What resonances are manifested in the Quadrantid meteoroid stream and asteroid (196256) 2003 EH1?

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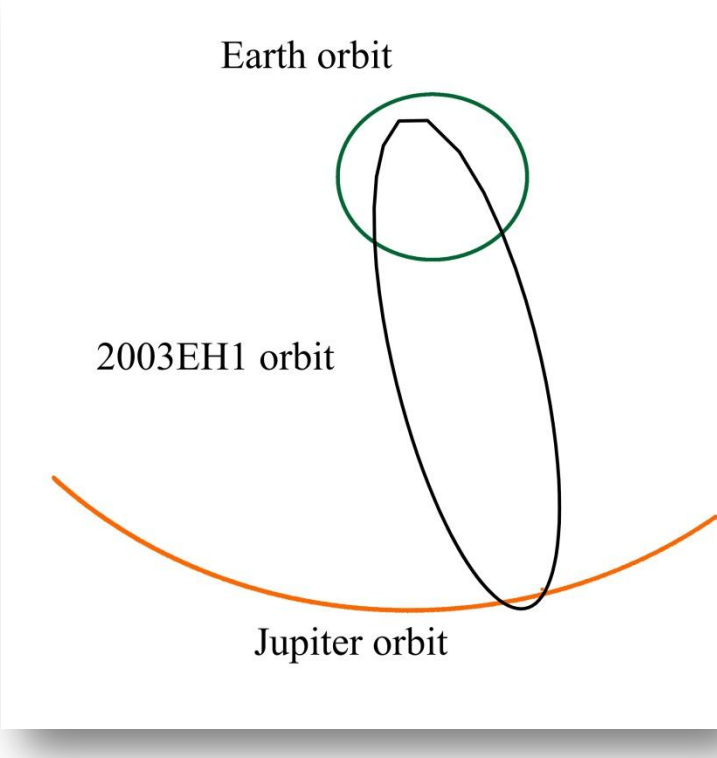
T. Galushina
O. Syusina

Introduction



t_0	2006 November 11.0	
	Value	Uncertainty
a (au)	3.1263813830	$2.3535 \cdot 10^{-6}$
e	0.6183959485	$6.2905 \cdot 10^{-7}$
i (deg)	70.7763019730	$1.5956 \cdot 10^{-7}$
Ω (deg)	282.9576698948	$5.9455 \cdot 10^{-7}$
ω (deg)	171.3340280548	$8.6951 \cdot 10^{-7}$
M (deg)	241.8394906380	$1.3432 \cdot 10^{-6}$

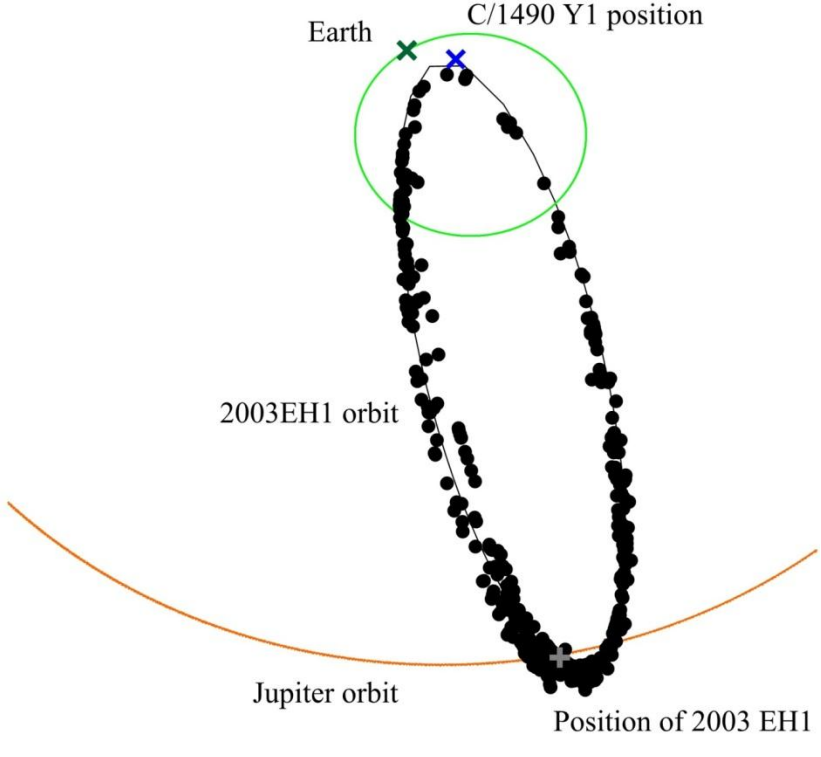
1. The parent body of Quadrantids is asteroid (196256) 2003 EH1.
2. The asteroid 2003 EH1 associated with comets C/1490 Y1 and C/1385 U1.
3. The asteroid (196256) 2003 EH1 and Quadrantids locate in the resonance zone.

Main questions

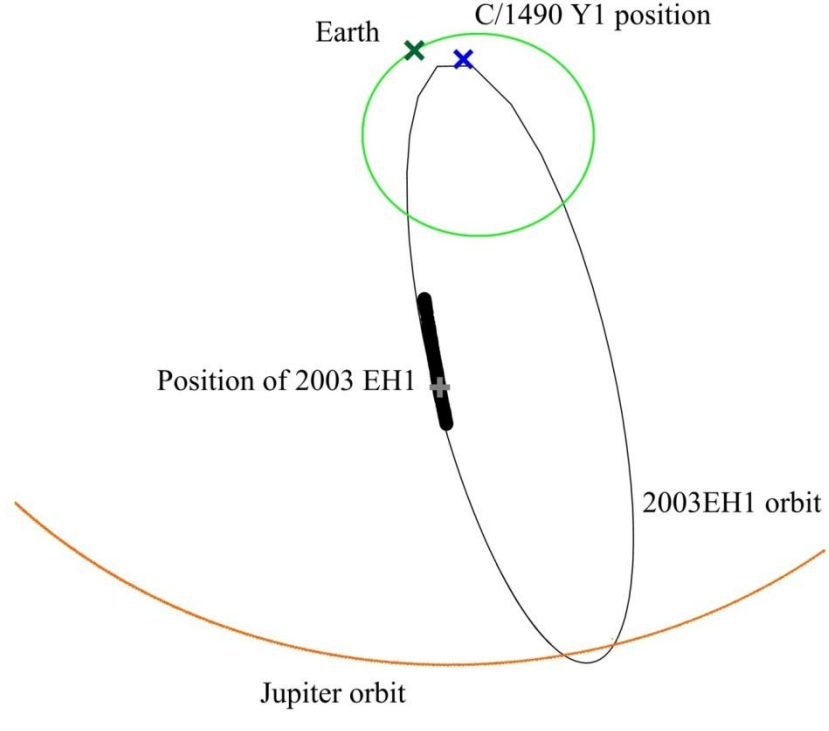
1. Is the asteroid 2003 EH1 associated with comets C/1490 Y1 and C/1385 U1?
2. What time interval is the asteroid's orbit stable?
3. What resonances are manifested in the Quadrantid meteoroid stream and asteroid (196256) 2003 EH1?

1. The asteroid (196256) 2003 EH1 is thought to be the remnant of a past cometary object, tentatively identified with the historical comets C/1490 Y1 and C/1385 U1.
2. We use all observations that present on MPC (www.minorplanetcenter.net) to exclude the proposed direct relationship of the asteroid with both of the comets.

