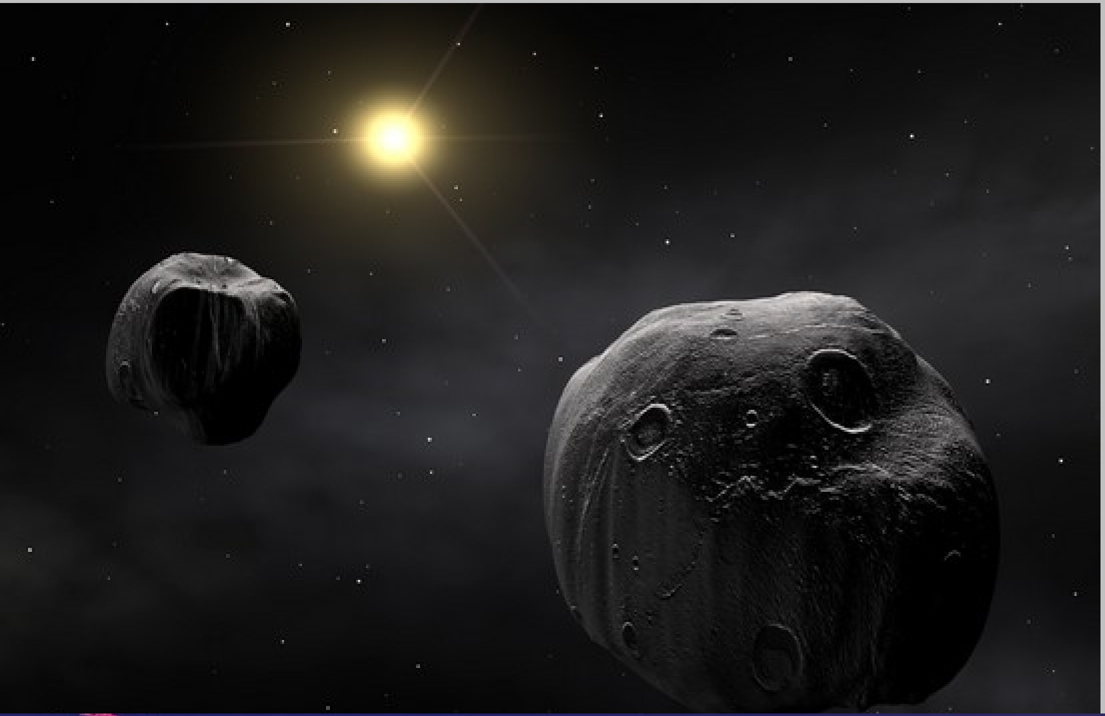
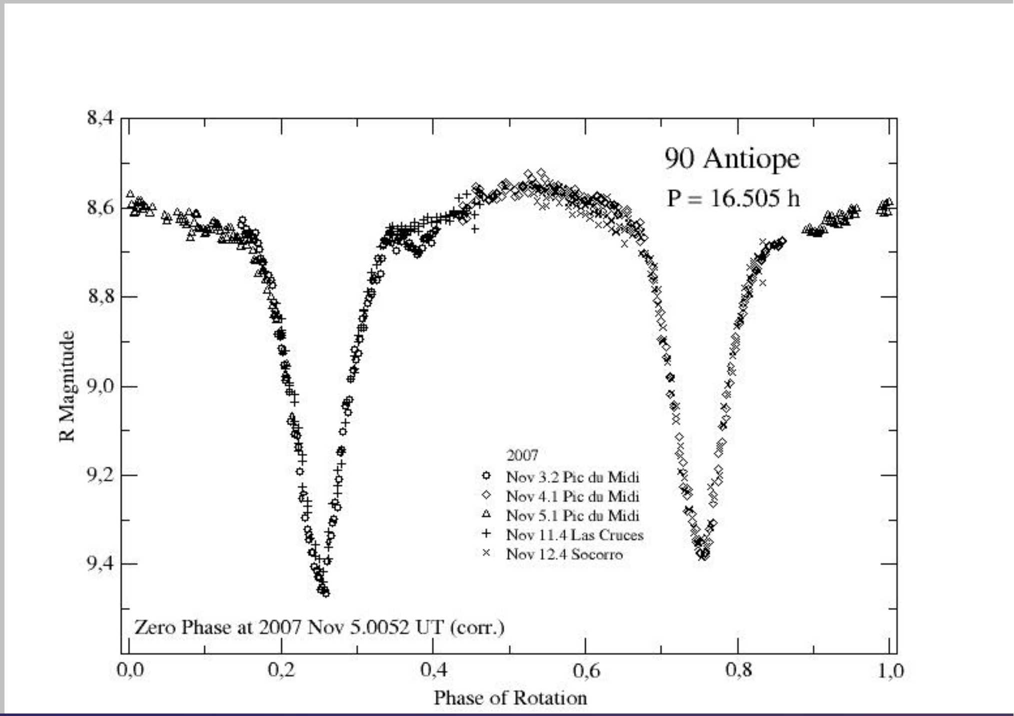
Asteroids masses from future ephemerides, densities from binaries

François COLAS *Institut de Mécanique Céleste – Observatoire de Paris*
Petr KUCHYNKA *Jet Propulsion Laboratory*





Densities measurements

Most of the asteroids have not evolved since solar system formation

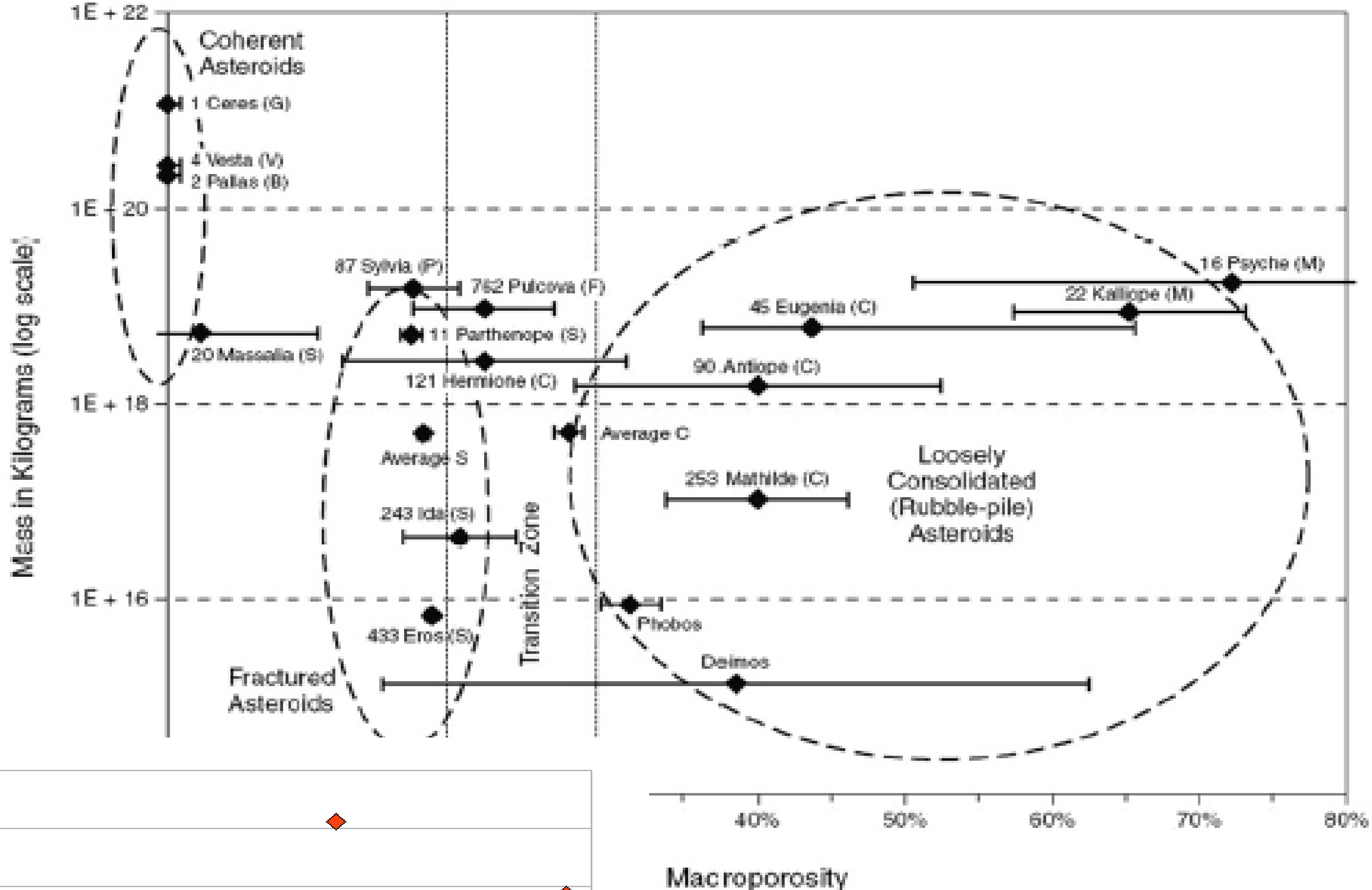
- Asteroids densities are keys for :

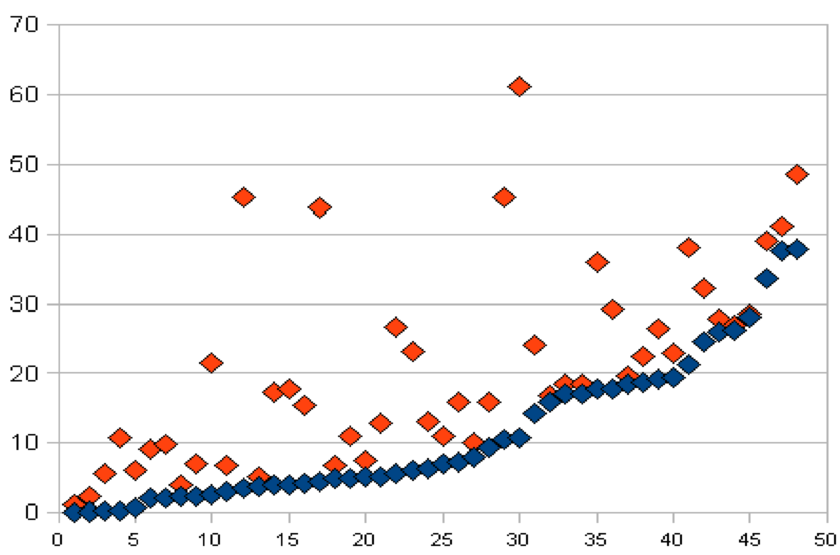
  - Solar system formation
  - Evolution
  - Impacts and evolution of the solar system

- Densities + Spectroscopic observations => macro porosity

  - fracturation
  - rubble piles
  - collisional history
  - ...

Actual situation





Accuracies of actual best masses (blue dots) and best densities (red dots)

About 200 asteroid masses will be known in the next 10 years using different ways,

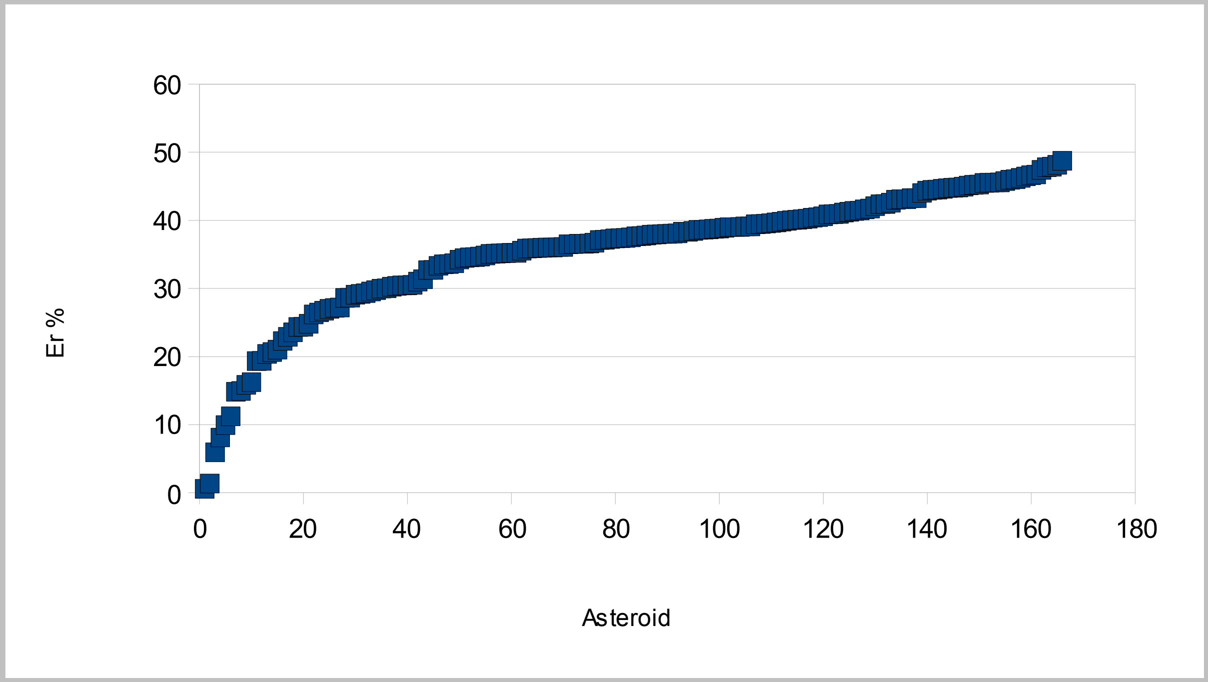
Mars orbit perturbations,
Mutual perturbations,
Flyby,
Binary asteroids

GAIA will permit to determine several masses

Mars perturbations

As we know Mars orbit with a meter accuracy and as asteroids can perturb Mars orbit of more than one kilometer, it is possible to measure some asteroids masses ***(INPOP-10a A.Fienga et al 2011)***

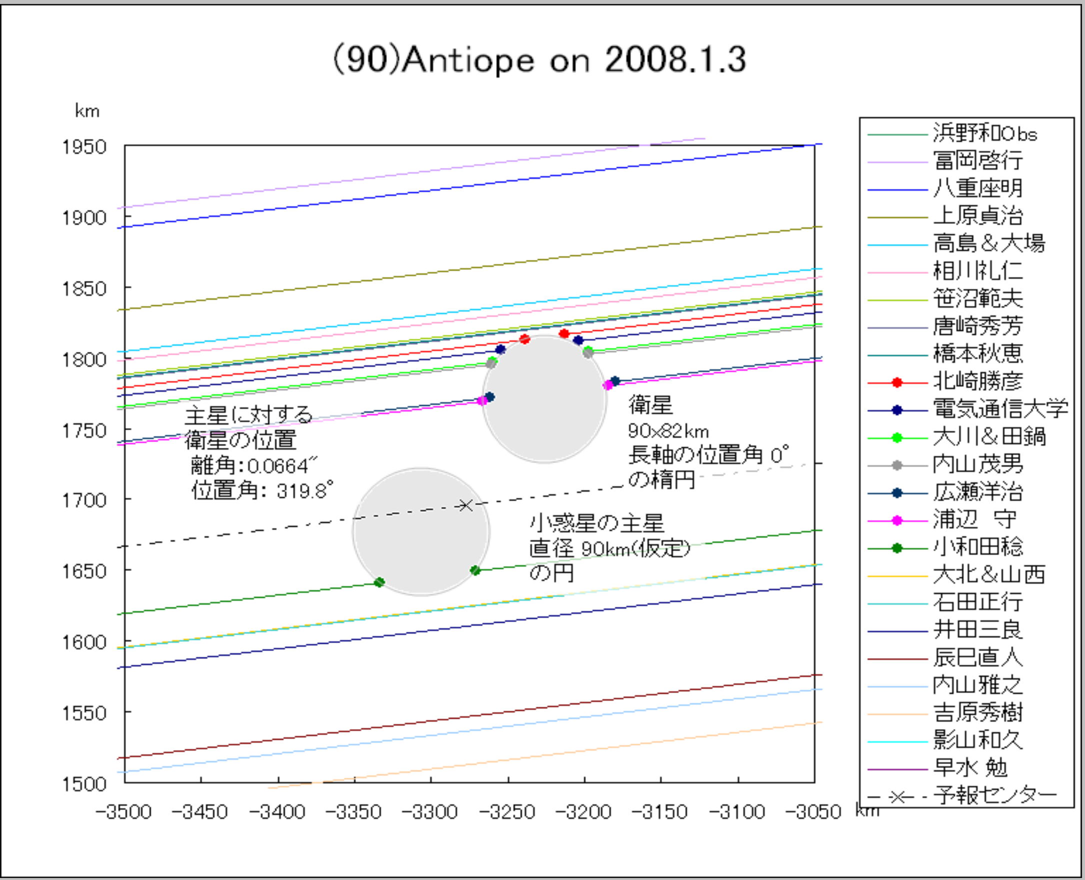
- we supposed that Mars orbit will be still known with an one meter accuracy until 2020, we found 167 objects with masses that can be measured with an accuracy better than 50%



