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MAMMOTH EXTINCTION AND RADIATION DOSE: A COMMENT[1]

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Recently, an article was published in this journal, discussing evidence for a solar flare cause of faunal extinction during the Late Pleistocene (LaViolette 2011). The article is based on the hypothesis that an increase in atmospheric radiocarbon concentration might have been produced by a giant solar proton event (SPE). This proposed SPE would deliver a lethal radiation dose of at least 3–6 Sv to the surface of the Earth, causing termination of the Pleistocene megafauna.

The article touches on many multidisciplinary aspects and thus-far unresolved scientific puzzles around the Pleistocene/Holocene transition. It is certainly clear that abrupt changes occurred at this time (Straus and Goebel 2011). One of these is the production of cosmogenic isotopes like ^{14}C, which does show a significant increase at the beginning of the Younger Dryas (YD) cold phase. The ^{14}C record of this period as well as the preceding deglaciation is difficult to explain in terms of global carbon cycle reorganizations, witness the name "mystery interval" (Broecker 2009). Recent work has highlighted the importance of deep ocean ventilation (Skinner et al. 2011; Thornalley et al. 2011) as another possible cause of the ^{14}C fluctuations. Another mystery still standing is the mass extinction of megafauna, including its icon the woolly mammoth (*Mammuthus primigenius*). For this, in particular, sometimes extraordinary theories have been suggested, the last one being the impact of a meteor or comet (Firestone et al. 2007). This theory now seems negated (Pinter et al. 2011), only to be replaced by the next spectacular one, the SPE hypothesis.

The question is, could this occur? Extraterrestrial radiation indeed could in theory explain both additional ^{14}C production and mass extinction. Hence the theory put forward by LaViolette (2011). This is an interesting hypothesis that probably will spawn discussions on a variety of subjects. Here we only comment on one significant aspect of the hypothesis: the killer radiation dose.

The estimated dose is stated as "at least 3–6 Sv to the Earth's surface." Indeed, that is a lethal dose. For humans, a dose of 3 Sv is the so-called LD50 dose, or Lethal Dose 50%, meaning there is a 50% chance of death if untreated within 60 days (ICRP 2007).

It is useful to note here that NASA has concerned itself for a long time with the possibility of lethal SPE events in space. A large SPE event in August 1972, close to the time of the Apollo 17 mission, had a fluence exceeding 5×10^9 protons/cm^2. If astronauts had been in space at that time, they would have received a lethal dose—some estimates put the estimated skin dose at around 15 Gy (Parsons and Townsend 2000). However, at the surface of the Earth, at lower altitudes, we are shielded by a factor of about 500 to 1000 from cosmic radiation. Hence, for a "killer" SPE, we would need a much higher SPE flux of close to about 10^{12} p/cm^2. LaViolette (2011) quotes an estimate that one or more events of $\sim 1.3 \times 10^{11}$ p/cm^2 could have occurred, based on the assumption that the ^{14}C rise observed at the beginning of the YD was caused by a large SPE event. We agree that his calculation is based on a reasonable assessment of previous data about SPE effects on $\Delta^{14}C$, although there is considerable variation in these estimates (e.g. Usoskin et al. 2006).

[1]The illustration on this issue's cover was drawn by J van der Plicht, and is meant to accompany this Comment.

However, this immediately illustrates one crucial problem with the SPE hypothesis. If the radiation is strong enough to extinguish mammoths, then the same argument holds for humans and other species. At the least, this level of radiation would have caused a significant death toll among the human population at the time. The only shielding possible could have been a large mass of rock. Most humans did not live in these conditions. Someone in a cave could have survived, but only if at home. There is no evidence at all for such a dramatic event in the archaeological record. In the case of the human expansion in the New World, the majority view is that the population was expanding during this time (Holliday and Meltzer 2010). Even in the case of a proposed declining population during Clovis, the estimate is within a factor of 2 (Anderson et al. 2011).

The same is true for most mammals and other organisms. One could argue that the lethal SPE damage is limited to the mammoth steppe and grasslands at higher latitudes. However, mammoths were spread over a large range of latitudes (Agenbroad 1984). The key mystery about the end of the Last Glacial is that many species, such as polar bears and reindeer, survived easily, but other species perished (Martin and Klein 1984).

