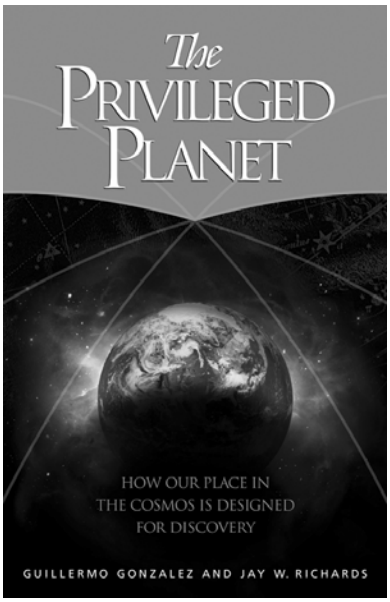

The Privileged Planet Teacher Guide

Guillermo Gonzalez and Jay W. Richards

CENTER FOR SCIENCE & CULTURE

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Preview copy, not for resale
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Publisher Information

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Published in the United States of America
First Edition, First Printing. March 2006.

Preface

This guide began its life as a set of notes developed by Michael N. Keas for use in his Unified Studies Natural Science survey course for non-science majors at Oklahoma Baptist University. At the time, Keas was an associate professor of natural science with expertise in the history, philosophy and rhetoric of science. With a particular interest in science education, he began incorporating *The Privileged Planet* into his lectures in 2002, when it was still in an incomplete manuscript. Today, Keas teaches at Biola University.

We are pleased that Dr. Keas has granted us permission to expand on and adapt his guide for a broader audience. It is appropriate for high school through advanced undergraduate students. It can be used as a supplement for an introductory astronomy or general science course, along with *The Privileged Planet* and accompanying documentary, an introductory astronomy textbook and perhaps a set of readings on the history of science (e.g., selected chapters from *The Book of the Cosmos* by Dennis Danielson).

The Privileged Planet and this guide can also be used as supplementary material for a college-level astrobiology course. In that case, the advanced questions would be particularly appropriate. It is not necessary to cover every chapter in the guide. Astrobiology courses, for example, can focus on the first eight chapters, and perhaps include some of the material on SETI. *The Privileged Planet*, along with *Rare Earth* by Peter Ward and Donald Brownlee, can serve to balance the more commonly available material with a strong pro-SETI slant. The astrobiology student would also benefit from the review paper published by one of us on habitable zones.[1] It expands on the astrobiology in *The Privileged Planet* with the latest research, including a more complete treatment of the Galactic Habitable Zone.

We welcome suggestions for improvement, reports of errors and particularly good answers to the advanced questions. We will acknowledge incorporated material in future versions of this guide. Please send correspondence to: csc@discovery.org.

Guillermo Gonzalez
Jay W. Richards
March 1, 2006

[1] Gonzalez G. (2005). Habitable Zones in the Universe. *Origins of Life and Evolution of Biospheres*, **35**, 555-606.

Introduction

Preview this study guide to know what to look for in your reading, then read the text of the Introduction of *The Privileged Planet,* then answer the questions below.

What event on Christmas Eve, 1968, attracted the largest single TV audience in history?

Probably a majority of scientists think that our Earthly existence is accidental and purposeless. *The Privileged Planet* challenges this view on scientific grounds. What matters most to the practice of science is not where scientists get their initial ideas (e.g., intuition, the Bible or a dream), but rather how well those ideas are tested against publicly accessible evidence. A scientist may begin assuming the importance or unimportance of our cosmic position, just so long as those initial assumptions are open to being accountable to the evidence of nature.

The Privileged Planet's main thesis: the conditions that allow for _____ on Earth also make it strangely well suited for _____ and _____ the universe.

Technical version of this thesis: _____ correlates with habitability.

Identify three views (among prominent scientists since the mid-20th century) of how common or uncommon life is in the cosmos (answer in the #1-#2-#3 outline below).

View #1: Drake-Sagan-SETI

Life, even intelligent life, is <u>common / uncommon</u> (circle one).

The late Carl Sagan (author of the novel *Contact*, upon which the motion picture by the same name was based) was fond of extolling the "billions" of stars in the cosmos; we will use this as a convenient device for remembering this most common twentieth century view. Frank Drake is the early SETI researcher who is especially remembered for his mathematical formula that attempts to calculate the number of advanced civilizations capable of communicating with radio signals in the Milky Way Galaxy.

