This paper is a first attempt to undertake a political spectroscopy, that is, to identify political process timescales, in the long history of the Indic (i.e. South Asian) civilization or "world system." (In our view, these entities are the same, and the labels interchangeable: see Wilkinson, 1995a.) Our observation period is 550 BC-AD 1800. Our approach is quantitative and heuristic. Our assumptions are those of social-complexity studies, as extensively developed elsewhere (see Iberall and Wilkinson, 1987, 1991; Iberall, Hassler, Soodak and Wilkinson 2000; Wilkinson and Iberall, 1986; Wilkinson, 2002).

The behavior of complex, self-organizing systems may include "mechanical," determined processes. Science, based on data derived from observation and experiment, attempts to arrive at principles adequate to recognize, describe, and relate phenomena such as equilibria, with and without movement, and change in systems in general.

Many historical processes invite scientific inspection: regional and city populations grow and decline; so do state territories and empires; so do world religions. An ever-intriguing pattern of historical change is the oscillation of centralization and decentralization of political power, seemingly affecting all hierarchical macrosystems up to the world-system level: witness the recent arguments concerning "multipolarity," "unipolarity," "hegemony" and "empire" in the emergent 21st century system. Are such developments random, or free-willed? May not rather (or also) some sociopolitical mechanisms lie beneath? One should at least investigate.

One route to investigation is the use of statistical techniques (such as time-series analysis) for quantitative detection of patterns not self-evident from inspection of data alone. This general approach has proved to be extremely successful in natural sciences. Can it be instrumental in locating sociopolitical cycles? We propose to test such techniques upon one particular long series of sociopolitical observations: data on the ancient and modern Indic/South Asian world system.

Power configurations: data. In an earlier paper (Wilkinson, 1996), a time series of macropolitical data upon the political trajectory of the Indic world system, from 550 BC onward, was derived from the monumental Historical Atlas of South Asia, edited by Joseph E. Schwartzberg. This 376-page volume contains far more than its title alone indicates: with 149 pages of plates and 132 pages of intensely analytic text, the result of 15 years of work by a 28-person internal staff at the University of Minnesota, plus 8 external authors and co-authors, 13 cartographers, and numerous other named contributors, it embodies a new and concrete approach to pan-Indian history. The 44 page-bibliography of this powerful and magisterial work, which is part of the "reference Series" of the Association for Asian Studies, reflects a stunning assemblage of sources, which it subsumes and surpasses in comprehensiveness and detail: more than 5000 works have been consulted, including bibliographies, chronologies, dictionaries, digests, encyclopedias, gazetteers, glossaries, handbooks, lexical, news abstracts, statistical yearbooks and collections, who's whos, yearbooks, government documents, periodicals and other serials, atlases, unbound maps, epigraphic and numismatic primary sources, textual primary sources, dissertations, and miscellaneous unpublished works. This **Atlas** may accordingly be treated with confidence by many audiences as the work of a large community of dedicated scholars of a variety of Indological questions. Although we have concerned ourselves with its political aspects alone, it may be said that with this **Atlas**, the study of the history of the Indic world system, long a laggard as compared to studies of the Eurocentric and Sinocentric world systems, has attained a new level which sets an example for others in the provision of competent, expert, accessible, and painstakingly detailed data.

Schwartzberg's political terminology and a summary graph of his own data appear upon the "End-Cover Pocket-Insert Chronological chart" chart **"Major States and Rulers of South Asia by regions. 7th Century B.C. to 1975 A.D. with comparative world chronology."** However, the greatest and most quantifiable detail in the atlas appears in the series of **"Dynastic Chronology"** charts (1992:15, 20, 21, 25, 26, 30, 31, 32, 37, 38, 40, 46, 55). The time scales for these charts are graduated in two-year intervals (represented by minor tick marks), with emphases at intervals of ten years (major tick marks) and fifty years (horizontal grid lines).

All the above charts are bar graphs. While (for comparison purposes) bars for certain "Western or Middle Eastern powers" are also placed toward the left edge of these graphs, the main burden of the charts is to set bars for each state/ruler exercising "significant power" in one or more of "the broad regions of South Asia" (1992: xxxviii). The **"regions"** mentioned by Schwartzberg are **"analytic."** Schwartzberg's chart contains graphs of powers for **"South Asia in General," "Northwest and Far Northwest," "North-Center," "Northeast," "West,"** and **"South"** (as well as a comparative chart for **"Areas Beyond South Asia"**). There is a map of these regions with the **"Major States"** chart (and a discussion, 1992:254). For the purposes of this paper, it will suffice to say that for Schwartzberg, the **"Regions of South Asia"** comprise today's India, Sri Lanka, Bangladesh, Nepal, Pakistan and Afghanistan, the last being the **"Far Northwest."** While we do not break our data down by region, we have followed Schwartzberg's judgment concerning the location of system boundaries; the most noteworthy consequence is that, for us as for Schwartzberg, powers sited in present-day Afghanistan are treated as within the South Asian system.

In Schwartzberg's charts, wider or narrower graph bars represent each state exercising **(1) "significant power in at least four of the broad regions of South Asia"**; **(2) "significant power in at least two of the broad regions of South Asia, but not over most of the Indian subcontinent"**; **(3) "significant power in but one of the broad regions of South Asia."** (1992: xxxviii.) (The chart legend contains qualifications regarding overlaps across regional borders and into other subcontinental areas which we will not repeat here.) Solid bars reflect independent (vs. vassal) states at periods when their existence was clear (vs. the **"obscure"** beginnings of many states) and their power real (vs. **"ephemeral for the period depicted"**). Schwartzberg labels class 1 **"pan-Indian powers,"** class 2 **"super-regional powers,"** classes 1 and 2 combined **"major powers,"** and class 3 **"smaller political entities"** (1992:254, 257). Schwartzberg's nomenclature poses no substantive problems, but, for comparative purposes, we would elect a more abstract and traditional terminology: class 1, superpowers; class 2, great powers; class 3, local or regional powers. The concepts appear fully analogous.

Schwartzberg recognizes ten actual recurrent power configurations in the subcontinent, which, in his terminology as cited above, are listed at the left below. Our own data series however uses the briefer and more inclusive labels at the right below, which correspond to the more customary nomenclature of political science.

Power Configurations

One superpower plus three great powers	Unipolar
One superpower plus two great powers	"
One superpower plus one great power	"
One superpower only	"
Five great powers	Multipolar
Four great powers	"
Three great powers	Tripolar
Two great powers	Bipolar
One great power	Unipolar
No great powers	Nonpolar

Multipolarity, bipolarity and unipolarity are perhaps transparent concepts. In application, we also found moments where there coexisted six and even seven great powers; these are treated as multipolar. Tripolarity requires to be distinguished from multipolarity (into which analysts often merge it) because in the Indic states system it plays a more salient role. The concept of "nonpolarity" had to be created because there were moments in the Indic states system when there were no great powers then to be found.

Unipolarity is a power configuration that potentially contains, and in the Indic states system in fact contained, substantial diversity. It would seem proper to treat a unipolar configuration which offered little opportunity to resist willful domineering by the polar state differently from one where substantial local resistance could be mounted, and in turn to distinguish that configuration from one in which a significant countercoalition was feasible. In this paper, the third of these conditions is labeled "unipolarity" without qualification, the second is called "hegemonic" unipolarity, or simply “hegemony,” while the first is styled "(universal) empire." The criteria employed for subclassification were: "empire" = one superpower, no great powers, no more than two local powers; “hegemony” = either (a) one superpower, no great powers, three or more local powers, or (b) no superpowers, one great power, no more than one local power. All other subconfigurations were labeled "unipolar" without qualification. This terminology should be considered as approximate rather than precise; precision would require more information regarding the dominance relationships among powers than is currently available for most.

Using the terminology just provided, we undertook to assess Indic power configurations, listing major powers, at ten-year intervals starting 400 BC. Relying mainly upon the already-mentioned **"Dynastic Chronology"** charts plus the **"Major States and Rulers of South Asia"** and, we also used the **"Major Powers of South Asia"** charts (1992:145-149), the explanatory text (1992:161-205), and the chronological notes on the main maps. Where the graphs show a change in power configuration at the turn of a decade, the later configuration was used. This sequence stops with AD 1800, on the grounds that that is the latest plausible date for the engulfment of the Indic world system by the larger world system to its west which we have elsewhere (1987) styled "Central" but which is more widely labeled "Western."

Figure 1 uses the following code to summarize our own data (previously published in full, with historical narrative, but not extensively analyzed: Wilkinson, 1996). The data are ordered, on the assumption that the sequence Nonpolarity → Multipolarity → Tripolarity → Bipolarity → Unipolarity → Hegemony → Empire is ordinal and reflects increasing centralization:

0=Nonpolarity
1=Multipolarity
2=Tripolarity
3=Bipolarity
4=Unipolarity “Concentration”
5=Hegemony “Unity”
6=Empire “Domination”

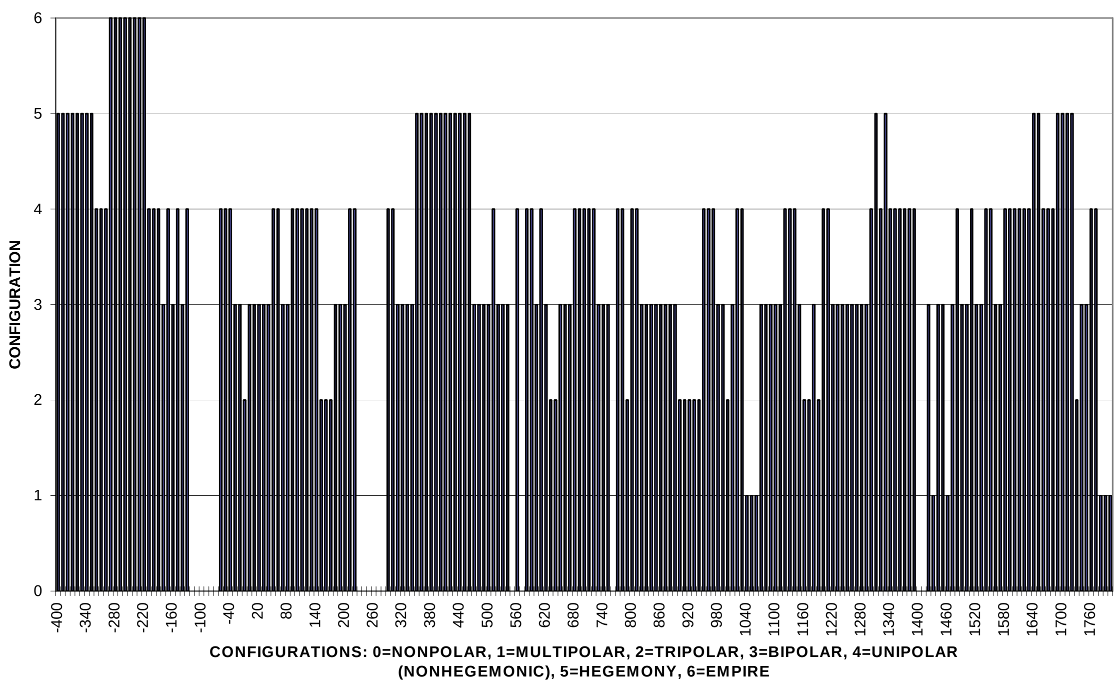

Figure 1. Configurations of the Power Structure of the Indic World System

Figure 2 contrasts our data (inverted in the lower half of the figure) with a direct coding of Schwartzberg’s data (upper half of figure), a count of the number of first, second, and third-class powers at each coding moment, first at fifty-year intervals, from 550 BC, then at ten-year intervals from 400 BC.

