Dynamics of satellite formations on eccentric orbits

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Spis treści

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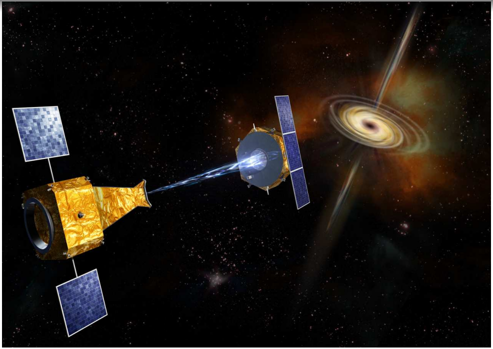
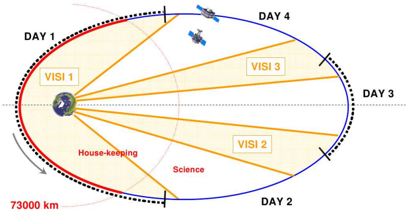
Simbol X



SIMBOL-X is a hard X-ray mission, operating in the 0.5-70 keV range, which is proposed by a consortium European laboratories (CNES and ASI). Observing this type of radiation requires a telescope with a long focal length, which can only be achieved using two cooperating satellites.



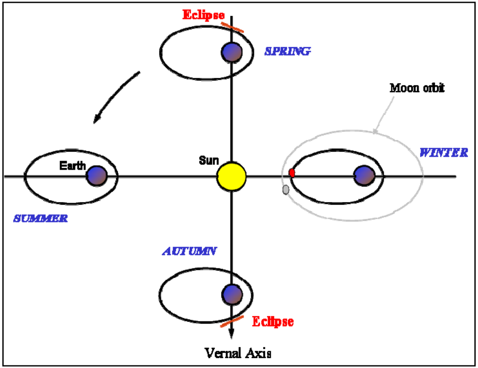
The 4-day orbit with the 73000km altitude limit and the visibilitis from a given ground station (Malindi) (P. Gamet, *Simbol-X: A Formation flying mission*.)

Orbit of SIMBOL -X

- hight eccentric orbit (HEO);
- very large semi-major axis 106 247km) ;
- short, strong perturbed passage around the perigee;
- long, weak perturbed passage around the apogee;
- alternative to Lagrange point orbits.

Observations are possible since the formation is above Van Allen radiation belt (>73 000km)

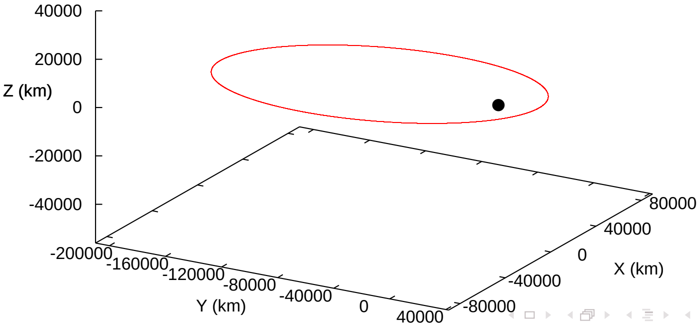
The orientation orbit of SIMBOL-X ($\Omega = 90°$, $\omega = 0°$).



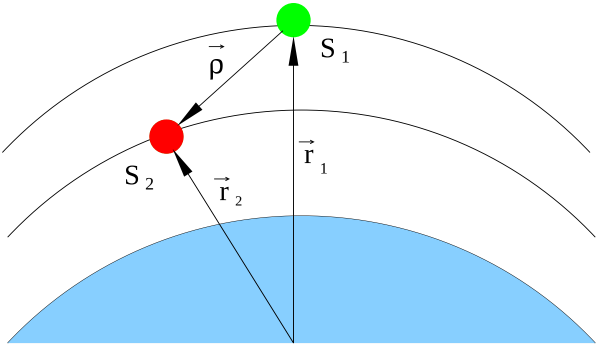
P. Gamet *Simbol-X: A Formation flying mission.*

The orbit of the main satellite S_1

a (km)	e	$I(^\circ)$	$\omega(^\circ)$	$\Omega(^\circ)$	M $(^\circ)$	q (km)	Q(km)
106 247	0.752	6.0	0.0	90.0	0.0	26 350	186 144



