THE FIRST NEO AND THE ORIGIN OF CHAOS

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Many of the ideas at the heart of our current understanding of the motion of NEOs date back to the XVIIIth and XIXth century. They were started by the discovery of a comet on the night between 14 and 15 June 1770 by Charles Messier, one of the most famous comet hunters of all times.

The comet was heading right towards the Earth: in hindsight, it can be considered the very first observation of a NEO approaching our planet. Within a few days, starting from 21 June, it became visible to the naked eye, reaching the second magnitude three days later. The minimum distance from the Earth was reached on 1 July, at about six times the lunar distance, and in a few more days the comet became no longer visible due to its proximity to the Sun. Yet Messier was able to see the comet again starting from the beginning of August and it was observed until the first days of October.

"Portrait of Charles Messier
by Jean Henri Cless (1774–1812)"

A serious problem soon became clear to astronomers: the ephemerides used to recover the comet after its perihelion passage, based on a parabolic orbit, were incapable of accounting for the entire set of observations. It was the Swedish astronomer Anders Lexell who showed that the comet was on an elliptical orbit, such that of Comet Halley (the only other case known at the time). However, it had a period of revolution of 5.5 years, far shorter than Halley's (76 years). Messier then questioned why the comet had not been observed during previous returns, given its short orbital period and its small perihelion distance. The answer by Lexell was that in May 1767, the comet and Jupiter had been very close to each other and the action of the gravity of the giant planet had greatly transformed the orbit

Photo available through creative commons) Adam Christian Gaspari, Christian Gottlieb Reichard (1802) Allgemeine geographische Ephemeriden, Band 10, Weimar: Landes - Industrie - Comptoir Retrieved on 25 November 2011.

of the comet. In fact, before 1767 the comet had a much larger perihelion distance, which meant that it could not become very bright. This explained the fact that it had not been observed before.Lexell did not content himself with these findings. He went on to say that in 1779 the comet would encounter Jupiter again and would be expelled from the inner solar system into an orbit of large perihelion distance and period. This would make it invisible again for the telescopes available at that time. The comet, in fact, was not observed in 1782, as it should have been if it had remained in its 1770 orbit.

In recognition of his findings, the comet, although discovered by Messier, was given Lexell's name.

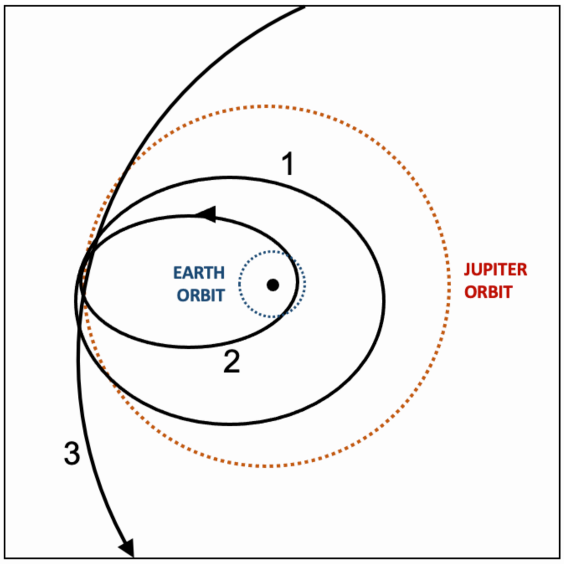
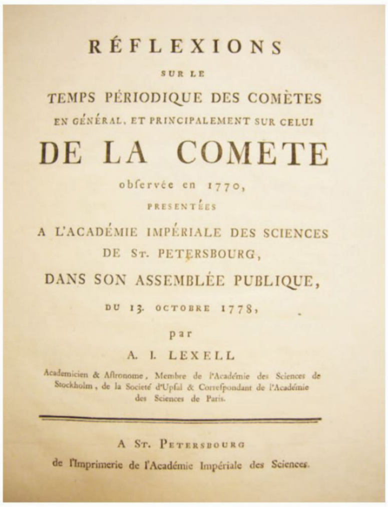


Figure caption: Comet Lexell orbits:
1) before the 1767 Jupiter encounter;
2) during the 1770 discovery apparition;
3) after the 1779 encounter with Jupiter.



RÉFLEXIONS
SUR LE
TEMPS PÉRIODIQUE DES COMÈTES
EN GÉNÉRAL, ET PRINCIPALEMENT SUR CELUI
DE LA COMETE
obfervée en 1770,
PRESENTÉES
A L'ACADÉMIE IMPÉRIALE DES SCIENCES
DE St. PETERSBOURG,
DANS SON ASSEMBLÉE PUBLIQUE,
DU 13. OCTOBRE 1778,
par
A. I. LEXELL
Academicien & Aftronome, Membre de l'Académie des Sciences de Stockholm, de la Societé d'Upfal & Correfpondant de l'Académie des Sciences de Paris.

