An Independent Verification of Ivanka Charvátová's Solar Inertial Motion (SIM) Curves

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versions: **incomplete, uncorrected second draft** 18Jun08

Summary

Since 1988, Ivanka Chárvatová has published many papers on the Solar Inertial Motion (SIM) of the sun around the solar system's barycenter (center of mass), and it's relationship to solar activity (sunspots), climate, and more recently it's relationship to the geomagnetic index.

NASA' Jet Propulsion Laboratory (NASA-JPL) "Horizons" ephemeris program was used to generate SIM comparisons, and the results are directly overlain on graphs from Charvatova's papers in 1990, 2000, and 2008. Given that the Charvatovan data was in graphical format, no detailed statistical comparisons were made, but the excellent visual comparison is obvious and sufficient for the current author's purposes. In general there is excellent agreement between the author's results and those of Charvatova, but three classes of differences stand out:

1. it is clear that small discrepancies between SIM curves are more noticeable the further back in time that one goes (2560 BC was the earliest comparison);
2. the "start-end" points of the curves differ by ?0.2 to 5? years, depending on how many of thousands of years in the past the comparison is made.
3. the "orientation" (angle with respect to the x,y axis) is different, and there are noticeable differential rotations over time between the two sets of results.

It has been shown that the timing of SIM curves and solar activity seems to be very precise for the two comparative examples that have been made from historical data. This is very important for the application of Charvatova's theory of an SIM influence on solar activity. The current author is aware of no other concept that can produce long-term timing solar activity predictions at all, let alone of the accuracy that Charvatova's approach demonstrates, or at least suggests, in spite of the limited data availability.

But when comparing sections of Solanki etal's proxy sunspot data over the last 11,000 years, comparable SIM periods do NOT seem to be similar, which calls into question the applicability of Charvatova's theory for longer periods of time (and perhaps shorter periods as well). Given that the sunspot proxies are based on berylium 10 (10Be) and carbon 14 (14C), it's possible that the isotopic "pathway" (atmospheric retention, deposition processes etc), intrinsic geomagnetic activity, or other processes would "camouflage" somewhat the actual solar activity. Initial "timeshifts" of the data show some limited potential. However, at the current time it's best to use the data that we have, and state that there isn't yet long-term support for an SIM-solar activity relation. Perhaps marine varve data will tell a different story.

It has not been claimed, nor is it expected, that SIM will alone explain solar activity and its many components. For example, solar dynamo models presumably contribute independent influences on solar activity, and there may be many other drivers. In that light, the degree of agreement from one SIM period to another similar period is actually quite surprising.

Versions:

15Jun08	initial, incomplete, uncorrected draft
18Jun08	Added results of shifting 10Be dates for earlier 2,400 year periods. Provided two more "SIM curve" comparisons. Still need to generate corresponding SIM curves.

Cleanup items:...
Search & Replace Chavatova -> Charvátová
Complete several sections, change titles
Double check references and several data

endpage

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1. Introduction

Since 1988, Ivanka Chárvatová has published many papers on the Solar Inertial Motion (SIM) of the sun around the solar system's barycenter (center of mass), and it's relationship to solar activity (sunspots), climate, and more recently it's relationship to the geomagnetic index. That planetary motions might drive soar activity cycles was first proposed by Johann Rudolf Wolf in ca. 1852, based on the recent discovery of sunspot cycles by Samuel Heinrich Schwabe. But although many attempts have been made over the last 150 years to provide a statistical and physical basis for this concept, these have thus far not suceeded. The recurring story of this theory is described by [Charbonneau 2002].

Charvatova established the very close correspondance of spectral peaks for SIM and climate ranging from just under two years through several thousad years, including essentially all of the well-known climate cycles (see [Howell 13N0v07 - Climate and food production]. The following table illustrates the periods,

		Charvatova		Bucha etal	Niroma	
		Motion	Temperature			
Solar Inerial Motion basic cycle		178.7	n/a			
Major	Major periods	7.8	7.8	7.8		
	JN - Jupiter-Neptune	12.8	12.8	12.8	12.7	Niroma says reflection of Jovian year - two times the distance of the Jovian year from the mean cvcle
Minor periodicities	JN/2	6.5	6.5	6.4		
	JU/2			6.9		
		7.4	7.3-7.4		9.3	Niroma - maybe - intensity but not lengths
		8.4	8.4-8.5			
	JS/2			9.9	9.9	Niroma - intensity but not lengths
		10.4	10.3-10.5		10.3	Niroma - actual lengths not intensity
	Jupiter	11.9		11.9	11.9	Niroma - intensity & length - Jovian year
		12.0	n/a		11.1	Schwabe half cycle of sunspots and magnetic pole double-reversal Niroma - intensity and theoretical lengths only
	JU - Jupiter-Uranus	13.8	n/a	13.8		
		n/a	14.3			
Mid-term	Jupiter-Saturn			19.9		
	Saturn			29.0		?why longer than Jupiter!! - oops Jupiter closer to sun then Saturn
	SN - Saturn-Neptune			35.0		
	SU - Saturn-Uranus			45.0		
	treffoils	50-60	n/a	60.0		
	Uranus			84.0		
Longer term			60			
			90			~Gleissberg quasi-cycle 70-90 y
			120			
	SIM basic period	178	150-200			~Suess quasi-cycle
			850-950			~"great inequality" of the motion of Jupiter and Saturn
			1000-1200			
			1500			~Bond quasi-cycle
		2200	2280			Damon etal 1988
			2000-2400			

In a series of papers, Charvatova and colleagues analysed the form of the SIM curves, and identified "ordered" and "disordered" periods. The former seemed to be associated with periods of relatively high solar activity, and also formed part of major historical "warm periods" as clearly identified in human history. In the mid-1990's, Charvotova apparently made the best prediction of solar cycle 23.

The current author has reproduced graphs from three of Charvatova's papers, taken from 1990, 2000, and 2008. NASA-JPL's "Horizons" ephemeris program was used to generate the comparisons, and the results are directly overlain on graphs from Charvatova's papers. Given that the Charvatovan data was in graphical format, no detailed statistical comparisons were made, but the excellent visual comparison is obvious and sufficient for the current author's purposes.

The purpose of this verification was:

- to provide an independent, publicly available verification of Charvatova's graphs. This is published on the author's website, www.BillHowell.ca together with:
    - a spreadsheet of SIM data back to 3,000 BC;
    - GIMP graphical results to allow the reader to rescale and rotate the author's graphs directly over top of Charvatova's.(transparently);
- to ensure that the current author's own work and approach is compliant with literature "standards";
- to provide some idea of the uncertainty of the SIM calculations by comparing different sources;
- to verify that the timing of SIM and sunspot activity is consistent, as this is critically important to the application of Charvatova's theory of an SIM influence over phases of solar activity.

2. Methodology

a) Charvatova's graphs

Graphs were taken from three of Charvatova's publications [1990, 2000, and 2008], which provided a check on the current author's methodology, but also on the consistency of Charvatova's results over time.

It is not known to the current author whether Charvatova "up-graded" the Solar Intertial Motion (SIM) curves over time as a direct comparison was not made. However, based on the fits with the same NASA-JPL calculated curves in the current paper, Charvatova's SIM curves are substantially the same over the time-span, with possibly some refinements (these do not really stick out to me - but the reader can check the graphs in the appendix for themselves).

b) NASA-JPL "Horizon's" ephemeris program

NASA's Jet Propulsion laboratory has posted an excellent "Ephemeris" program on their website, which allows the public to generate information on astronomical (stars, planets, many asteroids) motions and their apparent position in the sky from any point on Earth (or other planets, for that matter). One can even calculate the dates that planets would appear from within tunnels in ancient architectures (pyramids, temples etc) in the distant past. But for this paper, only information on the relative positions of the sun and solar system barycenter (center of mass of the solar system) was required.

The reader should refer to the website: http://ssd.jpl.nasa.gov/horizons.cgi, as well as the description by Jon Giorgini [?date? - http://ssd.jpl.nasa.gov]. This system is well set up and is easy to use. For the purposes of the present paper, it was NOT necessary to interpolate between data points produced by the program, although that was necessary in previous work on Holocene climate [Howell 2007].

A printout describing my selections for the program is:

```
*******************************************************************************
 Revised: Sep 12, 1996             Sun                              10

 PHYSICAL PROPERTIES:
  GM (10^11 km^3/s^2)   = 1.3271243994    Mass (10^30 kg)       =    1.9891
  Radius (photosphere)  = 6.960(10^5) km  Angular diam at 1 AU  = 1919.3"
  Mean density          = 1.408 g/cm^3    Surface gravity       =  274.0 m/s^2
  Moment of inertia     = 0.059           Escape velocity       =  617.7 km/s
  Adopted sidereal per  = 25.38 d         Pole (RA,DEC in deg.) =  286.13,63.87
  Obliquity to ecliptic = 7 deg 15'

  Solar constant (1 AU) = 1367.6 W/m^2    Solar lumin.(erg/s)   =  3.846(10^33)
  Mass-energy conv rate = 4.3(10^12 gm/s) Effective temp (K)    =  5778
  Surf. temp (photosphr)= 6600 K (bottom) Surf. temp (photosphr)=  4400 K (top)
  Photospheric depth    = ~400 km         Chromospheric depth   = ~2500 km
  Sunspot cycle         = 11.4 yr         Cycle 22 sunspot min. =  1991 A.D.

  Motn. rel to nrby strs= apex : RA=271 deg; DEC=+30 deg
                          speed: 19.4 km/s = 0.0112 AU/day
  Motn. rel to 2.73K BB = apex : l=264.7+-0.8; b=48.2+-0.5
                          speed: 369 +-11 km/s
*******************************************************************************


*******************************************************************************
Ephemeris / WWW_USER Sat May 24 08:21:04 2008  Pasadena, USA     / Horizons
*******************************************************************************
Target body name: Sun (10)                        {source: DE406}
Center body name: Solar System Barycenter (0)     {source: DE406}
Center-site name: BODY CENTER
*******************************************************************************
Start time      : B.C. 1000-Jan-01 00:00:00.0000 CT
Stop  time      : A.D. 1000-Jan-01 00:00:00.0000 CT
Step-size       : 14400 minutes
```

```
*******************************************************************************
Center geodetic : .000000000,.000000000,.00000000 {E-lon(deg),Lat(deg),Alt(km)}
Center cylindric: .000000000,.000000000,.00000000 {E-lon(deg),Dxy(km),Dz(km)}
Center radii    : (undefined)
Output units    : AU-D
Output format   : 03
Reference frame : ICRF/J2000.0
Output type     : GEOMETRIC cartesian states
Coordinate systm: Ecliptic and Mean Equinox of Reference Epoch
*******************************************************************************
JDCT ,   , X, Y, Z, VX, VY, VZ, LT, RG, RR,
*******************************************************************************
$$SOE
```

Due to output data size limitations, this was run 3 times: from 3,000 to 1,000 BC, from 1,000 BC to 1,000 AD, and from 1,000 to 3,000 AD. the data files were then merged, but there is a "timing glitch" at their junctions (it doesn't show up visibly in the graphs).

c) NGDC - National Geophysical Data Center, USA

Sunspot data was obtained from the National Geophysical Data Center, USA (NGDC). A spreadsheet containing the data (and graphs t display it over top of Charvatova's graphs) is on my website:

- Howell - NGDC Geophysical Data Center retr08 - Group sunspot numbers, File descriptions.ods

d) GIMP image editing program

To transparently overlay the NASA-JPL generated graphs onto Charvatova's, a number of image editing features are required (transparency, rotation, scaling, merging layers, etc). For this the freely available Gimp program was selected (www.gimp.org). It took some time to get used to the program, so the initial graphs are noticably "clumsy".

It seems that image "distortion does occur to some extent when rotating images, but at least the graphs are scaled so the reader can check the ultimate status of the graphs. Initially, the NASA-JPL graphs were scaled directly on the corresponding Charvatova graph, then rotated. But part way through, it was found to be much faster to rotate them first, then re-scale them. The danger with this latter approach is that the scalings for the Charvatova and generated graphs may differ somewhat, but given the apparent (unconfirmed impression) that scaling had been affected by rotation anyways,

As noted in the previous sub-section, the NASA-JPL curves were colored blue so that they would be easily differentiated from the underlying (black) Charvatovan curves.

The gimp-format image files (.xcf) are available on www.BillHowell.ca together with the other files associated with this paper. By downloading gimp and loading these files, the user may move the transparent (blue curve) layer over top of the underlying Charvatova graph, getting a much better idea of the fit. Furthermore, the user may rotate and resize the transparent layer, producing fits of their own.

