EPSC Abstracts
Vol. 6, EPSC-DPS2011-653-3, 2011
EPSC-DPS Joint Meeting 2011

A Detailed Picture of the (93) Minerva Triple System

F. Marchis (1,2,3), P. Descamps (3), P. Dalba (2), J.E. Enriquez (1), J. Durech (4), J.P. Emery (5), J. Berthier (3), F. Vachier (3) J. Melbourne (6) A.N. Stockton (7), C.D. Fassnacht (8), T.J. Dupuy (7)
(1) Carl Sagan Center at the SETI Institute, Mountain View, CA, (2) Department of Astronomy at University of California, Berkeley, CA, USA, (3) IMCCE, Paris, France, (4) Charles University, Prague, Czech Republic (5) University of Tennessee at Knoxville, TN, USA, (6) CALTECH, Pasadena, CA, USA (7) University of Hawaii, Honolulu, HI, USA, (8) University of California at Davies, CA, USA (contact: fmarchis@seti.org)

Abstract

We developed an orbital model of the satellites of (93) Minerva based on Keck II AO observations recorded in 2009 and a mutual event between one moon and the primary detected in March 2010. Using new lightcurves we found an approximated ellipsoid shape model for the primary. With a reanalysis of the IRAS data, we derived a preliminary bulk density of 1.5±0.2 g/cc. We will present a detailed analysis of the system, including a 3D shape model of the 93 Minerva primary derived by combining our AO observations, lightcurve, and stellar occultations.

1. Introduction

The number of known multiple asteroid systems (197 in May 2011) is growing with the monthly discovery of small (D_{eq}<15 km) inner main-belt asteroids and NEAs binary systems by lightcurve observations [e.g. 1]. Direct observations of multiple asteroid systems using adaptive optics (AO) systems on ground-based telescopes or the Hubble Space Telescope are less common due to the scarcity of time available on these facilities and also the limited sensitivity of these instruments which can only detect satellites larger than 5-10km in diameter at more than 0.3-0.4" from the primary. In Aug. 2009, we announced the discovery of 2 moons around the large main-belt asteroid (93) Minerva with the W.M. Keck II AO [2]. In Section 2, we describe AO observations recorded in 2009. In Section 3, we report the detection of a mutual event between the innermost moon and its primary. In Section 4, we present a preliminary study of (93) Minerva system and describe our future work.

2. Adaptive Optics Observations

Shortly after the discovery of two satellites around (93) Minerva [2], our collaborators collected additional observations in September 2009 with the Keck II telescope in the narrow band filter Fe II with a total exposure time of 10-15 min (Fig. 1). Both moons are revealed on these 5 epochs of observations:

- Minerva's primary is resolved and seen face-on.
- S/2009 (93) 1, the outer moon (nickname Minerva I) has a diameter of 4±2 km assuming the same albedo for the moon and the primary
- S/2009 (93) 2, the inner moon (nickname Minerva II) may be slightly smaller D= 3 ± 1 km

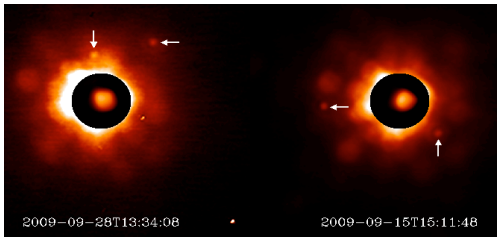

Figure 1: Two Keck-II AO observations of (93) Minerva triple system. The horizontal and vertical arrows show the position of Minerva I and Minerva II. The primary shown in the center is resolved and seen almost face-on.

3. Lightcurve Observations

To refine the shape model of Minerva's primary, we collected photometric observations with the super-LOTIS robotic telescope from March 5 to March 12 2010. From the composite lightcurve shown in Fig. 2 we derived a rotation period of 5.982 ± 0.001 h for the primary, and an irregular shape with a Δm~0.2. More interestingly an attenuation of 0.07 mag is detected on March 9 from 4:45 UT to 7:11 UT suggesting a mutual event between the primary and one of the moons of the system.

