Pattern Recogn. Phys., 2, 21–26, 2014
www.pattern-recogn-phys.net/2/21/2014/
doi:10.5194/prp-2-21-2014

Pattern Recognition in Physics
Open Access

Responses of the basic cycles of 178.7 and 2402 yr in solar–terrestrial phenomena during the Holocene

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Received: 11 December 2013 – Revised: 6 January 2014 – Accepted: 7 January 2014 – Published: 17 January 2014

Abstract. Reconstructions of solar–terrestrial (ST) phenomena, in sufficient quality, several thousands of years backward by means of radiocarbon (^{14}C), ^{10}Be or ^{18}O isotopes have been employed for study of possible responses of the ordered (trefoil) and disordered intervals (types) of the solar inertial motion (SIM) as well as of the 370 yr exceptional segments occurring in steps of 2402 yr in these phenomena. The trefoil intervals are about 50 yr long, and the Sun returns to the trefoil intervals always after 178.7 yr, on average. During intermediate intervals the Sun moves along chaotic (disordered) lines. It was also found that very long (nearly 370 yr) intervals of the solely trefoil orbit of the SIM occurred in steps of 2402 yr. Such exceptional intervals occurred in the years 159 BC–208 AD, 2561–2193 BC, 4964–4598 BC, etc. A stable behaviour of ST phenomena during these long segments is documented. It was also found that the deepest and longest solar (temperature) minima (of Spörer or Maunder types) occurred in the second half of the 2402 yr cycle in accordance with the respectively most disordered types of the SIM. The SIM is computable in advance: the SIM comparable with that after 1873 is before us. Corresponding behaviours of ST phenomena can be expected.

1 Introduction

In recent years many papers considering possible planetary influences on solar–terrestrial (ST) and climatic variability were published (Beer et al., 2000; Abreu et al., 2012). These authors primarily dealt with the tidal influences of the planets on the Sun and computed the spectral analyses of ST and climatic data. The results show good correlations. The papers published up to the 1970s showed that a tidal enhancement from planets is in the order of millimetres. The latest papers employ the data (reconstructions) from nearly the whole Holocene.

This paper will deal with the solar inertial motion (SIM). The SIM is not negligible, it is a very noticeable phenomenon. The Sun moves within an area of a diameter of 4.3 r_s, where r_s is the solar radius (see Fig. 1), or 3×10^6 km. Our contributions (several tools) for the SIM-ST and climatic studies have been employed as follows:

1. The periods found in the SIM (in all its motion characteristics such as the velocity, the acceleration, the radii of curvature, etc.) are higher harmonics of the basic period of 178.7 yr (Bucha et al., 1985; Jakubcová and Pick, 1987). The basic period of 178.7 yr was found by Jose (1965) and further described by Fairbridge and Shirley (1987). Charvátová and Střeštík (2004) detected such periods, between 6 and 16 yr, in European temperature series and Charvátová-Jakubcová et al. (1988) detected these periods between 10 and 60 yr in global aurora records (cf. also Scafetta, 2012b). Since the solar motion characteristics are underlaid by variable geometries of the solar orbit, the results of spectral analyses are dependent on the intervals being employed (Charvátová and Střeštík, 1995). Scafetta and Wilson (2013) detected these periods in Hungarian aurora records since 1523.

2. Separation of the SIM into two basic types, the ordered (in JS trefoils) and disordered (Charvátová, 1990, 1995).

3. The very long, regular cycle of 2402 yr represents a repetition of the exceptional, nearly 370 yr-long interval of trefoil solar motion.

