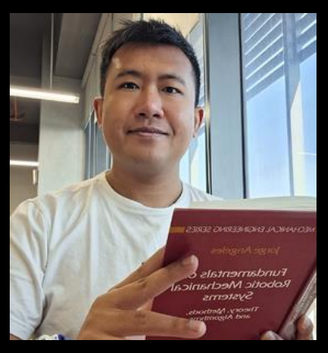


Do Astrophysical Hazards Solve the Fermi Paradox?

Deriyan Senjaya[1*], Tomo Goto[1,3], Tetsuya Hashimoto[2], Shotaro Yamasaki[2], Tomoki Wada[2], Seong-Jin Kim[3], Amos Y.-A.Chen[1], Yuri Uno[2], Sridhar Gajendran[3], and Terry Long Phan[3]

[1] Department of Physics, National Tsing Hua University, Hsinchu City, Taiwan
[2] Department of Physics, National Chung Hsing, Taichung City, Taiwan
[3] Institute of Astronomy, National Tsing Hua University, Taiwan
* Email : d_senjaya@gapp.nthu.edu.tw

Why can't we see Alien Civilizations?

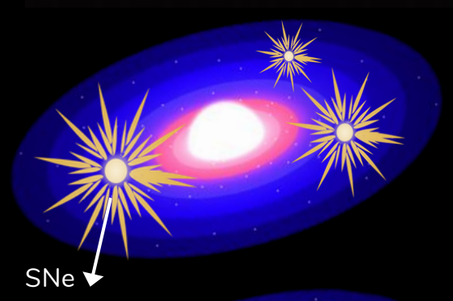
- The Fermi Paradox questions why we don't see aliens.
- Intelligent life may be too far for detection in the vast universe.
- However, simulation in [1] shows the alien could rapidly colonize a Milky Way (MW) galaxy ⟶ Rotation of stars help two stars closer ⟶ alien easy to migrate

Do Astrophysical Hazards Kill Aliens?

Astrophysical events such as asteroid impacts, supernova (SNe) explosions, and giant molecular clouds (GMC) may threaten alien life.

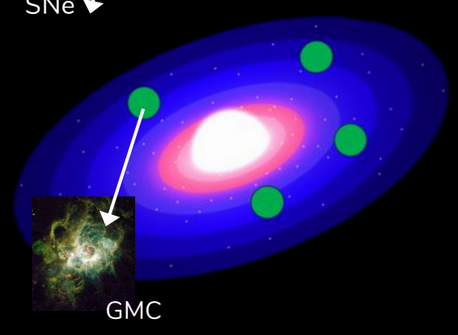
Asteroids Impact

- Asteroid impacts can obliterate biosphere
- Transfering huge momentum and energy
- Characteristic Timescale = 316.22 Myr [2] ⟶Capable of driving mass extinction
- Modelled using probabilistic occurence



Supernovae (SNe) Explosion

- SNe release high-energy radiation
- Aliens within the blast radius (0.05 kpc [3]) of the SNe would be killed by the radiation
- SNe events are 0.023 SNe/yr [3]



Giant Molecular Clouds (GMCs)