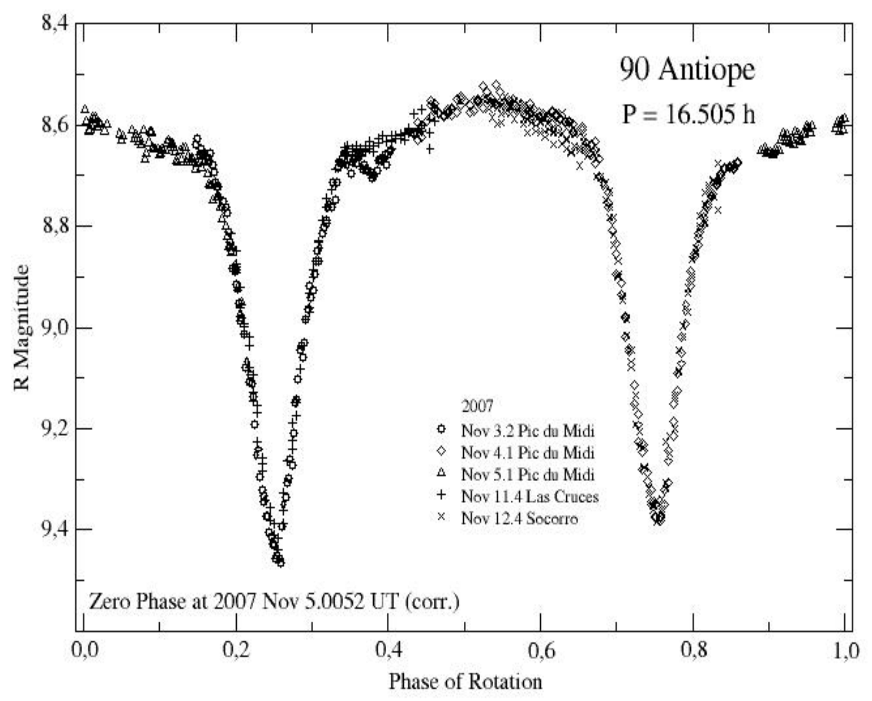
Mass determination

40% => 115
30% => 50

Binaries

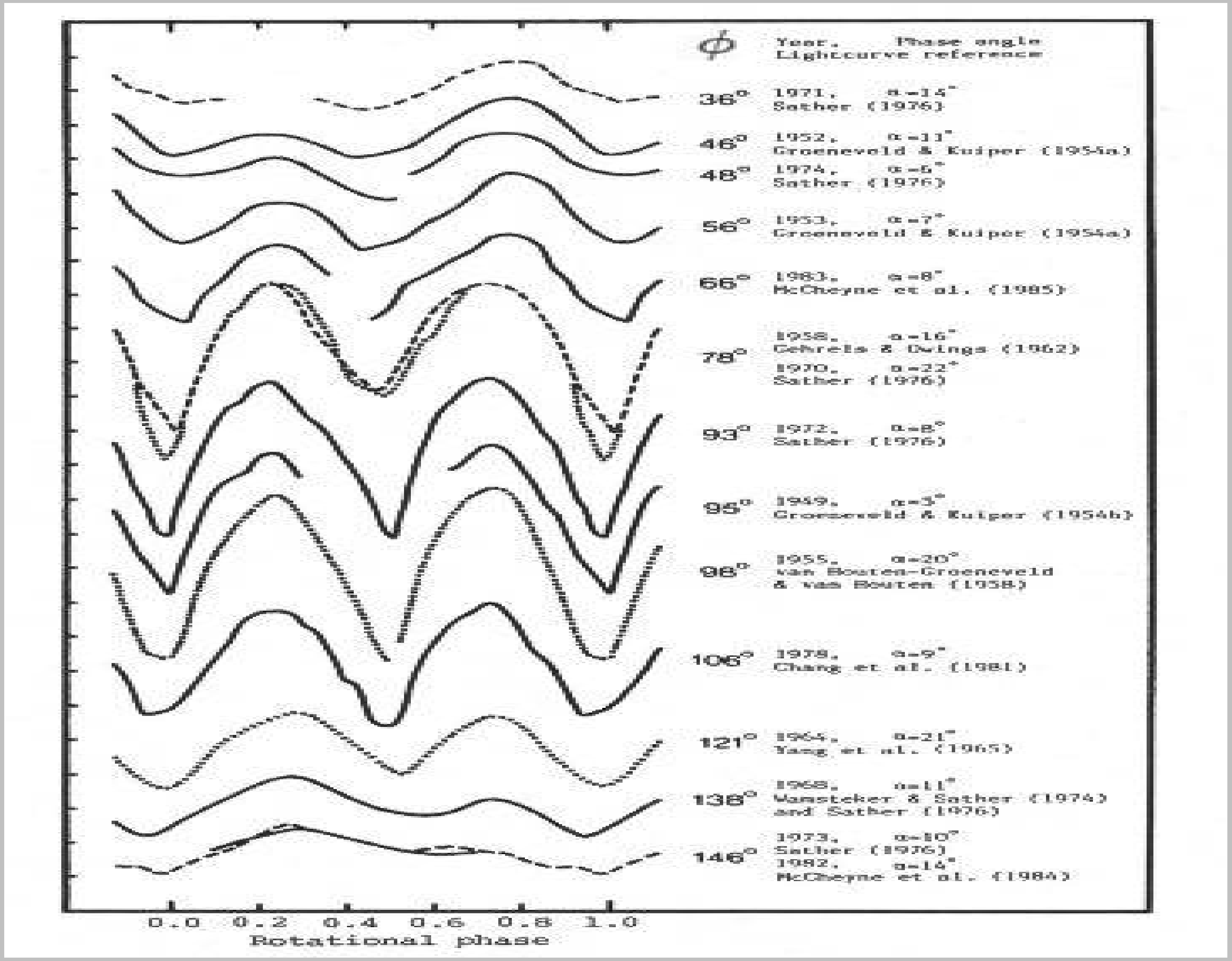


Occultations

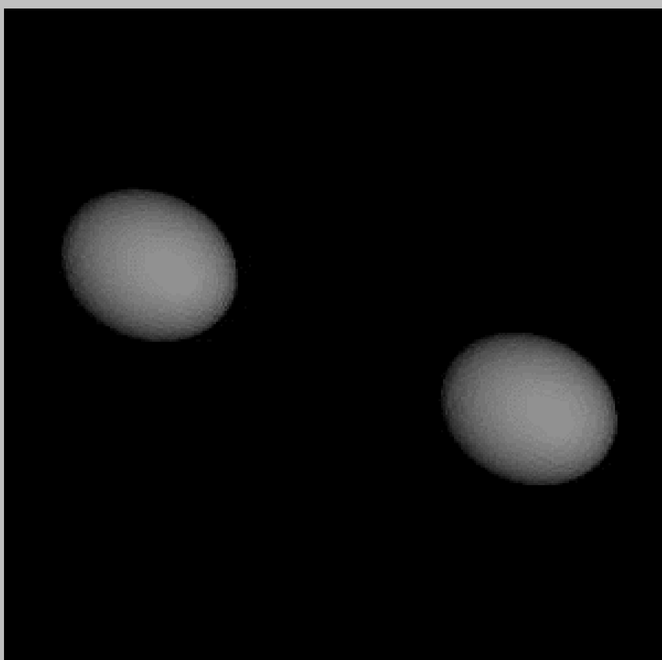


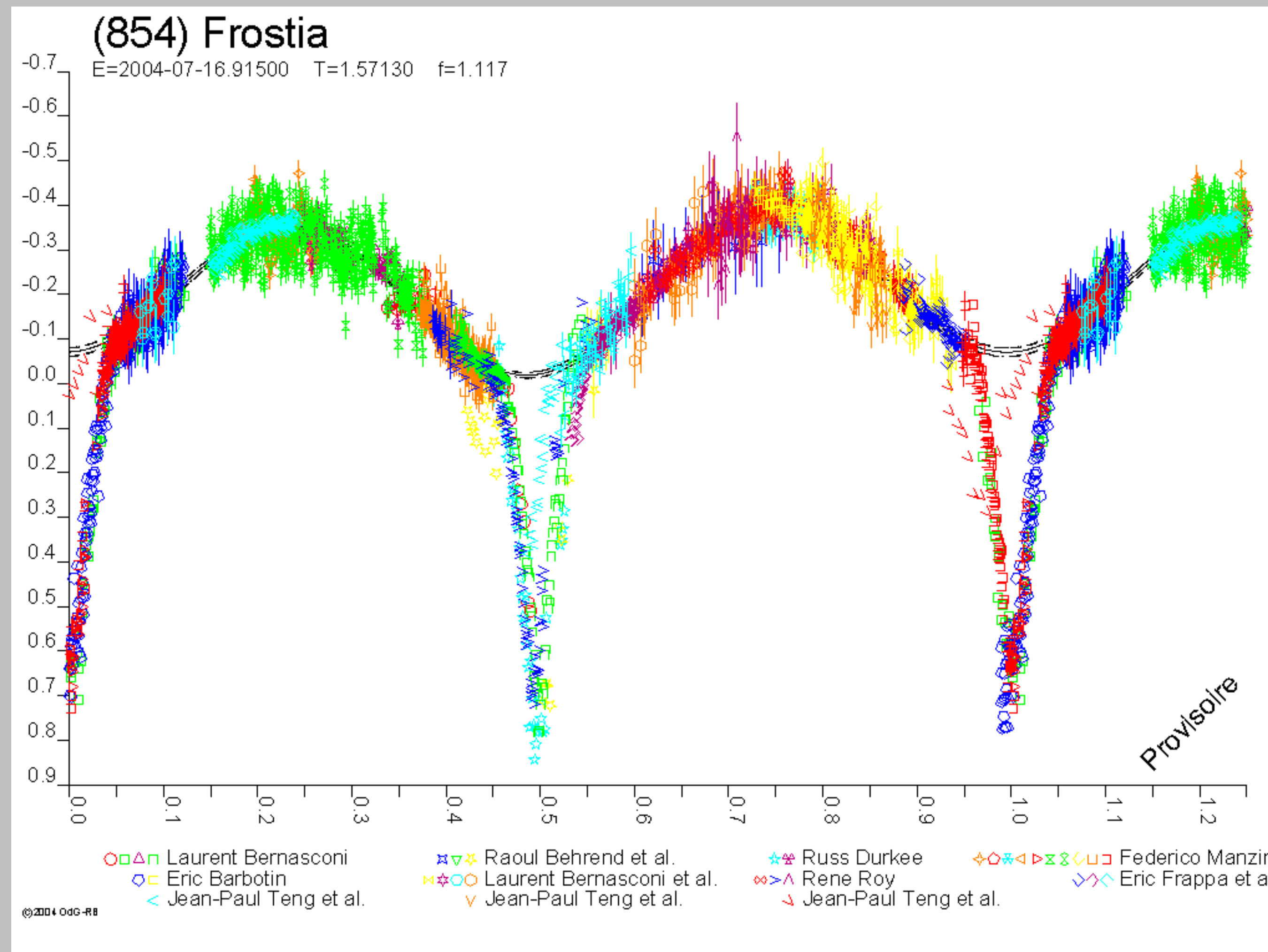
Light curves

Single 39 Laetitia light curve



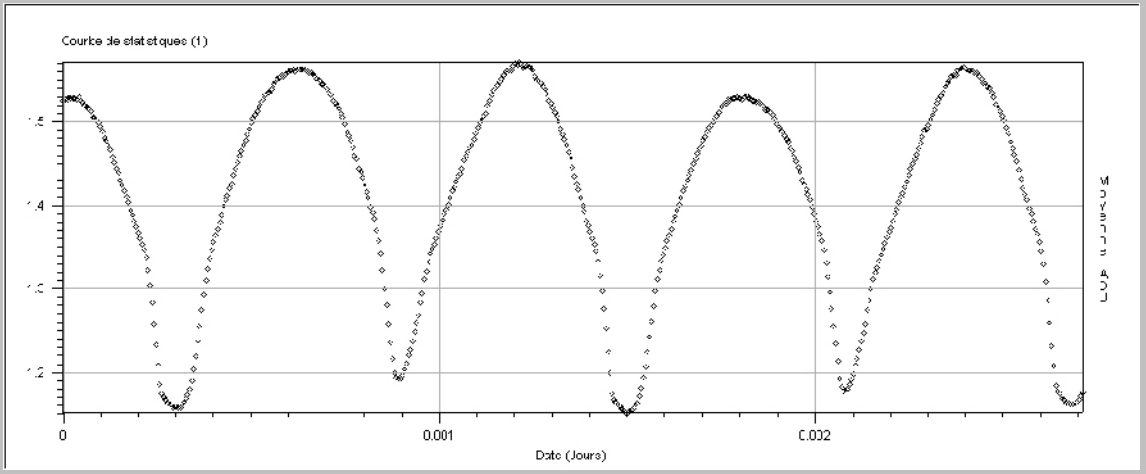
Binary asteroid light curves



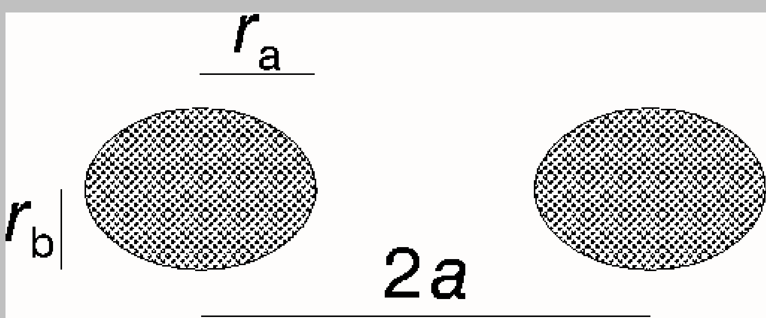


PHOTOMETRIE : Eléments physiques (λp,βp) – travaux pratiques

Réalisation du Lycée de l'Arc



Direct density estimation

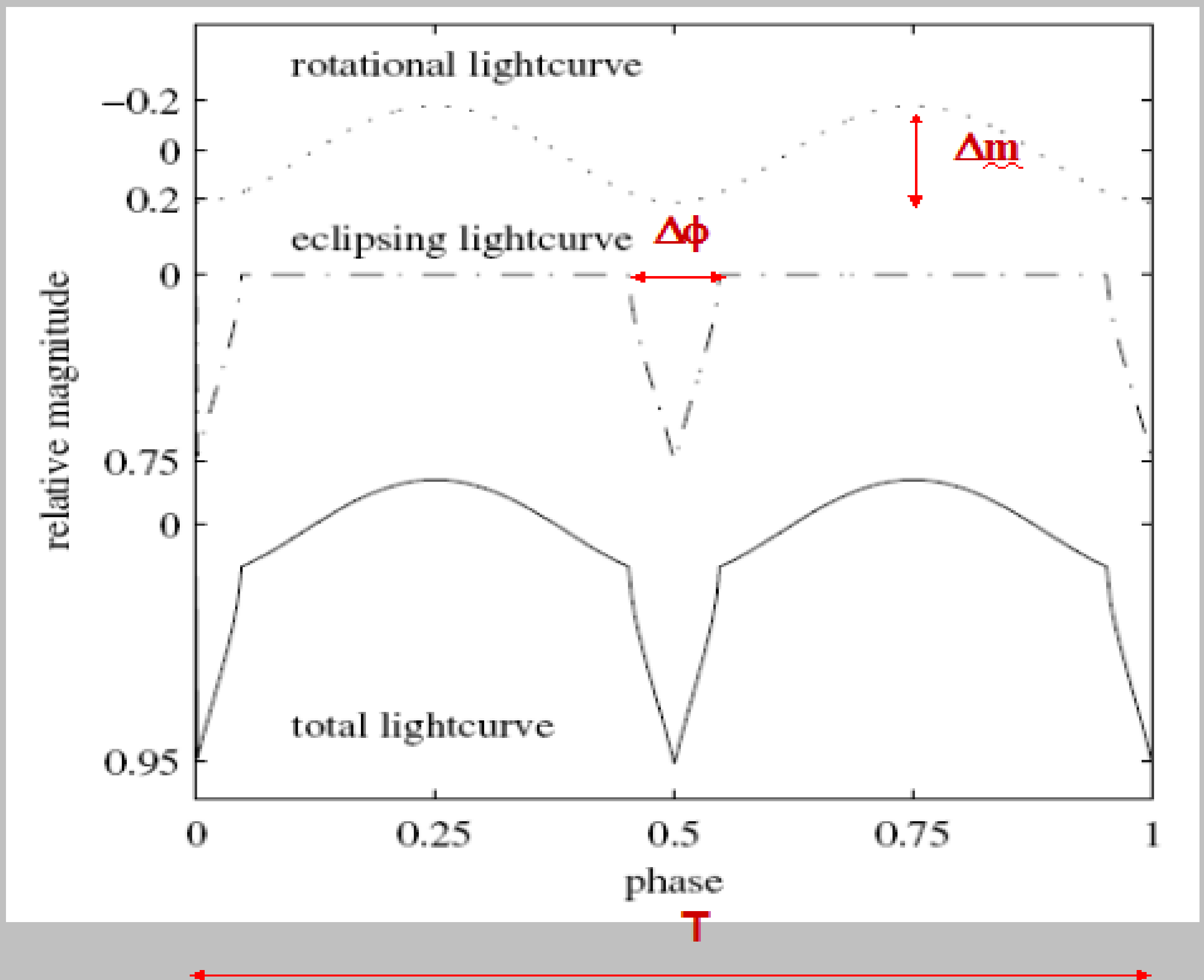


$$r_b/r_a = 10^{-0.4\,\Delta m}$$

$$a = \frac{r_b}{\sin(\Delta\phi/2)}.$$

$$M = \frac{16\,\pi^2\,a^3}{G\,T^2}$$

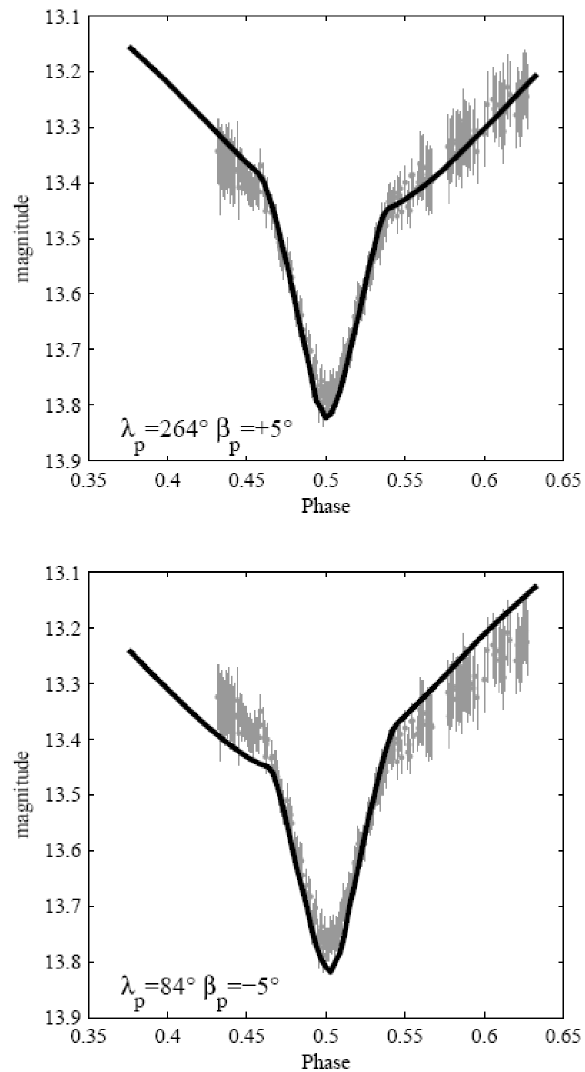
$$\rho = \frac{M}{\frac{4}{3}\,\pi\,r_a\,r_b{}^2}.$$

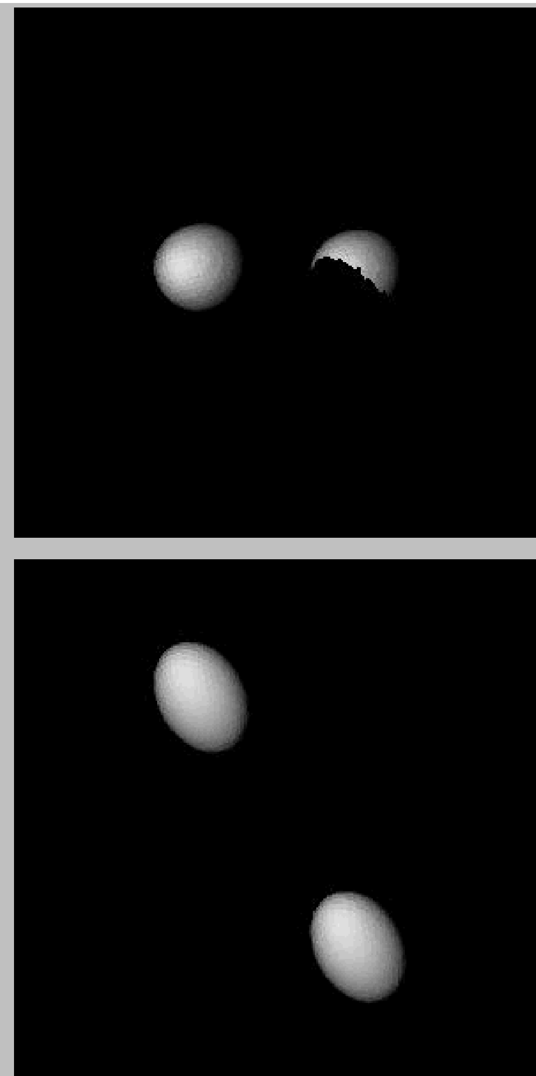


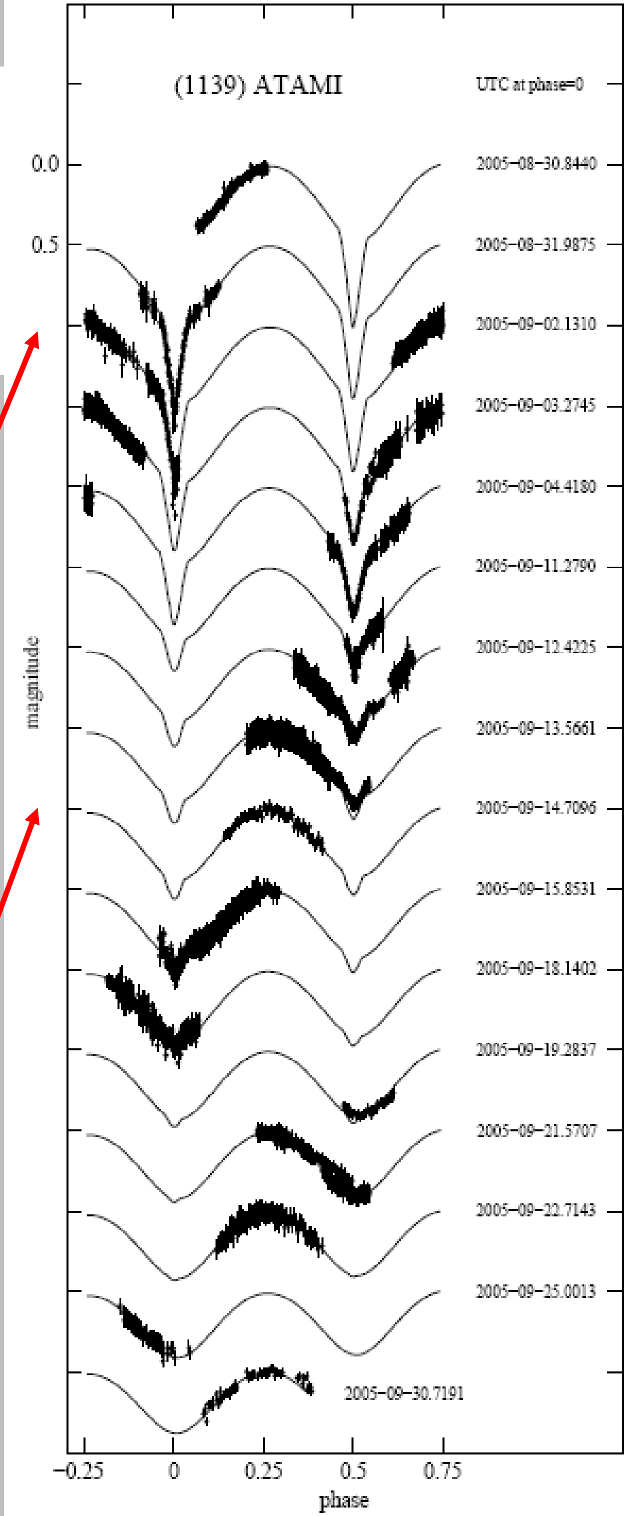
$$\rho = \frac{12\,\pi}{G}\,\frac{1}{T^2}\,\frac{10^{-0.4\,\Delta m}}{\sin^3(\Delta\phi/2)}.$$

Discovery of the binary nature of the Mars–crosser (1139) Atami ⋆

R. Behrend[1], F. Manzini[2], A. Klotz[3,4], F. Colas[5,6], Y. Damerdji[3,4], S.J. Ostro[7], P. Antonini[8,6], E. Barbotin[6], L. Bernasconi[9,6], C. Cavadore[10], S. Charbonnel[11,6], J. Coloma[12], R. Cripa[13], F. Kugel[14], A. Leroy[15], J.M Llapasset[16], A. Oksanen[17], P. Pääkkönen[18], R. Poncy[19,6], R. Roy[20,6], and D. Starkey[21]



