Estimation of the fraction of life-bearing planets that evolve intelligence f_i in the Drake equation by the terrestrial extinction history

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The Drake equation is a simple algebraic expression for quantifying the number of communicative civilizations in our Galaxy. Although some factors in the Drake equation can be reliably estimated by recent astronomical observations, remaining other factors are largely or entirely based on conjecture. One of such conjectural factors in the Drake equation is f_i, which is the fraction of planets with life on which an intelligent civilization emerges. The previous estimates of f_i range from pessimistic (f_i ~0) to optimistic (f_i ~1).
In this presentation, a new approach to estimate f_i is introduced based on the terrestrial extinction history, which is our only available data. Since its birth, life on the Earth has gone through any magnitudes of extinction due to various external factors such as the changes in the environment or the impacts of meteorites. In this study, f_i was calculated as a probability that we have continued to "win the lottery of extinction" since the birth of life, assuming that the intensity of extinction is determined by a probability density function, and also assuming that complex life essentially always becomes intelligent if it does not become extinct first like the terrestrial evolution history. The probability density function of extinction was deduced from the histogram of extinctions in the Phanerozoic eon of the Earth, covering from 540 Myr ago to present with 3 Myr resolution (Rohde & Muller 2005).
The histogram of the extinction intensity in the Phanerozoic eon was fitted by a log-normal function very well (reduced chi-squared of the fitting is ~1). The choice of the log-normal distribution function is supported by the statistical principle that a random multiplicative process converges to a log-normal distribution owing to the Central Limit Theorem. Because the terrestrial extinctions were basically caused by random events such as volcanic activities of the Earth or asteroid impacts, it can be justified that the terrestrial extinction intensity is expressed by the log-normal probability distribution as a result of the random multiplicative process. Assuming that the fitted log-normal function is a probability density function of the extinction intensity of terrestrial life, the survival probability for a unit time (3 Myr), p, is calculated as $p = 0.9985^{+0.0012}_{-0.0058}$. The factor f_i in the Drake equation can be expressed as $f_i = p^{T/\Delta T}$, where T is the evolution time of intelligent life and ΔT is the time resolution of the probability distribution function (ΔT = 3 Myr in this case). Recent geological evidences suggest that the first life on the Earth occurred 3.7-4.1 Gyr ago. Assuming that the obtained probability distribution function of extinction can be extended to this era, the evolution factor f_i can be calculated as $f_i = 0.13^{+0.52}_{-0.13}$ (99% confidence level) for 4.1 Gyr. This is the first data-based estimation of f_i. Because f_i is the two-parameter function of p and T, this method can be extended to the other life-bearing exoplanets by estimating these two parameters in some way, although this estimation is still based on the one-sample statistic of the Earth.

Keywords: Drake equation, SETI, mass extinction

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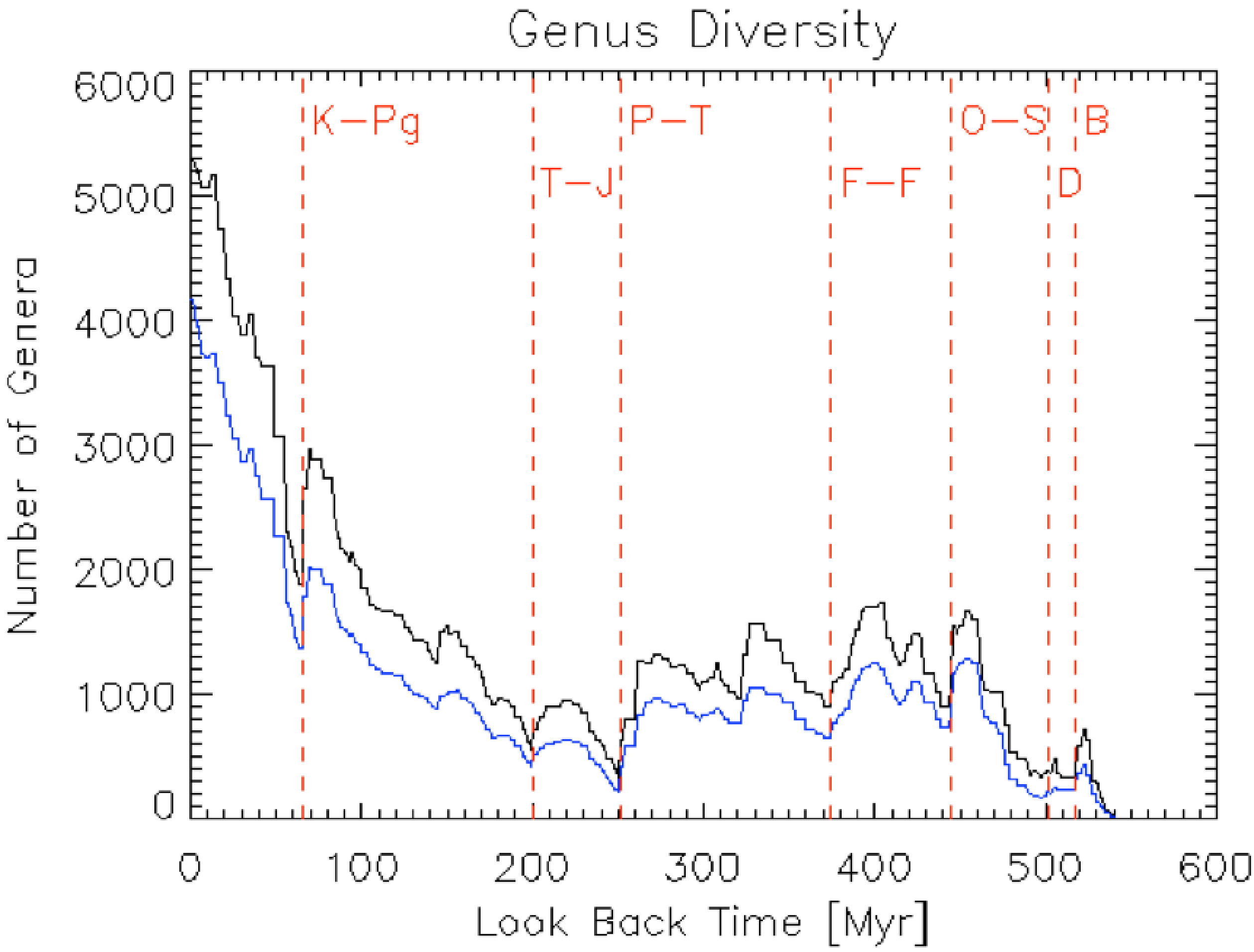

