DOES 146 LUCINA HAVE A SATELLITE? AN ASTROMETRIC APPROACH J.-B. Kikwaya[1,2], W. Thuillot[2], P. Rocher[2], R. Vieira Martins[3], J.-E. Arlot[2], Cl. Angeli[3], [1]Vatican Observatory, V00120, Vatican City State, kikwaya.eluo@free.fr,[2] Institut de mécanique céleste et de calcul des éphémérides IMCCE/Paris Observatory, 77 avenue Denfert Rochereau 75014 Paris (France) thuillot@imcce.fr, [3]Observatorio Nacional, 586 Sao Cristovao 20921

Introduction: Several observational methods have been applied to detect asteroid satellites. Rotation lightcurves, stellar occultations and space observations have moved the existence of binary systems from supposition to certainty. More recently, direct imaging with adaptive optics and radar has confirmed the existence of a significant population of such objects. Nevertheless, the detection of new systems and the acquisition of accurate data about them remain a challenge.

We are applying an astrometric method to detect new asteroidal satellites, based upon the reflex effect of the primary object due to the orbital motion of a possible satellite. Such an astrometric signature, as searched for by Monet & Monet [4], may reach several tens of milliarcseconds (mas). Here we propose to apply a spectral analysis to detect this signal, which however requires a good signal/noise ratio, high quality astrometric measurements and coverage at different observation sites.

Purpose and method: The detection of binary asteroidal systems has many implications. It can help us understand the origin of the asteroid families and the collisional processes involved in their evolution. It gives observational constraints for the dynamical study of their stability. It also improves our knowledge of their morphology and physical characteristics, particularly their mass and density determination, and consequently the nature of their material.

According to Monet & Monet [4], a wobble effect due to the revolution of a satellite around a primary object can be detected by classical astrometric CCD measurements when such a system is close to the observer, provided that at least 50 mas of accuracy is obtained. Thus NEA companions appear to be good candidates for this type of detection. Here we attempt to extend this idea to the detection of more distant objects.

Figure 1 shows the values of the wobble effect on the primary caused by the motion of the system around a barycenter computed assuming uniform circular orbits. Few milliarcseconds have to be detected.

Depending on the closeness to its pericenter, each binary asteroid may be in favorable (•) or unfavorable (°) configuration to allow us to detect this effect. Furthermore, the astrometric detection of the wobble effect requires the measurement of the position of the main component alone. This is why in Figure 1 the diameter ratio D2/D1 can be used to select asteroids with a main component brighter than the satellite. Contact binaries or double asteroids (e.g. 90 Antiope) with a diameter ratio close to 1 will not be well suited for this detection.

The method consists in performing accurate astrometric observations of suspected periods of revolution of the satellite, getting O-C quantities from the adjustment of the dynamical model, and searching for a periodical signal in these quantities by Fourier analysis.

Application to 146 Lucina: 146 Lucina is a suspected binary asteroid [1] since a short occultation event was observed from Meudon (France) in 1982. The astrometric analysis, simultaneously performed, was confirmed by Spanish observers using the occultation method. However, the existence of this satellite has not been confirmed by further investigations; space observations could neither confirm nor refute this result [5].

377 observations, usually in the R filter, were made at the 1.2 m f/6 telescope of the Haute-Provence Observatory in the south of France from 1998 to 2000, using a 12'x12' field of view CCD camera with a resolution of 1024x1024

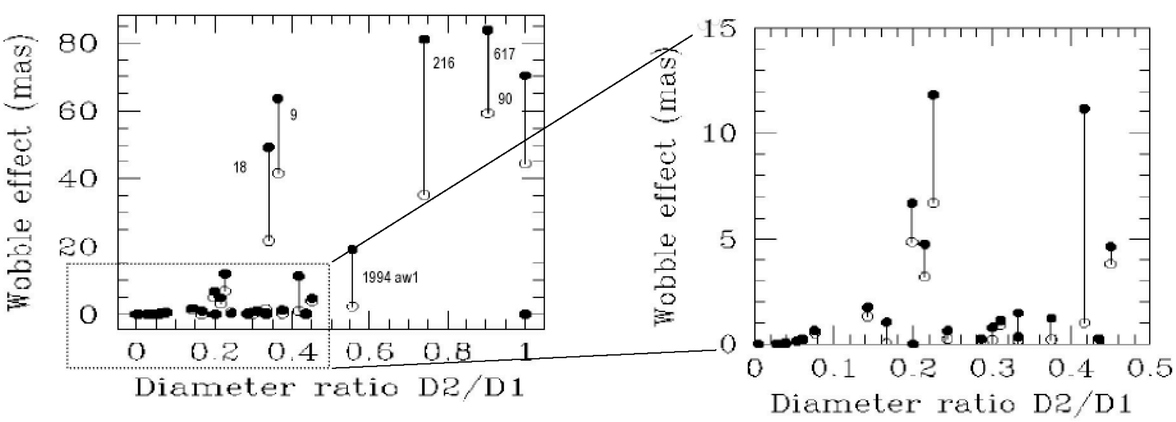

Fig. 1 Values in mas of the wobble effect for favorable (•) and unfavorable (°) opposition of several binary (or suspected) asteroids (labeled by their number) versus the diameters ratio (enlarging of the zone of low values is given at

pixels, and a typical exposure time of 30 seconds.

To get observed positions in ICRF2000 equatorial coordinates, we used the PRIAM (Procedure de Reduction d'Images Astrometriques) software developed by the IMCCE (Institut de Mecanique Celeste et de Calcul des Ephemerides) at Paris Observatory [7] with the Tycho-2 Catalogue, whose accuracy is about 60 mas.

