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DIM SUN, WARM EARTH

Ken Tapping, 30th May, 2017

In the shallow waters of Shark Bay, Australia, and other locations around the world there are strange, stony, mushroom-shaped structures. These are stromatolites: structures formed by sticky films of cyanobacteria and other organisms. Sand and other material get trapped in the films, forming a gritty layer, after which a new film builds up. The result is a stony body consisting of multiple layers. These creatures are very primitive and were among the first to appear on our planet. We find their fossils in rocks more than four billion years old, and in rocks ever since. Stromatolites played a major role in converting the original, poisonous atmosphere of our planet into the breathable oxygen/nitrogen one we enjoy today. The presence of stromatolites throughout the history of our world means there must have been warm oceans for them to live in. This is fortunate but puzzling, because our understanding of how stars work suggests that when the first stromatolites and their fellow creatures were living in those ancient oceans, the Sun was 20-30% fainter than it is now. The Earth should have been frozen, not bearing warm oceans. Today, even a change in the Sun's energy output of 1% would be tragic for us, yet over billions of years the Earth's ecosystems have survived a far larger change.

Stars are fascinating things. They are big balls of mainly hydrogen gas and magnetic fields. The pressures and temperatures in their cores are high enough for nuclear fusion to take place, providing the energy for the star to shine. How bright they shine and for how long depends on how much material they accumulate when they form. Massive stars burn far brighter and burn out sooner. However, in most cases there is a period where a mixture of feedback processes stabilize their energy outputs. For middle-of-the-road dwarf stars like the Sun, this period can be several billion years long, and for less massive stars, far longer. Stable conditions for long periods of time make the development and evolution of life on their planets more likely. However, during these stable periods stars brighten slowly. This is due to the increasing amount of waste material resulting from energy production in their cores. With our ability to study many stars, of all kinds, ages and brightnesses, we are confident that this brightening process happens. It ends when ageing stars swell into red giants, brighten enormously and incinerate any planets they might have.

One suggestion is that the Earth's original atmosphere was rich in greenhouse gases, like methane and carbon dioxide. As the Sun brightened, ancient living creatures removed that carbon dioxide and replaced it with oxygen, which is not a greenhouse gas. Enormous amounts of carbon were used in making animal shells, which accumulated as great thicknesses of limestone rock. However, it is puzzling that they did it at just the right rate to compensate for the brightening of the Sun. James Lovelock, in his "Gaia Hypothesis" suggested the idea that living ecosystems can to some extent stabilize their environment. On the other hand the planets Venus and Mars might present evidence that this does not always work. Venus is a planet where the greenhouse effect has run away. If there were any ancient living creatures on Venus billions of years ago, they have long been incinerated. Mars on the other hand is a planet where the greenhouse effect has not been sufficient. When the core of Mars solidified and its magnetic field decayed, the solar wind started scrabbling away the top of the planet's atmosphere, turning the planet into an almost airless, frozen desert. Maybe beneath those deserts there lies evidence that life started on Mars, but then died out, or maybe there are some survivors eking out an existence underground.

Jupiter lies in the south after sunset. Saturn rises soon after dark, and Venus about 4am. The Moon will reach First Quarter on the 1st.

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