Note that the transparent layers in these files are generated by "merging" layers containing the individual graphs, so independent adjustments of each individual graph cannot be done with these "final" images. Presumably the user can still do so by selecting-copying individual graphs, and pasting them onto their own independent layers.

Sunspot data series

- Charvatova - recent millenium - moveable transparency.xcf
- Charvatova - long warm periods - moveable transparency overlay.xcf
- Charvatova Nov08 - SIM curves - moveable transparency.xcf
- Charvotova 1990 - current millenium graphs - moveable transparency.xcf

3. Results

a) SIM curve shapes - Comparisons between the results of Charvatova and the current author

In the "overlay" figures (A.3, B.3, C.1, C.2), the current author's graphs (blue curves) have been superimposed over the same graph taken directly from one of Charvatova's papers [1990, 2000, or 2008]. The units for all graphs are milli-Astronomical Units (mAU - where AU is the "standard" sun - Earth distance).

In general, each superimposed graph has been re-scaled and rotated to fit the Charvaota graph, but this has been done by visual inspection, and it is not an exact process, especially in Figure A.3 where the author was first learning the tricks of using the www.Gimp.org software. One can easily see the occasional error in adjusting the fit. Normally, one would expect the graphs to have the same scale, but distortion and improper re-scaling by the current author will have resulted in different scales. At least the relative scaling can be directly measured on the graphs. In a few cases (for example figure C.2 1450-1520) graphs are strongly skewed, which should not occur, but realistically speaking there is likely a bit of skew to most NASA-JPL graphs.

Similarities

In spite of the approximate nature of the overlay comparisons and the occasional error in re-scaling and rotating, by inspection one can see that the graphs match very well, particularly for the recent millenium (figures B.3, C.1 and C.2), and for the "ordered" periods as defined by Charvatova. The "ordered periods" have radially near-symmetrical treffoil patterns, and are associated with relatively warm, stable periods (eg Figure A.3).

Differences

(NOT completed yet....)

Figure .B.3: The Maunder minimum

This is the only graph for which there is a very large "surplus" curve for one source (the current author's) as compared to thje other. This is quite distinct from the "start-stop" shift referred to above, and may be due to an error in reporting the starting and stopping dates .

b) Timing of sunspots for SIM "ordered" periods of the last millenium

The timing of the SIM points is critical, as it has a direct bearing on the predictability of SIM movements and relating those to other phenomena, such as climate on Earth. By inspection, it appears that most of the graph endpoints (current author versus Charvatova) are within one year of one another, but on occasion this is exceeded (examples?). But in looking at Charvatova's 1990 paper, it seems that the endpoints are not necessarily the dates specified in the graph captions, so the comparisons may not be absolute.

It seems to the current author that more detailed and accurate comparisons on timing should await until the original background data from Charvatova's papers are available. But the graphical results are quite good.

Timing data is available from the use of the NSA-JPL curves alone, as shown in Appendix D. Those curves show excellent agreement for the start and stop dates of SIM curves that are used in to select timeframes for comparing solar activity (sunspot only) data in Appendix E. This correspondence is extremely important - the current author suspects that the prediction of precise timing (phase) of solar activity is even more critical as a first step than the amplitude of a cycle.

c) Timing of the SIM and Solanki etal sunspot proxy over 11,000 years

Appendix F - "SIM periods and sunspot proxy data from Solanki etal", compares historical berrylium 10 (10Be) and carbon 14 (14C) "pseudo-decadal" data from [Solanki etal 2004], for periods of "equivalent SIM curves" (warm periods only at this stage). Decadal resolution appears to be the limit of the isotopic data, with 14C subject subject to longer atmospheric residence time and processes other than solar activity. Both isotopes were used to reconstruct solar activity estimates over the last 11,000 years, and cvomparisons with slar activity during hte last 400years seem to be reasonably good [Usoskin etal 2004]. The original data plus the graphics generator used by the current author are posted on the website together with othe material related to this paper:

- Howell - Solanki sunspots (10Be & 14C).ods

Figure F.2 shows very different proxy curves for "oredered" periods of the last millenium. However, the "rotated" shapes of the curves appear to be somewhat similar. It is not known if that is significant. For example, perhaps solar dynamo or cosmic ray variances may set the trend, but perhaps the SIM fingerprint still shows through?

There is no apparent correlation (even considering tie lags "by inspection") between 10Be / 14C proxy curves for historical warm periods in Figure F.3. These SIM-suggested warm periods last for 366 years.

The current author [Howell 2007] has made a crude attempt to reconstruct solar irradiance and insolation (and not just sunspot estimates) on the basis of the Usoskin etal data, based on approximate relations developed by [Tapping etal]. There may be some historical significance to that reconstruction.

Ordered SIM periods over the last millenium

As can be seen from Figure F.2, there is not a good correlation between ordered SIM periods on the basis of the 14C / 10Be proxy sunspot numbers, for the last millenium.

Ancient warm periods

When comparing sections of Solanki etal's 14C / 10Be proxy sunspot data for three warm periods over the last 11,000 years (figure F.3), comparable SIM periods do NOT seem to be similar, which calls into question the applicability of Charvatova's theory for longer periods of time (and perhaps shorter periods as well).

By time shifting two of the three curves (figure F.4), the fit is a "bit" better, though it's certainly not a complete match. However, the fit of the corresponding "disordered" SIM curves (figure F.5) is "not so impressive, but somewhat similar (??)". This "time-shift" is equivalent to saying that their timing of the Greenland ice core data used to generate the 10Be curves may have been a bit off. That wouldn't be a huge surprise at it is analogous to the carbon 14 calibration curves, but I have no idea of what the timing accuracy is.

Further comments

As shown in figures throughout the appendices, the "orientation" of the ordered SIM curves does change significantly, even over the most recent millenium. As 10Be and 14C formation are supposedly created due to higher energy galactic rays, which are shielded by the helio- and geo-magnetospheres, then perhaps this orientation could affect the proxy numbers, but I can't think of a good mechanism why. It would seem at first glance that shielding would NOT be affected by orientation, but only by the timing. And the ordered SIM motions occur over 50 years, as opposed to the annual revolution of the Earth.

Given that the sunspot proxies are based on berylium 10 (10Be) and carbon 14 (14C), it's possible that variations of the galactic rays over the scale of decades and centuries, the isotopic "pathway" (atmospheric retention, deposition processes etc), intrinsic geomagnetic activity, or other processes would "camouflage" somewhat the actual solar activity. Indeed, Veizer [Scherer etal 2006] suggests the possibility that some of the 10Be variability may be the result of inherent galactic ray variability, independent of the solar activity changes (see Figure F.6). But again, the Solanki-Usoskin results for solar activity over the last 400 years do seem reasonable. Note that many other periods of similar SIM motion might be within the 10Be data (apart from the obvious "ordered periods!).

While 10Be/ 14C data don't support the matching of decadal averages of solar activity taken from long (50 to 366 years) periods of similar SIM curves, perhaps marine varve data will tell a different story. [Wan ?year before 2005?] "successfully" modelled modern solar activity on the basis of "priming" the model with ancient varve (mud layer) data from 680 million years ago (figure F.7)! While this does not directly support a varve-sunspot correspondance, other datasets and analysis are available, and varve data can give annual estimates, not just decadal averages as for 10Be.

However, at the current time it's best to use the data that we have, and state that there isn't yet long-term support for an SIM-solar activity relation.

4. Questions

Results so far don't explain doesn't explain why last 5 years highest level of solar activity in 8000 years.

What is the minimum lenth of time required to establish "similar" solar activity responses (or at least an SIM imprint on solar activity)?

Does this minimum period depend on the the "class" of SIM? (beyond the distinction of "ordered" vs "disordered" curves)

If one subtracts a transformed "SIM signal" from proxy solar activity data, will it help to reveal other drivers? (assuming that SIM itsef is a causal driver)

What is the variability & influence of Jupiter's magnetosphere on solar activity, as opposed to the role of it's gravitational field?

[Many other questions to come....]

5. Conclusions

The current paper confirms the SIM graphs of Charvatova, as presented in papers in 1990, 2000, and 2008. While there is a very tight fit between graphs over the last millenium, slight differences become noticeable approximately 2,000 and 4,500 years ago. This is perhaps to be expected given the cumulation of errors that occurs with ephemeris calculations. For example, the NASA-JPL program only goes back to ?3,000 BC?, perhaps partially for that very reason.

A significant difference between the current author's results and Charvatova's is the "orientation" (as defined by the x,y coordinates, the the changes in orientation over time - especially noticeable with data from 2000 and 4500 years ago. While this may not be important for solar activity (eg sunspots as one component of solar activity), it could possibly be important for Earth-Sun processes such as geomagnetic activity, climate, human history [Howell etal 2007 preliminary], and many others. For example, it is known that galactic rays have a direct, and very important influence on cloud cover, and that solar activity "shields" Earth to some extent from the galactic rays. To the extent that some of these rays may come from the center of the Milky Way, then the orientation of the sun-barycenter SIM might produce important timing differences between peak seasonal (eg winter on Earth) solar activity, and relative exposure to galactic rays.

A second "apparently significant" difference (lacking formal statistical analysis), is the start-stop positions of the curves, which vary apparently by typically less than a year, but perhaps as much as ?2 to 5? years, depending on how many thousands of years in the past the comparisons are made. Its possible that the actual start/ stop dates of the curves are different than stated in either Charvatova's or the current author's results (most likely the current author). Also, the timing differences especially several thousand years ago, may be the result of additive errors in the ephemeris programs, and while it wouldn't affect the approximate timing and type of SIM, that kind of difference is extremely important to determining the exact solar minima. In that sense, archeological and geological data may be essential in "calibrating" the timing of the astronomical processes in the past, as we need (want) solar activity estimates to plus or minus less than a year!!

So far, historical 10Be proxy data (10 year averages) for solar activity back to 2 to 7 thousand years ago does not support the Charvatovan theme that SIM curves relate directly to solar activity. However, simply shifting the 10Be curves in time relative to one another does reveal some interesting correspondance (figure F.4).

It has not been claimed, nor is it expected, that SIM will alone explain solar activity and its many components. For example, solar dynamo models presumably contribute independent influences on solar activity, and there may be many other drivers. In that light, the degree of agreement from one SIM period to another similar period is actually quite surprising.

6. Next Steps

With greater confidence in the SIM curves, the next step may be to:

- use geological varve data going back 10 to 15,000 years to see if that provides a solid data-set comparison of similar SIM curves.
- can the Usoskin/ Solanki proxy decadal average sunspot numbers be explained by incorporating one or more "missing variables"? (magnetic polarities, z coordinate - which looks like a possibility, sun-Earth distances as in [Howell 2007 Holocene climate]).
- use available SIM and sunspot data, back to approximately 1600, to see if more matches of the type that Charvatova has already identified can be found over the last ~5,000 years to build estimates of sunspot activity prior to 1600. Clearly, there is a big variation in the quality of sunspot data, particularly prior to ~?1850?, and there may be very sparse coverage of periods prior to 1600 given the high variability of SIM motions/ curves. Indeed, some measure of "similarity" will be required for SI curves - how much difference is allowable before the solar activity would be significantly different? And how much of solar variability can be attributed to the influence of, or correlation with, SIM?
- push for the further development of physics-based models that describe the relation (if any) between SIM and solar activity, based on the solid solid support provided by the Charvatovan cycles. Such models will be necessary to predict or explain SIM/solar activity relations for much of the last 5000 years. Although attempts to build SIM/ solar activity models have failed for 150 years, but perhaps the right model can now be found. Note that it is NOT proposed that SIM is the only, or even necessarily the dominant, driver of solar activity, as there are dynamo and other models that may also prove to be important. However, SIM appears to be better supported by data than any alternative theories for solar activity, and to the author's knowledge it is the only theory at present with any significant predictability. Furthermore, based on the sparse sunspot data available to date (only 150 to 400 years, depending on the quality needed), much of the phasing AND amplitude of sunspot activity seem to be well explained by SIM curves (see [Charvatova Nov08] for examples].).

