Maybe he was slightly mollified by his belief that his work at the NRAO would be temporary—Drake reported that Struve believed radio astronomy was “barren”[267] and all useful work to be done in the field would shortly be finished off—but Struve was still extremely unhappy at the NRAO. He found the jargon and instrumentation incomprehensible. “It’s a pity Struve never caught our enthusiasm for the subject, or foresaw how it would grow and change,” Drake lamented. “It would have made his time at Green Bank so much happier.”[268]

Struve never cast aside his characteristic formality with the NRAO staff. Drake did not get to know Struve well (nor did anyone else at the observatory, as far as Drake could tell) and never got to express how much Struve’s lectures at Cornell had touched him. Ironically, Struve's most enthusiastic social interaction during his years among the radio astronomers consisted of conversations with two optical astronomers, whom Struve had specifically hired at the NRAO upon assuming his directorship. Mostly, Struve kept to himself, jetting off to New York City every few months to spend several days attending movie after movie. Mary Martha Struve was similarly reclusive, so much so that she developed a kind of fantastical persona among the NRAO staff.[269] "We would see her from time to time," Drake said, "walking around the back roads and around the observatory in a long purple robe, like some mythical figure out of a Fellini movie."[270]

Despite how depressing Struve's directorship at the NRAO evidently was, the Struve name brought prestige to the field of radio astronomy[271] and—as though he had a compulsive need to improve observatories and organize astronomers—Struve devoted much of his time at the NRAO to planning the construction of a 140-ft telescope, one of the largest in the world at the time. He also organized the first American-Soviet radio astronomy symposium in 1961.[272]

So, depending on which source a reader chooses to believe, Otto Struve was either one of the few forward-thinking astronomers who saw the potential in radio astronomy and bravely took it upon himself to help bring this field into the fold of real science, or a martyr who grudgingly fell on his sword for the sake of a field he didn't truly believe in. This is a rather dichotomous perspective, and maybe Struve's true feelings about radio astronomy fell somewhere between these two extremes. But regardless of Struve's personal feelings about radio astronomy, his role at the NRAO ultimately led to his involvement in one area of research that *did* interest him: the search for extraterrestrial intelligence.

Struve Lights Up for Ozma

According to Drake, if there were one outlet for Struve's astronomical curiosity among the daily drudgery at the NRAO, it was Project Ozma. Although Struve was never directly involved with the project, he relished the idea of scouring the skies for alien broadcasts.[273] At this point, Struve was nearing retirement, had already made a name for himself as one of the most prominent astronomers of the century, and probably had very little to lose by supporting such an exotic research proposal. And if he believed radio astronomers would soon run out of natural phenomena to gainfully observe, why not? Through Ozma, Struve continued his characteristic support for young astronomers with imaginative projects, which was fortunate not only for Drake, but SETI astronomers for decades to come. Without Struve's backing, Project Ozma might never have come to fruition and played its pivotal role in the birth of modern SETI.

When the Cocconi-Morrison paper came out in 1959, Drake felt relieved and validated that there were other scientists who took the search for extraterrestrial life as seriously as he did. Struve did not share Drake's positive reaction. Instead, he was incensed. Struve saw Cocconi and Morrison as a threat to the glory that the NRAO stood to gain for spearheading SETI. The *one* radio astronomy endeavor Struve was excited about, and someone else was going to get all the attention? Not if Struve could help it. He was scheduled to lecture at MIT a few weeks later, and saw that as the perfect opportunity to tell the world about Ozma, which had hitherto been kept under wraps.[274] Struve concluded his MIT lectures with the bold proclamation, "There can be little doubt today that the free will of intelligent beings is not something that exists only on earth. We must adjust our thinking to this recognition."[275]

Struve's announcement of Ozma was met with the same polarity of reactions that Cocconi and Morrison experienced upon the publication of their *Nature* paper. On the one hand, there was an outpouring of support and interest from members of the scientific community and public alike. On the other, some astronomers viewed Ozma as pseudoscience. In response to all the hullabaloo, Struve composed an article for *Physics Today*, wherein he emphasized his support for Project Ozma because "there is every reason to believe that the Ozma experiment will ultimately yield positive results when the accessible sample of solar-type stars is sufficiently large."[276] This article solidified Struve's public position on the search for extraterrestrial life, thereby setting up the NRAO as the prime venue for the Order of the Dolphin meeting.

Struve was officially roped into hosting the Order of the Dolphin meeting in July 1961 when he received a letter from the Executive Director of the National Academy of Sciences Space Science Board, Hugh Odishaw. Odishaw attached a list of nearly twenty suggested participants and a tentative conference program, and urged Struve's discretion in hosting the meeting.[277]

Struve was thrilled. He had organized meetings of scientists before, but he had never summoned such an eclectic group to discuss such an unconventional topic, especially one of great personal interest. In late September, Struve mailed the invitations, complete with a list of possible discussion topics and a request for paper presentations from participants,[278] and then sent follow-up correspondence to those who would be attending. On the first day of the conference,[279] Struve formally welcomed his guests and turned over the floor to Frank Drake to present his Drake Equation.[280]

During the Drake Equation discussion, Struve's weightiest contribution was, of course, regarding the fraction of stars surrounded by planetary systems. Struve was now firmly rooted in his belief that sunlike stars revolved so slowly due to the presence of companion stars or planetary systems stealing their angular momentum. Since only about half of sunlike stars were seen with stellar companions, Struve assumed that each of the remaining stars must be girded by a belt of planets. He was met with some contention for this bold statement, particularly by Philip Morrison, who believed the fraction of sunlike stars with planets to be much smaller.[281] Struve also contributed to the discussion of planets in "habitable zones" around sunlike stars, though his former graduate student Su-Shu Huang marshaled most of the expertise in this area.[282]

How to Find Exoplanets

By the time the Order met in 1961, Struve was so certain that planetary systems existed around other stars that he had even published a paper suggesting ways to seek them out. In 1952, Struve figured there were two feasible means of spotting planets around other stars: *radial velocity measurements* and *transit detections*.[283]

Radial velocity (RV) measurements detect the minor gravitational effects that planets have on their host stars as they swing around their orbits. Starlight appears to observers on Earth slightly bluer or redder, depending on whether the star is moving toward us or away from us (such effects are called blueshift and redshift, respectively). An exoplanet's gravitational tug causes a star to wobble ever so slightly as the planet orbits, giving astronomers a view of the star that is slightly redshifted, then blueshifted, then redshifted, and so on. By teasing out this variance in the star's color, astronomers can infer the presence of a planet. What's more, astronomers can calculate the mass of the planet based on how much the star wobbles: the more massive the planet, the more the star moves.

The other exoplanet discovery method that Struve suggested in his 1952 paper was transit detection, which involves observing the dip in a star's apparent brightness when a planet passes in front of it. Struve figured that exoplanets throughout the galaxy should orbit their stars at random inclinations, as seen from Earth. As a result, a decent percentage of sunlike stars should occasionally be eclipsed by their planetary companions.

In Struve's final book, *Astronomy of the Twentieth Century*, published a year after the Order of the Dolphin conference and a year before his death, Struve also proposed examining stars' back-and-forth motions in the plane of the sky, known as their *proper motions*. Similar to radial velocity measurements, these motions could clue astronomers in to the presence of an orbiting planet that is making its star wobble. However, this method has never been widely utilized by astronomers.[284]

By the time *Astronomy of the Twentieth Century* was published, Struve was convinced not only that exoplanets existed, but also that those planets were probably home to alien life forms. "The possibility of intelligent life in space cannot be brushed aside," he wrote. "The number of solar-type stars in the Milky Way and other galaxies is very large, and life appears to be an intrinsic property of certain types of complicated molecules."[285]

Despite his rather radical attitude toward the existence of alien life, Struve was not given to wild, imaginative ideas about the origins or characteristics of such creatures. He thought aliens were unlikely to exist outside the realm of Earth-like planets orbiting sunlike stars and, unlike other SETI pioneers, he had his doubts about whether such creatures would develop the kind of intelligence necessary for communicating across interstellar space. Struve was also more jaded than some of his bright-eyed, younger SETI contemporaries like Drake when it came to envisioning future scientific searches for intelligent life. Having run both private and national research institutions, Struve was no stranger to the struggle of soliciting funds, and he doubted very much that a full-scale program to search for alien radio signals would be established for many years.[286]

In light of the Order of the Dolphin meeting and the burgeoning field of SETI, Struve used his final book to issue caution and plug exoplanet research, writing, “In their excitement about the probability of artificial radio signals, a crucial point seems to have been overlooked by many astronomers. Before any such full-scale program is initiated, there should be a systematic search for planetary bodies accompanying solar-type stars and perhaps also relating to stars having other physical properties that may yet be amenable to life.”[287]

Planet-hunting Dynasties

Astronomers would not discover the two objects now recognized as the first confirmed, bona fide exoplanets until almost three decades after Struve’s death. Ironically, it was two radio astronomers, Aleksander Wolszczan and Andrew G. Lyne, who found the planets orbiting a pulsar—a rapidly rotating star that projects beams of radiation like a lighthouse, such that it appears to periodically “pulse” from our perspective on Earth. Wolszczan and Lyne measured the pulses of light from PSR 1257 and inferred that there must be two planets careening around the compact, blinking star.[288]

As exciting as it was to have finally discovered exoplanets, astronomers thought the conditions surrounding a pulsar were too extreme to foster life. The news everyone was really waiting for came in 1995, with the discovery of a planet around a normal, main sequence star.[289] The planet was determined to be at least half the mass of Jupiter, whizzing around its parent star with nearly circular orbit in just over four days. And the star, 51 Pegasi? It was a dead ringer for the type of star Struve had predicted would host inhabitable worlds: a slowly rotating, sunlike star. What's more, this planetary system was detected via Struve's first suggested method: radial velocity measurement.[290]

The Swiss astronomers who made the discovery, Michel Mayor and Didier Queloz, had been tracking the radial velocities of nearly 150 sunlike stars since spring of 1994 using a state-of-the-art spectrograph on a telescope at Haute-Provence Observatory in France. Their instrumentation was so precise that they could detect stellar jiggling at a mere 12 meters per second (about 25 miles per hour).[291]

When Mayor and Queloz announced their find in late 1995, they sparked a decade-long rivalry between two planet-hunting powerhouses: their own research group in Geneva and a group of American astronomers led by Geoff Marcy and Paul Butler in Pasadena, California. Marcy and Butler had been using telescopes at Lick Observatory for several years, searching over a hundred sunlike stars for signs of planet-induced wobbling. The Americans were at their wits' end when the Swiss discovered the planet around 51 Pegasi. Marcy and Butler had not even entertained the idea that stars could be home to "hot jupiters" like the one around 51 Pegasi (a class of exoplanets first suggested by Struve),[292] and they immediately re-combed through their own data for any overlooked exoplanets. Luckily, they had many years' worth of observations stocked up, and Marcy and Butler quickly discovered two more hefty planets around 47 Ursae Majoris and 70 Virginis.[293]

Thus began a radial velocity (RV) measurement race between two exoplanet discovery dynasties. The rivalry lasted until 2007, when personal disputes between Marcy and Butler broke up their dynamic duo and opened the doors for several new planet-hunting teams to join the competition.[294] Along the way, astronomers tuned RV precision to one meter per second—a brisk walking pace—and uncovered dozens of other smaller rocky exoplanets, known as “super Earths” on the edges of habitable zones around their stars.[295]

RV has proved to be a particularly useful technique for detecting hot jupiters because their mammoth size and close proximity to their host stars gives these planets an especially strong influence on stellar motion. The method is not foolproof, though. There are several stellar phenomena like pulsation, convection, or spots on the star’s surface that can influence astronomers’ RV measurements.[296] Another limitation of the RV method is that it only tells astronomers about a star’s motion along the line of sight from Earth to that star, not about the star’s motion side to side across the plane of the sky. Since astronomers cannot get a full picture of the star’s motion, they can only use RV measurements to determine the *minimum* mass of the surrounding planet that is causing the star to wobble. To measure the planet’s full mass, RV observations must be paired with another method of exoplanet surveillance, like transit detections.[297]

