Straight from Heaven: Wooden clock

Archaeologists use the fact that the radioactive element is present in studied samples to determine their age. Once produced, carbon-14 turns back into nitrogen, with a half-decay time of about 5750 years. Living organisms maintain roughly constant levels of radioactive elements due to continuous uptake and excretion of matter, while a dead organism contains a certain initial amount of carbon-14, which becomes less and less with time.

When high-energy cosmic radiation collides with the upper layers of the Earth's atmosphere, some collisions lead to the formation of neutrons, leading to the neutron-proton $n{-}p$ reaction, which is the conversion of nitrogen nuclei $^{14}_{7}\mathrm{N}$ into radioactive carbon-14, $^{14}_{6}\mathrm{C}$: $^{14}_{7}\mathrm{N} + \mathrm{n} \rightarrow {}^{14}_{6}\mathrm{C} + \mathrm{p}$. Carbon-14 falls to the Earth's surface, taking part in the normal biochemistry of living organisms, including becoming bound during tree growth.

By examining the wood, and in particular the differences in carbon-14 content in individual annual growth rings (wood grain), it is possible to determine the initial amount of radioactive material and therefore study the evolution of the amount of cosmic radiation in the past dating back as far as thousands of years. The carbon-14 content also depends on other factors, such as the magnetic field of the Earth and the Sun, which acts as a shield for the Earth's surface against cosmic radiation coming from outside the Solar system (more particles reach Earth when these magnetic fields are weaker and fewer when they are stronger). Changes in carbon-14 levels in growth rings store a history of changes in Earth's magnetization as well as the 11-year cycle of the solar dynamo, which is related to the solar magnetic field.

The wood, however, contains the data that we cannot explain. In 2012, a Japanese physicist Fusa Miyake discovered a significant jump in the carbon-14 content of tree rings dating back to the year 774. The difference was so large that it must have been caused by cosmic radiation many times larger than average. Subsequent "Miyake events" were in the years 993 and 663 BCE, as well as even earlier events of 5259, 5410 and 7176 BCE. The well-located events in the wood (and in time) make it possible to precisely date specific events to the exact year, e.g., the event of 993 allowed to pinpoint the timing of the the establishment of the first European settlement in America, a Viking village in New Fundland, to the year 1021.

How does such massive and short-lived radiation occur? Among the "suspects" are nearby supernovae, gamma-ray bursts, emission from magnetized neutron stars, and even comets. Currently, the best explanation is that Miyake events are associated with solar superstorms. These (hypothetical) eruptions from the Sun are 50-100 times more energetic than the largest recorded in the modern era: the solar storm observed by Richard C. Carrington and Richard Hodgson in 1859.

In a paper by Q. Zhang and colleagues, the authors analyse available material from the tree rings finding evidence that events can occur at any moment of the Sun's 11-year activity cycle (which we wrote about in e.g. Δ^{1}_{21}). On the other hand, solar flares tend to occur near the maximum of the cycle. Several of the recorded spikes in of radioactivity appear to last longer than would be suggested by a model of a single solar superstorm. This suggests that these events can sometimes last longer than a year, which is not expected for a single giant solar flare, i.e., that we would be dealing with a long-lasting solar superstorm solar weather.

Such an event happening today would destroy power grids, telecommunications and most satellites. If they occur randomly, for example, once every thousand years, there is about a 1% chance per decade, which is a non-negligible probability.

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"Modelling cosmic radiation events in the tree-ring radiocarbon record", Qingyuan Zhang i inni, Proc. R. Soc. A. 478 2022.0497, 2022.

The Night Sky in July

Throughout the month, the Sun will lower its altitude by over 4.5°, reducing its time above the horizon in central Poland by over an hour. On July 24th, the Sun will cross +20° declination and thus the period of the longest days and shortest nights will end. As every year at the beginning of July, the Earth is at the aphelium of its orbit, which means that the Sun has the smallest visible disc in the year. Therefore, it is easier for it to be covered by the Moon during a potential eclipse – and such eclipses also can last longer.

In July, the solar system's brightest planets are not well visible on the sky. *Mercury* will begin the month with an upper conjunction with the Sun and will move toward maximum eastern elongation, which it will reach in the first ten days of August, moving away then by 27° from the Sun. Unfortunately, at this time of year the ecliptic is tilted unfavourably to the horizon, making the planet set less than an hour after the Sun, and it is invisible from high latitudes. Notably, with each successive day the planet's brightness lowers, from -0.4^m on July 19th to $+0.1^m$ on July 31st. A pity, because on July 28th the planet will pass less than 20′ from Regulus, the brightest star of Leo constellation.

Observational conditions in July for *Venus* are even worse. The second planet from the Sun, after June's maximum elongation, is rapidly moving toward August's lower conjunction with the Sun. This means that the planet is rapidly approaching us, while