The relative motion



$$\vec{\rho}(t) = \Delta\vec{r}(t) = \vec{r}_2(t) - \vec{r}_1(t).$$

The differential perturbations

In orbital elements

$$\Delta(\delta\varepsilon^n(t)) = \delta\varepsilon_2^n(t) - \delta\varepsilon_1^n(t)$$

$$\delta\vec{\varepsilon}_i^{\,n}(t) = \vec{\varepsilon}_i^{\,n}(t) - \vec{\varepsilon}_i^{\,0,n} \quad i = 1, 2, \quad n = 1, 2, \ldots, 6$$

The differential perturbations

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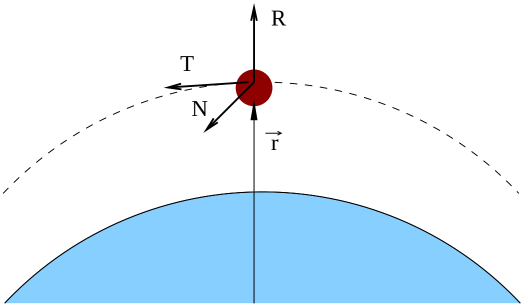
In satellite positions

$$\begin{aligned}\Delta(\delta\vec{r}(t)) &= \delta\vec{r}_2(t) - \delta\vec{r}_1(t)\\ \Delta(\delta\vec{r}(t)) &= (\vec{r}_2(t) - \vec{r}_2^{\,0}(t)) - (\vec{r}_1(t) - \vec{r}_1^{\,0}(t))\end{aligned}$$

$$\delta\vec{r}_i(t) = \vec{r}_i(t) - \vec{r}_i^{\,0}(t) \quad i = 1, 2$$

The differential perturbations in the radial, transverse and normal directions

$$\Delta(\delta\vec{r}(t)) = \delta\vec{r}_2(t) - \delta\vec{r}_1(t) = \Delta r_1 \vec{e}\,^r_1 + \Delta\lambda_1 \vec{e}\,^t_1 + \Delta b_1 \vec{e}\,^n_1,$$



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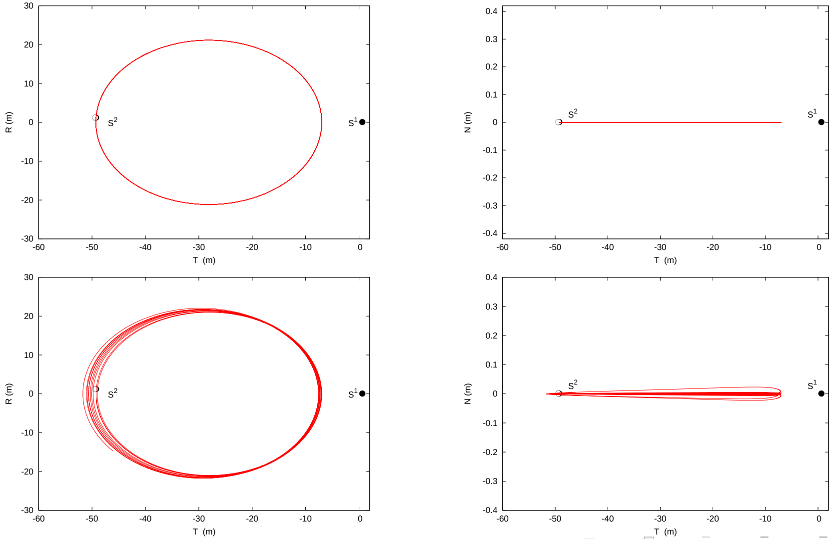
Orbital elements of satellites - Pair I

a (km)	e	$I(^\circ)$	$\omega(^\circ)$	$\Omega(^\circ)$	M $(^\circ)$	n
106 247	0.752	6.0	0.0	90.0	0.0	0.252
106 247	0.752	6.0	0.0	90.0	0.00001	0.252