Though RV measurement dominated the first several years of the exoplanet-finding game, Struve’s second method, transit detection, has been even more fruitful. Around 30 exoplanets had been discovered by RV when astronomers first successfully spotted an exoplanet transiting a star in 1999.[298] HD209548b (unofficially dubbed "Osiris")[299] was initially discovered using RV measurements, which astronomers then used to predict when Osiris would pass in front of its star. When Osiris partially eclipsed its parent star, the total starlight visible from Earth dipped less than two percent, but this miniscule flicker was enough for astronomers to determine the planet's mass and radius. Osiris, like many of the planets discovered with RV, was a hot jupiter orbiting its star about one eighth the distance of Mercury from our own sun.[300]

Kepler Revolutionizes Transit Detection

For a while, RV measurements and transit detections were neck-and-neck, in terms of exoplanet discovery rate, but the transit method got a serious boost with the launch of NASA's $600 million Kepler Space Telescope in 2009.[301] Kepler is not like ordinary spacecraft that whip around Earth every couple of hours in tight orbits. Instead, it's a solar satellite that tails after our planet by about a thousand miles, which initially gave the spacecraft a virtually unimpaired view of the galaxy to fulfill its sole purpose of identifying exoplanet transits.[302]

Kepler's four-year stint as a purely planet-hunting machine brought on a deluge of new exoplanet discoveries. As of March 2016, Kepler had glimpsed over 1,000 different planets with some additional 4,600 unconfirmed candidates.[303] In May 2013, a spacecraft malfunction crippled Kepler so that it could no longer stay pointed at a particular field of view. Nowadays, Kepler is confined to observing in the ecliptic plane (the plane of Earth's orbit around the sun). Kepler's eyes are still peeled for the starlight blips that indicate exoplanet transits, but astronomers use the paralyzed spacecraft to observe other targets like star clusters, supernovae, and M-type stars, which are notorious for hosting

Earth-sized exoplanets. Astronomers are still slogging through Kepler data from before the malfunction, uncovering new exoplanets all the time,[304] and at the time of writing this chapter, the Kepler team has reported nearly 40 additional planets since its 2013 malfunction.[305]

The Next Revolution: Exoplanet Atmospheres

These days, exoplanet detection is so routine that to make headlines, even in popular science publications, a new world has to be pretty remarkable—and usually, "pretty remarkable" means "pretty Earthlike." Even publications like *Sky & Telescope* have started to exhibit this kind of exoplanet fatigue in the last few years, narrowing their focus to smaller, more Earthlike planets instead of reporting on the whole haul of recent discoveries. Astronomers still care about the exotic hot jupiters, which are unlikely to host life (as we know it), because they provide valuable planet demographic data. They tell us about planet formation and how frequently Earthlike worlds pop up among the planetary population. But the Holy Grail of exoplanet discovery is Earth's twin—or better yet, a whole fleet of Earthlike worlds—that might show signs of life. Space Telescope Science Center Director Matt Mountain once predicted, "By the time we get to 2020, Earth-mass planets in habitable zones will be boring."[306] Exoplanet discovery is a momentous step in the history of astronomy, but as far as discovering another habitable world out there, finding the planet itself is only the first step.

The next big push in exoplanet science is the investigation of individual exoplanetary atmospheres for biosignatures—chemicals that indicate a habitable (or inhabited) surface.[307] As exoplanet hunter James Kasting said, "None of these announcements of planets in or near the habitable zone should be big news by themselves. They are in a way meaningless, because we presently can't follow up on the initial act of discovery. The big news will only come when we are able to actually look at one of these planets to discern whether or not it is actually habitable and see if there is evidence of life, right? And if we do that—excuse me, when we do it—the real revolution will begin."[308]

Within the next few decades, it's possible that astronomers might spot a habitable or inhabited world among the plethora of planets in the Milky Way. Unless radio astronomers are exceedingly lucky in the near future, the discovery of life on other worlds might unfold just as Struve suggested: systematic searches for exoplanets first; direct, intentional signal sending (or receiving) second. But whatever the future of exoplanet exploration holds, there can be no doubt that Struve was one of the field's forerunners—half a century before the field really hit its stride. Struve's (possibly) grudging position at the NRAO might have been his most direct link to the Order of the Dolphin and origins of modern SETI, but he helped lay the groundwork for the line of astronomical research that might one day find a Gem.

Alas, Otto Struve's fame has dwindled since his death in 1963. For all his all-nighters in the observatory dome, for all the research students he mentored, for all the books[309] and popular science magazine articles he published,[310] for all the conferences he organized and all the weight his name once carried among the astronomical community—what vestiges of Otto Struve's legacy still remain? The "Struveana" asteroid honors three other members of the Struve dynasty, not including Otto.[311] The "Otto Struve" lunar crater has been rebranded the "Struve" crater to commemorate the Struve dynasty as a whole, rather than Otto as an individual.[312] The 82-inch telescope at McDonald remains the sole tribute to Otto Struve, the once legendary astronomer and observatory director.[313]

No exoplanet-hunting enterprise has ever been named in Otto Struve's honor.[314] This is even sadder when one considers that the Kepler space mission was originally named FRESIP (for its mission to find the **Fr**equency of **E**arth-**S**ize **I**nner **P**lanets), but Carl Sagan helped convince the mission's principal investigator to change the name to Kepler, in honor of the astronomer who figured out the laws of planetary motion.[315] If Sagan had suggested the name of his fellow Order of the Dolphin member instead, FRESIP might have been dubbed the Struve Space Telescope. And since discovered exoplanets—unless they are individually granted nicknames, like Osiris—are named after the space mission that discovered them (i.e., Kepler-90 g), the galaxy might have been full of worlds named "Struve." As it is, not even a single discovered exoplanet bears the Struve name.

So close yet so far away doesn't even begin to cover it.

John Lilly and the Cetacean Conversation

When the Order of the Dolphin met in 1961, a few of its members, such as Otto Struve and Melvin Calvin, were already famous. A couple of its younger members, like Frank Drake and Carl Sagan, had yet to become famous. John Cunningham Lilly, though, was probably the only Order member who could ever be described as *in*famous.

John Lilly was a man of many hats. Colleagues and biographers have granted him the titles of neuroscientist, physician, and psychoanalyst, as well as psychonaut and philosopher. He was also a bestselling author.[316] Lilly's career certainly provided him with abundant fodder for popular science books and autobiographies. He conducted a few of the most controversial experiments of the twentieth century, most of which involved dolphins, isolation tanks, drugs, or some combination of the three.[317] A strange synthesis of mysticism and the modern scientific method characterized Lilly's professional and personal life—and primed Lilly to delve deeply into research concerning the mind[318] (human or otherwise) and communication (human or otherwise). Given his penchant for cutting-edge, unconventional research, it was probably inevitable that John Lilly ended up at the first ever conference on alien intelligence.

Sensory Deprivation

Lilly was always a bit prone to mystical experiences. He claimed to have had his first vision as a seven-year-old while under the influence of ether,[319] which had been administered for his tonsil surgery. That same year, he had another vision while sitting in a Catholic church (an experience that he apparently relived during his first acid trip, with the addition of Beethoven's Ninth Symphony as background music).[320] When he was sixteen years old, Lilly wrote an extremely cerebral essay entitled "Reality," which asked the question, "How can the mind study itself?"[321] Already, he was preoccupied with questions about human consciousness.

Lilly, like Philip Morrison, decided to study science despite his father's wishes that he pursue a more practical career, perhaps in business. He entered the California Institute of Technology intending to study physics, but switched his focus to the life sciences after reading Aldous Huxley's *A Brave New World*. Lilly was fascinated by Huxley's ideas about humankind augmenting its own potential with technology.[322]

Lilly graduated with his biology degree and went on to earn a medical degree from the University of Pennsylvania.[323] But instead of practicing medicine, Lilly took a job at the Johnson Foundation for Medical Physics, where he acted as a guinea pig in experiments that studied the effects of explosive decompression of pilots for the Air Force.[324] After the end of the Second World War, Lilly embarked on his own neuroscientific and psychoanalytic research.

Lilly's first claim to fame was his invention of the isolation tank in 1954. Throughout the 1950s, there had been much debate among scientists about how much brain function relied on outside stimuli.[325] To answer this question, Lilly created a sensory-deprivation chamber: a soundproof enclosure where occupants could float in body-temperature salt water in complete darkness. Lilly found that floaters' minds did not shut down when they were cut off from sensory input inside the tank. On the contrary, their brains compensated for the absence of external stimuli by conjuring up hallucinations—or, as John Lilly liked to call them, experiences of "psychological free-fall,"[326] in which floaters tumbled into a "black hole in psychophysical space."[327]

Although Lilly invented floatation tanks to use in his research on human consciousness, these tanks became widely popular in the 1970s, thanks to claims that sensory deprivation could help people access the previously untapped wellsprings of artistic, spiritual, and athletic talent deep inside their minds. Celebrities like Yoko Ono, Robin Williams, and several Dallas Cowboys took up floating. Every year, hundreds of enthusiasts still flock to annual Float Conferences to discuss the latest in tank technology and collect souvenirs, such as salt samples and rubber duckies.[328]

In spite of their current popularity, floatation tanks were but a mere stepping-stone in John Lilly's colorful career. Inside his floatation tanks, Lilly conducted many "innerconsciousness"[329] investigations into his own mind, and while he was floating, Lilly wondered what it would be like to spend one's entire life submerged in saltwater.[330] These musings helped seed Lilly's future fascination—almost to the point of obsession—with the lives of dolphins.

The Beached Whale

Lilly had first become intrigued by the minds of marine mammals back in 1949, when he accompanied a couple of neuroscientist colleagues to dissect the brain of a whale that had washed ashore in Maine. Lilly's cohort was curious as to whether whales had brains much larger than humans'.[331] On their way to the beach, Peter Scholander, a researcher at the Marine Biological Lab in Woods Hole, Massachusetts regaled Lilly with facts about how deep whales could dive and how they played at Marineland in Florida—the world's first oceanarium.[332] When Lilly's party arrived at the beach, he was awed by the sight of the whale. "I wondered how such a small hill of flesh lived, what it thought, if it talked to its companions," Lilly recounted in his book *Man and Dolphin*. "We were all silenced by the awesome mystery of the whale."[333]

As Lilly and the others approached the dead animal, they were assaulted with an odor akin to "rotten beef and extremely rancid butter."[334] Undeterred by the disgusting nature of their endeavor, the scientists proceeded to climb atop the whale and saw into its skull. Lilly was fascinated by the size and shape of its brain, which was much larger than that of a human and had a more spherical shape. Lilly and his colleagues tried to scoop the whale's brain out of its skull, but accidentally punctured the organ, causing it to collapse and a putrid liquid to spill all over the ground.[335]

Although Lilly's party did not succeed in procuring the whale's brain for further examination, the mental image of that enormous cerebrum was something that John Lilly would carry with him for the rest of his life. On the car ride home from Maine, Scholander told Lilly that the brains of cats and chimps—the animals Lilly was studying at the time—were interesting, but marine mammals…*those* were the brains really worth examining.[336] Decades down the road, Lilly still found himself wondering, "What would a brain six times the size of mine think about?"[337] Lilly did not think it was too far a stretch to say that creatures with such enormous minds might be "godlike"[338] in their mental capacities, with "religious ambitions and successes"[339] far beyond human comprehension. If humans had difficulty understanding each other's thoughts, Lilly wondered, could they ever hope to comprehend the mind of a whale?

