Relativistic precession model of the Earth for long time interval

Kai Tang, Michael H. Soffel, Jin-He Tao, Zheng-Hong Tang

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Contents

Vondrak's long-term precession

an extension of IAU 2006 model of precession (Vondrak et al., 2011)

- the precession of the ecliptic: P_A, Q_A
  (Mercury 6 package)
- the precession of the equator: X_A, Y_A
  (La93 (Laskar et al., 1993), additional corrections due to IAU2006)
- a cubic polynomial plus 8 to 14 periodic terms
- $\pm$200 millennia from J2000.0

points

- consistent with the IAU 2006 precession
  (differences are less than a few arcseconds in the vicinity of J2000.0)
- no effects from General Relativity

Goals

a relativistic theory of Earth's rotation

- Klioner, Gerlach and Soffel (2010)
- consistent with General relativity

(1) the Earth's long-term precession in a relativistic framework

- the precession of the ecliptic:

  integrated numerically as in most previous works.
- the precession of the equator:

  based on the 1PN model of Earth's rotation (Klioner et al., 2010)

(2) the relativistic effects on the precession

Contents

the Precession of the Ecliptic

Dynamical model (Laskar et al., 2010):

- the Sun, all 8 planets of the solar system and Pluto
- the Moon is treated as a separate object
- the quadruple moment of the Sun and the Earth
- the tidal dissipation in the Earth-Moon System
- the solar mass loss

Relativistic effect

- The 1PN correction due to the Sun

Numerical integration:

- BCRS
- the symplectic SABA4 scheme (Laskar et al., 2001)
- ± 1 Myr, 1-day step

the Precession of the Ecliptic

The approximations for the precession of the ecliptic P_A and Q_A:

$$P_A = 5440'' - 1''.98 \times 10^{-4} T + \sum_{i=1}^{26} C_i \cos(2\pi T/P_i) + S_i \sin(2\pi T/P_i),$$

