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Why ice ages could be unpredictable in spite of the action of the astronomical forcing

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There are numerous evidences that the variation of Earth's orbit and obliquity have a control on the timing of glacial-interglacial cycles that occurred throughout the Pleistocene.
Evidence is mainly based power spectrum analysis of palaeoclimate records, and on the statistical analysis of the timing of deglacial transitions (terminations), by comparison with the variations of earth orbital elements known from the laws of celestial mechanics. However, these evidence are not sufficient to conclude that Earth's astronomical elements tightly determine the timing of glacial-interglacial cycles. Here, we explain why glacial-interglacial cycles could be partly unpredictable.

We consider a general model according to which glacial-interglacial cycles arise from a natural climatic cycle \textit{synchronised} on the astronomical forcing. This model has been presented and discussed many times in the literature under various forms. It remains too date one of the most successful explanations of the observed timing of Pleistocene glacial cycles.
Then we use mathematical concepts to study and characterise the nature of the synchronisation of climatic cycles, by taking gradually into account the complexity of the full spectrum of astronomical forcing.

It is found that the complex nature of the astronomical forcing has a number of overlooked consequences: (a) compared to a periodic forcing, the astronomical forcing is more likely controls the timing of ice ages; (b) however, the bifurcation structure of the synchronisation regimes is particularly intricate. The consequence is that the synchronisation of ice age cycles on astronomical forcing can be unreliable: random climatic fluctuations may have large consequences on the timing of future glacial inceptions and deglaciations. The resulting dynamical behaviour is then intermediate between chaotic and fully predictable.