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Galactic civilizations: Population dynamics and interstellar diffusion

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Abstract

The interstellar diffusion of galactic civilizations is reexamined by potential theory; both numerical and analytical solutions are derived for the nonlinear partial differential and difference equations which specify a range of relevant models, drawn from blast wave physics, soil science, and, especially, population biology. An essential feature of these models is that, for all civilizations, population growth must be limited by the carrying capacity of the planetary environments. Dispersal is fundamentally a diffusion process; a directed density-dependent diffusivity describes interstellar emigration. We concentrate on two models, the first describing zero population growth (ZPG) and the second which also includes local growth and saturation of a planetary population, and for which we find an asymptotic travelling wave solution. For both models the colonization wavefront expands slowly and uniformly, but only the frontier worlds are sources of further expansion. For nonlinear diffusion with growth and saturation, the colonization

wavefront from the nearest independently arisen galactic civilization can have reached the Earth only if its lifetime exceeds $2.6 \tilde{\text{A}} - 10^6$ years. If discretization can be neglected, the critical lifetime is $2.0 \tilde{\text{A}} - 10^7$ years. For ZPG the corresponding number is $1.3 \tilde{\text{A}} - 10^{10}$ years. These numerical results depend on our choices for the specific emigration rate, the distribution of colonizable worlds, and, in the second model, the population growth rate; but the dependence on these parameters is entrancingly weak. We conclude that the Earth is uncolonized not because interstellar spacefaring societies are rare, but because there are too many worlds to be colonized in the plausible lifetime of the colonization phase of nearby galactic civilizations. This phase is, we contend, eventually outgrown. We also conclude that, except possibly early in the history of the Galaxy, there are no very old galactic civilizations with a consistent policy of conquest of inhabited worlds; there is no Galactic Empire. There may, however, be abundant groups of $\hat{a}^{1/4} 10^5$ to 10^6 worlds linked by a common colonial heritage. The radar and television announcement of an emerging technical society on Earth may induce a rapid response by nearby civilizations, thus newly motivated to reach our system directly rather than by diffusion.



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