Binary Asteroids with Gaia photometric observations

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GAIA-FUN-SSO Workshop, Paris 19-21 September 2012

- Properties of binary asteroids
- Work on binary asteroids carried out at *Poznań Observatory*
- Simulation of Gaia photometric observations for binary objects

DO ASTEROIDS HAVE SATELLITES?

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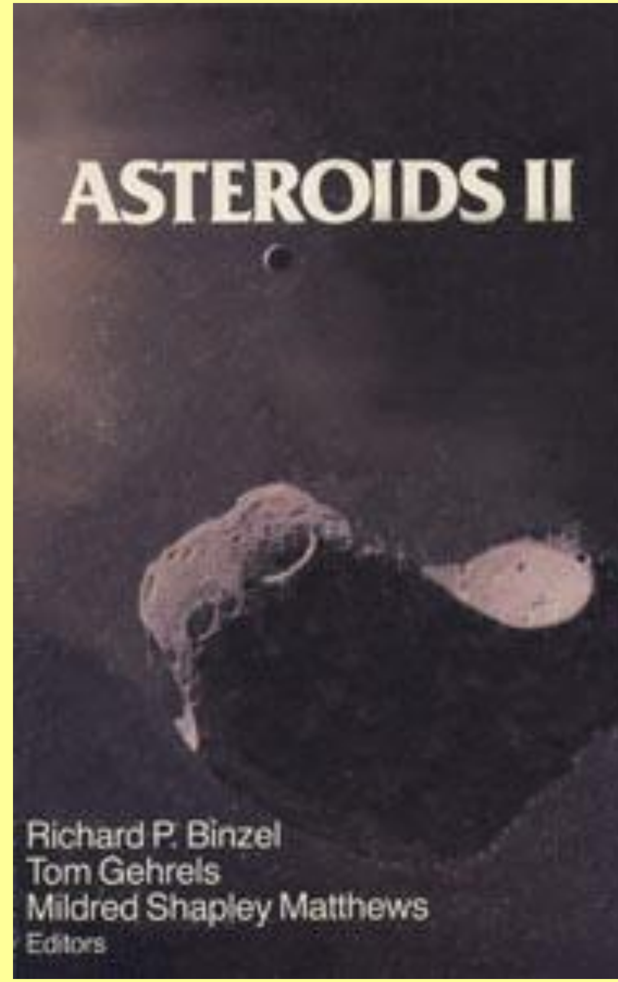
A substantial body of indirect evidence suggests that some asteroids have satellites, although none has been detected unambiguously. Collisions between asteroids provide physically plausible mechanisms for the production of binaries, but these operate with low probability; only a small minority of asteroids are likely to have satellites. The abundance of binary asteroids can constrain the collisional history of the entire belt population. The allowed angular momentum of binaries and their rate of tidal evolution limit separations to no more than a few tens of the primary's radii. Their expected properties are consistent with failure to detect them by current imaging techniques.

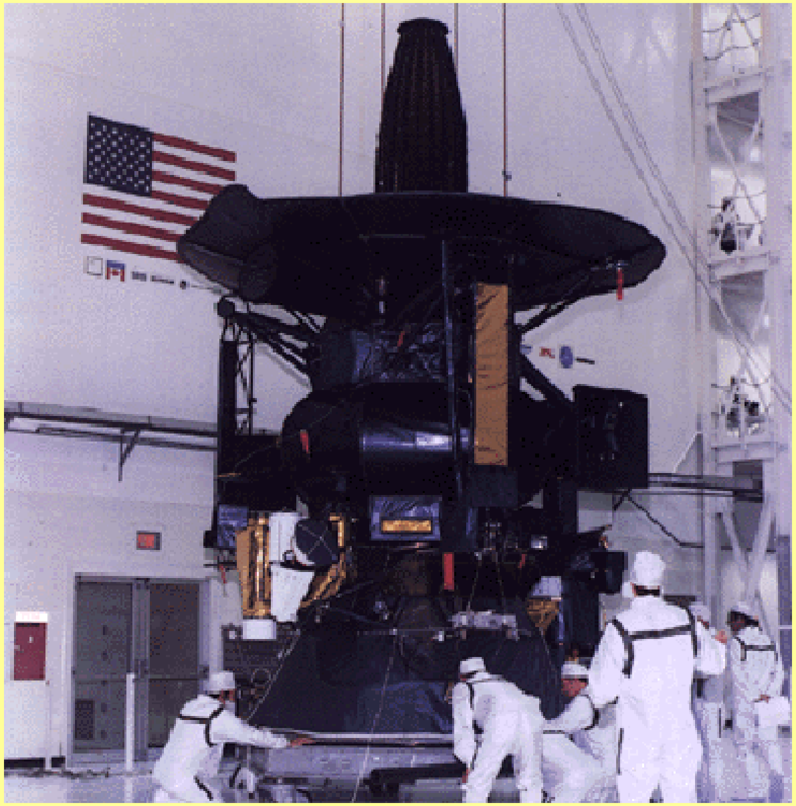
I. INTRODUCTION

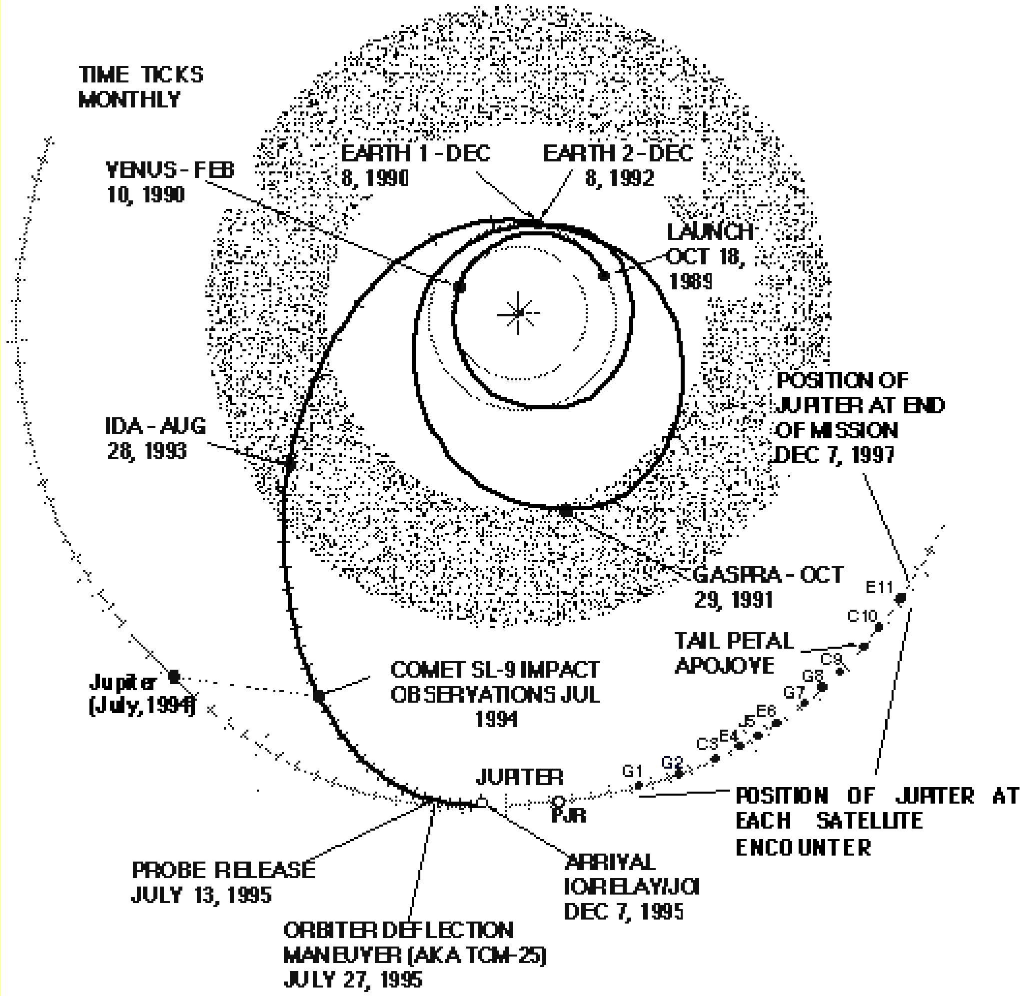
The first suggestion of the existence of binary asteroids was due to Andre (1901), who noted the similarity between lightcurves of 433 Eros and of some eclipsing binary stars. Bobrovnikoff (1929) made the prescient comment that "if an occasional asteroid were not a single body but consisted of several pieces . . . we could never tell the difference." In more recent years, Cook (1971) proposed a contact binary model to explain the lightcurve of 624 Hek-



(1989)

Galileo Spacecraft





951 Gaspra and 243 Ida

243 Ida and Dactyl

Binary Asteroids

(13 August 2012)

Near Earth Asteroids	41
Mars Crossers	14
Main Belt Asteroids	76
Trojans	4
Trans-Neptunian Objects	79
Total	214

http://www.johnstonsarchive.net/astro/asteroidmoons.html

Binary Asteroids

(13 August 2012)

			imaging		radar	lightcurve
			ground	space		
NEA	41				27	14
Mars Crossers	14					14
MBA	76		17	4		54
Trojans	4		2			2
TNO	79		15	63		1
Total	214		34	67	27	86

http://www.johnstonsarchive.net/astro/asteroidmoons.html

Asteroids *Do* Have Satellites

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Southwest Research Institute

Stuart J. Weidenschilling
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Towson University

After years of speculation, satellites of asteroids have now been shown definitively to exist. Asteroid satellites are important in at least two ways: (1) They are a natural laboratory in which to study collisions, a ubiquitous and critically important process in the formation and evolution of the asteroids and in shaping much of the solar system, and (2) their presence allows to us to determine the density of the primary asteroid, something which otherwise (except for certain large asteroids that may have measurable gravitational influence on, e.g., Mars) would require a spacecraft flyby, orbital mission, or sample return. Binaries have now been detected in a variety of dynamical populations, including near-Earth, main-belt, outer main-belt, Trojan, and transneptunian regions. Detection of these new systems has been the result of improved observational techniques, including adaptive optics on large telescopes, radar, direct imaging, advanced lightcurve analysis, and spacecraft imaging. Systematics and differences among the observed systems give clues to the formation mechanisms. We describe several processes that may result in binary systems, all of which involve collisions of one type or another, either physical or gravitational. Several mechanisms will likely be required to explain the observations.

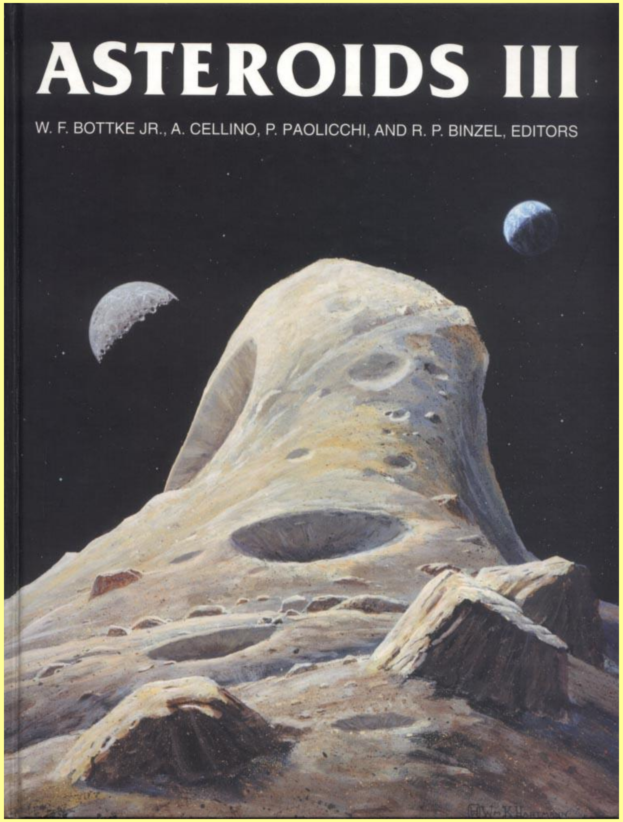
1. INTRODUCTION

1.1. Overview

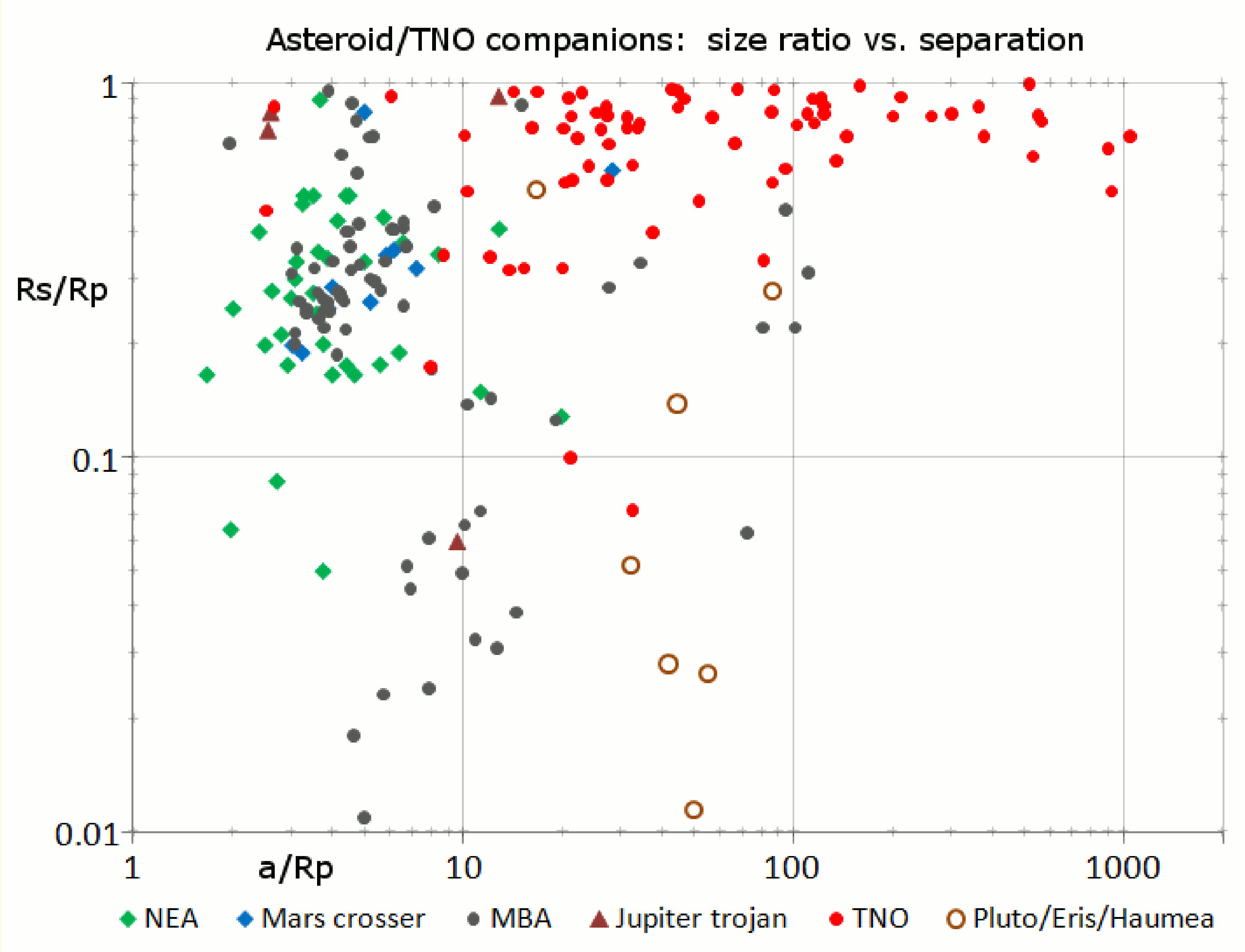
Discovery and study of small satellites of asteroids or double asteroids can yield valuable information about the intrinsic properties of asteroids themselves as well as their history and evolution. Determination of orbits of these moons can provide precise determination of the total (primary + secondary) mass of the system. In the case of a small secondary, the total mass is dominated by the primary. For a binary with a determinable size ratio of components (e.g., double asteroids), an assumption of similar densities can yield individual masses. If the actual sizes of the primary or the pair are also known, then reliable estimates of the primary's bulk density — a fundamental property — can be made. This reveals much about the composition and structure of the primary and will allow us to make comparisons between, for example, asteroid taxonomic types and our inventory of meteorites. In general, uncertainties in the asteroid size will dominate the uncertainty in density. We define satellites to be small secondaries, a double asteroid to be a system with components of similar size, and a binary to be any two-component system, regardless of size ratio.

