Cosmic radiation causes fluctuations in global temperatures, but doesn't cause climate change

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The Crab Nebula from VLT . Credit: FORS Team, 8.2-meter VLT, ESO

(Phys.org)—Unlike electromagnetic radiation, which consists of massless and accelerated charged particles, galactic cosmic rays (CR) are composed mostly of atomic nuclei and solitary electrons, objects that have mass. Cosmic rays originate via a wide range of processes and sources including supernovae, galactic nuclei, and gamma ray bursts.

Researchers have speculated for decades on the possible effects of galactic cosmic rays on the immediate environs of Earth's atmosphere, but until recently, a causal relationship between climate and cosmic rays has been difficult to establish.

A research collaborative has published a paper in the *Proceedings of the National Academy of Sciences* that mathematically establishes such a causal link between CR and year-to-year changes in global temperature, but has found no causal relationship between the CR and the warming trend of the 20th century.

Understanding cosmic radiation and global climate

In 1911, Charles Thomas Rees Wilson determined that ionizing radiation leads to atmospheric cloud nucleation. Increased cloudiness in the upper troposphere reduces long-wave radiation and results in warmer temperatures. Increased cloudiness in the lower troposphere leads to reduced incoming radiation, thereby decreasing global temperatures.

But the flux of cosmic rays interacting with the atmosphere is affected by the solar wind and Earth's own magnetic field. The solar wind, particularly at the region between the sun's termination shock and the heliopause, acts as a barrier to cosmic rays and decreases the flux of low-energy cosmic radiation. Earth's magnetic field deflects cosmic rays toward the poles, which produces the aurorae observed at certain latitudes. Therefore, researchers have theorized that the extent to which cosmic rays affect the Earth's climate depends on this combination of factors.

Going to the data

To study the effects of cosmic radiation on global temperature, the researchers compared two sets of data and devised a method to examine their causal connection. Past statistical analyses, while suggesting correlation of the effects of CR and temperature flux, were unable to actually establish causation. The authors applied a recently developed analytical method called convergent cross mapping (CCM) that was specifically designed to measure causality in nonlinear dynamical systems.

The data sets they analyzed included a CR proxy called the aa index that characterizes magnetic activity resulting from the interaction of the solar wind and Earth's magnetic field. In the set, a stronger solar wind and stronger magnetic disturbances yield a higher aa index. They compared it with the United Kingdom's Met Office HadCRUT3 data set of global temperature in the post-1900 period.

CCM helps to distinguish causality from spurious correlations in the time systems of dynamical systems, detecting whether two variables belong to the same dynamical system. If variable X is influencing variable Y, causality is established—but only if states of X can be recovered from the time series of Y. "Simply put," the authors write, "CCM measures the extent to which the historical record of the affected variable Y (or its proxies), reliably estimates states of causal variable X (or its proxies)."

Modestly cosmic results

The CCM method can identify both bidirectional causality (in which X and Y are mutually coupled) and unidirectional causality (in which X influences Y, but Y has no influence on X). The analysis produced the expected unidirectional causality between global temperature change and cosmic radiation—information about global temperature is not present in the cosmic radiation time series, but mapping from global temperature change to cosmic radiation succeeded, indicating that CR information was actually recoverable from analysis of GT fluctuations.

"Our results suggest weak to moderate coupling between CR and year-to-year changes of GT," they write. "However, we find that the realized effect is modest at best, and only recoverable when the secular trend in GT is removed." This "secular trend" is the warming widely believed to be caused by excess carbon in the atmosphere, an effect the researchers accounted for by first-differencing. "We show specifically that CR cannot explain secular warming, a trend that the consensus attributes to anthropogenic forcing. Nonetheless, the results verify the presence of a nontraditional forcing in the climate system, an effect that represents another interesting piece of the puzzle in our understanding of factors influencing climate variability," they write.

More information: "Dynamical evidence for causality between galactic cosmic rays and interannual variation in global temperature." *PNAS* 2015 ; published ahead of print March 2, 2015, [DOI: 10.1073/pnas.1420291112](http://dx.doi.org/10.1073/pnas.1420291112)

Abstract
As early as 1959, it was hypothesized that an indirect link between solar activity and climate could be mediated by mechanisms controlling the flux of galactic cosmic rays (CR) [Ney ER (1959) *Nature* 183:451–452]. Although the connection between CR and climate remains controversial, a significant body of laboratory evidence has emerged at the European Organization for Nuclear Research [Duplissy J, et al. (2010) *Atmos Chem Phys* 10:1635–1647; Kirkby J, et al. (2011) *Nature* 476(7361):429–433] and elsewhere [Svensmark H, Pedersen JOP, Marsh ND, Enghoff MB, Uggerhøj UI (2007) *Proc R Soc A* 463:385–396; Enghoff MB, Pedersen JOP, Uggerhoj UI, Paling SM, Svensmark H (2011) Geophys Res Lett 38:L09805], demonstrating the theoretical mechanism of this link. In this article, we present an analysis based on convergent cross mapping, which uses observational time series

data to directly examine the causal link between CR and year-to-year changes in global temperature. Despite a gross correlation, we find no measurable evidence of a causal effect linking CR to the overall 20th-century warming trend. However, on short interannual timescales, we find a significant, although modest, causal effect between CR and short-term, year-to-year variability in global temperature that is consistent with the presence of nonlinearities internal to the system. Thus, although CR do not contribute measurably to the 20th-century global warming trend, they do appear as a nontraditional forcing in the climate system on short interannual timescales.

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