Rapprochements mutuels intersatellites

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Intérêts du positionnement

Objectif

Affiner avec toujours plus de précision les modèles dynamiques satellitaires !

- Analyse des effets cumulatifs en complément des observations anciennes
- Mesure de la dissipation dans les corps
- Mesure des flux de chaleur en surface
- Amélioration de l'extrapolation des éphémérides
- Validation des scénarios de formation des satellites
- ...

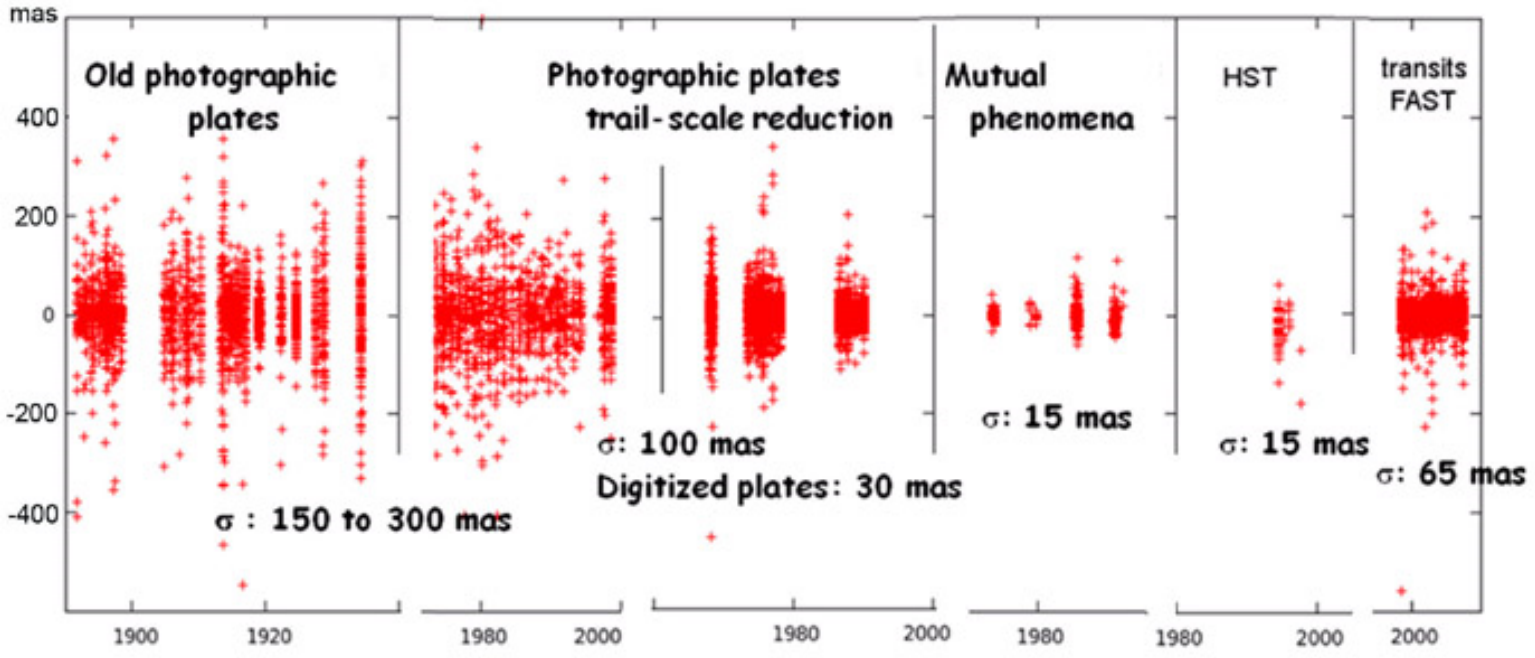
Astrométrie "classique" CCD : calcul de positions (α, δ)

- processus de réduction adaptables et éprouvés (+)
- automatisation/routinage possible (+)
- difficultés liées au système de référence (-)
- problèmes de l'instrumentation –> champs limités (-)
- magnitude des corps et compensation –> peu d'étoiles (-)

Phénomènes mutuels : occultations et éclipses

- grande précision –> photométrie différentielle (+)
- rareté des événements à 1/2 période synodique (-)

Précisions astrométriques



Dérives en longitude sur le mouvement des satellites.