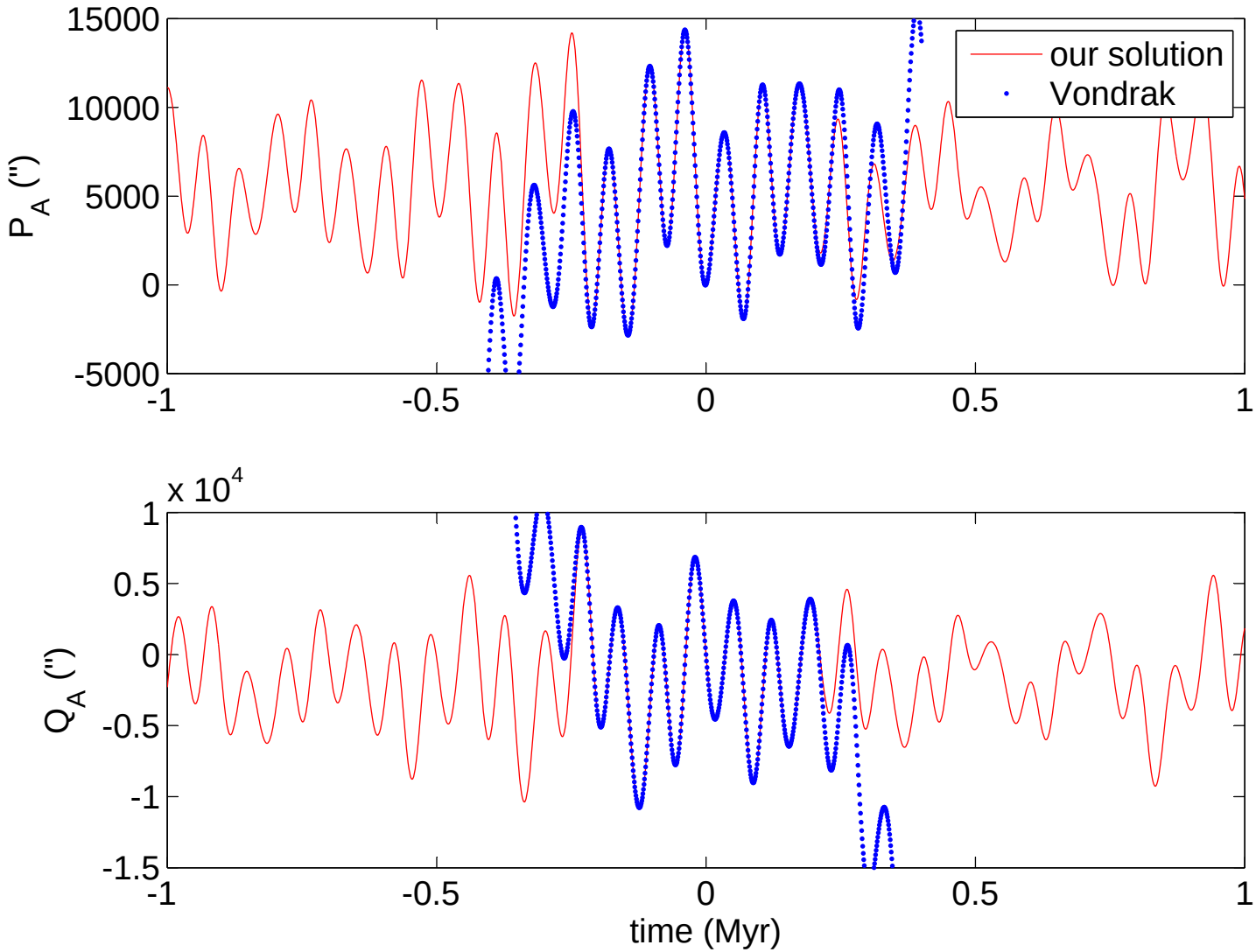
$$Q_A = -1608'' - 2''.06 \times 10^{-4} T + \sum_{i=1}^{26} C_i \cos(2\pi T/P_i) + S_i \sin(2\pi T/P_i) \qquad (1)$$

where T is in TDB from J2000.0.

Table 1: The Main Periodic Terms in P_A, Q_A.

	P_A		Q_A			
Term	$C_i['']$	$S_i['']$	$C_i['']$	$S_i['']$	$P[yr]$	$f_i['' /yr]$
$-s_3$	-3720	1259	-1290	-3698	68975	18.789505
$-s_1$	657	-2586	2508	736	235535	5.502369
$-s_4$	-2068	-302	288	-2056	72488	17.878769
$-s_2$	-855	-570	548	-838	192342	6.7377991
$-s_6$	438	338	-334	435	49178	26.35311

the Precession of the Ecliptic



the Precession of the Equator

Dynamical model:

Relativistic effects

- Geodetic precession
- the post-Newtonian inertial torque
- several relativistic reference systems with corresponding time scales and relativistic scaling of parameters
  (Klioner, Gerlach, Soffel (2010))

Numerical integration:

- GCRS, BCRS, TRS
- 8th-order Runge-Kutta
- ± 1 Myr, 0.1-day step

the Precession of the Equator

The approximations for the precession of the equator X_A and Y_A:

$$X_A = 5128'' - 1''.054 \times 10^{-3} T + \sum_{i=1}^{25} C_i \cos(2\pi T/P_i) + S_i \sin(2\pi T/P_i),$$