The upper half of Figure 2 well displays the fluctuating number and types of state actors in the Indic system. It will be noted that the number of actors generally increased over time, doubtless a function of the increasing population, population density, and city inventory of the civilization. The lower half displays the fluctuations in the power structure of the whole system. Some analytical points concerning the ordinal time series of power configuration codes graphed in Figure 1 and the lower half of Figure 2 are fairly straightforward, and require only inspection of the graph to sustain them. The hypothesis that civilizations tend over time to increase their centralization, ending in empire and collapse, common among civilizationists, is not supported for the Indic system. Nor does the theory of alternation between hegemony and multipolarity (dear to world-systems analysts) describe the Indic case.

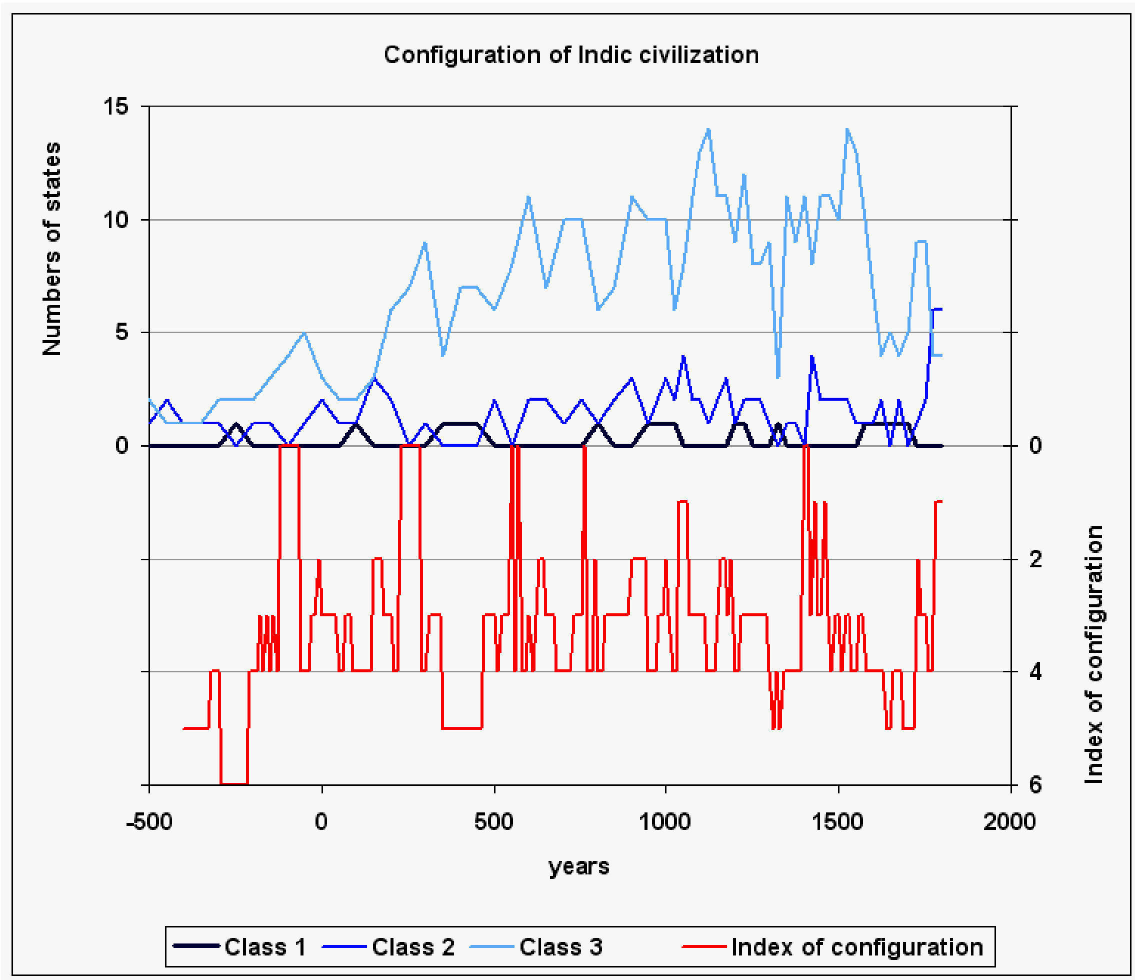

Figure 2. Indic World System: Number of States vs. Index of Configuration

Power configurations: preliminary analysis. Various analyses of the power configuration and polar state data suggest themselves: frequency counts, trends, cycles, specific transitions, durations, power turnovers. Schwartzberg himself undertakes analyses of recurrent vs. infrequent power loci (1992:255, 259-262), power configuration trends (1992:256-258), and trends in size, and duration of major powers (1992:254-255, 257-258). We shall begin with an examination of the distributions of configuration types and durations.

In the sequence of decades 400 BC-AD 1800, there are 221 data points. Configuration observations at these points are distributed as follows:

Table 1. Distribution of the index of configuration

Index of configuration	Characteristic of power configuration	Number of observations
0	Nonpolar	17
1	Multipolarity	8
2	Tripolarity	17
3	Bipolarity	72
4	Unipolarity	71
5	Hegemony	28
6	Empire	8
Total		221

The distribution is consistent with Schwartzberg's overall tally of the number of decades from c. 560 BC to AD 1976 which conform to each of his power configurations (1992:145-149, 255-256).

Durability of Indic power structures. How stable (durable) were Indic power configurations? From 400 BC, a given configuration persisted through one or more observations with the following frequencies:

Table 2. Durations of Indic power configurations

Duration (measured in the number of observations) – 10 year intervals	1	2	3	4	5	6	7	8	12	χ_7^2	ACF	
											Phase shift	
											1	2
Frequency	32	22	13	3	4	5	0	4	1	9.4	0.14	0.05

Note 1. Thus all 221 observations are accounted for in 84 sequences: 32*1 + 22*2 + 13*3 + 3*4 + 4*5 + 5*6 + 1*8 + 1*12 = 221.
Note 2. In the last columns of the table the values of the chi-square test and autocorrelation function (ACF) with phase shifts 1 and 2 changes of configuration are given (see discussion below).

A configuration that perdured through only one observation cannot have lasted more than 19 years (it might have lasted only a year). Two observations indicate a duration of 20-29 years; three, of 30-39 years; etc. The great majority (54 / 84 ≈ 65 %) of all sequences had lengths of one or two observations (i.e. were observed once or twice): the half-life of a configuration was therefore less than 30 years. This distribution, similar to that discovered long ago for war onsets and terminations (Richardson, 1960: 128-131), and for war durations (Weiss, 1963; Horvath, 1968; Wilkinson 1980) gives rise to the thought that there may have been a Poisson process at work, implying that there were in any decade a very large number of opportunities for structural political change to occur, and a very small probability of its actually occurring at any particular opportunity.

The most interesting property of a Poisson process is that the situation at one moment does not depend upon the situation at the preceding moment; e.g. the probability of a collapse of a given structure does not depend upon the duration of existence of the structure, but is the same at any given moment. If political change at the macrolevel in the Indic system is a Poisson process, political theories (such as those of the Chinese "dynastic cycle") that imply increasing fragility of power structures with increasing age also fail to describe the Indic case.

One way to check the affinity of actual processes to the theoretical Poisson process is to examine the closeness of the actual distribution of durations to the exponential distribution. To check the similarity of durations of political power configurations to the Poisson process two groups of criteria were used: 1. Criteria of similarity of interval between configuration changes of the Indic system (e.g. chi-square); 2. Criteria of the significance of autocorrelation between configurations at neighboring intervals (see below). Both checks demonstrated the similarity of the examined process to the Poisson process (see table 2).

But we can go farther. The time series of configuration codes graphed in Figure 1 lends itself to further examination by various more demanding quantitative techniques of time-series analysis. All of these techniques are designed to locate potentially significant relationships among earlier and later moments in the series, i.e., in this case, in the career of the Indic world system's power structures.

If the configuration changes of the Indic system indeed reflect a Poisson process, the system should be indifferent to its current state, in the sense that each configuration ought to show the same tendency to persist or change from one measurement to the next. However, as Table 3 shows, this is not the case.

Table 3. Persistence frequencies of the Indic configurations in two successive periods.

Nonpolarity:	64.7%
Multipolarity:	57.1%
Tripolarity:	47.1%
Bipolarity:	61.1%
Unipolarity:	57.7%
Hegemony:	78.6%
Empire:	87.5%

The configurations are unequally lasting. This suggests that the system "knows" which configuration it is in. Does it also "know" or "care" to which configuration it goes? Have its transitions, in other words, preferred destinations associated with their different origins? For instance, the seven-valued power configuration variable implies that each configuration is most like the ones defined as "adjacent" to it. It is proper to ask whether this "adjacency" also appears empirically: does the system "know" its neighborhood and prefer to remain there? i.e., does the system tend to "prefer" to transition shorter rather than longer distances on the configuration variable?

Empirical topology of the configuration variable. This question can be explored by constructing the table of transitions between configurations.

Table 4. Transitions between Indic power configurations*

Old state of system	New state of system						
	Nonpolarity	Multipolarity	Tripolarity	Bipolarity	Unipolarity	Hegemony	Empire
Nonpolarity	11			1	5		
Multipolarity		4		3			
Tripolarity			8	6	3		
Bipolarity	2	2	6	44	17	1	
Unipolarity	4	2	2	17	41	4	1
Hegemony			1	1	4	22	
Empire					1		7

* For percentages, see Table 7.

The 221 observations produce 220 transitions; the row and column totals for multipolarity and hegemony are unequal by one because the sequence begins with hegemony and ends with multipolarity.

The transitions are very unevenly distributed. As Table 3 would lead us to expect, there is a strong concentration (137 / 220 ≈ 62 %) on the main diagonal, which contains "transitions" which are in fact persistences of the old configuration. Many configuration-pairs have no direct transition linkage: there are no transitions between the most extreme forms, i.e. hegemony and empire do not collapse to nonpolarity or even multipolarity. The largest fraction (34 / 83 ≈ 41 %) of transitions between different configurations are between the two most prevalent configurations, Bipolarity ←→ Unipolarity, which are "adjacent." Transitions between other "adjacent" configurations (Bipolarity ←→ Tripolarity; Unipolarity ←→ Hegemony) are also noticeable (20 / 83 ≈ 24 %). However, the transitions to and from the nonpolar, multipolar and imperial configurations do not show any adjacency effects; rather they are apparently "captured" by the attraction of Bipolarity/Unipolarity, which is indeed so strong that only one transition (Tripolarity to Hegemony) does not involve either Bipolarity or Unipolarity as either the old or the new configuration. Four cases of transition from unipolarity to nonpolarity may be seen to satisfy the classic transition pattern of "overexpansion and disintegration" (e.g. Collins, 1978: 23-26); however, these constitute a minor part of the total transition set.