Question

Peut-on synthétiser les méthodes astrométrique visuelle et photométrique pour allier fréquence des phénomènes et précision ?

Quelques critères et recommandations :

- accessibilité
- praticité
- pallier le manque d'informations récentes et constantes

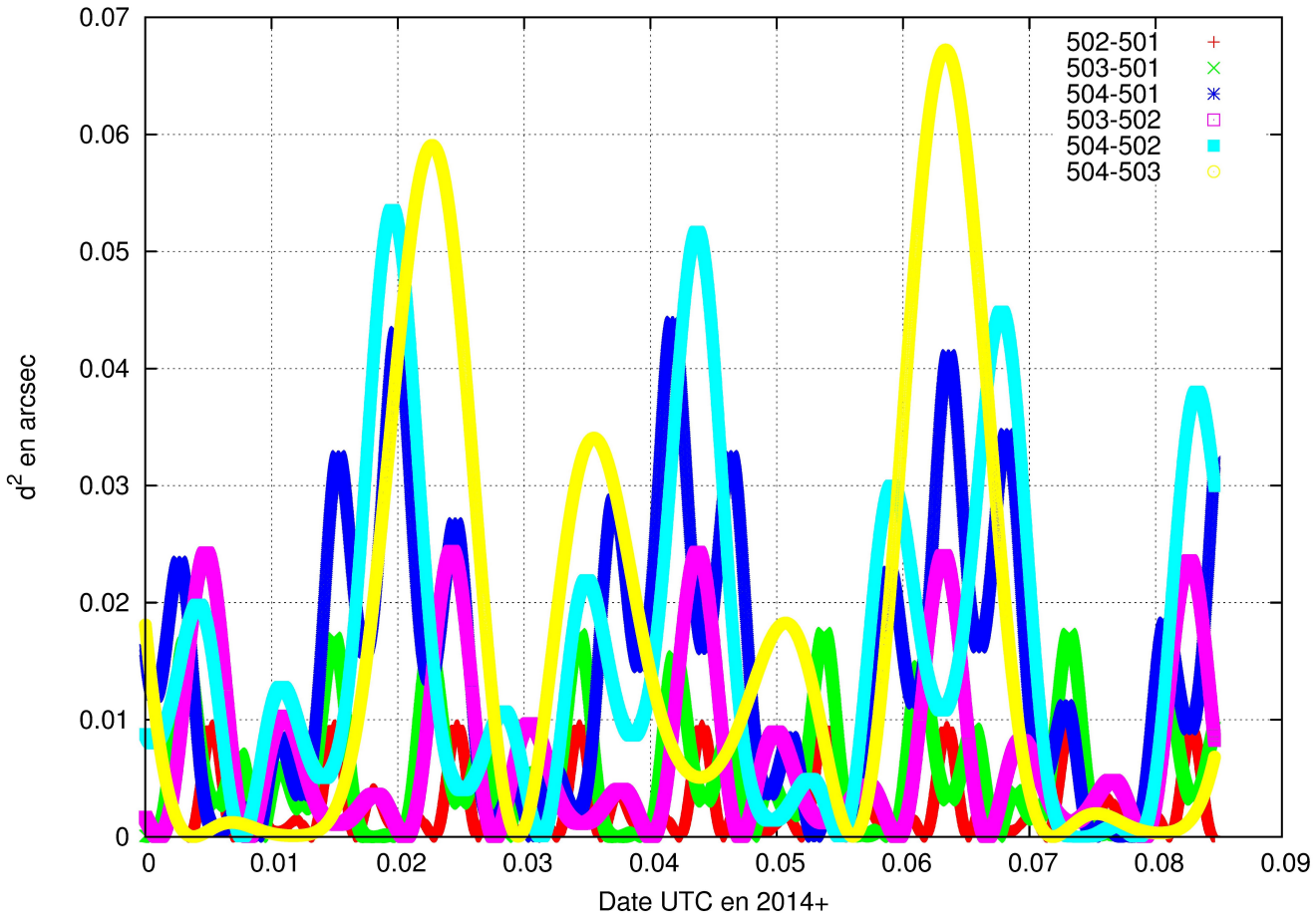
Généralités et tests préliminaires

En général

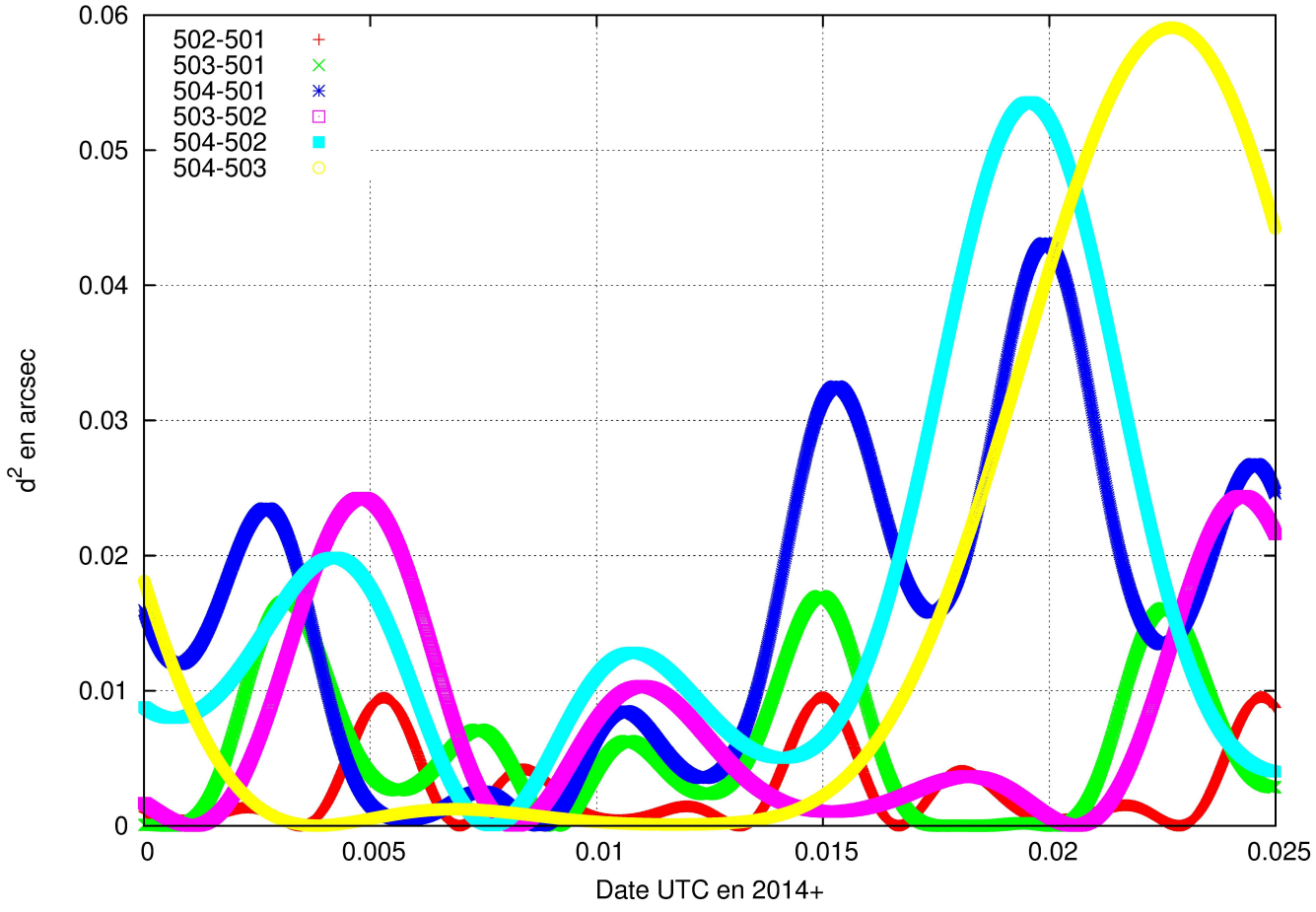
- Mesure échantillonnée des distances entre deux satellites au moment de leur approche minimale ou éloignement maximal
- Mesure de l'instant précis de l'extremum

Avantages

- Les effets atmosphériques et instrumentaux sont compensés
- Les effets de phase sont compensés
- Les transformations entre repères de référence sont inutiles



Phénomènes de distances des galiléens sur 1 mois.



