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Are mass extinctions and comet impacts correlated with Sun crossings through the Galaxy spiral arms?

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Abstract. We analyze investigations on possible correlations between Sun crossings on galactic spiral arms, comet impact and mass extinction events recorded in the terrestrial geological past. Our interest lies in the controversy between researchers that tried to establish the (in)viability of astronomical causes for mass extinctions. Catastrophic events possibly associated with arms crossings include comet impacts, due to gravitational perturbations on Oort cloud, and supernovae, from massive star clusters present on arms. Due to large data uncertainties it is difficult to decide clearly for any alternative. We intend to partially compensate for the geological data gaps with Moon cratering listing, where impact preservation will help us to perceive if there were occasions of high impact probability. It is our understanding that this would contribute to the knowledge of mass extinctions and elucidate the importance of galactic arm crossings.

Resumo. Analisamos investigações sobre possíveis correlações entre passagens do Sol pelos braços espirais galácticos, impactos cometários, e eventos de extinção biológica em massa registrados no passado geológico da Terra. Nosso interesse está no impasse entre os pesquisadores que tentaram estabelecer a (in)viabilidade de causas astrofísicas aos episódios de extinção em massa. Eventos catastróficos que podem ser associados à passagem pelos braços espirais incluem impactos cometários, devido a perturbações gravitacionais na nuvem de Oort, e supernovas, por conta dos aglomerados de estrelas massivas presentes nos braços. Graças às grandes incertezas nos dados, não parece possível decidir claramente por uma das alternativas. Pretendemos compensar parcialmente as lacunas existentes nos dados geológicos com listas de crateras lunares, onde a preservação dos impactos poderá nos ajudar a entender se houve ocasiões de elevada probabilidade de impacto para Terra e Lua. Entendemos que dessa forma será possível contribuir para a compreensão das extinções em massa e elucidar a importância das passagens pelos braços galácticos.

Keywords. Astrobiology

1. Introduction

Spiral arms are structures composed of dense gas and dust clouds, with a high rate of star formation, so there may be an increased probability for potentially catastrophic events to happen during Solar System crossings of them. Gravitational perturbations in the Oort cloud could cause comet collisions on Earth, leading to sudden global climate changes. Another possibility is the occurrence of nearby supernovae, generating dangerous levels of gamma radiation and increasing both species mortality and DNA mutation rates.

Some researchers vouch for associating spiral arms crossings by the Sun to mass extinctions (Gillman & Erenler 2008, Gillman, Erenler & Sutton 2019), and others against it (Beech 2011, Feng & Bailer-Jones 2013, Erlykin et al. 2017). Most investigations on correlations between arm crossings and mass extinction events look for a common periodicity between crossings, cratering and mass extinctions, the last ones based on data from Raup & Sepkoski (1984) and Bambach (2006). Our proposal is to check possible correlations between mass extinctions, the times when the Sun crossed the Galaxy spiral arms, and comet impacts occurred on Earth, including Moon cratering (better preserved than Earth ones due to the lack of atmospheric or geological activity there).

2. Analysis

The key factors for analysis are: (I) the extinction rate, which could indicate the reality of mass extinction events, periodic or not, obtained from the fossil record; (II) the solar orbit, to determine the occasions of spiral arms crossings, with uncertain periodicity, acquired by reconstruction from kinematic and dynamic data; (III) the impacts records, to establish the times when survival of species have been adversely affected, obtained from geological data. The three factors can be correlated or not, although authors typically assume correlation is granted for 2 chosen factors and go searching for correlation with the remaining factor.

A correlation between arm crossings and cratering would favor the hypothesis of increased impact probability during them. If arm crossings and mass extinctions correlate, it can be said supernovae (or their remnants, see Kataoka et al. 2014) bring danger to the biosphere. Finally, the identification of mass extinctions with impacts depends on finding a decisive correlation between extinctions and cratering. In order to validate the assumed connection between arm crossing, comet impacts and mass extinction, one needs to actually find correlations among the three factors.

A large fraction of the terrestrial surface has been underwater for the last billion years (not to mention erosion and weathering), so many impacts are beyond current scientific scrutiny. To somehow compensate for this, we will add Moon cratering. Although only impacts on Earth can contribute to extinctions, according to Ito & Malhotra (2006) the impact probability on Earth is about 20 times larger than on Moon. We expect to check those proposals with the lunar crater age list from Stöffler & Ryder (2001).

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