Classification of Extraterrestrial Civilizations Based on Their Ability to Modify Motion of Astronomical Objects

Irina K. Romanovskaya
irina.mullins@hccs.edu; irinakromanovskaya@gmail.com

Abstract

Various classifications of extraterrestrial civilizations have been proposed to account for their mastery of matter, energy, and information. I propose to classify extraterrestrial civilizations according to their ability to modify and control motion of astronomical objects. Class 0 civilizations are not capable of modifying motion of cosmic objects. Class 1 civilizations use astronomical engineering to modify motion of minor bodies, such as asteroids and comets, inside planetary systems. *Class 2* civilizations use astronomical engineering to modify motion of planets for the purpose of changing the orbits of such planets inside planetary systems. *Class 3* civilizations use astronomical engineering to eject minor bodies, dwarf planets, and planets from their planetary systems. *Class 4* civilizations use astronomical engineering to modify motion of non-stellar interstellar objects in the Galaxy (e.g., interstellar asteroids, free-floating planets). *Class 5* civilizations use astronomical engineering to modify motion of stars. Among other things, extraterrestrial civilizations can modify motion of astronomical objects to avoid existential threats and to take control of their journey through the Galaxy. This classification can be used to organize and categorize technosignatures that extraterrestrial civilizations produce when they modify motion of astronomical objects and use such astronomical objects for various purposes. Key words: extraterrestrial civilization, astronomical engineering, SETI, free-floating planet, stellar engine

Introduction

Extraterrestrial civilizations can produce technosignatures when they consume energy, manipulate matter, engage in space travel, engage in space colonization, etc. The first classification of extraterrestrial civilizations was based on the amount of energy that extraterrestrial civilizations can access and utilize. In his paper published in 1964 in the Journal of Soviet Astronomy, Kardashev proposed that advanced extraterrestrial civilizations can be of three types: Type I, II, and III (Kardashev, 1964). A Type I civilization can use and control all the energy available on its planet. A Type II civilization can harness the energy radiated by its star. For example, such a civilization can build a Dyson sphere (Dyson, 1960). A Type III civilization can use energy on the scale of its galaxy. Kardashev calculated that the energy consumption of these types of civilization would be separated by a factor of many billions. The practical application of the Kardashev scale is making predictions for technosignatures that civilizations of each type may produce. The Kardashev scale also addresses the ability of extraterrestrial civilizations to engage in interstellar messaging.

Modifications of the Kardashev scale have been proposed over the years. For example, another classification system, which is based on the scope of energy that civilizations can obtain, offers finer divisions between different classes: (1) Class 1 civilizations functions using energy exerted by individual beings or lower life forms, with help from simple tools; (2) Class 2 civilizations use their home planets' natural resources and rely on such constructions as wind sails and water wheels; (3) Class 3 civilizations use energy from fossils and fissionable isotopes; (4) Class 4 civilizations use energy of nuclear fusion, including the energy of their star; (5) Class 5 civilizations use antimatter for energy storage; (6) Class 6 civilizations use energy from spacetime (Tang and Chang, 1991).

Other methods using different criteria for classifying extraterrestrial civilizations were also proposed. For example, Barrow proposed microdimensional mastery approach based on extraterrestrial civilizations' ability to manipulate their environment over increasingly small scales. Barrow's classification is set to progress from Type I-minus to Type Omega-minus, where Type Omega-minus civilization can manipulate the basic structure of space and time (Barrow, 1998). Sagan proposed information mastery approach. In addition to energy usage, this approach classified extraterrestrial civilizations' ability to accumulate and transmit certain amounts of information (Sagan, 1973). Rubin proposed planet mastery approach based on extraterrestrial civilizations' ability to colonize planets and planetary systems and to use their resources. Rubin also adapted the Kardashev scale to refer to the extent of colonization process, from colonization of planets to colonization of a galaxy (Zubrin, 1999).