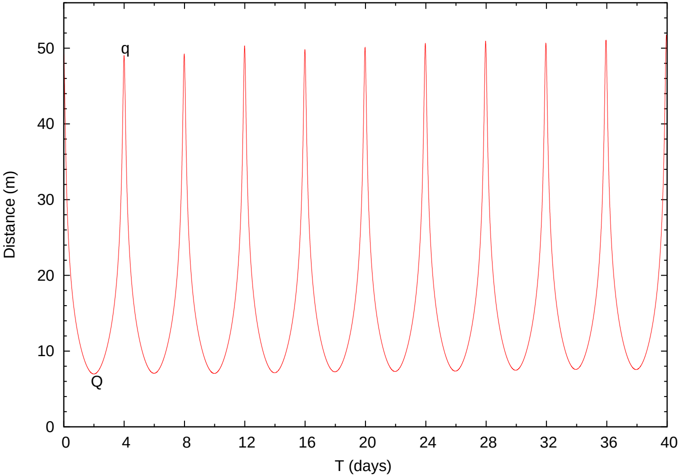
The initial relative distance 49 m.

The differential perturbations in positions were obtained by numerical integration of equations of motion in rectangular coordinates. Starting with the same initial conditions we calculated, for time span interval 180 days (45 revolutions), the differential perturbations $\Delta(\delta\vec{r}(t))$ using different models of forces acting on the satellites.

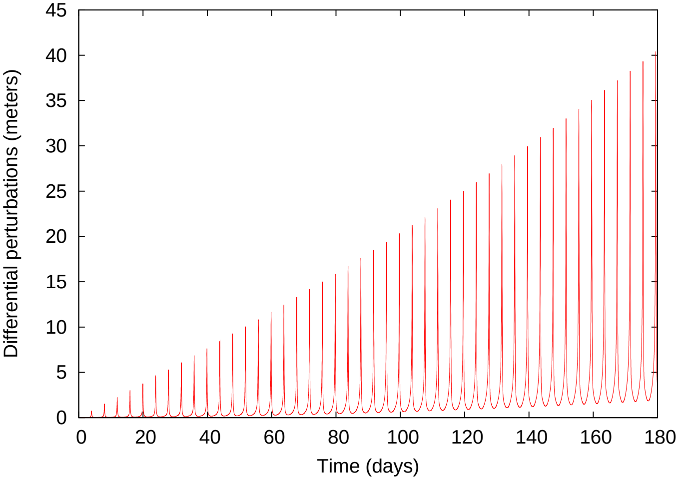
Unperturbed and perturbed relative orbits after 40 days



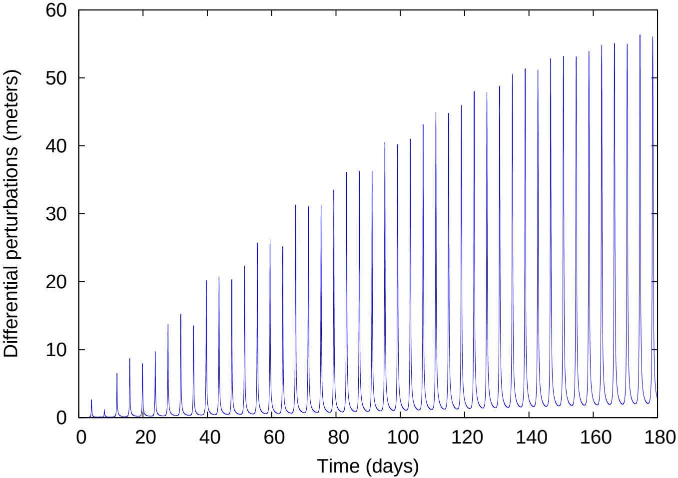
Relative distance between satellites



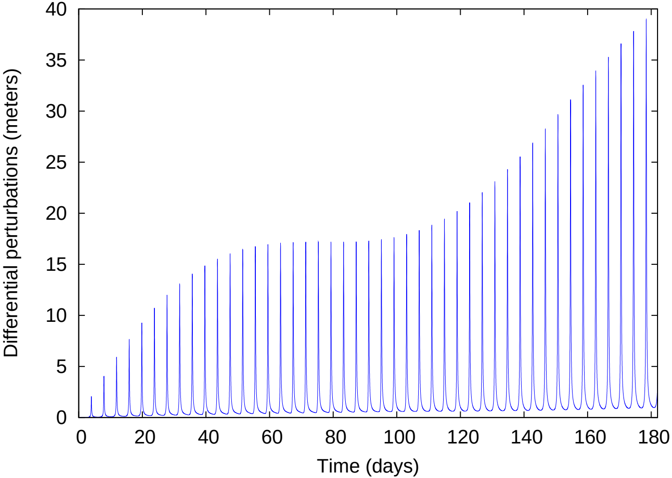
Zonal and tesseral harmonic coefficients up to order and degree 30



Pair I. The differential lunar perturbations.