Another interesting feature is apparent: the table of transitions is almost completely symmetric, i.e. transitions are reversible: there is no evident progression of forms, e.g. from less to more centralized. Is this a persistent characteristic of the Indic system? Let us divide the examined period in two (400 BC - AD 700 and AD 700 - AD 1800) and make two analogous tables of transitions between Indic power configurations (Table 5 and 6).

Table 5. Transitions between Indic power configurations
400 BC - AD 700

Old state of system	New state of system						
	Nonpolarity	Multipolarity	Tripolarity	Bipolarity	Unipolarity	Hegemony	Empire
Nonpolarity				1	4		
Multipolarity							
Tripolarity				3			
Bipolarity	1		2		9	1	
Unipolarity	3		1	9			1
Hegemony				1	1		
Empire					1		

Table 6. Transitions between Indic power configurations
AD 700 - AD 1800

Old state of system	New state of system						
	Nonpolarity	Multipolarity	Tripolarity	Bipolarity	Unipolarity	Hegemony	Empire
Nonpolarity					1		
Multipolarity				3			
Tripolarity				3	3		
Bipolarity	1	2	4		8		
Unipolarity	1	2	1	8		4	
Hegemony			1		3		
Empire							

There are some differences between these tables. There are more transitions in the latter half of the examined period (perhaps because of the greater number of states in the system: cf. Figure 2). The second half-period demonstrates more cases of unipolarity and bipolarity; nonpolarity appears in fewer instances, while multipolarity, previously absent, emerges in a few cases; and no united all-Indian empire appears between Magadha (5th – 2nd centuries BC) and the British conquest. Nevertheless, symmetry, preference for bipolarity and unipolarity, and limited adjacency effects are apparent in both halves of the examined period.

Markov process analysis. The power configuration is an "ordinal categorical variable" composed of a ranked set of categories reflecting different degrees of system power centralization. Markov analysis is a widely employed method for inspecting the evolution of categorical systems over time.

The basic question in Markovian analysis may be phrased as: given a system which is in state S_i at time t, what is the probability that it will be in state S_j at time t+1? This "transition probability" is labeled p_{ij}, and the whole set of transition probabilities for all $_{ij}$ is a transition probability matrix P.

One possibility for a "chain" or sequence of states of a stochastic system over time is that it reflects an "independent process" in which the present does not depend upon the past, nor the future upon the present. Another possibility is that it reflects a "first-order" "stationary" Markov process, in which the present state depends upon the immediately previous state, and the transition probabilities are invariant with respect to t, i.e. do not change over time. The strong patterning of the transition picture seen in Table 4, and its consistency during the whole period as shown in Tables 5 and 6, lead us to inquire whether the career of the Indic world system can be described as a first-order Markov chain homogeneous over its entire length.

A first-order Markov chain is a sequence of values of a variable governed by a first-order Markov process, such that the next value of the variable depends only upon the current value and a transition probability matrix that associates a different set of probabilities for the next value with each current value. In a real-world first-order Markov process, whenever a system enters a certain state, the prospects for its next change of state depend on that current state, but not on the system's previous states. A system governed by a first-order Markov process has a short-term memory (it "knows" the state it is in), but it has no medium-length memory (it does not "remember" its recent history). For whatever period a Markov chain is homogeneous, it does possess a very long-term memory, defined by its transition probability matrix: it "remembers" its rules as to what is be done in the given situation irrespective of how long it has not been in that situation.

Once we have found that there is a first-order Markov effect, such that the past state influences the present state, it becomes of interest to ask both how great this influence is, and whether more lags than one should be examined in search of the influence of more than one past state, i.e. higher-order Markov effects. Higher-order Markov processes remember the recent past step by step. A second-order Markov process has a slightly longer short-term memory: it "knows" its current state and "remembers" the state before the current state; a third-order process also remembers the last state but one; etc. The first-order Markov process is not the diametrical opposite of "path dependency"; rather it is the shortest possible form of path dependency.

The durability of the Indic system in what we shall call its "old" state (Table 2) is consistent with a Markov process as well as a Poisson process. The different persistences of the different configurations (Table 3) suggested a Markov process. We looked for both first-order and second-order Markov effects in the career of the Indic world system. The different distributions of exit transition frequencies for the different "old" states (Table 4) is strong evidence for the presence of a first-order Markov process. The similarity of early and late exit transition frequencies (Tables 5 and 6) is strong evidence for the homogeneity of the process over the entire chain of values from 400 BC to AD 1800. The pattern of first-order effects become more obvious if we use not the actual transition frequency, but the row percentages, i.e. the percentage distribution among all new states of all the transitions from a given old state (see Table 7).

Table 7. Markov process transition frequency matrix (row percentages)

Old state of system	New state of system						
	Nonpolarity	Multipolarity	Tripolarity	Bipolarity	Unipolarity	Hegemony	Empire
Nonpolarity	64.7%			5.9%	29.4%		
Multipolarity		57.1%		42.9%			
Tripolarity			47.1%	35.3%	17.6%		
Bipolarity	2.8%	2.8%	8.3%	61.1%	23.6%	1.4%	
Unipolarity	5.6%	2.8%	2.8%	23.9%	57.7%	5.6%	1.4%
Hegemony			3.6%	3.6%	14.3%	78.6%	
Empire					12.5%		87.5%

Note: rows may not add to 100%, as percentages are rounded.

To establish the presence and the order of any Markov chain, we used a standard method with the χ^2–criterion (Billingsley, 1961). Calculations show that the investigated process considerably differs from randomness ($\chi^2_{36} \approx 507$) and scarcely differs from a first-order Markov chain ($\chi^2_{79} \approx 76$). Therefore we may reject with a high degree of confidence (**p**< 0.0001) the hypothesis of a clearly random process. Some features of a second-order process appear; however, we do not have a basis ($p \approx 0.4$) for rejecting the hypothesis that the Markov chain is first-order in favor of a hypothesis that it is of the second order. And because of the small number of observations (N=221 for 7 possible states of the system), the given conclusion needs to be checked by other methods.

Information theory. Some other approaches to discovering the presence and length of the "shadow of the past" involve the measures of information theory, Shannon's derivation of Boltzmann's entropy concept (Lemay 1999). Per Boltzmann, the information value of the empirical observation that a given system has entered a particular state is zero when the observer already knows with certainty what that state will be: the observer is accordingly completely unsurprised by its occurrence. The information value of the same observation is maximum when all available states are equally likely and all actual outcomes equally surprising. This information value can be measured. The normal measure of information value is Shannon entropy, which may also be described as a measure of our ignorance of the state of a system: given that a system has some probability of being in any one of several states, how much information would we gain, and thus how much ignorance (or entropy) would we lose, if we knew the actual state of the system?

The Shannon entropy is commonly used as the measure of the dispersion or concentration of the actual values of a categorical variable. Shannon entropy is usually stated in "bits," to reflect the number of yes-no questions we would have to have answered before we could determine what state the system was in. The total entropy for a system described by a discrete variable x which may take any of m values is

$$H(x) = -\sum_{x=i}^{m} p_i(x) \log_2 p_i(x)$$

I.e. the actual entropy of the political configuration of the Indic system is computed by multiplying the probability of each category by its logarithm (to the base 2), summing the results, and taking the negative of the sum.

The minimum Shannon entropy (achieved when all actual values are concentrated in one category) is zero. The maximum entropy for a system described by a discrete variable x which may take any of m values is

$$H(x) = -\log_2 p(m)$$

That is: the maximum Shannon entropy, achieved when the actual values are evenly distributed among all possible categories, is the logarithm to the base 2 of the available categories, i.e. the available number of states of the system. In the case of the Indic political configurations, their available number is 7, so that the maximum Shannon entropy of the system ≈ 2.81 bits.

As we already know the frequency with which each possible configuration appears, we may compute what we may term the zero-order Shannon entropy. As Table 8 shows, there is a Shannon entropy of ≈2.35 bits associated with the distribution of the occurrences of the various states of the Indic system: it is a rather high-entropy system, at ≈83.6% (2.35/2.81) of its maximum uncertainty.

Table 8. Zero-order Shannon entropy of the Indic system

Configuration	Frequency	Prob	$\log_2(Prob)$	$-Prob^* \log_2(Prob)$
0	17	0.0769	-3.70044	0.28465
1	8	0.0362	-4.7879	0.17332
2	17	0.0769	-3.70044	0.28465
3	72	0.3258	-1.61798	0.52712
4	71	0.3213	-1.63816	0.52629
5	28	0.1267	-2.98055	0.37763
6	8	0.0362	-4.78790	0.17332
Sum	221	1.0000	-23.2134	2.34697

Several sorts of information measures may also be computed as between two or more variables; "mutual information" is one of them. "Mutual information" measures the amount of information shared by two variables. If two variables are independent, neither contains any information about the other, and their mutual information is zero; if they are identical, knowledge of either provides full knowledge of the other, and their mutual information equals the information conveyed by either alone. We have calculated the lagged mutual information in the Indic configuration data series (Figure 3). The maximum mutual information value, not represented in the figure, is the zero-order Shannon entropy of ≈2.35, reached only at a time-lag of zero: since the set of 221 observations is identical to itself at zero time-lag, the mutual information of the "two" variables must be identical to the zero-order Shannon entropy of the system.

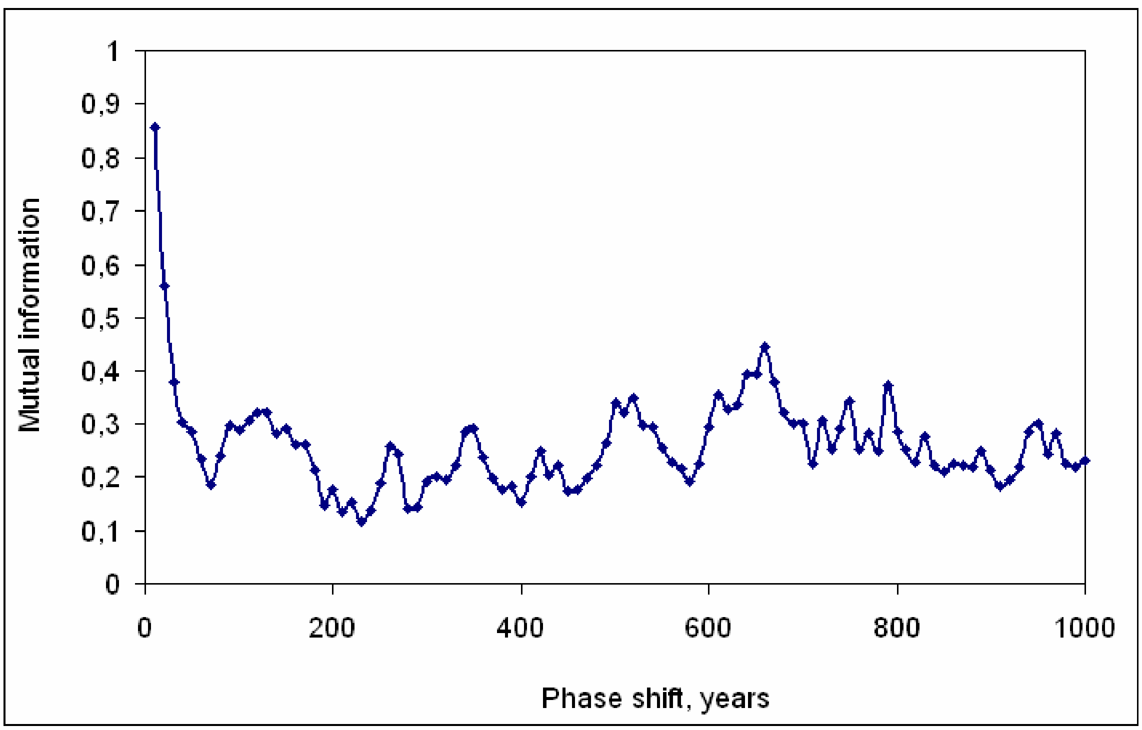

Figure 3. Mutual information of Indic configuration data as a function of time-lag.