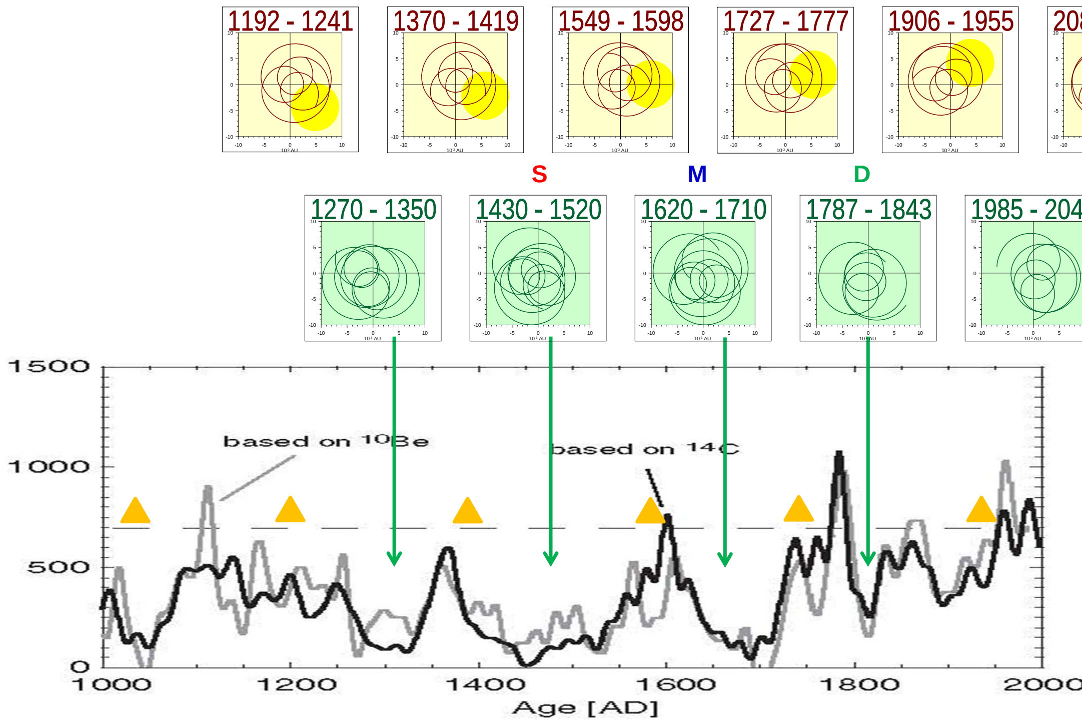

Figure 1. Above: the solar orbit divided into two basic types, the one ordered in JS (Jupiter/Saturn) trefoils (yellow) and one disordered (chaotic) (green). The Sun is returning at the trefoil orbits after 178.7 yr. The Sun moves in the area with a diameter of 4.3 r_s, where r_s is solar diameter or 3×10^6 km. The yellow circles denote the Sun. Below: a solar modulation record based on ^{14}C and on ^{10}Be since 1000 AD (taken from Muscheler et al., 2007). Long-term maxima in these records tend to coincide with the trefoil intervals (yellow triangles mark their centres). Grand prolonged minima occurred in accordance with the intervals of the chaotic motion of the Sun (see lower green orbits), S – Spörer, M – Maunder, D – Dalton minima. A moderate chaotic (green) type of the SIM (1980–2040) indicates lowered both solar activity and surface air temperature.

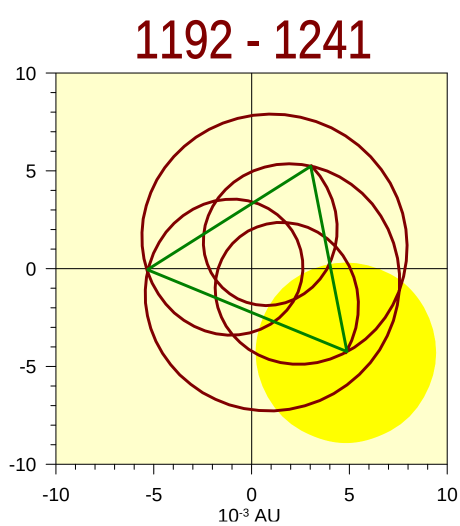

Figure 2. Triplet of loops (brown) and the characteristic triangle (green). The trefoils are characterized by nearly equilateral triangles.

4. Nearly identical parts of the SIM were found (e.g. 1840–1905 and 1980–2045 AD), which were employed for predictive assessments (Charvátová, 2009).

2 The cycle of 178.7 yr in the SIM, ST and climatic relations

Important insight into the SIM, ST and climatic relations gradually appeared since the geometry of the SIM was studied. The geometry of the SIM consists of loops and arcs. It was found that the geometry of the SIM can be divided into two basic types, the ordered (in JS trefoils) and disordered (chaotic) types (Charvátová, 1988, 1989, 1990; Charvátová and Střeštík, 1991). The average length of the loop-arc pair is 19.85 yr (Jupiter/Saturn synodic period). The Sun returns at the trefoil orbit after 9 cycles, i.e. 178.7 yr, on the average. The precise basis for the study of the relations between the SIM and solar–terrestrial and climatic variability thus arose. The SIM can be computed into the future, providing new predictive possibilities.

