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The Dynamics of the Transition from Kardashev Type II to Type III Galaxies Favor Technosignature Searches in the Central Regions of Galaxies

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Abstract

We present a video of a simulation showing the expansion front of a technological species settling a Milky Way-like galaxy, created using the model described in Carroll-Nellenback et al. It illustrates how even very conservative rates of settlement ship launches and ship ranges can quickly lead to a galaxy endemic with technology, and how the rotational and peculiar motions of stars contributes to the expansion. This video confirms and validates previous work showing that the centers of galaxies are promising search directions for SETI.

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If technological life in the universe spreads among the stars, then there may be many more locations of technology than sites of abiogenesis, and SETI may be more likely to succeed than other forms of astrobiology. In particular, if such spreading is common, then one might expect life to spread throughout a galaxy much the way it has spread across the Earth, and be quite ubiquitous. Indeed, this is a common starting point for discussions of the Fermi Paradox (see Carroll-Nellenback et al. 2019, and references therein for an extensive discussion).

In a generalization of the work of Kardashev (1964), Zubrin (2000) and Wright et al. (2014a) referred to "Type II" species as those that have extended their technology to a significant fraction of the space around their host star, and "Type III" species as those that have spread throughout their galaxy. Many authors, such as Newman & Sagan (1981), argued that the transition to Type III could be slow enough that we might expect it to be currently underway in the Milky Way, and Carrigan (2012) and others recommended searching for localized regions within other galaxies that might represent a partial settlement of a galaxy undergoing such a transition. Wright et al. (2014b) and others, however argued the process would be quite fast, and that arguments that it might proceed slowly often ignored the motions of the stars, which would "mix" things and prevent growth-inhibiting phenomena such as slow-growing settlements blocking the expansion of fast-growing ones.

Zackrisson et al. (2015) modeled the effects of realistic stellar motions to explore what such a transition would look like given settlement ships with velocities not much larger than the peculiar velocities of the stars themselves, and found that, in agreement with Wright et al. (2014b), galactic shear would work to "mix" regions of settlement into complex shapes.