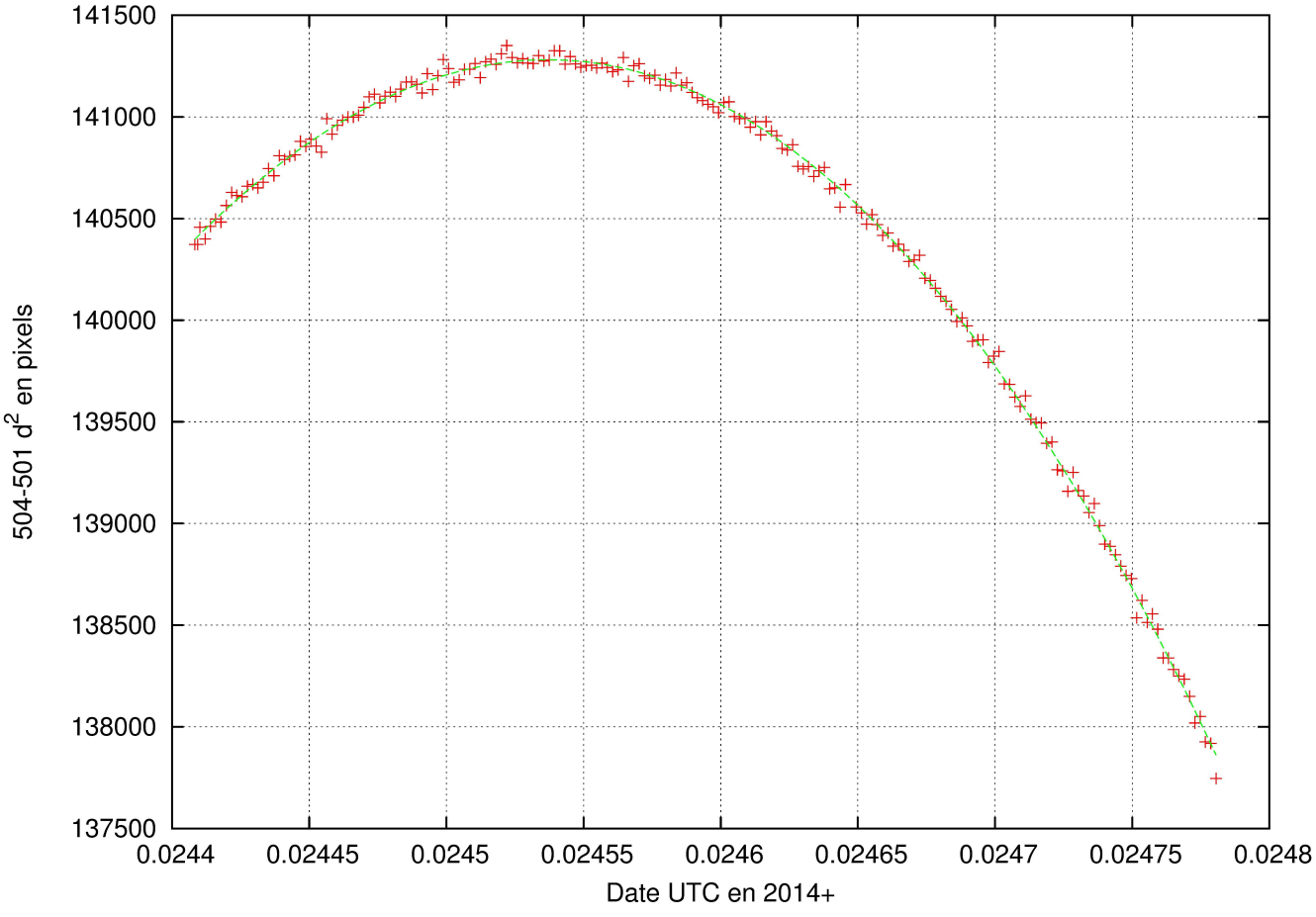
Phénomènes de distances des galiléens sur 1 semaine.