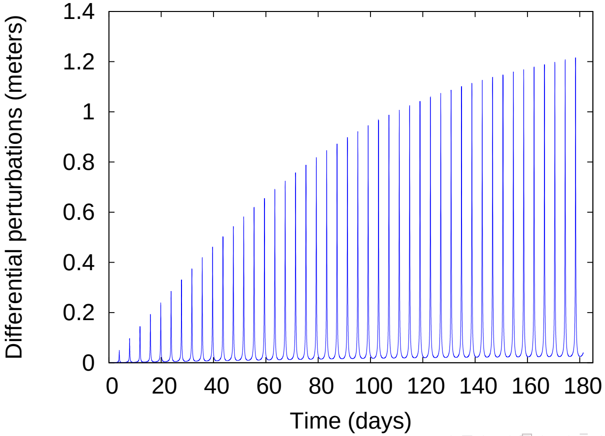


Pair II. The differential solar perturbations.



The solar radiation pressure due to relative distance

$S = 10m^2,\ m = 800kg,\ S/m = 0.0125\ m^2/kg,\ C_R = 1.3$

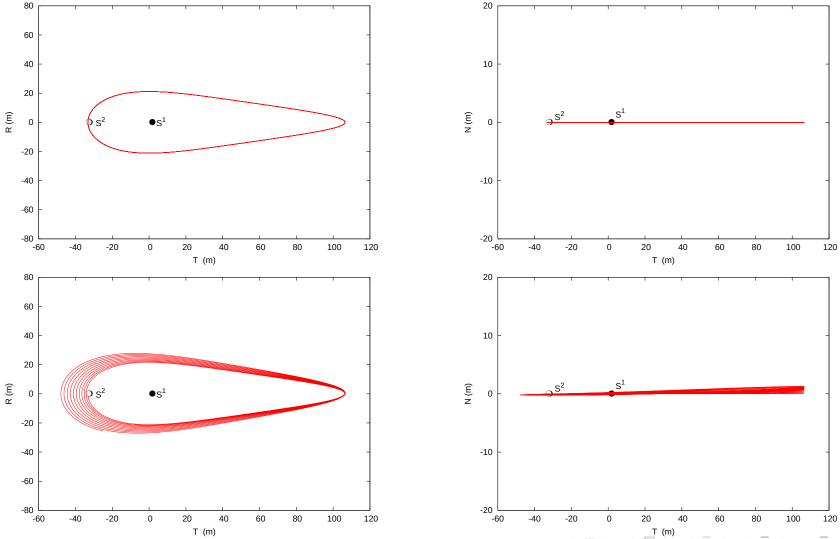


Orbital elements of satellites - Pair II

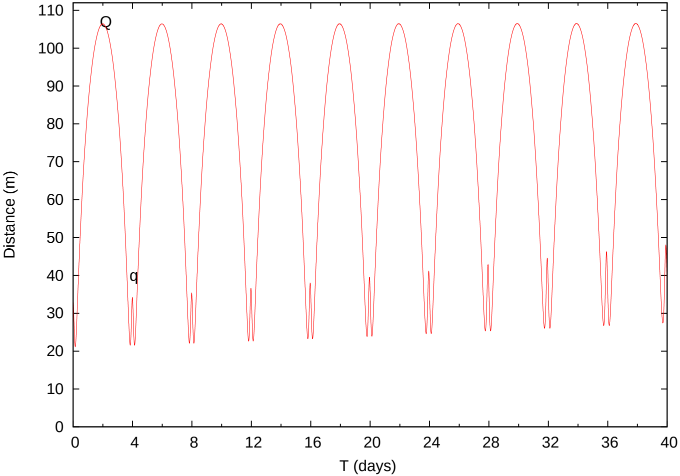
a (km)	e	$I(^{\circ})$	$\omega(^{\circ})$	$\Omega(^{\circ})$	M $(^{\circ})$	n
106 247	0.752	6.0	0.0	90.0	0.0	0.252
106 247	0.752	6.0	-0.0000349	90.0	0.00001	0.252

The initial relative distance 30 m.