(196256) 2003 EH1 and C/1490 Y1 on 1491 January 7

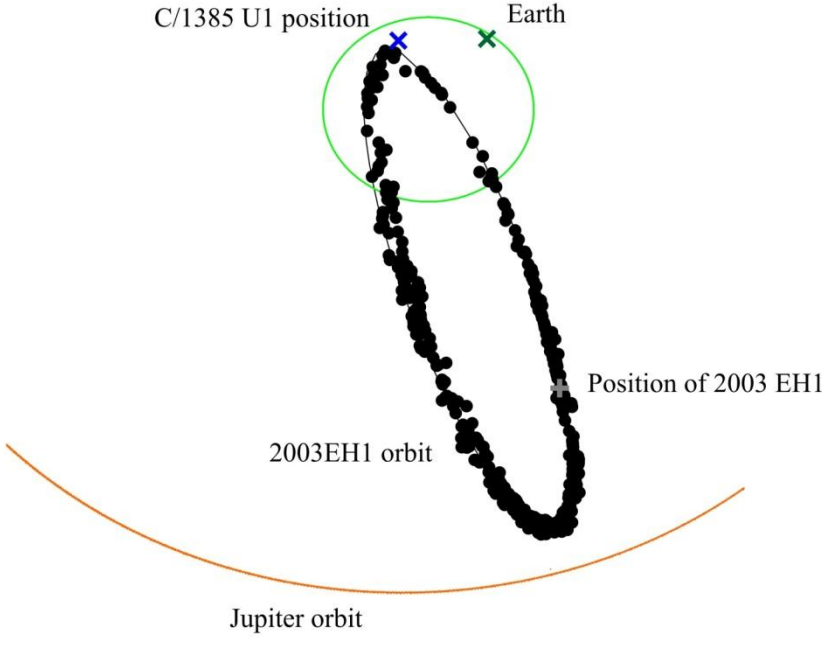


44 observations from March 6, 2003 to April 23, 2003

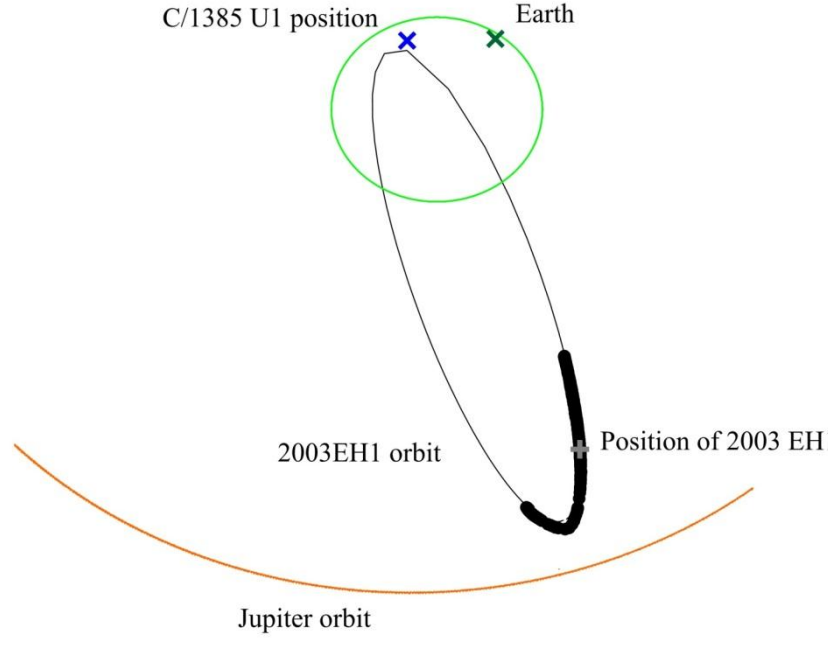


95 observations from March 6, 2003 to March 23, 2014

(196256) 2003 EH1 and C/1385 U1 on 1385 November 1



44 observations from March 6, 2003 to April 23, 2003



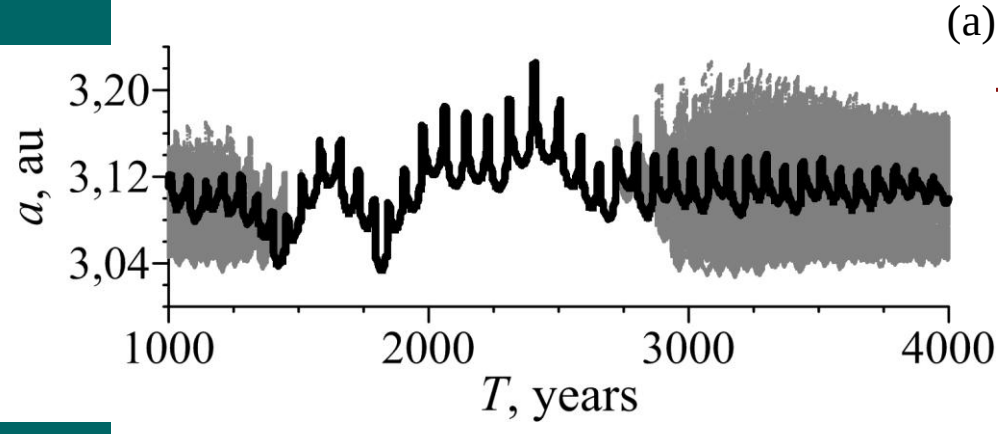
95 observations from March 6, 2003 to March 23, 2014

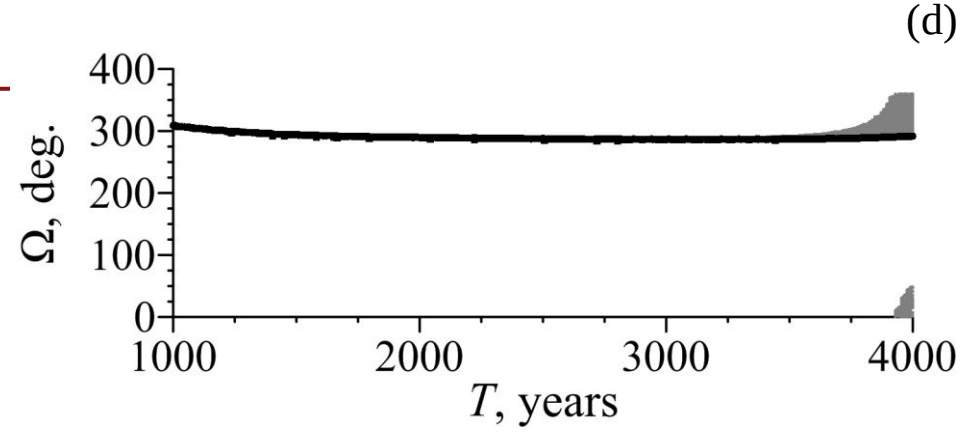
The results obtained in this section exclude the proposed identification of comets C/1490 Y1 and C/1385 U1, as the historical cometary phenomena of the asteroid (196256) 2003 EH1.

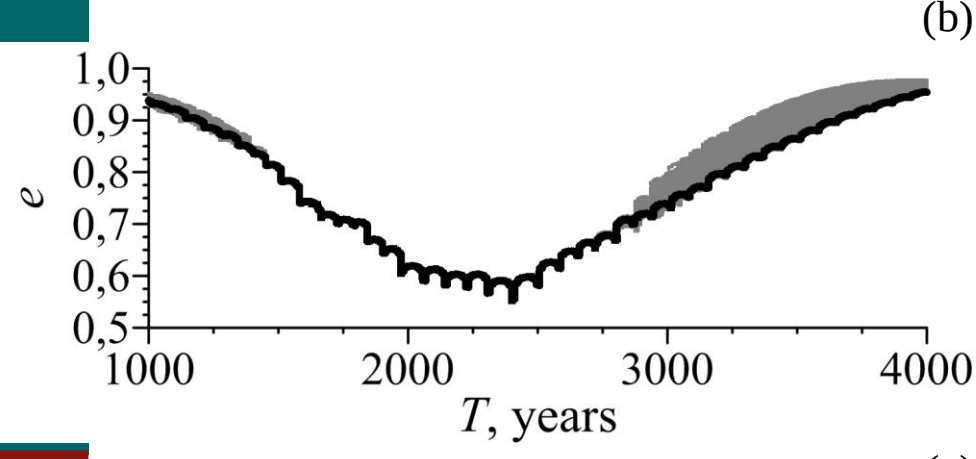
None of the integrated orbits obtained from the full set of observations from 2003 March 6 to 2014 March 23, is consistent with the situation and the movement of objects in 1491 or 1385 AD.

