Nature **308**, 709 - 712 (19 April 1984); doi:10.1038/308709a0

Terrestrial mass extinctions, cometary impacts and the Sun's motion perpendicular to the galactic plane

Michael R. Rampino* & Richard B. Stothers

National Aeronautics and Space Administration, Goddard Institute for Space Studies, 2880 Broadway, New York, New York 10025, USA
*Present address: Department of Geological Sciences, Columbia University, New York, New York 10027, USA.

Episodes of mass extinctions on the Earth are now strongly suspected to be cyclical[1]. We report here that our analysis of the data of Raup and Sepkoski[1] suggests that the dominant cyclicity in major marine mass extinctions during at least the past 250 Myr is 30 ±1 Myr, with the standard deviation of an individual episode being ±9 Myr. We find this terrestrial cycle to be strongly correlated with the time needed for the Solar System to oscillate vertically about the plane of the Galaxy, which is 33 ±3 Myr according to the best current astronomical evidence. It is argued that galactic triggering or forcing of terrestrial biological crises may arise as a result of collisions (or close encounters) of the Solar System with intermediate-sized to large-sized interstellar clouds of gas and dust, which are sufficiently concentrated towards the galactic plane to produce the observed cyclicity and its scatter. Among other consequences, a nearby interstellar cloud would gravitationally perturb the Solar System's family of comets and thereby increase the flux of comets and comet-derived bodies near the Earth, leading to large-body impacts. We find a dominant cyclicity of 31 ±1 Myr in the observed age distribution of impact craters on Earth, the phase of this cycle agreeing with that shown by the major biological crises. Our galactic hypothesis can thus simultaneously account for the mean interval between major terrestrial crises and for the 50% scatter of the time intervals about their mean value.

References

1. Raup, D. M. & Sepkoski, J. J. *Proc. natn. Acad. Sci. U.S.A.* **81**, 801−805 (1984). | ChemPort |
2. Stothers, R. *Astr. Astrophys.* **77**, 121−127 (1979). | ISI |
3. Fischer, A. G. & Arthur, M. A. *Soc. Econ. Paleont. Miner. Spec. Publ.* **25**, 19−50 (1977).
4. Raup, D. M. *Geol. Soc. Am. Spec. Pap.* **190**, 277−281 (1982).
5. Palmer, A. R. *Geology* **11**, 503−504 (1983). | ISI |
6. McCrea, W. H. *Proc. R. Soc.* A**375**, 1−41 (1981). | ISI |
7. Dilke, F. W. W. & Gough, D. O. *Nature* **240**, 262−294 (1972). | ISI |
8. Hoyle, F. & Lyttleton, R. A. *Proc. Camb. phil. Soc.* **35**, 405−415 (1939).
9. Shapley, H. *Sky Telesc.* **9**, 36−37 (1949).
10. Steiner, J. & Grillmair, E. *Bull. geol. Soc. Am.* **84**, 1003−1018 (1973).
11. Williams, G. E. *Earth planet. Sci. Lett.* **26**, 361−369 (1975). | Article | ISI |
12. McCrea, W. H. *Nature* **255**, 607−609 (1975). | ISI |
13. Innanen, K. A., Patrick, A. T. & Duley, W. W. *Astrophys. Space Sci.* **57**, 511−515