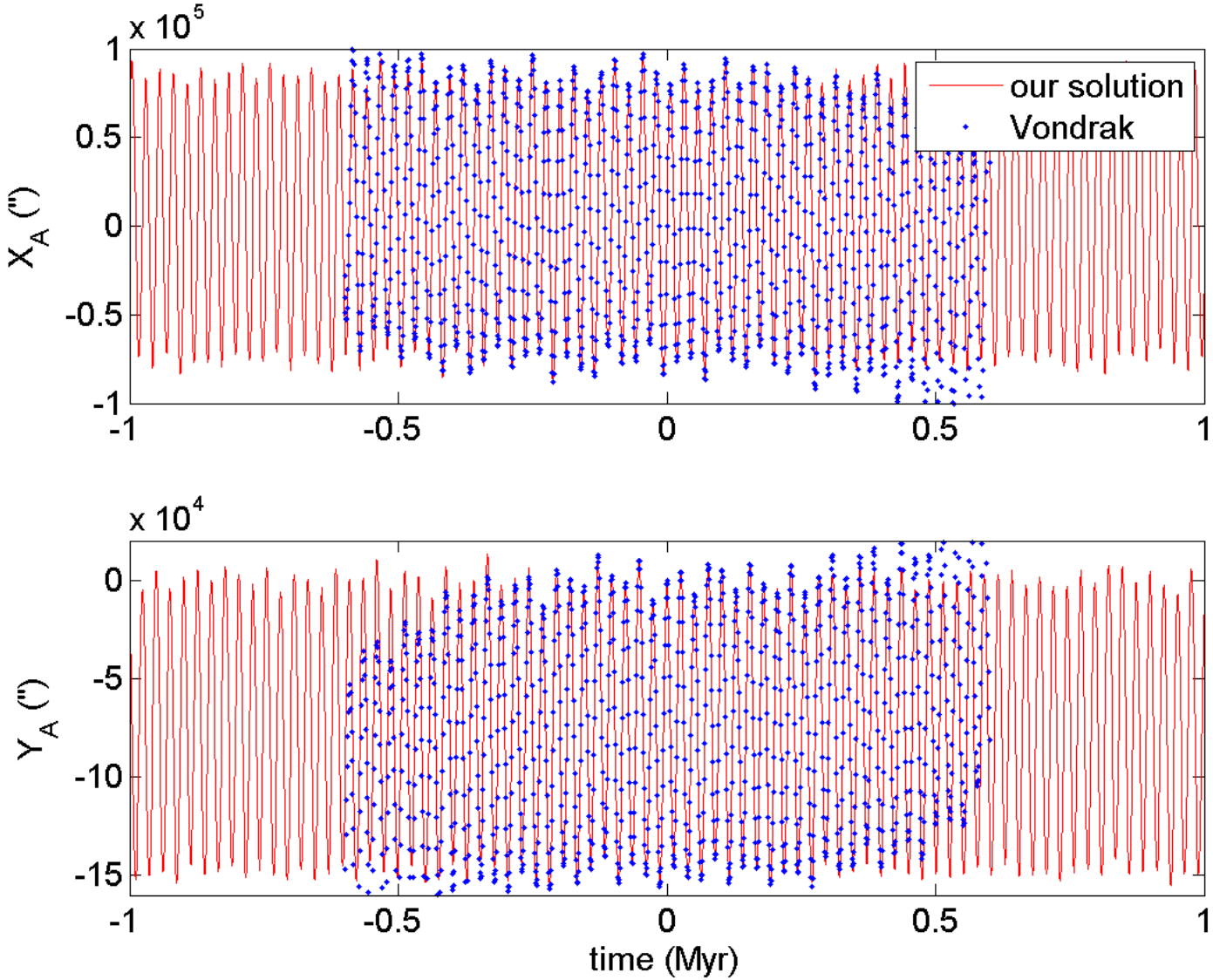
$$Y_A = -74120'' - 2''.86 \times 10^{-5} T + \sum_{i=1}^{25} C_i \cos(2\pi T/P_i) + S_i \sin(2\pi T/P_i) \qquad (2)$$

where T is in TT from J2000.0.

Table 2: The Main Periodic Terms in X_A, Y_A.