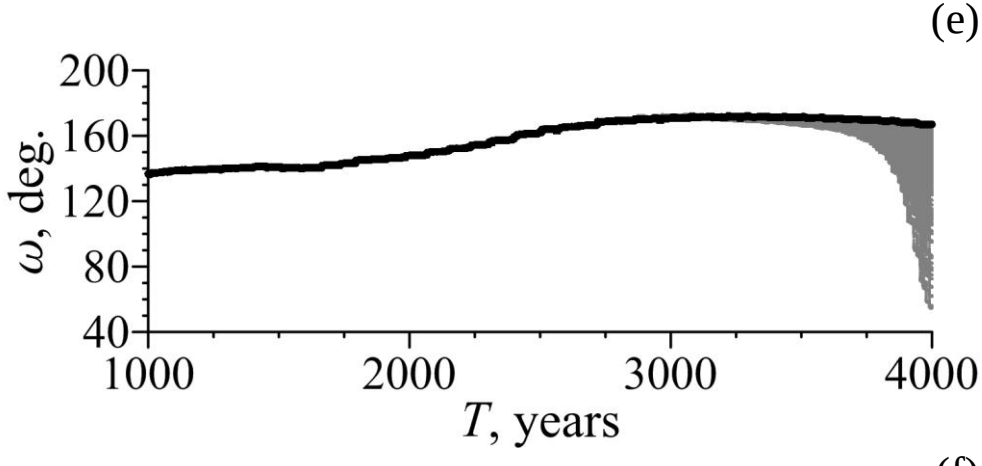
Although new observations appear to exclude the identification of the asteroid (196256) 2003 EH1 with comets C/1490 Y1 and C/1385 U1, it cannot be ruled out that they are fragments of the same parent body that have long since split.

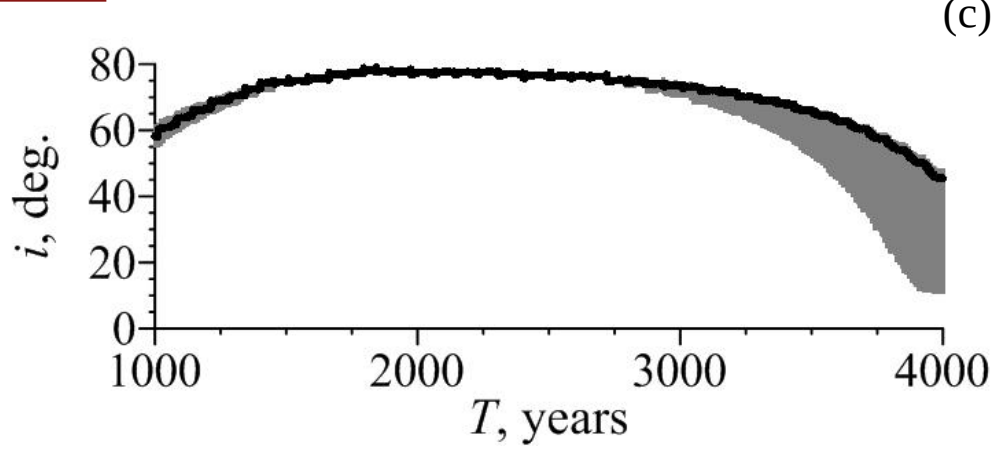
The evolution of the orbital elements of the asteroid (196256) 2003 EH1