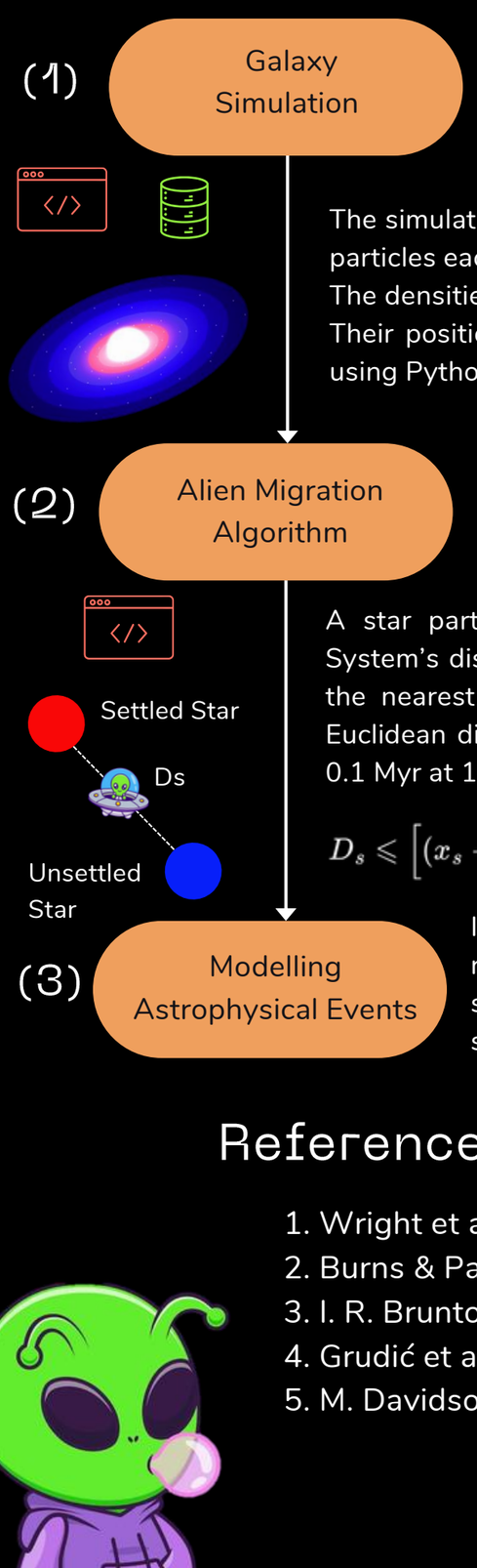
- GMCs are dense gas cloud with the typical radius of 0.1 kpc [4]
- GMC blocks heat from the host star at the alien habitat ⟶ environment temperature will be down ⟶ alien will die

Simulations are used to assess how these astrophysical hazards impact alien life

Let's simulate!

How to Simulate?

To simulate how the astrophysical hazards like asteroids impact, SNe, and GMCs, one can refer to this following flowchart



$$D_s \leqslant \left[(x_s - x_u)^2 + (y_s - y_u)^2 + (z_s - z_u)^2\right]^{0.5} \quad (1)$$

Result and Discussion

In Fig.1(a), without any astrophysical events, alien migrate spirally toward the galactic center due to star particles rotation. In Fig.1(b), some aliens vanish because of the astrophysical hazards presence, slightly diffusing the spiral pattern.

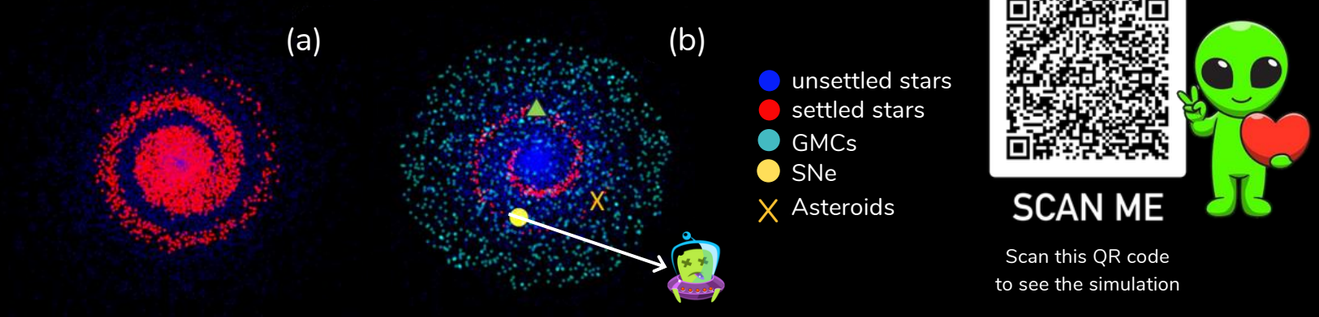


Fig.1. The alien Colonization to the galaxy. (a) without any astrophysical hazards and (b) with three astrophysical hazards (Asteroids, SNe, and GMCs)