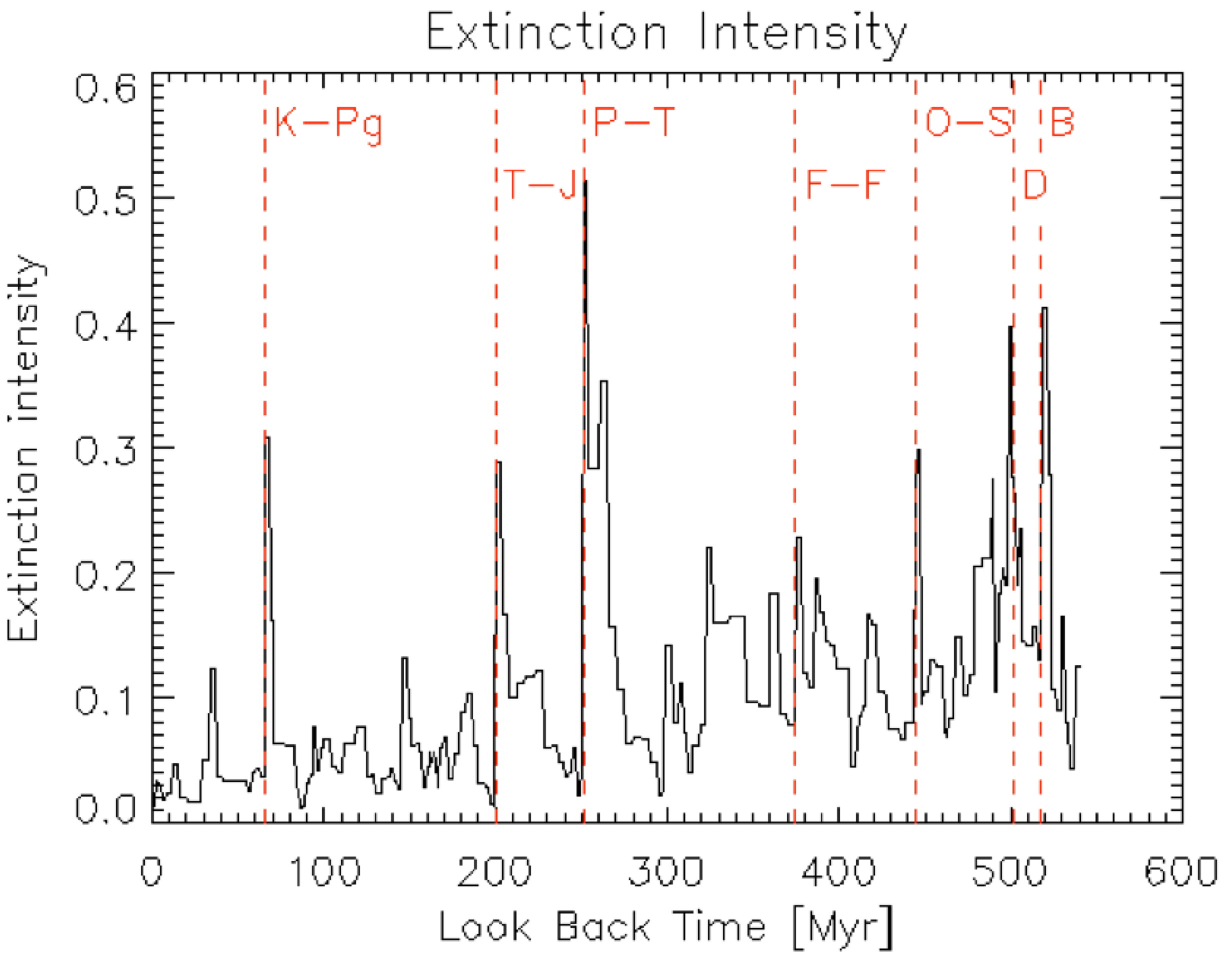

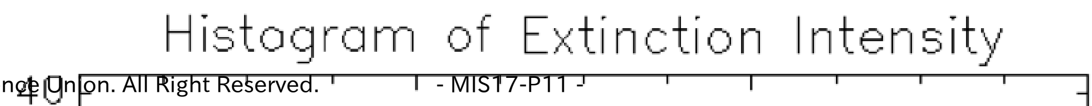

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