THE COSMIC HISTORY OF GALACTIC HABITABILITY

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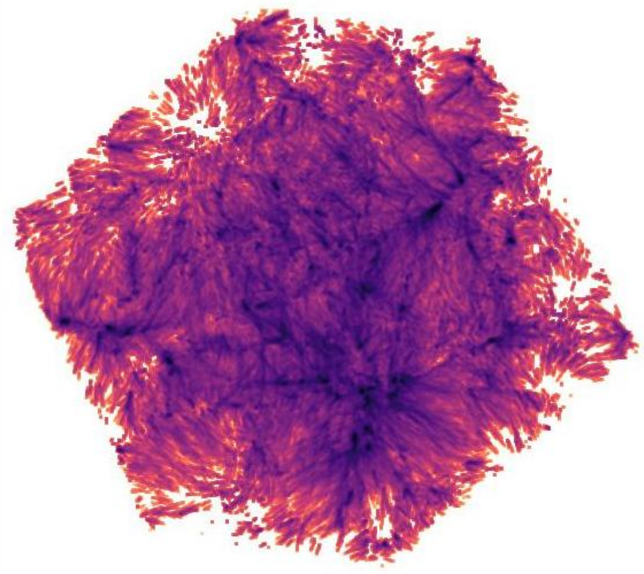
LIFE IN THE UNIVERSE

Life has yet to be detected anywhere beyond Earth. Our own experience on Earth provides us with only limited insight into what qualifies as a suitable environment for developing complex life. Here we examine how conditions change within galaxies over a 14 billion year history of the universe, and the way this may determine the inception and longevity of habitable epochs that could play host to advanced civilizations.



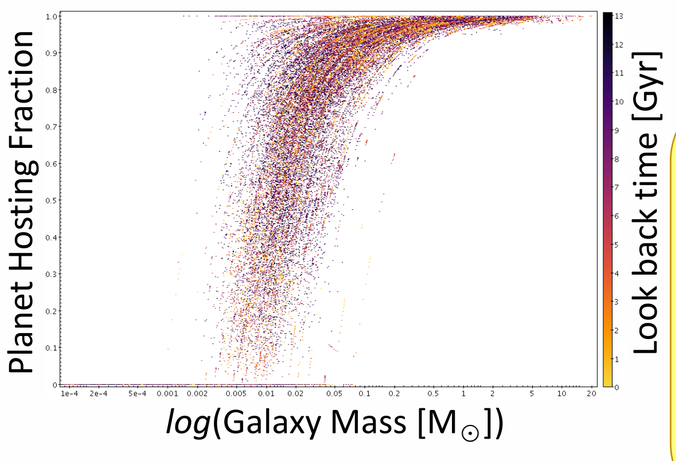
The simulation data volume plotted in 3D

COSMIC SCALE HABITABILITY

On a cosmological scale, we do not consider individual star systems and how each one will evolve. Instead volume averaged rates are statistically applied to large numbers of galaxies, to see what patterns emerge. Our first step was to determine the important events, processes, and values that will affect the life-hosting ability of a galaxy.

Our key requirements for life are that it has a suitable environment to develop in, and that it is not catastrophically affected by radiation. Thus, we focused on the following:

- **Metallicity** – Planet-like objects will be required to host life.
- **Star Death** – Large stars undergo energetic explosions such as supernovae and gamma ray bursts.
- **Active Galactic Nuclei** – Massive black holes can wipe out the inner region of a galaxy.
- **Galactic Mergers** – Collisions of galaxies can wipe out potential life across entire galaxies.



Planet hosting fractions of all galaxies

COMPUTATIONAL REQUIREMENTS

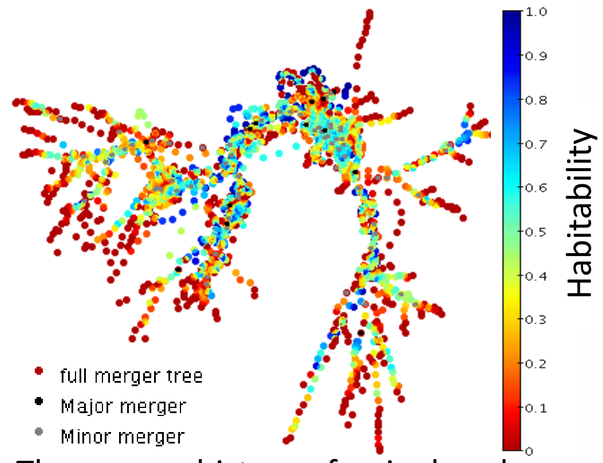
For each time frame in a 60Mpc simulation cube, we calculated the effect of the above factors on habitability for each individual galaxy. These were calculated from data outputted by the Millennium simulation[2] and from BPASS[3].

Phenomena such as stellar explosions and active galactic nuclei outbursts affect a well defined region of space, and so their effects are accumulated in each time bin. Tracking metallicity and galactic mergers must be done by referring to the same galaxies in different time frames, so a different computational approach is required.

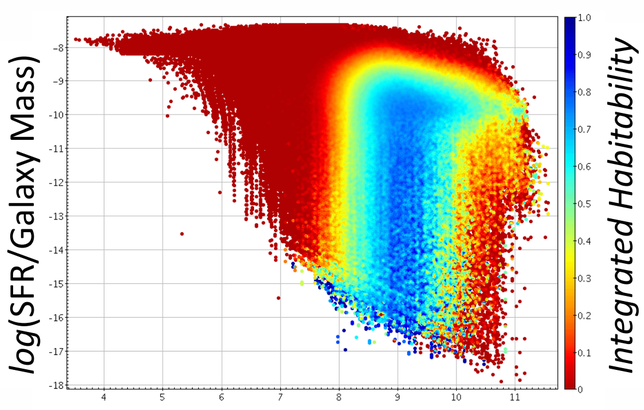
GALAXY HISTORIES

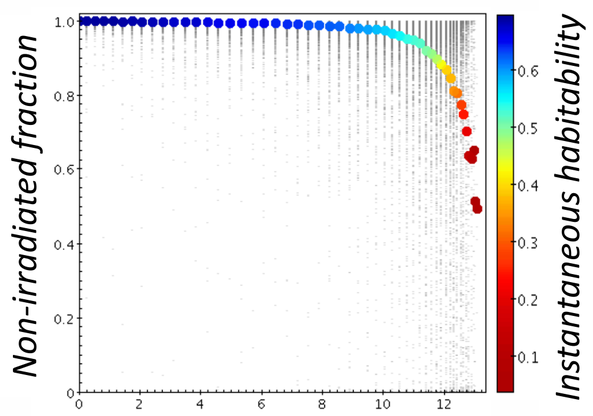
We tracked galaxy merger trees through cosmic time and integrated over the habitable portion. This let us examine when habitable epochs emerge in the history of each galaxy, and to determine the dominant inhibitors of life for a wide range of galaxies.

As a result of the comprehensive data outputted by *Millennium*, we now have information on how habitability correlates with a huge number of key galaxy variables, and how these correlations vary over the duration of the universe.



The merger history of a single galaxy





Star formation rate against galaxy mass (left) and irradiated fraction against time (right) coloured by different measures of habitability

FURTHER WORK

At time of writing, our program and datasets are being packaged for review by our project supervisors. We hope to be able to continue developing and refining this program, and to incorporate more phenomena that are likely to affect habitability.

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[2]Millennium data available at http://gavo.mpa-garching.mpg.de/Millennium/

[3]BPASS available at www2.warwick.ac.uk/fac/sci/physics/research/astro/research/catalogues/bpass