We conclude that even if an SPE had occurred, the dose rate could not have been high enough to cause or significantly contribute to the demise of the megafauna. If there were such a massive event, there would be nobody to discuss this interesting hypothesis. It is also worth noting here that not all mammoths became extinct during the Late Pleistocene. Some survived the deglaciation in refugia like the Pribilof Islands (Veltre et al. 2008) and in dwarf form on Wrangel Island (northern Siberia). Veltre et al. (2008) dated mammoth remains at 6480–6640 cal yr BP. The dwarf mammoths of Wrangel Island survived longer, with the most recent specimen dated by ^{14}C to about 4000 yr old (Vartanyan et al. 1995).

REFERENCES

Agenbroad LD. 1984. New world mammoth distributions. In: Martin PS, Klein RG, editors. *Quaternary Extinctions: A Prehistoric Revolution*. Tucson: University of Arizona Press. p 90–108.

Anderson DG, Goodyear AC, Kennett J, West A. 2011. Multiple lines of evidence for possible human population decline/settlement reorganization during the early Younger Dryas. *Quaternary International* 242(2): 570–83.

Broecker W. 2009. The mysterious ^{14}C decline. *Radiocarbon* 51(1):109–19.

Firestone RB, West A, Kennett JP, Becker L, Bunch TE, Revay ZS, Schultz PH, Belgya T, Kennett DJ, Erlandson JM, Dickenson OJ, Goodyear AC, Harris RS, Howard GA, Kloosterman JB, Lechler P, Mayewski PA, Montgomery J, Poreda R, Darrah T, Que Hee SS, Smith AR, Stich A, Topping W, Wittke JH, Wolbach WS. 2007. Evidence for an extraterrestrial impact 12,900 years ago that contributed to the megafaunal extinctions and the Younger Dryas cooling. *Proceedings of the National Academy of Sciences (USA)* 104: 16,016–21.

Holliday VT, Meltzer DJ. 2010. The 12.9ka impact hypothesis and North American paleoindians. *Current Anthropology* 51:575–607.

ICRP. 2007. *The 2007 Recommendations of the International Commission on Radiological Protection*. Annals of the ICRP, publication 103. Ontario: ICRP.

LaViolette PA. 2011. Evidence for a solar flare cause of the Pleistocene mass extinction. *Radiocarbon* 53(2): 303–23.

Martin PS, Klein RG, editors. 1984. *Quaternary Extinctions: A Prehistoric Revolution*. Tucson: University of Arizona Press.

Parsons JL, Townsend LW. 2000. Interplanetary crew dose rates for the August 1972 solar particle event. *Radiation Research* 153(6):729–33.

Pinter N, Scott AC, Daulton TL, Podoll A, Koeberl C, Anderson RS, Ishman SE. 2011. The Younger Dryas impact hypothesis: a requiem. *Earth-Science Reviews* 106(3–4):247–64.

Skinner LC, Fallon S, Waelbroeck C, Michel E, Barker S. 2011. Ventilation of the deep Southern Ocean and deglacial CO_2 rise. *Science* 328(5982):1147–51.

Straus LG, Goebel T. 2011. Humans and Younger Dryas: Dead end, short detour, or open road to the Holocene? *Quaternary International* 242(2):259–61.

Thornalley DJR, Barker S, Broecker WS, Elderfield H, McCave IN. 2011. The deglacial evolution of North Atlantic deep convection. *Science* 331(6014):202–5.

Usoskin IG, Solanki SK, Kovaltsov GA, Beer J, Kromer B. 2006. Solar proton events in cosmogenic isotope data. *Geophysics Research Letters* 33: L08107, doi: 10.1029/2006GL026059.

Vartanyan SL, Arslanov KA, Tertychnaya TV, Chernov SB. 1995. Radiocarbon dating evidence for mammoths on Wrangel Island, Arctic Ocean, until 2000 BC. *Radiocarbon* 37(1):1–6.

Veltre DW, Yesner DR, Crossen KJ, Graham RW, Coltrain JB. 2008. Patterns of faunal extinction and paleoclimatic change from mid-Holocene mammoth and polar bear remains, Pribilof Islands, Alaska. *Quaternary Research* 70(1):40–50.