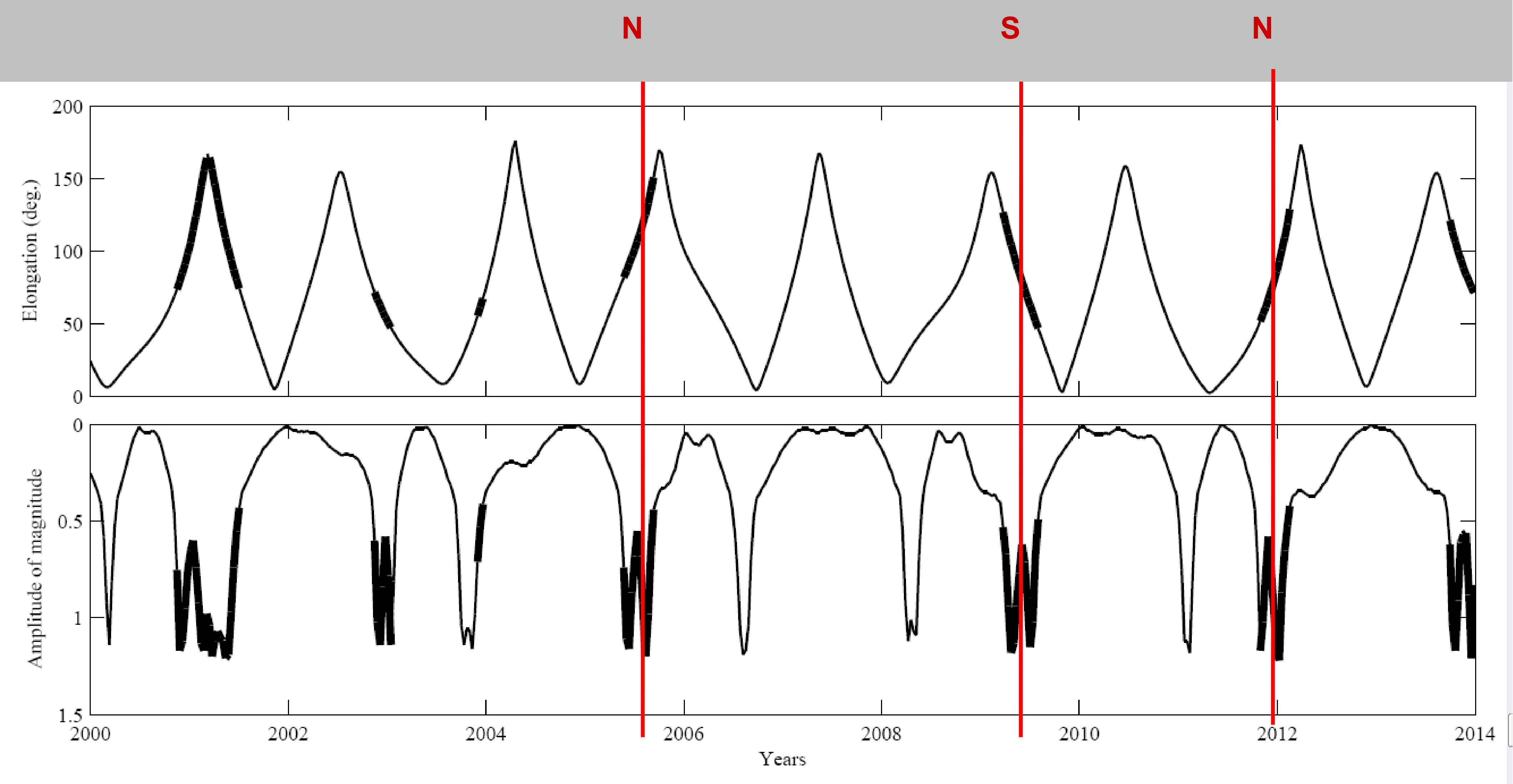




Prédictions...

Discovery of the binary nature of the Mars–crosser (1139) Atami ⋆

R. Behrend[1], F. Manzini[2], A. Klotz[3,4], F. Colas[5,6], Y. Damerdji[3,4], S.J. Ostro[7], P. Antonini[8,6], E. Barbotin[6], L. Bernasconi[9,6], C. Cavadore[10], S. Charbonnel[11,6], J. Coloma[12], R. Cripa[13], F. Kugel[14], A. Leroy[15], J.M Llapasset[16], A. Oksanen[17], P. Pääkkönen[18], R. Poncy[19,6], R. Roy[20,6], and D. Starkey[21]



Four binaries founded on 400 light curves

	(854) Frostia	(1089) Tama	(1313) Berna	(4492) Debussy
r_a (km)	4.08–9.65	5.08–5.99	4.48–10.7	2.99–7.09
r_b (km)	2.95–6.99	3.48–4.11	3.54–8.39	1.92–4.56
a (km)	9.57–25.0	9.47–12.2	9.63–24.8	5.23–13.5
M (10^{13} kg)	11–201	57–121	25–426	3.7–63
ρ (g cm^{-3})	0.75–1.02	2.23–2.82	1.07–1.36	0.80–1.01
r_b/r_a	0.724	0.685	0.790	0.643
a/r_a	2.34–2.59	1.86–2.03	2.14–2.33	1.74–1.90
a/r_b	3.23–3.59	2.71–2.95	2.71–2.96	2.71–2.96
1-ϵ	0.84–0.89	0.72–0.79	0.76–0.82	0.71–0.77

If we admit the validity of the detection criteria given above, and a mean value $\frac{r_b}{2a} \sim \frac{1}{6}$, we can compute