Similarities and differences among the detected systems reveal important clues about possible formation mechanisms. Systematics are already being seen among the main-belt binaries; many of them are C-like and several are family members. There are several theories to explain the origin of these binary systems, all of them involving disruption of the parent object, either by physical collision or gravitational interaction during a close pass to a planet. It is likely that several of the mechanisms will be required to explain the observations.

The presence of a satellite provides a real-life laboratory to study the outcome of collisions and gravitational inter-



(2002)



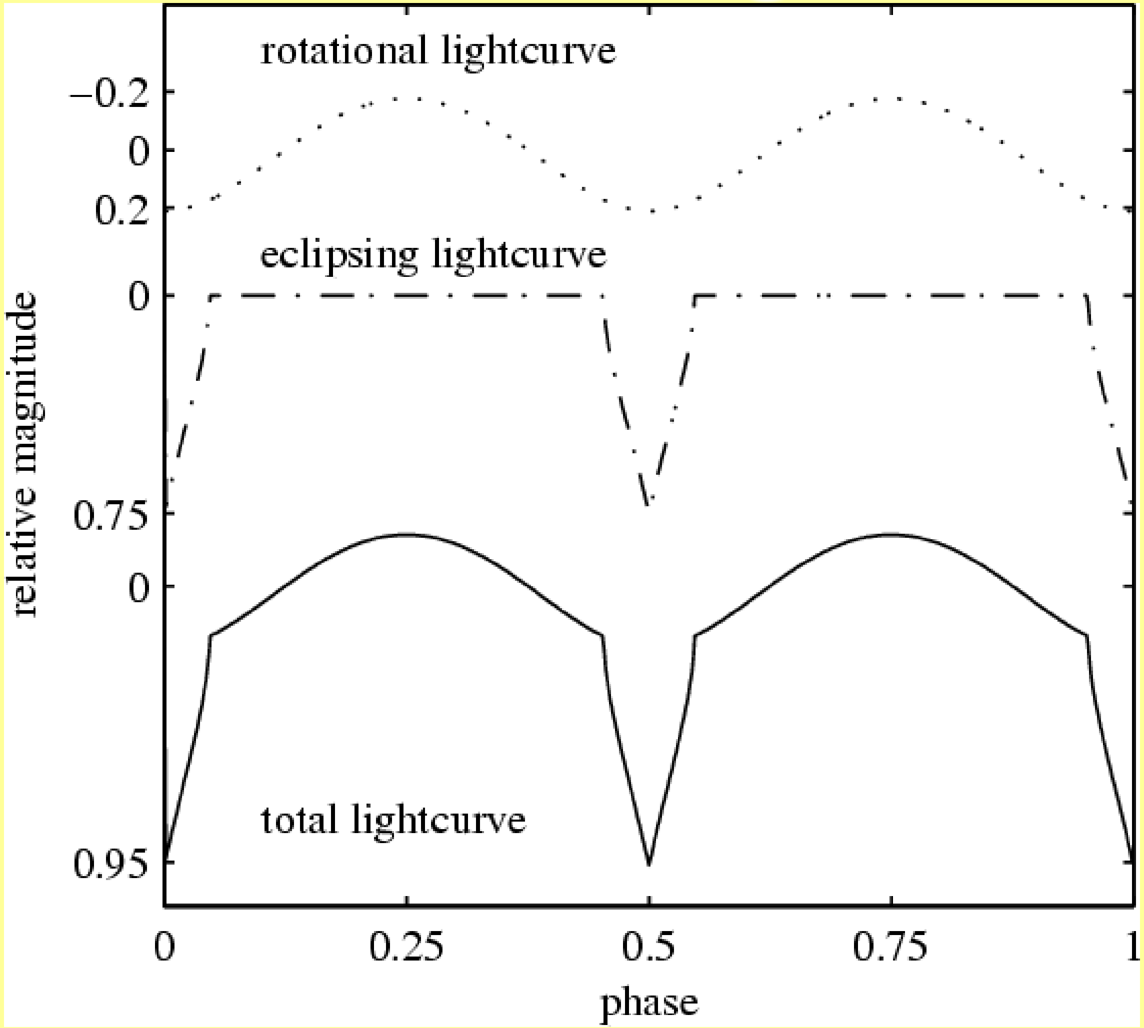
http://www.johnstonsarchive.net/astro/asteroidmoons.html

Synchronous binary asteroids

Asteroid		$D_{P.}$ [km]	$D_{s.}/D_p$	P [hr]	Discovery
90 Antiope	MB	84	0.97	16.505	AO, phot.
617 Patroclus	Tr.	101	0.92	102.8	AO, phot.
809 Lundia	MB	7	0.9	15.418	phot.
854 Frostia	MB	9	0.98	37.711	phot.
1089 Tama	MB	9.4	0.9	16.444	phot.
1139 Atami	MC	5	0.8	27.45	phot.
1313 Berna	MB	10	0.97	25.464	phot.
2478 Tokai	MB	7	0.86	25.897	phot.
4492 Debussy	MB	11	0.93	26.576	phot.
4951 Iwamoto	MB	4	0.88	118.0	phot.
7369 Gavrilin	MC	5	0.70	49.12	phot.
12008 Kandrup	MC		~1	31.992	phot.
69230 Hermes	NEA	0.6	0.9	13.894	radar

http://www.johnstonsarchive.net/astro/asteroidmoons.html

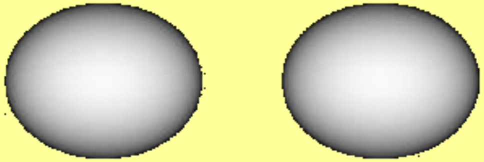
Synchronous system – lightcurve



$P_{rot} = P_{orb}$

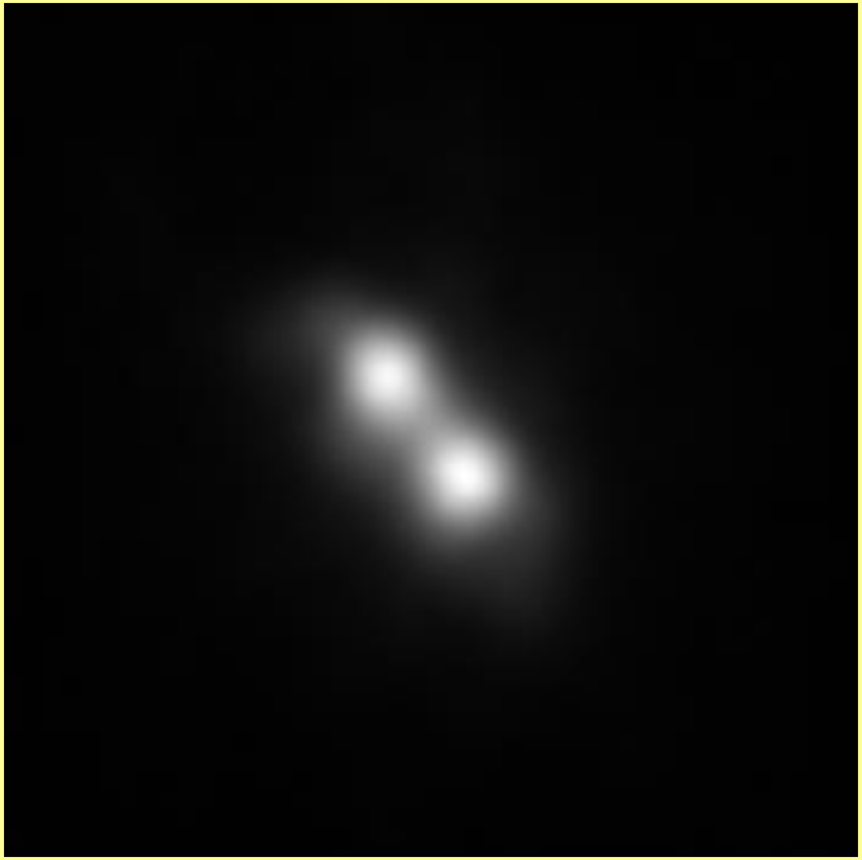
circular orbit

$D_{s.}/D_p = 0.8 – 1$



Behrend et al. 2006, *A&A* 446, 1177

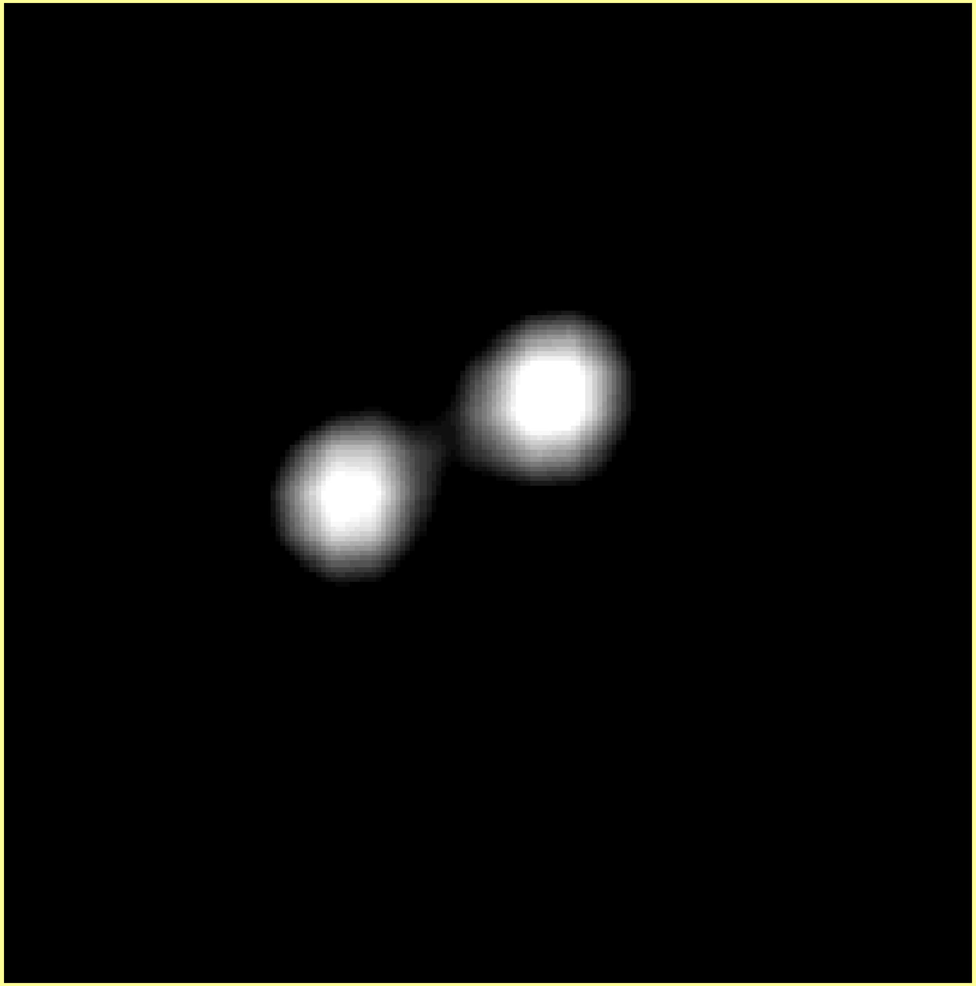
90 Antiope



10 August 2000, Keck II

Merline et al.

