GLOBAL FUTURE RESEARCH

GFR LUMINES

Short, illuminating answers to life's biggest questions

Red Giant Planet Killer

Based on Insight 1: The Ultimate Fate of Planet Earth

People are always fascinated about how the future of our planet will play out, what that means for human societies, and if, and when, we will need to leave the planet to survive. In Insight 1 we look into these questions - and beyond - to the 'Ultimate Fate of Planet Earth'. What we find is that much depends on our Sun.

It's all about our Sun

Like all stars, our Sun goes through a life cycle: from birth, to a long, mature 10 billion-year main sequence phase, and eventually towards an end. The Earth and our Sun formed at the same time 4.6 billion years ago, and the Sun is now firmly in its longest and most stable phase, burning huge stockpiles of hydrogen into helium in its core, powering life as we know it. Our Sun though is evolving as it uses up its nuclear fuel. The continuous fusion of hydrogen into helium means that the Sun's core becomes denser and hotter, accelerating nuclear fusion and solar energy output. Over its 4.6 billion-year lifetime, the Sun has become 30-40% more luminous, and its rate of energy output will continue to increase around 10% every billion years, making life on Earth increasingly uncomfortable.

Becoming a Red Giant

In about 5 billion years the hydrogen fuel in the Sun's core will finally be exhausted, leaving only helium. As fusion ceases, the core contracts under gravity and heats up until hydrogen fusion ignites in a thin shell around the core. This new source of energy expands the Sun's size, leading to a cooling of its outer layers, as the heat generated in the core is spread over a much larger area. This cooling will turn the Sun reddish as it enters its Red Giant phase.

During its relatively brief helium-burning phase, our Red Giant Sun will become so large and distended that its gravitational hold on its outer layers is weakened. Combined with intense outward radiation pressure, the outer layers of the Red Giant will propel into space, forming a planetary nebula – a historical name from when little was known about these objects.

While our Red Giant Sun loses its outer layers, in its core it fuses helium entirely into carbon and oxygen, but with insufficient heat to initiate carbon burning. The extremely dense, electron degenerate, remnant core, becomes a carbon-oxygen hot white dwarf star of size comparable to the Earth today. The white dwarf Sun will slowly radiate its energy away, fading eventually into an invisible black dwarf.

Life on Earth ends while the Sun shrinks

As our Sun approaches and enters its Red Giant phase, the Earth will be subjected to heat so intense that oceans will boil, the atmosphere will be stripped away by extreme solar winds, the planet's crust will be melted, and all remaining life destroyed.

At its peak, our Red Giant Sun will be 250 times bigger than now, but will also have lost a third or more of its mass to space. Losing mass will reduce its gravitational pull on the planets, causing them to move outwards from the Sun. Scientists expect our Red Giant Sun to easily expand pass the orbits of Mercury and Venus, eventually reaching Mars' current orbit. By then, though, Mars will have moved further away, escaping absorption by the Sun. For Earth, however, it's a close call...

Will Earth escape its Red Giant Sun or not?

Researchers back into 2008 undertook elaborate modelling that indicated Earth will not escape the Sun's expansion, even though the Earth could expand to an orbit 50% more distant than where it is today as the Sun loses mass from its surface.

According to their modelling, the expanding Red Giant Sun will engulf the Earth before it reaches the end of its Red Giant phase, with Earth needing to be 15% further from the Sun than its current orbit to avoid this fate.

New support for this finding comes from recent observations of nearly half a million Red Giant stars that show exoplanets are much less likely to be found the older the Red Giant becomes, supporting the idea that Red Giant stars consume their closest planets.

As our Red Giant Sun expands to fill the space within Earth's orbit, a combination of Earth-Sun tidal interactions, along with frictional drag from immersion in the Sun's chromosphere, will cause the Earth to spiral into the Sun. The intense heat will melt, then vaporise, the Earth's surface, gradually removing the Earth's crust and mantle, until only the iron core remains. As Earth spirals in further, its core will also melt down and vaporise, with Earth vanishing in as little as 200 years.

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Einstein's final answer

If Earth. by some fortuitous happenstance, survives into the very deep future, Einstein will have the final say. Earth's orbit loses energy and momentum by radiating gravitational waves. The effect is small with Earth radiating about 200 watts (joules per second), leading to a reduction in its orbital radius by 10^{-15} metres per day. Over very long periods of time, possibly 10^{20} to 10^{25} years, Earth would slowly spiral into the Sun.

Is there an escape route?

Although death by being swallowed up by our Red Giant Sun seems a virtual certainty, there are some alternative fates to be considered. One possibility is a close encounter with another star or stellar black hole. New research shows that Earth has a 0.2% probability of planetary collision or ejection from the Solar System over the next 5 billion years, possibly via a gravitational slingshot by Jupiter if Earth moved close.

A second possibility is the expected collision of our galaxy, the Milky Way, with our closest neighbour galaxy, Andromeda, in the next several billion years. A close encounter with the super massive black hole at the galactic centre could catapult our Sun out of the merging galaxies into intergalactic space, taking Earth with it.

A third possibility is dynamical instability within our Solar System, whereby orbits, which are fundamentally chaotic, undergo large unpredictable changes over very long time periods of time. This 'violent relaxation' could happen on a timescale of 10^{19} (10 quintillion) years, propelling Earth, if it survived that long, into interstellar space.

Life on Earth could survive another 1 billion years or so at best. What remains of Earth will, most likely, be absorbed by our expanding Red Giant Sun in about 7.5 billion years. In this process, strong tidal forces and chromospherical drag will cause Earth to spiral into the Red Giant Sun where it will be vaporised in a very short period of time.

4.6 BILLION YEARS AGO

Earth and the sun are formed

NOW

Life on Earth thrives as the sun steadily ages

1 BILLION YEARS ON

Life on Earth perishes as sun approaches red giant phase

5 BILLION YEARS ON

Hydrogen burns out, sun expands and enters red giant phase

7.5 BILLION YEARS ON

Planet Earth is absorbed by the expanding Red Giant sun.

GFR sets out to provide current scientific information on some of the big questions of our time. The information shared in its Insights and Lumines series has been compiled using relevant journal articles and other credible sources, as well as the Author's own knowledge and expertise. In publications that are not peer-reviewed, the thoughts published are entirely the Author's and the Author takes no responsibility for any errors or omissions. Readers are encouraged to undertake their own independent research through other sources to validate the claims contained herein. The information published in this series has been gathered from a multitude of sources believed to be both credible and current at the time of publishing. Comments and feedback from readers are welcome, please email nick@globalfutureresearch.com.