(1978). | ISI |
14. Tamrazyan, G. P. *Izv. Acad. Nauk Azerb. SSR* **12**, 85−115 (1957).
15. Hatfield, C. B. & Camp, C. J. *Bull. geol. Soc. Am.* **81**, 911−914 (1970).
16. Meyerhoff, A. A. *Mem. Can. Soc. petrol. Geol.* **2**, 745−758 (1973).
17. Oort, J. H. in *Galactic Structure* (eds Blaauw, A. & Schmidt, M.) 455−511 (University of Chicago, 1965).
18. Eggen, O. J. *Publ. astr. Soc. Pacif.* **81**, 741−753 (1969). | Article | ISI |
19. Krisciunas, K. *Astr. J.* **82**, 195−197 (1977). | Article | ISI |
20. Hill, G., Hilditch, R. W. & Barnes, J. V. *Mon. Not. R. astr. Soc.* **186**, 813−830 (1979). | ISI |
21. Rohlfs, K. & Kreitschmann, J. *Astrophys. Space Sci.* **79**, 289−319 (1981). | ISI |
22. Klugh, H. E. *Statistics, the Essentials for Research*, Ch. 10 (Wiley, New York, 1970).
23. Knude, J. *Astr. Astrophys.* **126**, 89−93 (1983). | ISI |
24. Talbot, R. J. Jr. & Newman, M. J. *Astrophys. J. Suppl.* **34**, 295−308 (1977). | Article | ISI | ChemPort |
25. Ilovaisky, S. A. & Lequeux, J. *Astr. Astrophys.* **18**, 169−185 (1972). | ISI |
26. Clark, D. H. & Caswell, J. L. *Mon. Not. R. astr. Soc.* **174**, 267−305 (1976). | ISI |
27. Terry, K. D. & Tucker, W. H. *Science* **159**, 421−423 (1968). | PubMed | ISI | ChemPort |
28. Ruderman, M. A. *Science* **184**, 1079−1081 (1974). | ISI | ChemPort |
29. Whitten, R. C., Cuzzi, J., Borucki, W. J. & Wolfe, J. H. *Nature* **263**, 398−400 (1976). | ISI | ChemPort |
30. Clark, D. H., McCrea, W. H. & Stephenson, F. R. *Nature* **265**, 318−319 (1977). | ISI |
31. Stark, A. A. in *Kinematics, Dynamics and Structure of the Milky Way* (ed. Shuter, W. L. H.) 127−133 (Reidel, Dordrecht, 1983). | ChemPort |
32. Clube, S. V. M. & Napier, W. M. *Q. Jl. R. astr. Soc.* **23**, 45−66 (1982). | ChemPort |
33. van den Bergh, S. *J. R. astr. Soc. Can.* **76**, 303−308 (1982).
34. Sanders, D. B., Scoville, N. Z. & Solomon, P. M. Preprint, Univ. Massachusetts (1984).
35. Cohen, R. S., Cong, H., Dame, T. M. & Thaddeus, P. *Astrophys. J.* **239**, L53−56 (1980). | Article | ISI | ChemPort |
36. Chandrasekhar, S. *Principles of Stellar Dynamics*, 190 (University of Chicago, 1942).
37. Vidal-Madjar, A., Laurent, C., Bruston, P. & Audouze, J. *Astrophys. J.* **223**, 589−600 (1978). | Article | ChemPort |
38. Begelman, M. C. & Rees, M. J. *Nature* **261**, 298−299 (1976). | ISI |
39. Talbot, R. J. Jr, Butler, D. M. & Newman, M. J. *Nature* **262**, 561−563 (1976). | ISI |
40. Butler, D. M., Newman, M. J. & Talbot, R. J. Jr *Science* **201**, 522−525 (1978). | ISI |
41. McKay, C. P. & Thomas, G. E. *Geophys. Res. Lett.* **5**, 215−218 (1978). | ISI | ChemPort |
42. Hills, J. G. *Astr. J.* **86**, 1730−1740 (1981). | Article | ISI |
43. Oort, J. H. *Bull. astr. Inst. Neth.* **11**, 91−110 (1950).
44. Urey, H. C. *Nature* **242**, 32−33 (1973). | ISI |
45. Napier, W. M. & Clube, S. V. M. *Nature* **282**, 455−459 (1979). | ISI |
46. Clube, S. V. M. & Napier, W. M. *Earth planet. Sci. Lett.* **57**, 251−262 (1982). | Article | ISI |
47. Silver, L. T. & Schultz, P. H. (eds) *Geol. Soc. Am. Spec. Pap.* **190**, 1−528 (1982).
48. Pollack, J. B., Toon, O. B., Ackerman, T. P., McKay, C. P. & Turco, R. P. *Science* **219**, 287−289 (1983). | ISI |
49. Grieve, R. A. F. *Geol. Soc. Am. Spec. Pap.* **190**, 25−37 (1982).
50. Seyfert, C. K. & Sirkin, L. A. *Earth History and Plate Tectonics*, 383−389 (Harper & Row, New York, 1979).
51. Alvarez, L. W., Alvarez, W., Asaro, F. & Michel, H. V. *Science* **208**, 1095−1105 (1980). | ISI | ChemPort |
52. Hsü, K. J. *Nature* **285**, 201−203 (1980). | ISI |

53. Ganapathy, R. *Science* **216**, 885−886 (1982). | ISI | ChemPort |
54. Alvarez, W., Asaro, F., Michel, H. V. & Alvarez, L. W. *Science* **216**, 886−888 (1982). | ISI | ChemPort |
55. Keller, G., D'Hondt, S. & Vallier, T. L. *Science* **221**, 150−152 (1983). | ISI |
56. Negi, J. G. & Tiwari, R. K. *Geophys. Res. Lett.* **10**, 713−716 (1983). | ISI |