90 Antiope



d" = 0.17" → d = 170 km

D = 120 km (IRAS) → D_1=D_2=85 km

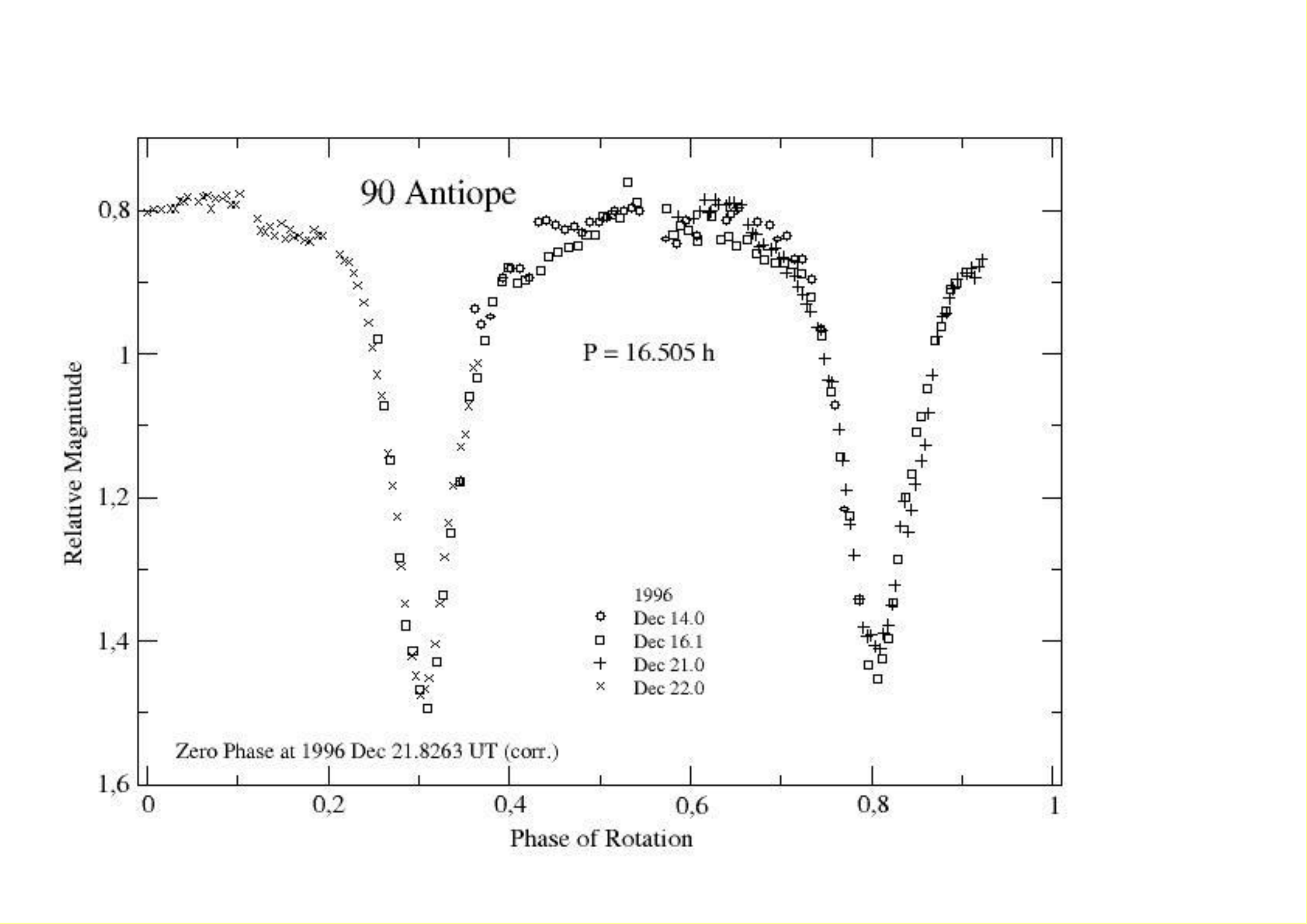
P_{orb} = 16.5 h

$M_1 = M_2 = 4.12*10^{20}$ g

ρ= 1.3 g/cm^3 ± 0.4 g/cm^3

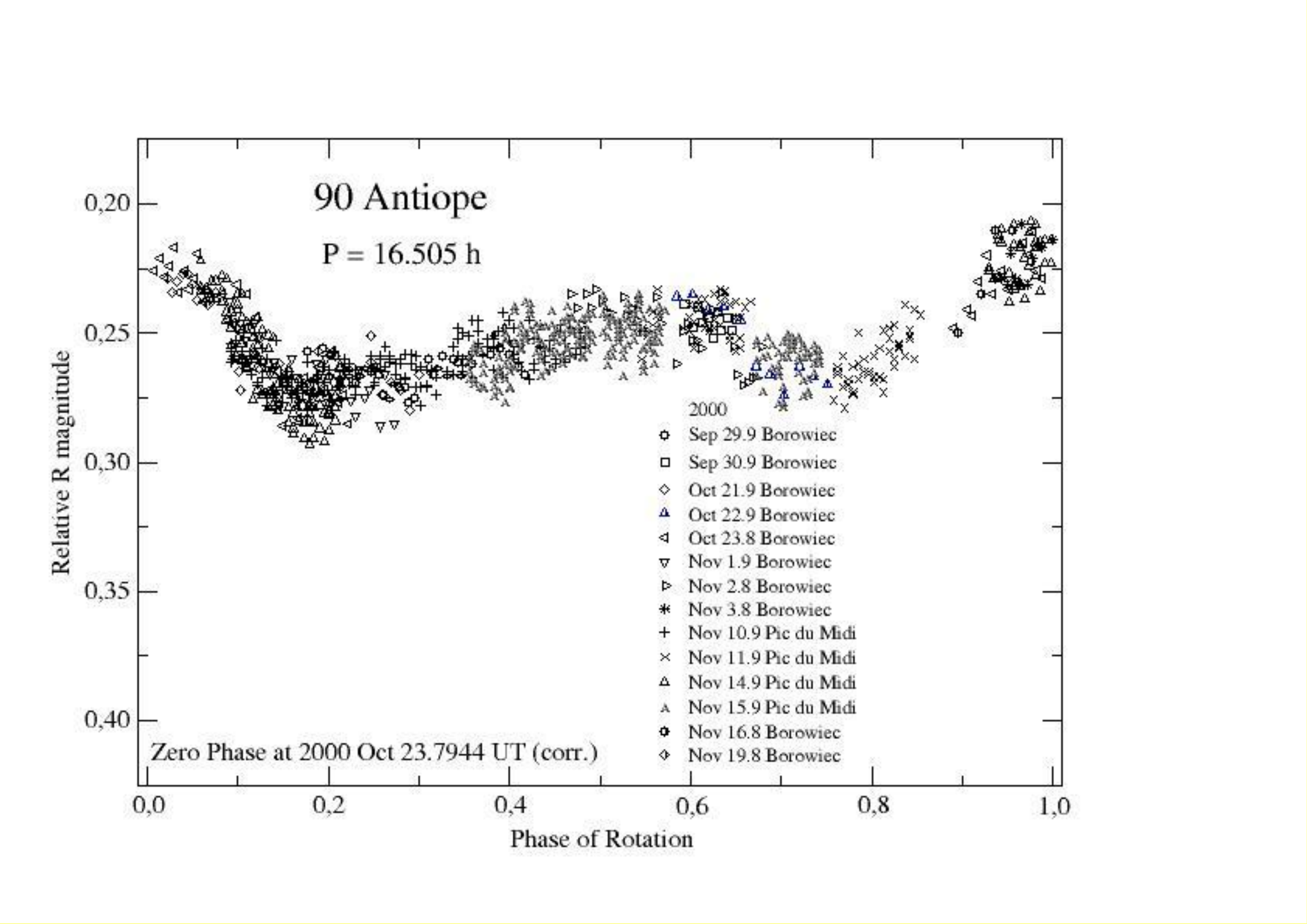
Themis family

90 Antiope - 1996



Hansen et al. 1997, *MPB 24,17*

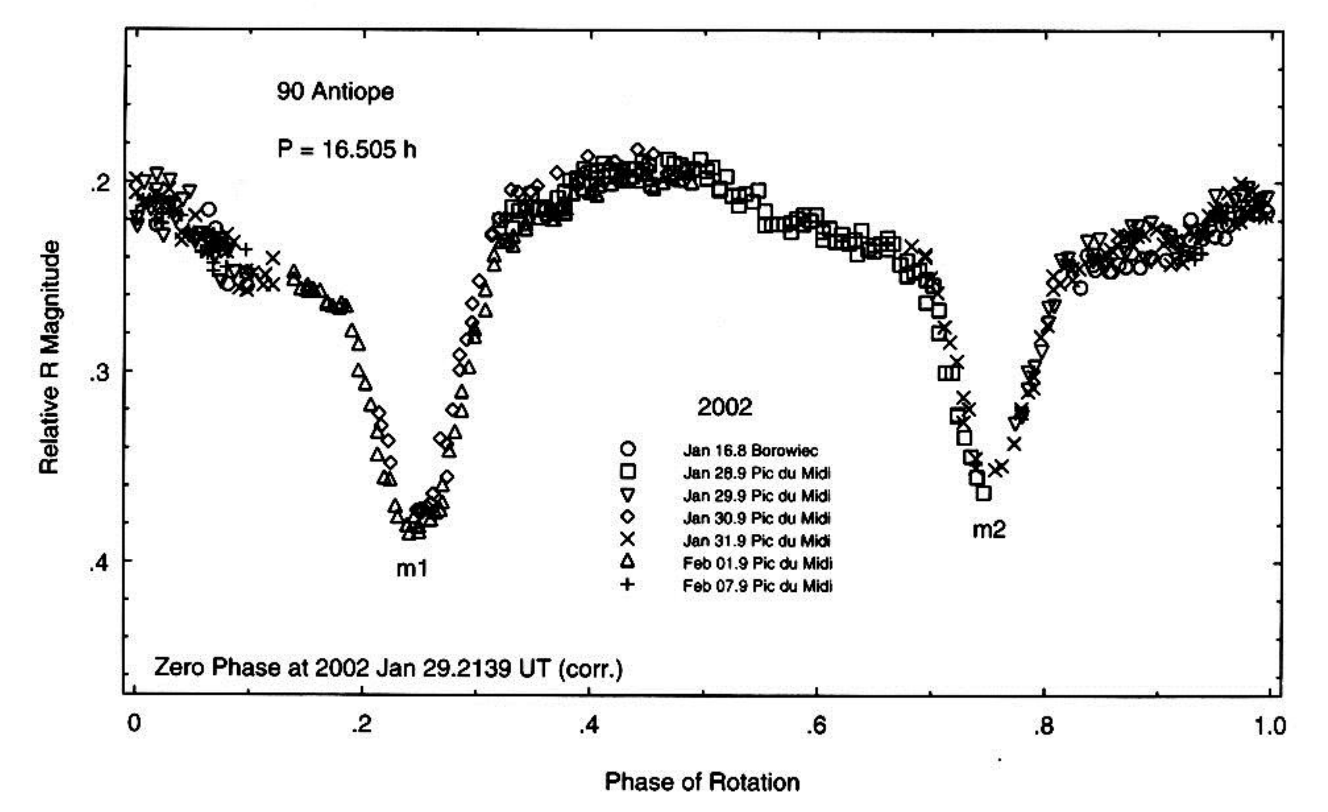
90 Antiope - 2000



Michalowski et al. 2001, A&A 378, L14

90 Antiope – 2001/02

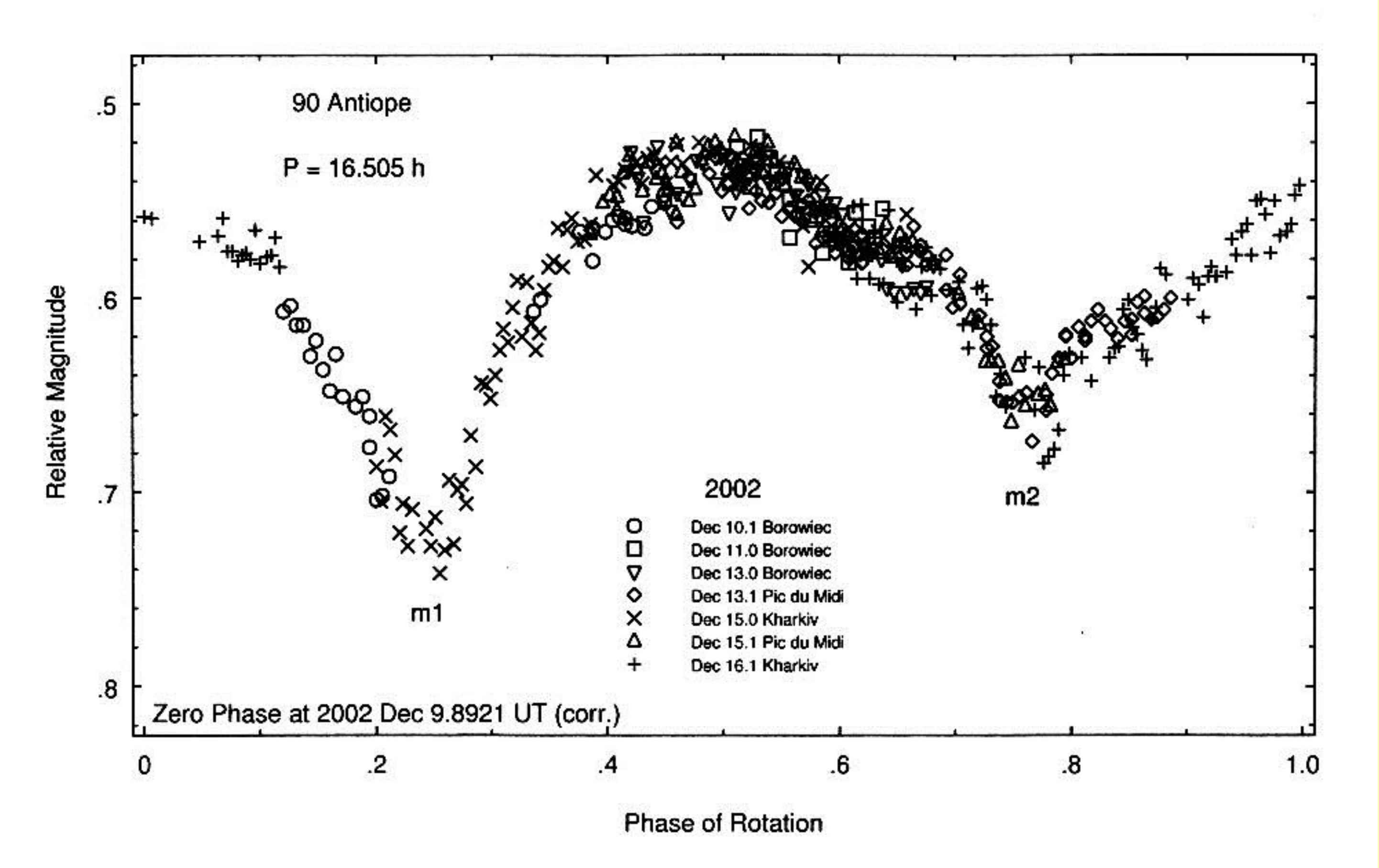
20 Oct 2001 — 7 Feb 2002



Michałowski et al.
2002, A&A 396, 293

90 Antiope – 2002/03

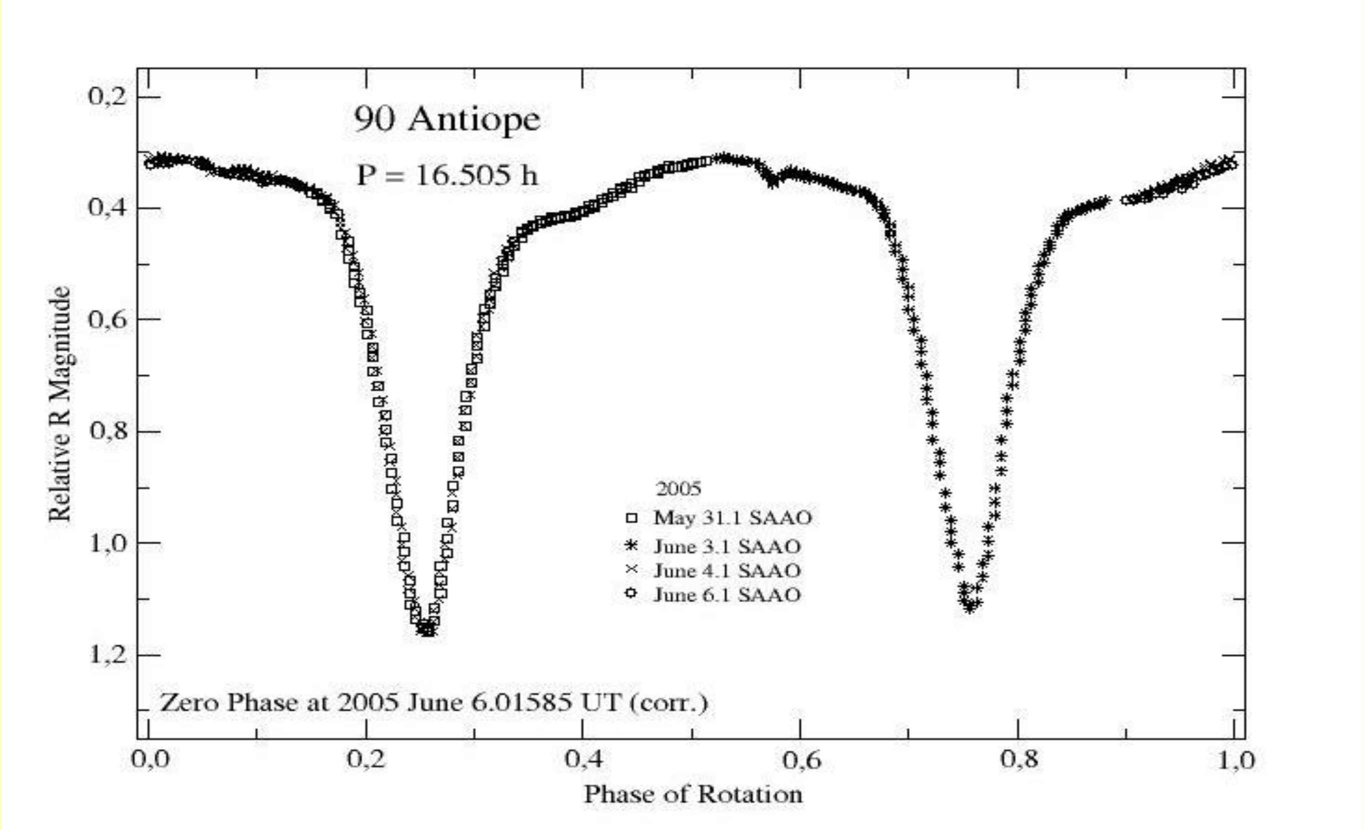
10 Dec 2002 — 8 Apr 2003



Michałowski et al.
2004, A&A 423, 1159

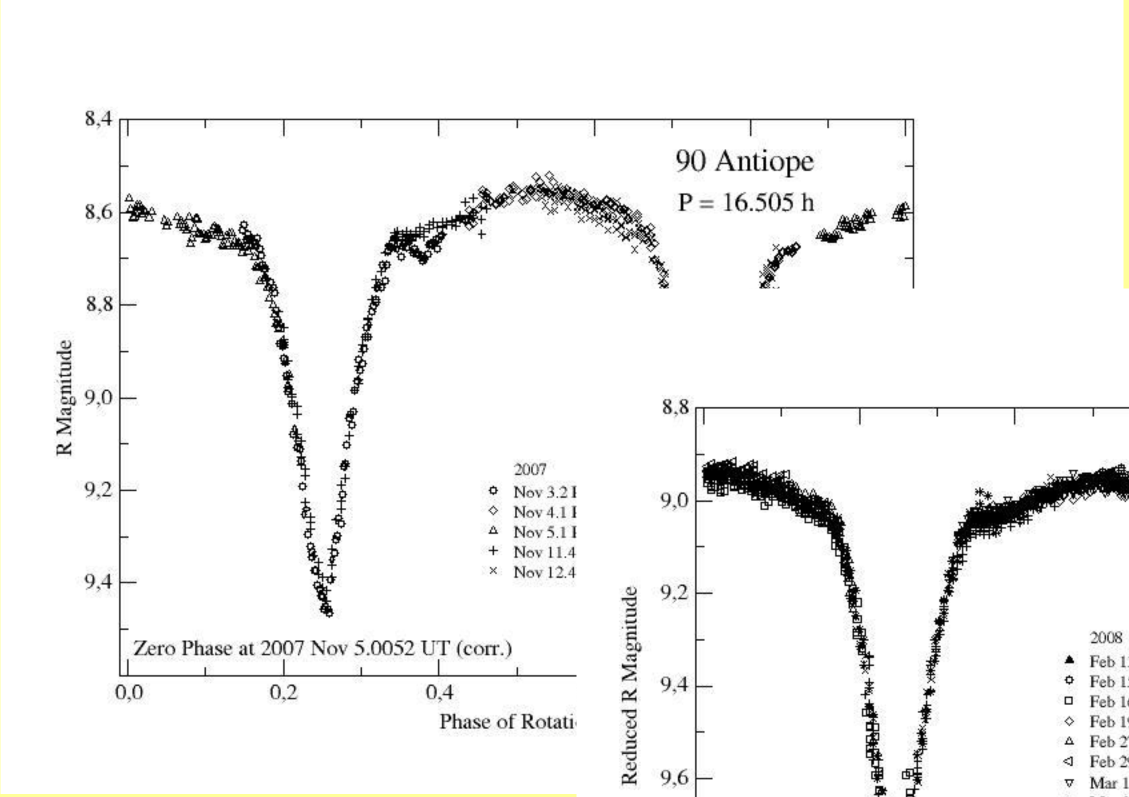
90 Antiope - 2005