The trefoil is a stable shape. A movement of the Sun along one loop or arc lasts for 10 yr (JS/2). Here it seems pertinent

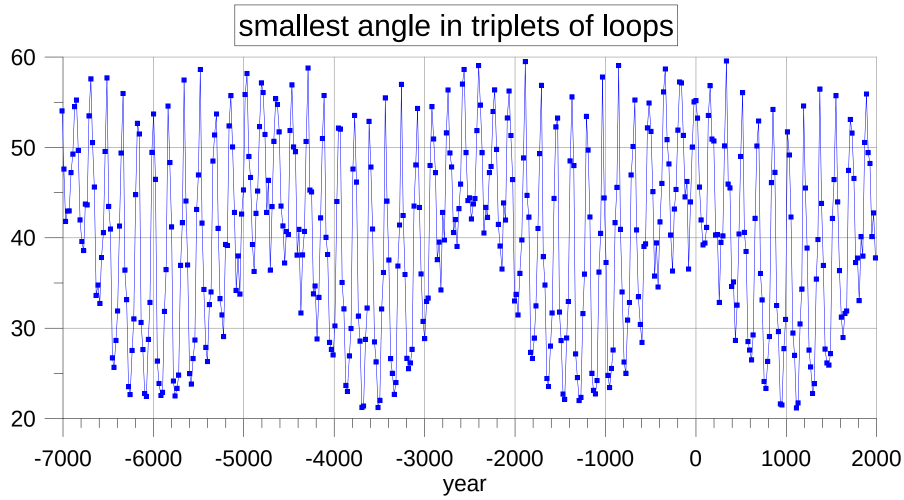

Figure 3. The smallest angle of the characteristic triangle of triplets of loops. The basic cycle of 171.4 yr (UN) as well as the long cycle of 2402 yr is well demonstrated. The cycle of 2402 yr is 14 cycles of 171.4 yr.

for a short review of our previous results dealing with behaviour of solar–terrestrial (ST) phenomena during the trefoils: the last trefoil occurred in 1906–1956. The lengths of the respective sunspot cycles (15–19) varied between 10.0 and 10.6 yr, being 10.3 yr on average, a mean value of the lengths of cycles from −1 to +3 (in the previous trefoil) is also about 10 yr. This supports a bimodality of sunspot cycle lengths with modi of 10 and 12 yr found by Rabin et al. (1986). The dominant period in geomagnetic index aa is also 10 yr (Charvátová and Střeštík, 2007). The series of sunspot cycles in the trefoil interval of the 18th century nearly coincide with that in the trefoil in the 20th century. This was also confirmed by methods of nonlinear dynamics, i.e. quantitatively (Paluš et al., 2000). Instrumental temperature series measured since 1750 in central Europe, in Jesuit monasteries, show temperature maxima in centres of the trefoils (in about 1760 and in about 1940) (Charvátová, 1995). During the trefoil intervals volcanic activity is attenuated, there is a general absence of large volcanic events (Charvátová, 1997).

Further back in time we can use reconstructed data. Figure 1 shows the reconstruction of solar activity by means of the amount of ^{14}C (radiocarbon) in tree rings and surface temperature by means of ^{10}Be since 1000 AD. It is seen that long-term maxima of both solar activity and of surface temperature tend to coincide with the mid-points of the trefoil intervals. The great prolonged minima such as the Spörer or Maunder minima, on the other hand, coincide with the chaotic motion of the Sun. The last prolonged solar minima were recently studied by Cionco and Compagnucci (2012), Mörner (2013), Salvador (2013), and Solheim (2013).

We may conclude that the SIM is the central factor which causes ST and climatic variability. It can be held as a driving force of climatic changes

3 The cycle of 2402 yr in the SIM and its response in ST phenomena

The ordered (trefoil) intervals of the SIM are characterized by a triplet of loops whose vertices form a nearly equilateral triangle (see Fig. 2). On the other hand, loops in disordered parts are often distributed along a straight-line and the corresponding triangle has at least one small angle (see e.g. Dalton period in Fig. 1). The smallest angle of the triangle is a good characteristic of this feature (if the smallest angle is close to 60°, all angles must be nearly equal). As it follows from Fig. 3, the number of loop-arc pairs between neighbouring maxima varies between 9 and 8. The average distance between maxima computed from the interval 7000 BC–2000 AD is 171.1 yr, which is very close to the Uranus/Neptune (UN) synodic period of 171.4 yr. Many solar–terrestrial phenomena thus fall between 171.4 and 178.7 yr (Scafetta and Wilson, 2013).