Mapping Dolphin Minds

Lilly got his first opportunity for hands-on research with dolphins in 1955, when he gathered with eight neuroscientists at Marineland to map out the different sections of the dolphin brain. This work involved surgically removing part of a dolphin subject's skull, which Lilly had done on chimp test subjects before. Lilly's team had five animals and two weeks to conduct their study.[340]

To perform dolphin brain surgery, Lilly and his colleagues strapped their animal subjects into slings that were submerged in tanks of water. Lilly had been commissioned to construct a respirator that would keep the dolphins breathing while they were under the anesthesia. But even with this apparatus, the anesthetized dolphins suffocated.[341] One of the dolphins did not die in the experiment but suffered such severe brain damage that he was unable to swim. Lilly's team resorted to euthanizing him so that they could dissect his brain. The team tried different anesthetics, but to no avail. Although their five-week project at Marineland did garner some useful information about dolphin brain structure, Lilly's group was deeply disturbed by the deaths and injuries of their dolphins.[342]

Lilly was particularly struck by the observation that even when dolphins suffered maltreatment at the hands of their human captors, they were docile, generally agreeable creatures. For better or worse, this experiment cemented John Lilly's belief that dolphins were the ideal animals for research on large brain systems. Moreover, the recordings of dolphin vocalizations that Lilly's team collected during the experiment stimulated his curiosity about the intelligence of these creatures.[343]

Probing Chimp Brains

After accidentally killing so many dolphin test subjects at Marineland, Lilly returned to the National Institute of Mental Health determined to figure out how he could study live dolphins without having to use anesthesia. To that end, Lilly designed a non-traumatic[344] method of inserting electrodes into animals' heads so that he could electrically stimulate different parts of their brains. He first tested his technique on chimps. After applying a local anesthetic, Lilly hammered a small tube into the chimp's skull to penetrate the brain cavity, but not the brain itself. Next, he slipped an electrode through the tubing and into the brain. Lilly stimulated chimps' brains by passing small electric currents through the electrodes or injecting the brains with chemicals.[345] By stimulating different regions of the chimps' brains and observing the animals' reactions, Lilly was able to map which sections of the brain controlled which bodily functions and sensations.

Lilly was so concerned about the care and comfort of his animal subjects that he tested this electrode insertion method on his own head. Regarding this experience, Lilly commented that the pain was not nearly as jarring as the ringing sound that reverberated through his head as he hammered tubing into his skull.[346] Armed with his new, non-injurious technique for conducting brain research, Lilly was ready to start studying dolphins again.

The Pleasure Switch

Lilly returned to Marineland in 1957 to apply his electrode insertion method to dolphins. Despite the self-testing he had done, Lilly was still concerned about the potential pain involved in this procedure for the dolphins, and he noted with relief that although his subjects flinched (presumably due to the loud noise) when he hammered tubing into their brains, they did not appear to be in pain. Still, Lilly thought, for an animal as sensitive as a dolphin, the procedure might be "psychologically traumatic without being painful."[347]

Fortunately, given the risk of psychological harm involved, the electrode insertion technique provided much more useful information than Lilly's 1955 research method. Lilly and his colleagues were able to map out which regions of the dolphin brain contributed to different aspects of motor control. For example, Lilly's team found that stimulating one section of the brain caused a dolphin's eye to look in various directions. Even more eerily, Lilly encountered some "silent" areas of the dolphin's brain, where stimulation did not produce any observable reactions.[348]

Unfortunately, this round of Lilly's research also resulted in a few dolphin casualties. One of Lilly's subjects suffered an epileptic seizure and died because the stimulation to his brain was too intense.[349] Another dolphin suffered bodily harm while Lilly's team was trying to restrain her for an electrode insertion.[350] One good thing to come of the dolphins' pain, Lilly said, was that he quickly learned to recognize what he called a dolphin "distress call:" a pair of whistles (one crescendo and one decrescendo) that dolphins emitted whenever they were in psychosocial or physical distress.[351] Thus, when he stimulated the pain center of a dolphin's brain during an electrode insertion experiment, Lilly was able to immediately identify the region and turn off the stimulation.[352]

As excited as Lilly was to finally map the brains of dolphins without hurting them (for the most part), this round of research constituted a pivotal point in his career for a different reason. It was in 1957 that Lilly started to entertain the idea that dolphins might be able to engage in meaningful communication with humans. Lilly's conception of dolphins as conversational creatures was influenced by several key observations of the animals at Marineland. For one thing, now that Lilly was able to stimulate different parts of a dolphin brain at will, he had started using electrodes to study the different types of sounds that dolphins produced under different conditions. Lilly noticed that the dolphins sounded like they were complaining when they didn't receive pleasurable stimulation.[353] One dolphin in particular whistled whenever his brain was pleasurably stimulated, each whistle getting higher and higher until eventually it was too high for Lilly to hear. Lilly stopped stimulating the pleasure center when he could no longer hear the whistles, and the dolphin, apparently realizing the problem, lowered the pitch of his whistles until Lilly started stimulating his reward center again. Lilly was amazed by how rapidly the dolphin realized the communication breakdown and adjusted his behavior accordingly.[354] For another experiment, Lilly constructed a switch that dolphins could hit with their noses to turn pain and pleasure stimulations on or off for themselves. Lilly was delighted by the dolphins' ability to quickly learn this system and use it to their advantage. He became further convinced that these were very special, highly intelligent creatures.[355]

Dolphin Mimicry

What really sealed the deal, in regards to Lilly's perspective of dolphins as intelligent, communicative creatures, was that the dolphins at Marineland seemed to enjoy imitating human speech. Lilly's first wife, Mary, was the first one to point this out.[356] Lilly had noticed that some of the dolphins' vocalizations seemed to mimic the patterns of human laughter—short, explosive sounds akin to a jovial "ha-ha-ha!"[357] But when Lilly reviewed the tape recordings of his experiments, he realized something even more startling. Mary was right. One dolphin seemed to be doing a "very high-pitched Donald Duck, quacking-like"[358] imitation of words that Lilly was dictating about experimental data. Lilly slowed the tapes down and picked out even more sounds that seemed to be crude reproductions of human words.[359]

"If anyone had said to me in 1947 that a [cetacean] could mimic human words, I would not have believed him," Lilly declared. "But in 1957, I was forced to believe."[360] As Lilly and his colleagues listened to the tapes, their "minds began to open,"[361] and Lilly felt as though he were breaching some sort of "transparent barrier"[362] between himself and the dolphins. Unsurprisingly, the best word Lilly could find to describe this experience was "weirdness,"[363] but it was a good kind of weirdness. Lilly loved working on the brink of total mystery, and he thrived on having his beliefs about the world shaken by new information. To Lilly, the fact that dolphins were apparently trying to imitate human speech would certainly revolutionize animal research. In fact, Lilly and the other scientists started to catch each other talking about the dolphins as though they were people, and Lilly referred to his subjects as "the humans of the sea."[364]

Critics of Lilly's work claimed that a dolphin's attempt to mimic human-produced sound did not necessarily imply intelligence. After all, parrots and mynah birds could mimic human speech, and they were literally birdbrained.[365] (This dismissal of bird intelligence would later be called into question by interspecies communication research with parrots.)[366] Lilly countered his critics' argument with the point that even humans first learn to speak by mimicking their parents' speech. What was more, babies needed sufficiently prolonged, frequent contact with other humans in order to develop their communication skills.[367] Given enough prolonged, frequent contact with humans, Lilly was sure that dolphins could achieve the same. Thus, Lilly shifted his focus from working *on* dolphins to working *with* them instead.

Dolphin Qualifications for Interspecies Research

John Lilly's past experience with dolphins was a major factor in his decision to work with these animals on interspecies communication research, but dolphins were also ideal candidates for these kinds of experiments for a laundry list of other reasons. First and foremost, the Atlantic bottlenose dolphin has a brain about 40% larger than that of a grown human, so these creatures definitely fit the bill for large, complex brain systems.[368] The chimps Lilly had worked with at the National Institute of Mental Health had only had brains about a quarter the size of a human adult's, so he had little hope of ever drumming up conversation with them. On the other hand, Lilly feared that animals with *much* larger brain systems, like the beached whale, might be "too alien"[369] for humans to understand.

Moreover, since dolphins are mammals, they have some similarities to humans that facilitate human-dolphin interaction—i.e., they breathe air and sleep at night. Dolphins are also much smaller and easier to manage than other mammals with large brains, like elephants, and have a generally benign temperament.[370] One of John Lilly's oft-repeated fond memories of dolphin altruism took place at an oceanarium, where he once saw an injured dolphin pushed up to the surface by his fellows so that he could breathe. Lilly marveled at the dolphins' sociable, sympathetic nature.[371]

Perhaps most importantly, dolphins vocalize at least partially in the range of frequencies that humans can hear.[372] In the wild, dolphins produce a variety of sounds underwater and in the air, including (but not limited to) what Lilly described as: creaking, putt-putting, whistling, quacking, squawking, and blasting. In captivity, close contact with humans conditions dolphins to produce more sounds above water, both spontaneously and on command.[373]

Of course, there were a couple of logistical difficulties when it came to working toward discourse with dolphins. In addition to vocalizing at pitches that humans cannot hear, dolphin chatter is extremely fast—hence why Lilly had to slow down his tapes to pick out the supposedly human words he discerned among the dolphins' vocalizations.[374] Lilly also recognized that there was a high degree of subjectivity involved in his work. He admitted that his descriptions of dolphin speech might be "inexact, and even completely mistaken."[375] Still, Lilly had high hopes for engaging dolphins in dialogue someday. After his experience at Marineland in '57, Lilly started investigating the possibility of establishing his own research institute, where dolphins could have the consistent, extended contact with humans they would need to have any chance of learning English.[376]

The Dolphin House

In August of 1958, Lilly made his first visit to the U.S. Virgin Islands to scope out a location for his laboratory-to-be. He was drawn to the Caribbean because the warm waters would keep his dolphin subjects comfortable year-round. Lilly eventually chose a plot of land on the island of St. Thomas and set about designing his laboratory. Lilly, like Otto Struve, was jaded from his experiences working at private and national research institutions, so he knew it would be tricky to solicit financial support for cutting-edge research that required such expensive facilities. But Lilly was not about to let that stop him. He had to sell all his other personal properties to buy the St. Thomas land on a mortgage, but Lilly was able to personally finance the construction of his research institute. Lilly knew that eventually he would need to seek outside sources of funding for his experiments, but he hoped that risking his own financial security so drastically would at least prove his commitment to the project.[377]

Lilly's gamble paid off. He started applying for grant money in the spring of 1959, and by 1962, he boasted financial support from the Office of Naval Research, the Air Force Office of Scientific Research, the National Institute of Mental Health, the National Institute of Neurological Diseases and Blindness, and the National Science Foundation.[378] [379] Lilly also solicited money from NASA, and he reaped the benefits of other biological scientists like Josh Lederberg convincing the new space administration that life sciences research should be a priority. Lilly earned his NASA grant by arguing that space scientists could use communication with dolphins as a model for interspecies interaction, in the event that they ever discovered aliens.[380] All told, Lilly raked in enough money to keep his research going for about five years.[381]

The beginning of the 1960s was a busy, exciting time in Lilly's personal life as well. He divorced Mary and got remarried to a model,[382] resigned from the National Institute of Mental Health, and moved to the Virgin Islands to take up residence at his new research facility, which he dubbed the Communication Research Institute Incorporated (CRII).

