An Answer to Fermi's Paradox In the Prevalence of Ocean Worlds?

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Introduction: The Fermi Paradox asks the question about extraterrestrial civilizations, "Where are they?" Given speculations based on numerical evaluations of the Drake Equation that would seem to indicate that the likelihood of precisely N=1 communicating extraterrestrial civilizations in the Universe is small (i.e., that we are unique), the Fermi Paradox has not been resolved. Many explanations have been proffered [1]. We suggest another, that the great majority of worlds with biology and civilizations are interior ocean worlds, cut off from communication because they are inside of their host world, therefore not easily revealing themselves.

The Fermi Paradox: The Fermi Paradox (hereafter, FP) is the apparent contradiction between the lack of evidence for detected extraterrestrial civilization in an old universe and the oftentimes-large number estimates (e.g., those given by the Drake Equation) for the number of extant extraterrestrial civilizations. As summarized in [1] a range of potential explanations for the Fermi Paradox have been proffered; we offer a new potential explanation, namely that most life, and most intelligent life in the universe inhabits interior water ocean worlds (WOWs) where their presence is cloaked by massive overlying burdens of rock or ice between their abode and the universe.

Interior Ocean Worlds Are Likely More Conducive to Life: Whereas it was once thought that among the worlds of our solar system only Earth sports a water ocean, that conclusion turned out to be an observational selection effect. Earth, it turns out, is an uncommon type of water ocean world—at least in our solar system, because it wears its oceans on its exterior. Beginning in the early 1980s and extending to the present, an increasing number of worlds in our solar system have been shown to through gravitational, magnetic, or geological/geophysical evidence to indicate that they are likely to possess water oceans [2]. As a result, water ocean worlds are now thought to be common in our solar system [3]. There are three types of these worlds known, which we classify as follows: (Type I) solid bodies with external oceans (currently only Earth, but apparently also Venus or Mars or both in the distant past), (Type II) icy satellites and small planets with interior oceans (e.g., Europa, Enceladus, and Pluto), and (Type III) giant planets like Uranus and Neptune with high-pressure interior oceans. The predominant Type of ocean world in our present day solar system is of Type II, though late in the Sun's evolution when it becomes a red giant, Type (i) WOWs are likely to dominate as numerous icy worlds and small planets in the Kuiper Belt develop exterior liquid oceans on their surface [4]. Water ocean worlds of Type II appear to be particularly conducive to the development of life owing to several key advantages, including: (1) *Environmental Independence to Stellar Type, Multiplicity, and Distance*. Owing to the several to hundreds of kilometers depth of typical Type II liquid water oceans, and the overlying thermal insulation provided by the planetary lid atop these oceans, the energy balance, temperature, pressure, and toxicity in Type II ocean worlds is only weakly coupled to their host star's stellar type, stellar multiplicity, stellar distance, and stellar evolutionary stage (i.e., from protostars with winds and high activity through the main sequence to stellar remnants). And (2) *Environmental Stability*. Again owing to the depth of typical Type II oceans and the overlaying thermal insulation provided by the planetary lid atop these oceans, these environments are protected from numerous kinds of external risks to life, such as impacts, radiation, surface climate and obliquity cycles, poisonous atmospheres, and nearby deleterious astrophysical events such as novae and supernovae, hazards stellar flares, and even phenomena like the Faint Early Sun. As a result of these factors, WOWs of Type II require much less of their parent planet and star to remain oceans viable for life than do ocean worlds of Type I. In contrast, the latter can only remain oceans in a comparatively limited range of insolation conditions, thereby in turn eliminating most combinations of planet-star distance, stellar multiplicity, orbital eccentricity, and planetary spin states from creating a habitable zone for such ocean worlds. Similarly, Type II WOWs do not require planetary magnetospheres for protection, nor do they suffer from external threats due to asteroid/comet impacts, supernovae and novae induced insolation and charged particle radiation, obliquity extremes, and they are also immune to the passage of their host star through giant molecular clouds of high opacity. Indeed, Type II WOWs can even remain liquid and therefore candidate abodes to life on unbound planets that orbit no star. This makes Type II WOWs attractive sites for the potential development of biologies.

A New Solution to Fermi's Paradox: Ocean Worlds Isolation May Naturally Sequester Intelligent Civilizations: Because ecosystems inside Type II WOWs are, by definition, isolated from their surface environments by thick shells of ice or rocks or both, these potential abodes cannot communicate directly to space using most electromagnetic means. Indeed, it is not even clear that intelligent species living in Type II WOWs know of the external surface of their worlds, and if they do it is unclear why they would explore much less inhabit such an alien (and likely lethal) environment. Even if they do, such civilizations would be at a disadvantage to persist there or to travel off their home worlds into space, compared to residents of Type I (external) WOWs, since they are likely to be constrained by the need to carry copious and therefore heavy water supplies to live in on their world's surface or in space. Taking this logic a step further, it is not even clear that civilizations in Type II WOWs that explore their world's surface would even recognize or take up astronomy to learn that the sky above their world is filled with other worlds across space. And even if they did they might naturally be biased to only consider life and extraterrestrial civilizations as residing inside other far away worlds, thereby obviating most rationales and methods for extraterrestrial communications, particularly with worlds like ours. "Where are they?" The answer may simply be, "At home in their type II WOWs where they either cannot communicate or are simply not aware that other worlds exist or would have communicable civilizations."

References: [1] Hart, M.H., 1975. QJRAS, Vol. 16, p.128-135. [2] Lunine, J.I., 2017. Acta Astronautica, 131, 123-130. [3] Sherwood, R., et al. 2017. Proc. Global Space Exploration Conference 2017. GLEX-17,6.4x36541, Beijing, China. [4] Stern, S.A., 2003. Astrobiology, 3, 317.