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First Satellite to a B-type Asteroid, (702) Alauda: Dynamical Mass and Density

P. Rojo(1) and J.-L. Margot(2)
(1) Departamento de Astronomía, Universidad de Chile, Chile (pato@oan.cl/Fax: +56 2 229 3973) (2) University of California, Los Angeles, Los Angeles, CA 90095, USA

Abstract

Observations with the adaptive optics system on the Very Large Telescope reveal that the outer main belt asteroid (702) Alauda has a small satellite with primary to secondary diameter ratio of 56. The secondary revolves around the primary in 4.9143 ± 0.007 days at a distance of 1227 ± 24 km, yielding a total system mass of (6.057 ± 0.36) × 1018 kg. Combined with an IRAS size measurement, our data yield a bulk density of 1570 ± 500 kg m-3 for this B-type asteroid. Because B-type asteroids may represent relatively primitive material with similarities to carbonaceous meteorites [1, 7, 9], their characterization can further our understanding of the primordial building blocks of planets.

Full results are published in the Astrophysical Journal, Vol 727, p. 69.

1. Introduction

The discovery of solar system binaries has a considerable impact on key problems in planetary science, partly because the binaries allow direct measurements of fundamental physical and chemical properties that are otherwise only obtainable with spacecraft. Characteristics of the mutual orbit provide crucial information about asteroid bulk properties and internal structure, such as mass, density, porosity, and mechanical strength. Additionally, they help us refine our understanding of planet formation since the current proportion of binary systems and their configuration are strong tracers of the collisional and dynamical evolution of small bodies in the solar system. The very high science priority of characterizing binary systems has been reviewed by [8, 3, 4].

Here we report on the discovery [5] and tracking of the first satellite to a B-type asteroid, (702) Alauda, which allows us to provide a direct mass measurement and improved density estimates for this class of asteroids.

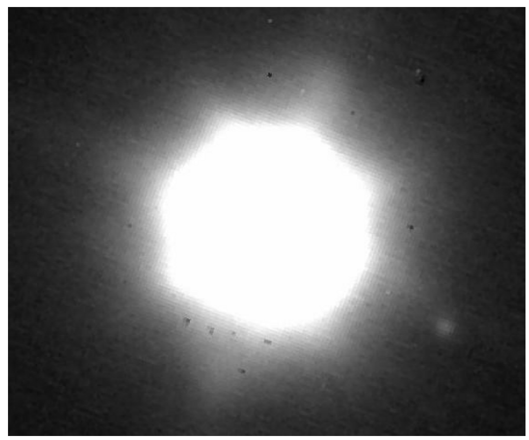

Figure 1: H-band image of the (702) Alauda binary system. The companion is clearly seen in the lower-right quadrant.

2 Observations

Using a highly optimized observing strategy, we were able to observe a total of 111 unique main belt and Trojan asteroids during three nights in visitor mode at the Very Large Telescope (VLT). We used the adaptive optics (AO) instrument NaCo [2, 6] in its S13 mode, resulting in a pixel scale of 13.72 mas.

The companion to (702) Alauda was identified in a 40-second composite image in the Ks filter. Follow-up observations that night and the next fully confirmed the binarity of the system.

The binary system was observed at 6 epochs during the last 2 nights of the observing run with different filters. The H-filter was found to give the best compromise between SNR and AO correction (Fig. 1). In order to secure additional astrometric measurements, we submitted a Director's Discretionary Time (DDT) proposal to follow-up the system in queue mode, using the same observing instrument and strategy.

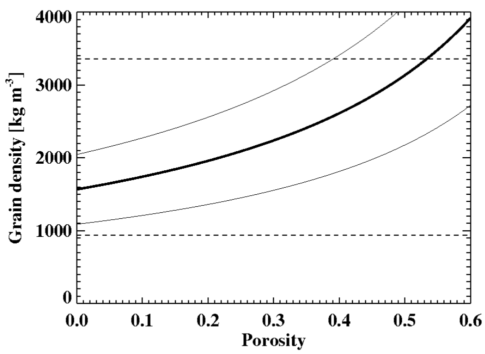

Figure 2: Range of porosities and grain densities admitted by our density measurement (our nominal solution is the bold solid line, with density uncertainties captured by the solid lines above and below). The densities of water ice and anhydrous silicates are shown as dashed lines.

3 Results and Conclusions

The satellite is small, with a ratio of primary to secondary radii of about 50. The secondary revolves around the primary in 4.91 days at a distance of 1,230 km, corresponding to 12.6 primary radii.

We fit a 7-parameter orbital solution to the 16 measurements at 8 epochs. Our mass measurement of $6.057 \pm 0.36) \times 10^{18}$ kg provides an important new constraint on the composition and internal structure of B-type asteroids. Combined with an IRAS size measurement, the mass yields a bulk density of 1570 ± 500 kg m^{-3}. This density admits an ice-to-rock mass ratio in the range 0-80%, depending on the porosity of the asteroid (Fig. 2). Our density determination is significantly lower than previous estimates for the B-type asteroid (2) Pallas (the third largest asteroid), which may be related to different porosities.

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