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Appendix A: Historical long warm periods

I. Charvátová: Can origin of the 2400-year cycle of solar activity be caused by solar inertial motion? 403

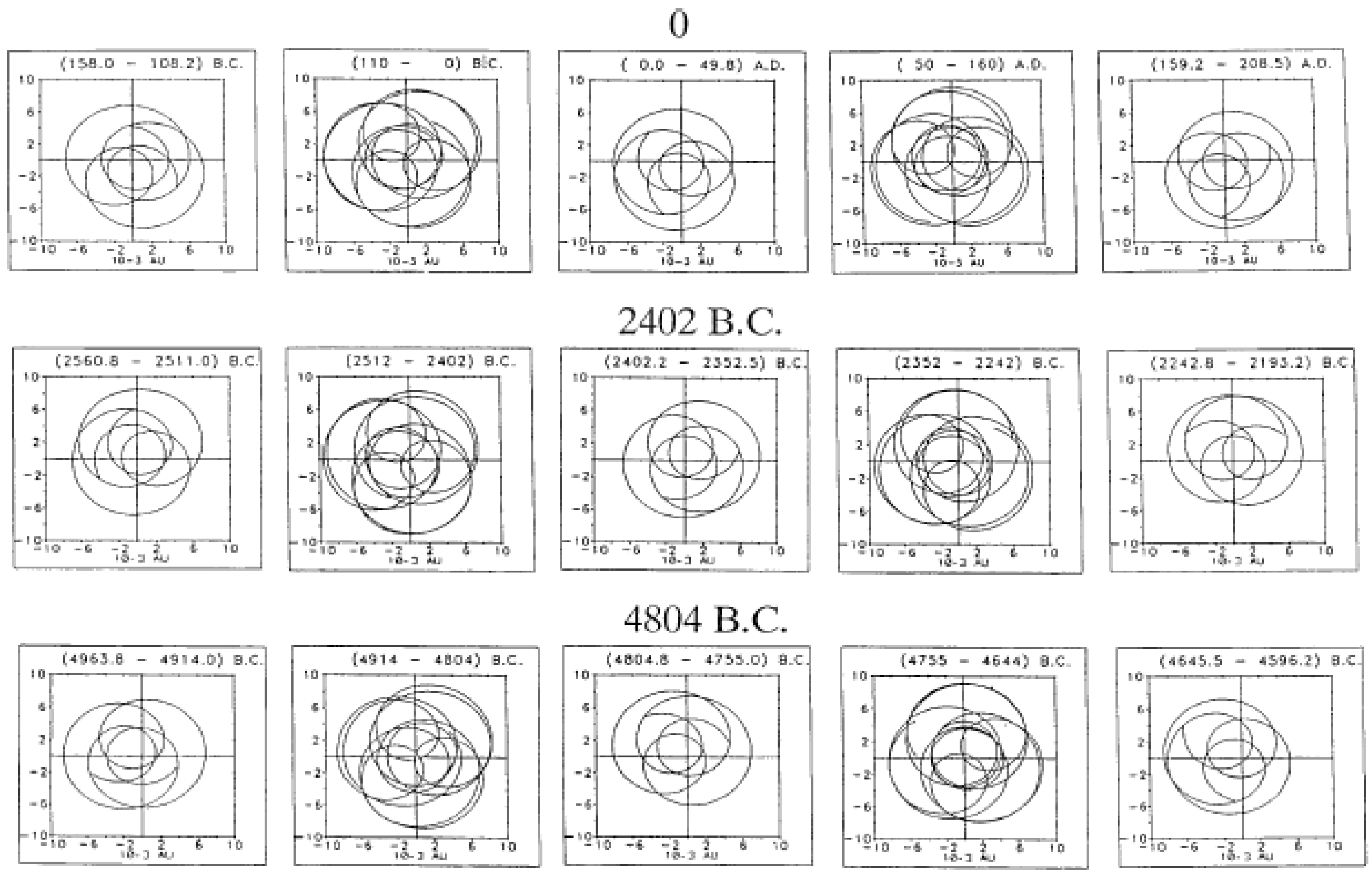
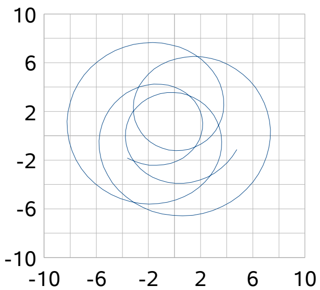


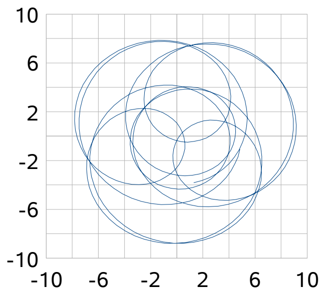
Fig. 4. The 370-year segments of the exceptional, stable pattern of solar motion recurring in steps of 2402 years: notice the twice shortened distance of 159 years between the three trefoils in each segment (from 158 BC to 208 AD, from 2561 BC to 2193 BC and from 4964 BC to 4596 BC). The next such segment will occur between 2240 and 2610 AD

Figure A.1 - Charvatova's original graphs for long warm periods

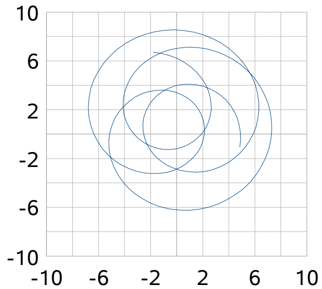
a) Roman warm period:



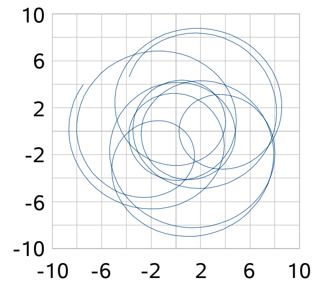
158.0 - 108.2 BC



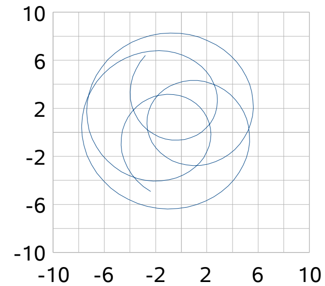
110 - 0 BC



0.0 - 49.8 AD



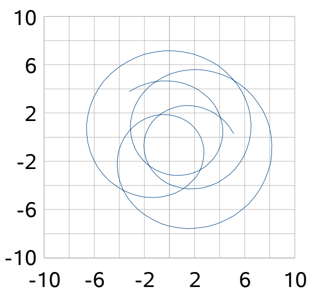
50 - 160 AD



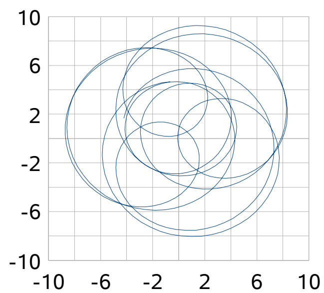
159.2 - 208.5 AD

b) Egyptian Old Kingdom, Mesopotamian, ?Harrupan? 2560 - 2193 BC

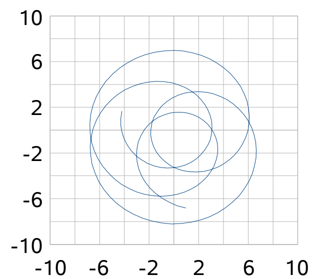
2560.8-2511.0 BC



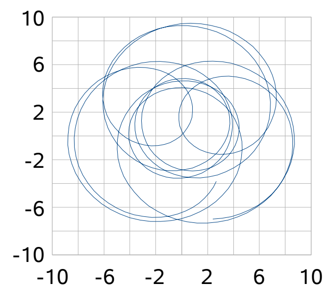
2512 - 2402 BC



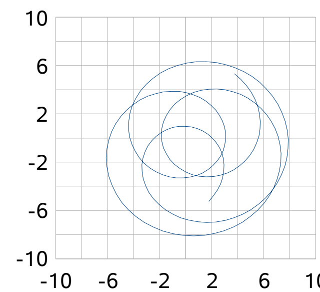
2402.2 - 2352.5 BC



2352 - 2242 BC



2242.9 - 2193.1 BC



??? No NASA-JPL outputs for the 4804 BC Warm times (4964 to 4596 BC) ???

Figure A.2 - Howell's graphs for long warm periods, based on NASA-JPL Horizon Software

Scaling is in mili-Astronomical Units (mAU)

I. Charvátová: Can origin of the 2400-year cycle of solar activity be caused by solar inertial motion? 403

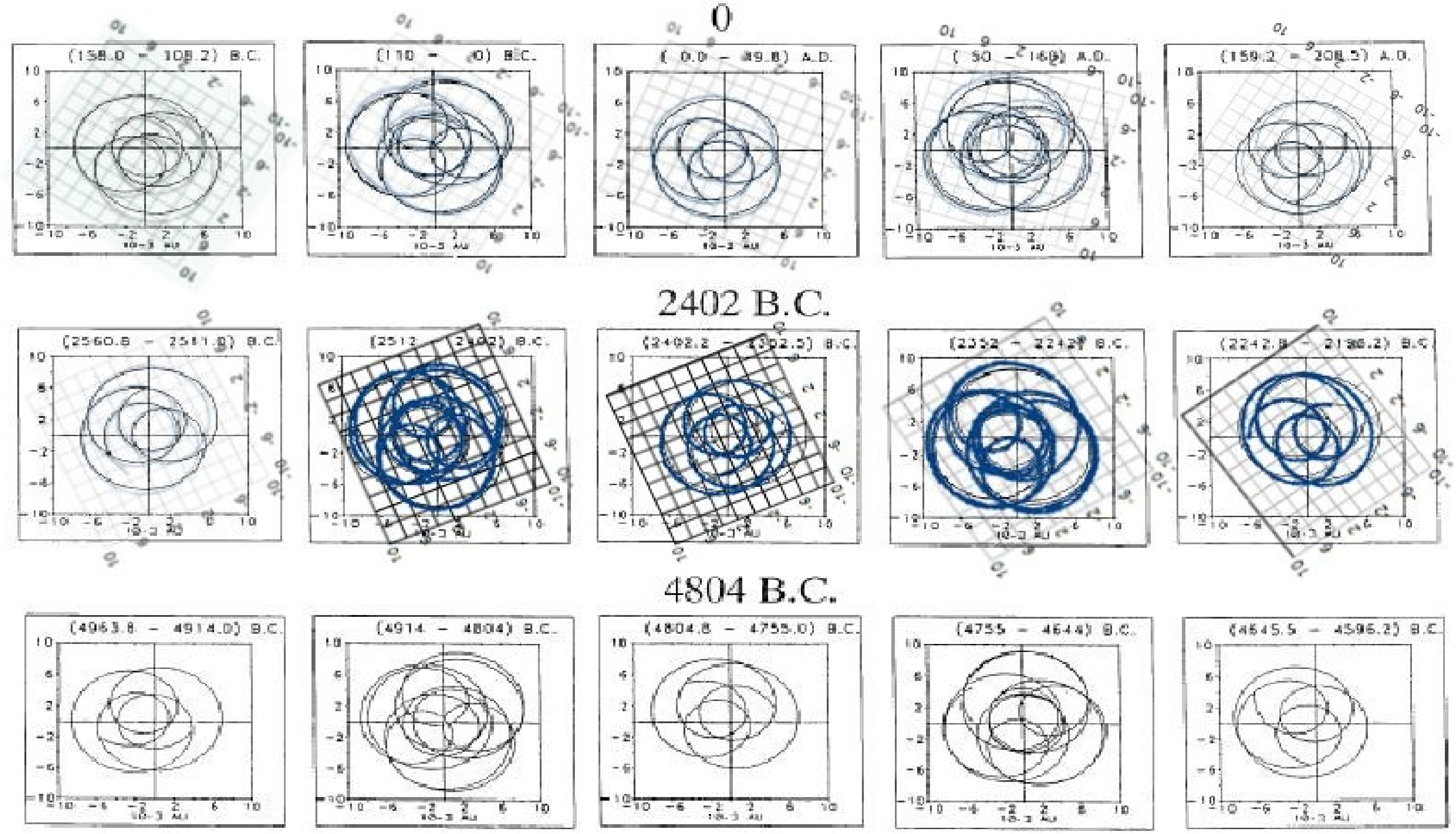


Fig. 4. The 370-year segments of the exceptional, stable pattern of solar motion recurring in steps of 2402 years: notice the twice shortened distance of 159 years between the three trefoils in each segment (from 158 BC to 208 AD, from 2561 BC to 2193 BC and from 4964 BC to 4596 BC). The next such segment will occur between 2240 and 2610 AD

Figure A.3 - Overlay of graphs for long warm periods

Note that some of the misalignment is due to the author's inexperience in using the Gimp image software, http://www.gimp.org/

Scaling is in mili-Astronomical Units (mAU)

