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Interstellar Colonization and the Zoo Hypothesis

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Michael Hart (1975) and others have pointed out that current estimates of the number of technological civilizations arisen in the Galaxy since its formation (perhaps 2.5×10^9 [Freeman and Lampton 1975]) is in fundamental conflict with the expectation that such a civilization could colonize and utilize the entire Galaxy in 10-20 million years (Jones 1976, 1978). This dilemma can be called Hart's Paradox.

The first element of the Paradox notes that very few stars have metallicities below $Z=0.01$ so that we can be fairly confident that most stars formed in the 10^{10} year history of the Galaxy have the necessary materials to form planets. If the formation of the Solar system is a normal occurrence for a Solar type star as indicated by the abrupt change in rotational characteristics of main sequence stars at type FaV and if life is a frequent consequence of planetary system formation, then technological civilization have been a frequent occurrence throughout the life of the Galaxy. If there have been other technological civilizations than ours, virtually all arose much longer than 10-20 million years ago.

The second element of the Paradox notes that a ship capable of 0.1c cruise speed requires a fuel-to-payload mass ratio of only 7 for a one-way journey (Hart 1975). No great technological or theoretical breakthrough is required. One need not invoke relativistic speeds or hydrogen ram jets. A modified O'Neill colony (O'Neill 1974) could transport interstellar colonists for a voyage of 100-200 years in relative comfort. A technological civilization possessing such ships could fill the Galaxy in the 10-20 million years mentioned above.

The resolution of Hart's Paradox requires that one or more of the following statements is true:

1) We are the Galaxy's first technological civilization
2) Interstellar travel is immensely impractical or simply impossible
3) Technological civilizations are very short-lived
4) We inhabit a Wilderness Preserve

The last statement is the Zoo Hypothesis, first introduced into the scientific literature by Ball (1973). Variations of the Zoo Hypothesis can be found in science fiction of the 1940's and earlier.

Colonization calculations (Jones 1976, 1978) place quantitative

limits on the applicability of the Zoo Hypothesis. If, in fact, technological, colonizing civilizations arose early in the history of the Galaxy, then the Solar Wilderness Preserve has existed for most of the Sun's 4.5×10^9 billion year life. The typical orbital period around the galactic center of stars in the Solar neighborhood is roughly 2.5×10^8 years. The Sun's orbit is elliptical and the orbital period in roughly 2.9×10^8 years. As a consequence, each typical older stars at the Sun's distance from the Galactic center has been near the Sun 2-1/2 times! This result suggests that maintenance of the Solar Wilderness Preserve for 4.5×10^9 years is very unlikely.

We can quantify the argument in the following way: let us define a "poaching" civilization as a technological civilization which would utilize the Solar system for its own purposes if given the opportunity. Let us define L as the colonizing radius. That is, a colonizing society expands a distance L from its homeworld and then quits. Let R be the creation rate of technological civilizations. A current estimate is 2×10^{-11} pc^{-2} yr^{-1}. Finally, let f be the fraction of colonizing civilizations which are potential poachers.

The probability that the Solar Preserve has survived for 4.5×10^9 years is

$$P = \exp\left(-4.5 \times 10^9 \pi L^2 R f\right) \quad . \qquad (1)$$

The Zoo Hypothesis requires $P \simeq 1$ or

$$L^2 R f << 7 \times 10^{-11} \qquad (2)$$

Figure 1 is a graphical representation of the equation

$$L^2 R f = 7 \times 10^{-11} \qquad (3)$$

Clearly, if the creation rate of technological civilization is anywhere near 2×10^{-11} and L is as much as 10 persecs, then the poaching fraction must be small. I personally expect L is of the order of the galactic radius ($L = 10^4$ pc) and that either f or R must be very small. Human experience suggests that f is not as small as 10^{-3}. I favor the explanation that R 10^{-15} and that we may be the Galaxy's first Technological Society.

All is speculation.

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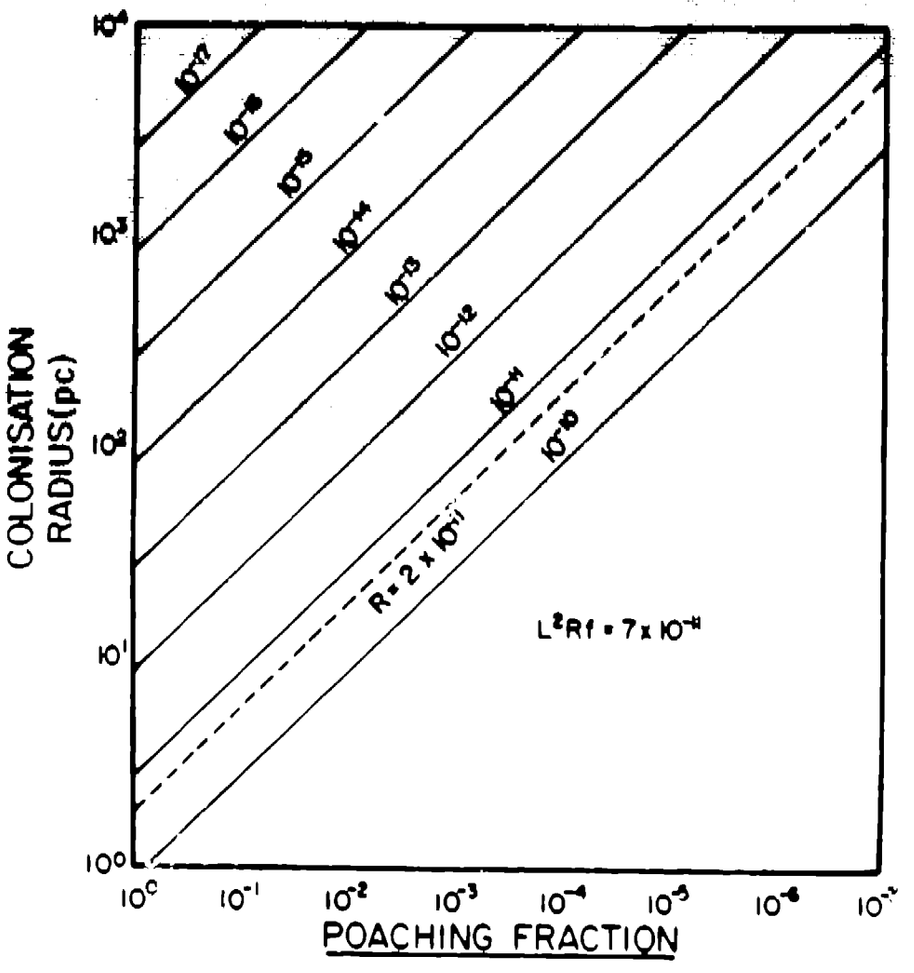

Relation of Poaching fraction (f), colonization radius (L) and creation rate of technological civilizations (R) for a 0.37 probability that the Solar Preserve has not been poached.

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