Fréquence des événements :

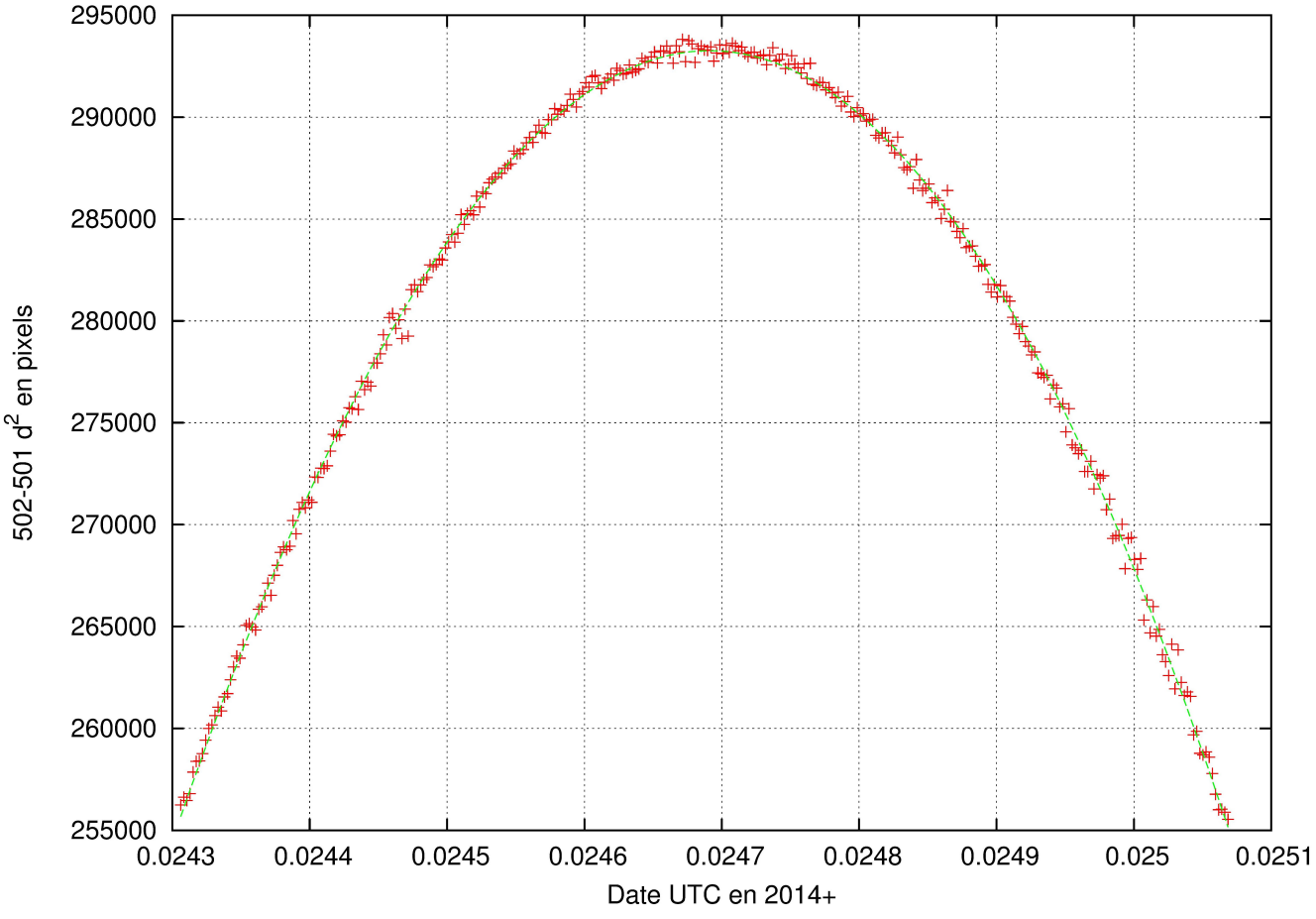
- on considère une probabilité à C_n^2 phénomènes
- 7 événements possibles pour les galiléens
- 36 événements possibles pour les satellites de Saturne