Fig.2(b) shows three astrophysical hazards hinder alien to colonize the MW galaxy within 700 Myr

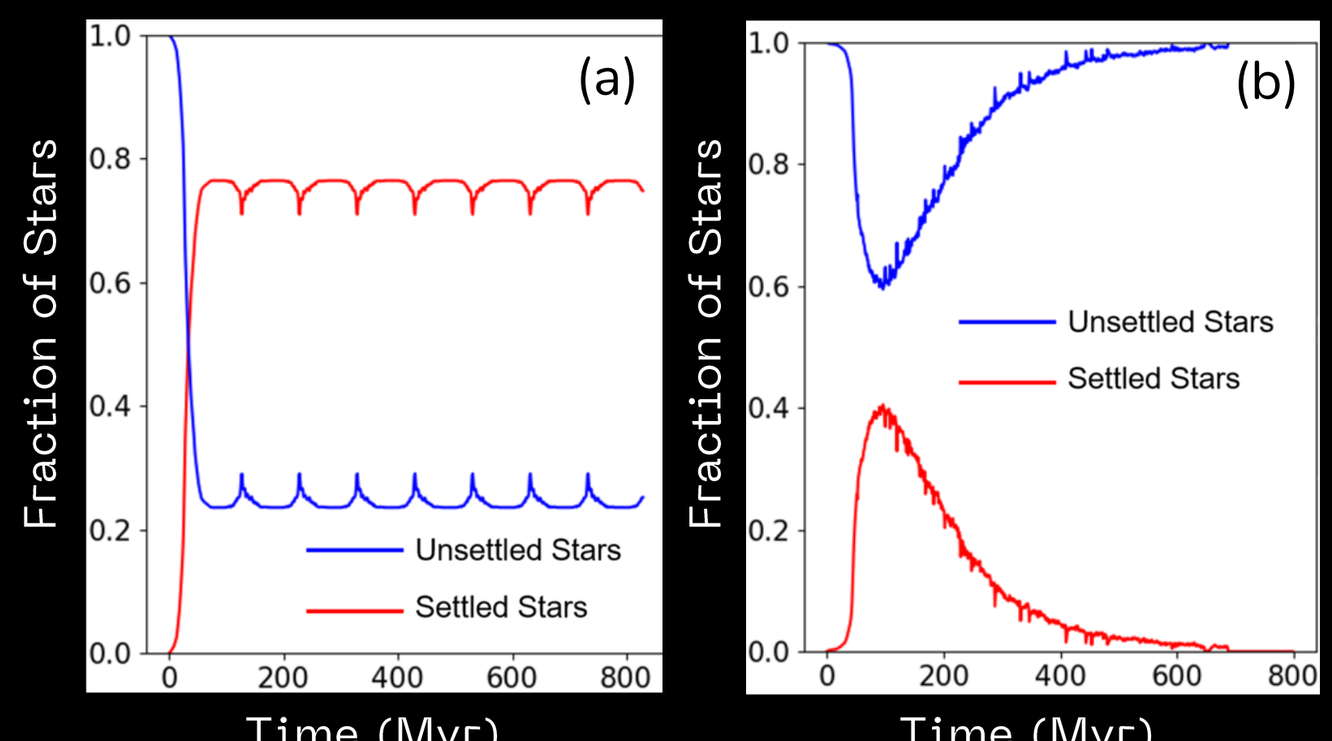


Fig.2.The plot for quantifying the simulation results. (a)-(b) Fraction of Stars versus time in Myr for without and with astrophysical hazards