Appendix B: Charvatova - recent millenium

I. Charvátová: Can origin of the 2400-year cycle of solar activity be caused by solar inertial motion? 401

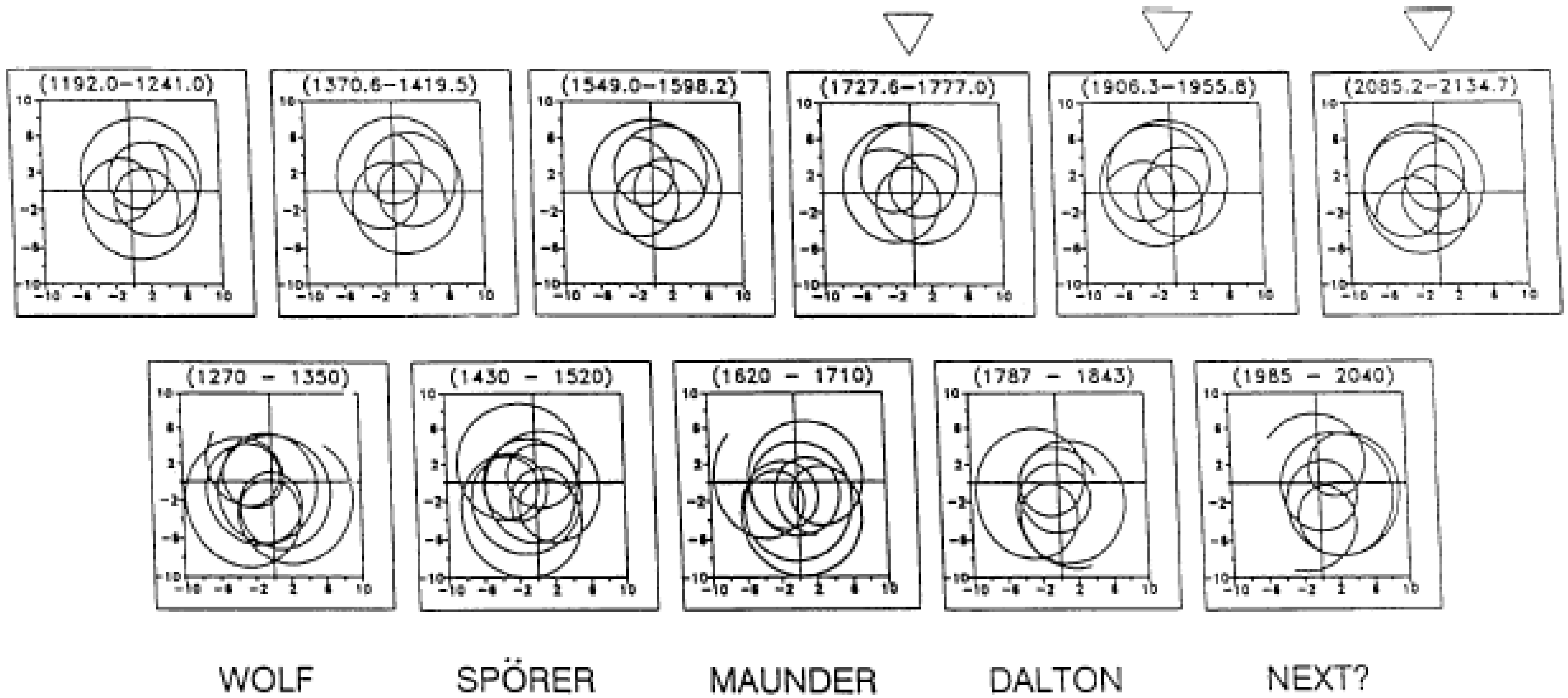


Fig. 2. The orbit of the centre of the Sun around the centre of mass of the solar system (in units of 10^{-3} AU) separated into two basic types, the ordered (in a JS-trefoil) (*top*) and the disordered (*bottom*). The area in which the Sun moves has a diameter of 0.02 AU or 4.4 r_s, this being the solar radius, or $3 \cdot 10^6$ km. The most disordered sections of the intervals lying between the trefoils are plotted. The Sun enters into the trefoils with a periodicity of 178.7 years, on the average (see the times, years at the *top* of the respective figures). The value represents the first basic cycle of solar motion. While the trefoils are nearly identical (after a rotation), the disordered orbits differ one from the other. The Wolf, Spörer, Maunder and Dalton prolonged minima of solar activity coincide with the intervals of disordered solar motion. The Sun moves along a trefoil (along one of the loops), over 50 (10) years, respectively. The two latest and the following trefoils are denoted by *triangles*

Figure B.1 - Charvatova's original graphs for the recent millenium

Scaling is in mili-Astronomical Units (mAU)

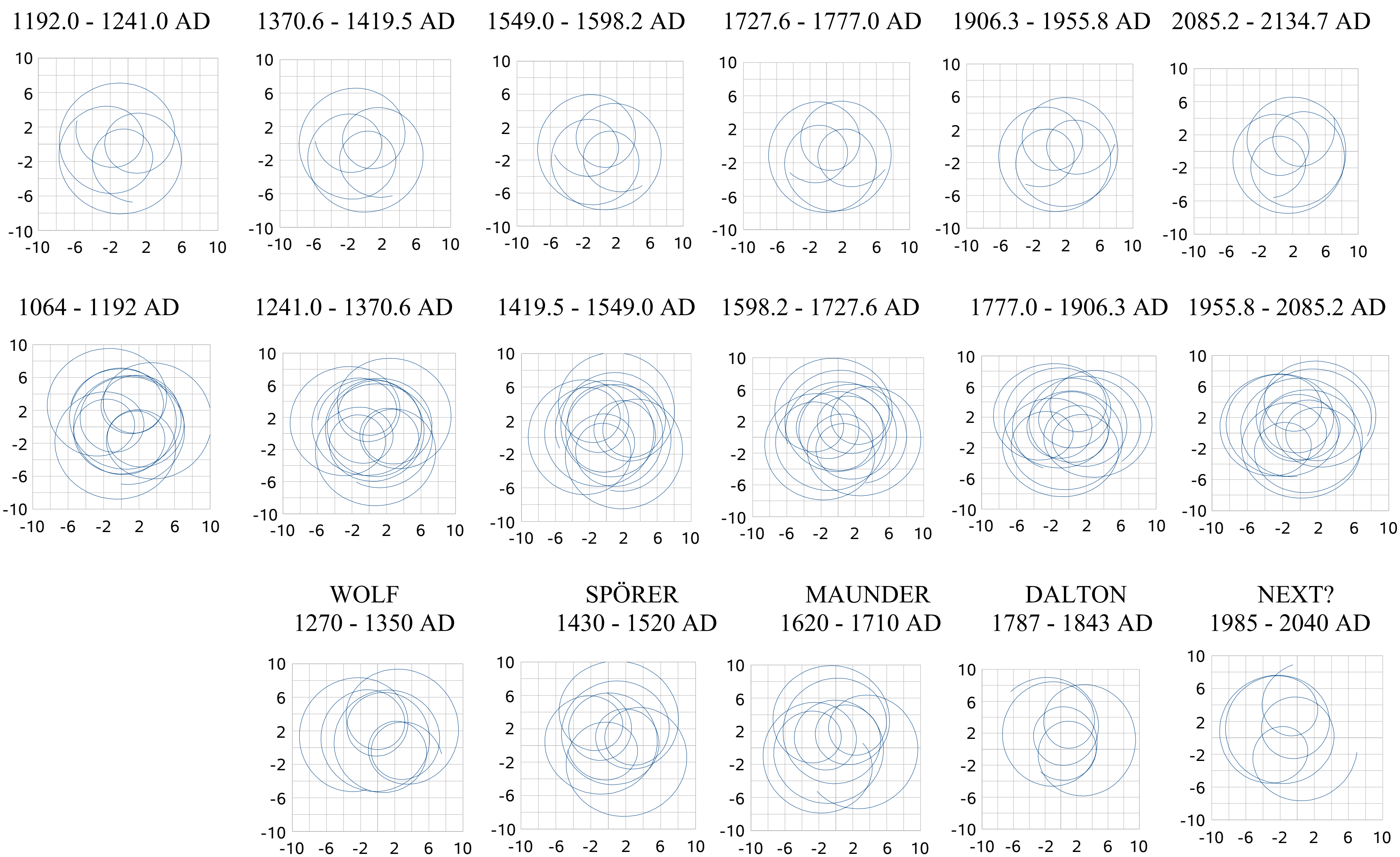


Figure B.2 - Howell's graphs for the recent millenium, based on NASA-JPL Horizon Software

NOTE: These graphs ?may not? correct for the Julian-to-Gregorian 10 day "calendar jump-the-gap" from 1582-Oct-04 to 1582-Oct-15

Delays from start of disordered period to hibernation: ~29, 10, 22, 10, ?was this 20 years - i.e 1976?

Scaling is in mili-Astronomical Units (mAU)

I. Charvátová: Can origin of the 2400-year cycle of solar activity be caused by solar inertial motion? 401

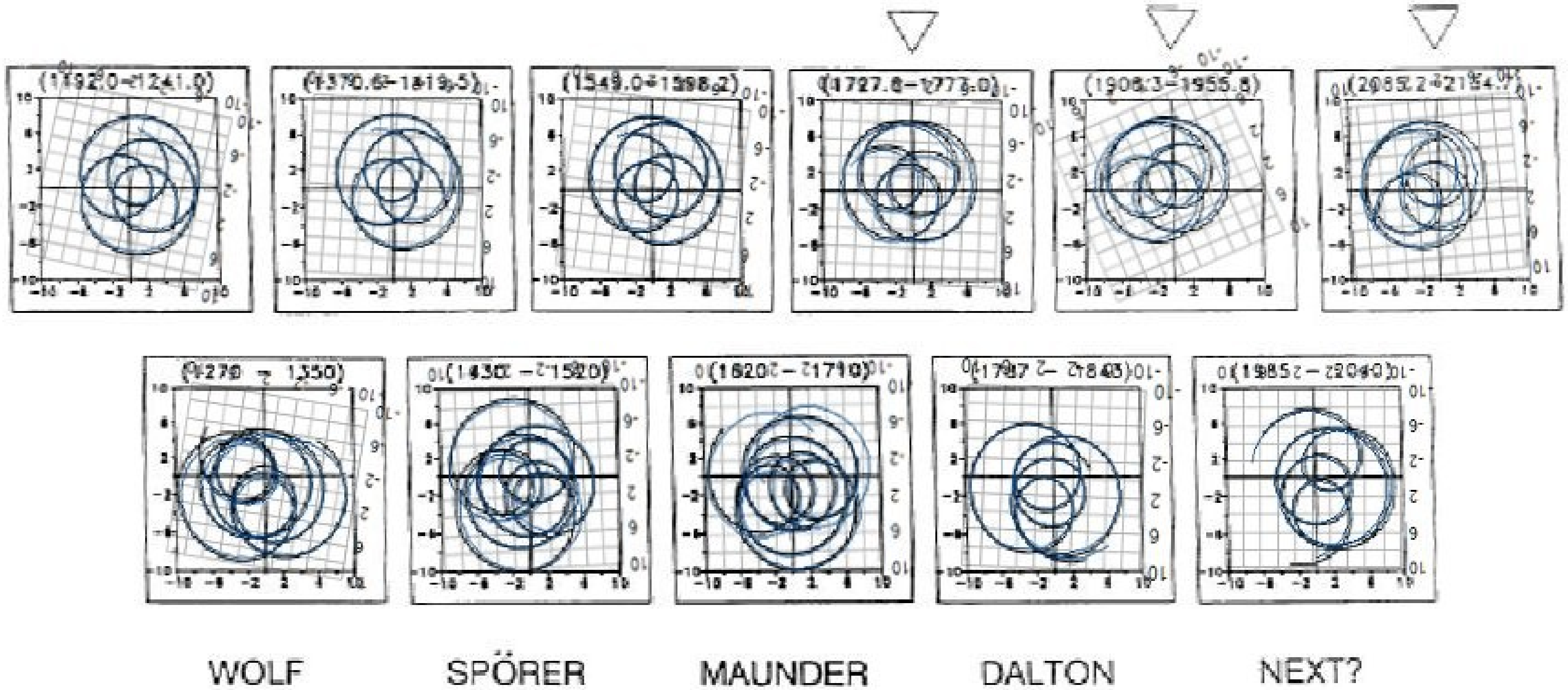


Fig. 2. The orbit of the centre of the Sun around the centre of mass of the solar system (in units of 10^{-3} AU) separated into two basic types, the ordered (in a JS-trefoil) (*top*) and the disordered (*bottom*). The area in which the Sun moves has a diameter of 0.02 AU or 4.4 r_s, this being the solar radius, or $3 \cdot 10^6$ km. The most disordered sections of the intervals lying between the trefoils are plotted. The Sun enters into the trefoils with a periodicity of 178.7 years, on the average (see the times, years at the *top* of the respective figures). The value represents the first basic cycle of solar motion. While the trefoils are nearly identical (after a rotation), the disordered orbits differ one from the other. The Wolf, Spörer, Maunder and Dalton prolonged minima of solar activity coincide with the intervals of disordered solar motion. The Sun moves along a trefoil (along one of the loops), over 50 (10) years, respectively. The two latest and the following trefoils are denoted by *triangles*

Figure B.3 - Overlay of graphs for the recent millenium

Note that most of the misalignment is due to the author's inexperience in using the Gimp image software, http://www.gimp.org/

Individually, the graphs fit very well, except as noted in the text (in particular, "extra" curve length for the Maunder).