Tests préliminaires :

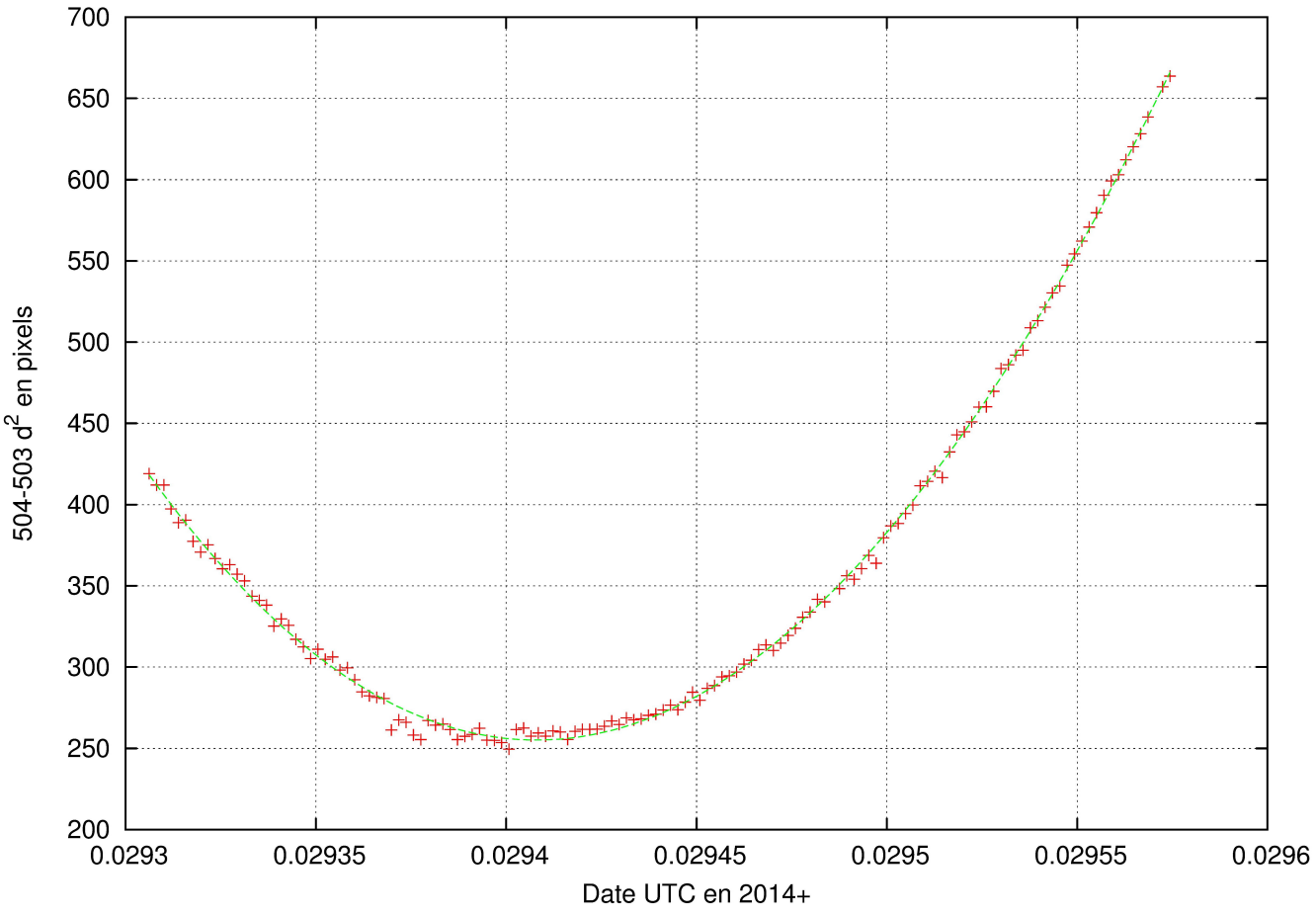
- 3 amateurs ont répondu : MM. Anfray, Conseil et Moindrot
- courbes et ajustements réalisés sur les phénomènes de décembre 2013 et janvier 2014



Éloignement Io/Callisto le 09 janvier 2014.