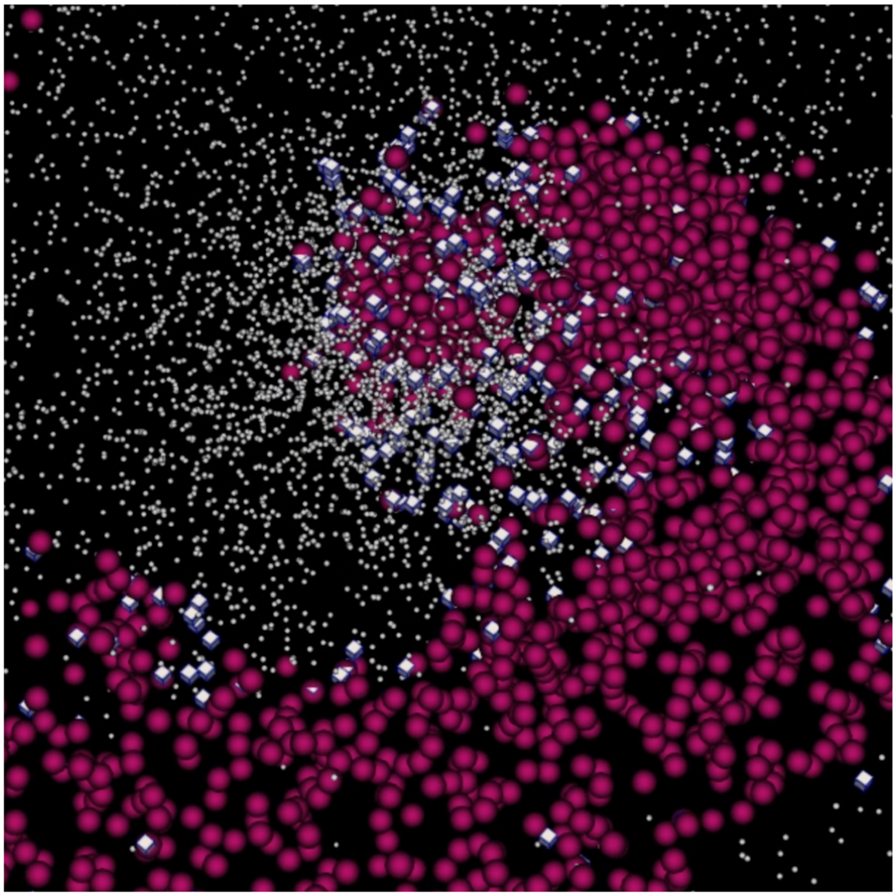

Figure 1. A snapshot of the animation showing the settlement of the galaxy. White points are unsettled stars, magenta spheres are settled stars, and white cubes represent a settlement ship in transit. The spiral structure is due to galactic shear as the settlement wave expands. The full, low-resolution video is available in the HTML version of this research note, and a high resolution version can be found archived at ScholarSphere (see footnote 7).

(An animation of this figure is available.)

In this research note, we present a snapshot and video [7] of a new simulation of the transition using the model we developed in Carroll-Nellenback et al. (2019). That work explored how settlement front expansion depended on parameters like ship range and settlement lifetime.

Our new simulation illustrates both the speed of the transition and its morphological character in a case where stellar motions play a significant role. This simulation make different assumptions from Zackrisson et al. (2015): in particular we start with a single settled star system near the Solar Circle, and do not "turn off" settlement after 50% of the stars have been settled.

Here, we have chosen ship parameters at the very conservative end of the range that allows for a transition to Type III: ships from the home system and all settlements are launched no more frequently than every 0.1 Myr, technology persists in a settled system for 100 Myr before dying out, and the ship range is ~3 pc (scaled up in a manner that preserves the qualitative and quantitative behavior of settlement given the small number of stars, chosen to keep the computation time manageable). This represents settlement ship speeds of order 10 km s^{-1} (i.e., similar to our own interstellar probes and consistent with acceleration via gravitational slingshots from giant planets) and journey times of up to 0.3 Myr, but the dynamics are set by the ship range and so are unchanged with faster ships. The simulation spans 1 Gyr. We refer the reader to Carroll-Nellenback et al. (2019) for more details of the model.

Interestingly, it shows how rapidly expansion occurs once the settlement front reaches the galactic bulge and center. The speed of the settlement front depends strongly on the ratio of the maximum ship range to the average stellar separation. Here, we deliberately set this ratio to near unity at the stellar density of the first settlement, so the time constant on the settlement growth starts out small but positive. Eventually, the inward-moving part of the front encounters exponentially increasing stellar densities and accelerates, while the outward-moving part stalls in the rarer parts of the galaxy. Note that at around 0:33 a halo star becomes settled, and at 0:35 it settles a disk star near the top of the movie and far from the other settlements. This creates a second settlement front that merges with the first around 0:42.

Prior work has been conflicted on whether the Galactic Center is a good or poor place to look for life, based on is hospitality or hostility for abiogenesis and sustaining habitable conditions (see Gajjar et al. 2021, and references therein).

This video dramatically confirms the conclusion of Gajjar et al. (2021) that interstellar migration is very "easy" in the central regions of galaxies because they are very dense, and so if such migration occurs and if technological life is resilient against the conditions in galactic bulges, it may be in these places that SETI work will be most fruitful (a conclusion also reached by Di Stefano & Ray 2016, with respect to globular clusters).

This reason to search galactic central reasons is complementary to previous work suggesting a focus on the Galactic center for a variety of other reasons, including interest in the central supermassive black hole (e.g., Vallee & Simard-Normandin 1985; Vidal 2011; Maccone 2012), overall stellar density (e.g., Sullivan & Mighell 1984), and Schelling point considerations (e.g., Lederberg 1973; Frisch & Melia 1983).

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Footnotes

7 https://doi.org/10.26207/q4cd-8b39