When it was finished, Lilly's laboratory had the outward appearance of a standard, decadent Virgin Island villa, with its twisting spiral staircase and ocean-view balcony.[383] But John Lilly oversaw the construction of his laboratory literally from the ground up to make certain that its design would best serve him and his dolphins. He had the land for his laboratory cleared straight from the jungle and shoreline of St. Thomas, and he even commissioned a U.S. Navy Underwater Demolition team to blast out parts of the beach to create pools deep enough for his dolphins to inhabit—much to the chagrin of the neighbors, whose picture frames and light fixtures kept getting dislodged from the walls by the reverberations of dynamite explosions.[384] Once the shoreline had been custom-carved out, though, Lilly's house oversaw a single outdoor pool where the dolphins would live, with a window in the basement that allowed underwater observation of the animals. Lilly even rigged up an underwater speaker system in the pool so that the dolphins would be able to hear the humans speaking into the air, and the humans would be able to hear the dolphins speaking underwater.[385]

Lizzie, Baby, and Elvar

Lilly's research at the CRII got off to a grim start. He brought his first two bottlenose dolphins, Lizzie and Baby, to the St. Thomas laboratory in March of 1960. Lilly thought he had selected a pair of subjects who would fare well in the Virgin Islands, since bottlenose dolphins prefer warm water, socialization, and live well in small pools.[386] Unfortunately, the journey from Florida to the Virgin Islands was long and grueling. Baby arrived at the St. Thomas laboratory seemingly unharmed. She started to eat immediately and had no qualms about approaching humans in the water. Lizzie, on the other hand, kept her distance. She was disturbingly tilted to one side as she swam, wouldn't eat, and bore lesions and sores on her skin from rough handling during the transportation process. Soon, she started hacking up black mucus and died after only a few weeks at the research institute. To make matters worse, it was not long before Baby stopped eating and started coughing up dark mucus. Despite Lilly's desperate attempt to tube-feed Baby, she soon died as well. Lilly was deeply saddened by the deaths of these animals, but his brief time with them seemed only to encourage his interest in dolphin communication. By July, Lilly and his second wife were back in Florida to obtain new dolphins and figure out how they could ward off whatever infection Lizzie and Baby had contracted en route to St. Thomas.[387] In his 1961 bestseller *Man and Dolphin*, Lilly predicted that many more people and dolphins would lose their lives in the quest to achieve interspecies communication—glossing over the fact that thus far, dolphins seemed to be the only ones bearing the brunt of experimental design flaws.[388]

Lilly had better luck with the third dolphin he bought to St. Thomas, Elvar.[389] After several weeks, Lilly observed that Elvar's vocalizations "began to be less 'dolphinese' and to break up into more humanoid, wordlike, explosive bursts of Donald Duckish quacking."[390] Lilly also noticed that Elvar mimicked the soothing, affectionate noises that his colleague Alice often made when she was around the dolphin.[391]

In addition to observing the dolphins in the pool, Lilly conducted experiments while the dolphins were restrained in tanks. The tanks were generally 15 inches by 7.5 feet long and filled with 10-15 inches of water. He recorded their vocalizations, both those emitted in response to human activity and those emitted spontaneously, and played back the tapes eight to sixteen times slower than normal time.[392] Lilly identified three distinct types of dolphin vocalizations—whistles, buzzings, and sounds emitted in bursts (quacks, squawks, and blats)—and tried to discern which types of sounds dolphins emitted in different situations.[393] In a 1961 paper that detailed his findings, Lilly said there could be no doubt that dolphins had precise, accurate control over the sounds they produced. "Those sounds are classified as vocalizations used for communication,"[394] he asserted. Later that year, Lilly added a fourth type of dolphin vocalization to the list—the simultaneous emission of whistles and buzzings—and continued to explore the possible meanings of these different types of sounds.[395]

Dolphinese Culture

The more time Lilly spent listening to dolphins emit their own natural babbles and (it seemed to Lilly) try to mimic human words, the more entrenched he became in his view that they were not only *intelligent* creatures, but likely also *civilized*, with their own language and customs.

This perspective begged the question of why humans seemed to rule the Earth, rather than marine mammals. Lilly, who had witnessed firsthand the docile dispositions of these creatures many times, surmised that dolphins were perhaps "too wise to try to rule the world."[396] He expected civilized marine species to have peaceful cultures. Their folk tales and legends might be memorized and passed down to younger generations the way human tales once were. They likely had their own advanced laws and codes of ethics that were similarly transferred from one generation to the next.[397] Lilly wondered whether these animals lived in nomadic bands that followed or herded fish, and whether dolphins ever popped their heads out of the water to study and navigate by the stars.[398]

With four-fifths of the world underwater, Lilly mused, the globe might be crisscrossed with territorial boundaries completely unknown to man.[399] Dolphins were probably content to maintain their undersea domain and refrained from attacking humans because they recognized that humans were the most treacherous species on Earth. "Even if they have not been warned by our atomic testing," Lilly said, "the whaling industry has kept them well informed of our dangerous abilities."[400] Again, he glossed over the fact that several dolphins had already died at the hands of Lilly and his colleagues.

The deeper Lilly tumbled down the rabbit hole of speculation about dolphin society, the more reasons he contrived for why it might be difficult (if not impossible) to teach dolphins English, despite their intelligence. For one thing, societal differences would make it extremely difficult to find common ground for conversation with dolphins. After all, dolphins had no writing implements, modes of transportation, food storage techniques, clothing, shelter…the list went on and on.[401] Lilly was quick to remind skeptics that just because dolphins lacked these seemingly basic elements of civilized society, that did not mean they were uncivilized. "Man is said to be the most intelligent species because of what he does with his huge brain," Lilly said, "[but] may there not be other paths for large brains to take, especially if they live immersed in some other element than air?"[402] In Lilly's eyes, the fact that dolphins possessed no recognizable cultural artifacts simply meant that there were more mysteries to uncover about the dolphin community.

Lilly went so far as to say that dolphins might actually have more difficulty picking up English *because* of their intelligence. If dolphins already had their own native language—and Lilly strongly suspected they did—then their predisposal for using "dolphinese"[403] linguistic constructions might make it difficult for them to learn human language. Maybe English would be easier to learn for an animal whose mind was a blank slate, so to speak, like a human baby's.[404] Even if dolphins did learn English, Lilly continued, their "dolphinese" accent might be so severe that their words would be incomprehensible to human listeners.[405] Barring all else, Lilly was willing to chalk up a failure to achieve human-dolphin communication to human ineptitude.[406] All in all, Lilly had quite a few mental safety nets to protect his view of dolphins as intelligent, linguistically capable creatures.

Over the course of his career, Lilly unsurprisingly encountered many colleagues who accused him of anthropomorphizing his dolphin subjects—something of a cardinal sin in the biological sciences. Lilly agreed that, in certain instances of animal research, it was necessary to "dehumanize"[407] the animal subject to prevent experimental bias. But Lilly thought this was only advisable if the subject's brain was much smaller than a human's. According to Lilly, "there is a converse 'sin' of science, as it were, which is called 'zoomorphizing.'"[408] Scientists commit zoomorphizing when they analyze the behavior of a large-brained creature as though it were small-brained. The way Lilly saw it, humans were limiting their own potential for interspecies cooperation by refusing to recognize that there might be other species on Earth worth regarding as intellectual equals.[409]

Implications of Success

Despite all his explanations for why genuine dialogue with dolphins might not be possible, Lilly operated under the assumption that he was just on the cusp of success. In 1961, Lilly predicted, "Within the next decade or two the human species will establish communication with another species: nonhuman, alien, possibly extraterrestrial, more probably marine."[410] Given that he always felt on the brink of a breakthrough, Lilly spent a lot of time speculating about the implications of interspecies communication for society, both human and dolphin society.

Lilly suspected that dolphins' status in human society would largely depend on how adept they proved at speaking English. If dolphins were capable of learning a few words, they would be regarded like parrots. If they demonstrated a higher language aptitude than parrots, they would achieve a status on par with chimps. And if dolphins proved their capacity for human conversation "corresponding, say, to a low-grade human moron and well above a human imbecile or idiot,"[411] as Lilly put it, then dolphins would raise some serious ethical, legal, and social questions in human society. People would petition for dolphins' medical and legal protection. This was Lilly's ideal scenario; since he believed that dolphins were humans' intellectual equals, then to treat them as "glorified seeing-eye dogs"[412] would be nothing short of slavery. Lilly looked forward to the day when humans and dolphins might collaborate in a variety of scientific fields—oceanography, marine biology, navigation, linguistics, and neuroscience, just to name a few. Given their somewhat alien perspective, dolphins might posit new solutions to human problems of technology and warfare.[413]

Of course, Lilly said, establishing intelligent communication with dolphins could only have a peaceful outcome if it were handled correctly. "When the time comes, I hope that [my research] will help those men of goodwill to lead wisely, and that they will be a bit better informed than they were in 1945 concerning another scientific advance, that time in applied nuclear physics,"[414] Lilly wrote in *Man and Dolphin*, unaware that just a few months after the book's publication, he would be sitting down with a Manhattan Project physicist to discuss aliens.

In addition to envisioning Earth's future as a planet with two collaborating intelligent species, Lilly was fascinated by the implications of his work with dolphins for establishing contact with extraterrestrials. Lilly did not want humanity's first experience with interspecies communication to be forced by alien invaders.[415] Achieving peaceful interaction with dolphins would give humans the opportunity to converse with creatures who had evolved in a very different environment.

Lilly knew that it might seem like he was getting ahead of himself when he considered the implications of the not-yet-achieved feat of human-dolphin communication to the even-more-speculative scenario of alien encounters. But Lilly was not overly concerned with the opinions of people who did not appreciate his forward-thinking attitude. Reflecting on his work in 1957, Lilly said, "We must realize that we are still babies in the universe taking steps never before taken. Sometimes we reach out from our aloneness for someone else who may or may not exist. But at least we reach out."[416] As Lilly saw it, his willingness to take new steps and reach out to new species made him a pioneer.

The Order of the Dolphin

1961 was a big year for John Lilly, and not just because a secret society of SETI scientists named itself in honor of his work. It was also the year that John Lilly published his international bestseller *Man and Dolphin*, which described much of Lilly's research and personal experiences with marine mammals, and detailed his hopes for the future of interspecies communication. Lilly's narrative captivated readers and stirred up quite a bit of controversy[417] because it was the first book to claim that dolphins were creatures with complex thoughts and feelings.[418] *Man and Dolphin*'s popularity earned Lilly a cover feature in *Life* and an appearance on the Jack Parr show.[419] Perhaps it also snagged the attention of J.P.T. Pearman.

According to Drake's story of the Green Bank recruitment phone call, Drake jokingly commented to Pearman, "We've got astrophysicists, astronomers, electronics inventors, and exobiology experts. All we need now is someone who's actually spoken to an extraterrestrial,"[420] which prompted Pearman to say that they should invite John Lilly. Drake and Pearman's correspondence from the National Radio Astronomy Observatory archives indicates that Drake was the first one to mention Lilly's name.[421] In any case, one or both of them wanted Lilly at the conference.