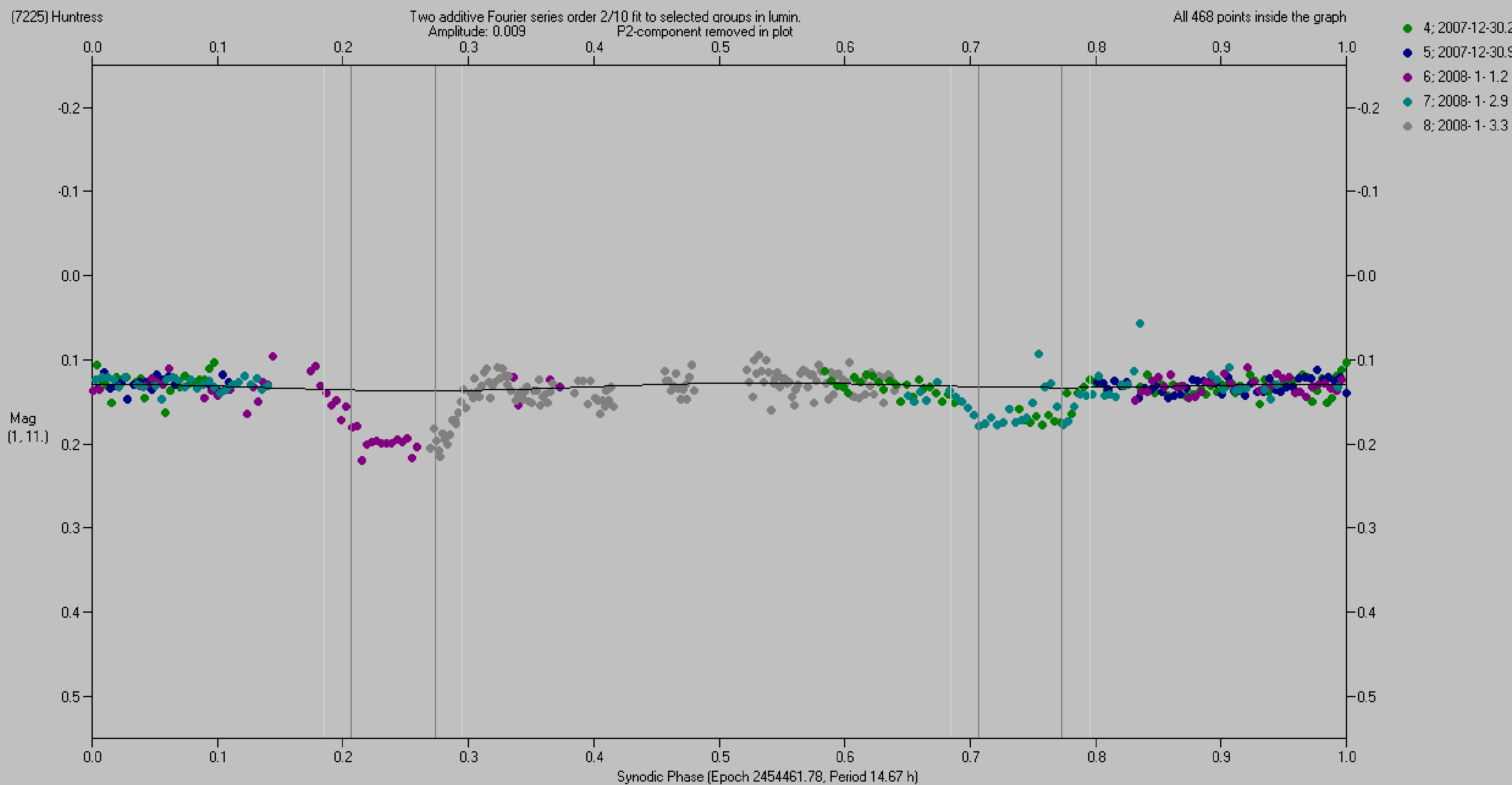
$$p\left(\zeta = \frac{1}{6}\right) \sim 0.17.$$

This means that only 17% of the binary asteroids that have a ratio $r_b/(2a) \sim 1/6$ can be detected at a given opposition. As four asteroids were recognized as binary, about $4/0.17 \simeq 24$ of the total (4.0×10^2) should be of the same type. Taking account of the uncertainties, the proportion of binary systems in the main belt is thus probably around 6 ± 3 percents.

No bias on statistic

We can do the same with Gaia by searching light curves with anomamies

(7225) Huntress
An exemple of low amplitude transit / occultation



P_{orb} = 14.67 ± 0.01 h
D_2/D_1 = 0.21 ± 0.02
P_1 = 2.4400 ± 0.0001 h
A_1 = 0.11 mag

P.Pravec

We know 162 multiple astéroids (5 triples, 1 quadruple) *(may 2010)*

35 NEOs, 7 Mars-Crossers, 62 MBO, 2 Trojans, 56 TNOs

- ***Discoveries*,**
  - **HST (47) --**
  - **Ground based (29) – 8 m class telescopes (8-10m) with AO**
  - **Ground based, light curves (62) – Small telescopes (1m-30cm),**
  - **Radar (21) – Mainly Arecibo - NEO**
  - **Space missions (1) .....**

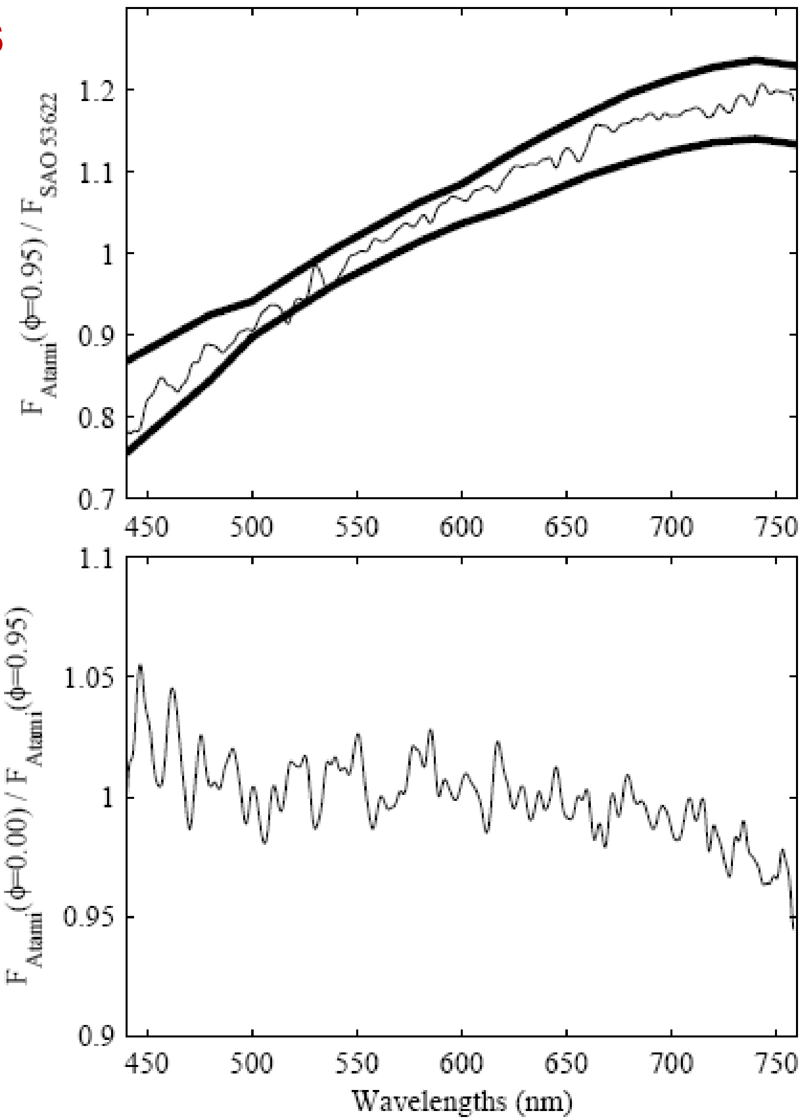
Low resolution spectrography : minéralogy

Discovery of the binary nature of the Mars–crosser (1139) Atami ⋆

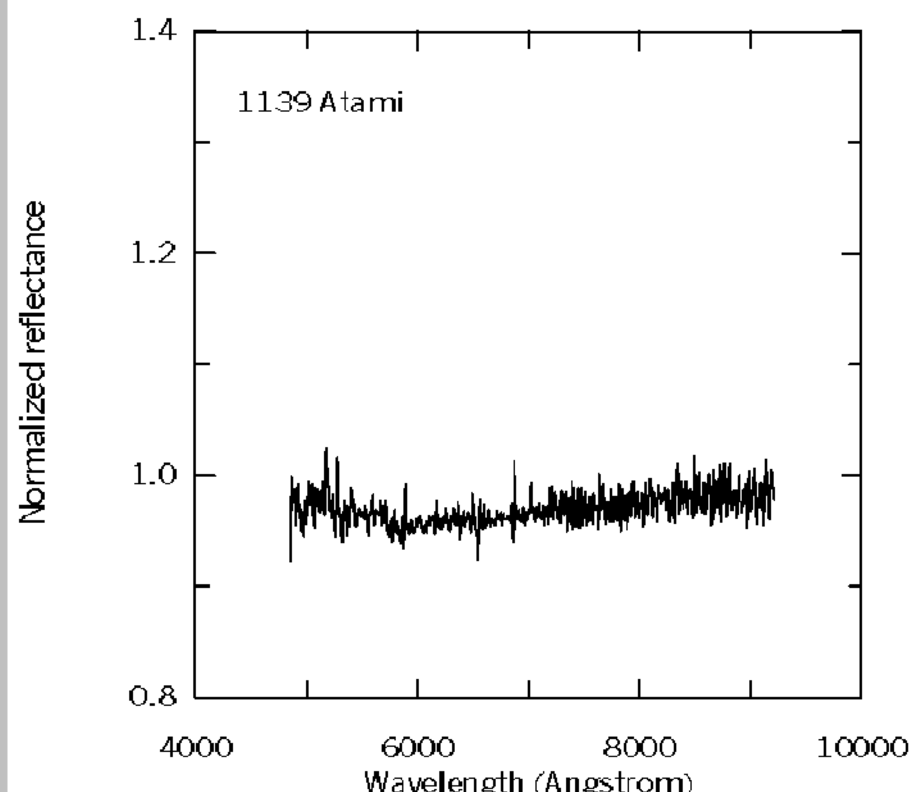
R. Behrend[1], F. Manzini[2], A. Klotz[3,4], F. Colas[5,6], Y. Damerdji[3,4], S.J. Ostro[7], P. Antonini[8,6], E. Barbotin[6], L. Bernasconi[9,6], C. Cavadore[10], S. Charbonnel[11,6], J. Coloma[12], R. Cripa[13], F. Kugel[14], A. Leroy[15], J.M Llapasset[16], A. Oksanen[17], P. Pääkkönen[18], R. Poncy[19,6], R. Roy[20,6], and D. Starkey[21]

Infrared photometry from ground based observations
=>
Thermal inertia (eclipse observations)

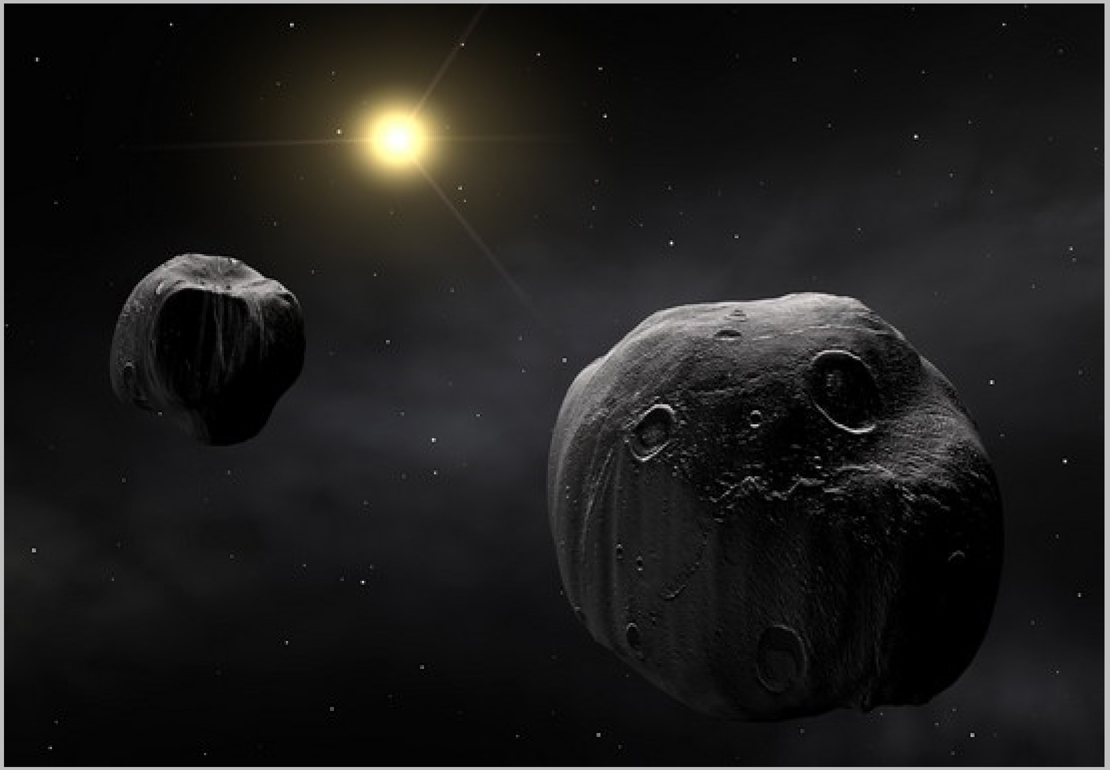
2005 type S (pôle N)