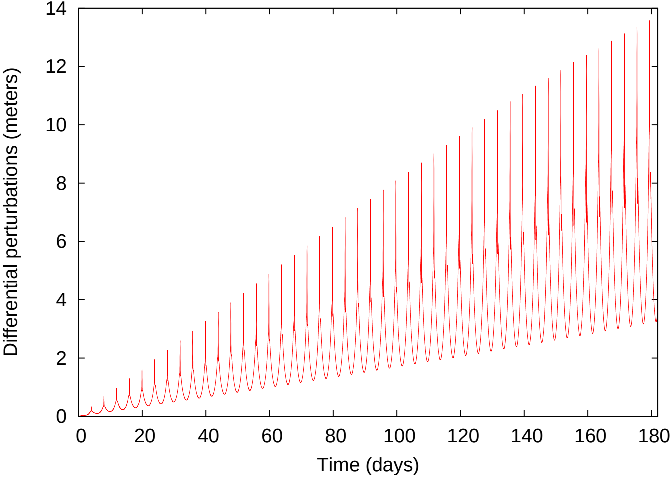
Unperturbed and perturbed relative orbits after 40 days



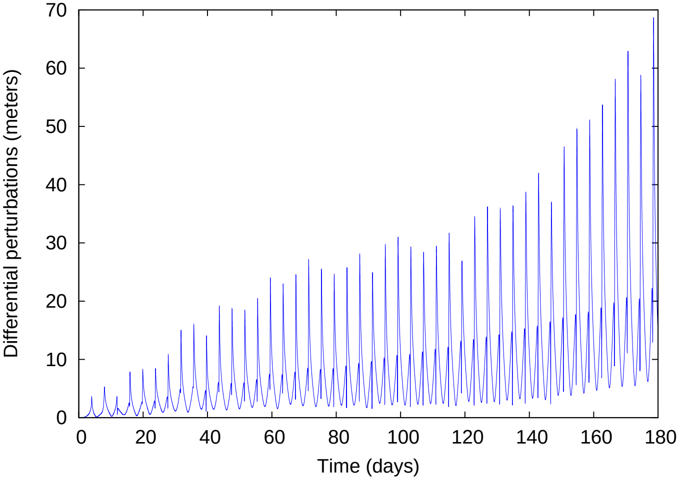
Relative distance between satellites



Zonal and tesseral harmonic coefficients up to order and degree 30



Pair II. The differential lunar perturbations.



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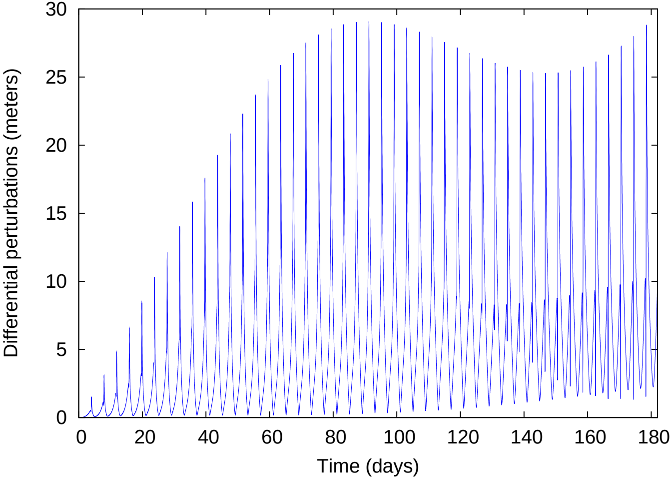