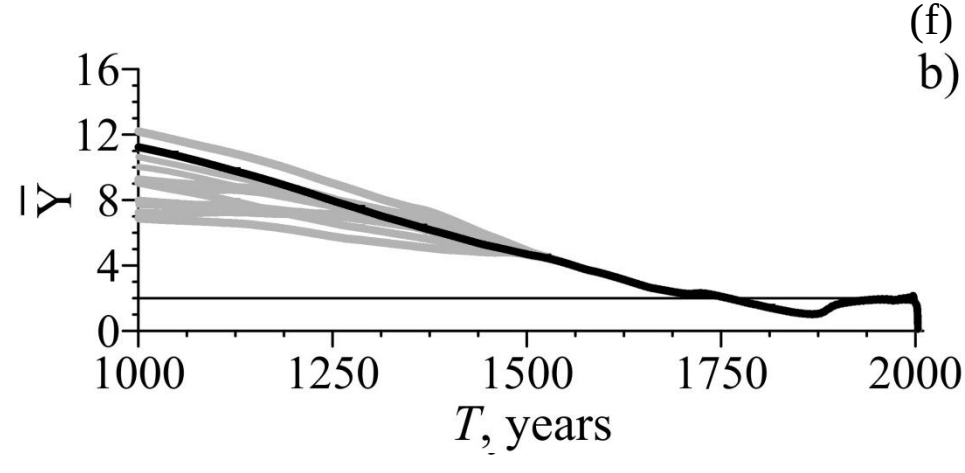










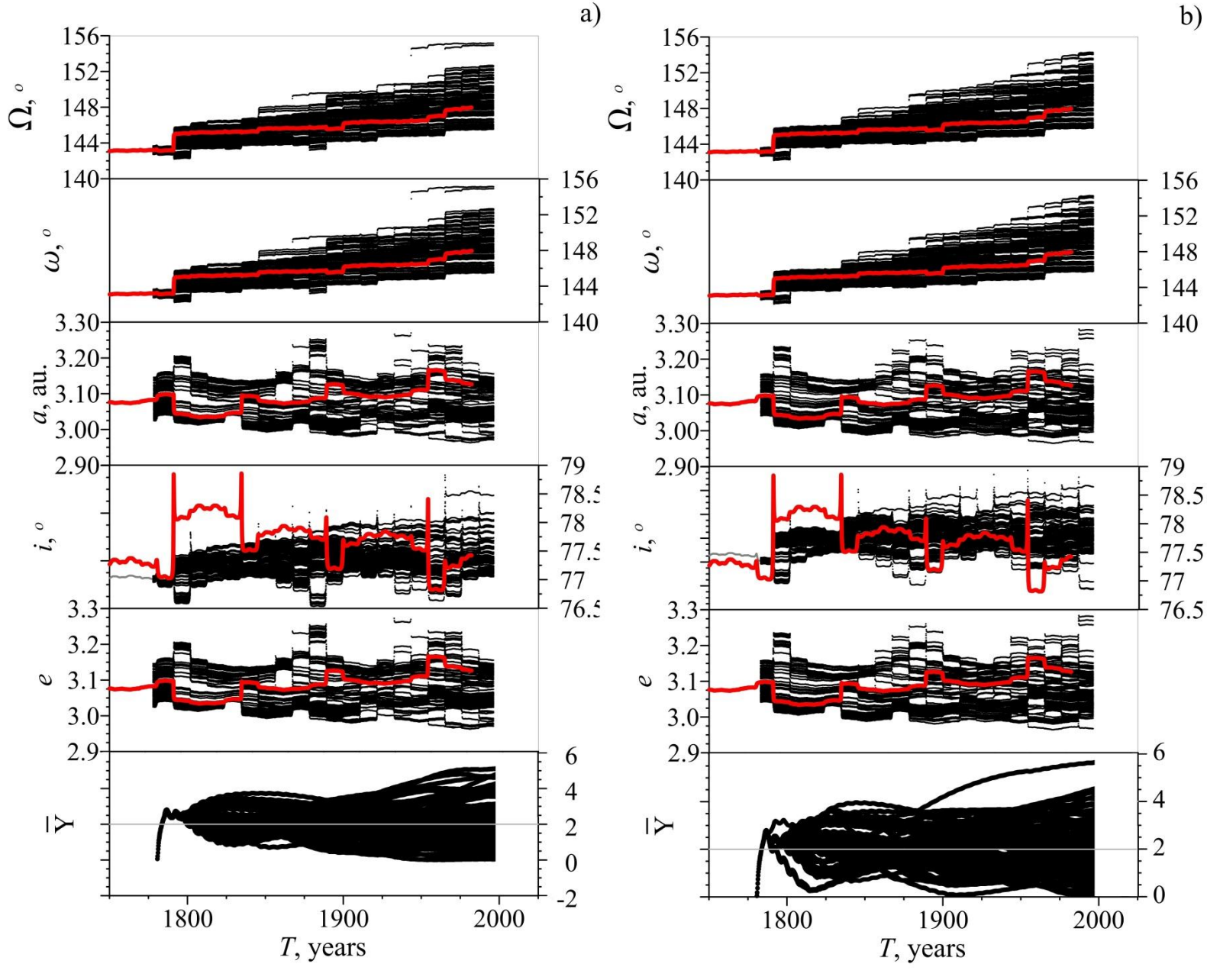


Modeling meteoroid ejection

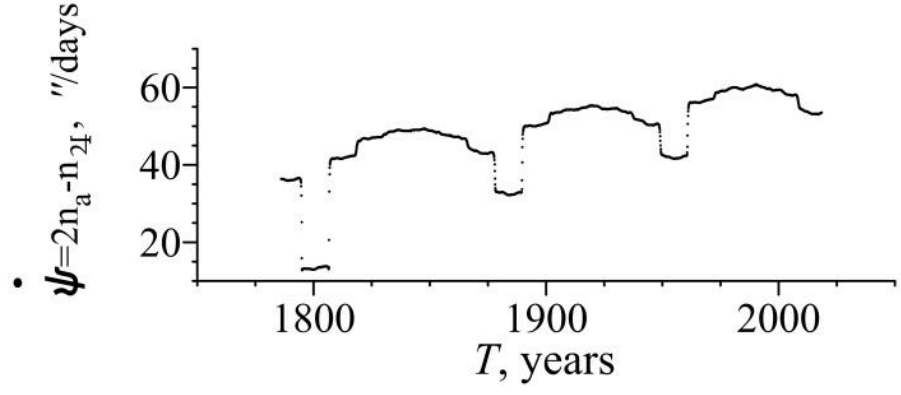
In this experiment we confined ourselves to the following points:

1. The first observation the shower around 1835AD (Quetelet,1839).
2. The asteroid 2003EH1 is the "core" of the stream (Abedin et.al. 2015).
3. The asteroid orbit is stable on the time interval 1760-2003 according to MEGNO parameter.
4. The asteroid 2003EH1 is parent body of Quadrantids, and it is not associated with comets C/1490 Y1 and C/1385 U1.