What is the so-called Copernican Principle?

Define naturalism by completing Carl Sagan's secular liturgy: nature is "all that _____, or ever _____, or ever _____." If naturalism is true, the Copernican Principle seems to naturally follow.

SETI = Search for _____ Intelligence. Drake & Sagan were leading SETI advocates.

View #2: Rare Earth Hypothesis
Simple life is common / uncommon, but complex life is common / uncommon (circle correct)

The name of this viewpoint comes from Peter Ward and Donald Brownlee in their book *Rare Earth* (2000). This view has taken its contemporary form within the new discipline of astrobiology, which is the study of the conditions necessary for life in the universe.

In what limited regard does the Rare Earth view (#2) *challenge* the Copernican Principle (CP)? Answer: it challenges the CP in regard to simple / complex life (circle one)?

Does the "Rare Earth" view keep faith with the broader naturalistic philosophy that supports the Copernican Principle? Explain.

View #3: Privileged Planet Hypothesis (thesis of *The Privileged Planet*)

Part A, Habitability Thesis: Life, both complex *and "simple,"* is common / uncommon (circle one). This thesis, although not new, has taken on an unprecedented degree of scientific rigor in its latest form within the new discipline of astrobiology. Views #2 and #3 both recognize the precise fine-tuning (or "just right" arrangement of natural laws and events) that is required for the possibility of life's existence.

Part B, Habitability-Measurability Correlation Thesis: The conditions that allow for intelligent life on earth also make it strangely well suited for measuring (analyzing) the universe.

Measurability [definition]: "refers to those features of the universe as a whole, and especially to our particular _____ in both in space and time which allow us to detect, observe, discover, and determine such features as the size, age, history, laws, and other properties of the physical universe."

Does the Privileged Planet Hypothesis keep faith with the broader naturalistic philosophy that underwrites the Copernican Principle? Explain (compare with the Rare Earth Hypothesis).

"All design involves conflicting objectives and hence compromise, and the best designs will always be those that come up with the best compromise." How does this insight, called constrained optimization, guide the Privileged Planet thesis? How does laptop computer design illustrate constrained optimization?

Advanced questions

1) Discuss the subtle differences among observability, discoverability, and measurability. Illustrate your answer with real-world examples.

Ch. 1: Wonderful Eclipses

Kinds of Solar Eclipses

- Total Eclipse (figure 1.1A): The fully shaded umbra of the Moon's shadow reaches Earth. This is called a total eclipse for those located on Earth where the umbra touches, because the Moon totally covers the Sun.

- Annular Eclipse (figure 1.1B): The semi-shaded penumbra of the Moon's shadow reaches Earth, while the dark umbra falls short. The Moon fails to totally cover the Sun for *any* observer on Earth.

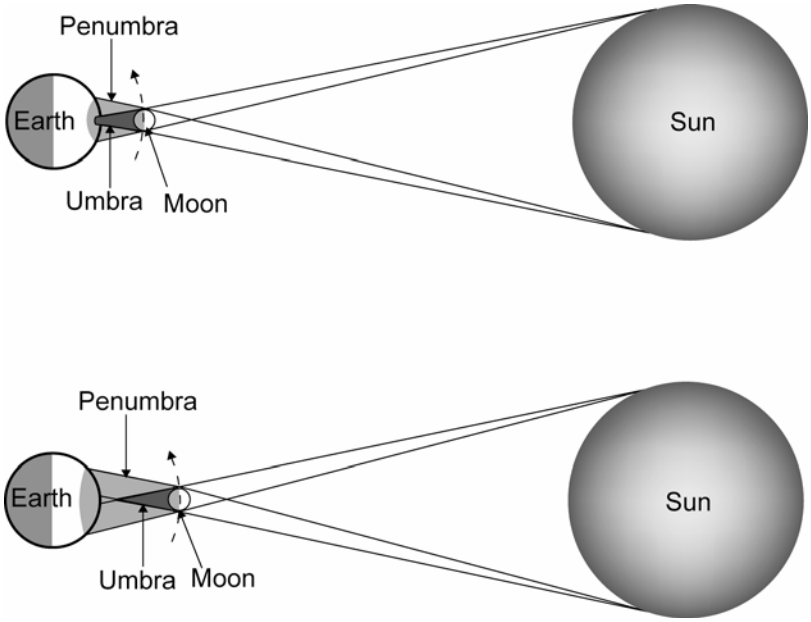

Figure 1.1A&B

More Detail on Total Solar Eclipses (figure 1.1A)

1. Moon's disk is large enough to cover the bright solar disk (Sun's photosphere)
2. Centers of the two disks at least approximately meet
3. Umbra touches Earth's surface
4. There are two kinds of total eclipses: super & perfect

    a. **Super eclipse**: Moon's disk appears _____ than the solar disk and thus more than covers it.

b. **Perfect eclipse**: Moon's disk is just large enough to cover the bright solar disk.