Still, the figure is not uninformative. The "shadow of the past" is high for short lags, but drops rapidly, never reaching zero, and then fluctuates. With respect specifically to the order of the Markov chain, the mutual information values of the ten-year lag (≈0.856) and the twenty-year lag (≈0.380) are noticeably higher than those of the remaining lags. It is interesting that a low peak appears at 660 years, a period which is impractical to include in Markov process analysis. Other features are practically imperceptible; but here it should however be noted that this information-theory approach, best suited to nominal data, takes no account of the orderliness of ordinal data such as ours. (Other approaches which do so will be employed later.)

Van der Heyden et al. (1998) have developed an information-theory method using constrained symbolic surrogate data for testing the null hypothesis that a symbolic sequence has *m*th order Markov structure. Numerical modeling of the Indic system in accordance with this procedure did not show significant deviation from a first-order Markov chain. The model with a second-order Markov chain did deviate ($p \approx 0.5$); unfortunately, in accordance with Bavaud's (1998) formula (per Lemay, 1999) for estimating the minimal length of a sequence which information-theory techniques can be applied, for our sequence of 221 values of an index with 7 possible values (0, 1, 2,.. 6), no information-theory methods can reliably reveal the absence or presence of attributes of a second-order Markov process. However, a sequence of 221 values of an index with 2 possible values (0,1) could be so evaluated. This suggests the desirability of constructing an index which reduces the 7 values of the power-structure variable to 2.

Data quality control. There are additional reasons for developing reduced indices. It is possible that our insights are limited by the fact that we are using only one set of indexes of centralization, i.e. the seven-valued power configuration variable. To depend upon a single index to some degree invites both positive errors (perceiving a pattern where none exists) and negative errors (overlooking an actual pattern). There are several roads open to alternative datamaking in this case. We have chosen to create and examine three "reduced" indexes, each combining several adjacent codings so as to create coarser, dichotomous variables, which by reason of their very "coarseness" should be less vulnerable to subtle mistakes of classification.

The three reduced indexes are:

(1) an index of "Domination," which groups Empire and Hegemony vs. all others;
(2) an index of "Unity," which groups Empire, Hegemony and Unipolarity vs. all others;
(3) an index of "Concentration," which groups Empire, Hegemony, Unipolarity, Bipolarity and Tripolarity vs. multipolarity and nonpolarity.

There is some conceptual warrant for each of these reductions: (1) empire and hegemony are both relations of dominance, and the borderline between them is often fuzzy — e.g. more distant provinces of an "empire" may have greater autonomy than ones nearer the metropole, and look more as if they were under "hegemony"; (2) unipolarity, hegemony and empire are all likely to have their politics revolve around one single chief actor and focus upon that superpower's relations with the rest of the system; and (3) a system with many great powers, and a system with none, may be alike in that both allow local and regional politics to prevail everywhere, while systemwide political issues are neglected to the point that both systems seem "anarchic." Table 13 will give the durations of the periods defined by these indices. A straightforward interpretation of Figures 4-6 would suggest that the Indic system had only a few bursts of domination (which tended to persist for a while once established); that it was highly concentrated, but with lapses into relative anarchy which might have some periodic character; and that there was a rather complex, perhaps multicyclic, alternation between episodes of unity and of plurality.

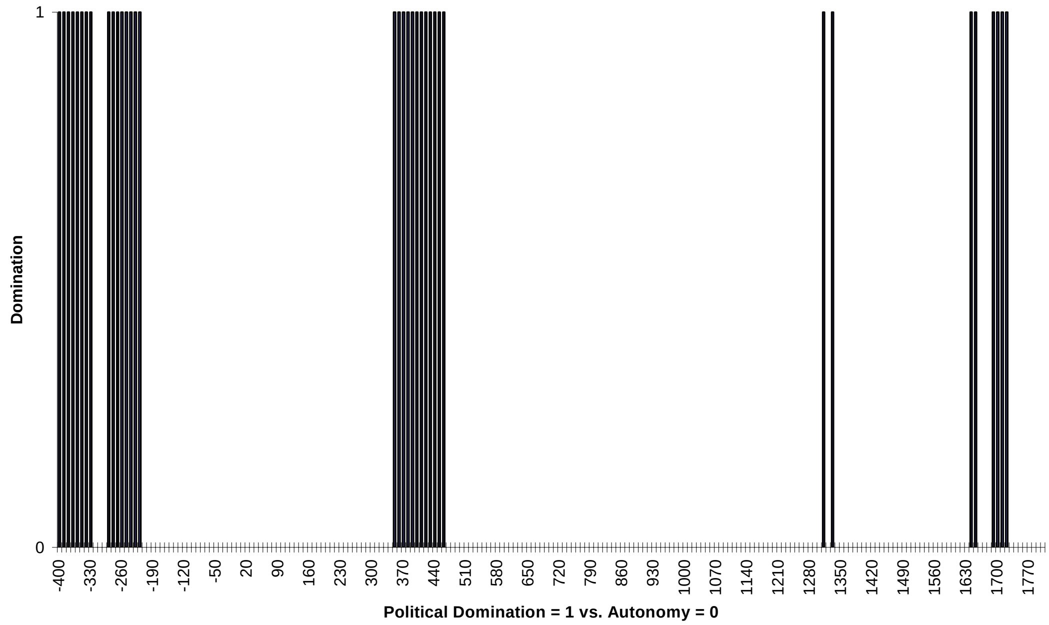

Figure 4. Indic World System: Political Domination vs. Autonomy

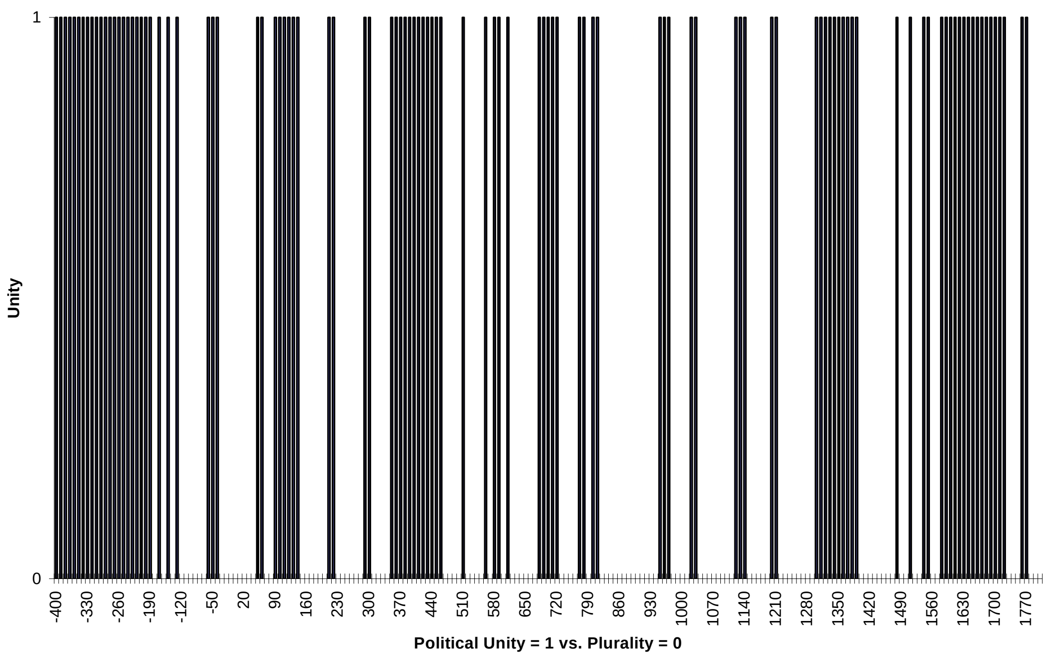

Figure 5. Indic World System: Political Unity vs. Plurality

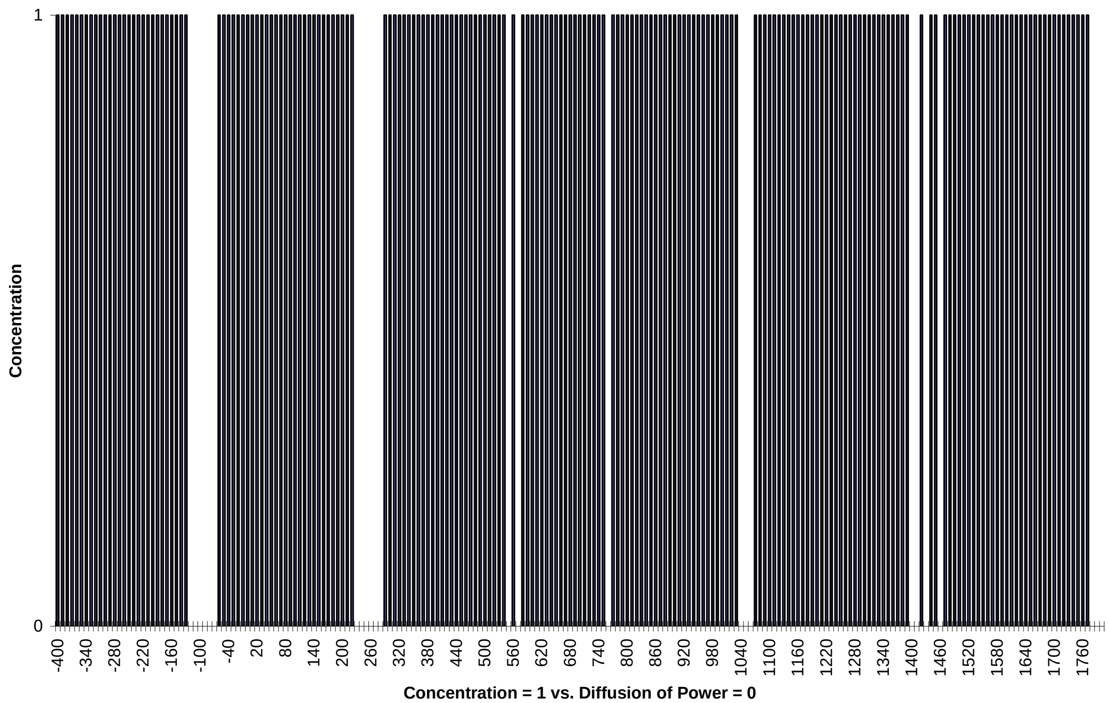

Figure 6. Indic World System: Concentration vs. Diffusion of Power

Order of the Markov process reconsidered. The three reduced indexes invite another attempt to determine the order of the Markov structure in the Indic sequence, since sequences of 221 binary values fall within Bavaud's limits (as previously noted). The basic idea (Van der Heyden et al., 1998) that for $\boldsymbol{n} > \boldsymbol{m}$ (when $\boldsymbol{m}$ is the true order of a Markov process)

$$\mathbf{h_m = h_n}, \text{ i.e.}$$
$$\mathbf{h_m = h_{m+1} = h_{m+2} = h_{m+3} = \ldots}$$

Or in other words that, once the entropy at the actual order of a Markov process has been determined, adding further orders will not diminish that entropy.