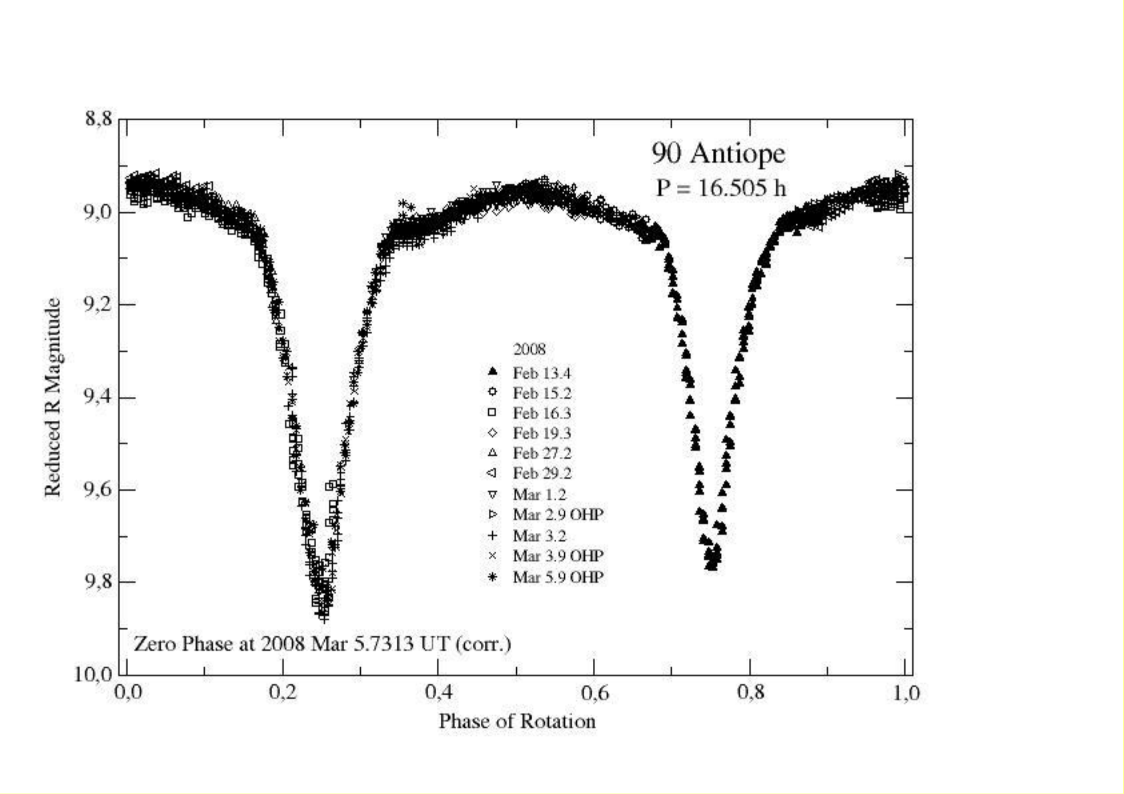
31 May –24 Nov



Descamps et al. 2007,
Icarus 187, 482

90 Antiope – 2007/2008





Model of the Antiope system

based on *Adaptive Optics* and *Lightcurve* observations

(Descamps et al. 2007, Icarus 187, 482-499)

Roche ellipsoids:

Primary (a x b x c):

46.5 x 43.5 x 41.8 [km^3]

Secondary (a x b x c):

44.7 x 41.4 x 39.8 [km^3]

Separation:

170 ± 1 km

Density:

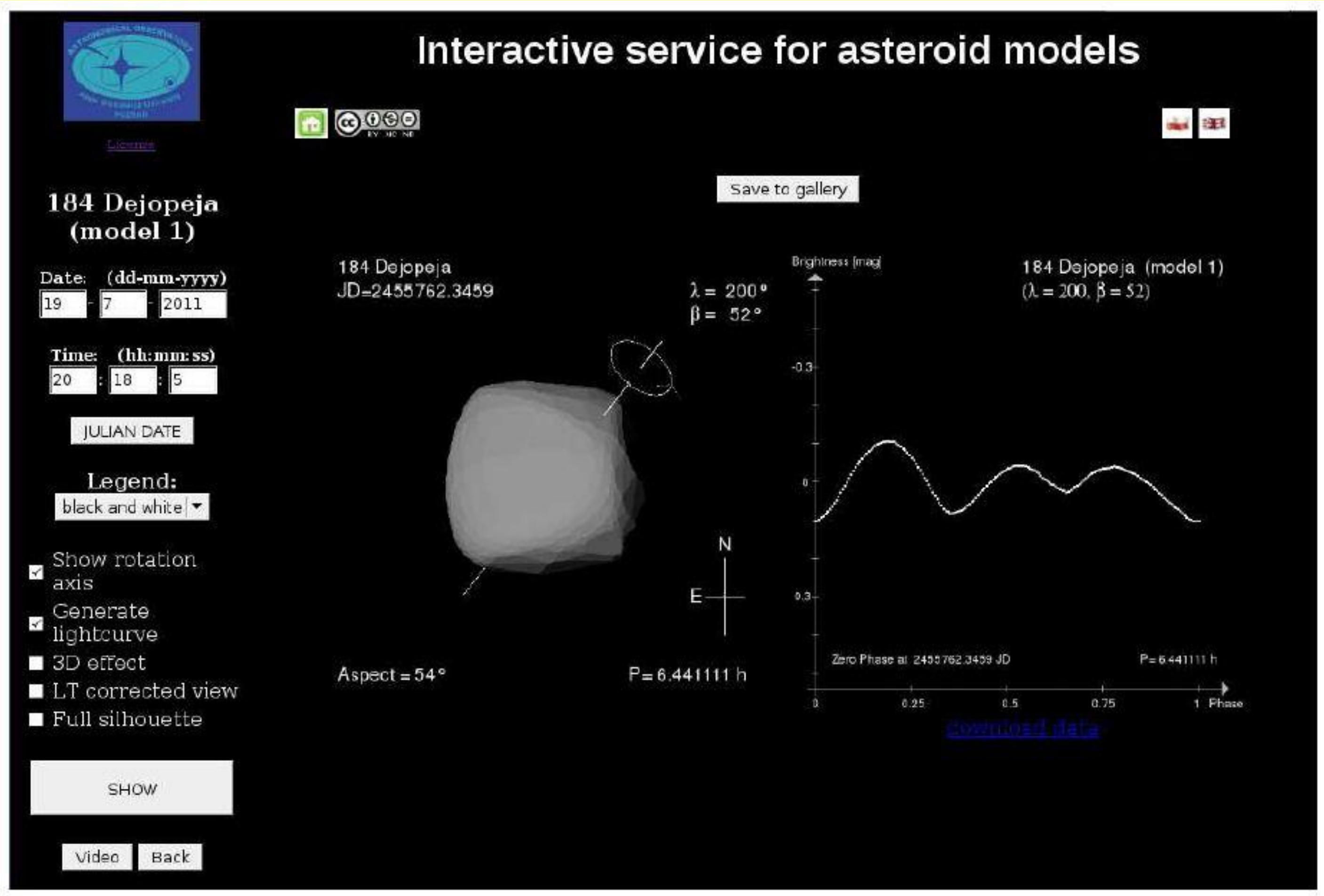
1.25 ± 0.10 g/cm^3

$P_{orb} = 16.5051 \pm 0.0001$ h

$\lambda_0 = 200° \pm 2°$

$\beta_0 = 38° \pm 2°$

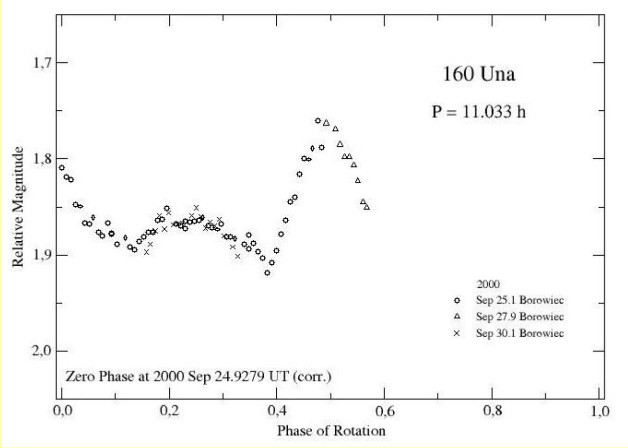
Interactive **S**ervice for **A**steroid **M**odels



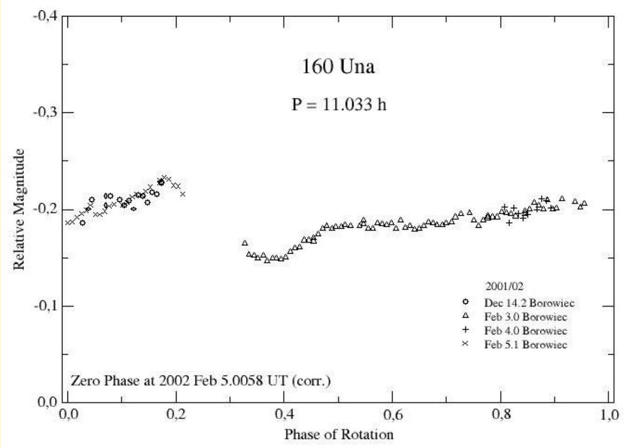
http://isam.astro.amu.edu.pl Webmaster: Przemysław Bartczak