What causes a perfect solar eclipse? The relative Earth-Moon and Earth-Sun distances just about exactly compensate for the real size difference between Moon and Sun, making both appear the same angular size as viewed from Earth.

What can one see during the 7.5 minutes (or less) of a perfect solar eclipse? See Plate 3 in the book (all color plates are in the middle of the book). See especially the top photograph for an excellent look at a perfect eclipse. **Observe two things:**
(1) pink _____ around the edge of the Moon, which looks like a thin jagged crown with protruding pink flames; this is an irregular layer of gases on the Sun within which sunspots, flares, and prominences (protruding pink flames) occur.
(2) silvery-white _____, which is the Sun's outer atmosphere, and extends out several times the Sun's diameter.

More Detail on Solar Eclipses that are *Not* Total (figure 1.1B)

1. Annular Eclipse (figure 1.1B): The Moon's disk is too _____ to cover the bright solar disk (photosphere of the Sun), but the centers of the two disks at least approximately meet. Explanation: More than half the time nowadays the Moon is far enough from Earth (relative to the changing Earth-Sun distance) that it appears a bit smaller than the Sun. During such periods, the Moon (if lined up with the Sun) fails to totally eclipse (cover) the bright solar disk. Under these conditions, the Sun's bright light prohibits observations of the following scientifically interesting effects: (1) pink chromosphere and (2) silvery-white corona. These two solar phenomena are otherwise visible during a total solar eclipse (especially during a *perfect* total solar eclipse as described above).

2. Partial Eclipse: A solar eclipse in which an observer is located in the penumbera. One may experience either a total or annular eclipse as a "partial eclipse" if one is situated in the penumbera.

Earth-Moon-Sun Configuration is Well Suited for Earth's Habitability and Measurability

Gonzalez discovered the habitability-measurability correlation after first seeing it in the Earth-Moon-Sun configuration that makes possible complex life and science-friendly solar eclipses.

Four planet-moon-sun features required for the support of complex life on a planet:

#1. "A moon large enough to just cover the Sun also _____ the rotation of its host _____." This keeps planet's tilt within a narrow range that is important for sustaining complex life.

#2. What celestial body is the main cause of ocean tides? Sun / Moon (circle one). In the absence of this body, ocean currents would be less effective at regulating global climate and mixing nutrients from the continents into the oceans.

OBJECTION: "As long as they are the right relative sizes and distances apart, a perfect total eclipse could happen with a larger or smaller moon or sun." So, there is nothing special about our perfect total eclipses.

ANSWER: This objection evaporates in light of additional evidence (e.g., points 3 & 4 below) that few of the eclipse-friendly planet-moon-sun arrangements also provide these two correlated benefits:

- Able to support complex life on the host planet (habitability)
- Able to support highly useful scientific measurements (measurability)

#3. A star similar to the Sun's mass is required for complex life.

A less _____ sun requires that a planet orbit closer to keep liquid _____ on its surface. The band around a star wherein a terrestrial planet must orbit to maintain liquid water on its surface is called the _____ habitable zone. But, if the planet orbits too close, you get rapid _____-locking (one hemisphere of planet always faces its sun). What's bad about this?
_____
_____
What difference between our Moon's ____-lock and this hypothetical planetary ____-lock stands out? Hint: Why is one side of our Moon *not* perpetually dark? _____
_____

#4. If a planet is much bigger or smaller than ours, then complex life is much less likely there. Why? Because the host planet needs to be about Earth's size to maintain the following features that are critical for the support of complex life:

A. Plate tectonics
B. Maintenance of some _____ above the oceans
C. Retention of an _____.

Planet-moon-sun configurations that support life are more likely to produce science-friendly perfect solar eclipses

#1. The planet-Moon-Sun configuration that is best for complex life is also most likely to produce solar eclipses. Over most of its history only super eclipses were visible from Earth. Today, perfect eclipses are visible.