In Lemay (1999), Bavaud's idea is expressed more particularly as

$$\mathbf{h_m - h_{m+1} > h_{m+1} - h_{m+2}}$$

i.e. the speed of reduction of $\boldsymbol{h}$ decreases with growth of $\boldsymbol{m}$.

Our main interest is to determine the status of $\boldsymbol{m} = 2$, i.e., we wish to know, whether there are any properties of a second-order Markov process in the Indic system data. Here we must introduce the information-theory concept of "conditional entropy." As between two variables ***X*** and **Y**, the entropy of **Y** conditional on ***X*** is the entropy/uncertainty remaining to ***Y***, given full knowledge of the value of ***X***. It is computed by using the conditional probability of ***Y*** given the probability of ***X***:

$$H(y|x) = \sum_{x=i}^{m_1} p_i(x) \sum_{y=j}^{m_2} p_{ij}(y|x) \log_2 p_{ij}(y|x)$$

where $\boldsymbol{p_{ij}}$ represents the probability of the system being in both category $\boldsymbol{i}$ of variable ***X*** and category $\boldsymbol{j}$ of variable ***Y***. The conditional entropy of ***Y*** given ***X***, ***H(Y|X),*** is zero when knowledge of the value of ***X*** provides full knowledge of the value of ***Y***, and is maximal (and equal to the entropy of ***Y***) when the two variables are independent, so that knowledge of the value of ***X*** provides no information concerning the value of ***Y***.

One form of conditional entropy which can be computed is the conditioning of a system at time ***t*** upon the state of the same system at time ***t*-1**. The transition probability matrix provides us with the conditional probability of each state ***j*** of the Indic configuration at time ***t***, given that at time ***t*-1** it was in state ***i***. Conditional entropy may be further used to investigate the order of a Markov chain, searching for the presence of influences at multiple lags. In order to accomplish this for the Indic case, since its 221-number 7-state configuration time series is too short to allow a significance estimate, we instead examine the reduced 2-state indices.

We use the ***n***-gram method (Lemay 1999). ***N***-grams are formed by concatenating the last ***n*** states of a system into a single symbol. For the reduced indexes, the 1-gram's (or unigram's) 2 possible symbols are 0 and 1. The 2-gram or digram may be 00, 01, 10, or 11; the 3-gram or trigram ranges from 000 to 111, with 2x2x2=8 possible trigrams; there would be 16 4-gram symbols, 32 5-gram symbols….

We have computed the Indic system's ***n***-gram reduced-index empirical frequencies for digrams, trigrams, 4-grams and 5-grams. Table 9 gives these ***n***-gram frequencies for the most complex reduced index, the index of Unity. The table is read from right to left. Taking the highest-frequency lines: for ***n***=1, the unigram **0** (Plurality) is found 114 times in the observation sequence 221 unigrams; for ***n***=2, the digram **00** (Plurality followed by the same) is found 87 times in the sequence of 220 digrams (one ***n***-gram drops out for each higher order); for ***n***=3, the trigram **000** (three successive observations of plurality) occurs 66 times; and so on.

With the ***n***-grams, we can now ask whether taking a longer series of observations into account reduces our uncertainty about the final state, and if so, how much. The digrams reflect the first-order Markov chain we have already examined. The trigrams add the possibility of a second-order dependence. 4-grams and 5-grams allow us to examine third and fourth-order dependences.

A preliminary inquiry into the value of previous-states data uses frequencies. If we lacked all the ***n***-grams, and tried to guess the value of the Unity index for some random moment, we would have no reason to prefer 0 or 1, and would expect a 50% probability of guessing correctly. Knowing the unigram distribution (the distribution of the variable), we would always guess 0, with an expectation of being correct 114/221 ≈ 51.6% of the time, a very slight improvement. Knowing the digram distribution and the prior state, we would however always guess that it would be repeated, and expect to be correct (80 + 87)/220 ≈ 76.0% of the time, a very marked improvement. Knowing the trigram distribution and the two previous states of the system changes nothing: we would still always be wisest to guess that the immediately prior state would repeat itself. Knowing the 4-gram distribution and the three previous states of the system makes for a slight improvement, since if the previous-states trigram were **011** or **101** we would reverse our guess; knowledge of the 5-gram distribution also makes for some improvement, reversing the guess for the previous-states 4-grams **0101 1011 1101**--but here the number of cases becomes very small. The crucial case is that of the trigram distribution, i.e. where ***m*** = 2; its ineffectiveness militates against the idea of a second-order Markov process.

Table 9. ***N***-gram frequencies for the Indic unity variable

Unigram	f(1)	**Digram**	f(2)	**Trigram**	f(3)	**4-gram**	f(4)	**5-gram**	f(5)
0	114	**00**	87	**000**	66	**0000**	49	**00000**	34
								00001	15
						0001	16	**00010**	3
								00011	13
				001	20	**0010**	4	**00100**	3
								00101	1
						0011	16	**00110**	8
								00111	8
		01	26	**010**	8	**0100**	5	**01000**	3
								01001	2
						0101	3	**01010**	2
								01011	1
				011	18	**0110**	10	**01100**	8
								01101	2
						0111	8	**01110**	3
								01111	5
1	107	**10**	27	**100**	21	**1000**	17	**10000**	15
								10001	1
						1001	4	**10010**	1
								10011	3
				101	6	**1010**	4	**10100**	2
								10101	2
						1011	2	**10110**	2
								10111	0
		11	80	**110**	19	**1100**	16	**11000**	14
								11001	2
						1101	3	**11010**	2
								11011	1
				111	61	**1110**	9	**11100**	8
								11101	1
						1111	52	**11110**	6
								11111	46
TOTALS	221		220		219		218		217

The more precise determination of the order of dependence uses the conditional entropy provided by each additional higher-order ***n***-gram. The conditional entropy for order ***i*** is computed as the difference between the entropy of the ***i***-gram and the (***i*** + 1)-gram (Gottman and Roy, 1990; Lemay, 1999). Table 10 shows the conditional entropy for each ***n***-

gram order of the Indic reduced indexes (the unigram entropy is the total entropy at the zero-order); Figure 7 illustrates Table 10 graphically.

Table 10. Conditional Entropies for the reduced indexes at orders 0-4

***N*-gram**	Markovian Order	Unity	Domination	Concentration
Unigram	0	0.999276	0.641193	0.509262
Digram	1	0.796248	0.291425	0.351027
Trigram	2	0.798161	0.284701	0.335637
4-gram	3	0.743772	0.265641	0.319973
5-gram	4	0.69798	0.228223	0.28402

The examination of conditional entropy directly specifies a Markov process of the first order

$$\mathbf{h_0 > h_1 = h_2 = h_3 = h_4}$$

in that, in all cases, there is a strong contribution of the first order, little or no contribution of the second order, and minimal contributions of the higher orders (***p*** <0.0001: the significance test is applied to the difference in conditional entropy created by taking into account each additional order).

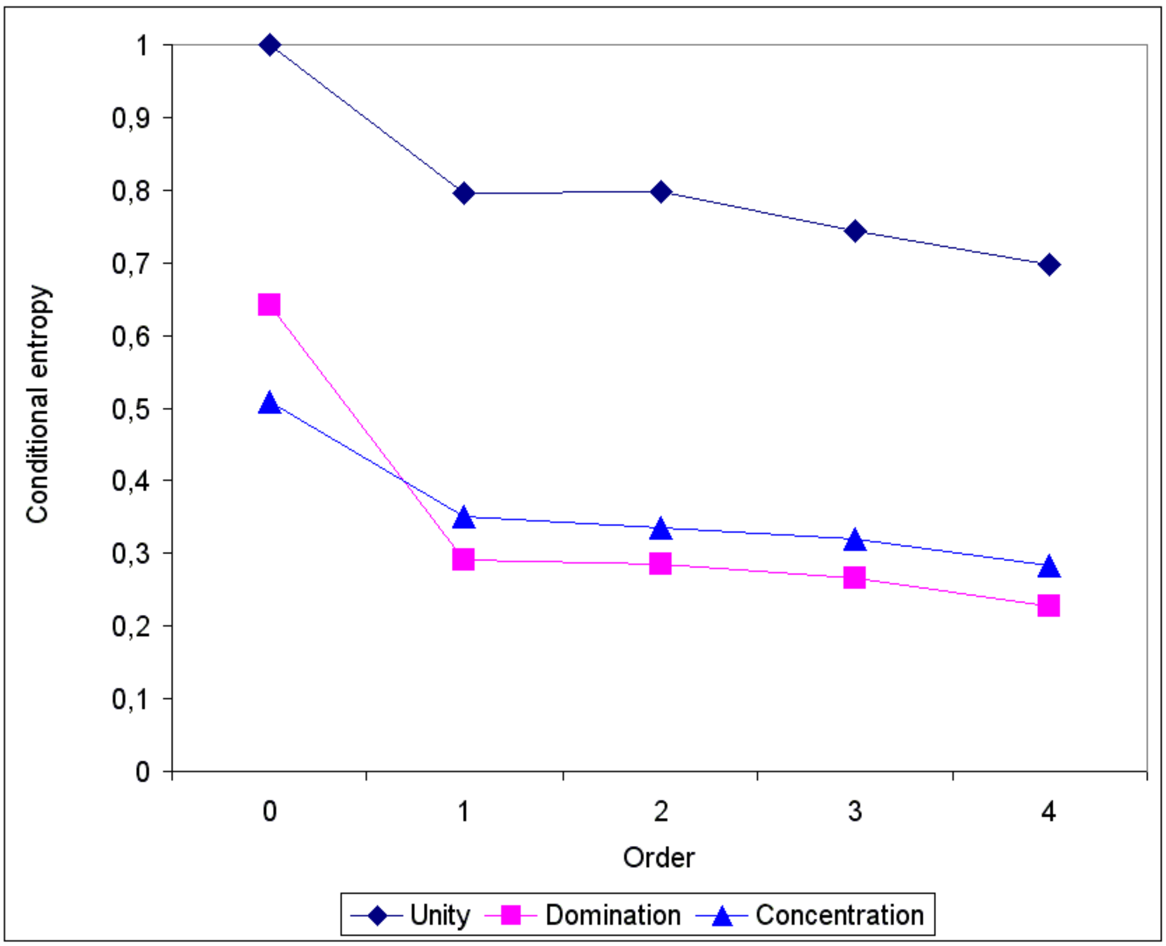

Figure 7. Conditional entropies for the reduced indexes at orders 0-4

Inspection of particular transitions. The reduced indexes, while they have the advantage of lending themselves to analysis by statistical measures, do not show many of the more intricate features of the process. To check for possible deviations in detail from the general conclusion that second-order effects are absent, it is desirable to make a direct inspection of particular transitions among the 7 configurations for signs of any second-order effect. Indeed, in one case (only) it did appear that a second-order Markov effect might be operating: the case where the "old" state for the transition is Unipolarity and the previous ("pre-old" state is Hegemony (see Table 11), which introduces a bias in favor of the "new" state being Hegemony rather than the ordinarily favored Bipolarity. Conceivably, the experience of hegemony could be sufficiently "memorable" for the system that enters a more path-dependent condition, provided that it goes no farther away from hegemony than into unipolarity; this would make sense if the same actor were the hegemon and the non-hegemonic superpower at each point in the Hegemony→Unipolarity→Hegemony sequence, as nostalgia for lost influence could strongly motivate it to recapture such influence, and the other actors' memory of the superpower's past hegemony could incline them to expect its influence to revive. However, the significance level of this deviation is only approximately 4-5%, since we have only 4 cases when Hegemony precedes Unipolarity (calculations of significance were carried out by means of the multinomial distribution, taking into account that one set is a subset of the other).