To get calculated positions, we used a numerical integration Gragg-Bulirsh-Stoer method [3] with a dynamical model including planetary pertubations issued from the VSOP87 planetary theory [2]. This model has been fitted in the observations to get residuals (O-C measurements).

The spectral analysis facilities of the Midas software (Scargle and Analysis of Variance methods) [6] were then used to detect frequencies due to the wobble effect of the main component (Figures 2 and 3).

Projects and conclusion: One of the main utilities of this method is to be able to both detect a satellite and to solve directly for its rotation period. In the present work, we have tried to detect periodic signals of the suspected satellite asteroid 146 Lucina [1] using astrometric measurements. Despite a rather poor astrometric accuracy, a periodic signal has been detected; this now must be confirmed by further observation and analysis of the relationship between the derived frequency and the frequency of rotation of the primary component itself, again using spectral analysis. If this detection is confirmed, we will also attempt to characterize of the orbital plane of the probable satellite.

This preliminary result has been obtained from a short series of astrometric observations. At the present time, the only two stations involved in this work are the Itajuba observatory (Brazil) 0.60 and 1.60 m telescopes and the Haute-Provence Observatory (France) 1.20 m telescope. Several other asteroids have also been observed from those stations (9 Metis, 87 Sylvia, 61 Danae, 107 Camilla, 791 Ani). We intend to do a similar analysis of these data. Nevertheless, we would like to coordinate several stations of observations in order to get more continuous and wide series of astrometric measurements. Observers interested by this project are invited to contact the authors (see contact addresses above).

References: [1] Arlot J.-E. et al. (1985) *Icarus 61*, 224. [2] Bretagnon P. et al. (1988) *Astron. Astrophys. 202,* 309. [3] Bulirsh R. et al. (1966) *Num.Math. 8,* 1. [4] Monet K. B. & Monet D. G. (1998), *BAAS 30*, 1144. [5] Storrs A. et al. (1999) *Icarus 37*, 260. [6] Warmels R.H.: (1991), The

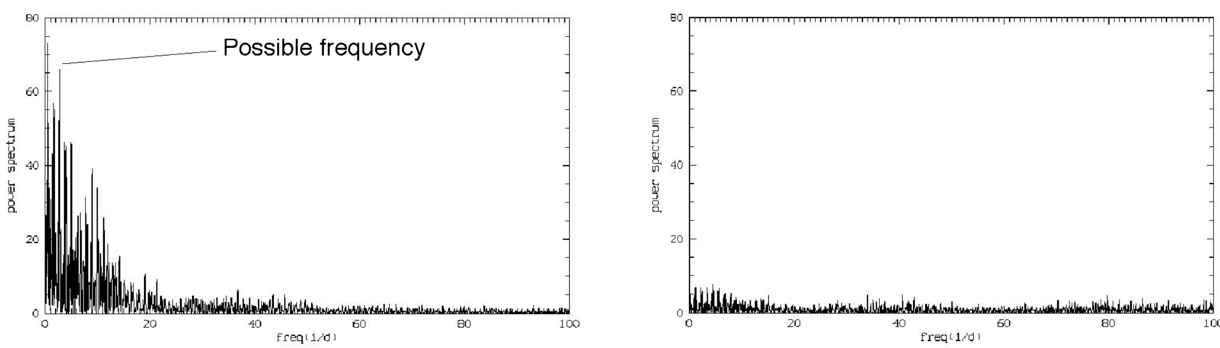

Fig 2: Right ascension: Left: Spectral analysis of O-C in right ascension of 377 observations of 146 Lucina. **Right**: Spectral analysis where the possible signal is pulled out. (Numbers of observations: 377, average: 26 mas, mean deviation: 97 mas, the possible frequency in this shorter sample appears to be $0.467 \pm 0.026 d^{-1}$).

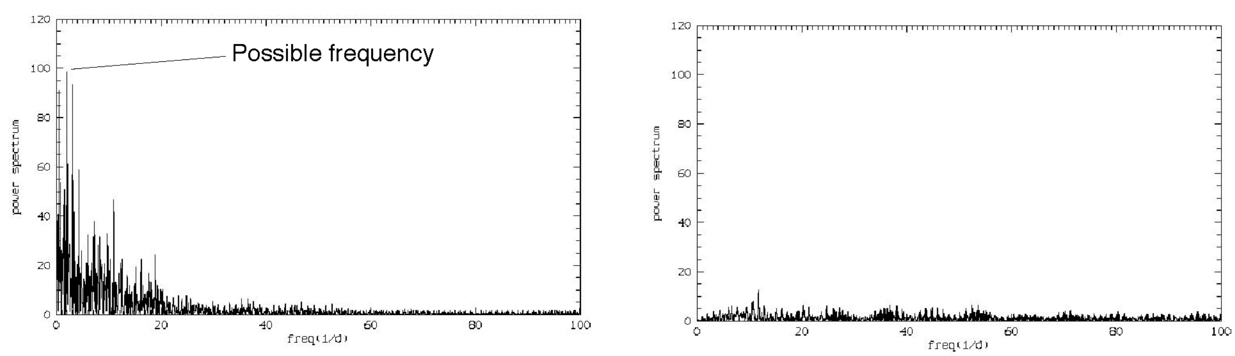

Fig 3: Declination: Left: Spectral analysis of O-C in declination of 377 observations of 146 Lucina. **Right**: Spectral analysis where the possible signal is pulled out. (Numbers of observations: 377, average: 29 mas, mean deviation: 225 mas, the possible frequency is 0.469 ± 0.041 d^{-1}, corresponding to the period of 2.13d.)