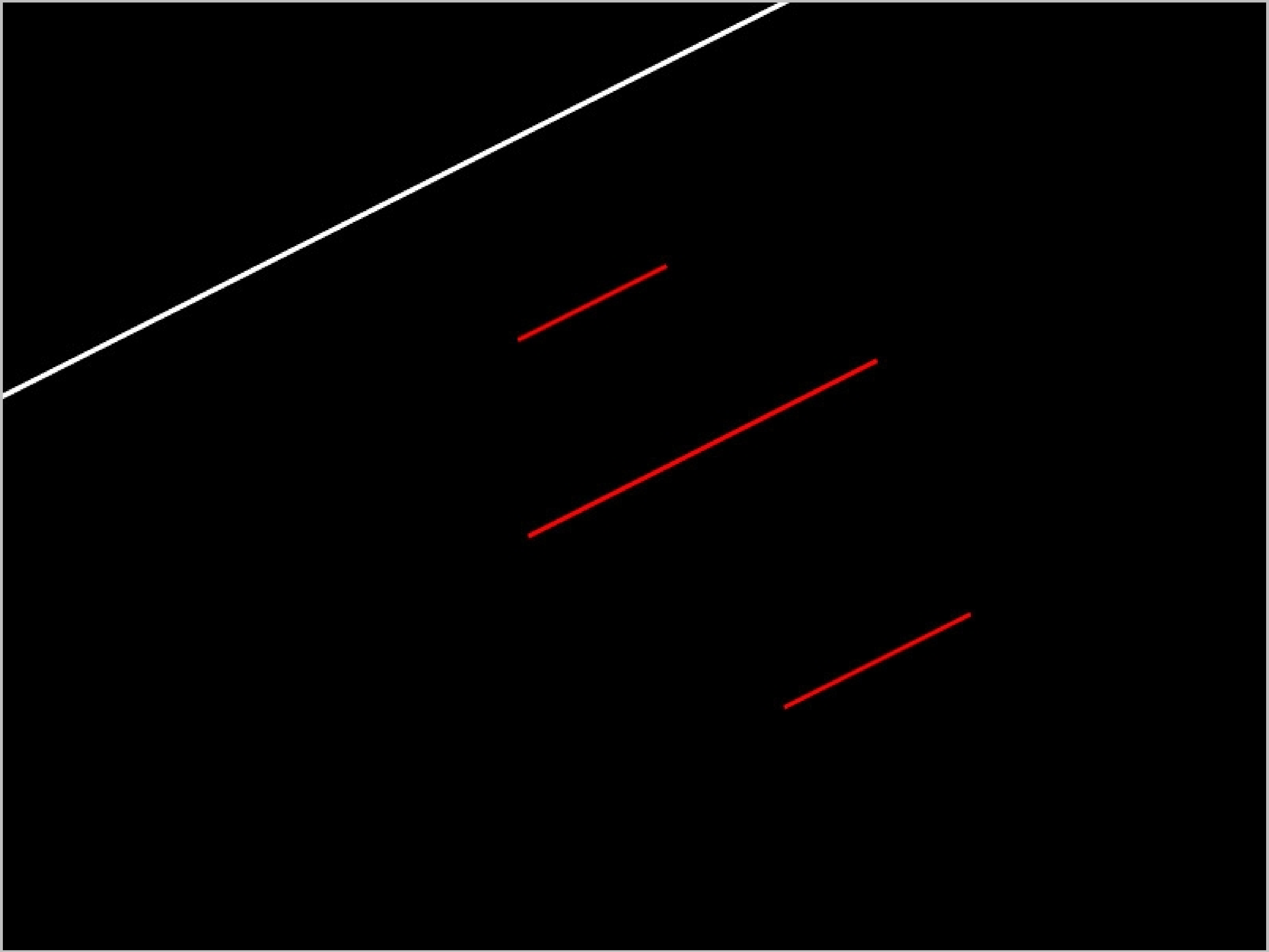


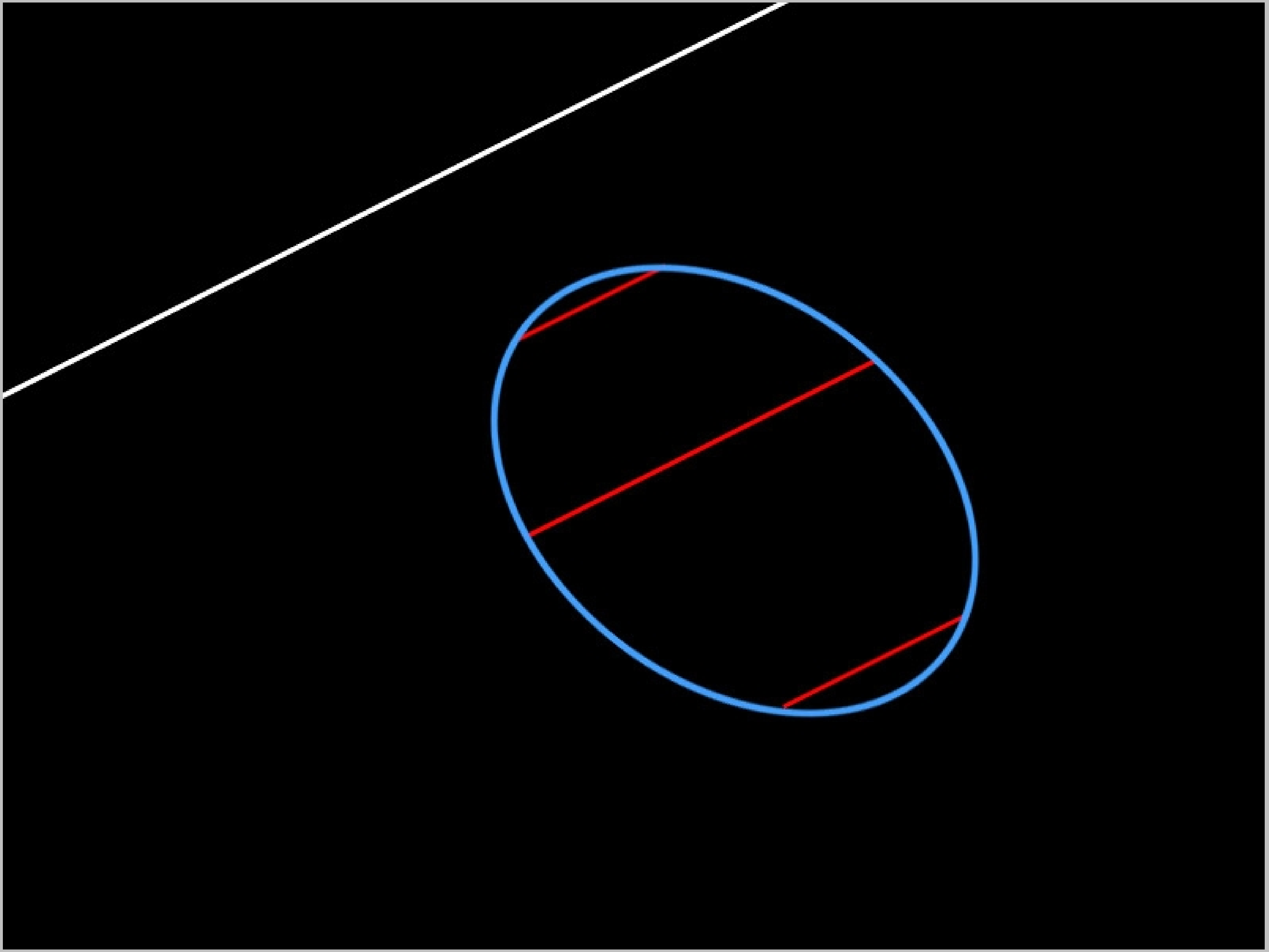
1996 type S (pôle N)
1997 type C (pôle S)

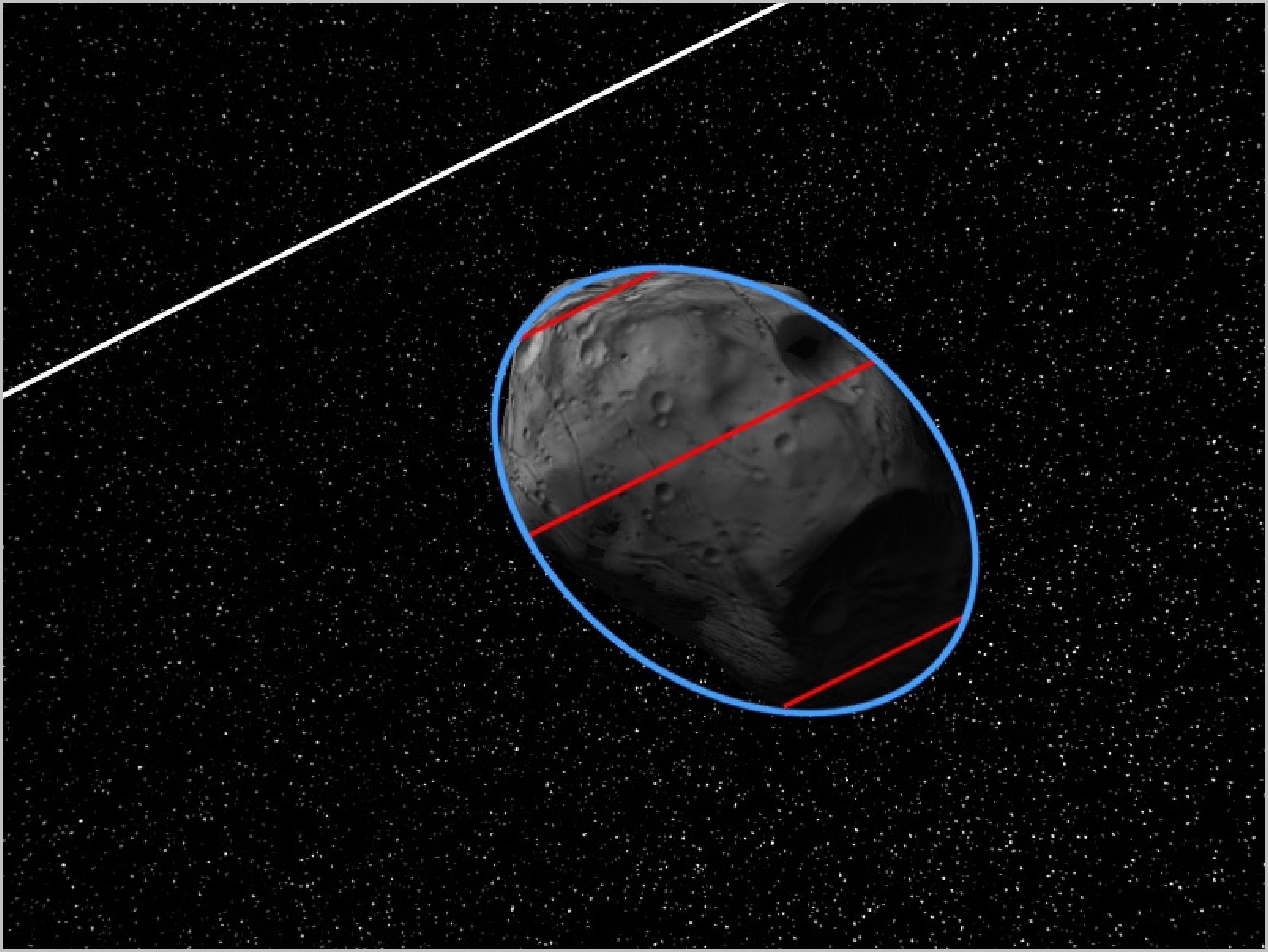


Occultations

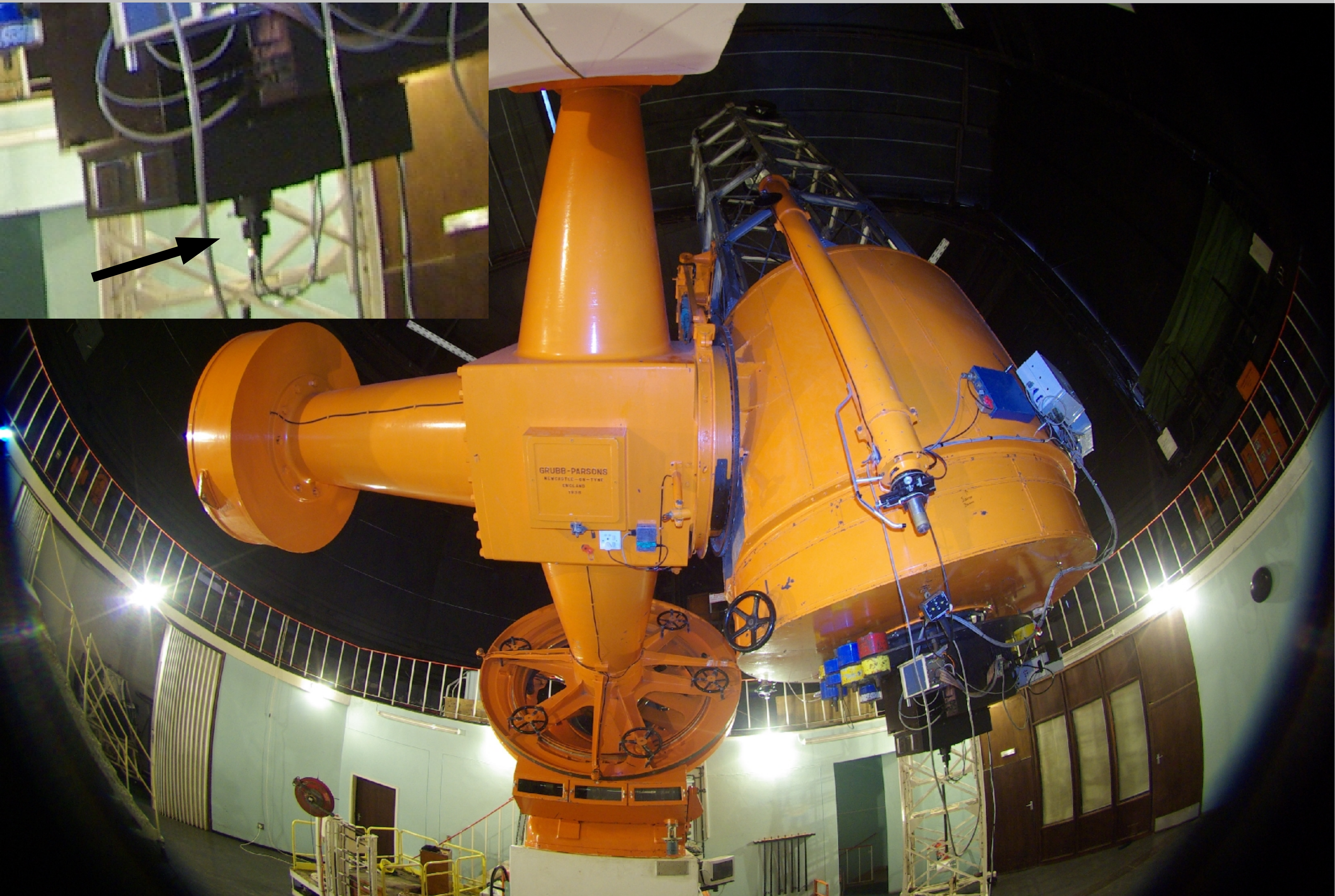






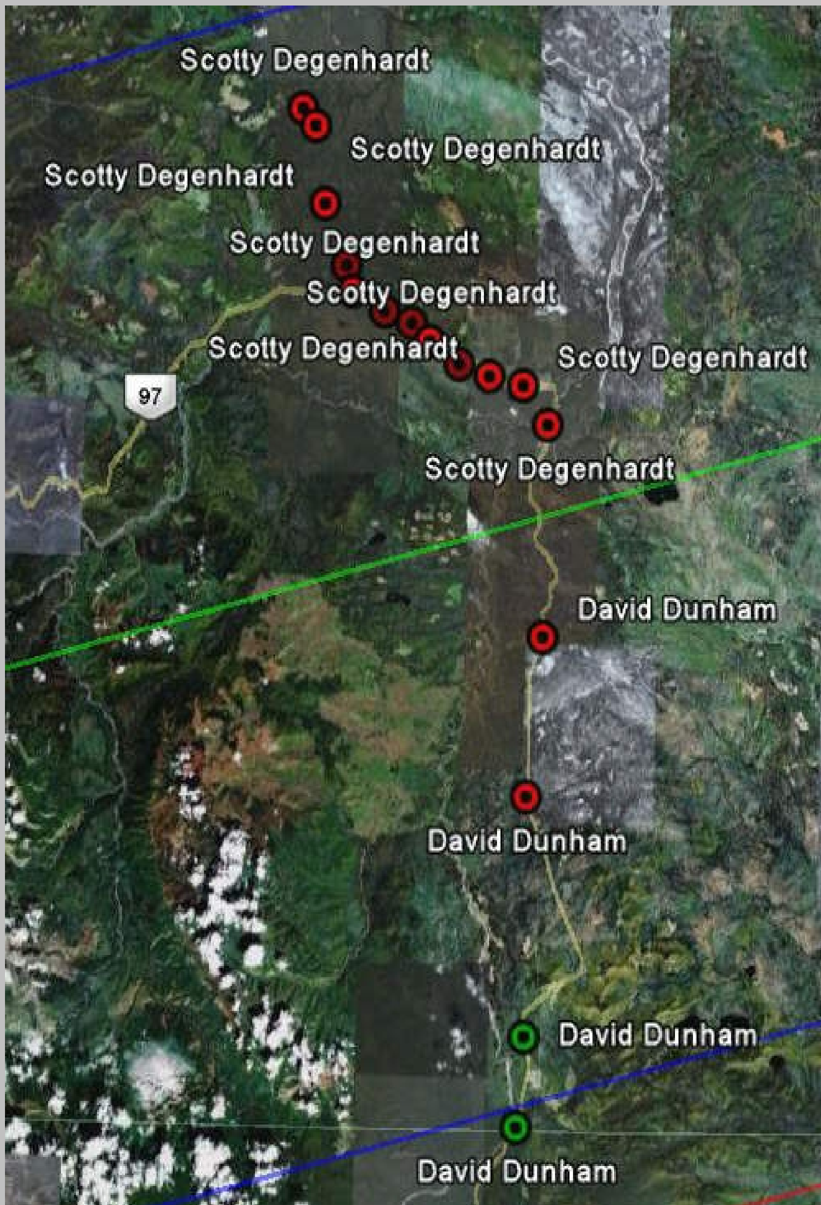


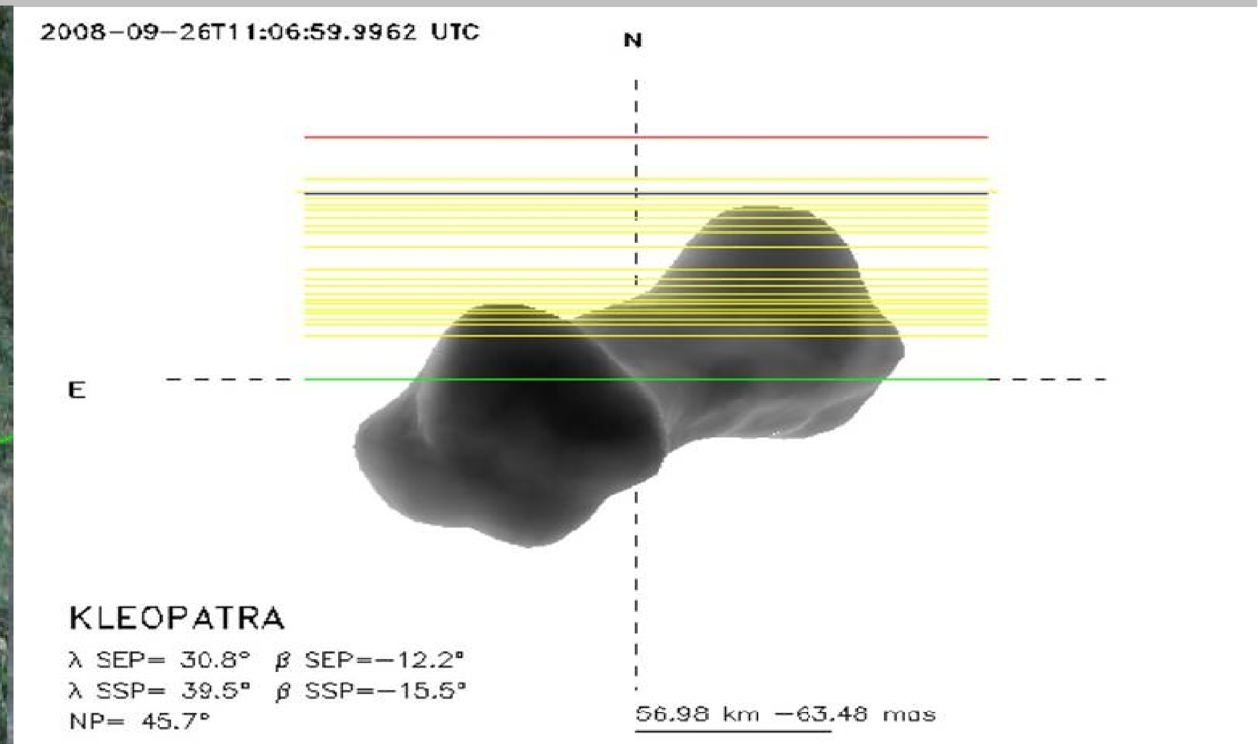
T 193 – Sutherland RSA – Pluto Occultation – june 2008



Small size observatory !