Éloignement Io/Europe le 10 janvier 2014.



Rapprochement Ganymède/Callisto le 11 janvier 2014.

Précision

La précision d'ajustement est inférieure au 1/10ème de seconde !

Justesse

Des biais allant jusqu'à plusieurs secondes persistent !

Premiers éléments :

- travail de qualité à fort potentiel
- une précision au rendez-vous
- une méthode éprouvée et revue

En vrac :

- quelques rapprochements problématiques selon la configuration apparente
- éloignements plus simples à traiter ?
- quid du FOV ?
- quid du calage temporel ?

Conclusion et perspectives

Méthode d'observation

Le plus simple possible ! ! !

Méthode d'observation

1. Checker la liste des phénomènes disponibles
2. Utilisation APN/CCD.. en mode RAW/FITS
3. Calage temporel
4. Utilisation d'une densité
5. Début des poses 10 minutes avant l'instant théorique de l'extremum choisi
6. Fin des poses 10 minutes après l'instant théorique de l'extremum choisi
7. Taux d'échantillonnage le plus faible possible

Participation “simple” :

- observation
- transfert des données sur FTP

Participation “avancée” :

- observation
- détermination des positions
- ajustement des courbes et détermination des instant extremums
- transfert des données et résultats sur FTP

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Observation techniques : improving the dynamics of planetary systems with time constraints

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ABSTRACT

Context. The measurements from photographic plates and CCD observations and the photometry of the mutual occultations and eclipses are the two main methods used to infer accurate astrometric data of the observed planetary satellites. This is achieved by processing measured positions or light curves of the events.
Aims. This work focuses on a new observation method that merges visual and photometric techniques. The main goal is to provide an accessible, convenient and suitable method to constraint satellite ephemerides either by the positions but by the moments.
Methods. We first used a satellite model to look for time spans for which observed intersatellite distances should reach an extremum and we made corresponding visual observations when the satellites became closest or farthest. We finaly measured accurate times for which the distance derivatives were zero.
Results. We made sets of visual observations of the Galilean moons at the Observatoire de Haute Provence in 2013, November. We also encouraged observers to make observations and share their data, in order to experience the accessibility of the method and the accuracy of the results if we should organize campaigns. We processed available sets from 2013, November to 2014, January to provide "distance curves" that are analog to light curves and we determined the extremum moments in intersatellite distances. The root-mean-square (rms) of the time residuals with respect to the most recent IMCCE Galilean theory is equal to **XXX** sec, corresponding to **XXX** km.
Conclusions. In addition to providing precise times to constraint satellite ephemerides instead of positions, our method offers many advantages compared to visual and photometric techniques. It is a merging of these two methods and because of its ease of application, it is accessible to professional and non-professional astronomers, and convenient because it is independent of various spherical effects. Extremum moments in the relative satellite distances also appear more ofently than mutual events, at least at each satellite elongation, thus more constraint informations with comparable accuracy are available to improve the satellite ephemerides.

Key words. observation methods – ephemerides – planets and satellites: general

1. Introduction

Visual observations and photometric observations of mutual events of the natural planetary satellites are the two main methods used to infer accurate astrometric data. On the first hand, the positioning accuracy mainly depends on the object measurements, the number and the accuracy of the reference stars used to calibrate the field, and on the spherical and instrumental corrections applied. The positioning accuracy is generally provided in mas, or in kilometers. On the other hand, the accuracy of the phenomena observations mainly depends on the size of the objects and their shadows. The corresponding accuracy is generally provided in kilometers.

We need astrometric visual observations and/or photometric observations to study the dynamics of the natural planetary satellite systems. These observations should be sampled over an interval of time as long as possible, in order to quantify the long period terms which may help to analyse the evolution of the motion. Concerning the visual observations, the problem is that no major observation campaigns are maintained to get regular positioning data of the natural planetary satellites. More, the accuracy of the astrometric data fisrt depends on the quality of the observations, that is not accessible to non-professional observers. Concerning the photometric observations, the problem is that the number of observable events of planetary satellites fisrt depends on the ground location and the geometric configuration of the planetary system with respect to the Earth, and is also very limited. In these two cases, we do not have enough recent and regular positioning informations to constraint satellite ephemerides.