Marciniak, A., Bartczak, P., Santana-Ros, T., Michałowski, T., et al. 2012, Photometry and models of selected main belt asteroids IX. Introducing Interactive Service for Asteroids Models (ISAM), *Astronomy & Astrophysics*, in press

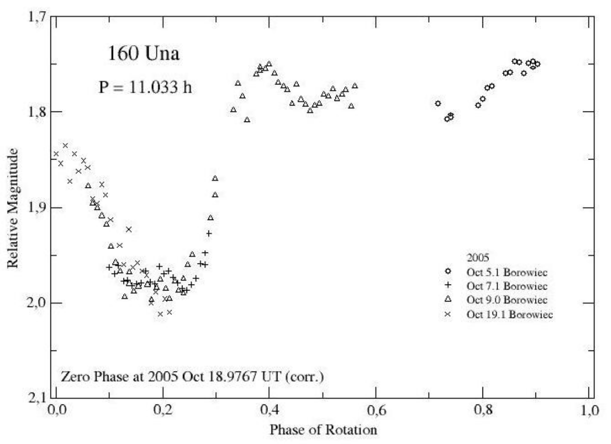
160 Una - lightcurves



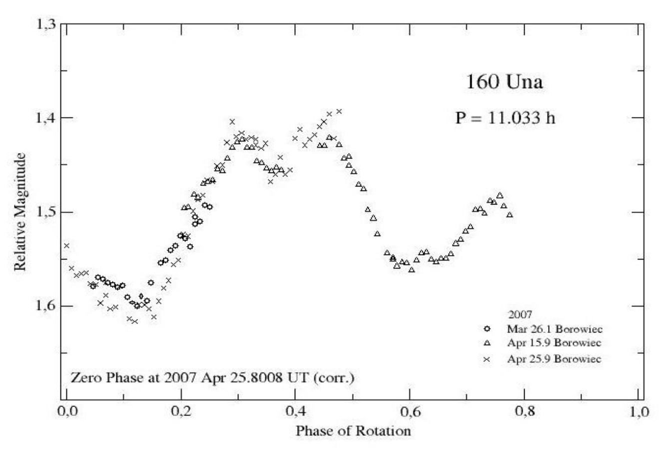
2000



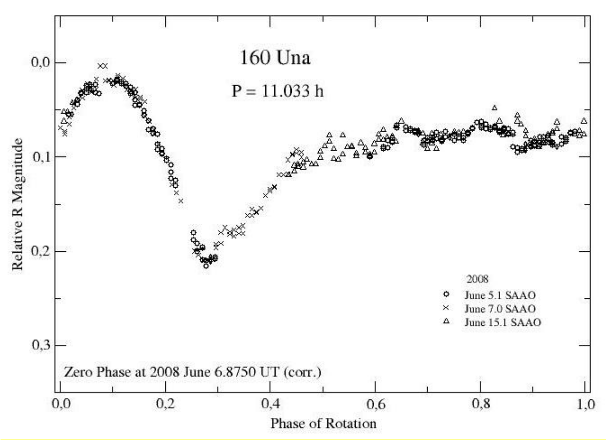
2002



2005



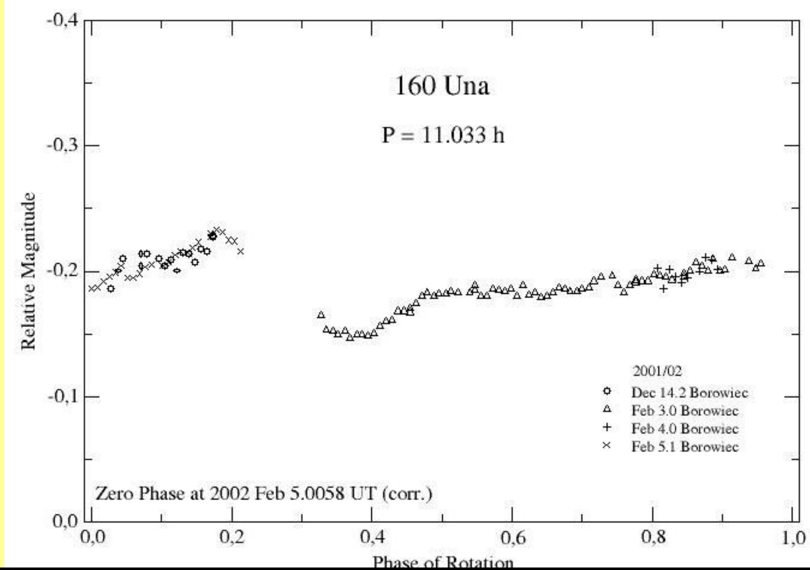
2007

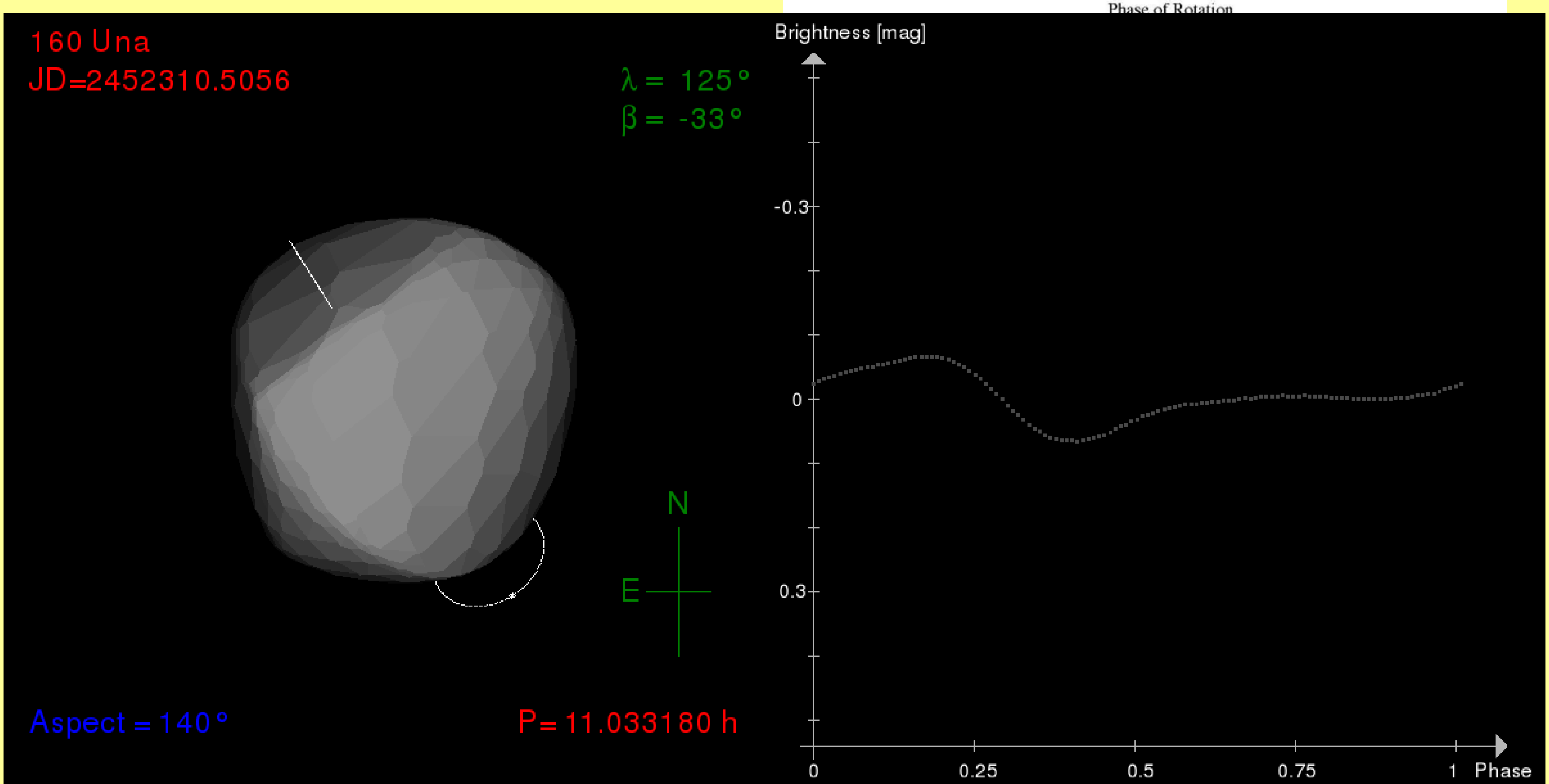