Scaling is in mili-Astronomical Units (mAU)

Appendix C: Charvatova - 1990 and November 2008 papers

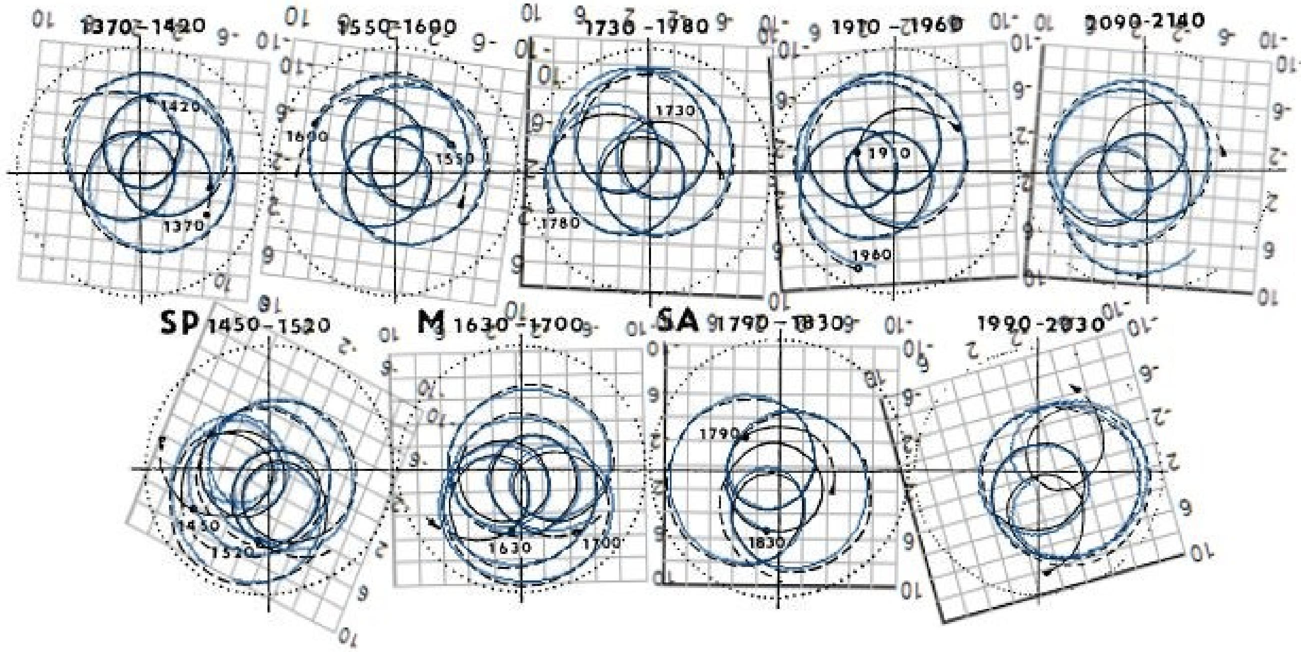


Fig. 1. The ordered and chaotic motion of the Sun alternately reoccurring every $\sim$180 yrs in the years 1730 to 2150 A. D. (SP — the Spörer, M — the Maunder, SA — the Sabine minima in solar activity). The dotted circle, radius $2{\cdot}2\, r_s$ (r_s is the solar radius) limits the area, in which the Sun moves.

Figure C.1- Overlay of graphs for Charvatova's 1990 paper

Scaling is in mili-Astronomical Units (mAU)

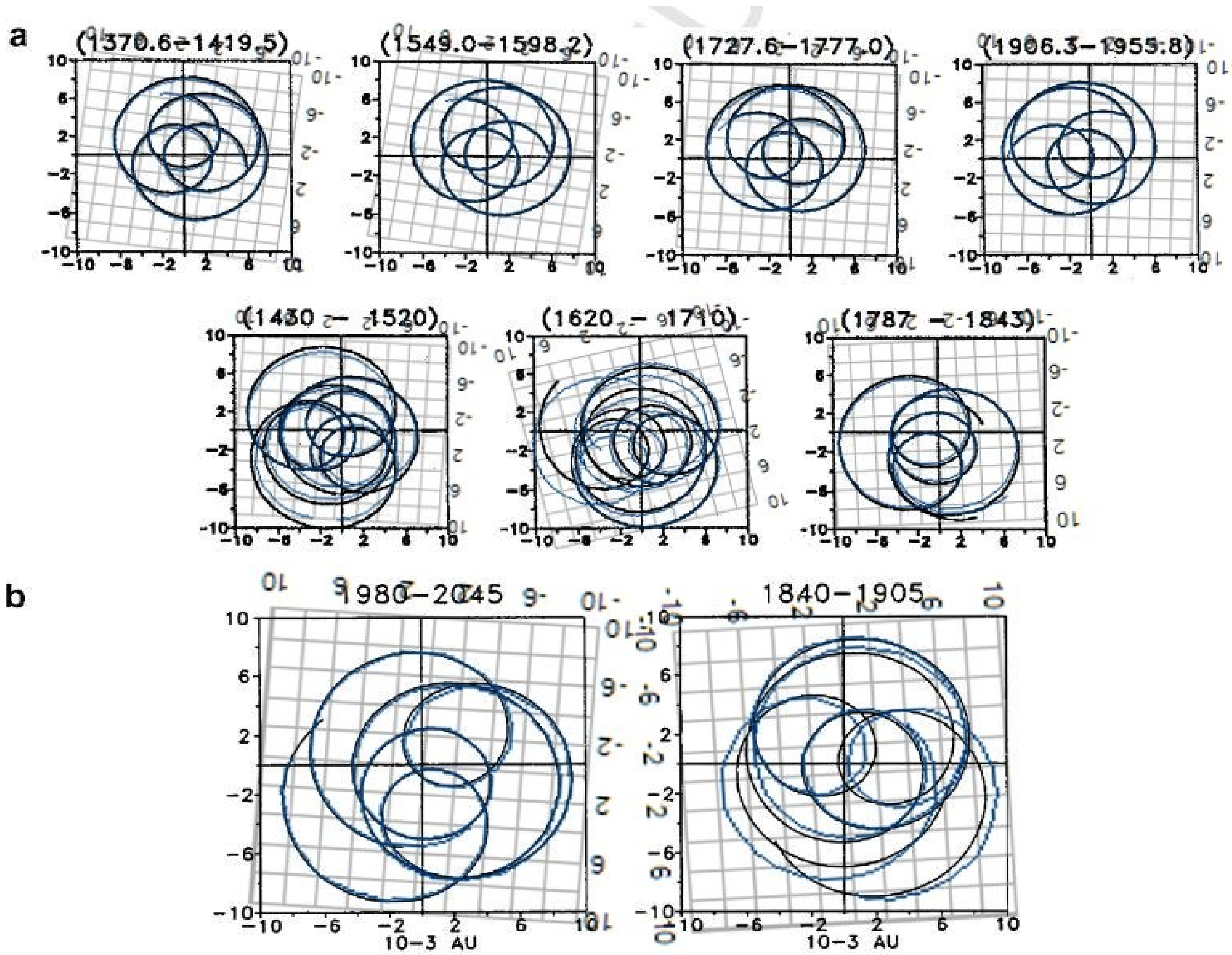
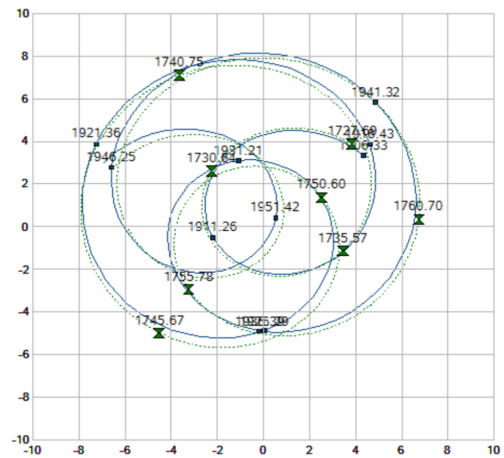


Fig. 1. (a) The solar orbit of the center of the Sun around the center of mass of the solar system (in units of 10^{-3} AU) separated into two basic types, the ordered (in a JS-trefoils) (top) and the disordered (bottom). The area in which the Sun moves has the diameter of 0.02 AU or $4.3r_s$, this being solar radius, or 3×10^6 km. The most disordered sections of the intervals lying between the trefoils are plotted. They coincide with the prolonged (Grand) minima of solar activity, such as, here, the Spörer, the Maunder and the Dalton minima. The Sun enters into the trefoils in steps of 178.7 years, on the average. The Sun moves along a trefoil (along one of the loops), over 50 (10) years, respectively. (b) The solar orbits in the intervals 1980–2045 and 1840–1905. Notice that they are, after a rotation of the whole orbit configurations (by about 90°), nearly identical.

Figure C.2 - Overlay of graphs for Charvatova's Nov08 paper

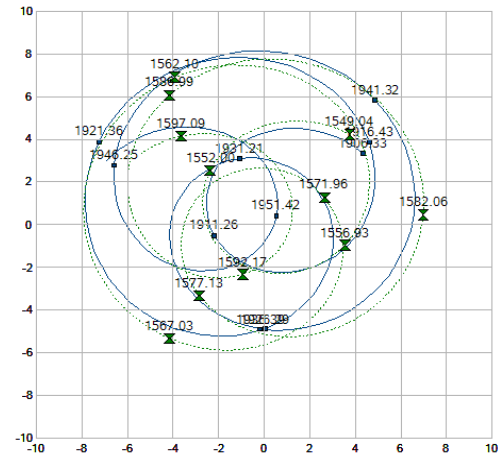
Scaling is in mili-Astronomical Units (mAU)

Appendix D: Comparisons of "ordered" SIM curves across time



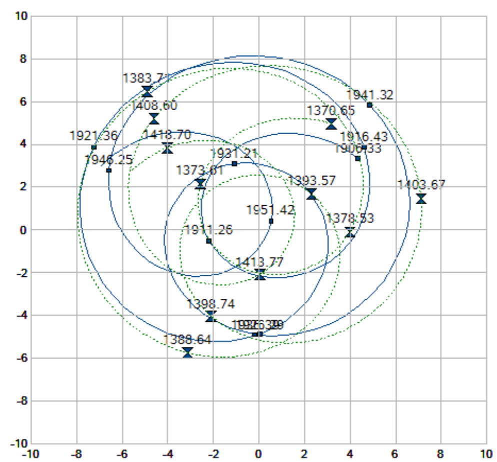
Rotation angles (° CCW): 1906.3 - 1955.8 AD 160 (solid line)
1727.7 select 190 (dotted)

1727.6 - 1777.0 AD



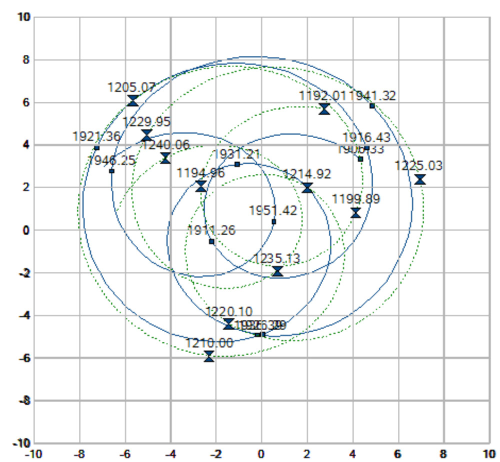
Rotation angles (° CCW) 1906.3-1955.8 base 160 ° (solid line)
1549.0 select 215.0 ° (dotted)

1549.0 - 1598.2 AD



Rotation angles (° CCW) 1906.3-1955.8 base 160 (solid line)
1370.6 select 240 (dotted)