We here provide an original observation method that is a merging of visual and photometric techniques. We wanted it to be accessible and convenient so that professional and non-professional observers could easily get informations to overcome the lack of accurate positioning data.

* Based on observations made at Observatoire de Haute Provence (CNRS), France and Observatoire de Meudon (CNRS), France

The paper is arranged as follow. We first describe the distance phenomena in Section 2. We then detail the observations made to experiment the method and the image-processing techniques. In Section 4, we provide intersatellite distance curves, the results of their analysis and the comparison with satellite models. We finally give conclusions in Section 5.

2. Distance phenomena

Just because of the motion of the natural planetary satellites around the center of mass of their system, one should figure that there are moments for which a satellite can be visually closest or farthest from another. In consequence we can focus on time spans for which intersatellite distances should reach an extremum, and measure the accurate time corresponding to a zero distance derivative that we here call "distance phenomena" or "phenomena".

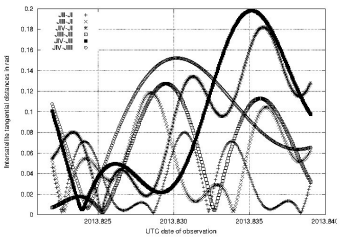

Fig. 1. Intersatellite tangential distances of the Galilean satellites over a week.

To illustrate these phenomena, Figure1 plots the intersatellite distances of the Galilean satellites over a week. We can easily find minimum and maximum relative distances and so that identify corresponding moments. We can also see numbers of phenomena: we there count 39 zero distance derivatives within several days.

More generally, we admit that the number of possible intersatellite relations is defined by the simple C_n^2 term, where n is the number of natural satellites of the considered planetary system. In that sense and for example, we could expect 7 different distance phenomena for the Galilean moons and 36 for the 9 major Saturnian satellites. The frequency of these phenomena will then depend on the respective orbital periods of the satellites, and their number will always be effectively greater than mutual events'. Finally, the magnitude of the relative distances will depend on the ground location of the observer and will not have any influence on the results.

3. Test data

3.1. Sites of observation

We first made sets of visual observations of the Galilean satellites in 2013, November with the T80-telescope at the Observatoire de Haute Provence (OHP, IAU code 511). Because we wanted to overcome the technical constraints and so that to observe in the easiest way as close as the non-professional's, we used the intrument with saturating CCD and a plain 1.0 density filter to reduce the brightness of the planet and satellites.

We also encouraged observers to make observations and share their data, in order to experience the accessibility of the method and the accuracy of the results if we should organize campaigns, and because our goal is to get as many information as possible. Three non-professional astronomers contributed and used different instruments and receptors, thus we got phenomena observations from 2013, December to 2014, January. The specifications of the materials and locations are given in Table1.

3.2. Observations and image-processing

There is no constraint with the instrument used while we can separate and measure the satellites involved in the observed phenomena, on the images. We then chose to begin observations at the minimum 1 hour before the extremum moment of the distance phenomena and finish at the minimum 1 hour after. This with observations made every 5 minutes in order to get enough data for the curve fitting.

The easiest way to provide distance curves is first to produce tables with (x, y) measured positions of the objects, in pixels, with regard to the most accurate dates of observations. One can use different solutions to process the images and extract the satellite positions, depending on the file format (FITS, JPEG, BMP, ...). A possibility is to use the Source Extractor software (Bertin et Arnouts, 1996) to determine the center of figure of the objects; free tools are also available on the Internet to do so, we think about the IRIS and PRISM softwares for example. We compared the positions given with these three solutions and no significant differences were noticed (Figure**??**).

4. Distance curves

Distance curves were deduced from CCD measurements without any spherical correction. We give in Figure**??** to Figure **??** squared intersatellite distances d^2 with regard to the UTC date of observation.

4.1. Time constraints

Time constraints...

4.2. Velocities

Velocities...

5. Conclusion

Conclusion...

References

[1996] Bertin, E. —— 1996
[1989] Kaplan —— 1989
[2006] Lainey, V. —— 2006
[1977] Lindegren —— ???

Questions