Introduction: Detectability of Future Earth

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Changes in the Earth system since the advent of civilization include alterations in continental land use, a rise in atmospheric greenhouse gases, and exponential increases in energy consumption from industrialization and modernization (IPCC 2013). The cumulative contribution of these effects may delay or prevent the onset of the next glacial cycle (Berger & Loutre 2002), while trace elements of manufacturing may betray the beginnings of industrialization in the geologic record (Waters et al. 2014). The permanency of such changes has led some geologists to propose that we are entering a new epoch known as the “Anthropocene,” which is characterized by geological and ecological developments that result from the human influence (Steffen et al. 2007). As human civilization ventures into the Anthropocene, it is becoming evident that our activities are becoming increasingly intertwined with the evolution of the Earth system.

The co-evolution of civilization and the planet will also affect the observable characteristics of Earth from a distance. Astrobiologists today are engaged in the search for spectroscopic “biosignatures” on extrasolar planets that would indicate the presence of surface life, a feat that is becoming increasingly feasible with the next generation of space telescopes (Schwieterman et al. 2018; Fujii et al. 2018). Likewise, astronomers engaged in the search for extraterrestrial intelligence (SETI) are seeking evidence of anomalous radio, optical, infrared, or other electromagnetic signals that originate from extraterrestrial technology (Wright 2017). Such efforts to detect extraterrestrial life, and intelligence, are based upon the remotely detectable features of life on Earth. Although scientists are prepared for a diverse assortment of possible biosignatures and anti-biosignatures (Catling et
the idea that life itself would exert a detectable signature on a planet’s atmosphere is based upon the observation of such phenomenon on Earth. More exotic means of achieving interstellar contact might exist in the distant future or far reaches of the galaxy, but as far as we know today, the search for electromagnetic evidence of life remains our best-available method for attempting to discover extraterrestrial life.

Understanding the evolution of Earth’s detectability across time, and into the future, provides important examples of biosignatures and “technosignatures” (Schneider et al. 2010) that could plausibly exist elsewhere. Such scenarios are also relevant as we think about the ethics of intentionally increasing or decreasing Earth’s overall detectability in order to alter the probability of contact with extraterrestrial intelligence (Vakoch 2011; Musso 2012). As human civilization is the only known example of an energy-intensive civilization, our history and future trajectories provide the basis for thinking about how to find life elsewhere. This special issue features contributions that consider the future evolution of the Earth system from an astrobiological perspective, with the goal of exploring the extent to which anthropogenic influence could be detectable across interstellar distances.

Examining the detectability of future Earth requires that we first consider the likely and possible trajectories for human civilization as we enter the Anthropocene and contemplate becoming a spacefaring civilization. In this special issue, Mullan and Haqq-Misra (2019) examine trajectories of human population growth and energy use to find that our technology may induce direct thermal heating (through the second law of thermodynamics) by the year 2260. Even if population growth stabilizes, these calculations indicate that exponential consumption of energy could eventually lead our civilization to a point where our energy use (fostered by the demand for higher standards of living) would contribute to additional global warming beyond fossil fuel emissions. The urgency of this situation is captured by David Grinspoon in his book *Earth in Human Hands*, which is reviewed in this issue by Riggio (2019) for its challenge to think even more broadly about the scale of change that is underway. Grinspoon’s book suggests that we are entering entirely uncharted territory in which our co-evolution with Earth represents the planet awakening to self-awareness. Finding solutions to some of these major global problems may come with greater recognition of civilization itself as a planetary phenomenon.