1370.6 - 1419.5 AD



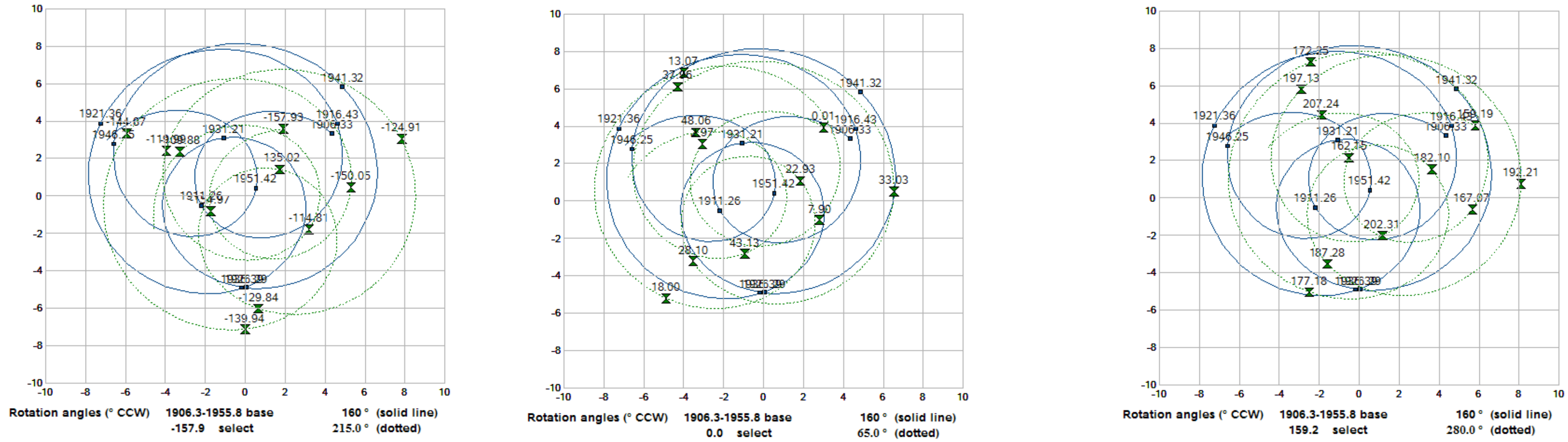
Rotation angles (° CCW) 1906.3-1955.8 base 160 (solid line)
1192.0 select 270 (dotted)

1192.0 - 1241.0 AD

Figure D.1- Comparison of recent millenia "ordered periods" to the 1906.3-1955.8 period

Uses Howell's results from NASA-JPL rather than Charvatova's results.

Scaling is in mili-Astronomical Units (mAU)

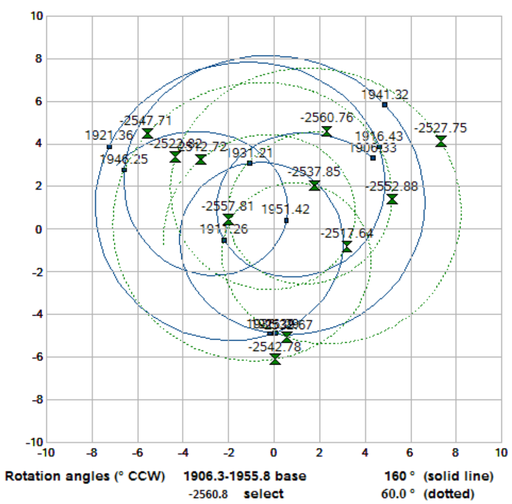


158.0 - 108.2 BC 0.0 - 49.8 AD 159.2 - 208.5 AD

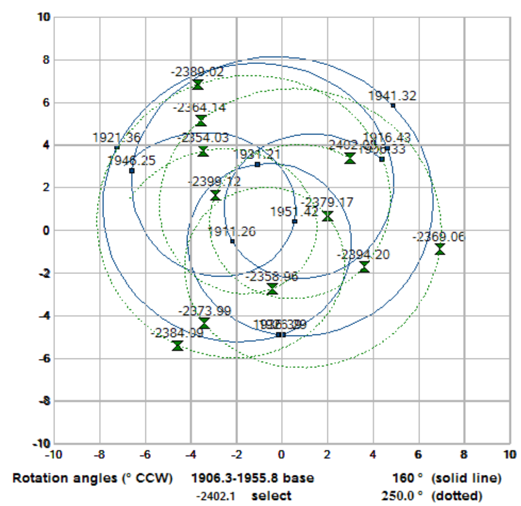
Figure D.2 - Roman warm period 2560 - 2193 BC: Comparison of "ordered periods" to the 1906.3-1955.8 period

Uses Howell's results from NASA-JPL rather than Charvatova's results.

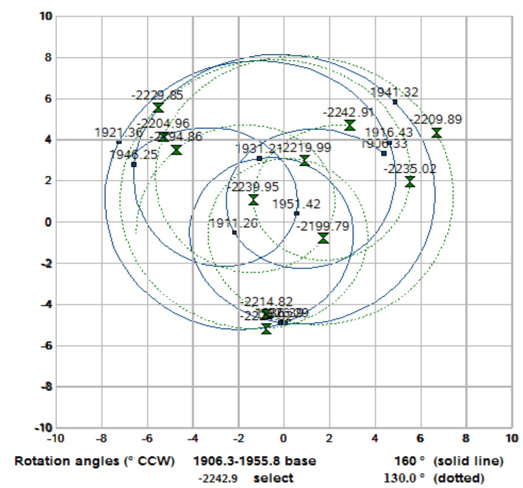
Scaling is in mili-Astronomical Units (mAU)



2560.8-2511.0 BC



2402.2 - 2352.5 BC



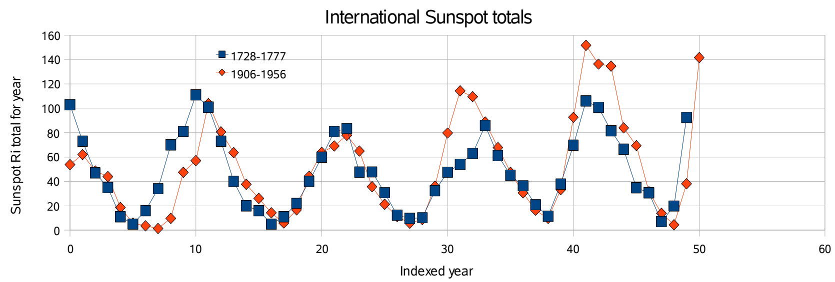
2242.9 - 2193.1 BC

Figure D.3 - Egyptian Old Kingdom, Mesopotamian, ?Harrupan? warm period 2560 - 2193 BC: Comparison of "ordered periods" to the 1906.3-1955.8 period

Uses Howell's results from NASA-JPL rather than Charvatova's results.

Scaling is in mili-Astronomical Units (mAU)

Appendix E - Timing of SIMs and solar activity (sunspots)



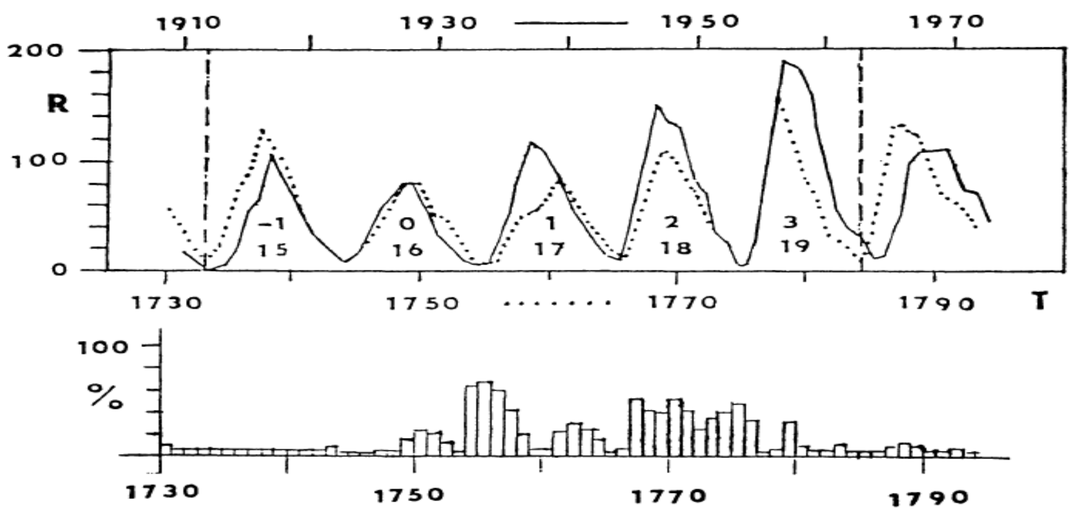


Fig. 3. The sunspot cycles in the years 1730-80 (i.e. cycles −1 to +3 — dotted line) and in the years 1910-60 (i.e. cycles 15 to 19 — solid line). The percentages of daily observations in the respective years of the 18th century are plotted at the bottom of the figure (after Mayaud 1977).

Figure E.1 - Sunspot activity for two "ordered" SIM periods: 1727.6 - 1777.0 AD and 1906.3 - 1955.8 AD

Scaling is in mili-Astronomical Units (mAU)

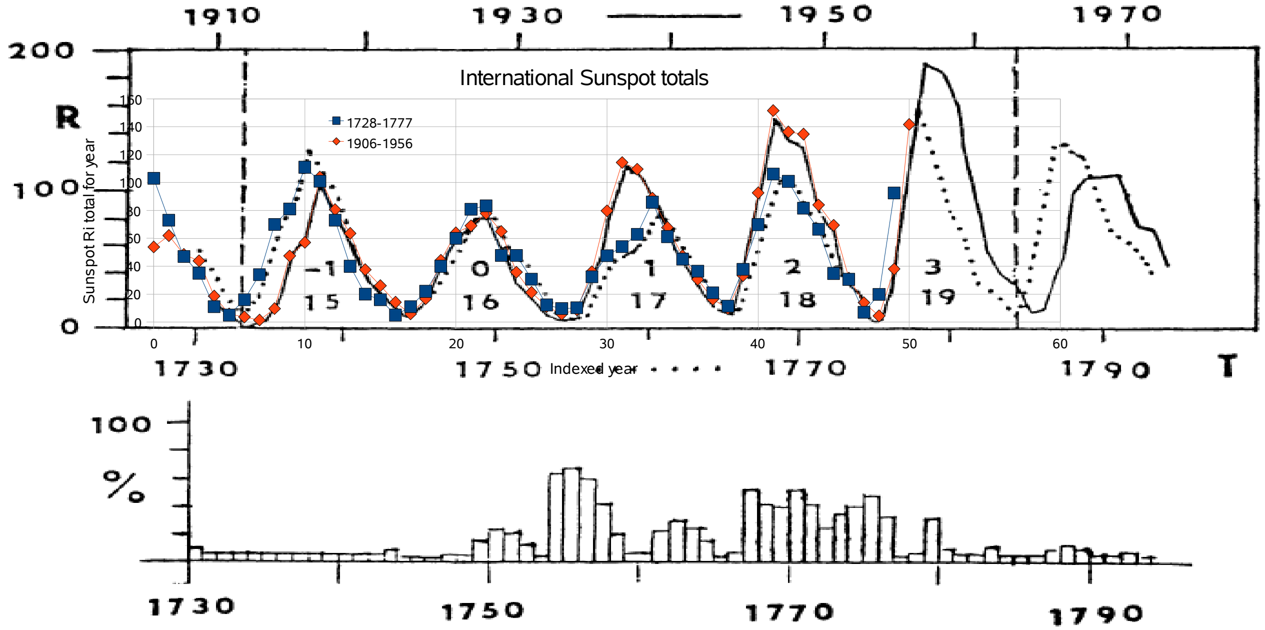


Fig. 3. The sunspot cycles in the years 1730-80 (i.e. cycles —1 to +3 — dotted line) and in the years 1910-60 (i.e. cycles 15 to 19 — solid line). The percentages of daily observations in the respective years of the 18th century are plotted at the bottom of the figure (after Mayaud 1977).

Figure E.2 - Overlay of Sunspot activity for two "ordered" SIM periods: 1727.6 - 1777.0 AD and 1906.3 - 1955.8 AD

Scaling is in mili-Astronomical Units (mAU)

The "ordered" Charvatovan periods which are being compared above run from 1727.6 - 1777.0 AD and 1906.3 - 1955.8 AD (see Appendix D figure D.1 1727.6 - 1777.0 AD for an overlay showing the excellent fit). That is why the comparisons should be ended in 1777 and 1956, beyond which the SIMs differ.

