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 increasing the size of the disc and decreasing the phase. At the beginning of July, Venus will present a disc of brightness -4.4^m, diameter $34''$ and phase of 31%. On the last day of the month, the corresponding magnitude, diameter and phase will be: -4.2^m, $53''$ and 5%. Unfortunately, the planet will dive several degrees below the weakly inclined ecliptic in the process, disappearing into the evening aurora at the end of the month. The disc of Venus in July is therefore an attractive observational target for owners of binoculars and telescopes, however not for those residing far north of the equator.

In early July after dusk, you can also try to spot *Mars*. The Red Planet originally travels less than 4° from Venus, but then Mars will travel further southeast and Venus will turn back toward the Sun, so by July 20th the distance on the sky between the planets will more than double. On July 10th, Mars will pass the aforementioned Regulus at a distance of just over 0.5°. Mars is the most difficult to see through the evening aurora, as it is already far from Earth and shines with a brightness of $+1.7^m$, so not much greater than the nearby brightest star Leo.

All of these planets in the last ten days of the month will be visited by the Moon in the waxing crescent phase. The new Moon falls on July 17th and in the following days it will move to the evening sky, but will also suffer from the low ecliptic. This situation will be somewhat improved by the fact that it will spend almost all of its time, until the first quarter, which falls on July 25th, north of the ecliptic. As early as July 18th, it is possible to try to spot the Moon's very thin sickle at a dusk, but this is a difficult task, requiring a very clear atmosphere and a low exposed skyline. Thirty minutes after sunset, the Moon's disc in phase of just 1% will take up a position at a height of 3°. At the same time 7% to the left of the Moon will be the planet Mercury, while another 15% further away – the planet Venus. In turn, 3.5° above Venus will show Regulus, 5° from Regulus, at 10 o'clock relative to it will be the planet Mars. The Moon, Mercury and Venus will set very quickly, Regulus and Mars a little later. To find all these celestial bodies, however, binoculars may be necessary. On July 19th, the Moon in phase will pass 4° over Mercury, while 24 hours later, with its phase increased to 8%, the Silver Globe will pass 3° over Regulus and at the same time 7° over Venus. At 6° to the left of the Moon will show Mars. On July 21st, the phase of the lunar disk will grow to 14%, and Mars should then be sought at a distance of 6° at 4 o'clock relative to the Moon.

After passing the planets, on July 24th and 25th, the Earth's natural satellite, in the first quarter, will meet Spika, the brightest star of Virgo. It is still worth mentioning the very close encounter between the Moon and Antares, on July 28. At the time of the Sun's setting, the Moon's disc in phase of 79% will show 0.5° from Scorpio's brightest star. Until the end of the month, the Moon will remain south of the ecliptic, wandering low over the horizon. The closer we get to the end of July, however, the fuller the lunar disk will become, as the Moon will pass through a full Moon on the evening of August 1st our time.

The beginning of July will also be influenced by the light of the Silver Globe's disc. July's full moon will fall on July 3rd in the constellation of Sagittarius. Before it, on the first two nights of the month, the Moon will visit Scorpio, shining first 6° to the right and then 8° to the left of Antares. On 7th July, presenting a disc illuminated in 83%, Earth's natural satellite will approach at 5° from Saturn. The ringed planet in August will move southwesterly less than 1° from the 5th magnitude double star *sigma* Aqarii. The planet's disk will exceed a diameter of $18''$, shining with a brightness of $+0.7^m$. Saturn will peak at dawn, rising to an altitude of over 25°.

The Silver Globe will meet with *Neptune* on July 9th, approaching it at a distance of 5°. The planet will pass through opposition to the Sun in September and also move in retrograde motion. This year Neptune will trace a loop on the border of the Pisces and Aquarius constellations, not far from the distinctive, miniature Ursa Minor-like system of 5th and 6th magnitude stars, which is formed by the stars 30, 33, 27, 29, 24 and 20 Piscium. In July, Neptune is located about 1° north of 24 Psc, shines with a brightness of $+7.8^m$ and around 2 o'clock rises to a height of more than 20° above the southeastern horizon.

The Moon will pass through the last quarter on July 10th, and then proceed towards the faintly visible planets *Jupiter* and *Uranus*. On the morning of July 12th, the phase of the lunar disk will drop below 30% and it will ascend just after midnight 2.5° from Jupiter and at the same time 9° west of Uranus. Both planets in the coming observing season will circle against the background of the constellation Aries at a distance of a few degrees from each other and in November both will pass through opposition to the Sun. For the time being, they are roughly 10° apart and at around 2 o'clock they rise 15° above the eastern part of the sky. Jupiter shines with brightness of -2.3^m, presenting a disc of diameter $38''$, so there is no trouble with spotting it. The situation is different for Uranus, whose brightness is $+5.8^m$ and because of its low altitude in the dark sky, its image depends on the quality of the atmosphere.

The new Moon falls on July 17th in the evening, our time, and thanks to the fact that its orbit is now almost maximally tilted north of the ecliptic, its thin crescent along with the so-called ash light will remain visible for the next 4 days. On the 13th day of the month, the Moon's crescent in phase of 20% will approach the Pleiades at 3°, 24 hours later its phase will drop to 13% and it will pass 8° over Aldebaran, while on July 15th, in phase of 7%, it will pass at a distance of just over 2° from El Nath, two bright stars of Taurus. On July 16th at dawn, the Moon in phase at just 3% will show itself at a height of 7° over 20° under Capella.

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