2008

160 Una

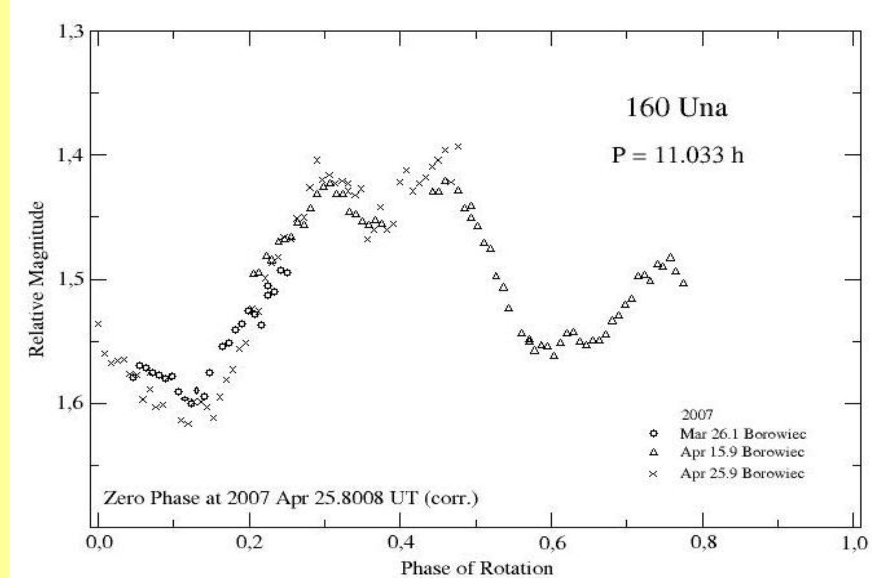
5 Feb 2002

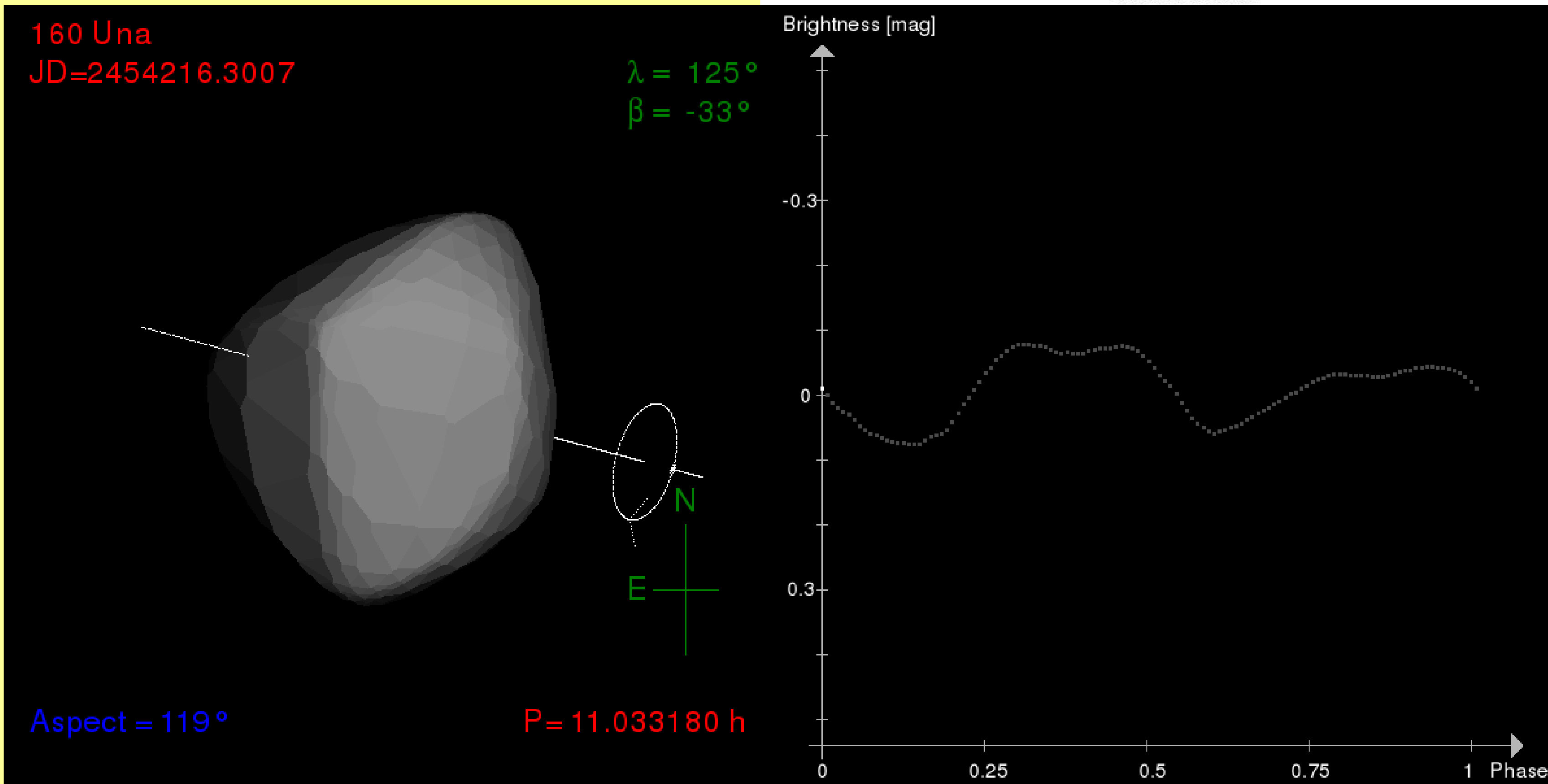




160 Una

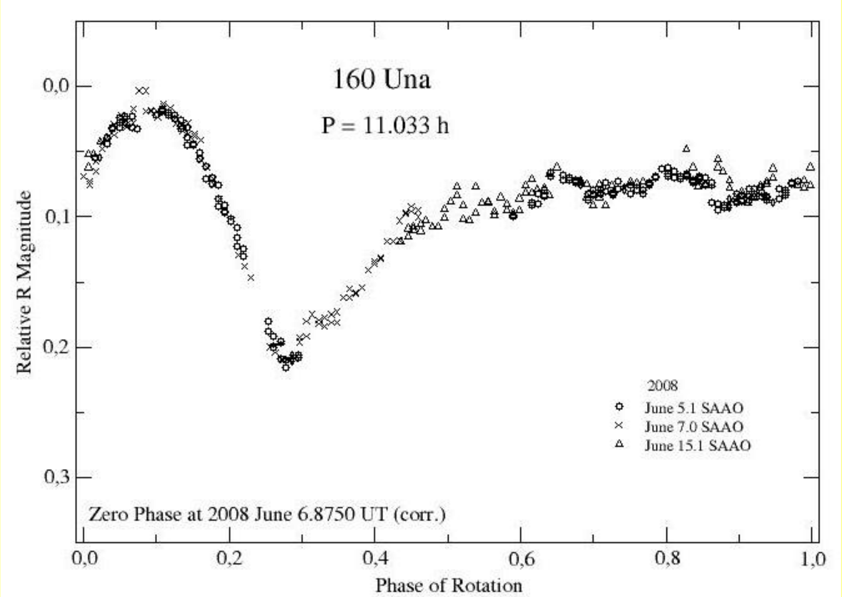
15 Apr 2007

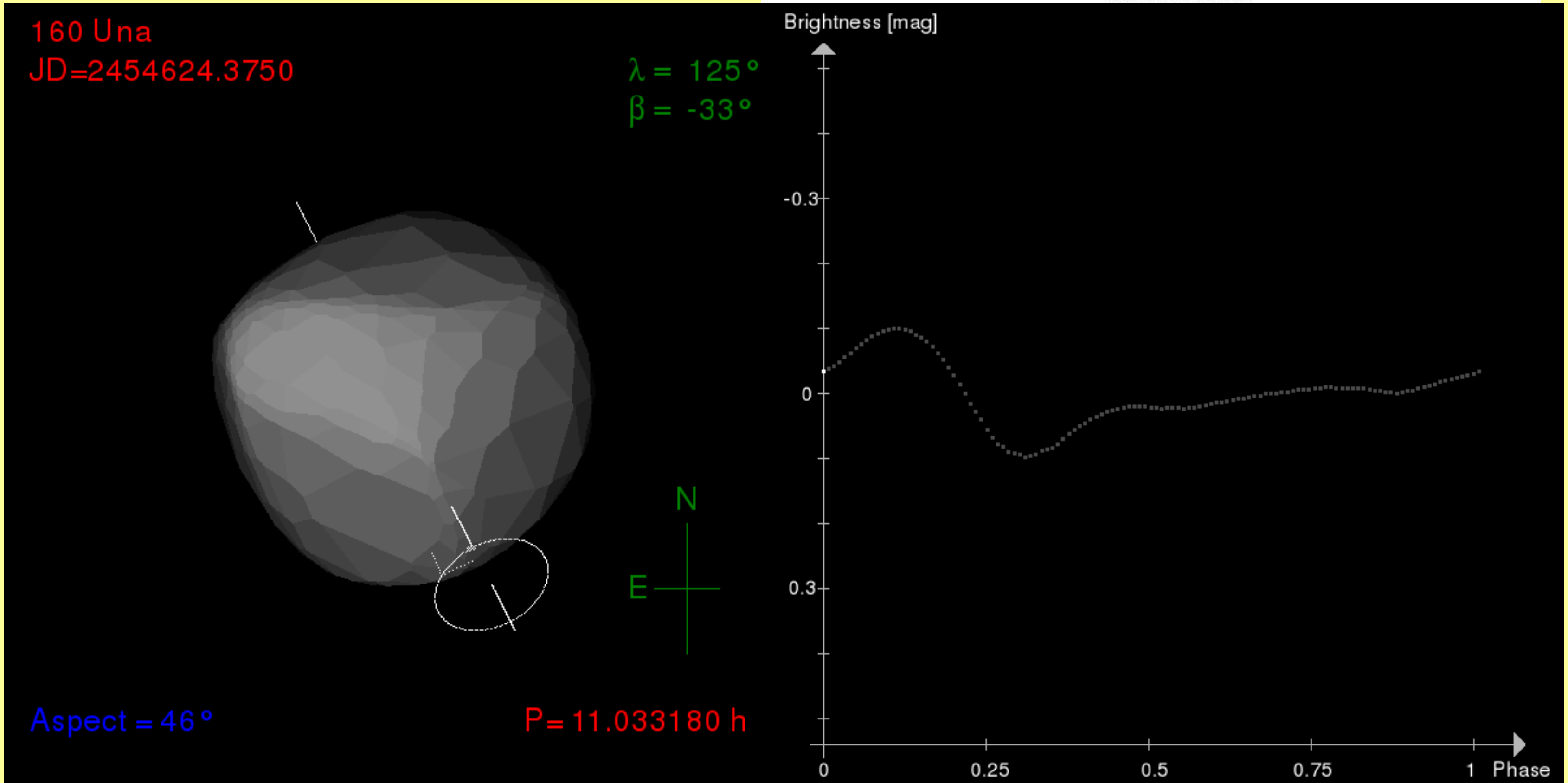




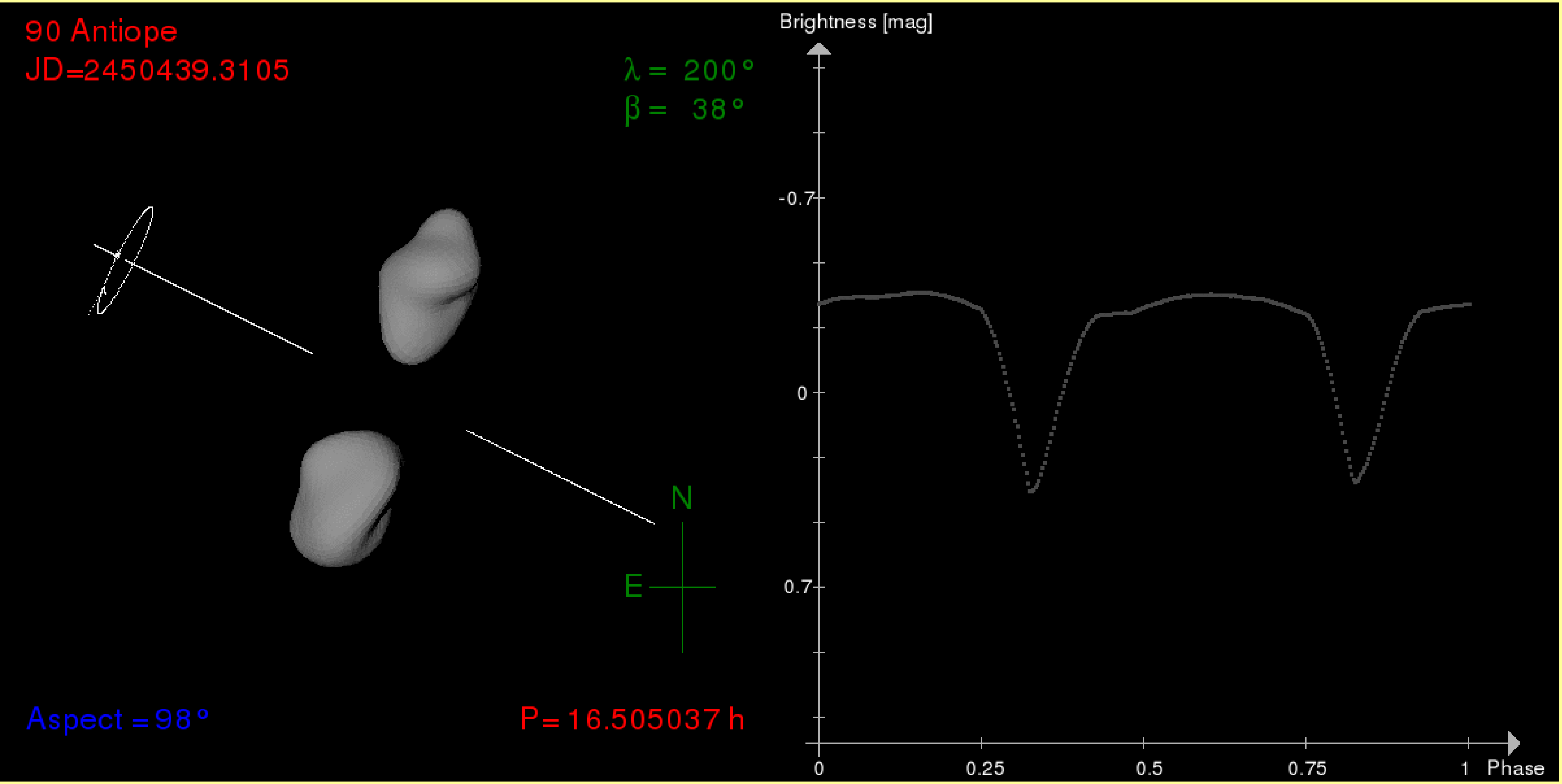
160 Una

6 June 2008

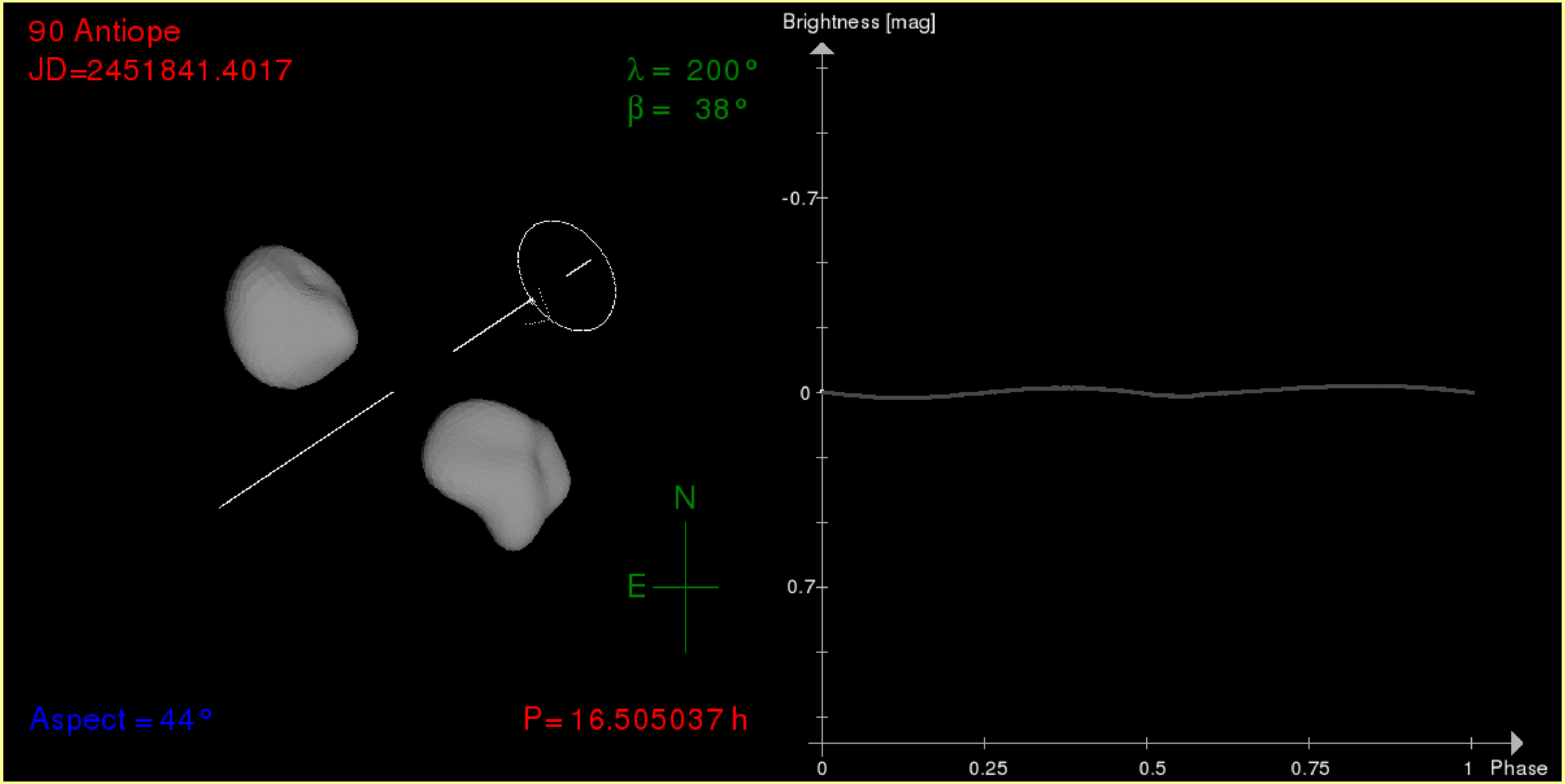




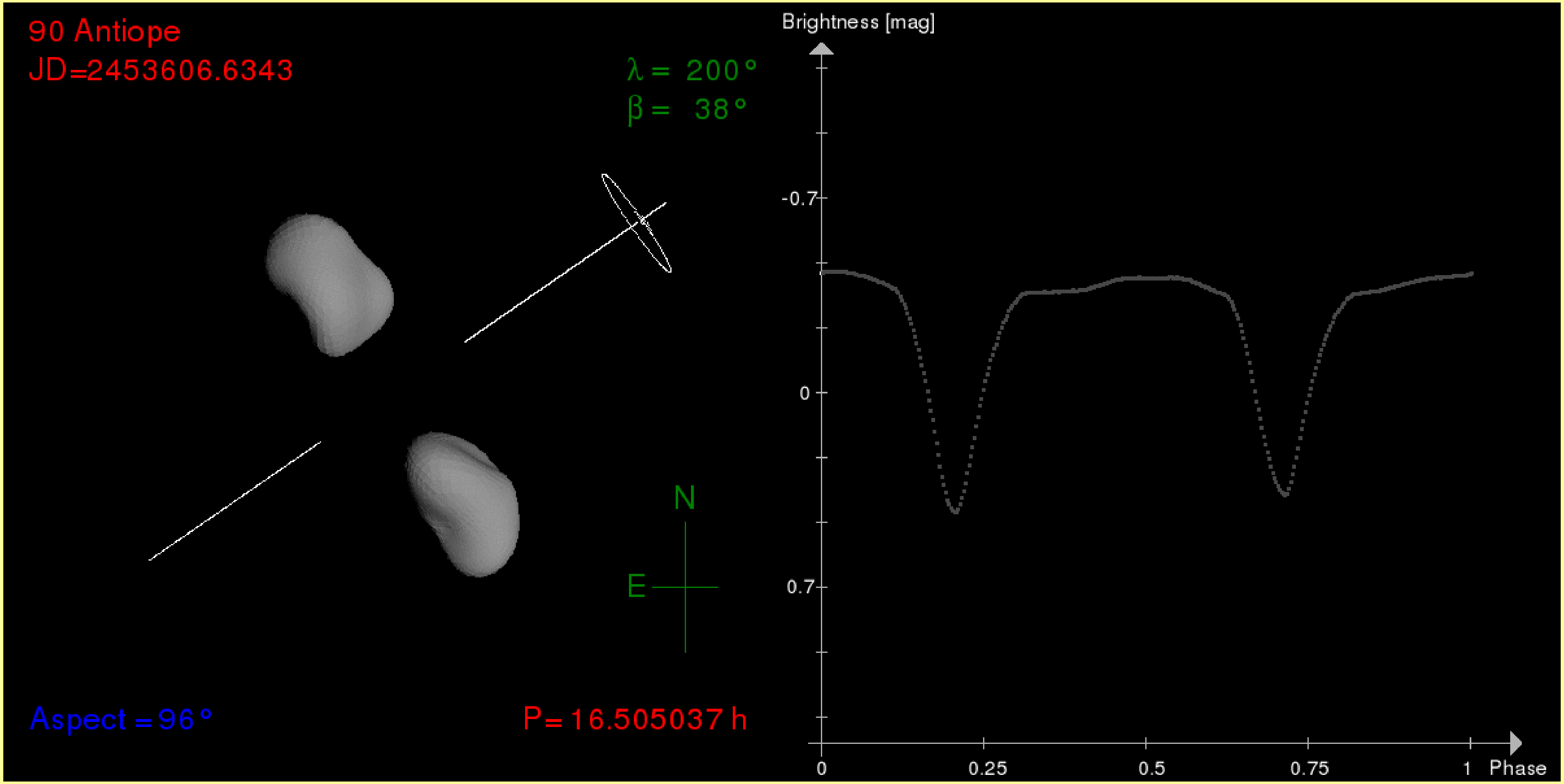
90 Antiope - 1996



90 Antiope - 2000



90 Antiope - 2005



How to verify the model ?