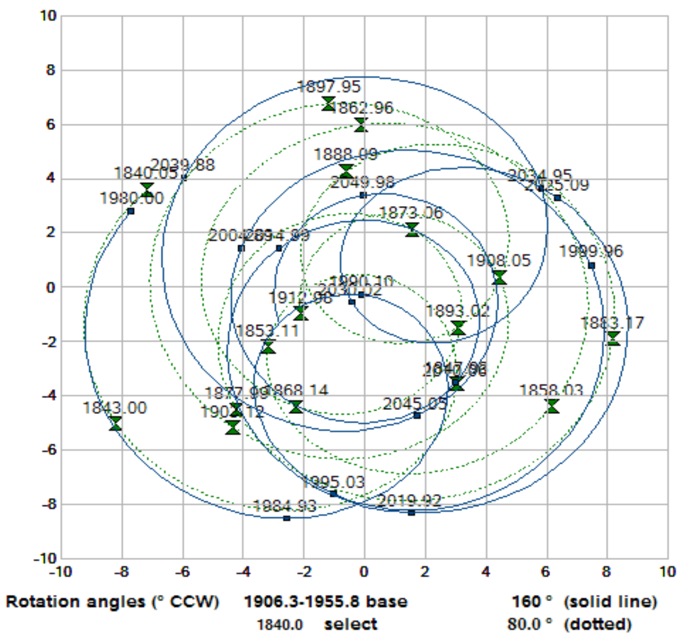


Figure e.1.a - Coincidence of 1840-1913 and 1980-2053 AD SIM curves

Scaling is in mili-Astronomical Units (mAU)

This figure shows the close "starting point" for both SIM curves, ensuring that the timing is comparable for sunspot data.

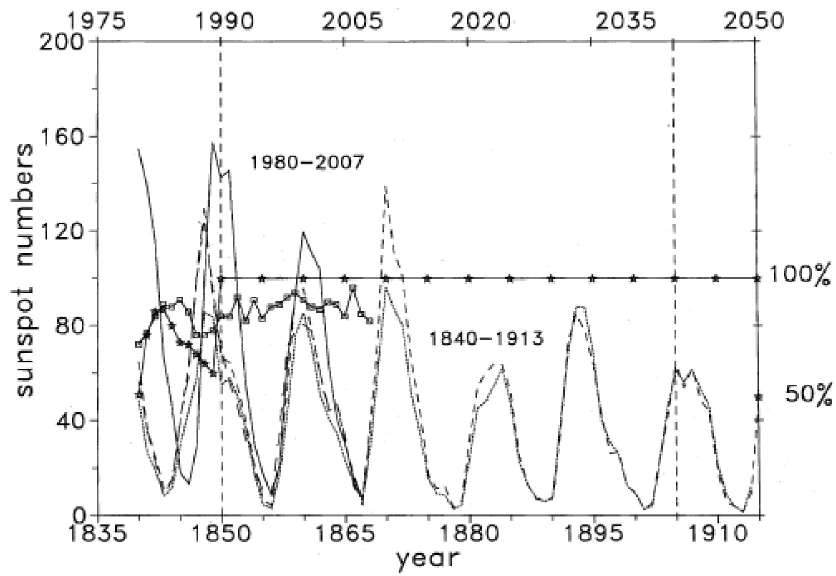


Fig. 2. The sunspot numbers in the years 1840–1905 (dashed line) and in the years 1980–2007 (solid line). The dotted line represents the Group sunspot numbers (Hoyt and Schatten, 1998). The data were taken from the database: http://ftp.ngdc.noaa.gov/stp/stp ... The numbers of daily observations (in percents) are plotted by solid line with asterisks. The long dashed line represents Schwabe's "Clusters of spots (Cs)" expressed as Wolf numbers W (Wilson, 1998). In this case, the numbers of daily observations (in percents) are plotted by solid line with squares. One can see lower coincidence before 1850 when the number of daily observations is low, incomplete, only between 53% and 85% and when sunspot numbers were not measured by any uniform method. Further, one can see that the numbers of daily observations of Cs in the interval 1840–1850 is higher (72–91%) than those of Wolf numbers. A better coincidence between cycles 9 and 22 occurrs between W and Cs. The yearly sunspot number for 2007 was taken from the database: http://sidc.oma.be. The sunspot cycles in the interval 1868–1905 (dashed line) represent a possible development of future cycles 24–26 (2008–2042).

Figure E.3 - Sunspot activity for two "un-ordered" SIM periods: 1840-1913 and 1980-2053 AD

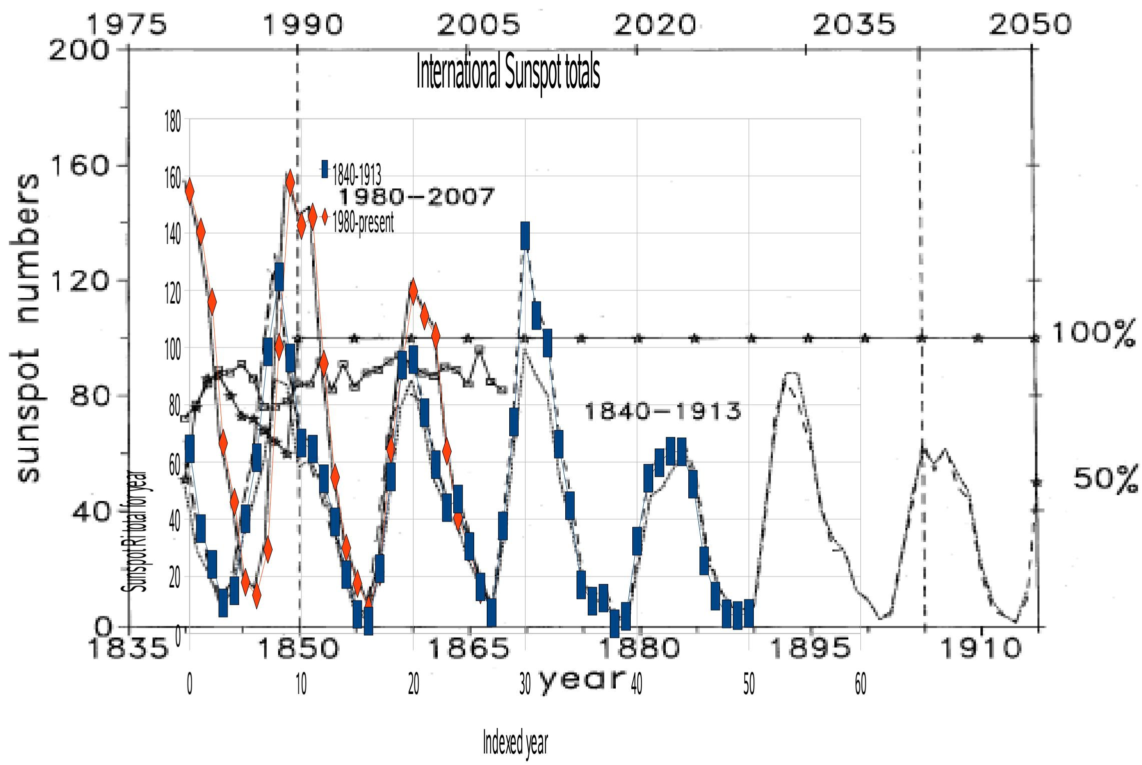


Figure E.4 - Overlay of sunspot activity for two "un-ordered" SIM periods: 1840-1913 and 1980-2053 AD

Appendix F: SIM periods and sunspot proxy data from Solanki etal (10Be & 14C)

Figure F.1 - [Usoskin etal 2003] reconstruction of decadal sunspot averages from 10Be data

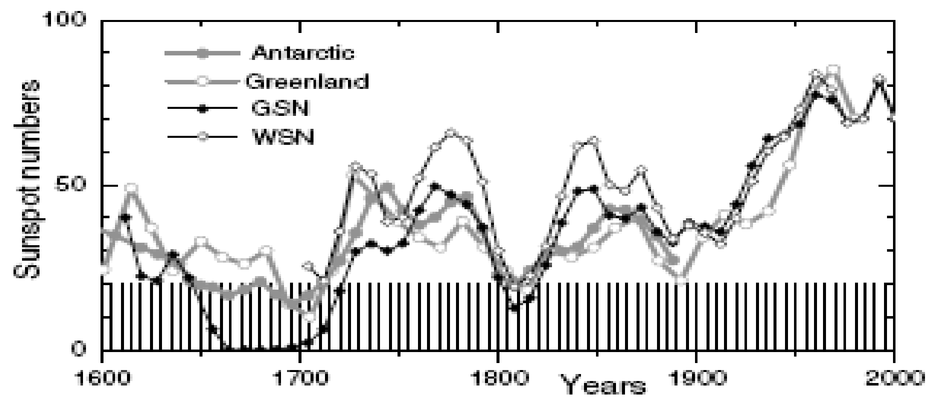
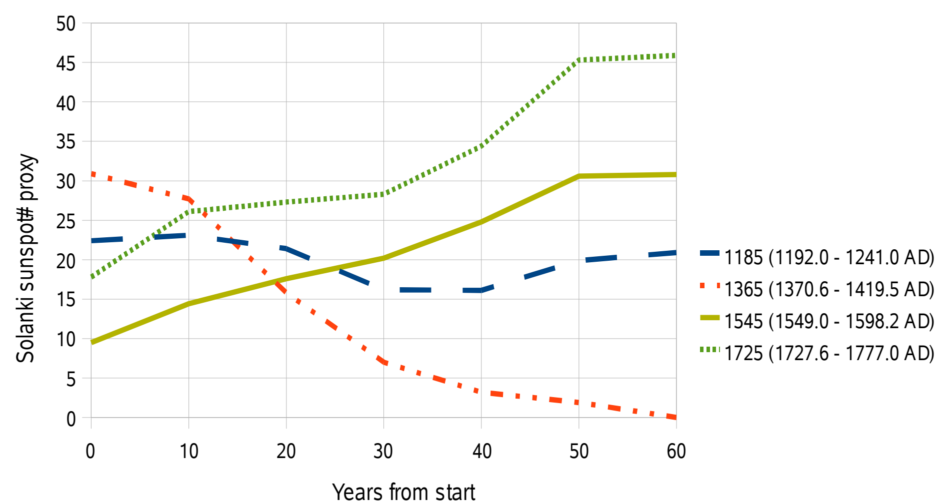
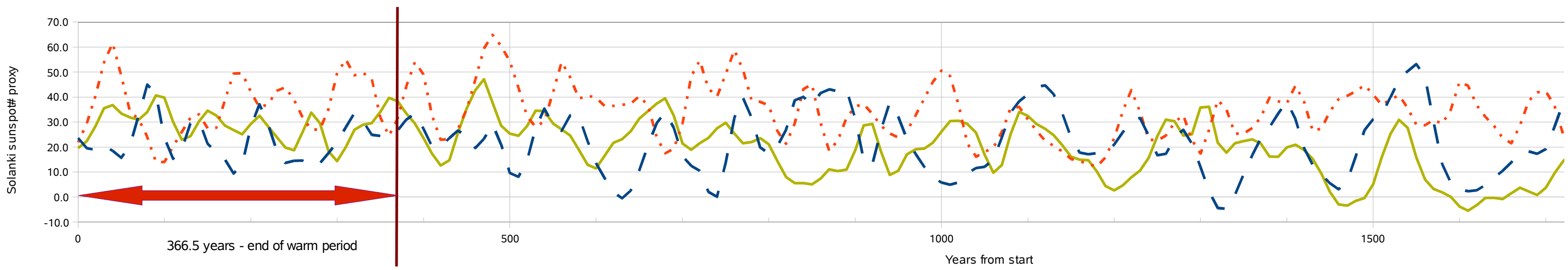


Fig. 5. 11-year averaged sunspot numbers for the last 400 years: group sunspot numbers (GSN), Wolf sunspot numbers (WSN), SN reconstructed from Greenland ^{10}Be and SN reconstructed from 1-2-1 filtered Antarctic ^{10}Be data. The shaded area roughly indicates the range of averaged SN for which the model is less reliable.

Figure F.2 - [Solanki etal] proxy sunspot# for "ordered" SIM periods in the recent millenium





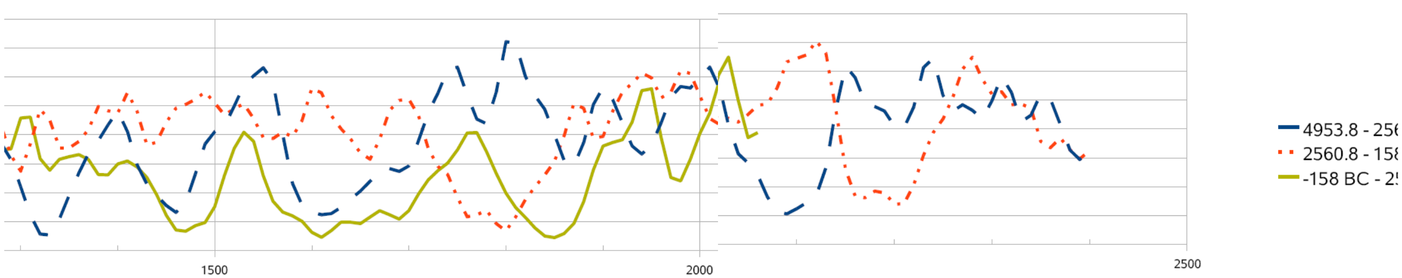


Figure F.3 - Solanki etal proxy sunspot# for "extended ordered" SIM warm periods in history

NOTE!!: Charvatova's theme relating SIM curves and solar activity applies to the 366 year "extended ordered" warm period, and and other extended (>> 250 year?) periods with the same SIM curves.

