**Work program for Altair Junior: (12 months)**

In the last decade, progress in astrometry and orbital modelling of planetary moons made possible the accurate estimation of tidal effects in natural satellites and their primary (Lainey et al. 2009; 2012). Important consequences for the interior of the celestial objects were derived. As an example, possible thermal equilibrium state within Io (the innermost of the large Jovian moons) was deduced from the agreement between orbital energy loss and heat evacuated at Io’s surface. Relying on large spanning time of observation, these studies provided important constraints on short and long term dynamics, up to formation processes (Charnoz et al. 2011). In that respect, the high tidal dissipation within Saturn obtained from astrometric data suggested that many moons could be much younger than the age of our Solar system. While these results still wait to be improved by more astrometric data, it is now time to look at further systems than Jupiter and Saturn. In particular, theoretical modelling of Giant planets (Remus et al. 2012) suggests that strong dissipation may occur in icy giants also, opening the way to a possible quantification from the moons orbit.

The current project consists in extending our monitoring of tides in planetary systems to the Neptune’s system. Recently, UFRJ and ONB could reduce about 7000 astrometric observations of Triton, the largest moon of Neptune, and its primary. This large dataset offers the opportunity to reinvestigate the dynamics of the Neptune’s system, having in mind possible secular effects on the longitudes associates with tides.

Here, we shall benefit from the venue of Mr Altair Junior at IMCCE for a full year. This will be a great opportunity for collaboration between IMCCE, UFRJ and ONB. The highly significant numbers of astrometric observations performed and reduced by Mr Altair Junior, and his expertise in the field, will largely contribute to improve our knowledge of tides in the system as well as assessing the real accuracy of Neptune’s ephemeris.

Moreover, there exist many older astrometric observations (from ground and space) that should be considered simultaneously in the fitting procedure. IMCCE has developed a methodology for gathering such a large amount of sparse data. Still, this method has not been applied to the Neptune’s system yet. As a consequence, Altair Junior shall devote some non-negligible time on this important step. Once a large dataset of astrometric observations will have been made available, Altair Junior will investigate the possible quantification of tides and their consequences on the dynamics.

To that aim, IMCCE has developed a numerical code called NOE (Numerical Orbit and Ephemerides) that has been extensively used for orbit fitting of natural moons (Lainey et al. 2007, 2008, 2009, 2012). Hence, during his stay, Altair Junior shall use NOE code to perform his study. We believe that four months should be enough for performing a global astrometric fit, including tides. Four other months may well be required to analyse the physical parameters obtained. It is noteworthy to recall that Neptune’s positions are also available, allowing the possibility to assess the accuracy of planetary ephemerides too. While planetary ephemerides are tightly constrained by many space mission data, most constraints for Uranus and Neptune systems arise from ground astrometry. In that respect the present study shall provide significant advances.

Last but not least, the quest for tidal acceleration on orbital longitudes of moons has gathered after few years many different expertise. This includes dynamics, planetology, stellar physics and of course astrometry. Hence, during his stay in France, Altair Junior shall be introduced to the ENCELADE 2.0 International team, funded by the International Space Science Institute. This shall be a perfect place for a PhD student to enlarge his knowledge of astronomy and astrophysics.

**References**

Charnoz et al. Icarus, Volume 216, Issue 2, p. 535-550 (2011).

Lainey et al., The Astrophysical Journal, Volume 752, Issue 1, article id. 14, 19 pp. (2012).

Lainey et al., Nature, Volume 459, Issue 7249, pp. 957-959 (2009).

Lainey, V. Planetary and Space Science, Volume 56, Issue 14, p. 1766-1772 (2008).

Lainey, Dehant, Paetzold, Astronomy and Astrophysics, Volume 465, Issue 3, April III 2007, pp.1075-1084 (2007).

Remus et al. Astronomy & Astrophysics, Volume 541, id.A165, 17 pp. (2012).

**Schedule:**

Task 1 (months 1-2): Collecting all old astrometric data of the Neptune’s system

Task 2 (month 3): Collecting spacecraft astrometric data

Task 3 (months 4-5): Fitting NOE code to the whole set of data (without tides solution)

Task 4 (months 6-7): Fitting NOE code to the whole set of data (with tides solution)

Task 5 (months 8-11): Analysis of tidal solution and Neptune’s ephemeris real accuracy

Task 6 (month 12): writing a publication

Task 1 consists in collecting the largest set as possible of old astrometric data of the Neptune’s system. Computation of residuals with already existing ephemerides may be done. The generation of a global observing file following the IMCCE-NOE format will be done.

Task 2 deals with Voyager astrometric data available from JPL website. The student will use IMCCE’s software to convert the .PSF files from JPL to internal fomat.

In task 3, the student will benefit from the use of NOE code to fit his large collection of astrometric data. One or two months may be required to learn the principles behind the code and its use.

Task 4 is similar to task 3, but now introduces tidal effects in the dynamics.

In task 5, the student will perform a detailed analysis of his results from tasks 3 and 4. In particular, he will try to estimate the error coming from the observations and Neptunes ephemeris, respectively.

Before the end of his stay in France, Altair Junior shall start writing a publication in common with IMCCE researchers.

NB: If time allows, or if the candidate shows some interest, it could be relevant during the project to look at unreduced images from VLT and HST of the Neptune’s system. Indeed, the system has been observed most of the time for other goals than astrometry. Reprocessing such images using astrometry techniques could be highly valuable.