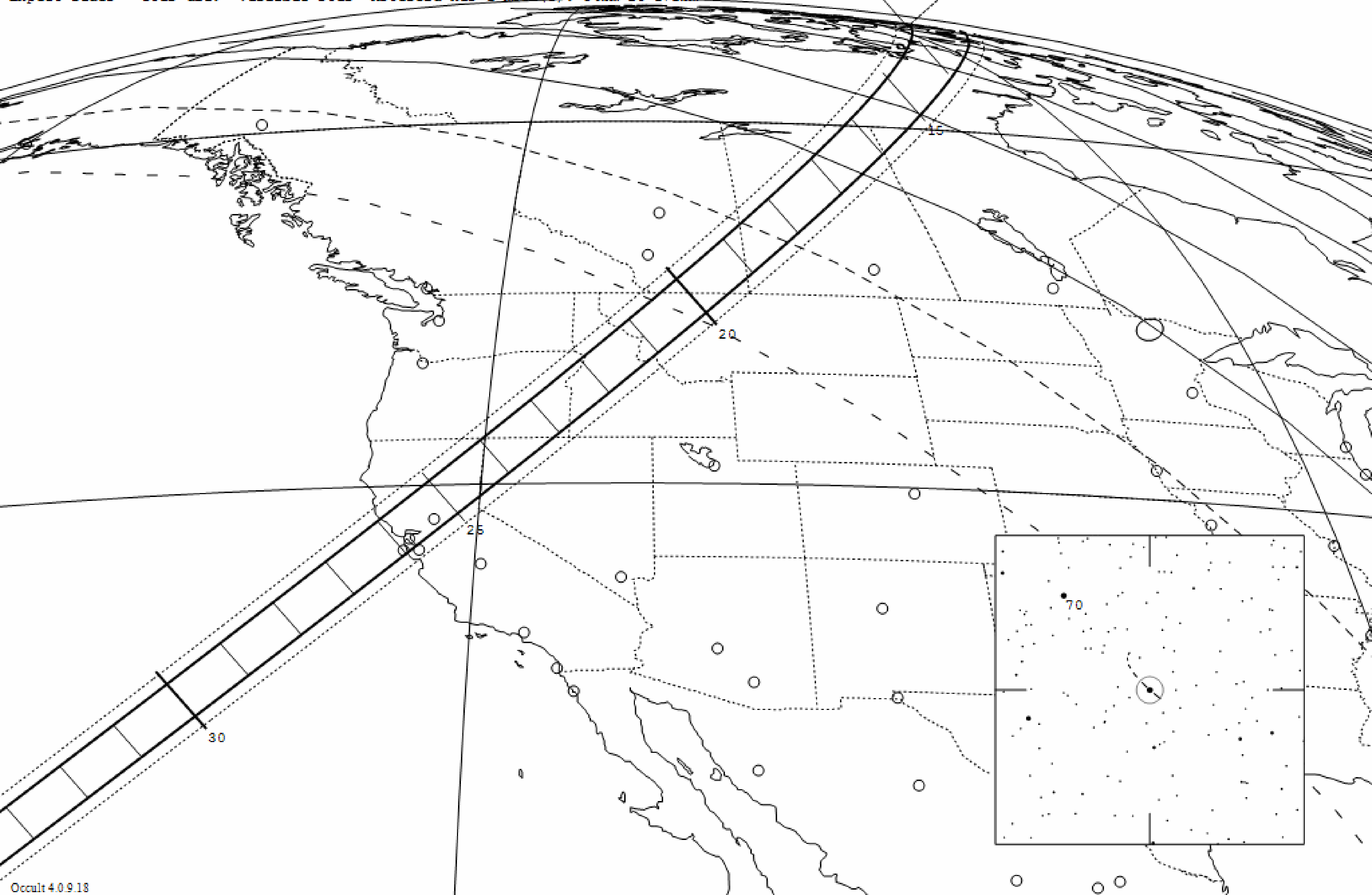
Star occultation by asteroids

International Occultation Timing Association

90 Antiope occults HIP 112420 on 2011 Jul 19 from 10h 13m to 11h 6m UT

```
Star:            Dia = 2mas                          Max Duration = 40.4 secs                       Asteroid:
 Mv =  6.7  Mp =  8.3  Mr =  5.8                        Mag Drop =  5.8 (6.2r)                        Mag =12.5
 RA = 22 46 14.2117 (J2000)                          Sun :    Dist = 138 deg                          Dia = 120km,   0.091"
Dec = -11  9 59.068    ...                           Moon:    Dist = 10 deg                       Parallax = 4.811"
[of Date: 22 46 53, -11  6  6]                          :  illum = 83 %                         Hourly dRA =-0.421s
 Prediction of 2011 Jun  8.0                         E 0.030"x 0.024" in PA 78                         dDec = -5.47"
```

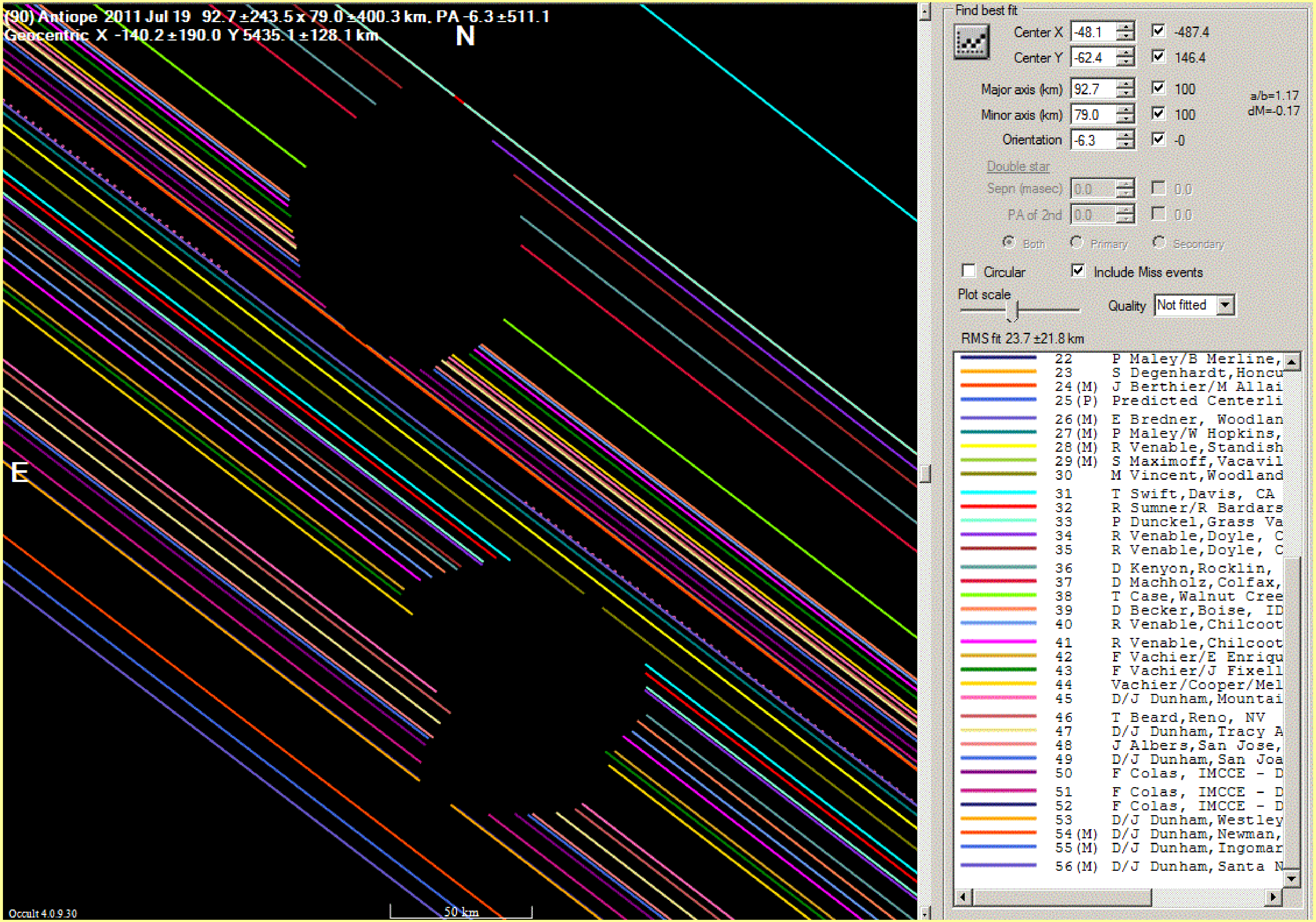
Expect fades - star dia. Variable star Asteroid has 1 moon(s). 84km at 171km



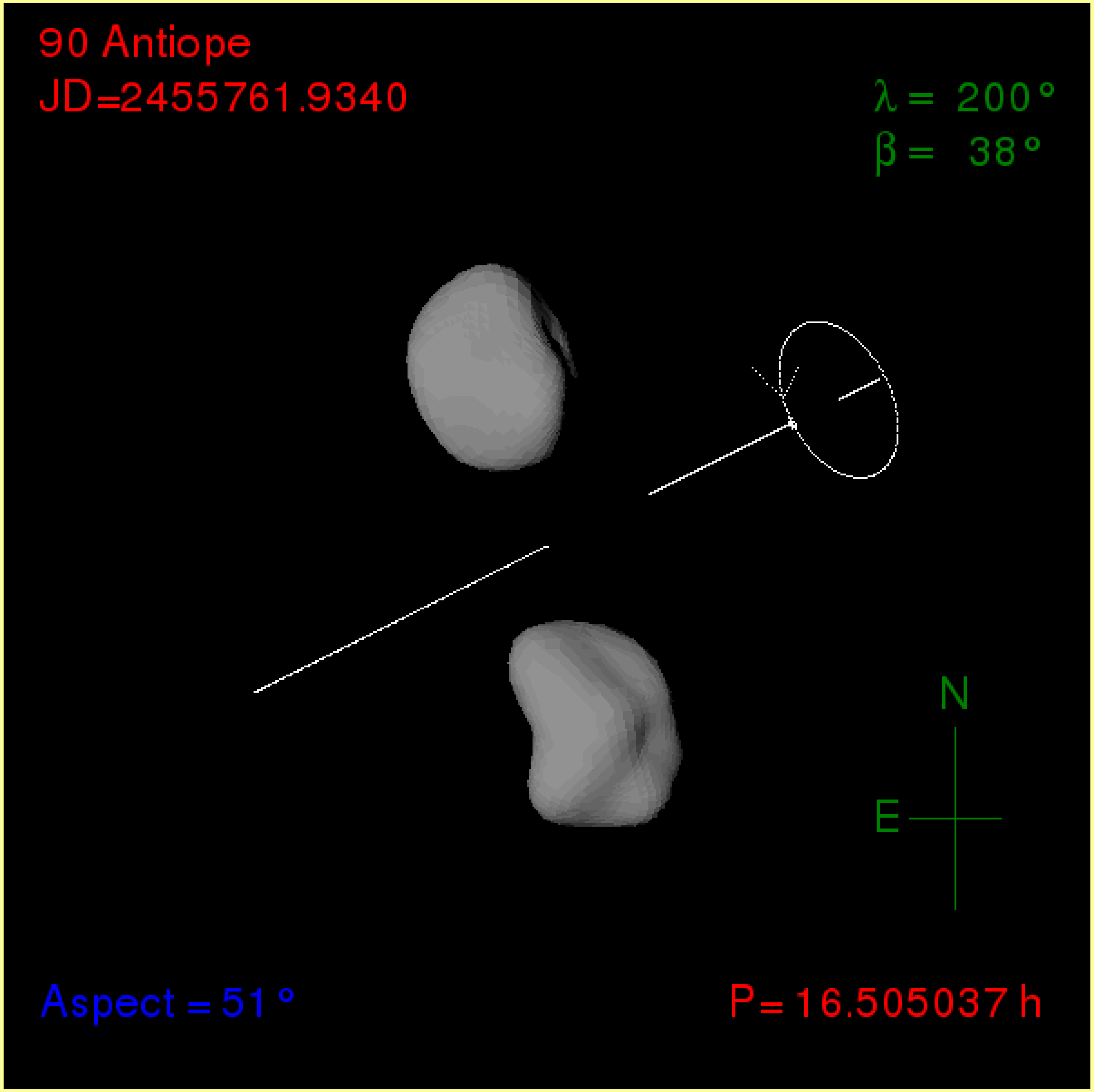
Occult 4.0.9.18

90 Antiope – 2011 July 19

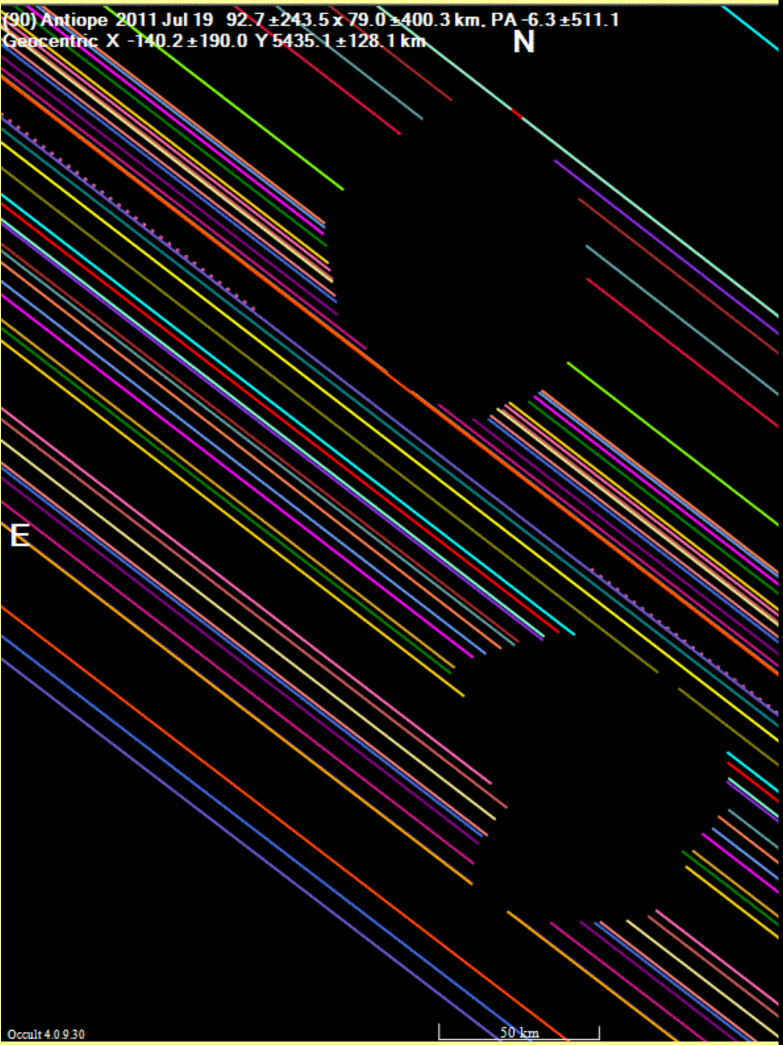
http://www.asteroidoccultation.com/observations/Results/index2011.html