Recently, a qualitative classification of extraterrestrial civilizations was proposed to be based on the abilities of ETCs to modify their environment and to integrate with it: Class 0 uses the environment as it is, Class 1 modifies the environment to fit its needs, Class 2 modifies itself to fit the environment, and Class 3 ETC is fully integrated with the environment. Combined with the Kardashev scale, this classification forms a 2-dimensional scheme for interpreting the properties of extraterrestrial civilizations (Ivanov *et al*., 2020) According to this classification, the integration of extraterrestrial civilizations with environment makes it impossible to distinguish technosignatures from natural phenomena.

I propose to classify extraterrestrial civilizations according to their ability to modify and control motion of cosmic objects, from asteroids and planets in their home planetary systems to free-floating planets and stars traveling through the Galaxy.

Classification of Extraterrestrial Civilizations According to Their Ability to Modify and Control Motion of Astronomical Objects

Engineering on an astronomical scale can be used as a criterion for classification of extraterrestrial civilizations and technosignatures they can produce. Also known as astronomical engineering or cosmic engineering, it involves operations with whole astronomical objects, such as asteroids, planets, stars, etc. I propose to classify extraterrestrial civilizations according to their mastery of astronomical engineering used to modify and control motion of cosmic objects, from asteroids and planets in planetary systems to free-floating planets and stars traveling through the Galaxy.

Humankind is already considering possibilities of using astronomical engineering to modify motion of minor objects in the Solar System. For example, NASA is researching astronomical engineering strategies that could change motion of selected asteroids in the Solar System. Other examples include theoretical considerations of astronomical engineering methods for modifying the orbit of Earth to make Earth migrate farther away from the Sun and using stellar engines to modify the orbital motion of the Sun around the Galactic center (Shkadov 1987; Shkadov 1988; Shkadov *et al.* 1989; Korycansky *et al.* 2001; McInnes 2002; Misiak 2013; Forgan 2018).

I propose a qualitative classification scheme, which categorizes extraterrestrial civilizations in accordance with their ability to use astronomical engineering in order to modify and control motion of astronomical objects as follows:

Class 0 civilizations

Class 0 includes civilizations not capable of modifying motion of astronomical objects.

Class 1 civilizations

Class 1 includes civilizations using astronomical engineering to modify motion of minor bodies, such as asteroids and comets, within a planetary system. For example, this can be done to avoid collisions of asteroids with planets and other objects of planetary systems. This can be also done to relocate asteroids for the purpose of mining. Humankind can become a Civilization of Class 1, as space agencies are researching development of technologies for modifying motion of selected asteroids in the Solar System.

Astronomical engineering strategies for modifying orbits of asteroids could include: (a) setting nuclear explosion in front of an asteroid; (b) shooting the asteroid by weapons from a selected planet's orbit, (3) attaching a huge solar sail to the asteroid (Misiak M, 2013).

Class 2 civilizations

Class 2 includes civilizations using astronomical engineering to modify motion of planets inside planetary systems for the purpose of changing their orbits. For example, a civilization can modify the motion of its home planet to move it to a larger orbit and away from its star that undergoes the post-main-sequence evolution. Otherwise, this can be done to avoid collisions.

For example, astronomical engineering strategy was proposed to change the location of Earth in its the orbit at a given moment by imparting a moderate velocity impulse to the Moon (Shkadov et al., 1989). Astronomical engineering strategy was proposed to use gravitational assists to transfer orbital energy from Jupiter to Earth to make Earth migrate farther away from the Sun (Korycansky D G, 2001). Astronomical engineering strategy was proposed to use a large reflective sail to produce a propulsive thrust caused by solar radiation pressure to cause a slow acceleration of the center-of-mass of the Earth-sail system (McInnes C R, 2002).

Class 3 civilizations

Class 3 includes civilizations using astronomical engineering to eject minor bodies, dwarf planets, and planets from their planetary systems in order to turn them into interstellar objects and to use them as a means of interstellar travel.

Class 4 civilizations

Class 4 includes civilizations using astronomical engineering to modify motion of non-stellar interstellar objects in the Galaxy (e.g., interstellar asteroids, free-floating planets).