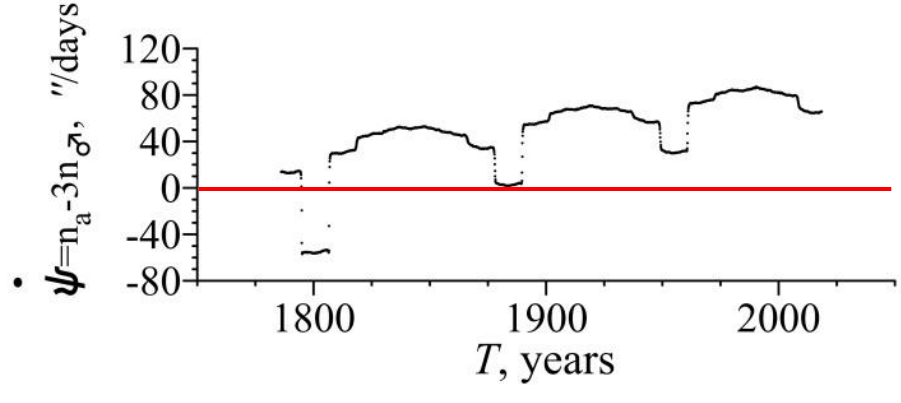
The evolution of the orbital elements



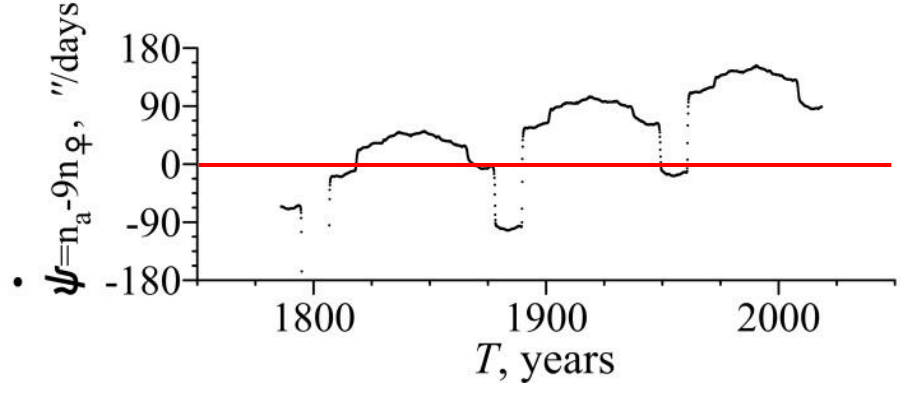
Mean motion resonances



2:1J with Jupiter

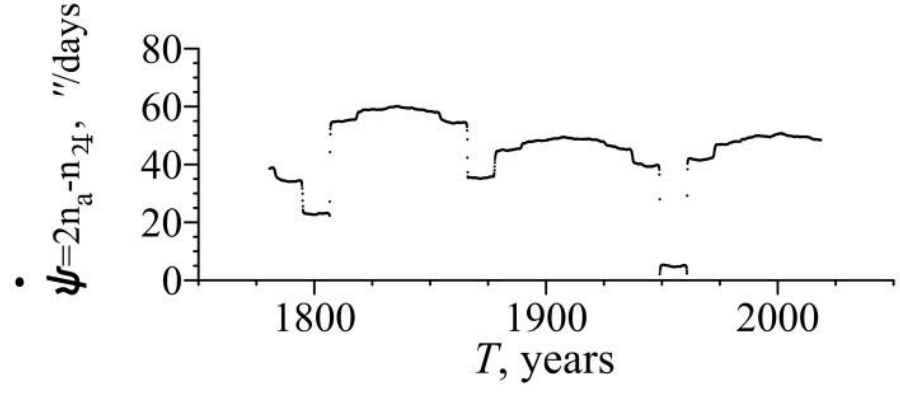


1:3M with Mars

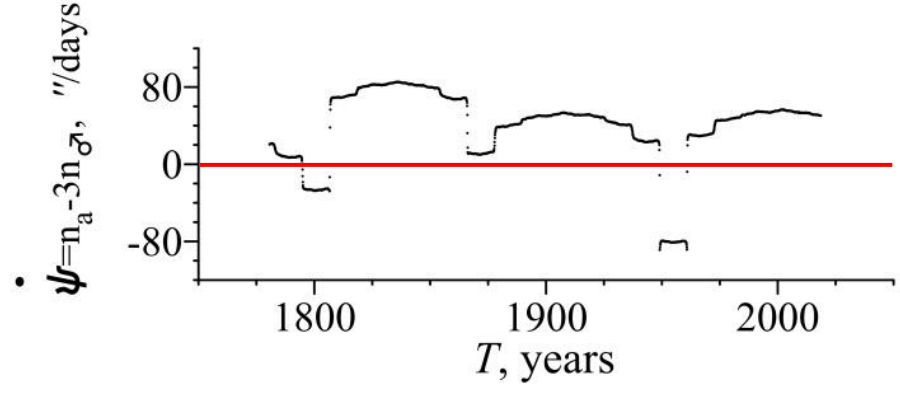


1:9V with Venus

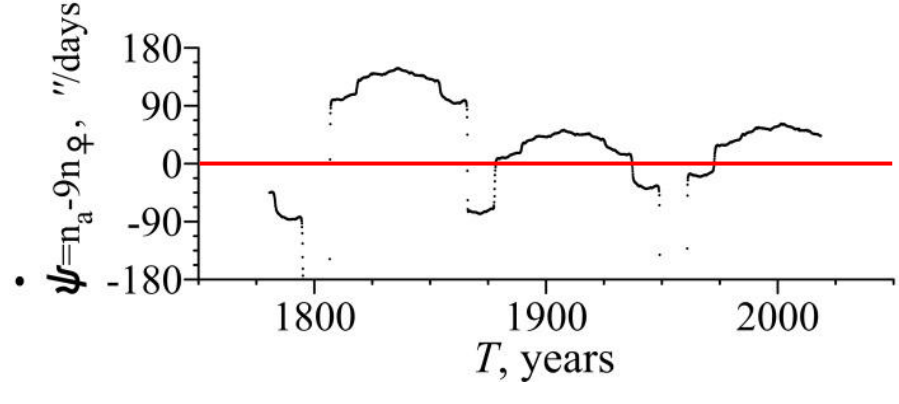
Mean motion resonances



2:1J with Jupiter

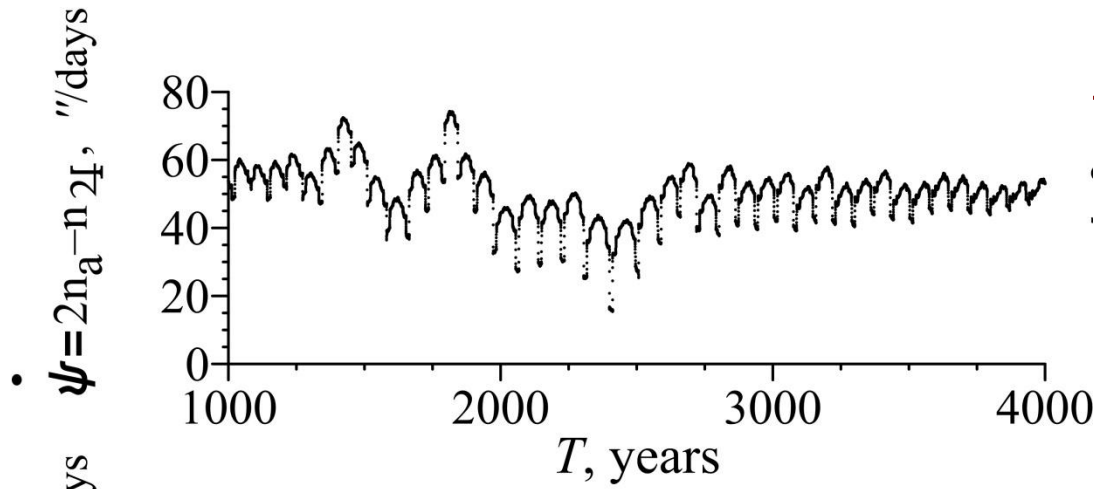


1:3M with Mars

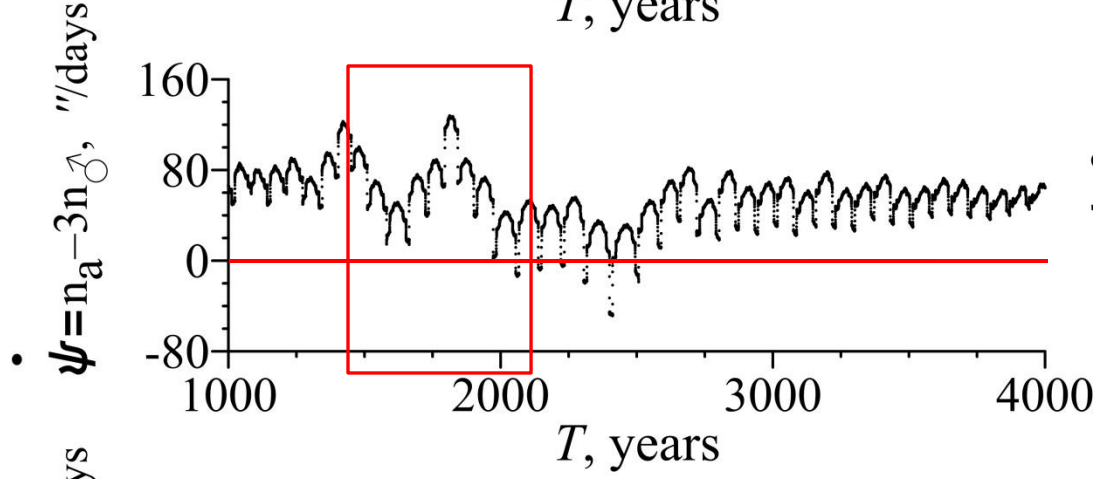


1:9V with Venus

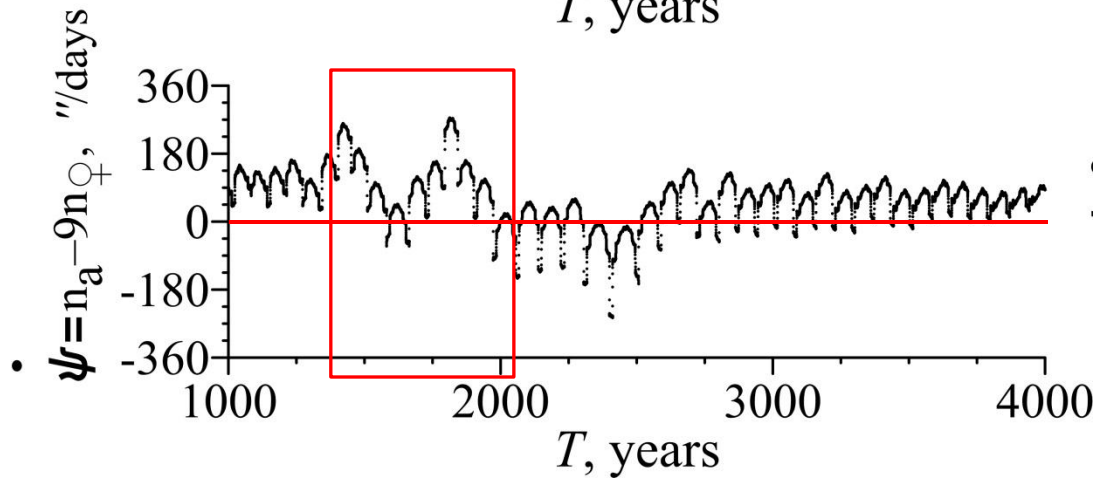
Mean motion resonances



2:1J with Jupiter



1:3M with Mars



1:9V with Venus

- The asteroid (196256) 2003 EH1 moves in vicinity of the following mean motion resonances: 2:1J with Jupiter, 1:3M with Mars and 1:9V with Venus.

- The nominal orbit and orbit of the particles ejection can be considered regular on the time interval 1760-2003.

- These particles are densely concentrated in space because they have had relatively little time since ejection to disperse.