Video Observatory
Caméra basse lumière
(2046XAI pour le test)
Garmin GPS16 HVS (1PPS)
GARMIN
Incrustateur vidéo
(blackboxcamera)
Video Text
Overlay Unit
Enregistreur numérique miniDV
(camescope Canon MV600i)
TEST INCRUSTATION VIDEO HEURE GPS 1PPS POUR MANIP OCCULTATION TITAN (LA REUNION - NOVEMBRE 2003)

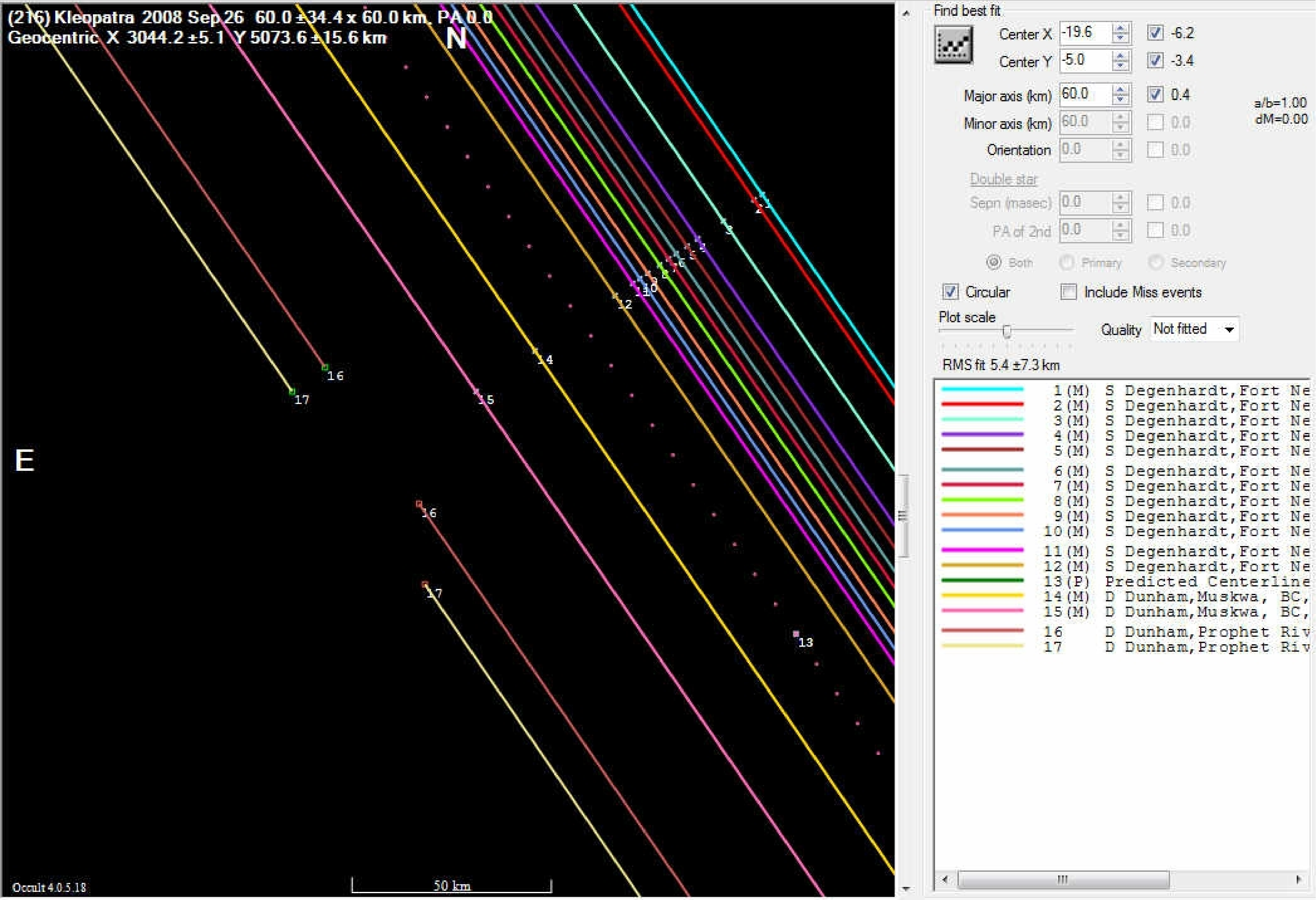




New observational strategy :

- good spatial resolution
- many small observatories
- bright occulted star
- go anywhere on Earth...

Résult :-((((We need a good astrometry !! (1 mas at 2UA = 1.5km)



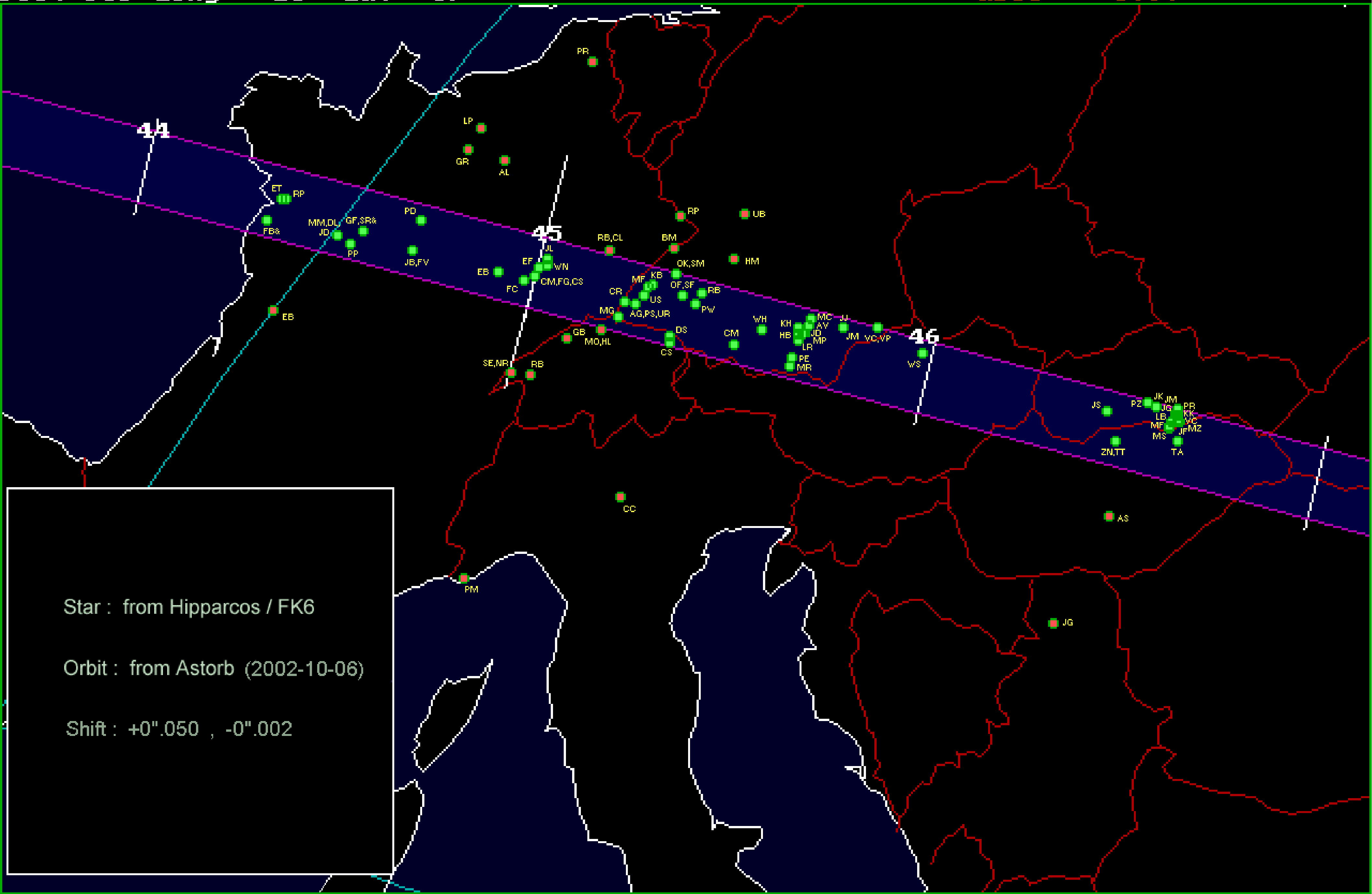
Occultation of HIP19388 by 345 Tercidina on 2002 Sep 17 at 0h 53.115m UT

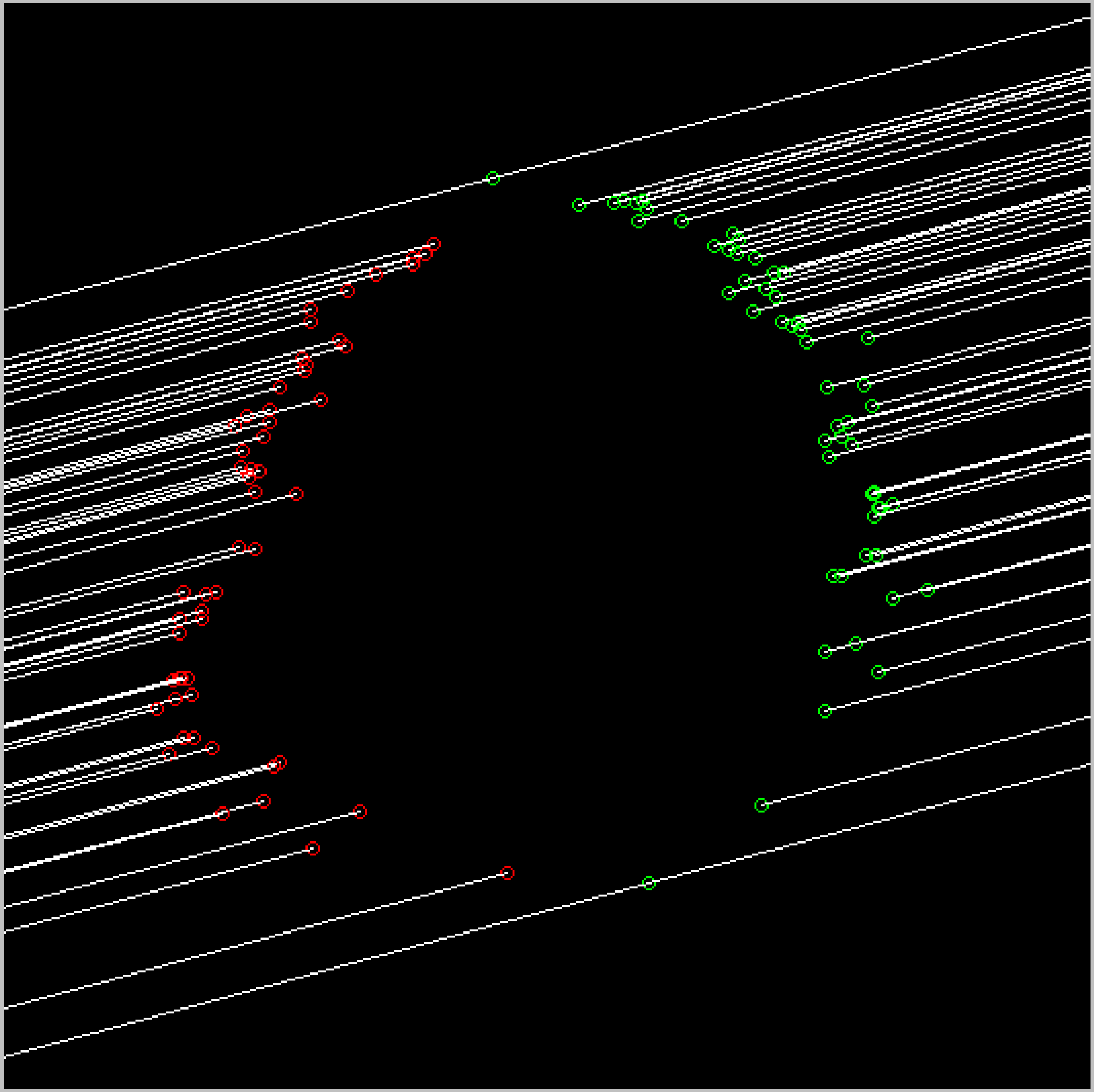
Star (2000):
Mag = 5.5
RA = 4 09 09.988
Dec = +19 36 33.10

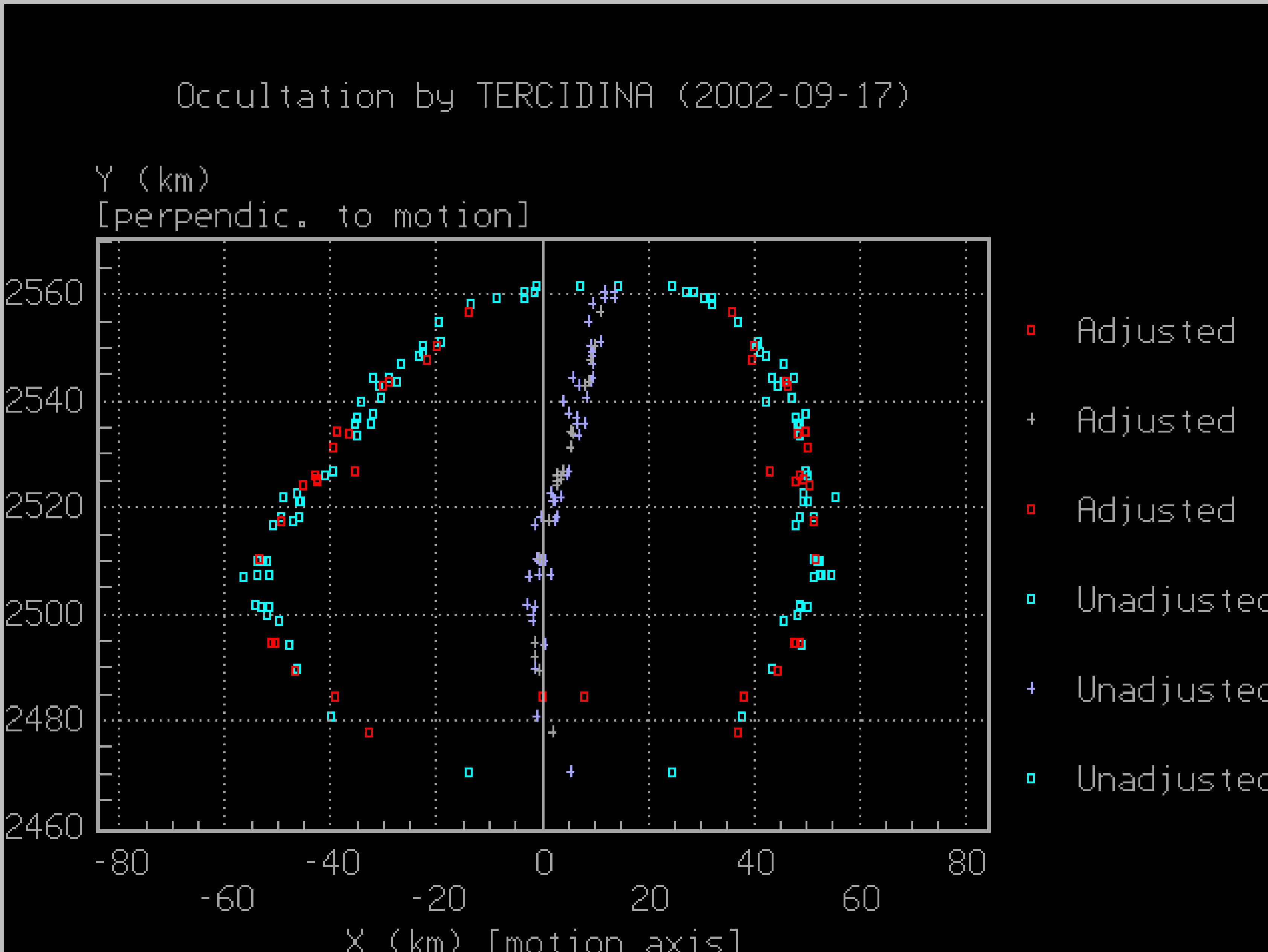
Max Duration = 10.5 secs
Mag Drop = 7.3
Sun : Dist = 110°
Moon: Dist = 122°
illum = 81%