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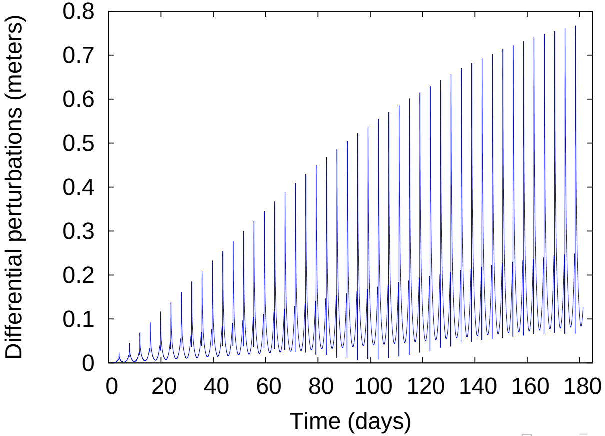
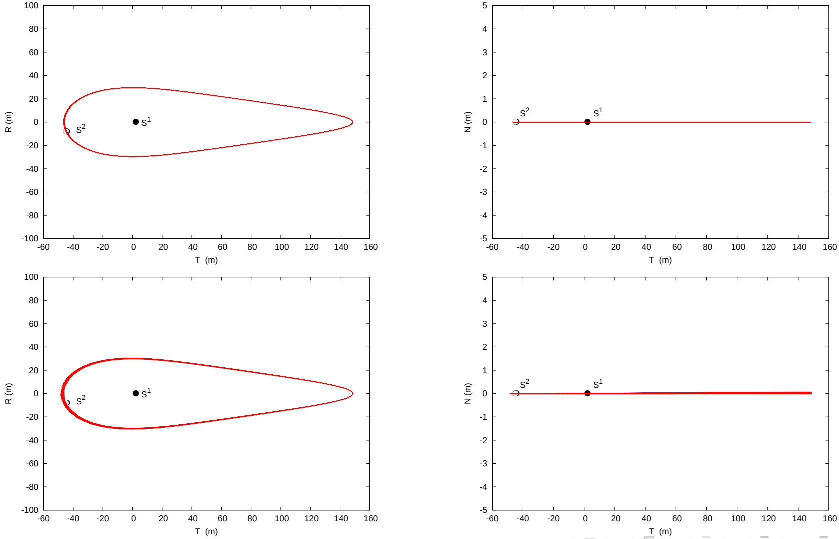


Orbital elements of satellites - Pair III

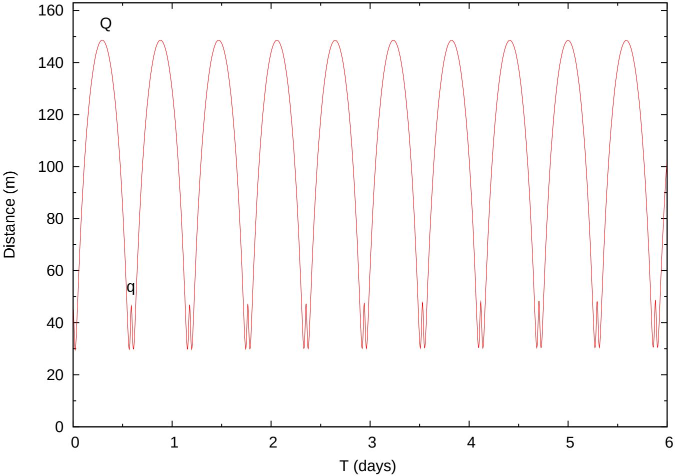
a (km)	e	$I(^\circ)$	$\omega(^\circ)$	$\Omega(^\circ)$	M $(^\circ)$	n
29 750	0.752	6.0	0.0	90.0	0.0	1.7
29 750	0.752	6.0	-0.000174	90.0	0.00005	1.7

The initial relative distance 30 m., q=1000 km, Q=52122 km

Unperturbed and perturbed relative orbits after 6 days (10 revolutions)