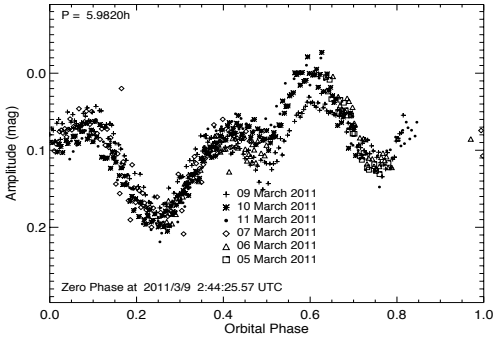

Figure 2: Composite lightcurve of (93) Minerva recorded with super-LOTIS telescope. An attenuation of 0.07 mag detected on March 9 suggests a mutual event between the primary and one of the moons.

4. Moon Orbital Model & Primary

Based on the AO astrometric positions of the moons and using the timing of the mutual event, we developed an orbital model of the system using the BOF algorithm and fitting the orbits independently [3]. Table 1 shows the satellites' orbital parameters.

Table 1: Orbital Parameters of (93) Minerva satellites

Parameters	Minerva I	Minerva II
Semi-major axis (km)	651±12	385 ± 14
Period (days)	2.408 ± 0.003	1.1142 ± 0.0007
Eccentricity	~0	0.005±0.005
Pole Orbit in deg ECJ2000	(27,-25)	(21,-25)
Inclination ECJ2000	103	105
Mass (1E18 kg)	3.8 ± 0.2	3.6±0.4
Avg (O-C)(x) arcsec	-0.0028	0.0015
Avg (O-C)(y) arcsec	-0.0024	0.0013

Assuming that the two moons orbit close to the equator of the primary as seen for other known triple systems (87 Sylvia, 216 Kleopatra [4]), we confirmed that the primary was almost face-on in September 2009 and was edge-on in March 2011. Our orbital model also showed that Minerva II was casting its shadow on the primary on March 9. Using IRAS measurements taken on Nov 6 1983 and our recent lightcurve we derived an approximated ellipsoid shape model for Minerva's primary with a_1=98.7, a_2=83.9 and a_3=69.1 km. Consequently, the averaged density of (93) Minerva is estimated to 1.5±0.2 g/cc. S3OS2 [5] and SMASS [6] classified Minerva as a C-type implying that the asteroid has a large porosity (>30%) considering the density of meteorite analogs [7].

5. Conclusions and Future Work

By combining the resolved AO observations with additional LC taken since 1980, and stellar occultation observations in 1982, 1996 and 2010, we will develop an accurate 3D shape model of the asteroid. This work will allow us to refine the size of the primary and the satellites, derived the averaged density of the system and determine its evolution & age due to tidal dissipations.

Acknowledgements

The National Science Foundation supported this work under award number AAG-0807468.

References

[1] Pravec, P. & Harris, A.W. Binary asteroid population. 1. Angular momentum content, Vol. 190, 1, pp. 250-259, 2007.

[2] Marchis, F., Macomber, B., Berthier, J., Vachier, F., Emery, J.P., IAU, 9069, 1, 2009

[3] Descamps, P. Orbit of an Astrometric Binary System, Celestial Mechanics and Dynamical Astronomy, 92,4, pp. 381-401, 2009

[4] Marchis, F. et al. Characteristics of Known Triple Asteroid Systems in the Main Belt, AAS, DPS #42, #46.05, 2010

[5] Lazarro ,D, Angeli, C.A., Carvano, J.M., Mothe-Diniz, T., Duffard,R. Florczak, M., Icarus, 172, 1, pp.179-220, 2004

[6] Bus , S.J & Binzel, R.P., Icarus, 158, 1, 106-145, 2002

[7] Britt, D.T., Yeomans, D., Housen, K., Consolmagno, G. Asteroid Density, Porosity, and Structure, Asteroids III, University of Arizona Press, Tucson, p. 485-500, 2002