

The Solar System

HWB

1 From Greeks to Kepler

The configurations and motion in the night sky have always puzzled mankind, especially when there were not so many big cities polluting the night-sky with light.

At least from the Greeks on, more or less systematic study was made of the motion of stars, planets and the Moon. Remarkable were the planets with their retrograde motions (backward loops).

Ptolemy came with a systematic way to describe these motions, based on the platonic concept of circles: it was like playing with complicated spirographs.

By the end of the Middle Ages Copernicus made the Sun more central. Still lateron Kepler came with his other notorious laws I, II and III, that some of you may have learned at school. In law I He introduced the ellipse as the orbit of a planet. (Law II describes the speed of the planet and law III compares ellipses and periods of two planets.)

This is quite a well known story, beautifully descibed in ‘The Sleepwalkers’ by Koestler.

2 Via Newton, Laplace and Poincaré

Then came Galileo and Newton. Galileo saw some satellites of Jupiter. Newton used their motion to dare postulate universal gravity: Kepler III also holds for these. (In certain philosophies of science this might be called a Crucial experiment.)

This led to perturbation theory. The interaction of the planets destroys the elliptic motions of Kepler I. This gave Newton headaches.

2.1 Social relevance

In the seventeenth century navigation relied on astronomical observation. Various devices were used to determine ones position at Sea (both altitude and lattitude). One method was by using documented starcoverings of the Moon.

This kind of ‘perturbation theory’ used to be a main stream part of Mathematics and Natural Sciences. Nowadays we have geostationary satellites ...

2.2 Philophy

There was also a more philosophical question, concerning the stability of the Solar system when the hand of God is lacking: Just good old Newton’s equations of motion. This went from Laplace on, say around 1800. Let me explain this.

2.3 Predictability

Mankind are used to a quite predictable Solar System, such as eclipses, conjunctions, Eastern dates.

This largely amounts to almost (or quasi-) periodicity: roughly speaking this is periodicity where the period grows with the precision of the observation. Think of the motion of the Moon, that in a very rough description has a period of around 28 days, but if for a more precise description needs almost 19 years.

3 Quasi-periodic versus Chaotic

Letting alone tidal effects to a large extent the Solar System can be considered conservative: there is no loss of energy. The heavenly bodies often are regarded as point masses or as rigid bodies, but not as something elastic.

3.1 Poincaré

Poincaré, a little before 1900, made it doubtful that in this conservative context the Solar System generally is so predictable. In systems like this, instead of the one evolution we ‘are’ on, he considered all possible evolutions. For non-mathematicians this may sound strange.

3.2 KAM

For a while it seemed possible that quite a lot of motions might still be almost periodic, and ‘our’ evolution might well be one of these. This kind of thought was announced by Kolmogorov in Amsterdam, at the IMU meeting of 1954. For a photo see the third floor of the IWI building.

Later on Kolmogorov’s ideas were proven by Arnol’d and Moser in the 1960’s.

3.3 Doubts remain

Nevertheless, for the formal proof, the interactions between the planets had to be unrealistically small and many people still had doubts.

4 Laskar

4.1 Modern Mathematics

Celestial Mechanics studies the motions inside the Solar System. Nowadays, concepts from the relatively new discipline of Dynamical Systems, permeate this. One of these concepts is INVARIANT MANIFOLD (already due to Poincaré). Also advanced numerical methods play an important role.

4.2 Organisation

From this point of view, not only all possible evolutions of ‘our’ Solar System have to be considered, but also other possible constructions of the Solar Systems. This may again be interesting for theologicians. It turns out that chaos and resonance are catchwords here. Let me now introduce the speaker to you.

4.3 Person

Professor Jacques Laskar has worked on the Newtonian Solar System from the Dynamical Systems point of view, also using modern computational techniques. Also he pointed out the role of the Moon for the stability of the Earth and its climate. Now his techniques are also applied to study the Earth climate in the past. Many of us have read about his works in the Scientific Columns of the Newspapers.

Laskar has a mathematical background, with a PhD at the OBSERVATOIRE de PARIS-MEUDON. Nowadays he leads a multidisciplinary team at the BUREAU des LONGITUDES, at Paris.

Jacques was distinguished several times:

1. by the Prix de Pontécoulant of the French Academy of Science (1993),
2. the IBM Price (1993) and
3. the silver medal of the CNRS (1994).

It is both an honour and a pleasure for us to have you here in Groningen.
May I invite you to deliver the the tenth Johann Bernoulli Lecture !