Except for this minor deviation, we conclude that the political configuration change pattern of the Indic world system can be treated as a first-order Markov chain. Table 7 is then not just the transition frequency matrix, but the transition probability matrix. Furthermore, Table 3 (and 7) can then be read as showing the relative stability of the different configurations. The most unstable configuration, as Fox (1944) proposed, is Tripolarity. The most stable, perhaps somewhat surprisingly in view of their relative infrequency in Indic society, are Hegemony and Empire.

Table 11. Differences of the index of political configuration change process from the first-order Markov process

Transitions	Frequency	Transitions	Frequency
Unipolarity →Nonpolarity	4	Hegemony →Unipolarity →Nonpolarity	1
Unipolarity →Multipolarity	2	Hegemony →Unipolarity → Multipolarity	0
Unipolarity →Tripolarity	2	Hegemony →Unipolarity → Tripolarity	0
Unipolarity → Bipolarity	17	Hegemony →Unipolarity → Bipolarity	0
Unipolarity →Hegemony	4	Hegemony →Unipolarity →Hegemony	2
Unipolarity →Empire	1	Hegemony →Unipolarity →Empire	1

.

Modeling and simulation. Having a Markov process transition probability matrix makes it possible to analyze certain aspects of the configuration-change process in the Indic world system. At the risk of introducing bias into the analysis, the ranked set of power-structure categories may be assigned numbers intended to reflect a "distance" between them, and the variable then treated as if it were continuous. If we thus treat the configuration variable as not merely nominal or ordinal, but as a ratio variable, then we could assert that the Indic system has an "average state" somewhere between Bipolarity and Unipolarity, but closer to Bipolarity (the common average value of the of configuration is approximately equal to 3.3, and the standard deviation approximately 1.9). In the interests of hypothesis-construction, we have examined the “relaxation” path of the system’s evolution into its average state from each possible “old state.” For all configurations except Unipolarity we obtain a monotonic evolution to the common average value. However, during the evolution from Unipolarity, in the first 40-50 years the average value decreases to 3.1, after which it slowly grows to the common average value (the period of decrease is 40 years for a totally symmetric matrix). Taking in account the great frequency of Unipolarity for the Indic world system, it would seem worthwhile to examine the (actually) ordinal data for cyclicity.

In the first instance, we were interested in whether there were any “periodic states” in the Indic Markov chain. A system state is “periodic” if, after having exited it, the probability of return to it is zero except after some number of other intervening states. Its “Markovian period” is the number of steps that must be traversed before a recurrence is possible; in our case, the number of intervening observations that would fail to note a recurrence. The general reversibility of transitions between pairs of states suggests the Indic Markov chain is, strictly speaking, aperiodic (i.e. lacks any periodic states). However, weaker periodicities might exist, i.e. the probability of a return to the “old state” might be reduced for some number of observations; and in this case, a single weakly periodic state might simultaneously display several weak periodicities. This aspect is so intriguing that we have tested it by two procedures. The first one was the study of long simulations of the Indic Markov process (10-50 thousand steps, i.e. 100-500 thousand years); the second was the averaging of a great quantity (5-20 thousand) of "short" simulations of the Indic process, of 220-240 steps (2200-2400 years), more resembling the actual total historical interval examined.

We used Table 7, treated as a probability matrix, to generate a simulation. We then did a spectral analysis of that simulation by the method of periodogrammetry, and determined the peaks of its periodogram, i.e. the periods for which the spectrum had maximal values. (Spectral analysis and periodogrammetry are discussed in more detail below). This process was repeated 20,000 times. We added up the spectra for the 20,000 simulations, and then divided the resulting curve by 20,000. This procedure produced the very smooth “Spectrum” curve shown in Figure 8; its smoothness is the result of adding 20,000 rough curves, with sharper maxima and minima, of the kind which will be displayed in the spectral analysis below of the single (actual) Indic system career. The “Spectrum” curve shows no Markovian period.

To examine the possibility that several Markovian periods, simultaneously operative, might be unequally influential, we employed a “special bonus function.” As above, we used Table 7 to generate a simulation, make a spectrum, and determine its peaks. We then awarded these periods different, unequal weights (“points”): 100 (10^2) points for the biggest maximum; 81 (9^2) points for the second maximum; 64 (8^2) points for the third maximum; … to one point for the tenth maximum.

This process was repeated 20,000 times, and the points were then added up. The resulting curve is also graphed in Figure 8. It is rough; to make it smooth, not 20,000, but millions of simulations would be needed, beyond the computer capabilities of the current investigators. The only Markovian period found is the shortest period of 20 years (two steps). This might indicate the existence of a second-order Markov process in which the “memory” of the pre-old state slightly increases the probability of its being replicated in the “new” state regardless of what “old” state intervened; but if so, it is extremely weak, or we should have expected it to be seen in the averaged spectrum as well.

Temporal symmetry, attractors and repulsors. It may also be of interest to know how far the "old state" can be predicted, or rather retrodicted, from the system's "new state." As Table 12 shows, and as we should expect by now in the Indic case, for any "new state" its most likely "old state" is itself, and, besides itself, Bipolarity and Unipolarity, which are so to speak "sources" as well as "collectors" for the whole system.

Recall that if it were not for one solitary case, the change from Hegemony in 1720 to Tripolarity in 1730, we would have found that every change of configuration in the Indic system was either a change from, or a change to, Bipolarity or Unipolarity. Instead of the anticipated adjacency effect, we seem to have found a system with "attractors."

The "attractor" of a "dynamical system" may be a steady state into which the system finally settles ("point attractor"), or a set of states through which the system finally cycles and keeps on cycling, endlessly revisiting each state ("cyclic attractor"). A system with a point attractor allows us to predict a single eventual outcome, a "destiny." A system with a cyclic attractor provides a regular pattern of change such that, if we know where it is in its cycle, we know where it will go next. Both system-types invite mechanical, deterministic treatment; but the Indic system seems to fit neither type.

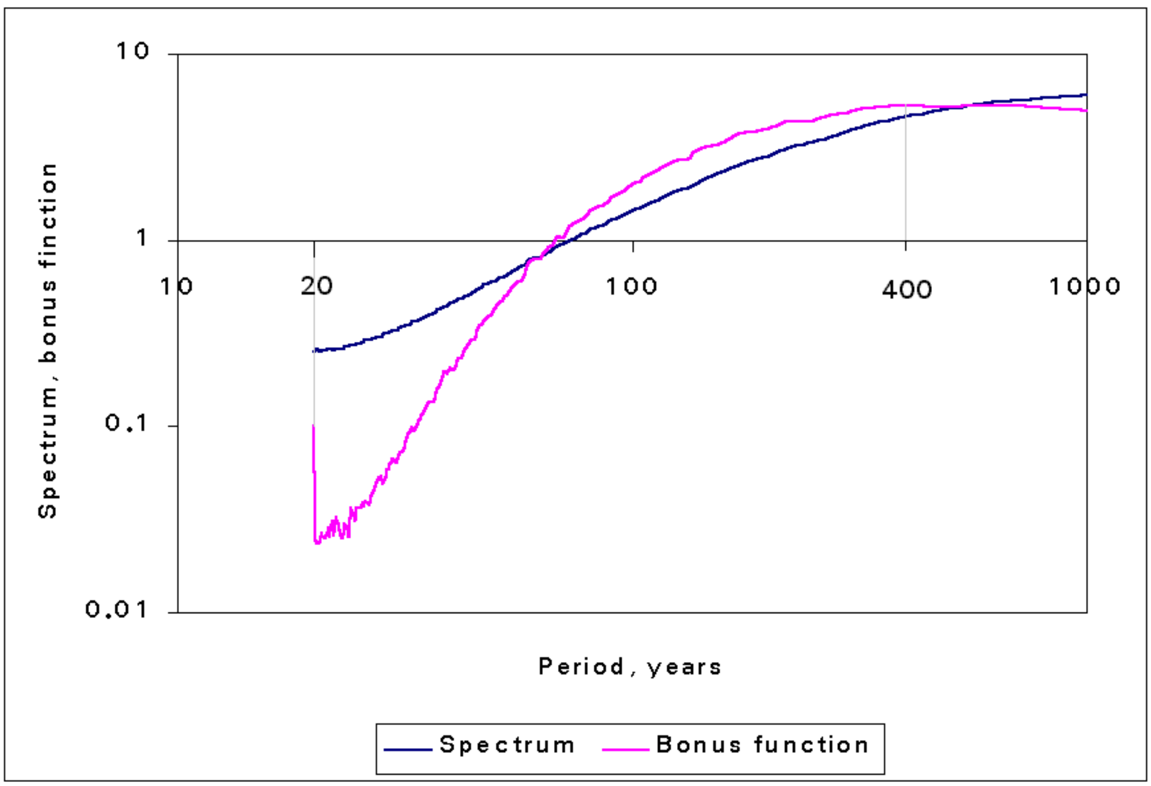

Figure 8. Averaged spectrum and bonus function for 20000 simulations of Markov process

Table 12. Markov process transition frequency matrix (column percentages)

Old state of system	New state of system						
	Nonpolarity	Multipolarity	Tripolarity	Bipolarity	Unipolarity	Hegemony	Empire
Nonpolarity	64.7%			1.4%	7.0%		
Multipolarity		50.0%		4.2%			
Tripolarity			47.1%	8.3%	4.2%		
Bipolarity	11.8%	25.0%	35.3%	61.1%	23.9%	3.7%	
Unipolarity	23.5%	25.0%	11.8%	23.6%	57.7%	14.8%	12.5%
Hegemony			5.9%	1.4%	5.6%	81.5%	
Empire					1.4%		87.5%

Note: columns may not add to 100%, as percentages are rounded.

A third type of attractor, "strange" or "ergodic," lacks an exact repetition pattern but varies with incomplete determination within a determinate set of values, hence invites statistical study. The Indic system is closer to this type, but fails to become entirely bound into a stochastic Bipolarity ←→ Unipolarity alternation. All the more because of the general (if unequal) "stickiness" of each configuration, the attractor of the Indic system might be conditionally labeled "weakly ergodic." But the reversibility of configuration changes means that the "attractor" is equally a "repulsor," so that Indic "history" is temporally symmetrical, and, like a palindrome, looks similar whether read backward or forward. We illustrate this point with Figure 9, in which one line repeats the series graphed in Figure 1, and the other reverses it. We doubt that, except for historians of India, many readers will be able to tell which is the true timeline and which the reversal without referring back to Figure 1. If Indic power-configuration history were in any sense "progressive," the reversed timeline would be obvious. It is not; rather Indic power-structure history is a continuing process of attaining, and losing, bipolarity and/or unipolarity.