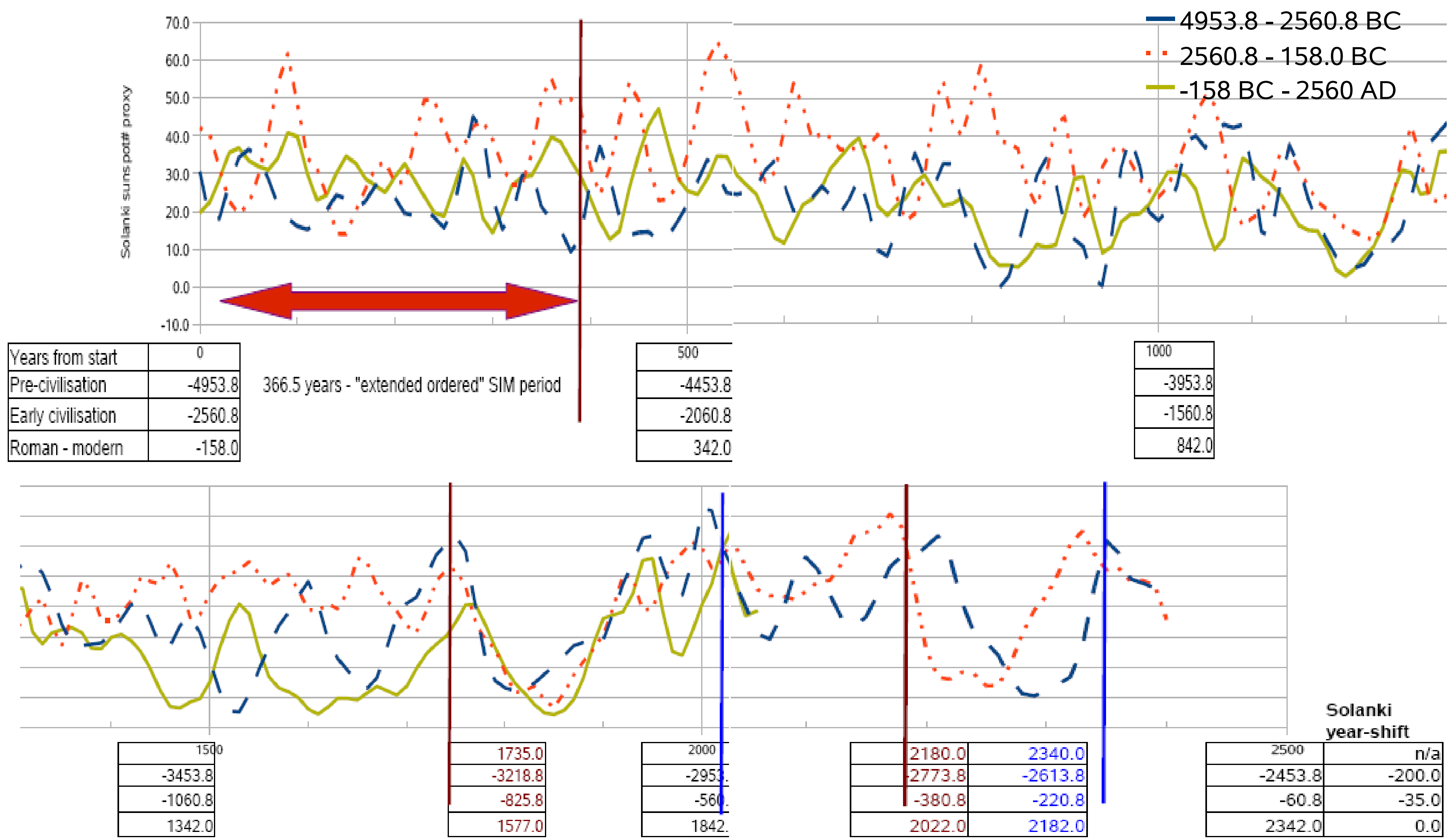
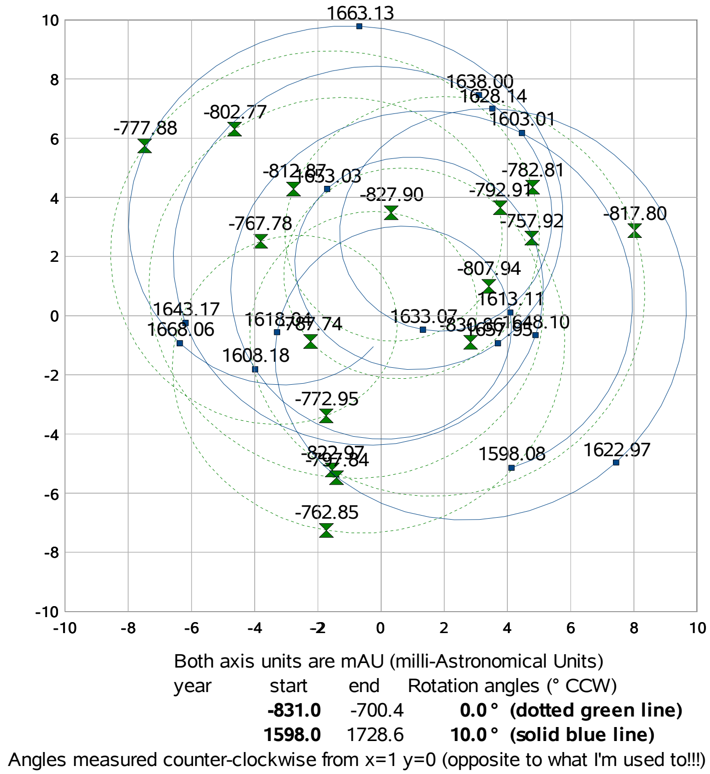


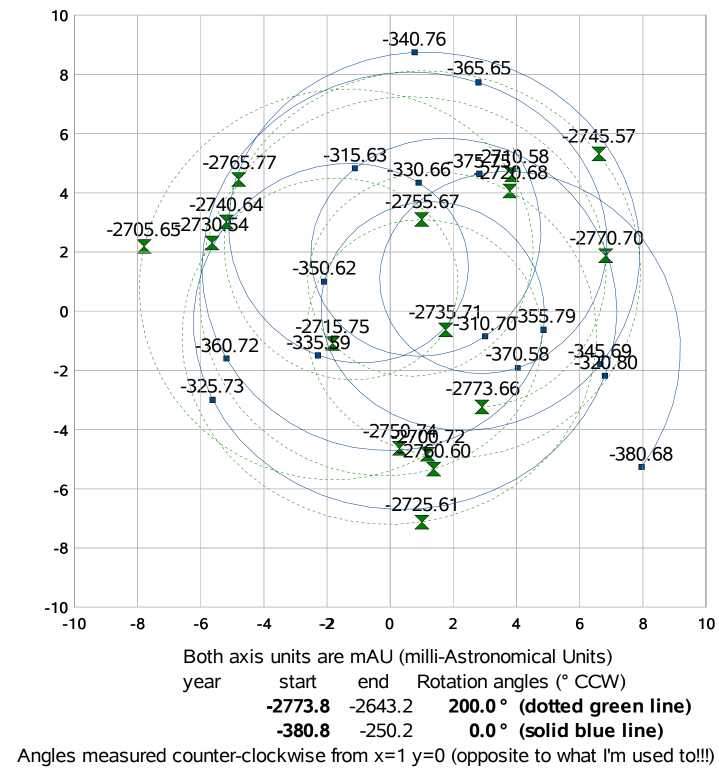
Figure F.4 - Solanki etal proxy sunspot# for "extended ordered & SHIFTED" SIM warm periods in history

NOTE!!: Charvatova's theme relating SIM curves and solar activity applies to the 366 year "extended ordered" warm period, and and other extended (>> 250 year?) periods with the same SIM curves. Note: dates are +- 200 years or so...

NOTE 2: In comparison with figure F.3, the 10Be dates of the earliest 2 periods have been advanced by 200 and 35 years respectively.



Homeric & Maunder solar hibernations?



?pre-Egyptian Old Kingdom? & pre-Roman hibernations (??)

Figure F.5 - Solanki etal proxy sunspot# for "extended ordered & SHIFTED" SIM warm periods in history

NOTE!!: See Figure F.4 for "10Be time-shifted" equivalent periods...

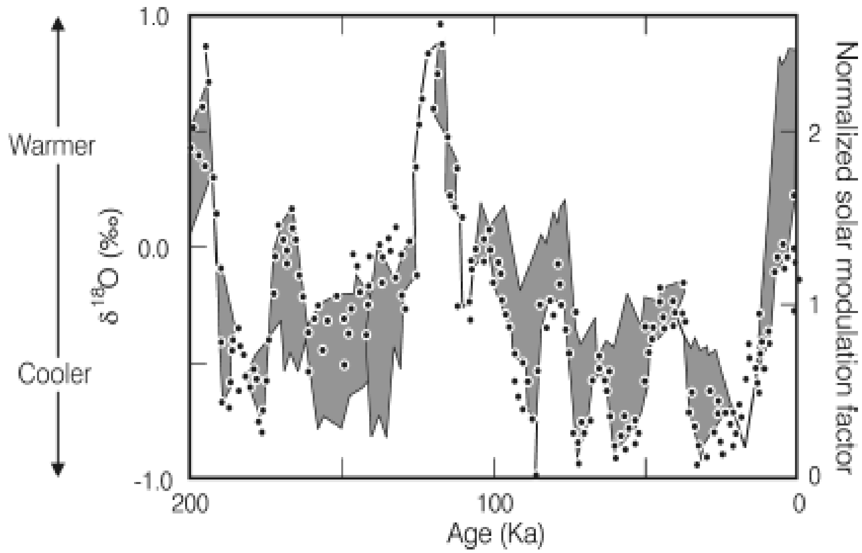


Figure 54. Calculated intensity of solar irradiance (dots) during the past 200 000 years juxtaposed with the normalized $\delta^{18}O$ record of the oceans (shading). Note that the magnitude of uncertainties in the derived curve are a matter of debate, but this would not necessarily impact the causation which could be only from Sun to Earth. Adapted from Sharma (2002).

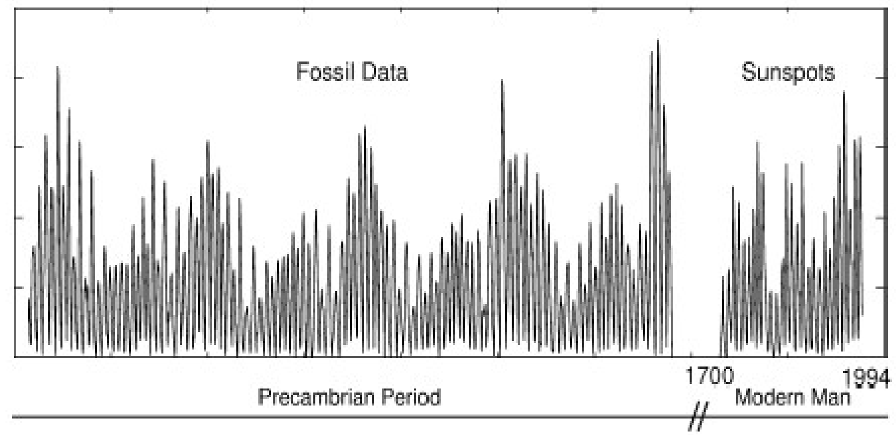


Figure 1. Fossil data and sunspot numbers.

Figure F.6 - Beryllium 10 based estimates of solar activity	**Figure F.7 - Ancient varve data as a basis of modelling modern solar activity**
This graph is a good illustration of the correspondance between 10Be and glaciations. But is this due to variations in galactics rays as well as the helio- and geo-magnetospheres, as questions by J. Veizer? [Scherer etal 2006]	Eric Wan "successfully" modelled modern solar activity on the basis of "priming" the model with ancient varve (mud layer) data from 680 million years ago! [Wan ?date?]

enddoc