Class 5 civilizations

Class 5 includes civilizations using astronomical engineering to modify motion of stars. Hypothetical stellar engines could be used to control to a certain extent the orbital motion of selected stars in the Galaxy. A few major classes of stellar engines were defined as follows (Badescu and Cathcart, 2000). Class A stellar engines use the impulse from a star's radiation to generate a thrust force. Proposed by Shkadov, a Class A stellar engine, or the Shkadov thruster, is in the form of a mirror placed at some distance from a star and reflecting a fraction of the star's radiation pressure, thus causing a force asymmetry, which exerts a thrust on the star (Shkadov 1987). The Class A stellar engine uses the impulse of the radiation emitted by the star to produce a thrust force that moves the star from its "natural" orbit. A Class B stellar engine harnesses the radiation emitted by a star and converts it into mechanical power (Badescu, 1995). The class B stellar engine is composed of two concentric spherical surfaces, which have different but uniform temperatures, centered on a star. The inner surface is a solar energy collector, and the outer surface is a thermal radiator. The difference in temperature between the surfaces determines a heat flux from the inner to the outer surface, which enters a thermal engine generating power. A Class C stellar engine combines elements of both Class A and Class B

stellar engines (Badescu and Cathcart, 2000). By using the impulse and the energy of a star's radiation, it provides a thrust force and mechanical power. A Class D stellar engine extracts mass from a star and expels the matter, thus generating a rocket effect to propel the star (Criswell 1985; Badescu & Cathcart 2006b). Class D stellar engines are also called "stellar rockets" (Fogg, 1989).

A study predicted that stars' speeds up to ~0.1 c might may be attained when using stellar engines, whereas natural astrophysical phenomena in the Galaxy may rarely produce such speeds (Lingam and Loeb, 2020). Stellar engines can be used by extraterrestrial civilizations to avoid a dangerous close approach to another star, dust cloud, or supernova (Shkadov 1987; Shkadov 1988; Badescu and Cathcart 2006a; Badescu and Cathcart 2006b; Forgan 2018; Caplan 2019; Lingam and Loeb, 2020).

Because of the amount of time required for a civilization to survive while technologically advancing to Class 5, the number of civilizations of Class 5 should be small as compared to the number of civilizations of other classes. The practicality of using this classification of civilizations is that it allows to organize and compare potential technosignatures of extraterrestrial astronomical engineering used to modify and control motion of cosmic objects.

A word of caution is needed as follows. If technosignatures are determined to be produced by a civilization changing the motion of astronomical objects in a planetary system, ejecting astronomical objects from the planetary system, or changing the motion of astronomical objects in the Galaxy, then it would most likely be impossible to determine whether the civilization is making changes to its home planetary system or to the planetary system that the civilization colonizes.

Conclusions

A classification of cosmic civilizations was proposed by Kardashev (Kardashev, 1964). On Kardashev scale, a technological civilization can be of Type I, II or III, if it can control the energy resources of a planet, star, or galaxy, respectively. Alternative classifications of civilizations have been proposed to account for their mastery of matter, energy, and information. I propose a classification of civilizations based on their ability to modify and control motion of astronomical objects for various purposes, from mining asteroids and avoiding existential threats to taking control of their space travel through the Galaxy:

Class 0 includes civilizations that are not capable of modifying motion of astronomical objects.

Class 1 includes civilizations capable of using astronomical engineering to modify motion of minor bodies, such as comets and asteroids, within their planetary systems.

Class 2 includes civilizations capable of using astronomical engineering to modify motion of planets inside planetary systems for the purpose of changing their orbits.

Class 3 includes civilizations capable of using astronomical engineering to eject minor bodies, dwarf planets, and planets from their planetary systems.

Class 4 includes civilizations capable of using astronomical engineering to modify motion of non-stellar interstellar objects in the Galaxy (e.g., interstellar asteroids, free-floating planets).

Class 5 includes civilizations capable of using astronomical engineering to modify motion of stars.

This classification can be used to organize and compare technosignatures produced by extraterrestrial civilizations, which are modifying motion of astronomical objects.

About the Author

The author's legal name is Irina Mullins. Irina Mullins writes under her maiden name, Irina K. Romanovskaya. Correspondence should be addressed to irinakromanovskaya@gmail.com or irina.mullins@hccs.edu

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