Supernovae and life on Earth appear closely connected

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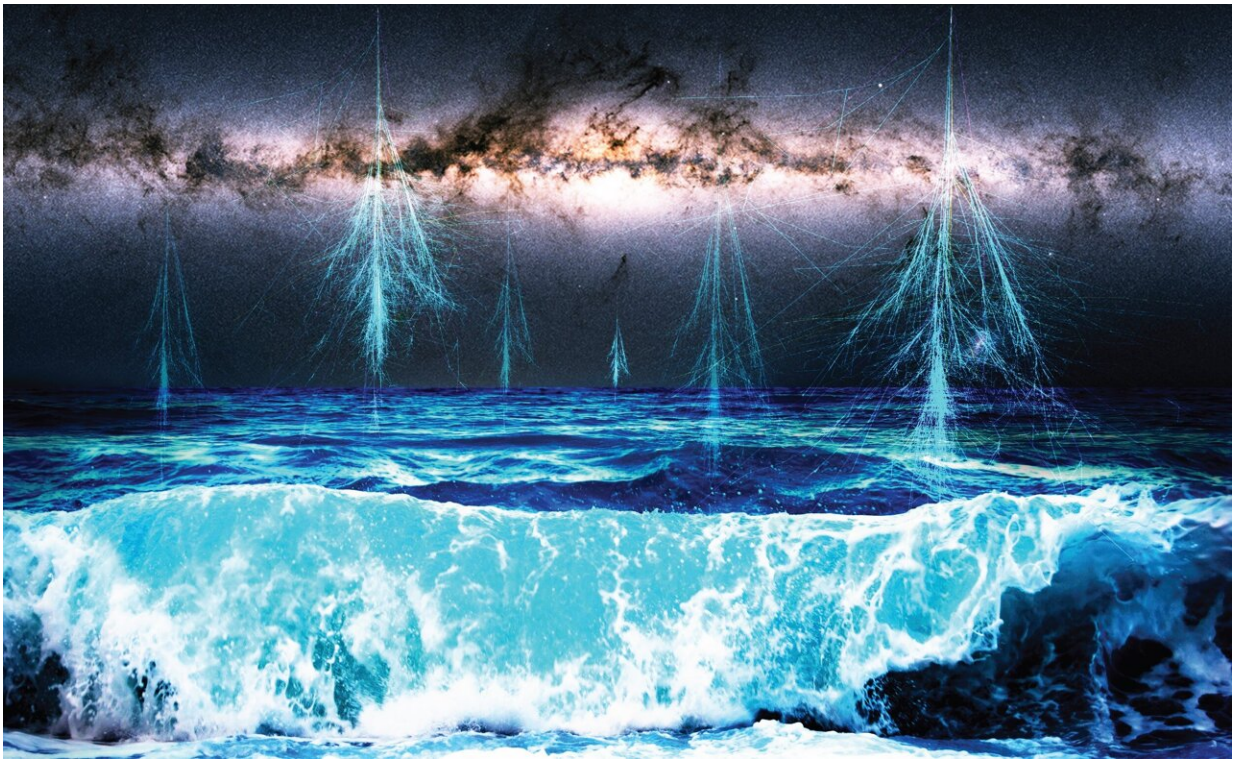

Illustration of the Milky Way seen from Earth where supernova accelerates cosmic rays to high energies. Some of these cosmic ray particles enterers the Earth's atmosphere, where they produce shower structures of secondary particles. A surprising result is that changes in cosmic rays through Earth's history have influenced life on Earth. Credit: H. Svensmark/DTU Space

A remarkable link between the number of nearby exploding stars, called

supernovae, and life on Earth has been discovered.

Evidence demonstrates a close connection between the fraction of organic matter buried in sediments and changes in supernovae occurrence. This correlation is apparent during the last 3.5 billion years and in closer detail over the previous 500 million years.

The correlation indicates that supernovae have set essential conditions for life on Earth to exist. This is concluded in a new research article published in the scientific journal *Geophysical Research Letters* by senior researcher Dr. Henrik Svensmark, DTU Space.

According to the article, an explanation for the observed link between supernovae and life is that supernovae influence Earth's climate. A high number of supernovae leads to a cold climate with a significant temperature difference between the equator and polar regions. This results in strong winds and ocean mixing, vital for delivering nutrients to biological systems. High nutrient concentration leads to a larger bioproductivity and a more extensive burial of organic matter in sediments. A warm climate has weaker winds and less mixing of the oceans, diminished supply of nutrients, lower bioproductivity, and less burial of organic matter.

"A fascinating consequence is that moving organic matter to sediments is indirectly the source of oxygen. Photosynthesis produces oxygen and sugar from light, water and CO_2. However, if organic material is not moved into sediments, oxygen and organic matter become CO_2 and water. The burial of organic material prevents this reverse reaction. Therefore, supernovae indirectly control oxygen production, and oxygen is the foundation of all complex life," says author Henrik Svensmark.

In the paper, a measure of the concentration of nutrients in the ocean over the last 500 million years correlates reasonably with the variations

in supernovae frequency. The concentration of nutrients in the oceans is found by measuring trace elements in pyrite (FeS_2, also called "fool's gold") embedded in black shale, which is sedimented on the seabed. Estimating the fraction of organic material in sediments is possible by measuring carbon-13 relative to carbon-12. Since life prefers the lighter carbon-12 atom, the amount of biomass in the world's oceans changes the ratio between carbon-12 and carbon-13 measured in marine sediments.

"The new evidence points to an extraordinary interconnection between life on Earth and supernovae, mediated by the effect of cosmic rays on clouds and climate," says Henrik Svensmark.

The link to climate

Previous studies by Svensmark and colleagues have demonstrated that ions help the formation and growth of aerosols, thereby influencing cloud fraction. Since clouds can regulate the solar energy that can reach Earth's surface, the cosmic ray/cloud link is important for climate. Empirical evidence shows that Earth's climate changes when the intensity of cosmic rays changes. Supernovae frequency can vary by several hundred percent on geological time scales, and the resulting climate changes are considerable.

"When heavy stars explode, they produce cosmic rays made of elementary particles with enormous energies. Cosmic rays travel to our solar system, and some end their journey by colliding with Earth's atmosphere. Here, they are responsible for ionizing the atmosphere," he says.

More information: Henrik Svensmark, Supernova Rates and Burial of Organic Matter, *Geophysical Research Letters* (2022). DOI: 10.1029/2021GL096376