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The cometary non-gravitational forces. Application to 19P/Borrelly

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Abstract

We present here a new model for cometary non-gravitational forces aiming to revisit the problem of non gravitational forces (NGF) calculation and nucleus density determination. The method is based on the modeling of the nucleus surface in several strips located at different latitudes. The contribution of each strip to the overall NGF and the density of the nucleus are fitted from the astrometric and photometric measurements.

1. Introduction

The gravitational orbit of a comet is affected by the sublimation of water molecules in the nucleus when the comet approaches perihelion. This anisotropic outgassing triggers a non-gravitational force (NGF) which significantly modifies the comet orbit. We can indeed imagine that only the sun light part of the nucleus is outgassing. The perturbation's amplitude depends on several parameters which can be constrained by different kind of observations (astrometry, photometry). It also depends on the nucleus mass, which in turn can be determined by modeling the effects of the NGF on the comet orbit. This method is the only one available so far to estimate the nucleus mass from the ground. Up to now, the modeling of these effect is mostly based on an empirical model defined in the early 70's by Marsden et al. [1] which used a simplified isotropic outgassing model. In this abstract, we present a new anisotric outgassing model. Section 1 present the hypothesis of the model. Section 2 describes the calculation and the fit. Section 3 presents an application to comet 19P/Borrelly.

2. Hypothesis

The nucleus is modeled as a triaxial ellipsoid divided into latitudinal bands (fig. 1). The latitude is defined as the angle between the normal to the surface of the ellipsoid and the plane perpendicular to the nucleus rotational axis. The thermal inertia of the nucleus is neglected and the gas velocity is considered proportional to the thermal gas velocity. These hypotheses allow seasonal effects.

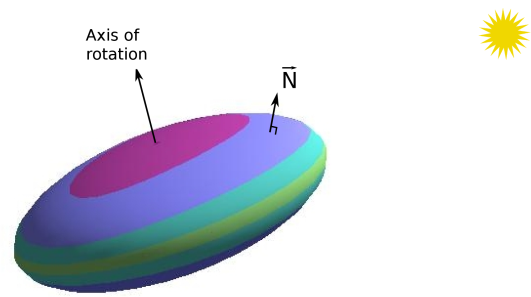

Figure 1: Geometrical view of a modelised nucleus with seven latitudinal strips

3. Calculations and fit

The acceleration due to water outgassing depends on the nucleus mass M_C and on C_i coefficients. C_i coefficients describ the activity of each surface band S_i ($C_i = 0$ if the band is not outgassing, $C_i = 1$ if the whole band is outgassing) :

$$A_{NG}(t) = \frac{1}{M_C} \sum_{i=1}^{k} C_i . S_i \left(\frac{d\overrightarrow{F(t)}}{dS} \right)_i \quad (1)$$

The surfacic force depends on the sublimation rate Z. Z depends on the incidence of the sun rays and the calculation of the gas velocity V_g. V_g depends on the temperature of the surface [2]:

$$\left(\frac{d\overrightarrow{F(t)}}{dS} \right)_i = Z_i(t).V_{g_i}(t).M_{H_2O}.\overrightarrow{N_i} \quad (2)$$

M_{H_2O} is the water molecular mass and $\overrightarrow{N_i}$ is the surface normal.
The total gas production rate of the comet is considered as a linear combination of the production rate of each band weighted by the non-gravitational parameters C_i :

$$Q_{H_2O}(t) = \sum_{i=1}^{k} C_i.Z_i(t) \qquad (3)$$

The fitting of the model is performed by the least square method. In order to decorrelate the mass of the nucleus and the non-gravitational parameters, two data are fitted : the astrometric measurements taken from MPC and the gas production rate that only depends on the non-gravitational parameters (cf. eq.3).
The fitted parameters are :

- The comet initial conditions
- M_C, the mass of the nucleus
- C_i, the non-gravitational parameters

4. Application to comet 19P/Borrelly : preliminary results

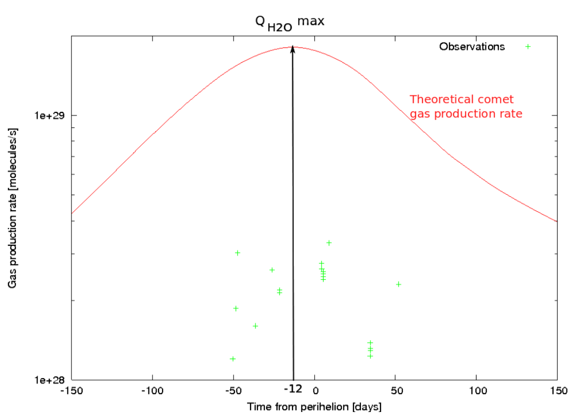

Figure 2: Gas production rate of a fully active nucleus with spin axis orientation $(\alpha, \delta) = (220°, -10°)$ [3] as a function of time

Figure 2 shows the gas production curve of a fully active nucleus. The displacement of the peak about 12 days before perihelion is due to the ellipsoidal shape of the nucleus and to the spin axis orientation allowing the seasonal effects. It also presents the observed prodution rate (dots). The theoritical gas production curve is greater than what is measured because we consider a fully active nucleus. The fit of the coefficient C_i is needed to reproduce the observations.
The fitting of the model is currently under progress and will be presented in the poster.

5. Summary and Conclusions

In a near future, the model will be fitted by the least square method to astrometrical and photometrical data in order to constrain the C_i coefficient and the mass of the nucleus. We will apply this model to other known comet like, 81P/Wild2, 1P/Halley and 67P/Churuymov-Gerasimenko (target of Rosetta mission). The future GAIA astrometric catalog will allow us to measure comet positions with an unprecedent accuracy and therefore to detect faint changes in NGF and better estimate the nucleus mass.

References

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