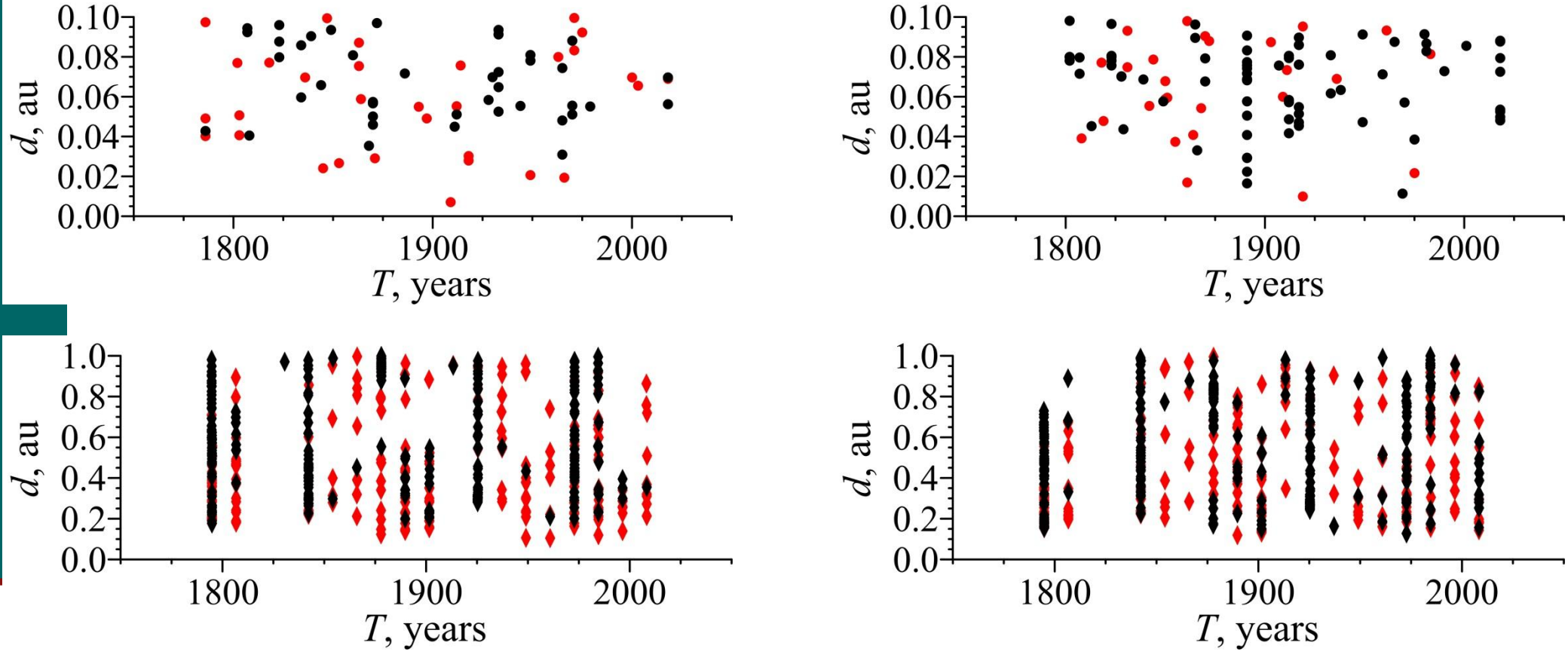
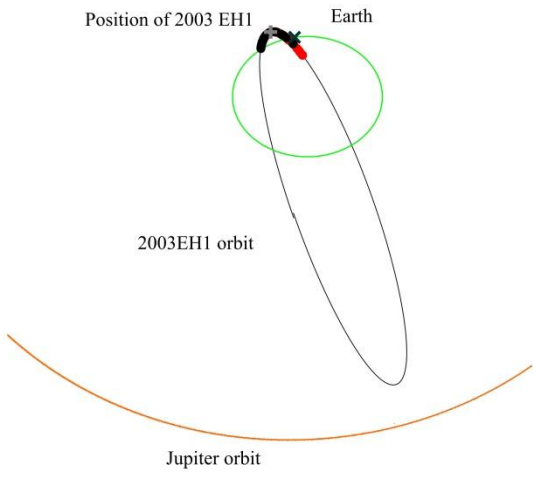
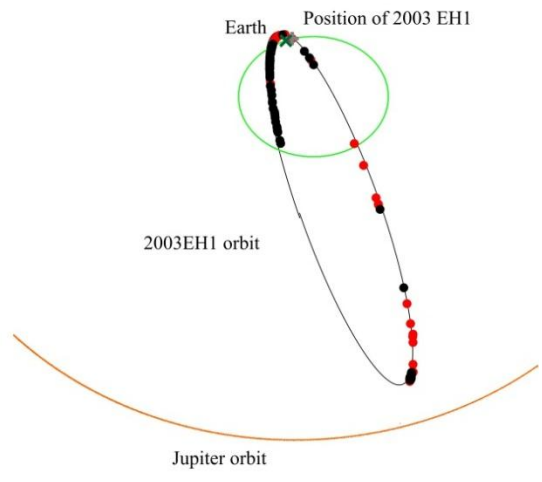


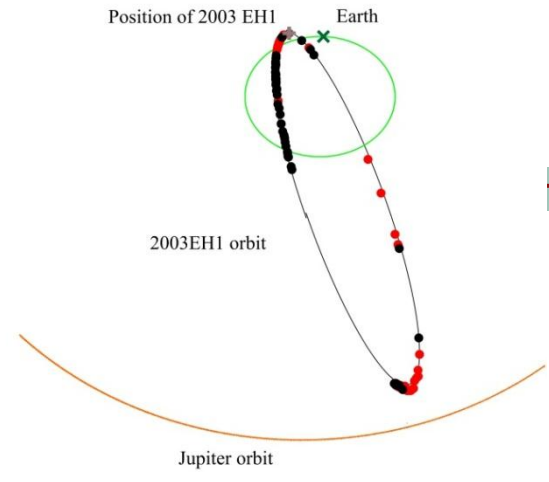
Fig. The simulated particles: close approaches with the Earth (•) and Jupiter (◊), d is a distance between the object and the planet. Also shown is the quasi-periodic motions of the meteoroids are designated by black dots/rhombus, and the chaotic motions are red dots/rhombus.



