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On the astronomical origin of the Hallstatt oscillation found in radiocarbon and climate records throughout the Holocene

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Abstract

An oscillation with a period of about 2100-2500 years, the Hallstatt cycle, is found in cosmogenic radioisotopes (^{14}C and ^{10}Be) and in paleoclimate records throughout the Holocene. This oscillation is typically associated with solar variations, but its primary physical origin remains uncertain. Herein we show strong evidences for an astronomical origin of this cycle. Namely, this oscillation is coherent to a repeating pattern in the periodic revolution of the planets around the Sun: the major stable resonance involving the four Jovian planets - Jupiter, Saturn, Uranus and Neptune - which has a period of about $p = 2318$ yr. Inspired by the Milanković's theory of an astronomical origin of the glacial cycles, we test whether the Hallstatt cycle could derive from the rhythmic variation of the circularity of the solar system disk assuming that this dynamics could eventually modulate the solar wind and, consequently, the incoming cosmic ray flux and/or the interplanetary/cosmic dust concentration around the Earth-Moon system. The orbit of the planetary mass center (PMC) relative to the Sun is used as a proxy. We analyzed how the instantaneous eccentricity vector of this virtual orbit varies from 13,000 B. C. to 17,000 A. D.. We found that it undergoes a kind of pulsations and clearly presents rhythmic contraction and expansion patterns with a 2318 yr period together with a number of already known faster oscillations associated to the planetary orbital stable resonances. There exists a quasi $\pi/2$ phase shift between the 2100-2500 yr oscillation found in the ^{14}C record and that of the calculated eccentricity function. Namely, at the Hallstatt-cycle time scale, a larger production of radionucleotide particles occurs while the Sun-PMC orbit evolves from more elliptical shapes ($e \approx 0.598$) to more circular ones ($e \approx 0.590$), that is while the orbital system is slowly imploding or bursting inward; a smaller production of radionucleotide particles occurs while the Sun-PMC orbit evolves from more circular shapes ($e \approx 0.590$) to a more elliptical ones ($e \approx 0.598$), that is while the orbital system is slowly exploding or bursting outward. Since at this timescale the PMC eccentricity variation is relatively small ($e = 0.594 \pm 0.004$), the physical origin of the astronomical 2318 yr cycle is better identified and distinguished from faster orbital oscillations by the times it takes the PMC to make pericycles and epicycles around the Sun and the times it takes to move