A St. Petersbourg
de l'Imprimerie de l'Académie Impériale des Sciences.

Lexell's original publication on the comet

But this is not the end of the story. About seventy years later, Urbain Le Verrier – who was soon to become a celebrity for predicting where to search for planet Neptune – critically re-examined the case for Lexell. He concluded that it was not possible to determine a reliable orbit of the comet because the observations were insufficient.

"Portrait of Urbain Le Verrier"

However, the situation was not totally desperate. Le Verrier was able to constrain the possible trajectories of the comet by expressing them as a function of a single unknown parameter, that he called mu: outside a certain range of mu values, the path of the comet on the sky would have been measurably different from the observed one. Note that his reasoning is surprisingly modern as it can be considered the direct ancestor of the determination of the so-called "confidence region" for the orbit of a near-Earth object. Finally, Le Verrier computed the effects of the 1767 and 1779 encounters with Jupiter undergone by comet Lexell for the admissible values of mu. In this way, he obtained a global view of all the possible outcomes. This procedure, again, was very similar to the systematic computations carried out nowadays by modern NEO impact monitoring systems.

Le Verrier concluded that in 1779 the comet could have approached Jupiter as close as less than three and a half radii of the planet from its centre, but could not have become a satellite for any allowed value of mu. The post-1779 trajectories included even the possibility, for the comet, to leave the solar system on a hyperbolic orbit, thus becoming what we call today an "Interstellar Object".

The reason for the wide range of possible outcomes found by Leverrier was the extreme sensitivity of the orbital evolution to the precise value adopted for mu. This sensitivity is a crucial part of the modern concept of chaos (small changes result into large differences), and in fact Le Verrier's computations probably represent the first instance of this concept in scientific literature. The studies of the dynamics of small solar system bodies on chaotic orbits, such as NEOs, had entered the modern era.

TUMBLING STONE REVISITED

This article first appeared on the on-line journal "Tumbling Stone", published by the Spaceguard Foundation. Historically, this was the first entity addressing planetary defense in the early 2000s. Luckily for us, some of the Neorockers were involved with Tumblingstone and with the kind permission of the journal editors, Nanni Riccobono and Livia Giacomini, we have the pleasure to revisit some of their excellent articles in our newsletter.

Photo available through creative commons) Commons upload by File Upload Bot (Magnus Manske) 13:07, 22 May 2006 (UTC).

GLOSSARY

What is the Magnitude?

The brightness of any celestial body (stars, asteroids, planets, etc) is measured by a quantity called magnitude. The modern magnitude scale relies on a mathematica exponential law which allows a precise expression of the brightness and extends to both extremely bright and very dim objects. The lower the magnitude (including negative values), the brighter the object. Naked-eye objects can reach up to magnitude 6 on an extremely dark night. The magnitude of the Moon is -12.5.

Who is Messier?

Charles Messier (1760-1817) became an astronomer, inspired by childhood sightings of comets and a by a solar eclipse visible from his home town of Badonvillier, in France. As a celebrated comet hunter, he kept careful records of his observations while hunting for comets which resulted in a detailed list of approximately 100 diffuse objects that were difficult to distinguish from comets but they were notsince they did not move with respect to the background stars. This list became famous as the "Messier Catalog" and is still well known as a collection of the most beautiful objects in the sky including nebulae, star clusters and galaxies.

Who is Lexell?

Anders Lexell (1740 – 1784) was born, studied and graduated in Sweden, where he became appointed professor of mathematics. He was then invited to the St Petersburg Academy of Science, where he started working from 1769 with Euler and other high quality scientists, becoming appointed professor of astronomy in 1771. Lexell stayed in St. Petersburg until his death, working mainly in the area of analysis and geometry. In astronomy, Lexell is famous for having computed the orbits of several comets, including the comet of 1770, that was named after him and for having recognized that the celestial body discovered by William Herschel in 1781 was actually a new planet (later named Uranus).

Who is LeVerrier?

Urbain Jean Joseph Le Verrier (Saint-Lô, 11 marzo 1811 – Parigi, 23 settembre 1877) was an oustanding celestial mechanician of his time. He is remembered worldwide for having contributed to the discovery of Neptune by predicting its position in the sky - a major result since until then discoveries were obtained only through extended sky surveys. He was director of the Observatory of Paris for almost 20 years.