When Lilly arrived at Green Bank, Drake was surprised by Lilly's appearance. Lilly did not look like the kind of mad scientist who floated in dark tanks of water and hammered electrodes into his own head. Rather, Drake thought Lilly was "handsome enough to be a movie actor playing the role of John Lilly."[422] (Interestingly, two movies were eventually produced based on Lilly's life and work—*Altered States* and *The Day of the Dolphin*—though Lilly starred in neither.)[423]

Lilly primarily contributed to the Order's discussion of f_i, the fraction of life-hosting planets that are home to intelligent species. Lilly detailed the size and complexity of the bottlenose dolphin brain to his enthralled fellow Order members. *Flipper* was a popular television series at the time, and Lilly enjoyed recounting some of the astonishing feats accomplished by his own dolphin subjects. He wove heartfelt tales of dolphins responding to one another's distress calls and saving human swimmers from drowning. Drake was struck by how Lilly referred to his dolphins as though they were people. Lilly claimed that he was more or less conversing with dolphins at the St. Thomas laboratory, and even brought slowed-down tapes of dolphin vocalizations to play for the Order, which Drake *did* think sounded like human speech.[424]

At the time, Drake was impressed and even excited by the apparently groundbreaking work Lilly was doing in the Virgin Islands. Lilly's research seemed to demonstrate that animals could develop intelligence even in radically different environments than the ones humans lived in.[425] Morrison thought it was worth pointing out that dolphins, even if they were intelligent, showed no interest in or capability for radio astronomy. But this did not curb the Order's enthusiasm for Lilly's experiments.[426] In his meeting report to the Space Science Board, Pearman specifically noted that Lilly's work merited continued support.[427]

However, Drake later admitted that he believed Lilly's work was bad science. Drake suspected that Lilly had gone through many hours' worth of tape to pick out the segments that most resembled human speech to play for the Order. "You know how that goes," Drake said, "If you give enough type-writers to enough chimps, one of them will type a Shakespearean sonnet."[428]

Lilly's Most Notorious Experiment

Drake was not the only one whose opinion of Lilly's scientific credibility soured in the years following the Green Bank meeting. Throughout the early '60s, Lilly continued publishing conventional papers on dolphin vocal behaviors.[429] [430] But as the decade progressed, Lilly strayed further and further from traditional scientific methods and began infusing more mysticism into his experimental techniques. He conducted increasingly radical research projects tucked away from prying eyes at his remote St. Thomas laboratory. The most notorious of these involved a twenty-three-year-old woman named Margaret Howe and a dolphin named Peter, who lived together in Lilly's partially flooded lab for ten weeks in the summer of 1965.[431]

Howe was a college dropout who had come to St. Thomas Island in search of adventure. She got a research assistantship at Lilly's institute when she wandered down to the laboratory one day, simply because she "was curious."[432] Lilly assigned her the task of encouraging dolphins to repeat human speech back to her. At that time, there was a trio of dolphin subjects living at the institute: Peter, Pamela, and Sissy. Howe was not the only young staffer at Lilly's lab, but, as Lilly stated in *The Mind of the Dolphin*, only the bravest worked at his institute for any significant period of time.[433] Howe certainly took the title of bravest when she suggested to Lilly that she live alone with Peter at the lab, so that he might learn English more quickly. For years, Lilly had been touting the idea that it was necessary to put dolphins in close, prolonged contact with humans to test the animals' language acquisition capabilities.[434] And Howe's talent and dedication to dolphin communication were unmatched by any of his other colleagues at the institute.[435] Consequently, Lilly was immediately on board with Howe's proposal.

Howe redesigned the layout of the laboratory's upper floor so that the interior of the lab, as well as the balcony, could be flooded with a few feet of water. Howe would sleep on a foam cushion suspended from the ceiling. She would eat canned food to minimize outside contact for the duration of the experiment. After a week-long trial period, Lilly concluded that ten weeks constituted the maximum time that a human and dolphin could healthily live in isolation. He laid out three objectives for Howe's summer with Peter:

1. Take notes on how Peter's isolation from the rest of his species affected him.
2. Teach Peter to speak English.
3. Record her experiences of the living conditions at the partially flooded laboratory, so that these conditions might be improved for a future experiment involving longer-term cohabitation between human and dolphin.[436]

The experiment turned out about as badly as one might expect. True, Howe found Peter to be an attentive, enthusiastic student. But Peter was a sexually mature dolphin, and eventually he began to make sexual advances on Margaret. He even became aggressive when she spurned his affections. Her legs were soon covered in bruises and abrasions from Peter bumping against and nibbling at them. Peter's sexual aggressiveness concerned Howe,[437] but she was reluctant to allow Peter conjugal visits with other dolphins, lest it stagnate his language learning progress.[438] Margaret eventually decided to give Peter a hand with the sexual stimulation he was seeking.[439]

By the end of the summer, Peter had failed to learn English, and Lilly's other colleagues at the institute were starting to seriously doubt his integrity as a scientist. They were not just concerned for Howe's safety, either—a few years after the experiment, Peter was taken back to Miami, where he lived under much more cramped, unhealthy conditions than he had enjoyed in the Virgin Islands.[440] The vet at Lilly's St. Thomas research institute said of Peter's separation from Howe: "I wondered about poor Peter. This dolphin was madly in love with [Howe]."[441] Shortly after the move to Miami, Peter committed suicide. (Unlike humans, for whom respiration is automatic, dolphins must consciously draw each breath. Peter simply refused to surface for air.)[442]

Howe was devastated to learn of Peter's death, and refused to even speak publicly about her experience for fifty years, despite the waves of criticism it elicited from the public.[443] When she finally broke her silence, Howe said that she wondered what she could have accomplished with Peter if she'd been given more time. Alas, the failure of Howe and Lilly's controversial experiment effectively ended serious interest in teaching dolphins to speak among the scientific community,[444] and Lilly's funding started to dry up.[445] After all the work Lilly had done to build up interspecies communication research as a legitimate, worthwhile endeavor in the eyes of the public and the scientific community, he was the one eroding the field's credibility.

Even among the forward-thinking SETI scientists, Lilly was starting to lose his prestige. Peter's death reinforced Drake's skepticism about Lilly's work. He had suggested that Lilly examine dolphins' capacity for transmitting and receiving complex messages by removing humans from the conversation entirely. Drake proposed that Lilly put two dolphins in separate pools, such that they were unable to see one another, but still able to able to hear each other. Then, human researchers could teach one dolphin to find food in its pool. If that dolphin were able to vocally teach the other dolphin how to find food in its own tank, then Lilly would know that dolphins truly did converse via some form of "dolphinese." Lilly never successfully ran this experiment.[446] Similarly, Carl Sagan visited Lilly's St. Thomas laboratory several times and tried to give his friend advice on how to design experiments that would prove the existence of "dolphinese." But Lilly rejected Sagan's ideas and forged ahead with his modes of "research."[447]

Straying from Science

Even after Margaret and Peter's ten-week cohabitation, Lilly still had not achieved human-dolphin communication, but he did not let these failures dishearten him. In his 1967 book, *The Mind of the Dolphin*, Lilly stuck by his estimation that humans and dolphins would be conversing within the next couple of decades.[448]

Back in 1961, Lilly had seemed willing to accept the possibility that interspecies communication was impossible. "If it turns out that I am wholly incorrect," he wrote in *Man and Dolphin*, "I shall remember that in research of the best scientific sort, no experiment is a failure: even experimental disproof of a thesis turns up new and valuable information."[449] Back then, Lilly viewed it as bad scientific practice to assume ahead of time what he would find, and then go about finding it by sheer force of will, rather than empirical investigation.[450] In the wake of Peter and Howe's failed cohabitation experiment, though, Lilly pinpointed 1965 as the year that he came to "no longer regard the scientific viewpoint of total objectivity as the be-all and end-all"[451] of exploring the world around him.

Lilly's new age research philosophy was epitomized in another experiment involving Howe in 1968. Lilly decided that he should start taking LSD with his subjects. Despite calling humans under the influence of drugs "simple-minded"[452] in 1961, Lilly had his own first (government-sanctioned) experience with LSD in 1963[453] and subsequently started dropping acid within the confines of his isolation tanks.[454] Lilly's perception of dolphins as humanity's intellectual equals led him to wonder if they, too, could reach heightened states of consciousness with the use of drugs. If so, this might open up a new channel for communication between human and dolphin.[455] Lilly coerced Howe into assisting him on this experiment, despite Howe's hesitation. He at least honored her request not to involve Peter in the experiment, and instead injected the dolphins Pam and Sissy with LSD, administered a dose of the drug to himself, and waited.[456]

According to Howe, ten or twenty minutes went by with apparently no results. A desperate Lilly, to Howe's horror, picked up and started drilling a jackhammer to elicit a response, *any* response, from the dolphins.[457] Lilly, on the other hand, later reported that he had a conversation with the dolphins while high. "It drove me crazy," he claimed.

"There was too much information, they communicated so fast."[458] Lilly's use of LSD on the dolphins was the last straw for a few of Lilly's colleagues, who decided to abandon their posts at the St. Thomas research institute,[459] and earned Lilly the nickname "Dr. Doolittle on acid."[460] Shortly thereafter, Peter was transported back to Miami, and Howe left the research institute to marry a photographer. Although Lilly was dismayed to lose his brave and devoted assistant, he was pleased that Howe's "intraspecies needs [were] finally being taken care of."[461]

Alien Encounters

After his 1968 LSD co-trip with dolphins, Lilly spent a decade away from dolphin research, moved to California, took more drugs, and "conducted consciousness-expanding group sessions called 'The Dolphin in You.'"[462] On the west coast, Lilly rubbed elbows with other well-known counterculture writers, philosophers, scientists, and drug-enthusiasts like Aldous Huxley, whose dystopian novel had put Lilly on the path to studying dolphins in the first place.[463] Lilly's friend Ric O'Barry, who had trained the dolphin stars of *Flipper*, later recalled, "I could see the difference in John Lilly as he went from being a guy with a tie and a white coat and a scientist to…a full blown hippy after a while."[464]

His psychic dialogue with dolphins in St. Thomas wasn't the only encounter with non-human intelligence that Lilly had while under the influence of psychedelic drugs. Once, while he was floating inside one of his isolation tanks, caught in the throes of an LSD trip, Lilly had a vision in which he telepathically communicated with extraterrestrial intelligences.[465] In a vision, Lilly sat on board a plane that was getting ready to land in Los Angeles. The pilot announced that a comet could be seen out the window, and when

Lilly turned to look, unseen alien creatures beamed a message into his brain: “We will now make a demonstration of our power over the solid-state control systems upon the planet earth. In thirty seconds, we will shut off all electronic equipment in the Los Angeles airport. Your plane will be unable to land there and will have to be shunted to another airport.”[466] Just as the aliens prophesied, Lilly’s plane landed in Burbank due to technical difficulties at the Los Angeles airport.

Lilly received another message shortly thereafter, which described the fate of humanity “in frightening detail.”[467] Humanity would eventually become wholly dependent on an intelligent entity composed of computers, satellites, and other electronic systems. The computerized intelligence would evolve to the point of operating outside human control. By the twenty-sixth century, the alien telepaths revealed to Lilly, this electronic intelligence would be in communication with other similar entities in the galaxy. Thus, a never-ending fight would ensue between water-based life forms—like humans—and electronic life forms for control over the universe.[468]

In an effort to protect mankind from being destroyed by its own technological creations, Lilly started to campaign against something he called the Solid State Intelligence, the network of electronic creatures that was out to destroy all organic life. Lilly declared that he had joined the Earth Coincidence Control Office—a “beneficent network of extraterrestrials”[469]—and, after injecting himself with ketamine, flew to New York to warn the world about the Solid State Intelligence, which resulted in his confinement in a psychiatric ward.[470]

SETI Scientist Through and Through

Even before telepathically making the acquaintance of extraterrestrial intelligence through LSD, Lilly always tied his research back to the broader vision of preparing humanity for alien encounters. In *The Mind of the Dolphin*, Lilly issued a blanket warning to all extraterrestrial visitors that they should avoid contact with humanity until humans proved that they could cooperate with dolphins.[471] "Currently we are faced with other species possibly as intelligent as we are," Lilly wrote, "[yet] we do not yet recognize their intelligence. We do not even attempt communication with them. We do kill them, eat them, and use their bodies as industrial products."[472] Mankind, as far as Lilly could tell, was in a sorry state, still too immature for extraterrestrial communication.

Lilly warned that if humans did not learn to properly interact with nonhuman intelligences in the case of dolphins, then an encounter with extraterrestrial intelligence might result in planet-wide destruction.[473] He thought it prudent to allot some of the money currently spent on space research to communication programs instead, "as a life insurance for the future of men,"[474] and envisioned the foundation of a communications research institute on the same order of magnitude as NASA.[475] "I want to emphasize the fact that even if we are successful [in establishing discourse with dolphins], we shall still not be fully prepared to encounter intelligent life forms not of this Earth," Lilly wrote. "At most we shall have graduated from the kindergarten of interspecies communication before it becomes absolutely essential for us…to enter the graduate school of interspecies relations."[476] Nonetheless, rudimentary preparation for extraterrestrial visitation was better than no preparation at all.