The second issue to consider about the detectability of future Earth is whether any other technological civilizations have already navigated through such trajectories. Forecasts are always prone to error and speculation, but observational evidence of extraterrestrial civilizations would provide an external basis of comparison for evaluating our options for the future. Adam Frank discusses the probability of extraterrestrial intelligence existing, as well our chances of finding any, in his book *Light of the Stars*, which is reviewed in this issue by DeMarines (2019). Frank’s book explores the relationship between searching for
technosignatures from energy-intensive civilizations and projecting the possible fate of our own civilization. If it turns out that energy-intensive civilizations are rare, then perhaps this suggests that our own civilization cannot maintain its current trajectory of consumption for much longer. Fundamental limits imposed by thermodynamics and sustainability would restrict the rate of growth of any technological civilization and slow its expansion into other planetary systems. Mullan and Haqq-Misra (2019) likewise emphasize that slower-growth, less energy-intensive civilizations are more likely to be prevalent than any civilization that expands beyond the limits of its carrying capacity. The lack of observations of any such energy-intensive civilizations in the galaxy is a challenge for human civilization to adopt long-term sustainable practices as we enter the Anthropocene.

The ongoing search for extraterrestrial life over about six decades has found no tell-tale signs of any energy-intensive or sustainable-growth civilizations. Such evidence could be forthcoming in coming years, but this state of affairs may also indicate that extraterrestrial intelligence does not exist at all. The argument famously known as “Fermi’s paradox” suggests that an advanced civilization could have rapidly spread across the galaxy, so if they do exist we should have already seen them. The absence of extraterrestrial visitors can be explained in many ways, which DeVito (2019) explores mathematically in this special issue. DeVito (2019) considers an expression for the rate of change of communicative civilizations in the galaxy, constrained by the fact that no such civilizations have yet been observed, and suggests that one explanation to Fermi’s paradox is that the number of civilizations in the galaxy grows very slowly (logarithmically) with time. observationally addressing the Fermi paradox will require continued efforts at SETI as well as the search for technosignatures, which Simons and Haqq-Misra (2019) suggest in this issue would be aided by a lunar observatory. The lack of an atmosphere on the moon makes infrared wavelengths available for observations that would be attenuated in terrestrial observatories by Earth’s atmosphere, while the presence of humans would make such an observatory more continuous and permanent than an orbiting space telescope. Addressing the question posed by Fermi’s paradox—“where are they?”—will help to constrain our expectations for the lifetime of energy-intensive civilizations like our own.

Our civilization’s population and energy growth may exert a detectable influence on our climate, but our use of communicative technology could be more easily limited through legislation, treaty, or other agreement. As SETI surveys continues to seek evidence of intentional transmissions or unintentional radio “leakage” from extraterrestrial civilizations, some critics have suggested that our own transmissions emanating from Earth might constitute an existential risk. In this issue, Haqq-Misra (2019) assesses the possible risk that might accompany intentional transmissions into space and suggests that our decision to become more radio-loud or radio-quiet in the future depends upon our presumption of the benefits
or harms that would accompany extraterrestrial contact. In the absence of any such decision to limit transmissions, our own radio leakage may otherwise be detectable by advanced extraterrestrial astronomers observing in our direction.

Underlying many of these concerns about Earth’s detectability is the longevity of our civilization. Thermodynamic constraints on energy use as well as observational constraints from the Fermi paradox indicate that our longevity depends upon our transition from an energy-intensive to a sustainable civilization. Adopting policies of sustainable development will require unprecedented effort on a global scale over many centuries. As a way of inspiring this perspective, Som (2019) suggests in this issue that efforts in early childhood psychology education could leverage the “overview effect” of Earth as seen from space in order to promote cross-cultural exchange. Our heterogeneous world often fails to recognize the limits of our global commons, but finding a shared identity as Earthlings would be an important step toward working toward a sustainable future and increasing the longevity of our civilization.

Earth’s future detectability depends intimately upon the trajectory of our civilization over the coming centuries. This collection of papers emphasizes the connection between the unfolding future of the Anthropocene with the search for extraterrestrial civilizations. Our rate of energy consumption will characterize the extent to which our energy-intensive society exerts direct influence on climate, which in turn may limit the ultimate lifetime of our civilization. If the answer to Fermi’s question is that we are alone, so that our civilization represents the only form of intelligent life in the galaxy (or even the universe), then our responsibility to survive is even greater. If we do find evidence of another civilization on a distant exoplanet, then at least we will know that our trajectory can be managed. But as long as our searches turn up empty, we must stay vigilant to keep our future secure.

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