Asteroid:
Mag = 12.8
Dia = 94km, 0.078"
Parallax = 5.279
Hourly dRA = 1.821s
dDec = -6.97"

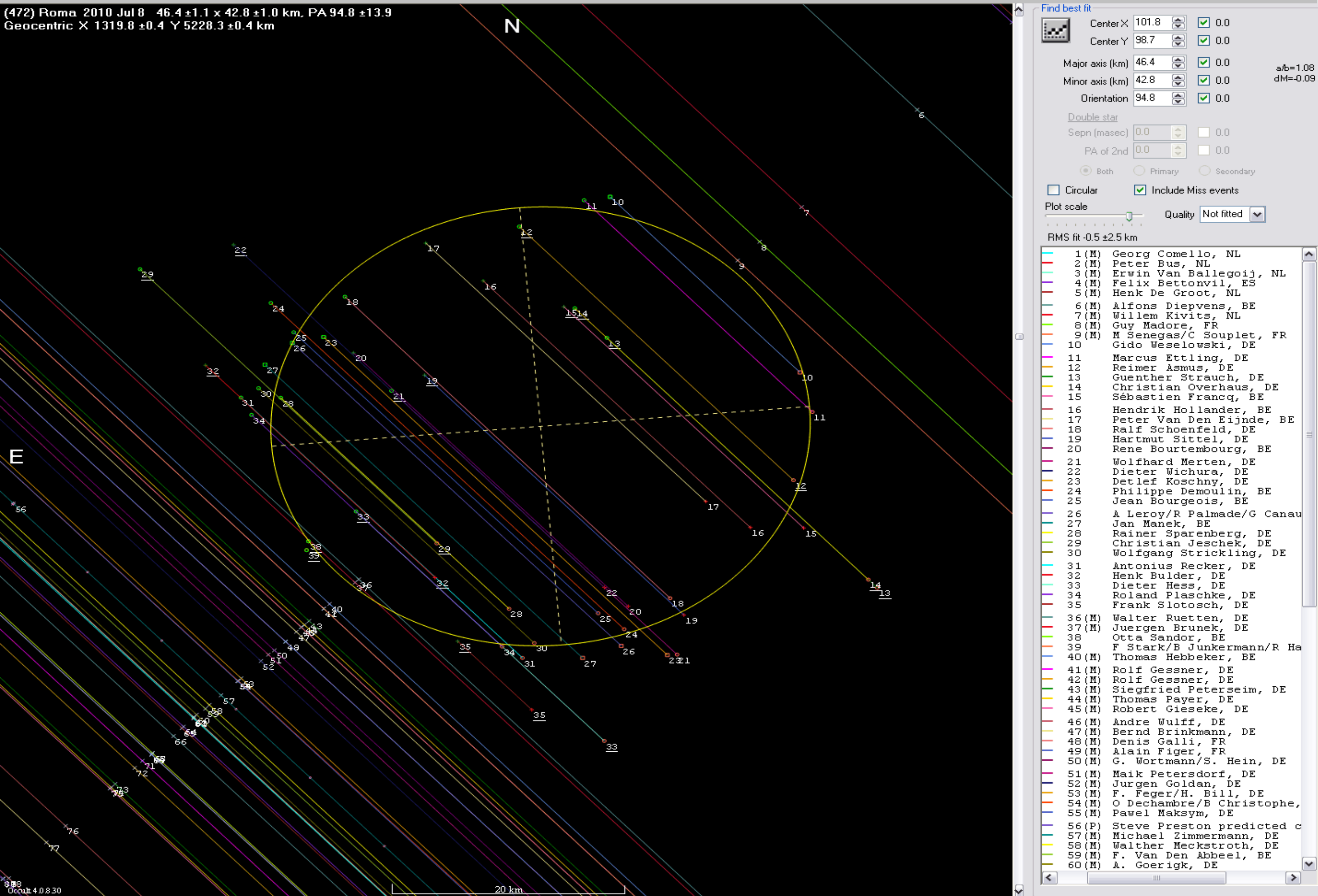
Plot for Long +16 Lat +47






Occultation by TERCIDINA (2002-09-17)
Y (km)
[perpendic. to motion]
2560
2540
2520
2500
2480
2460
-80
-60
-40
-20
0
20
40
60
80
X (km) [motion axis]
Adjusted
Adjusted
Adjusted
Unadjusted
Unadjusted
Unadjusted

Timing problems (472) Roma – 2011 July 8th



Accuracy ?

Occultation of HIP 19388
by (345) Tercidina
17 september 2002

Apparent motion on the sky :
25.92"/h => 7.2 mas/s

Timing accuracy: 0.04s

For tercidina 0.29 mas => 350m

Occultations of binary Asteroids

113

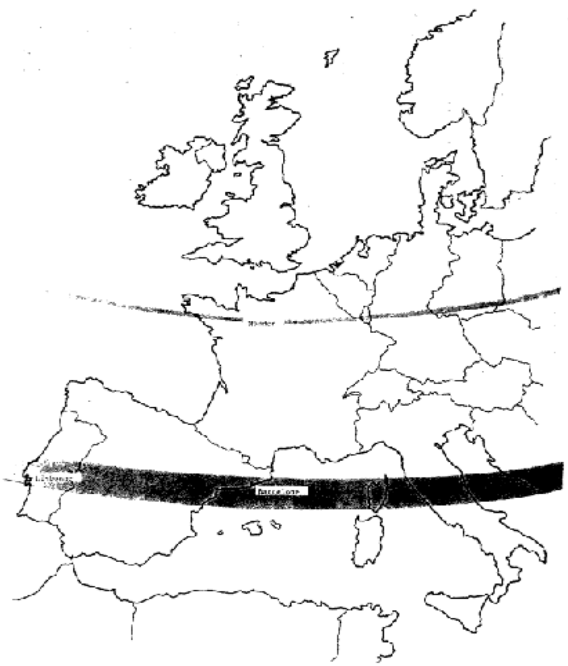


Figure 2. Occultation track of 146 Lucina and its probable satellite on 1982 April 18.

(532) Herculina	1978
(216) Kleopatra	1980
(146) Lucina	1982
(71) Niobe	2005
(22) Kalliope	2006
(90) Antiope	2008
(216) Kleopatra	2009
(234) Barbara	2010

Et bien sur :

(134340) Pluto - Charon

112

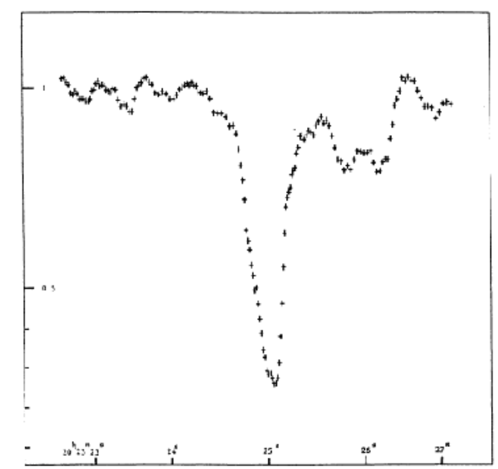
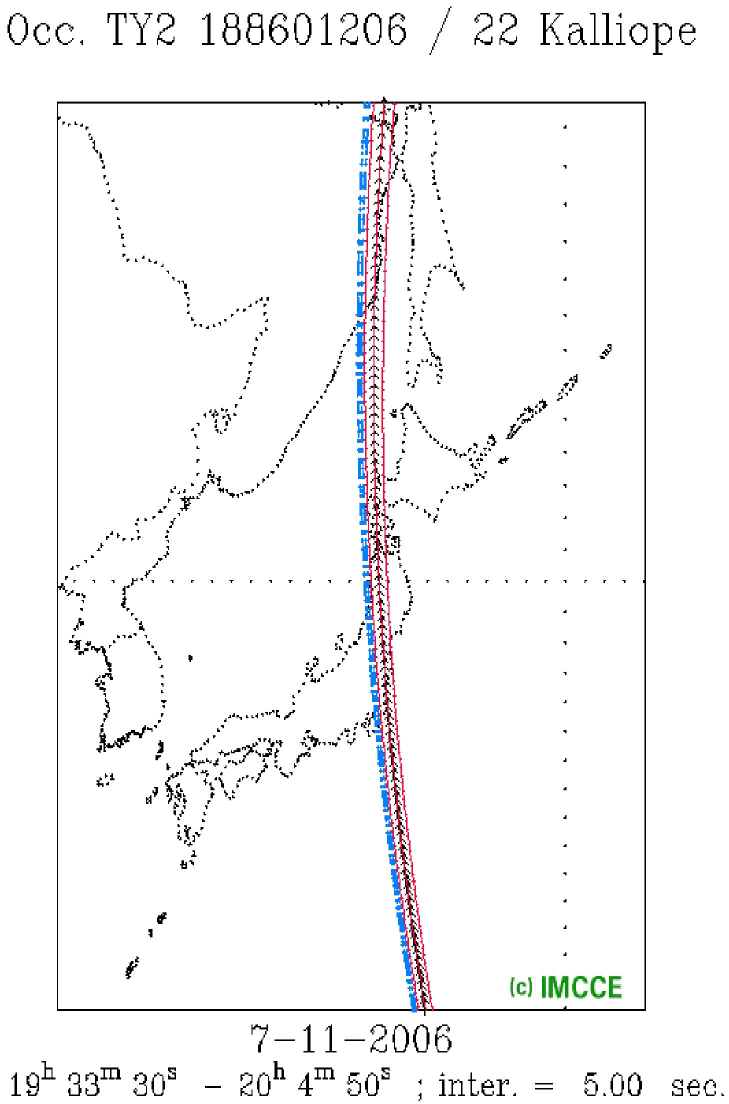
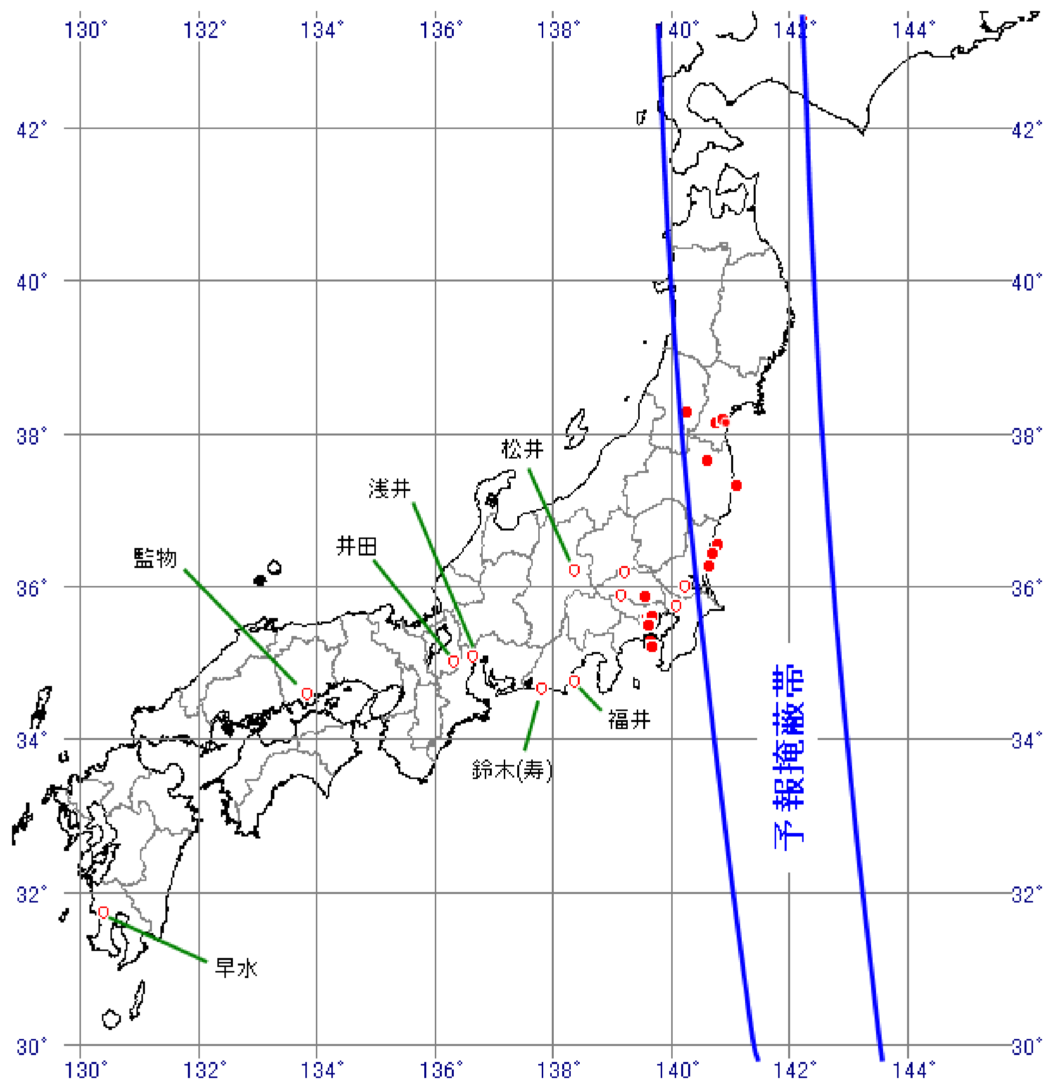


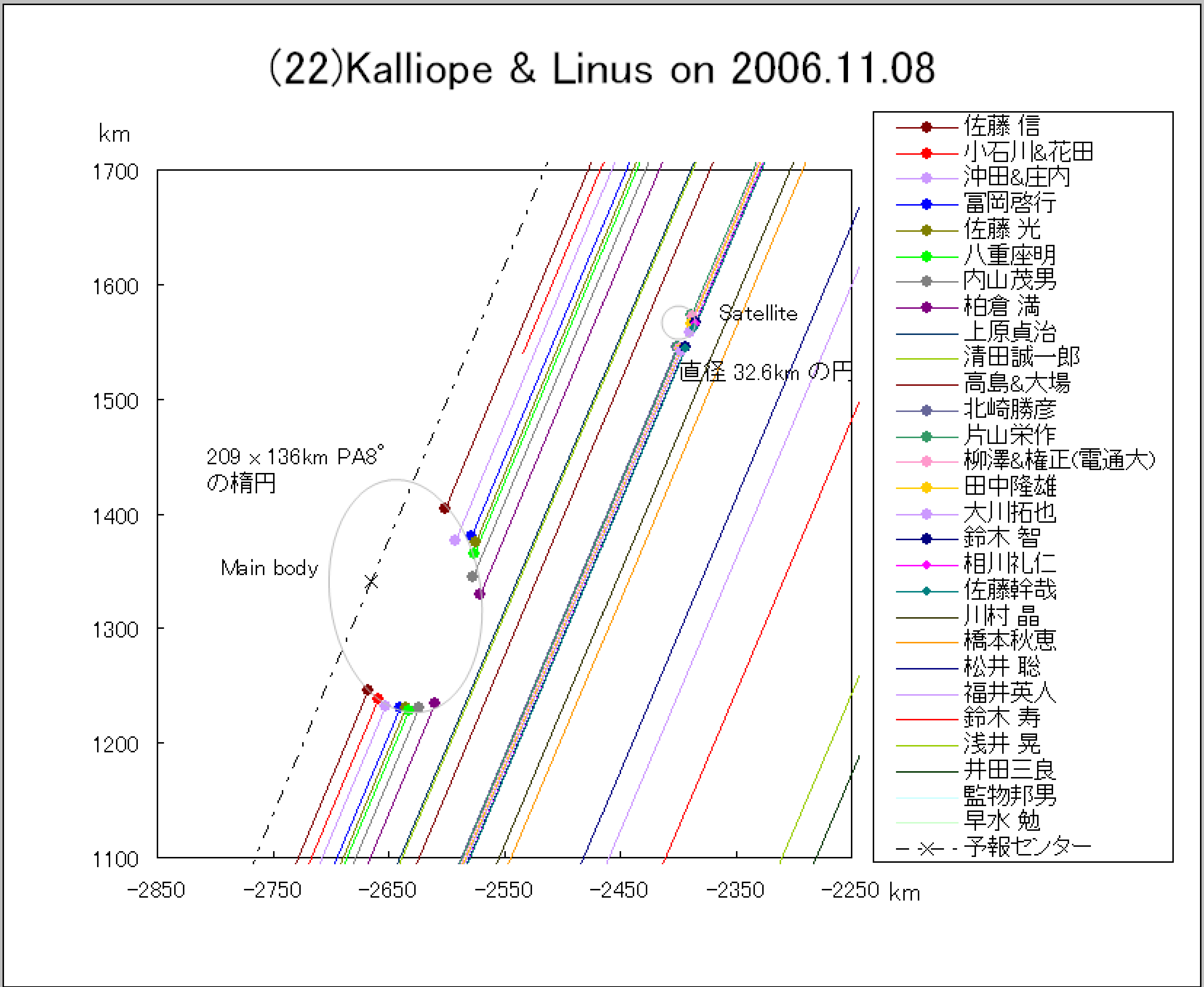
Figure 1. The light-curve of the secondary event recorded on 1982 April 18, at Meudon Observatory.