JANUS

After his decade hiatus, Lilly returned to dolphin communication research with project JANUS (Joint Analog Numeric Understanding System).[477] Lilly undertook this project from 1980 to 1985 at the Human-Dolphin Foundation, which Lilly had founded with his third wife, Toni, and *The Twilight Zone* actor Burgess Meredith. JANUS, named after the Roman god of portals,[478] was a computer system that translated forty human words into a series of synthetic dolphin whistles[479] and transmitted these sounds to Lilly's dolphin subjects through a system of underwater microphones.[480]

Lilly tested JANUS's human-dolphin code on two Atlantic bottlenose dolphins, Joe and Rosie, whom Lilly released into the wild after completing the experiment. The project demonstrated to Lilly that dolphins could indeed learn a human-coded whistle language—that is, they could be trained to associate Lilly's crafted whistle "words" with objects and actions. But JANUS did not produce real interactive communication between humans and dolphins. Moreover, the choice of whistles as the building blocks of JANUS's human-dolphin code was not the most conducive for dolphin communication, since most dolphin chatter occurs in the form of clicks at much higher pitches that are more difficult for humans to produce.[481] According to one of the volunteers on Project JANUS, Ed Ellsworth, humans and dolphins had much more meaningful interactions when they were swimming together than when they were trying to communicate through a computer interface.[482]

John Lilly never conclusively proved that dolphins spoke their own intelligent language or that they could learn English. However, through his papers and books, which sold millions of copies worldwide, Lilly did popularize the idea that non-primate species could possess complicated thoughts and emotions and perhaps even linguistic capabilities.[483] His work contributed to a paradigm shift about man's uniqueness, in regards to intelligence, and played a pivotal role in passing the Marine Mammal Protection Act of 1972.[484] This was a great personal victory for Lilly, who had been concerned about the possible extinction of dolphins along the southern coasts of the United States since the mid-sixties.[485] Even after he comfortably retired to Malibu in 1992,[486] Lilly continued to fight for marine mammal protection by campaigning against the Japanese whaling industry.[487]

"There were those who thought [Lilly] was brilliant, and there were those who just thought he was insane," said Jennifer Yankee Caulfield, another participant in the JANUS project. "I, of course, thought he was a little bit of both.''[488] Caulfield's dichotomous view of Lilly embodies his legacy as a scientist and a forerunner of SETI: he was either a mastermind or a madman, a pioneer or a pseudoscientist. Maybe Lilly lost sight of the scientific method, or perhaps he was simply ahead of his time.

Concluding Remarks

When I sat down in Professor Crider and Professor Weston's Life in the Universe class almost exactly four years ago, I was not quite sure what to expect. I assumed that I was in for a strange afternoon, and that the experience might make for a good story—surely none of my friends had observed classes on aliens during *their* college visits. I most certainly did not expect to return to my hotel room that night to order one of the class texts (Stephen Webb's *Fifty Solutions*) online. Or that I would cite this book in my Honors thesis four years later.

Even though I have only been researching and writing *The Order of the Dolphin: Origins and Future of SETI* for about a year, this project truly has been four years in the making. After writing my first college research paper in English 110 on the Fermi Paradox and taking Life in the Universe as a sophomore, I solidified my resolve to pursue undergraduate research related to SETI. I fumbled around a bit longer before settling on a project because I didn't want to actually *do* SETI. I just wanted to write about it. My sophomore history of science research project with Professor Crider and first forays into science journalism at *Sky & Telescope* got me hooked on science writing. Popular science satisfied both the STEM fangirl in me, who relished learning about scientific discoveries, and the creative writer, who wanted to spend all her time telling stories.

Professor Crider initially suggested that I write a book about the Order of the Dolphin because it could serve as supplemental material for an educational role-playing game that he was crafting for the Life in the Universe class. I was immediately drawn to the idea because (1) hello, it involved a lot of writing and (2) it sounded like I would get to explore a wide breadth of scientific fields, rather than entrench myself in one extremely narrow line of inquiry. I imagined seeding each of my chapters with a small biographical section on the Order member, and then discussing the nitty-gritty science of his field at great length, writing in the journalistic style I had used as a magazine intern. After all, most of the popular science I had read were books like *The Elegant Universe* by Brian Greene, or Neil Degrasse Tyson's *Death by Black Hole*, whose primary characters were nonhuman entities like subatomic particles or astrophysical objects.

I had no idea that the lives and work of the Order members themselves would turn out to be such a (largely untouched) goldmine of book material. A cornerstone concept of all my Elon creative writing classes was that character drives plot, not vice versa—circumstances organically arise and events unfold because of *who people are*. I gradually realized that this still holds true when writing history of science. *A group of the nation's top scientists met in the mountains for a few days to talk about aliens in 1961*. The surprising (and admittedly humorous) reality of that statement hinges on who those people were in 1961—what forces shaped them and led them to Green Bank.

Of course, historical accuracy mandates that I not take quite as many liberties with the Order characters as I would with people in my fictional pieces. Additionally, sticking to the facts as I know them means that ninety percent of the time, I must resort to outlining the course of events rather than painting a vivid scene. But regarding my selection process for which pieces of information I needed to include (and, as we say in creative writing, which of my babies I needed to kill) to create a cohesive story arc for each Order member, the composition of this thesis was heavily informed by my creative writing classes. When people ask what my thesis is about, my short answer is usually "aliens." But really, this thesis—and *The Order of the Dolphin* as a whole—is about the people engaged in the search. In that sense, the two years I spent in creative writing classes at Elon primed me to tell the stories of these weird and wonderful historical characters.

The type-A obsessive compulsive in me spent much of spring semester junior year wringing her hands over the fact that this project did not fit neatly into the category of physics or creative writing thesis. However, I am fortunate to have attended a small liberal arts institution like Elon, where the opportunity to take a diverse range of courses and the incredible support of a mentor like Professor Crider made it possible for me to pursue this kind of interdisciplinary project. And, in retrospect, it is easy to see how this thesis really is the culmination of my undergraduate experiences at Elon, even though I never took a science writing or history of science course.

It's strange to find myself writing a conclusion to a project that is nowhere near complete. I look forward to composing and revising more chapters as I hone my science writing skills in graduate school. But the Elon era of writing this book, as well as my time researching Messrs. Morrison, Struve, Lilly, and (to a lesser extent) Pearman, is drawing to a close. I do not know how these thesis chapters will compare to the final-draft chapters of a complete *The Order of the Dolphin* manuscript. However, for the purposes of this thesis, I hope I have done justice to the stories of these remarkable scientists. I am rather fond of them, after all.

Works Cited

Bahcall, John N. *Neutrino Astrophysics*. Cambridge: Cambridge UP, 1989. Print.

Bartolini, Laurie. "John Lilly, So Far...(Book)." *Libary Journal* 115.1 (1990): 120. *EBSCOhost*. Web. Feb. 2016.

Baur, Stuart. "Kneedeep in the Cosmic Overwhelm with Carl Sagan." *New York Magazine* 1 Sept. 1975: 26-21. Web. 6 Mar. 2016.

Bell, Alice and John Turney. "Popular Science: From Public Education to Science Bestsellers." *Routledge Handbook of Public Communication of Science and Technology*. Ed. Massimiano Bucchi and Brian Trench. New York: Routledge, 2014. 15-26. Print.

Bernstein, Adam. "Physicist, Educator Philip Morrison Dies." *Washington Post*. The Washington Post, 26 Apr. 2005. Web. Sept. 2015.

Billings, Lee. *Five Billion Years of Solitude: The Search for Life among the Stars*. New York: Current, 2013. Print.

Bloecher, Ted. *Report on the UFO Wave of 1947*. Washington?: National Investigations Committee on Aerial Phenomena, 1967. *Northern Ontario UFO Research and Study*. 2005. Web. Jan. 2016.

Bonnell, J. "A Brief History of the Discovery of Cosmic Gamma-Ray Bursts." *Astronomy Picture of the Day*. NASA, 17 Apr. 1995. Web. 23 Mar. 2016. <http://apod.nasa.gov/htmltest/jbonnell/www/grbhist.html>.

Bridges, Andrew. "Dr. John C. Lilly Dies At 86." *AP Online* [Los Angeles] 3 Oct. 2001: n. pag. *Newspaper Source Plus*. Web. 21 Jan. 2016.

"The Bruce Medalists: Iosif S. Shklovskii." Sonoma State University Physics and Astronomy Department, n.d. Web. Nov. 2015. <http://phys-astro.sonoma.edu/bruceMedalists/Shklovskii/index.html>.

Burnett, D. Graham. *The Sounding of the Whale: Science & Cetaceans in the Twentieth Century*. Chicago: U of Chicago, 2012. Print.

Campbell, Hank. "The Perils and Pitfalls of Communicating Science." *Communicating Astronomy to the Public* (2008): 22-23. Web. 30 Mar. 2016.

Chandrasekhar, S. "Otto Struve, 1897-1963." *Astrophysical Journal* 139 (1964): 423. *SAO/NASA Astrophysics Data System (ADS)*. Web. Mar. 2015. <http://adsabs.harvard.edu/full/1964ApJ...139..423C>.

Chyba, Christopher F., and Kevin P. Hand. "Astrobiology: The Study of the Living Universe." *Annual Review of Astronomy and Astrophysics Annu. Rev. Astro. Astrophys.* 43.1 (2005): 31-74. Web. 30 Mar. 2016.

Cocconi, Giuseppe, and Philip Morrison. "Searching for Interstellar Communications." *Nature* 184.4690 (1959): 844-46. Web. Feb.-Mar. 2015.

Davies, P. C. W. *The Eerie Silence: Renewing Our Search for Alien Intelligence*. Boston: Houghton Mifflin Harcourt, 2010. Print.

Dick, Steven J. *The Biological Universe: The Twentieth-century Extraterrestrial Life Debate and the Limits of Science*. Cambridge: Cambridge UP, 1996. Print.

Dick, Steven J. "Introduction: The Drake Equation in Context." *The Drake Equation: Estimating the Prevalence of Extraterrestrial Life through the Ages*. Ed. Douglas A. Vakoch and Matthew F. Dowd. Cambridge, U.K.: Cambridge UP, 2015. 1-10. Print.

Dick, Steven J. *Life on Other Worlds: The 20th-Century Extraterrestrial Life Debate*. New York: Cambridge UP, 1998. *Google Books*. Web. Mar. 2015.

Dick, Steven J. "Otto Struve, Stellar Rotation and Planetary Systems." *Bulletin of the American Astronomical Society* 23 (1991): 1355. *SAO/NASA Astrophysics Data System (ADS)*. Web. Feb. 2015. < http://articles.adsabs.harvard.edu/cgi-bin/nph-iarticle_query?1991BAAS...23Q1355D&data_type=PDF_HIGH&whole_paper=YES&type=PRINTER&filetype=.pdf>.

Drake, Frank D., and Dava Sobel. *Is Anyone out There? The Scientific Search for Extraterrestrial Intelligence*. New York, NY: Delacorte, 1992. Print.

Drake, Frank D. Letter to Members, Order of the Dolphin. N.d. MS. N.p.

Ellis, Kerry. "Kepler: The Long Road to Other Worlds." *APPEL Academy of ProgramProject Engineering Leadership*. NASA, 1 Aug. 2012. Web. 20 Mar. 2016. <http://appel.nasa.gov/2012/08/01/kepler-the-long-road-to-other-worlds/>.

"Extrasolar Planet Seen Transiting Its Star." *Sky & Telescope* Feb. 2000: 16. *EBSCOhost*. Web. Apr. 2015.