	P_A		Q_A			
Term	$C_i['']$	$S_i['']$	$C_i['']$	$S_i['']$	$P[yr]$	$f_i['']/yr]$
$-p$	-25597	1608	59383	55590	-857	50.63
$-s_3$	-68282	-4561	2390	2218	4238	18.98
$-s_1$	227568	488	-1639	-1553	-503	5.695
$-s_6$	48758	583	520	434	-499	26.58

the Precession of the Equator



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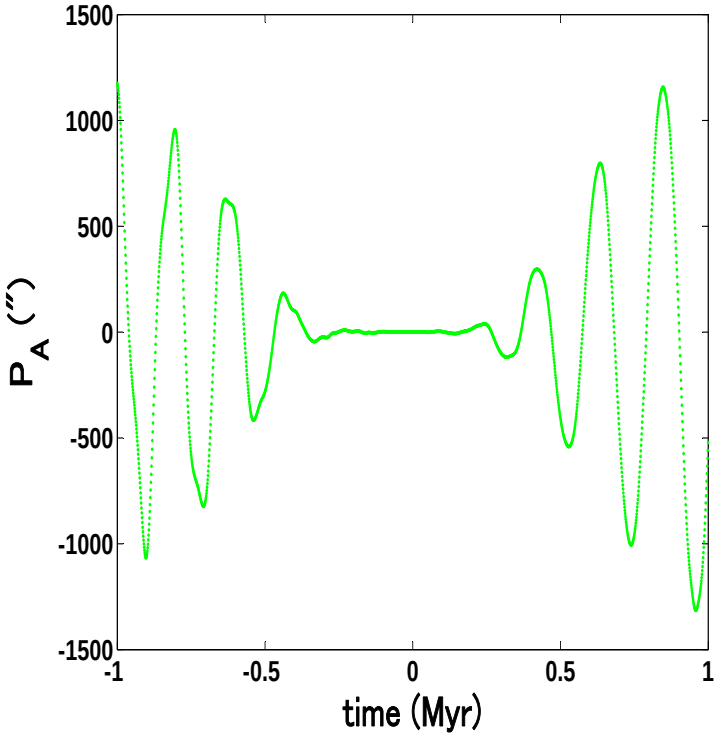
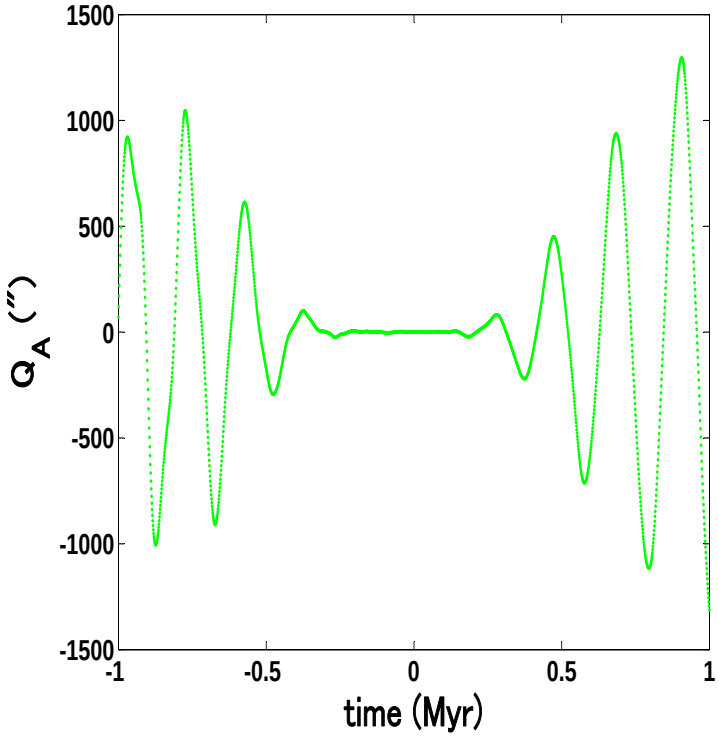
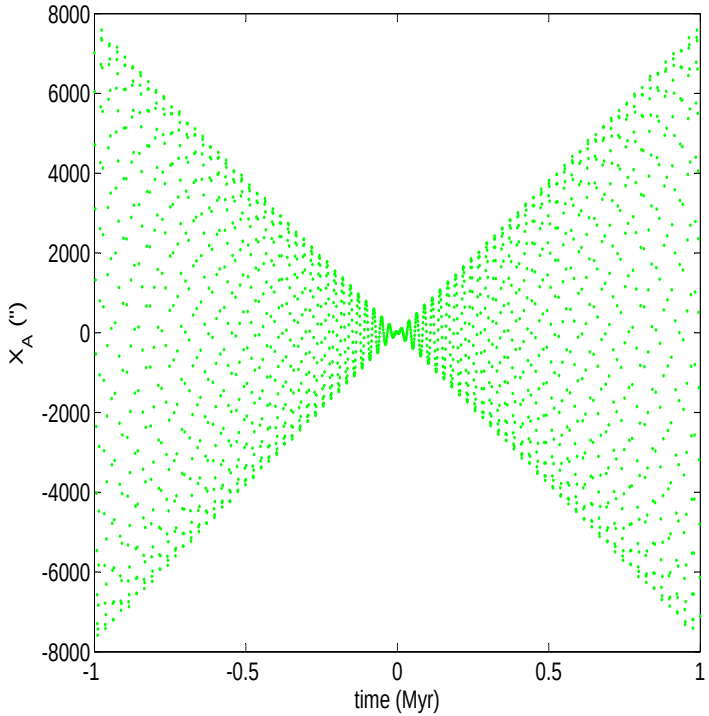
Relatvistic Effect on P_A, Q_A