#2. A comparative study of moons in our Solar System reveals something important about our Earth-Moon-Sun configuration: Earth is unusually well set up to be a platform from which to make scientifically useful measurements during solar eclipses. Summarize the evidence for this conclusion with the aid of the bullet points below:

- Figure 1.4 (page 11) shows that only two moons in our Solar System (ours and one of Saturn's) appear the same angular size as the Sun when viewed from their host planets.
    - By angular size of the Sun we mean the angle between two lines of sight:
        - To one edge of the Sun and
        - To the opposite edge of the Sun
    - Angular sizes of the moons and the Sun vary due to changes in the moons' distances from their host planets and also the change in distances of the planets from the Sun and so these moons sometimes appear smaller than the Sun (left of vertical line on the graph) and sometimes larger than the Sun (right of vertical line).
- Other reasons Earth's solar eclipses are better:
    - The Moon orbits around Earth slowly. Do the moons of the giant planets generally orbit their host planets faster or slower than ours? Why? Why is this important?
    - How does the potato-shaped Prometheus make matters worse for scientific measurements taken from the surface of Saturn during a total eclipse?
    - From which planet with a moon does the Sun subtend the largest angular size? Why is this relevant?

Research Aided by Perfect Solar Eclipses Led to Three Important Scientific Discoveries

#1. Perfect solar eclipses helped scientists discover how to determine the chemical (elemental) makeup of stars.

In 1811 Joseph Franhaufer first described the dark gaps that intersperse the smooth continuum of the solar light spectrum, called Franhaufer lines or _____ lines.

Atoms and molecules both emit and absorb light at characteristic wavelengths on the spectrum, called _____ and absorption lines, respectively. By learning to read this bar-code-like information, scientists have been able to determine the elemental makeup of _____. This major advance in science was made possible with spectroscopic measurements of the chromosphere and prominences (plumes of gas that surge out from the photosphere into the _____) during the few minutes of totality during a perfect solar eclipse. These discoveries helped confirm the proposal of Jesuit priest Angelo Secchi and John Herschel in 1864 that the Sun is a ball of hot _____.

Only because they discovered how absorption lines form in the Sun's atmosphere did astronomers learn how to interpret the spectra of distant _____, and thereby determine their chemical makeup, all without leaving our tiny planet. Such knowledge is the linchpin for modern astrophysics and cosmology.

#2. Total solar eclipses provided scientists the earliest and one of the most influential "confirming tests" of _____ Relativity (one of most important laws of nature)

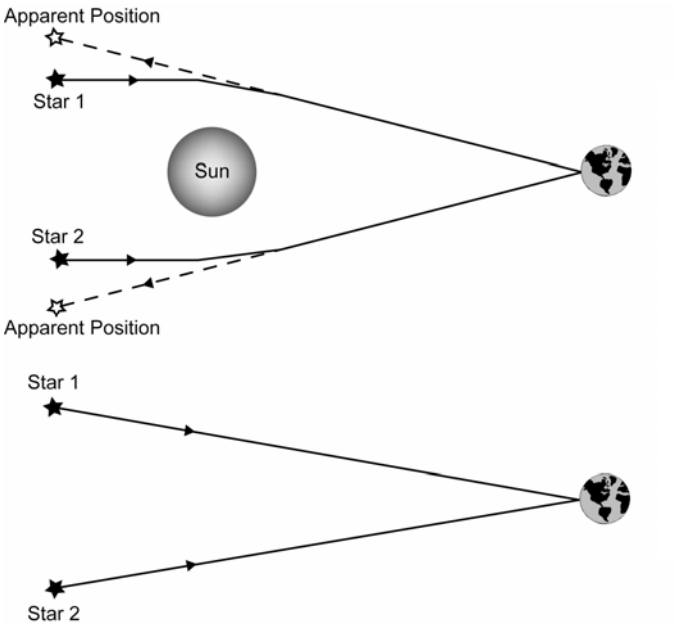

Figure 1.7: The Moon is not shown eclipsing the Sun in the drawings, but this was the case, and necessarily so in order to enable these early 20th century scientists to see the stars near the Sun during daylight hours. The bottom drawing shows that the angle measured between star 1 and 2 (at nighttime) would be less months later with the Sun out of the that part of the sky. The difference in angle between the stars results from the bending of starlight as illustrated in the top drawing.

#3. Total solar eclipses give scientists the best way of measuring the slowdown of Earth's _____ since ancient times.

