

Oort Cloud Comet Encounters with Mars or Earth

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December 10, 2014

Question: How often does Mars have an encounter with an Oort Cloud comet?
More precisely: what is the mean time between Mars' encounters with parabolic comets at flyby distances less than $d = 140,000$ km? (This is the encounter distance of Comet Siding Spring C/2013 A1 with Mars on October 19 2014. This is also the typical length of a comet's tail; comet tails have a wide range of lengths, some very short and some longer than ~ 30 million km.)

Answer: About once every three million years.

This frequency is estimated as follows.

Oort Cloud comets have a nearly isotropic distribution of orbital planes and an approximately uniform distribution of perihelion distances. The orbits of these comets are of extreme eccentricity, approaching parabolic shapes. The rate of new parabolic comets crossing the Earth's orbit is approximately 3 per 4 years, so very roughly 1 per year crossing Mars' orbit. The residence time of such parabolic comets within Mars' orbit is about 0.2 years. This yields the steady state number of parabolic comets within 1.5 AU of the Sun of about 0.2. So, the steady-state number density of parabolic comets in Mars crossing orbits is about 0.014 per cubic AU; we will denote this by ν . The relative velocity during a Mars' encounter of such parabolic comets is approximately in the range of 20-60 km/s (see Figure). We can estimate the mean time between encounters by imagining that comets are like gas particles moving randomly (in the space near Mars), with a mean speed $V = 40$ km/s relative to Mars. Then the number of encounters in a time interval T is the product of the comets' number density and the volume of the cylinder (or donut) of length $L = VT$, cross-section area $A = \pi d^2$. If we equate this number to one and solve for T , we find the mean time between encounters, $T \approx 1/(\pi d^2 V \nu)$. Plugging in $d = 140,000$ km, $V = 40$ km/s and $\nu = 0.014 \text{ AU}^{-3}$, we find $T \approx 3$ million years.

So, to have witnessed Comet Siding Spring's brush with Mars is truly rare luck!

What about Earth's encounters with Oort Cloud comets?

Also every two-to-three million years!

Because of higher encounter speeds at Earth (see Figure), the mean time between encounters can be expected to be slightly shorter, by 20–25%, but it is similar to Mars' few million years. That Earth is bigger than Mars is of little relevance because the near-brush is defined by the length of the long tail of the comet, not the size of the planet.

A good reference for the topic of comets is Julio Fernandez's monograph, "Comets – Nature, Dynamics, Origin and their Cosmological Relevance" (Astrophysics and Space Science Library, Volume 328 Springer, Dordrecht, 2005).

Oort Cloud comet encounter velocities with Mars and with Earth