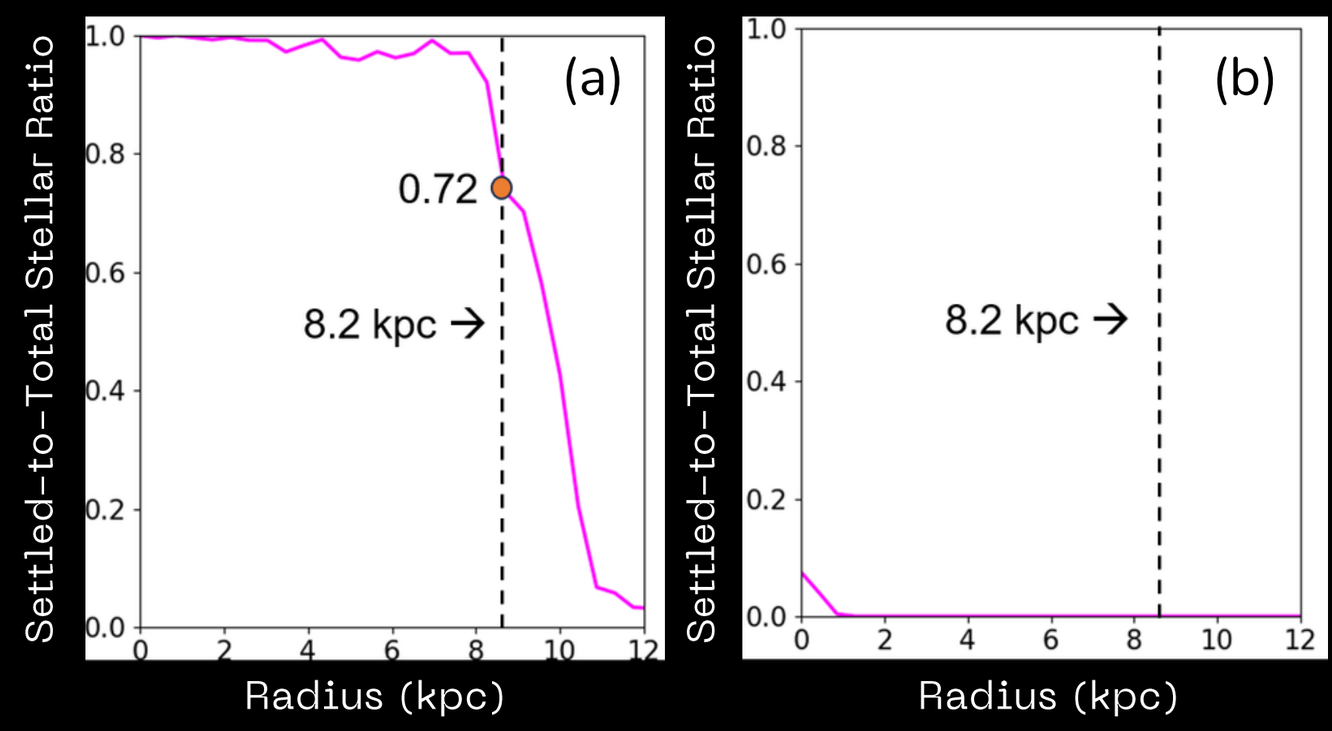


Fig.3. Number of Star versus Radius when the alien starts from (a) 3 kpc, (b) 8 kpc, and (c) 12 kpc from the center.

Fig.3 show the settled-to-total stellar ratio (STSR) versus the radius from the MW's center. (a)-(b) without and with three hazards. It is shown that the STSR at 8.2 kpc (Earth location) is dropping from 0.72 (72%) to Zero ⟶ The astrophysical hazards may be the answer of Fermi paradox.

Implication to SETI Research

Scientists should considering to continue the SETI research or not. The astrophysical hazards may kill all alien civilizations beyond 700 Myr and it is proven by the STSR value becoming zero.

Conclusions & Future Works

- **Asteroids, GMCs, and SNe can stop Aliens**
- **Alien at Earth's location is zero if the combination of the hazards included ⟶ Fermi Paradox Solution**
- **For the future work, the investigation of Galaxy Merger to be a possible astrophysical based Fermi paradox solution**

References

1. Wright et al., (2021), **Res Notes AAS5** 141
2. Burns & Parsons, (2022), **Int. J. Astrobiol** 21:6, 441–461
3. I. R. Brunton et al., (2023), ApJ 947 42
4. Grudić et al., (2019), MNRAS 488 (2).
5. M. Davidson, (1947), Nature 159, 387