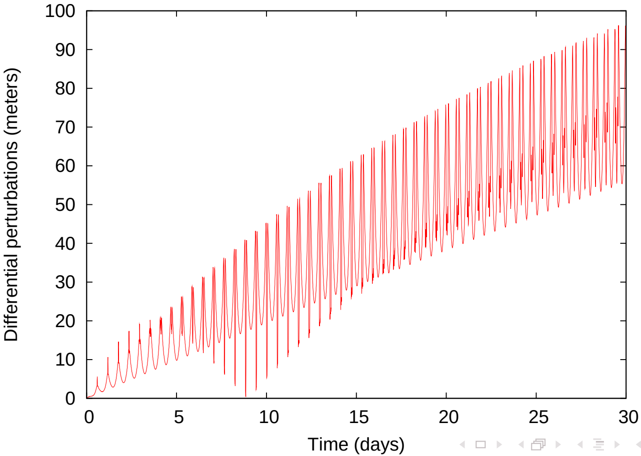


Relative distance between satellites

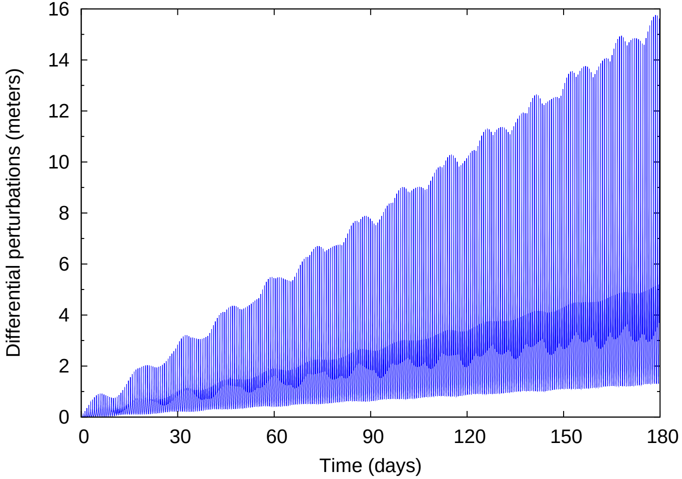


Zonal and tesseral harmonic coefficients up to order and degree 30

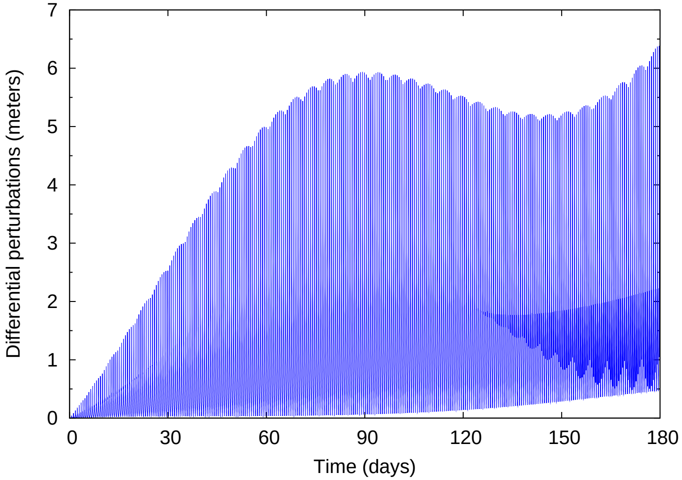
Time interval 30 days - 50 revolutions



Pair III. The differential lunar perturbations.



Pair III. The differential solar perturbations.



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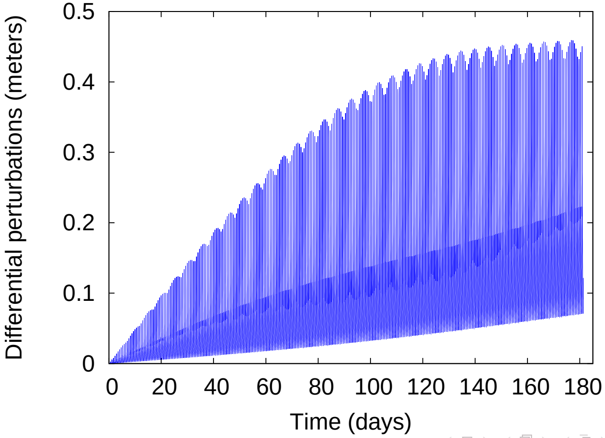

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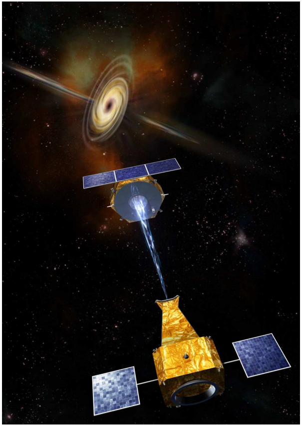
The solar radiation pressure due to $\Delta\frac{S}{m}$

Acceleration of a satelite due to the solar radiation pressure*

$$\ddot{\vec{r}} = -P_{\odot} C_R \frac{S}{m} \frac{\vec{r}_{\odot}}{r_{\odot}^3} AU^2$$

* Montenbruck O.,Gill E., *Satellite Orbits*



$P_{\odot}$ ≈ $4.56 \cdot 10^{-6} Nm^{-2}$

C_R – radiation pressure coefficient

S – cross-section area

m – mass of the satellite

$r_{\odot}$ – distance to the Sun from satellite

Dziękuję za uwagę!