Kalioppe

KALLIOPE
LINUS

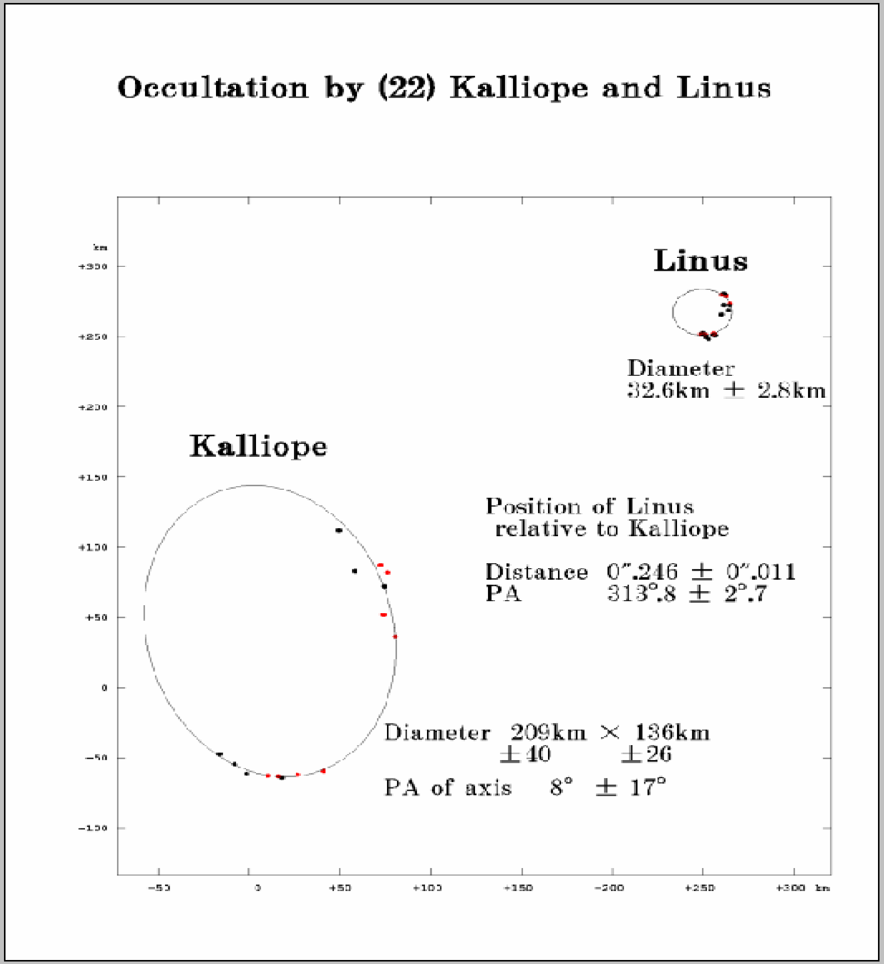


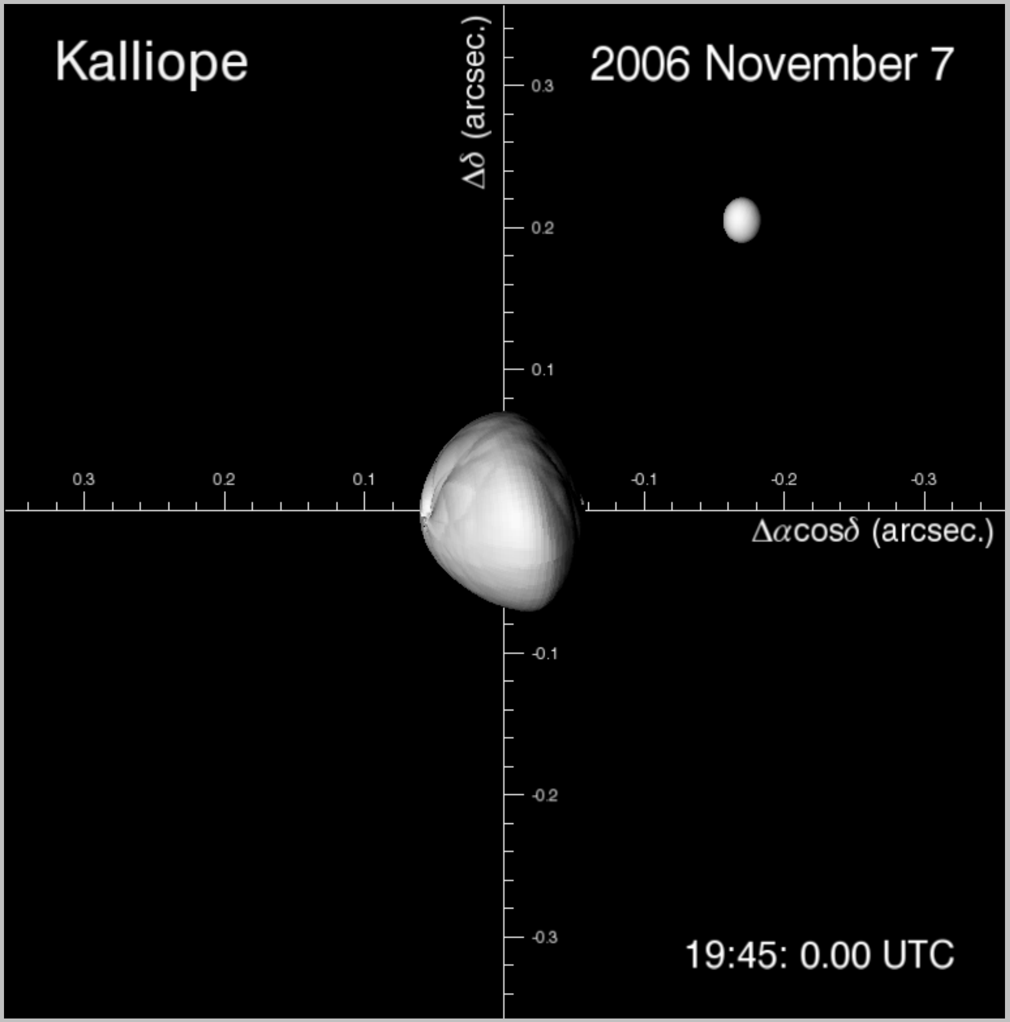




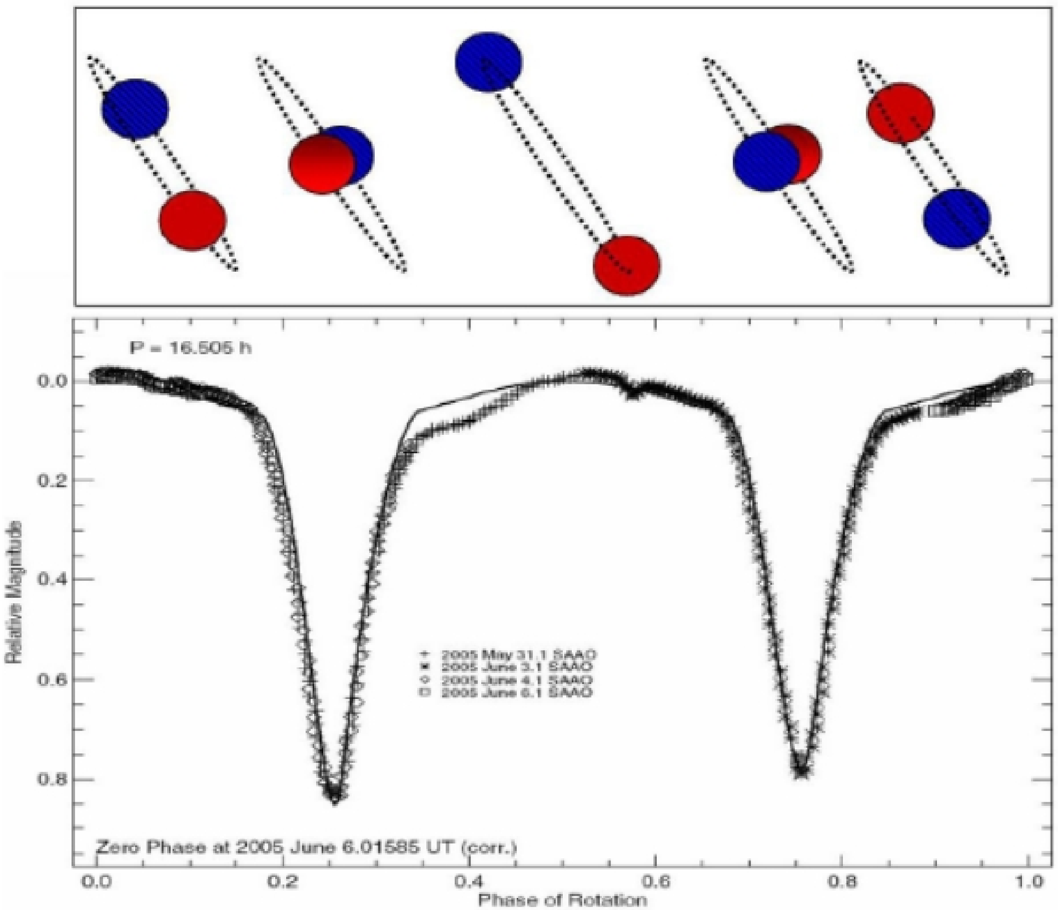
(22)Kalliope & Linus on 2006.11.08
km
1700
1600
1500
1400
1300
1200
1100
-2850
-2750
-2650
-2550
-2450
-2350
-2250 km
Satellite
直径 32.6km の円
209 × 136km PA8°
の楕円
Main body
佐藤 信
小石川&花田
沖田&庄内
冨岡啓行
佐藤 光
八重座明
内山茂男
柏倉 満
上原貞治
清田誠一郎
高島&大場
北崎勝彦
片山栄作
柳澤&権正(電通大)
田中隆雄
大川拓也
鈴木 智
相川礼仁
佐藤幹哉
川村 晶
橋本秋恵
松井 聡
福井英人
鈴木 寿
浅井 晃
井田三良
監物邦男
早水 勉
予報センター

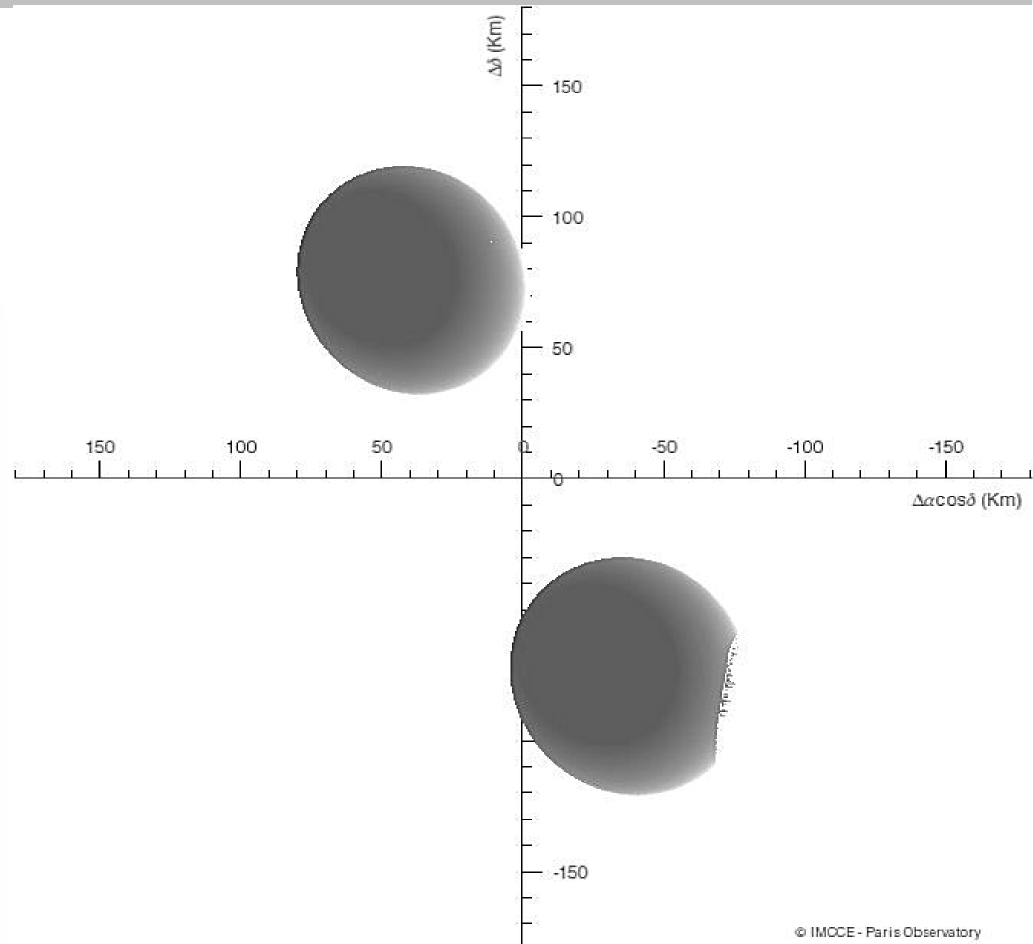
Observations





Antiope occultation – 2011 july 19th





90 Antiope occults HIP 112420 on 2011 Jul 19 from 10h 10m to 11h 5m UT

Star:
Mv = 6.7 Mp = 8.3 Mr = 5.8
RA = 22 46 14.213 (J2000)
Dec = -11 9 59.06 ...
[of Date: 22 46 53, -11 6 6]
Prediction of 2010 Sep 30.0

M1 III star

Max Duration = 26.7 & 25.4 secs
Mag Drop = 5.8 (6.2r)
Sun : Dist = 138 deg
Moon: Dist = 10 deg
: illum = 83 %
E 0.050"x 0.050" in PA 90

Asteroid:
Mag =12.5
Dia = 88 & 84 km, 66 & 63 mas
Parallax = 4.811"
Hourly dRA =-0.421s
dDec = -5.47"

Double (not in WDS) Variable star Asteroid has 1 moon(s). 84km at 171km

LQ Aqr