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The detection of tidal dissipation among planetary systems with the NAROO project: observing in the past

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Abstract

The systems of natural planetary satellites are often compared to a compact solar or extra-solar system. They are evolving fast with a typical period of revolution of a few days. The presence of a massive planet and eccentric orbits induces tidal dissipation in the satellites and their primary. Space probes have measured the heat flux induce by tides at the surface of Io and Enceladus but have not been able to provide the global dissipation inside celestial objects. Thanks to astrometric monitoring, dynamical studies of the satellites through astrometric observations allow measuring the global energy dissipated inside the satellites and their primary through the observation of the evolution of the orbit.

1. The cumulative effect of the tidal forces

Since tidal dissipation implies a time lag in the response of the tide raised body, secular exchange of energy and angular momentum between the satellites and their primary occur.

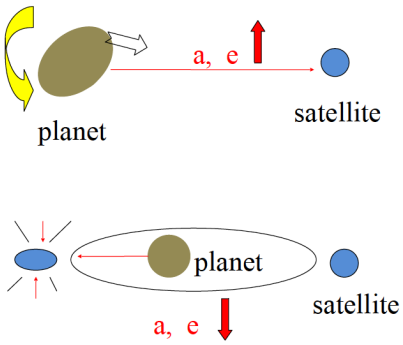

Figure 1: Tidal effects in a satellite and its primary.

As a consequence, secular accelerations (quadratic terms in time) on the longitudes of the satellites can be eventually determined from astrometric observation. In particular, these acceleration can be fairly well separated from other perturbations which usually provide secular trends (linear terms in time) on the orbits, only.

2. The astrometric observations

Astrometric observations are needed to fit the dynamical models. More, the time span of observations needs to be as large as possible to quantify properly the long periodic terms present in the systems.

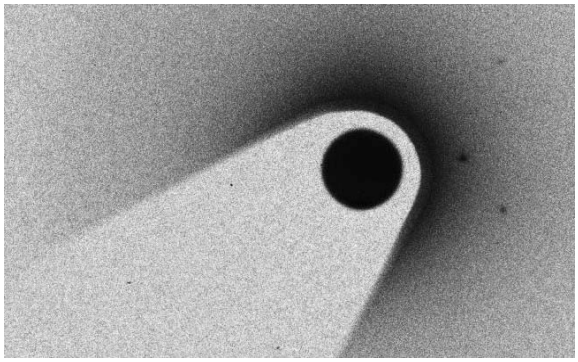

Figure 2: Photographic plate: the planet Mars under a metallic filter: at right, Phobos, Deimos and a star.

Astrometric observations are of different kinds: first the ground-based observations either direct positions on the celestial sphere or phenomena corresponding to a specific geometrical configuration providing positions of the objects in space; second the observations from space probes much more accurate but made on very short intervals of time and unable to describe long term evolution. Both are necessary. Ground-based observations are photographic plates made from the end of the XIXth century and CCD images made starting in the 1980's. Visual micrometer observations made during the XIXth century (and before) may be useful: in fact, only a few of them, made mainly with heliometers, are still used for the fit of the dynamical models. Visual observations of phenomena are used only in the case of the eclipses of the Galilean satellites: old eclipses observed at the end of the XVIIIth century are still

used. Older observations are not enough accurate to be useful with modern theories: biases and noise prevent to find any signal in the data.

3. Observing in the past: the NAROO project

3.1 A new reduction

Our project is to re-reduce old observations using new reference star catalogues. The near arrival of the Gaia catalogue, the accuracy of which being at least 100 times better than the present catalogues, will be a revolution. The limitation of the astrometric accuracy was in the use of catalogues. After Gaia, it will not be the case and all the reduction procedures should be improved. More, the proper motions of stars determined by Gaia will allow to go back in the past one century ago. We will be able to observe in the past with today accuracy.

3.2 Scanning photographic plates

We selected photographic plates made in the 1960's since the present catalogues do not allow to go back further in the past because of the poor determination of the star proper motions. We digitized the plates using the sub-micrometric scanner DAMIAN at the Royal Observatory of Belgium providing measurements accurate to 0.070 micrometers that corresponds to one to two mas on the celestial sphere. The reduction was made using the UCAC2 reference star catalogue. Of course we were limited by the accuracy of the star catalogue but we got results much better than the first reductions. We analyzed plates of the Martian and the Jovian systems made at the U.S. Naval Observatory in Washington DC, USA. Figure 2 shows an image of the Martian system: the digitization of the plate allowed us to extract much more stars than using the manual original measurements. More, all stars are now catalogued that was not the case 50 years ago. The accuracy obtained today with these plates is the same than the accuracy of observations made at the same time by the space probe Mariner.

4. First results on the Jovian system

We applied our new reductions to the satellites of Mars and Jupiter. We were able to determine right ascensions and declinations of the satellites allowing getting the positions of the planets that was not possible at the time of the first reduction.

Table 1: Results on the Jovian system: residuals and standard deviation in mas

	$\overline{(O-C)}_{\alpha\cos\delta}$	$\sigma_{\alpha\cos\delta}$	$\overline{(O-C)}_{\delta}$	σ_{δ}
DE421	-1.7	63.0	40.0	73.1
DE423	-1.8	62.8	38.1	71.5
INPOP06	-6.1	63.0	37.4	71.6
INPOP08	44.1	69.3	47.8	91.6
INPOP10	3.0	62.8	37.4	71.1
EPM08	-2.3	63.1	37.6	71.3

Table 1 shows results on the dynamics of Jupiter: several models are available and our new reduction of old data shows that some models are better for describing the motion of Jupiter. More, it is clear that all models are not able to describe the motion in declination. Concerning the satellites, we were able to determine an acceleration for Io, Europa and Ganymede, signature of a dissipation of energy using old data before a new reduction [1]. After reduction using the Gaia catalogue, it will be easier to determinate such accelerations for more satellite systems.

6. Conclusion

Our preliminary results show that a new reduction of old data is necessary and will be fruitful. Besides photographic plates, all CCD ground-based and space observations made before the arrival of the Gaia catalogue will be worth to be re-reduced.

Acknowledgements

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