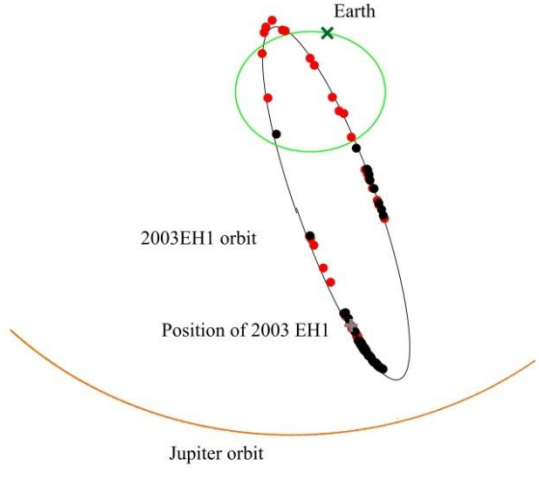
1786



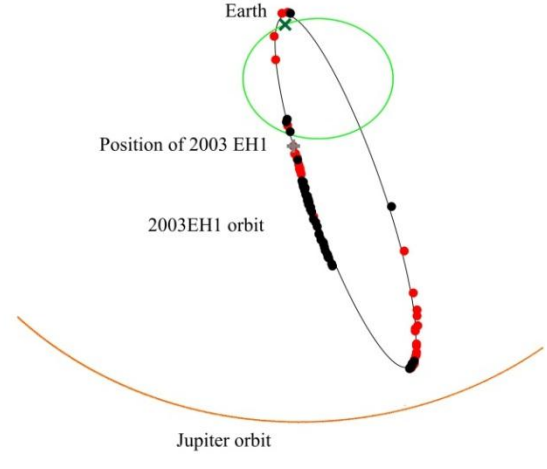
1818



1833

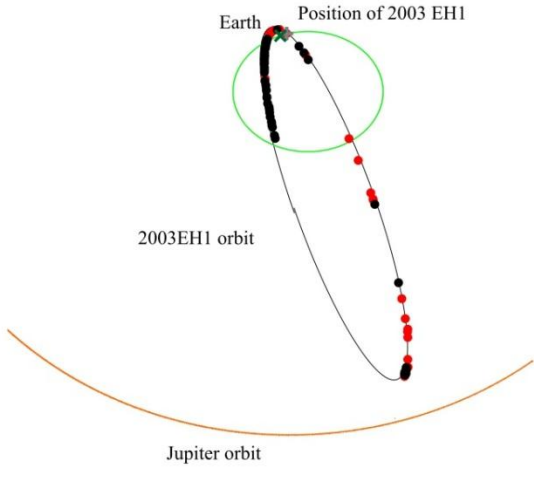


1835

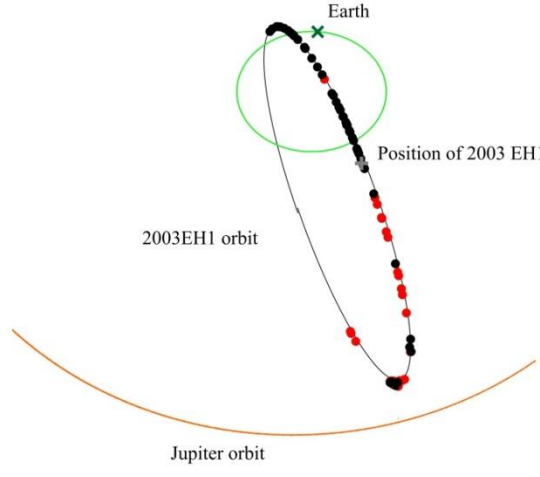


1840

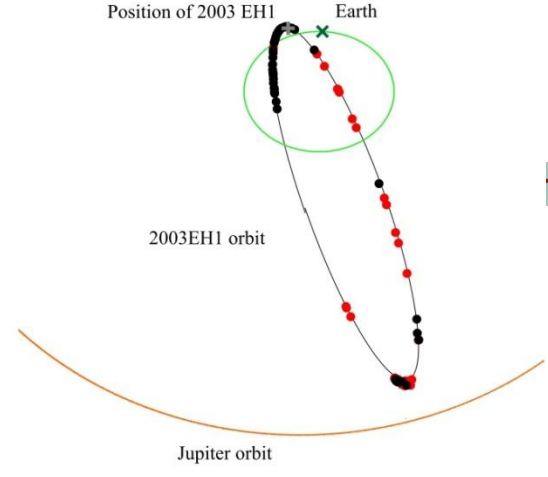
Fig. A projection on to the ecliptic of the nominal orbit of asteroid 2003 EH1, its actual position (large grey cross) and simulated particles ejected around 1780 (•) (in 1786, 1818, 1833, 1835 and 1840 years). Also shown is the quasi-periodic motions of the meteoroids are designated by black dots, and the chaotic motions are red dots. The green line is the Earth's orbit, the brown line is the Jupiter's orbit.



1818



1822



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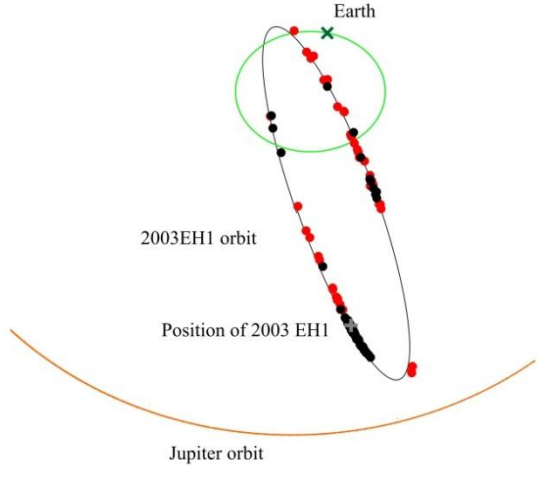

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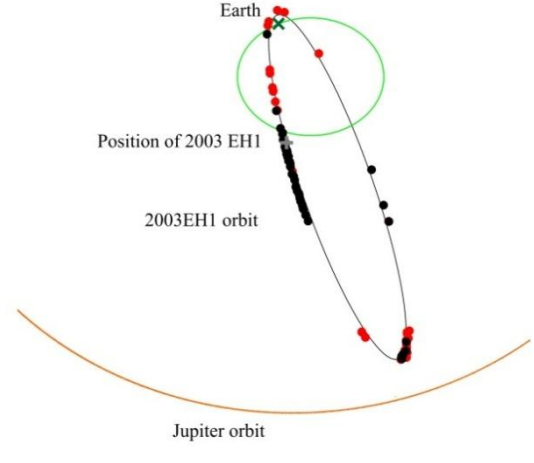


1840

Fig. A projection on to the ecliptic of the nominal orbit of asteroid 2003 EH1, its actual position (large grey cross) and simulated particles ejected around 1786 (•) (in 1818, 1822, 1833, 1835 and 1840 years). Also shown is the quasi-periodic motions of the meteoroids are designated by black dots, and the chaotic motions are red dots. The green line is the Earth's orbit, the brown line is the Jupiter's orbit.

Conclusion

1. The results obtained in this section exclude the proposed identification of comets C/1490 Y1 and C/1385 U1, as the historical cometary phenomena of the asteroid (196256) 2003 EH1.

2. Our analysis of the dynamics of meteoroid particles assumed to be released from the asteroid (196256) 2003 EH1 revealed the complicated dynamical structure of its meteoroid stream, which approaches Jupiter's and Earth’s orbits.

3. Meteoroids inherit the dynamic properties of the asteroid (196256) 2003 EH1 but not all this properties. The slight timing inconsistency is perhaps due to small number statistics.

Thank you for attention!

Conclusion

1. Our analysis of the dynamics of meteoroid particles assumed to be released from the near-Earth asteroid (196256) 2003 EH1 revealed the complicated dynamical structure of its meteoroid stream, which approaches Jupiter's and Earth’s orbits.

2. Meteoroids inherit the dynamic properties of the asteroid (196256) 2003 EH1 but not all this properties. The slight timing inconsistency is perhaps due to small number statistics.

3. If we have used a lot of high-precision Quadrantid orbits and integrated their orbits backward in time, along with the analysis of the dynamics structure, we could identified the most likely age of the core of the Quadrantid meteoroid stream.

1. The asteroid (196256) 2003 EH1 moves in vicinity of the following mean motion resonances: 2:1J with Jupiter, 1:3M with Mars and 1:9V with Venus.
2. The nominal orbit and orbit of the vertices of the confidence ellipsoid can be considered regular on the time interval 1760-2003.