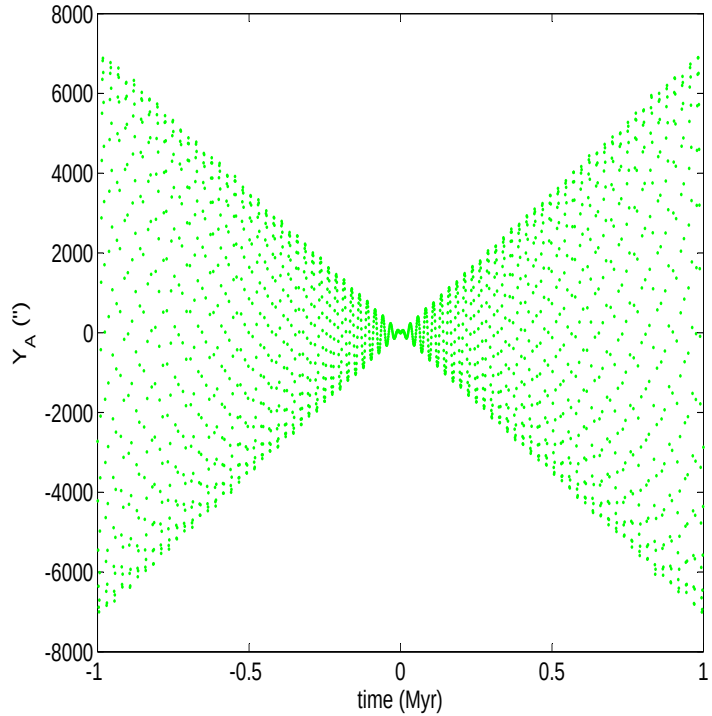




- the 1PN effect of the Sun
- the relativistic effect reach about 1300″ in ±1 Myr
- the main period is about 195 000 yr
- in ±0.2 Myr, this influence is smaller than 10″