Figure 3 also documents a very long cycle of 2402 yr found by Charvátová (2000). It looks like a vault under the cycle of 178.7 yr. In the intervals 159 BC–208 AD, 2561–2193 BC, 4964–4598 BC, etc., the same exceptional solar orbits of trefoil type were repeated in steps of 2402 yr. These exceptional intervals are nearly 370 yr long (see Fig. 4). The period of 2400 yr was found in the time series of cosmogenic nuclide production over the last millennia (e.g. Bard et al., 1997; Vasiliiev and Dergachev, 2002; McCracken et al., 2013). Figure 5 shows reconstructions of several phenomena since 9000 BP (before present). Vertical lines define the above mentioned intervals. It is possible to see that all phenomena show very small fluctuations inside these intervals. The greatest deviations occurred in the second half of the 2402 yr cycle. They represent prolonged (grand) minima of the Spörer or Maunder types.

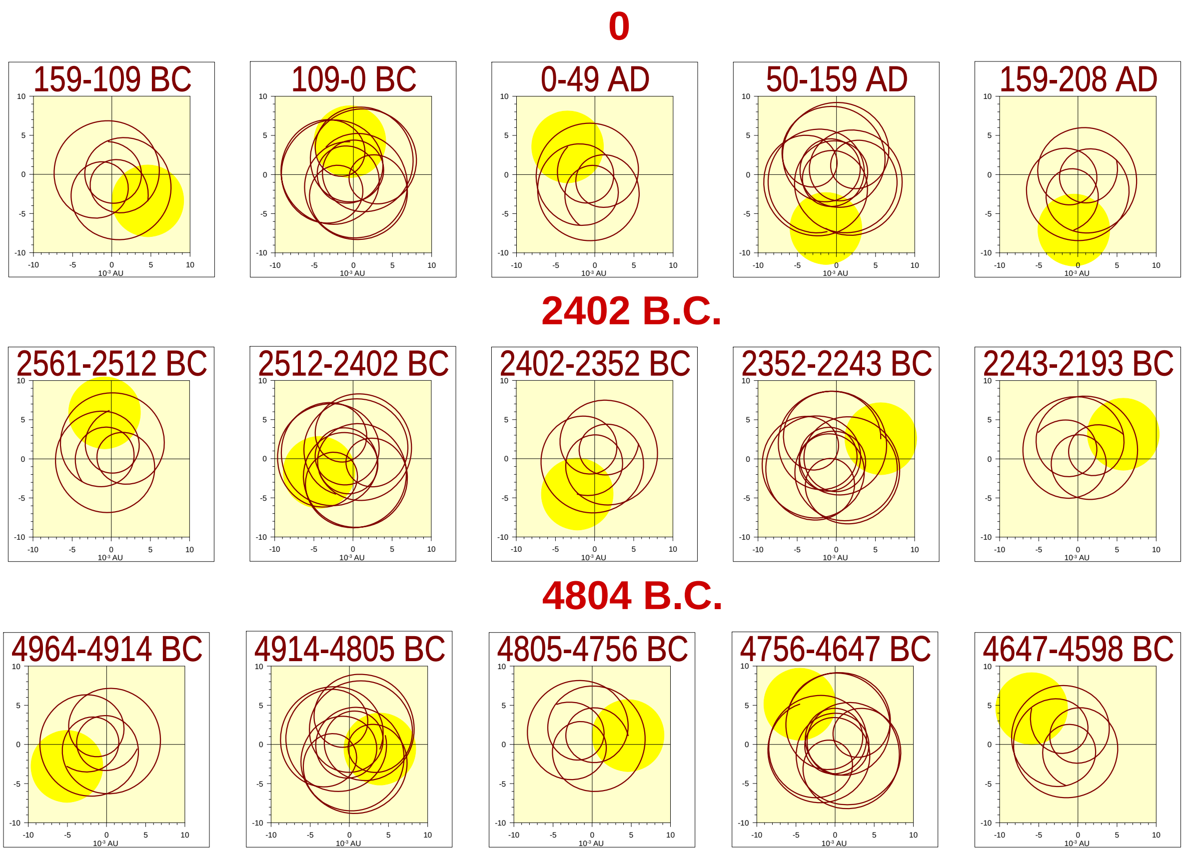

Figure 4. Alternation (in steps of 179 yr) of trefoil intervals of about 50 yr and chaotic intervals of about 130 yr of the SIM have been regularly overcome by the cycle of 2402 yr (Charvátová, 2000). The nearly 370 yr segments of the exceptional trefoil (stable) pattern of the SIM occurred in the years 159 BC–208 AD, 2561–2193 BC, 4964–4598 BC, etc. Notice the twice shortened distance of 159 yr between the three trefoils in each segment.