The apsidal-nodal resonances

- The perturbing function:

$$R=\frac{\mu'}{a'}\sum_{l=2}^{\infty}\alpha^{l}\sum_{m=0}^{l}(-1)^{l-m}\chi_{m}\frac{(l-m)!}{(l+m)!}\times\sum_{p,\,p'=0}^{l}F_{lmp}(i)F_{lmp'}(i')\times$$

$$\times\sum_{q,\,q'=-\infty}^{\infty}X^{l,\,l-2p}_{l-2p+q}(e)X^{-l-1,\,l-2p'}_{l-2p'+q'}(e')\times\cos\psi,$$

The argument of the perturbing function in the doubly-averaged problem:

$$\underline{\psi}=(l-2p')\omega'-(l-2p)\omega-\bar{m}(\Omega-\Omega').$$

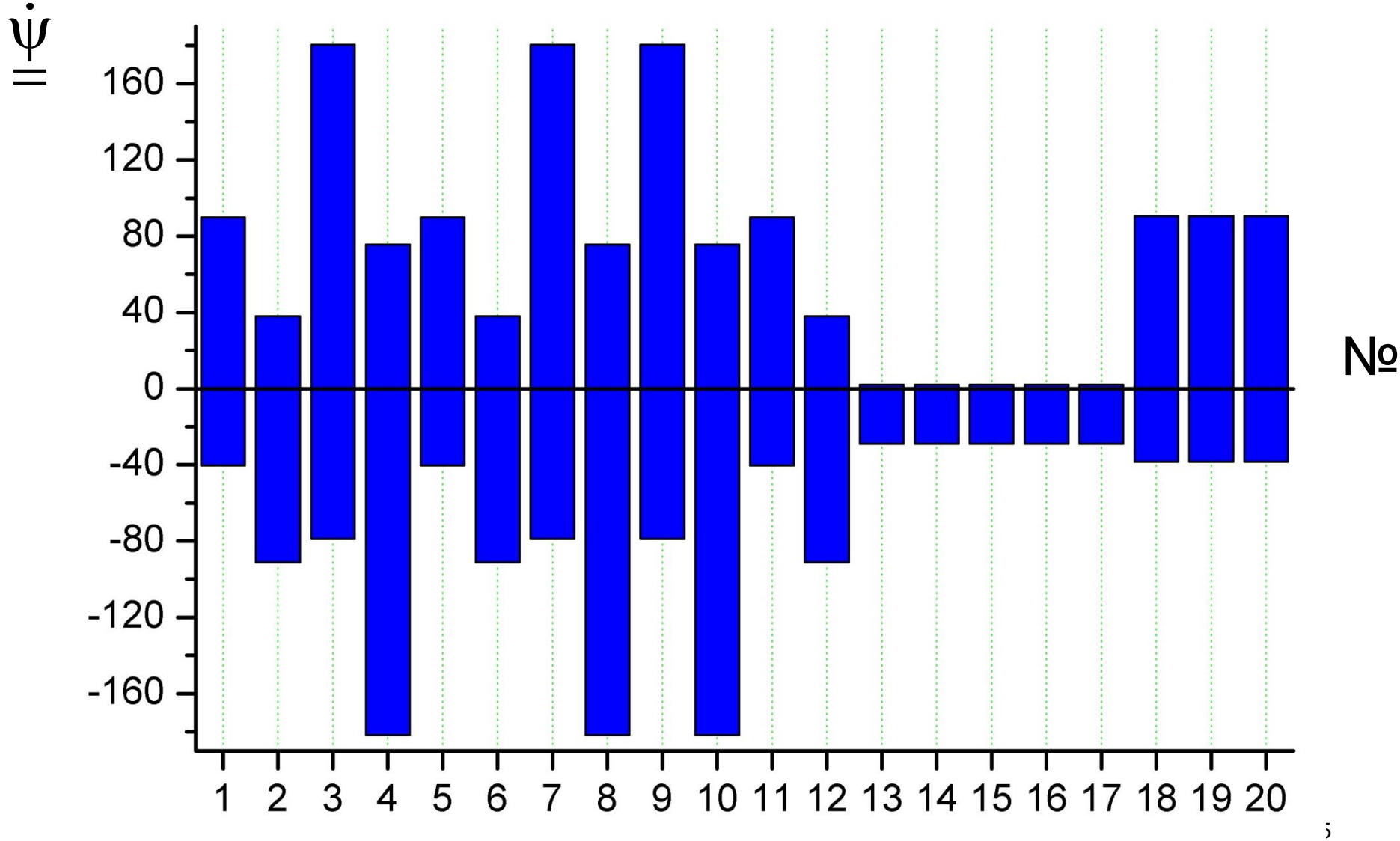
- The condition of resonance occurrence:

$$\dot{\underline{\psi}}\approx 0.$$

The apsidal-nodal resonances relations

№	The resonance relation	№	The resonance relation	№	The resonance relation
1	$\left(\dot{\Omega}-\dot{\Omega}'_{Jup}\right)+\dot{\omega}-\dot{\omega}'_{Jup}$	8	$\left(\dot{\Omega}-\dot{\Omega}'_{Jup}\right)-2\dot{\omega}-2\dot{\omega}'_{Jup}$	15	$\left(\dot{\Omega}-\dot{\Omega}'_{Jup}\right)-2\dot{\omega}'_{Jup}$
2	$\left(\dot{\Omega}-\dot{\Omega}'_{Jup}\right)-\dot{\omega}+\dot{\omega}'_{Jup}$	9	$\left(\dot{\Omega}-\dot{\Omega}'_{Jup}\right)+2\dot{\omega}$	16	$\left(\dot{\Omega}-\dot{\Omega}'_{Jup}\right)+2\dot{\omega}'_{Jup}$
3	$\left(\dot{\Omega}-\dot{\Omega}'_{Jup}\right)+2\dot{\omega}-2\dot{\omega}'_{Jup}$	10	$\left(\dot{\Omega}-\dot{\Omega}'_{Jup}\right)-2\dot{\omega}$	17	$\left(\dot{\Omega}-\dot{\Omega}'_{Jup}\right)$
4	$\left(\dot{\Omega}-\dot{\Omega}'_{Jup}\right)-2\dot{\omega}+2\dot{\omega}'_{Jup}$	11	$\left(\dot{\Omega}-\dot{\Omega}'_{Jup}\right)+\dot{\omega}$	18	$\dot{\omega}-\dot{\omega}'_{Jup}$
5	$\left(\dot{\Omega}-\dot{\Omega}'_{Jup}\right)+\dot{\omega}+\dot{\omega}'_{Jup}$	12	$\left(\dot{\Omega}-\dot{\Omega}'_{Jup}\right)-\dot{\omega}$	19	$\dot{\omega}+\dot{\omega}'_{Jup}$
6	$\left(\dot{\Omega}-\dot{\Omega}'_{Jup}\right)-\dot{\omega}-\dot{\omega}'_{Jup}$	13	$\left(\dot{\Omega}-\dot{\Omega}'_{Jup}\right)+\dot{\omega}'_{Jup}$	20	$\dot{\omega}$
7	$\left(\dot{\Omega}-\dot{\Omega}'_{Jup}\right)+2\dot{\omega}+2\dot{\omega}'_{Jup}$	14	$\left(\dot{\Omega}-\dot{\Omega}'_{Jup}\right)-\dot{\omega}'_{Jup}$		

The values of the resonance relations



Mean motion resonances

Resonance argument

$$\beta = k_0 \lambda_j - k_0 \lambda_j - (k_0 - k_j)\,\omega_0 - (k_0 - k_j)\,\Omega_0$$

Resonance relation

$$\alpha \approx k_0 n_0 - k_j n_j$$

n_0, n_j are mean motions
λ_0, λ_j are mean longitudes
ω_0, ω_j are arguments of pericentre
Ω_0, Ω_j are longitudes of ascending node
k_0, k_j are integers

The orbital elements, the physical parameters and information about observations

t_0	2006 November 11.0	
	Value	Uncertainty
a (au)	3.1263813830	$2.3535 \cdot 10^{-6}$
e	0.6183959485	$6.2905 \cdot 10^{-7}$
i (deg)	70.7763019730	$1.5956 \cdot 10^{-7}$
Ω (deg)	282.9576698948	$5.9455 \cdot 10^{-7}$
ω (deg)	171.3340280548	$8.6951 \cdot 10^{-7}$
M (deg)	241.8394906380	$1.3432 \cdot 10^{-6}$
H (mag)	16.2	
A	0.04	
R (km)	2	
N	99	
Δt (days)	4035.04	

e close encounters of (196256) 2003 EH1 with the planets