- What causes the slowing of Earth's rotation?
- A total solar eclipse is only visible as such by those in its _____ (dark shadow's) track
- The slowing of Earth's rotation translates into errors in prediction of where the _____ would sweep across Earth's surface for an ancient total solar eclipse
- By examining accounts of total solar eclipses at known dates and places, scientists can place ancient calendars on our modern calendar system.

Bizarre Conclusion

"There's a final, even more bizarre twist. Due to Moon-induced tides, the Moon is gradually _____ from the Earth, at 3.82 centimeters per year. In ten million years, the Moon will seem noticeably _____. At the same time, the Sun's apparent girth has been swelling by six centimeters per year for ages, as is normal in stellar evolution. These two processes, working together, should end total solar eclipses in about _____ million years, a mere _____ percent of the age of the Earth. This relatively small window of opportunity also happens to coincide with the existence of _____ life. Put another way, the most habitable place in the Solar System yields the best view of solar eclipses just when _____ can best appreciate them."

Advanced questions

1. Search the Internet for recent images of moons taken by orbiting probes or images of solar eclipses obtained from the surface of another planet. Look also for data on newly discovered moons. How do these new images/data bear on the claims made in this chapter about Earth's solar eclipses in comparison to others in the Solar System?

2. Look up data on the shapes, sizes, and densities of the known moons and asteroids that have had close flybys by probes. Discuss the trends of shape with size and density. If our moon were one-quarter its size, what do you think its shape would be?

3. In what major ways did Earth differ from its present state over its history? In what ways did changes in the Moon's distance affect Earth's habitability over its history?

4. If Earth's day were shorter by several hours, would the Moon still be necessary to stabilize Earth's axis? Discuss your answer within the context of the way the Moon formed and its effect on Earth's initial rotation period.

About the Authors

Guillermo Gonzalez is an Assistant Professor of Astronomy at Iowa State University. He received his Ph.D. in Astronomy in 1993 from the University of Washington. He has done post-doctoral work at the University of Texas, Austin and at the University of Washington and has received fellowships, grants and awards from such institutions as NASA, the University of Washington, Sigma Xi (scientific research society) and the National Science Foundation.

Gonzalez has extensive experience in observing and analyzing data from ground-based observatories, including work at McDonald Observatory, Apache Point Observatory and Cerro Tololo Interamerican Observatory. He is a world class expert on the astrophysical requirements for habitability and on habitable zones and a co-founder of the Galactic Habitable Zone (GHZ) concept. Astronomers and astrobiologists around the world are pursuing research based on my work on extra solar planets host stars, the GHZ, and several discoveries pertaining to stellar abundances.

Gonzalez has also published over sixty articles in refereed astronomy and astrophysical journals including Astronomy and Astrophysics, Monthly Notices of the Royal Astronomical Society, Astrophysical Journal and Solar Physics. His current research interests in astrobiology focus on the "Galactic Habitable Zone" which captured the October 2001 cover story of Scientific American, and the properties of the host stars of extra solar planets. He also is the co-author of the second edition of "Observational Astronomy" an advanced college astronomy textbook..

Jay Wesley Richards has a Ph.D.(honors) in philosophy and theology from Princeton Theological Seminary, where he was formerly a Teaching Fellow. His masters thesis (Th.M., Calvin Theological Seminary) treated philosopher of science Michael Polanyi. From 1996-1998, he was executive and associate editor of The Princeton Theological Review, and president of the Charles Hodge Society at Princeton Theological Seminary. He has published in academic journals such as Religious Studies, Christian Scholars' Review, The Heythrop Journal, Encounter, The Princeton Theological Review, Perspectives on Science and the Christian Faith: The Journal of the American Scientific Affiliation; as well as editorial features in The Washington Post, Seattle Post-Intelligencer and IntellectualCapital.com.

He is co-author, with astronomer Guillermo Gonzalez, of the book The Privileged Planet: How Our Place in the Cosmos Is Designed for Discovery (Regnery, 2004). He is editor and contributor, with William A. Dembski, of Unapologetic Apologetics: Meeting the Challenges of Theological Studies (InterVarsity Press, 2001), and editor and contributor with George Gilder of Are We Spiritual Machines?: Ray Kurzweil vs. the Critics of Strong AI (Discovery Institute Press, 2002). He is also author of The Untamed God: A Philosophical Exploration of Divine Perfection, Immutability, and Simplicity (InterVarsity Press, 2003).