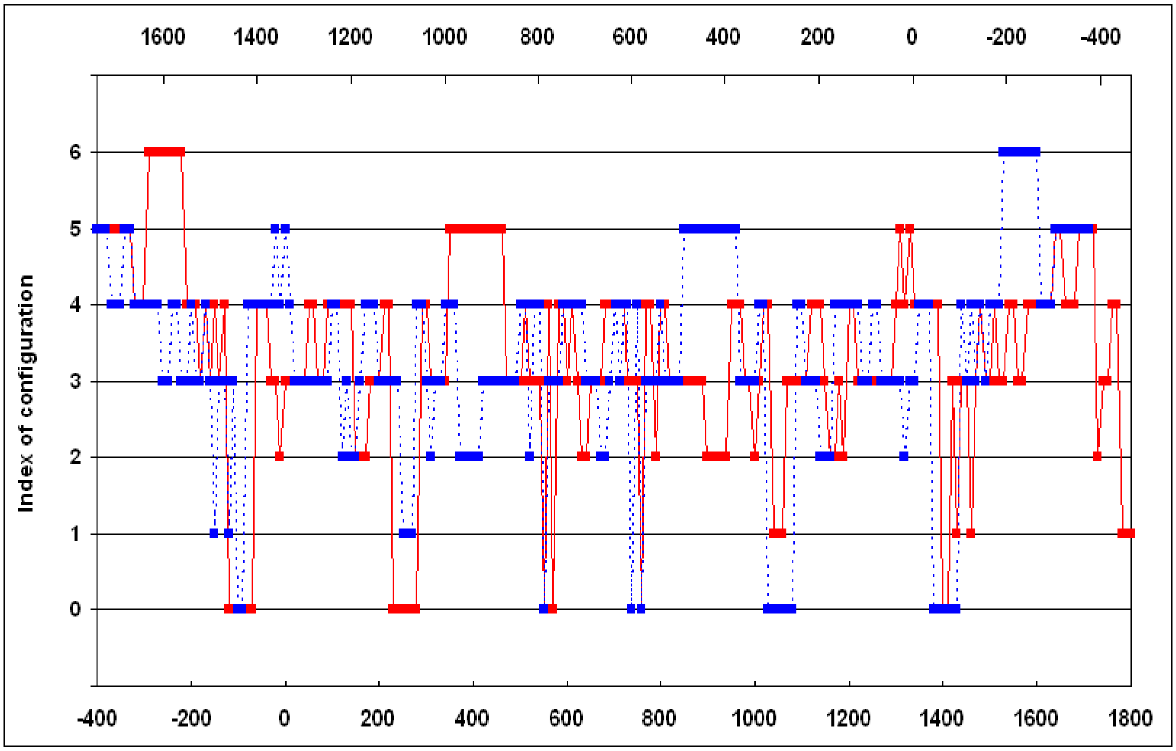

Figure 9. Temporal symmetry of Indic power configuration history.

Let us sum up our findings from the Poisson and Markov analyses. These analyses have led to a rather interesting conclusion: the political configuration changes of the Indic world system possess four peculiarities somewhat unexpected in a historical process.

1. The succession of the system state changes is near to a Poisson process, i. e. the probability of a change of configuration is hardly dependent on the age of the extant configuration.
2. Nearly all the changes are reversible, that is, for every two configuration types between which there can be a change in one direction, there can also be a change in the opposite direction. Even more surprising: both kinds of change occur with nearly the same frequency. In consequence, the entire process is time-symmetrical.
3. The overall process of configuration change is very similar to a Markov chain produced by a first-order Markov process, i. e. the transition from the current configuration into the next one is nearly independent of earlier configurations, but yet is subject to rules which are invariable (during 2000 years!).
4. Rather than changing directionally and progressively, or cycling, configuration changes seem to route preferentially through two adjacent and strongly connected configurations, Bipolarity and Unipolarity, Indic quasi-analogues (in the mind of the New York-born American co-author) to Times Square and Grand Central Station.

On the whole, such a kind of history does indeed seem in general to resemble the chaotic bustle of traffic back and forth, usually localized (thus the Indic system, decade by lively decade, usually stays in its most recent configuration), but otherwise along a very few predetermined roads which pass through major central nodes or traffic hubs (i.e. to and from Bipolarity and Unipolarity). In our opinion, such a traffic-theory or network-analysis concept of history would not be gratifying to either the partisans of historical development theories (for instance, followers of Marx, Weber or Rostow) or partisans of cyclic history theories (for instance, followers of Spengler or Toynbee). All of them prefer a history more organized and connected, and yet less stable. All the same, these four peculiarities of the Indic historical process have been obtained immediately from factual data.

However, as shown by the following analysis, the chaotic of the Indic world system is not fully captured by the traffic-network concept of a chaotic bustle along predetermined roads, but also possesses other interesting characteristics. Certain elements of order can be found in the chaos by the methods of autocorrelation and spectral analysis.

Autocorrelation. Autocorrelation is a particular application of the widely used statistical procedure of correlation. The "correlation coefficient" (Pearson's R, or for ranked data like ours, Spearman's rho, which can be computed with the same formula) is a way of expressing the degree (strength) of a dependence of one variable upon another. Graphically the correlation coefficient expresses the proximity of points (corresponding to the data under consideration) to a line that corresponds to a linear dependence. The correlation coefficient varies from –1 (the magnitude under study is a negatively sloped strict linear function of a given indicator) to +1 (a positively sloped strict linear function). The closer R approaches to +1 or –1, the closer the correlation dependence approaches a functional dependence; and, conversely, the closer R approaches to 0, the weaker the relationship. The "significance" (validity) of the relationship, however, depends not only on the value of R, but also on the quantity of data studied (the number of plotted points). With a very large quantity of points, even small values for R indicate a weak, but valid correlation; but if the quantity of data is very small, even a value for R approaching +1 or –1 may have occurred accidentally and be meaningless. The main difference between a correlational dependence and a functional one is that the former does not account for the entire dispersion (variability) of the magnitude under consideration, but only that part of it, equal to the square of the correlation coefficient – the "determination coefficient" (R^2). Furthermore, the correlation and determination coefficients do not show the directionality of the causal relationship, or even the presence of one (a correlation may be caused by the dependence of both variables on some third variable); their values merely express the degree (strength) of the relationship.

Autocorrelation is the simple linear correlation of a time series with some version of its own past. Autocorrelation measures the dependence of a time series of values upon its values at some selected earlier time. To obtain useful results, autocorrelation is computed not just once but over a range of "lags" or "phase shifts" in which the sequence of values under study is repeatedly correlated with that same sequence at some increasing number of time units earlier. This process produces an "autocorrelation function" (ACF), which examines the correlation of a time series of data with itself for the whole sequence of increasing lags, starting with a lag of zero. A lag of zero is always included, and the ACF at that lag always equals 1, the maximum positive value of the function, since at that point the series necessarily matches itself perfectly. If the time series is treated as a "signal" then ACF shows to what degree the future values depend on the previous ones. The ACF is used to detect the possible self-deterministic components of a "signal" that may look like noise because it is masked in a random background. The ACF ignores all "exogenous" variables, and asks how far the future of some individual entity (which may, like a civilization, be gigantic in size and complex in character) can be predicted from its own past and its past alone.

One key question asked of a series (sequence or "signal") by means of the ACF is whether the process that produced the series has one or more periodic components; and, if so, what might be the period or periods of the process(es)? If ACF values are high, and change their sign periodically, it may point to the existence of cycles. Autocorrelations, like all correlations, lie between values of +1 and –1. Values near +1 and –1 indicate strong autocorrelation or self-similarity (positive or negative), while values near zero indicate weak or absent self-similarity. The ACF, a series of autocorrelations taken at various lags starting with 0, accordingly varies between +1 and –1. When the ACF approaches its limits of +1 or –1, this implies high linear dependence at the particular lag where the ACF shows peaks or troughs. Accordingly, the ACF's peaks and troughs mark the time intervals over which a strong self-similarity or self-difference emerges out of the "noise" of the sequence, and thus indicate the period or periods of the underlying process(es).

As we have said, there is necessarily an autocorrelation of 1 at lag zero, inasmuch as a signal fully predicts itself with a delay of 0. Elsewhere an ACF of 1 at one or more time points indicates completely self-similar sequences that mirror prior values. On the other hand, if an ACF, having shown a value of 1 at lag 0, then drops to zero or near zero and remains there at all other lags, implying no or nearly no self-similarity at any lag but 0, there is no reason to believe that the signal has a periodic component, and no reasonable expectation of linear endogenous predictability. Otherwise, periodicities and linear determinism become plausible.

Figure 10 is the diagram of the autocorrelation function for the configuration sequence of the Indic civilization (ragged blue line) and for the above obtained Markov process (smooth red line). As befits a Markov process confined to the first order, the red line shows the erasure of the "shadow of the past" after about 100 years. The configuration ACF behaves in the same way at first: it shows a high value at the left end of the graph, diminishing to zero at a timelag of
about 100 years. This is quite consistent with the distribution of durations shown in Table 2, in which most (189 / 221 ≈ 85 %) observations appeared in sequences of 2 or more "repeats," but more often in shorter than in longer sequences. Such an ACF, and such sequences, are also consistent with a system tending noticeably to be "sticky," conservative, resistant to change, tending rather to remain in whatever condition it happens to be at any given moment in time, which we already know to be a very strong characteristic of the Indic system. However, having reached 0, the configuration ACF, unlike the Markov process ACF, does not settle there, but turns sharply negative, with a trough at about 200 years, and then rebounds, peaking at a c. 350 year lag, and then produces a less sharp trough and peak. This trace is consistent with the physical idea of an oscillatory process, such as is posited by Toynbee's "Helleno-Sinic" civilizational model (1961). The autocorrelation diagram suggests a cycle duration of approximately 350 years for the Indic world system power structure. The second peak (phase shift of 600-800 years might be only a doubling and "smearing" of the unary first peak at 350 years, but might alternatively be a separate cycle. This time lag is much too large to have been captured by the first-order Markov-process analysis.

So as to roughly evaluate the significance of the discussed deviations, Figure 11 shows the computed values of the difference between ACF of the real process and that of the ACF of the Markov process reduced by means of the Fisher transform. The greater the deviation of the difference from zero, the greater the probability of these differences being not random. However, even the greatest deviations could have been obtained by chance, with a probability of 22-25% (or of 12-15 % if the sign of the deviations were preset). That is why we cannot, on the basis of the ACF, determine the existence or absence of long cycles in the Indic data. This problem needs further investigation, undertaken below. At the same time, a strict analysis of Figure 11 does allow us to hypothesize the existence of weak short cycles with periods of 30 and 60 years, a hypothesis we shall also test below.

