Stones in the Sky: From the Main Belt to Earth-Crossing Orbits

Daniel Benest

Observatoire de la Côte d'Azur, Observatoire de Nice, B.P. 4229, F-06304 Nice Cedex 4, France (benest@obs-nice.fr)

Abstract. It is now well known that impacts play a great role in the formation of planetary bodies, and have some influence during their evolution -- particularly on the biosphere. The story begins officially in the early 19th century, with the discovery of the first asteroids and the recognition that stones can fall from the skies. Through the findings of the Kirkwood gaps, of Hirayama families and finally the importance of the 3:1 and other resonances, the processes that send Main Belt asteroids on trajectories crossing Earth's orbit have been gradually understood. A little paradox remained: computations show that the resonances become completely empty in less than a billion years, but observations reveal that celestial bodies orbiting in such Earth-crossing trajectories still exist; this has been explained by collisions in the Main Belt, the products of which are sometimes injected into nearby resonances and then continue to supply the population of possible Earth-crossers; non-gravitational forces may also inject bodies into resonances. Besides, hazards due to collisions between such Earth-crossers and our planet have been recognized. The example of asteroid 4179 Toutatis, discovered in 1989 (at the Observatoire de la Côte d'Azur), very near the 3:1 resonance, is presented.
"Stones do not fall from the sky, because there are not any stones in the sky!"

So said XVIIIth century's academics; it is said that they were exasperated to receive so many darkened stones called ‘fallen stones’: "These are thunderstones!", they repeated, "Once and for all, these are only thunderstones!"; we can understand their lost of patience - amateur geologists being then more numerous. Nevertheless, this academic attitude is only a parenthesis in history and, during other times, it was admitted that stones could fall from the sky. Many citations from ancient and modern literature testify to this. Without going back to the Holy Bible ("Josua", ch. 10, v. 11), I would like to cite:

"Je viens vous annoncer une grande nouvelle.
Nous l'avons en dormant, Madame, échappé belle;
Un monde, près de nous, a passé tout du long,
Est chu tout au travers de notre tourbillon;
Et s’il eût en chemin rencontré notre Terre,
Elle eût étébrisée en morceaux comme verre."
(Molière, "Les femmes savantes" -- 1672 --, Acte 4, sc. 3, v. 1265-1270)

together with, more recently, Jules Verne and his "La chasse au météore" (1908) where he tells humoristically of the ‘hijacking’ of a golden asteroid; nowadays, many stories are told or written, cartooned or filmed (like, e.g., Armageddon, a Michael Bay movie -- 1998) about the hazards from fallen stones.

It is now well-known that heavy stones can actually fall on our planet (and, more generally, on any celestial body), leave scars which are impact craters, and have even important consequences on the biosphere. But it was only in the early XIXth century that actual falls of stones from the sky were scientifically established. However, the determination of the origin of these stones remained to be done; for, as the shooting star showers were soon recognised to be linked with comets, a question was left open: where do the largest impactors come from?

It is also in the very early XIXth century that the first asteroids were discovered; and, subsequently, these bodies will give the answer. As soon as the beginning of the XVIIth century, Kepler himself was astonished by