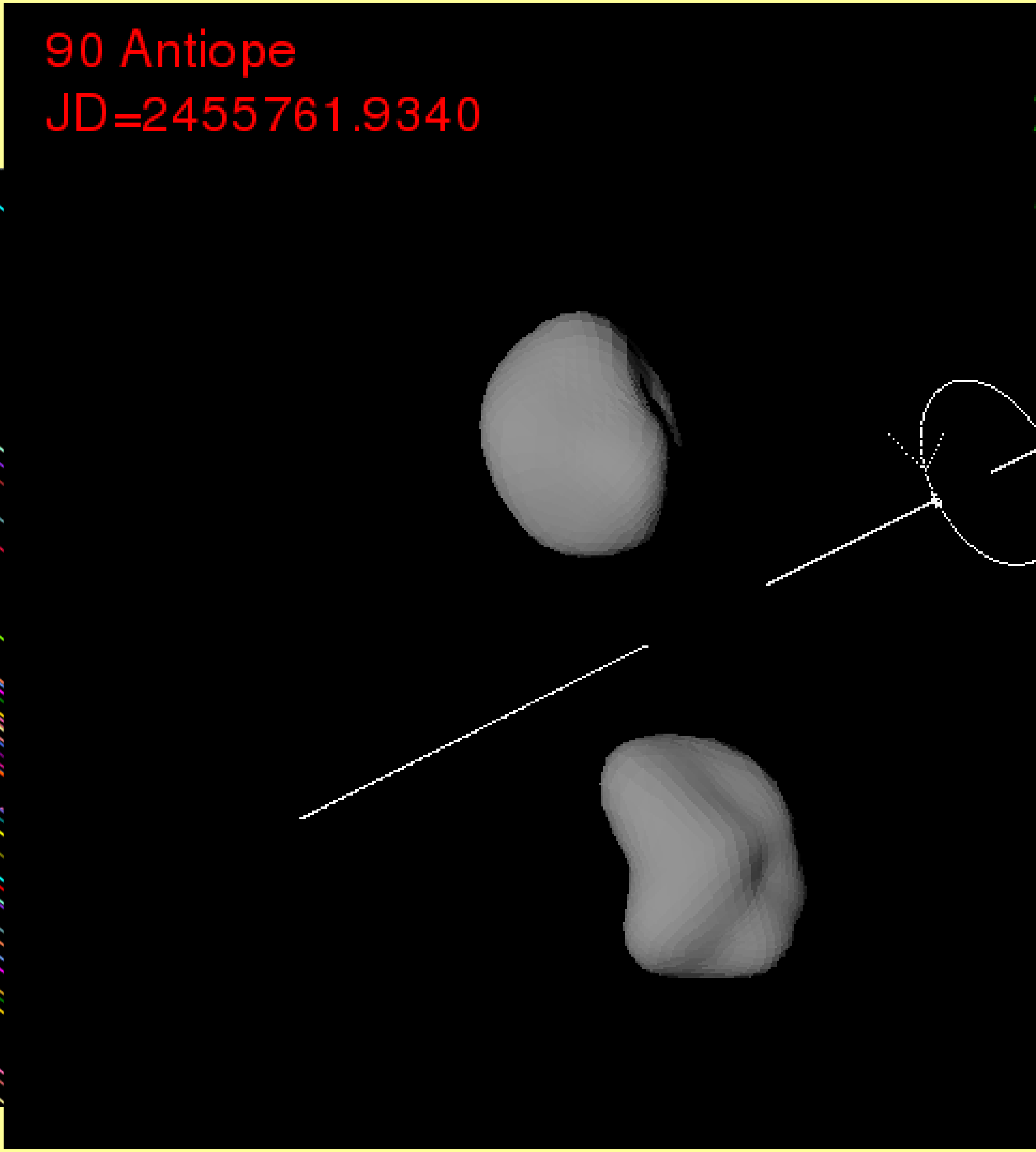


90 Antiope – 2011 July 19



90 Antiope – 2011 July 19



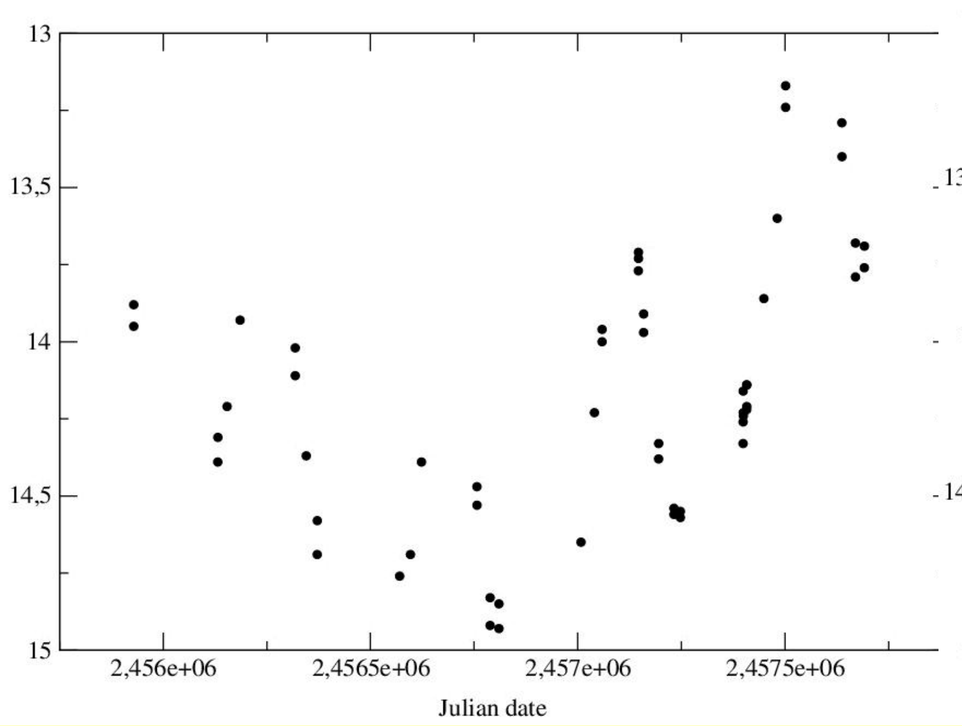


Simulation of Gaia photometric observations for binary asteroids

Toni Santana i Ros
(GREAT-ITN)

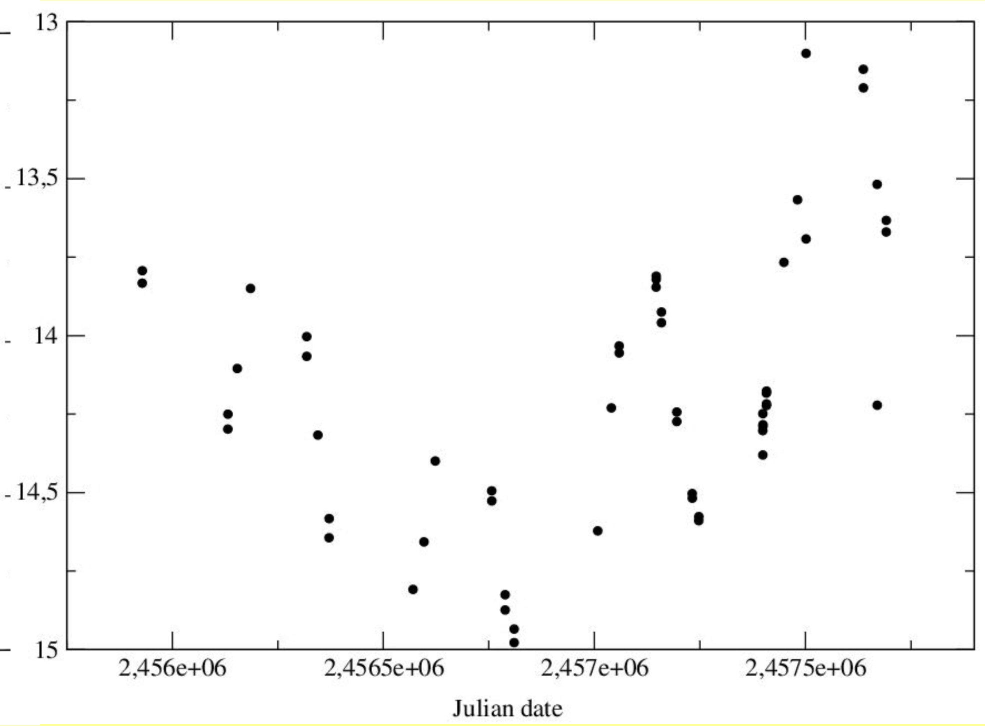
Antiope – like objects

Single body



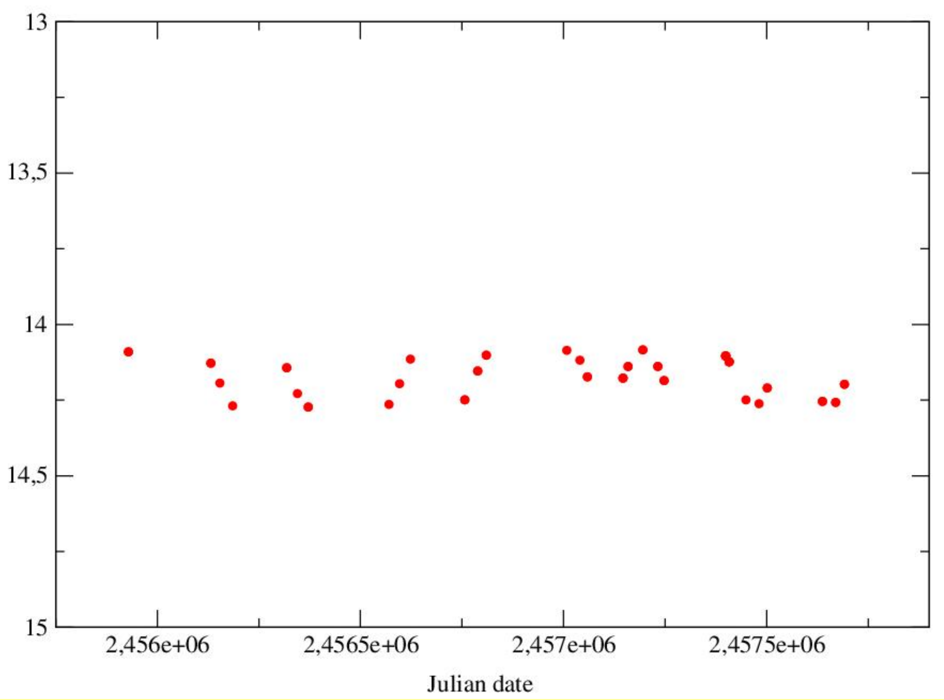
Binary system

$D_{s.}/D_p = 1$



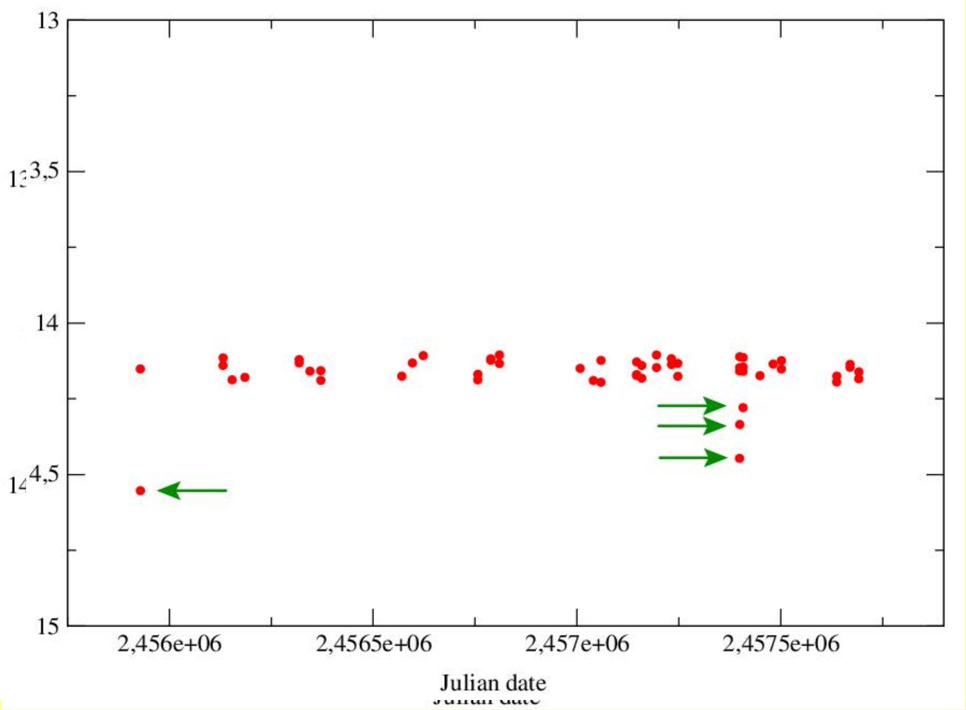
Antiope – like objects

Single body



Binary system

$D_{s.}/D_p = 1$



Reduction: geocentric and heliocentric distances
phase angle

Thank You