Fernie, J. D. "Otto Struve II." *Journal of the Royal Astronomical Society of Canada* 73 (1979): 65-66. *SAO/NASA Astrophysics Data System (ADS)*. Web. Mar. 2015. <http://articles.adsabs.harvard.edu//full/1979JRASC..73...65./0000066.000.html>.

French, A. P. "In Memoriam: Philip Morrison." *Physics in Perspective* 10 (2008): 110-22. *Springer*. Web. Sept. 2015.

The Girl Who Talked To Dolphins. Dir. Christopher Riley. *Dailymotion*. Dailymotion, 19 June 2014. Web. Feb. 2016. <http://www.dailymotion.com/video/x1zts6s_the-girl-who-talked-to-dolphins_animals>.

Goldberg, Leo. "Otto Struve (obituary)." *Quarterly Journal of the Royal Astronomical Society* 5 (1964): 284-90. *SAO/NASA Astrophysics Data System (ADS)*. Web. Feb. 2015. <http://articles.adsabs.harvard.edu//full/1964QJRAS...5..284./0000285.000.html>.

Gregg, Justin. "No, Flipper Doesn't Speak Dolphinese." *The Wall Street Journal - Eastern Edition* 21 Dec. 2013: C3. *Academic Search Complete [EBSCO]*. Web. Feb. 2016.

Hadhazy, Adam. "Top 10 Exoplanets: Weird Worlds in a Galaxy Not So Far Away." *Scientific American*. N.p., 11 Aug. 2008. Web. 4 Mar. 2016. <http://www.scientificamerican.com/article/top-10-exoplanets/>.

Hearnshaw, John B. "Rotation in Single Stars and the Correlation with Spectral Type." *The Analysis of Starlight: Two Centuries of Astronomical Spectroscopy*. 2nd ed. New York, NY: Cambridge UP, 2014. 118-20. Print.

"History." *Marineland Dolphin Adventure*. Marineland Dolphin Adventure, 2011. Web. Feb. 2016. <http://www.marineland.net/history.html>.

"How Many Exoplanets Has Kepler Discovered?" *NASA*. NASA, n.d. Web. 04 Mar. 2016. <https://www.nasa.gov/kepler/discoveries>.

"Human-Dolphin Foundation." *The Dolphin Trail*. Human-Dolphin Foundation, n.d. Web. 12 Mar. 2016. <http://dolphintrail.com/organizations/humandolphin-foundation/>.

"John Lilly." *The Times (United Kingdom)* 2001: n. pag. *Newspaper Source Plus*. Web. 21 Jan. 2016.

Jones, Barrie William. *Life in the Solar System and beyond*. London: Springer, 2013. Print.

"J. Robert Oppenheimer." *Famous Scientists*. N.p., n.d. Web. 08 Mar. 2016. <http://www.famousscientists.org/j-robert-oppenheimer/>.

Kardaras, Nicholas. *How Plato and Pythagoras Can save Your Life: The Ancient Greek Prescription for Health and Happiness*. San Francisco, CA: Conari, 2011. Print.

Krisciunas, Kevin. "Otto Struve." *Biographical Memoirs*. Vol. 61. Washington, DC: National Academy, 1992. 351-87. Print.

Kukarkin, B. V., and P. G. Kulikovskii. "Otto Struve, 1897-1963." *Soviet Astronomy* 7 (1964): 859-61. *SAO/NASA Astrophysics Data System (ADS)*. Web. Mar. 2015. <http://adsabs.harvard.edu/full/1964SvA.....7..859K>.

Lederberg, Joshua. Letter to J.P.T. Pearman. 11 Apr. 1961. MS. Stanford University Medical Center, Palo Alto, California.

Lilly, John C., and A. M. Miller. "Sounds Emitted by the Bottlenose Dolphin: The Audible Emissions of Captive Dolphins under Water or in Air Are Remarkably Complex and Varied." *Science* 133.3465 (1961): 1689-693. *JSTOR*. Web. Feb. 2016.

Lilly, John C., and A. M. Miller. "Vocal Exchanges between Dolphins: Bottlenose Dolphins "talk" to Each Other with Whistles, Clicks, and a Variety of Other Noises." *Science* 134.3493 (1961): 1873-876. *JSTOR*. Web. Feb. 2016.

Lilly, John C. *Center of the Cyclone*. Oakland, CA: Ronin, 1972. Print.

Lilly, John C. "Distress Call of the Bottlenose Dolphin: Stimuli and Evoked Behavioral Responses." *Science* 139.3550 (1963): 116-18. *JSTOR*. Web. Feb. 2016.

Lilly, John C. "A Feeling of Weirdness" *Mind in the Waters: A Book to Celebrate the Consciousness of Whales and Dolphins*. Ed. Joana McIntyre. Varawa. New York: Scribner, 1974. 71-77. Print.

Lilly, John C. "John Lilly: Altered States." Interview by Judith Hooper. *Erowid*. N.p., n.d. Web. Mar. 2016.

Lilly, John C., J. R. Hughes, E. C. Alvord, and T. W. Galkin. "Brief, Noninjurious Electric Waveform for Stimulation of the Brain." *Science* 121.3144 (1955): 468-69. *JSTOR*. Web. Feb. 2016.

Lilly, John C. *Man and Dolphin*. Garden City, NY: Doubleday, 1961. Print.

Lilly, John C. *The Mind of the Dolphin: A Nonhuman Intelligence*. Garden City, NY: Doubleday, 1967. Print.

Lilly, John C. *The Scientist: A Metaphysical Autobiography*. Berkeley, CA: Ronin Pub., 1997. Print.

Lilly, John C. "The Scientist: A Novel Autobiography." *The Complete Book of Extraterrestrial Encounters: The Ideas of Carl Sagan, Erich Von Däniken, Billy Graham, Carl Jung, John C. Lilly, John G. Fuller, and Many Others*. Ed. Randall Fitzgerald. New York: Collier, 1979. 146-47. Print.

Lilly, John C. "Vocal Behavior of the Bottlenose Dolphin." *Proceedings of the American Philosophical Society* 106 (1962): 520-29. *JSTOR*. Web. Feb. 2016.

MacRobert, Alan. "A Big New Step in the Search for ET." *Sky & Telescope*. N.p., 11 Apr. 2006. Web. Jan. 2016. < http://www.skyandtelescope.com/astronomy-news/a-big-new-step-in-the-search-for-et/>.

MacRobert, Alan, and Joshua Roth. "The Planet of 51 Pegasi." *Sky & Telescope* Jan. 1996: 38. *EBSCOhost*. Web. Apr. 2015.

Mayor, Michel, and Didier Queloz. "A Jupiter-mass Companion to a Solar-type Star." *Nature* 378.6555 (1995): 355-59. Web. Apr. 2015.

McLellan, Dennis. "Dr. John Lilly, 86; Pioneered Study of Dolphin Intellect." *Los Angeles Times*. Los Angeles Times, 4 Oct. 2001. Web. Feb. 2016. <http://articles.latimes.com/2001/oct/04/local/me-53368>.

Morrison, Philip. "Extrasolar X-Ray Sources." *Annual Review of Astronomy and Astrophysics Annu. Rev. Astro. Astrophys.* 5.1 (1967): 325-50. *SAO/NASA Astrophysics Data System (ADS)*. Web. 9 Mar. 2016. <http://adsabs.harvard.edu/full/1967ARA%26A...5..325M>.

Morrison, Philip. "Interstellar Communication." *Interstellar Communication: A Collection of Reprints and Original Contributions*. Ed. A. G. W. Cameron. New York: W.A. Benjamin, 1963. 249-71. Print.

Morrison, Philip. "Interview of Philip Morrison by Owen Gingerich on 2003 February 22." Interview by Owen Gingerich. *Niels Bohr Library & Archives, American Institute of Physics*. American Institute of Physics, n.d. Web. Sept. 2015.

Morrison, Philip. "My Forty Years of SETI." *SETI League*. SETI League, 4 Jan. 2003. Web. Oct. 2015. <http://www.setileague.org/editor/40years.htm>.

Morrison, Philip. *Nothing Is Too Wonderful to Be True*. Woodbury, NY: AIP, 1995. Print.

Morrison, Philip. "The Number N of Advanced Civilizations in Our Galaxy and the Question of Galactic Colonization: An Introduction." *Strategies in the Search for Life in the Universe: A Joint Session of Commissions 16, 40, and 44, Held in*

Montreal, Canada, during the IAU General Assembly, 15 and 16 August, 1979. Ed. Michael D. Papagiannis. Dordrecht, Holland: D. Reidel Pub., 1980. 15-19. Print.

Morrison, Philip. "On Gamma-ray Astronomy." *Il Nuovo Cimento (1955-1965)* 7.6 (1958): 858-65. *Springer Link*. Web. Oct. 2015. <http://link.springer.com/article/10.1007/BF02745590>.

Morrison, Philip. "Outlook Regarding Interstellar Communication." *Interstellar Communication: A Collection of Reprints and Original Contributions*. Ed. A. G. W. Cameron. New York: W.A. Benjamin, 1963. 316-7. Print.

Morrison, Philip. "Trinity Test, July 16 1945 Eyewitness Report by Philip Morrison." *Nuclear Files*. Nuclear Age Peace Foundation, n.d. Web. Sept. 2015. <http://www.nuclearfiles.org/menu/key-issues/nuclear-weapons/history/pre-cold-war/manhattan-project/trinity/eyewitness-philip-morrison_1945-07-16.htm>.

MrHasan1945. “First Atom Bomb Trinity Test Manhattan Project 15-16 July 1945.” Online video clip. *YouTube*. YouTube, 14 July 2012. Web. Oct. 2015.

NASA Exoplanet Archive. NASA Exoplanet Science Institute, n.d. Web. 19 Mar. 2016. <http://exoplanet.eu/catalog/>.

National Radio Astronomy Observatory. *"On Demand" Press Information Regarding NRAO Project Ozma*. Green Bank, West Virginia. 1959. Print.

"Neutrinos." *Fermilab*. Fermilab, 24 Dec. 2015. Web. Jan. 2016. <http://www.fnal.gov/pub/science/particle-physics/experiments/neutrinos.html>.

Odgers, G. J. "Otto Struve, 1897-1963." *Journal of the Royal Astronomical Society of Canada* 57 (1963): 170-72. *SAO/NASA Astrophysics Data System (ADS)*. Web. Mar. 2015. <http://adsabs.harvard.edu/full/1963JRASC..57..170O>.

Odishaw, Hugh. Letter to Otto Struve. 20 July 1961. MS. National Academy of Sciences Space Science Board, Washington, D.C.

Oliver, B.M. "Some Potentialities of Optical Masers." *Interstellar Communication: A Collection of Reprints and Original Contributions*. Ed. A. G. W. Cameron. New York: W.A. Benjamin, 1963. 207-22. Print.

Opik, E. J. "Otto Struve (1897-1963)." *Irish Astronomical Journal* 6 (1963): 153-54. *SAO/NASA Astrophysics Data System (ADS)*. Web. Feb. 2015. <http://adsabs.harvard.edu/full/1963IrAJ....6..153O>.

"Optical SETI @ UC Berkeley." *Berkeley SETI Research Center*. Berkeley SETI Research Center, n.d. Web. Jan. 2016. <https://seti.berkeley.edu/opticalseti>.

Order of the Dolphin. N.d. TS. National Radio Astronomy Observatory Archives.

"Otto Struve Telescope." *McDonald Observatory*. The University of Texas McDonald Observatory, n.d. Web. 19 Mar. 2016. <https://mcdonaldobservatory.org/research/telescopes/Struve>.

Overbye, Dennis. "Philip Morrison, 89, Builder of First Atom Bomb, Dies." *The New York Times*. The New York Times, 26 Apr. 2005. Web. 8 Mar. 2016. <http://www.nytimes.com/2005/04/26/science/philip-morrison-89-builder-of-first-atom-bomb-dies.html?_r=1>.