4 Conclusions

The results obtained indicate a primary, controlling role of the SIM in solar–terrestrial and climatic variability. The quite precise base for study of the SIM, ST and climatic relations occurred after the solar orbit had been divided into two basic types: the ordered according to trefoil, lasting for about 50 yr, and disordered, lasting for about 130 yr. The prolonged solar and temperature minima have coincided with the intervals of the chaotic SIM. Responses of two basic types of the SIM were described. A response of a stable character of very long (370 yr) trefoil intervals of the SIM was also shown (Fig. 5). The deepest and longest solar (temperature) minima (of the Spörer or Maunder types) occurred in the second half of the 2402 yr cycle in accordance with the most disordered types of the SIM.

The Sun has a layered structure and the greatest jump of physical parameters was found at the boundary between radiative and convection zones. The satellites (SOHO, etc.) found a thin shear layer between the radiative and convection zones, now called the tachocline. This layer is likely to be the place where the solar dynamo operates (Abreu et al., 2012; Mörner, 2013). The layered Sun is forced to move along the given loops and arcs, its velocity ranges between 36 and 64 km h^{-1}, its mean velocity is about 50 km h^{-1}. It would be interesting to compare a changing velocity of the Sun with a velocity of shear flows in the tachocline. Scafetta (2012a) showed that the Sun, by means of its nuclear active core, may be working as a great amplifier of the small, planetary tidal energy dissipated in it. Wolff and Patrone (2010) came to the conclusion that the Sun is subject to significant differential forces, not only from tides, but from the varying angular momenta of cells within it, which do not cancel out.

The SIM is computable in advance (celestial mechanics). This opens predictive possibilities. The intervals of the nearly identical SIMs will serve as the supporting bases in searching for mutual relations between the SIM and different types of solar–terrestrial phenomena, including climatic. Charvátová (2009) showed that the SIMs in the years 1840–1905 and 1980–2045 are nearly identical and of a moderately chaotic type. The future (forthcoming) behaviours of ST phenomena are likely to be analogous to those after 1873.

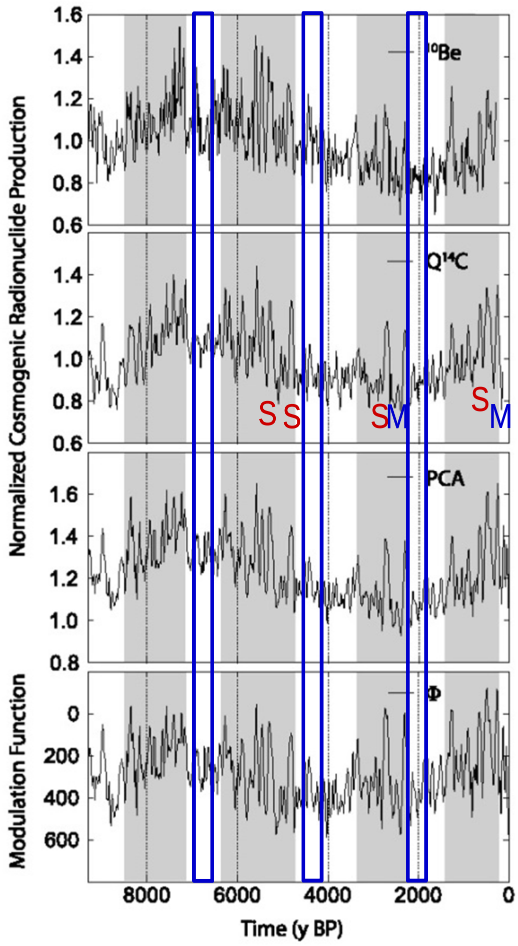

Figure 5. Normalized cosmogenic radionuclide productions since 9000 BP (taken from McCracken et al., 2013) and the cycle of 2402 yr in SIM ("present" means 1950). Blue vertical lines denote the exceptional trefoil intervals in steps of 2402 yr and the SIM is therefore of stable type within those lines. The smallest deviations occurred during these intervals, while the greatest deviations occurred in the second half of the 2402 yr cycle representing Spörer (S) or Maunder (M) type of prolonged (grand) minima in correspondence with chaotic intervals of the SIM.

Acknowledgements. This work was supported by the Ministry of Education, Youth and Sports of the Czech Republic under project OC09070. Fruitful discussions related to this topic took place during the Space Climate 5 Symposium held in Oulu in June 2013.

Edited by: N.-A. Mörner
Reviewed by: R. Tattersall and one anonymous referee

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