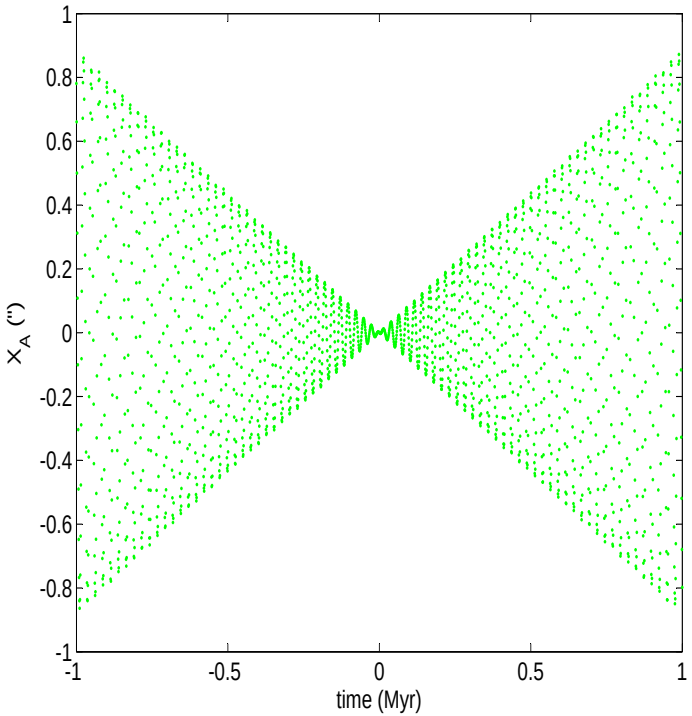
Relatvistic Effect of geodetic precession on X_A, Y_A

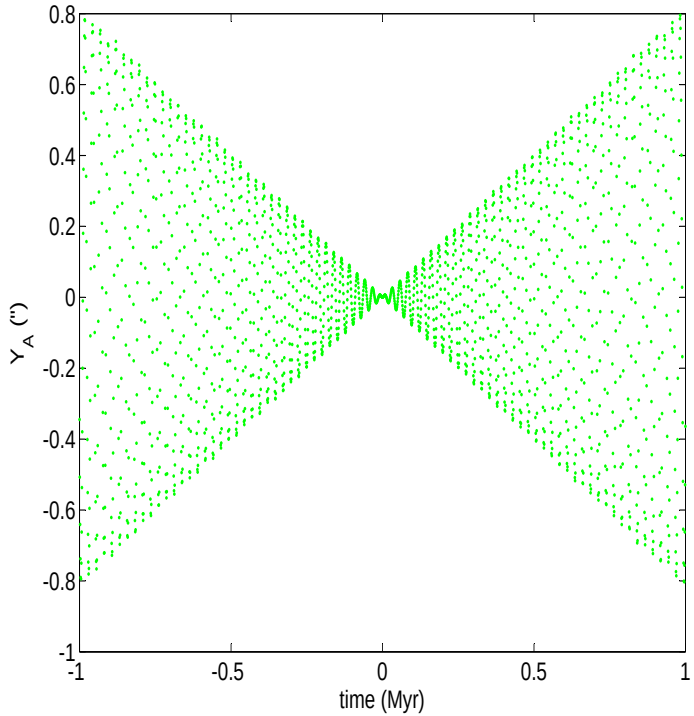




- the most important relativistic effect in Earth's rotation
- the influence is about $8000''$ in ± 1 Myr

Other relatvistic Effects on X_A, Y_A





- accumulate with time
- the amplitude of these effects is less than 1 arcsecond within ± 1 Myr
- too small to be considered in most cases over this time span

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Conclusions

1. Relativistic precession model of the Earth for long time interval

   (1)the difference to P03 is only several arcseconds in the interval $\pm$2000 years around J2000.0

   (2)consistent with other long-term precession theories

   (3)consistent with general relativity

2. Relativistic features

   (1) the 1PN effects related with the Sun

   (2) the geodetic precession/nutation,

   (3) the post-Newtonian torque,

   (4) several relativistic reference systems with corresponding time scales and relativistic scaling of parameters.

Thank you!