Owen, Robert M. "A Brief SETI Chronology." *SETI League*. SETI League, 4 Jan. 2003. Web. Jan. 2016. < http://www.setileague.org/general/history.htm>.

Pearman, J.P.T. “Conference on Extraterrestrial Intelligent Life." Preliminary report. National Academy of Sciences Space Science Board. Washington, D.C. N.d. Print.

Pearman, J.P.T. "Extraterrestrial Life and Interstellar Communication: An Informal Discussion." *Interstellar Communication: A Collection of Reprints and Original Contributions*. Ed. A. G. W. Cameron. New York: W.A. Benjamin, 1963. 287-93. Print.

Pearman, J.P.T. Letter to Frank Drake. 11 April 1961. MS. National Academy of Sciences, Washington, D.C.

Pearman, J.P.T. Letter to O. G. Villard, Jr. 13 Mar. 1961. MS. National Academy of Sciences, Washington, D.C.

Pearman, J.P.T. Letter to O. G. Villard, Jr. 15 Mar. 1961. MS. National Academy of Sciences, Washington, D.C.

Pearman, J.P.T. "Symposium on Extraterrestrial Intelligent Life." Memorandum for file. National Academy of Sciences Space Science Board. 9 June 1961. Print.

Pearman, J.P.T. "Symposium on Extraterrestrial Intelligent Life." Memorandum for file. National Academy of Sciences Space Science Board. 22 June 1961. Print.

Penny, Alan. "SETI: Peering into the Future." *Astronomy and Geophysics* (2011): 121-24. Web. 30 Mar. 2016.

Phillips, John G. "Otto Struve, 1897-1963." *PASP Publications of the Astronomical Society of the Pacific* 75 (1963): 501-04. *JSTOR*. Web. 11 Feb. 2015. <http://www.jstor.org/stable/40674056>.

Poundstone, William. *Carl Sagan: A Life in the Cosmos*. New York: Henry Holt, 1999. Print.

Rathi, Akshat. "The Nobel Prize in Physics Is Awarded for Discovering That the Universe's Most Elusive Particles Have Mass." *Quartz*. N.p., 6 Oct. 2015. Web. 09 Mar. 2016.

Reichhardt, Tony. "Kepler's Unusual Orbit." *Air & Space*. Smithsonian, 9 Mar. 2009. Web. 4 Mar. 2016. <http://www.airspacemag.com/daily-planet/keplers-unusual-orbit-54411507/?no-ist>.

Santos, Nuno C. "Extra-solar Planets: Detection Methods and Results." *New Astronomy Reviews* 52.2-5 (2008): 154-66. *ScienceDirect*. Web. Apr. 2015. <http://www.sciencedirect.com/science/article/pii/S1387647308000390>.

Sartori, Leo, and Kosta Tsipis. "Philip Morrison 1915-2005." (2009): 1-23. *National Academy of Sciences*. Web. Sept. 2015.

Schmadel, Lutz D. *Dictionary of Minor Planet Names*. 3rd ed. Vol. 1. New York: Springer, 1997. Print.

Schorn, Ronald A. "Struve, Otto." *Biographical Encyclopedia of Astronomers*. Ed. Thomas Hockey, Virginia Trimble, Thomas R. Williams, Katherine Bracher, Richard A. Jarrell, Jordan D. Marché, JoAnn Palmeri, and Daniel WE Green. New York: Springer-Verlag, 2014. 2093-095. Print.

Schwartz, R.N., and C.H.Townes. "Interstellar and Interplanetary Communication by Optical Masers." *Interstellar Communication: A Collection of Reprints and Original Contributions*. Ed. A. G. W. Cameron. New York: W.A. Benjamin, 1963. 223-32. Print.

"Science and Technology Working Group." *SETI Institute*. SETI Institute, 19 May 2000. Web. Jan. 2016. <http://archive.seti.org/seti/working-group/index.php>.

"Scientific and Medical Pioneer John Lilly Dies." *Alternative Therapies in Health & Medicine* 8.1 (2002): n. pag. *Academic Search Complete*. Web. Mar. 2016.

Serber, Robert. *Peace & War: Reminiscences of a Life on the Frontiers of Science*. New York: Columbia UP, 1998. Print.

Shane, C. D. "The Award of the Bruce Gold Medal to Dr. Otto Struve." *Publications of the Astronomical Society of the Pacific* 60 (1948): 155-58. *SAO/NASA Astrophysics Data System (ADS)*. Web. Feb. 2015. <http://articles.adsabs.harvard.edu/cgi-bin/nph-iarticle_query?1948PASP...60..155S&data_type=PDF_HIGH&whole_paper=YES&type=PRINTER&filetype=.pdf>.

Shuch, H. Paul. "Prof. Philip Morrison." *SETI League*. SETI League, 25 Apr. 2005. Web. Oct. 2015. <http://www.setileague.org/admin/philmorr.htm>.

Shuch, H. Paul. "Project Ozma: The Birth of Observational SETI." *Searching for Extraterrestrial Intelligence: SETI Past, Present, and Future*. Berlin: Springer, 2011. 13-18. Print.

Smith, Dinitia. "A Thinking Bird or Just Another Birdbrain?" *The New York Times*. The New York Times, 9 Oct. 1999. Web. 29 Mar. 2016.

Sobel, Dava. *Longitude: The True Story of a Lone Genius Who Solved the Greatest Scientific Problem of His Time*. New York: Walker, 1995. Print.

Strick, James E. "Creating a Cosmic Discipline: The Crystallization and Consolidation of Exobiology, 1957–1973." *Journal of the History of Biology* 37.1 (2004): 131-80. Web. Feb. 2016

"Struve (crater)." *World Public Library*. World Public Library Association, n.d. Web. 19 Mar. 2016. <http://www.worldlibrary.org/articles/Struve_(crater)>.

Struve, Otto. *Astronomy of the 20th Century*. New York: MacMillan, 1962. Print.

Struve, Otto. "Continuous Creation." *Astronomical Society of the Pacific Leaflets* 6 (1951): 154-60. *SAO/NASA Astrophysics Data System (ADS)*. Web. Mar. 2015. <http://adsabs.harvard.edu/full/1951ASPL....6..154S>.

Struve, Otto. "The Cosmological Significance of Stellar Rotation." *Popular Astronomy* 53 (1945): 201-17. *SAO/NASA Astrophysics Data System (ADS)*. Web. Feb. 2015. < http://adsabs.harvard.edu/full/1945PA.....53..201S>.

Struve, Otto. Letter to Invitees, Conference on Extraterrestrial Intelligent Life. 18 Sept. 1961. MS. National Radio Astronomy Observatory, Green Bank, West Virginia.

Struve, Otto. Letter to Invitees, Conference on Extraterrestrial Intelligent Life. 25 Oct. 1961. MS. National Radio Astronomy Observatory, Green Bank, West Virginia.

Struve, Otto. "The National Radio Astronomy Observatory: The Outlook in 1960." *Publications of the Astronomical Society of the Pacific* 72 (1960): 177-87. *SAO/NASA Astrophysics Data System (ADS)*. Web. Mar. 2015. <http://articles.adsabs.harvard.edu/cgi-bin/nph-iarticle_query?1960PASP...72..177S&data_type=PDF_HIGH&whole_paper=YES&type=PRINTER&filetype=.pdf>.

Struve, Otto. "On the Axial Rotation of Stars." *The Astrophysical Journal* 72 (1930): 1-18. *SAO/NASA Astrophysics Data System (ADS)*. Web. Feb. 2015. <http://adsabs.harvard.edu/full/1930ApJ....72....1S>.

Struve, Otto. "Proposal for a project of high-precision stellar radial velocity work." *The Observatory* 72 (1952): 199-200. *SAO/NASA Astrophysics Data System (ADS)*. Web. March 2015. < http://articles.adsabs.harvard.edu/full/1952Obs....72..199S/0000199.000.html>.

Struve, Otto. "Some Problems of the Evolution of Stars." *Proceedings of the National Academy of Sciences* 35 (1949): 161-67. *Proceedings of the National Academy of Sciences of the United States of America*. National Academy of Sciences. Web. Feb. 2016. <http://www.ncbi.nlm.nih.gov/pmc/articles/PMC1062991/>.

"Submitting a Book Proposal to the MIT Press." *The MIT Press*. Massachusetts Institute of Technology, n.d. Web. 20 Mar. 2016. <https://mitpress.mit.edu/index.php?q=content/submitting-book-proposal-mit-press>.

Sullivan, Walter. "Contact With Worlds in Space Explored by Leading Scientists." *The New York Times* 4 Feb. 1962: 1+. *ProQuest Historical Newspapers: The New York Times*. Web. 6 Mar. 2016.

Swift, David W. "Philip Morrison." *SETI Pioneers: Scientists Talk about Their Search for Extraterrestrial Intelligence*. Tucson: U of Arizona, 1990. 19-48. Print.

Tarter, Jill. 2001. “Searching for Extraterrestrial Intelligence (SETI).” *Annual Review of Astronomy and Astrophysics.* 39: 511-48.

Tassoul, Jean Louis. *Stellar Rotation*. Cambridge, U.K.: Cambridge UP, 2000. Print.

Temming, Maria. "Kepler: Revived and Working Again." *Sky & Telescope*. N.p., 10 June 2014. Web. Apr. 2015. <http://www.skyandtelescope.com/astronomy-news/kepler-revived-working-partially/>.

Topping, Seymour. "Khrushchev Says Tests Will Go On; Cites 'Hysteria.'" *The New York Times* 28 Oct. 1961: 1+. *ProQuest Historical Newspapers: The New York Times*. Web. 6 Mar. 2016.

Townes, Charles. "Charles H. Townes - Biographical." *Nobelprize*. Nobel Media AB, Mar. 2006. Web. 09 Mar. 2016. <http://www.nobelprize.org/nobel_prizes/physics/laureates/1964/townes-bio.html>.

Townes, Charles H. "The First Laser." *A Century of Nature: Twenty-One Discoveries That Changed Science and the World*. Ed. Laura Garwin and Tim Lincoln. Chicago: Chicago, 2003. 107-12. Print.

Turkewitz, Julie. "Climb In, Tune In: A Renaissance for Sensory Deprivation Tanks." *The New York Times*. The New York Times, 17 Oct. 2015. Web. Feb. 2016. <http://www.nytimes.com/2015/10/18/us/climb-in-tune-in-a-renaissance-for-sensory-deprivation-tanks.html?_r=1>.

United States of America. National Academy of Sciences - National Research Council. Space Science Board. *Minutes: Ninth Meeting*. By R. C. Peavey. Washington, DC: n.p., 1961. Print.

Waters, Florence. "Secrets Of The Dolphin House." *Sunday Telegraph* [London] 1 June 2014: n. pag. *Newspaper Source Plus*. Web. Feb. 2016.

Webb, Stephen. *If the Universe Is Teeming with Aliens ... Where Is Everybody?: Fifty Solutions to the Fermi Paradox and the Problem of Extraterrestrial Life*. New York: Copernicus in Association with Praxis Pub., 2002. Print.

Wolszczan, Aleksander, and Dail A. Frail. "A Planetary System around the Millisecond Pulsar PSR 1257+ 12." *Nature* 355 (1992): 145-57. Web. Apr. 2015. <http://www.astro.umontreal.ca/~doyon/PHY6795O/Revues/Revue1/Woszczan1992.pdf>.

Zalasiewicz, Jan, and Mark Williams. *Ocean Worlds: The Story of Seas on Earth and Other Planets*. Oxford: Oxford UP, USA., 2015. Print.

Zhang, Sarah. "A Russian Tycoon Is Spending $100 Million to Hunt for Aliens." Editorial. *WIRED*. Conde Nast Digital, 20 July 2015. Web. 30 Mar. 2016. <http://www.wired.com/2015/07/russian-tycoon-spending-100-million-hunt-aliens/>.

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