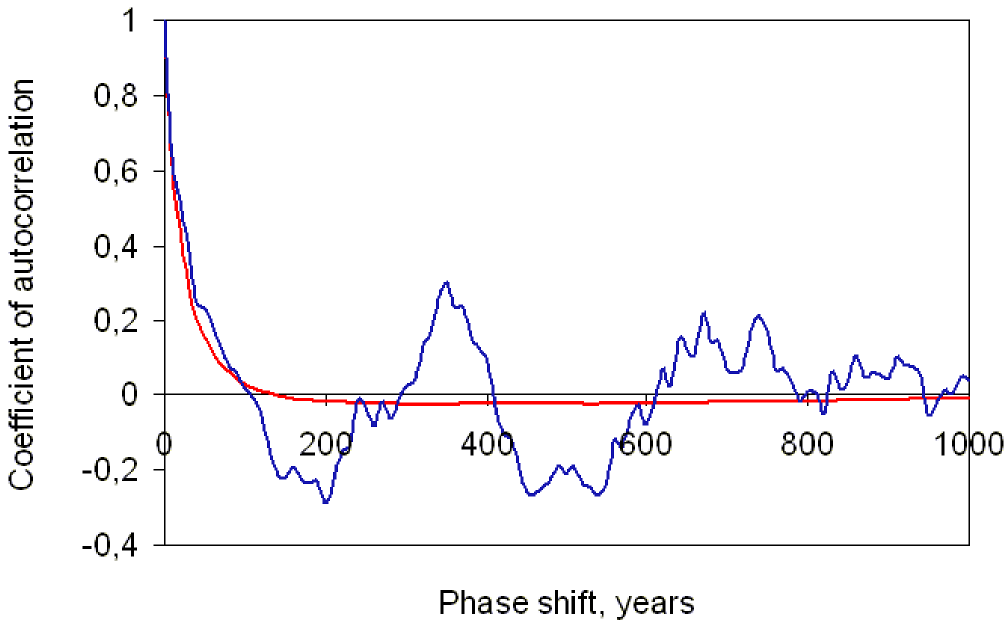

Figure 10. Autocorrelation function for the Indic world system

The three reduced indexes also allow us to revisit the apparently Poisson-like character of Indic power configuration changes. Do the durations of these three indexes match the exponential distribution? And is there autocorrelation in the sequence? The answers are shown in Table 13.

The Poisson condition of matching the exponential distribution is carried out for the indexes of unity and domination, but not for that of concentration, because the distribution of periods of duration of concentrations has a bimodal character. (To calculate the chi-square test for the index of domination with acceptable precision is impossible as we lack data.).

Although none of the four ACFs (Figure 12) falls to zero and stays there, only the autocorrelation function for the index of concentration reaches significance: with a probability of 95%, there is a certain sequence of duration of intervals between changes in the value of the Indic index of concentration. This is the sequence:

290 → 60 → **260** → 10 → **10** → 10 → **180** → 10 → **270** → 30 → **330** → 20 → **10** → 10 → **20** → 10 → **310** → 20

In the bold font is given the count of years spent by the system at a concentration of 1, the normal font at 0. This sequence suggests a cycle: approximately 300 years of presence of poles of force and 10-60 years of their absence, for what is perhaps a 350-year overall cycle. Still, there is much irregularity, which should be explored.

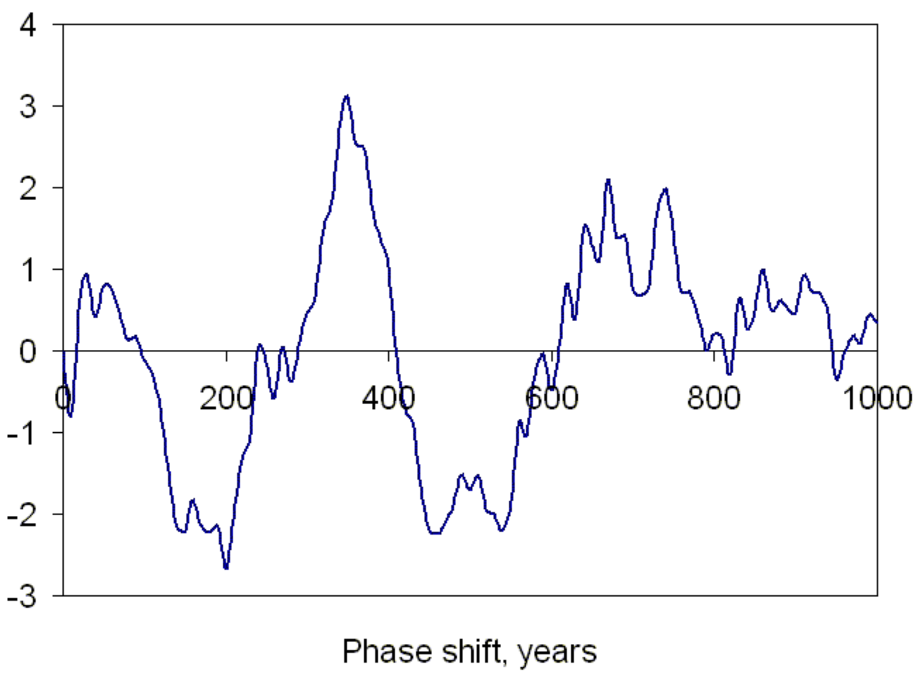

Figure 11. Reduced difference between the ACF of real and Markov process

Table 13. Durations of Indic Domination, Unity and Concentration (see Figs. 4-6)

Duration (measured in the number of observations)		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Frequency	Domination	3	1	2	1	0	0	1	1	1	0	0	1	0	0	0
	Unity	15	15	5	4	2	5	0	4	0	2	0	1	0	0	1
	Concentration	7	3	1	0	0	2	0	0	0	0	0	0	0	0	0

Duration (measured in the number of observations)		18	23	26	27	29	30	31	33	55	84	χ_6^2	ACF Phase shift	
													1	2
Frequency	Domination	0	0	0	0	0	1	0	0	1	1	-	-0.12	0.20
	Unity	0	1	0	0	0	0	0	0	0	0	9.8	-0.01	-0.11
	Concentration	1	0	1	1	2	0	1	1	0	0	36.7	-0.38	0.46

What next? There are more refined techniques which can be applied to data sequences that suggest periodicity, in order to extract further suggestive information, for instance with respect to multiple rhythms, or rhythms which persist through only a portion of the duration of a system. These are the techniques of **spectral analysis,** to which we shall turn next..

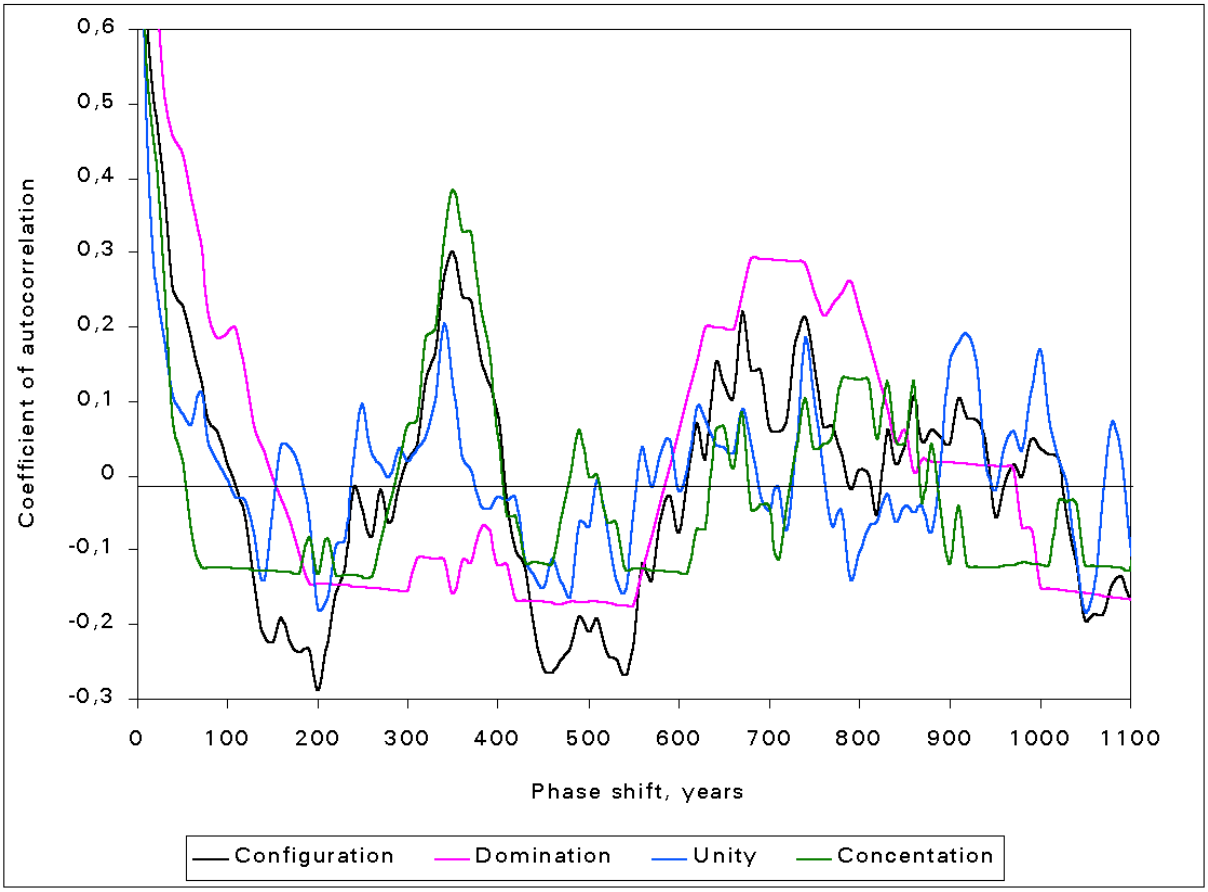

Figure 12. Autocorrelation functions for Indic Configurations, Domination, Concentration, and Unity

Spectral analysis. Spectral analysis is the resolution of composite waves (signals, vibrations, radiations, sounds, lights etc.) into more homogeneous elements which have definite periodicities (wavelengths, frequencies, etc.) The spectra which are the products of spectral analysis show, for the range of time periods at which a repetition of a phenomenon or observation may occur, the intensity of the contribution made by each possible homogeneous component to the actual composite signal.

By Fourier's theorem, any waveform (e.g. the trace produced by a time series of data), however apparently irregular or nonperiodic, can be decomposed into a series of regular, periodic sine waves and cosine waves, such that the sum of these waves reconstructs or approximates the given waveform. Thus any time series of data, such as our Indic indexes, can be seen as an irregular function of time f(t), and represented more or less exactly as the sum of some set of smooth, regular, periodic rhythms, and its irregular graph can be generated by summing the smooth graphs of the regular functions.

The purpose of spectral analysis is to separate irregular-seeming time series into orderly component periodicities, wavelengths, frequencies, etc., whose duration may in turn suggest orderly process components. Any phenomenon whose behavior, when captured in sets of observational data, suggests that it may possess underlying periodic features, may be subjected to spectral analysis in order to locate potential periodicities. These in turn may be used to direct the investigation and suggest the character of any regular component processes which may be at work. Conversely, conjectures proposing underlying regular processes may be modeled, the processes being represented as sine/cosine waves, and these summed to produce a “signal” which, if the conjecture is correct, should well match the actual observed data.

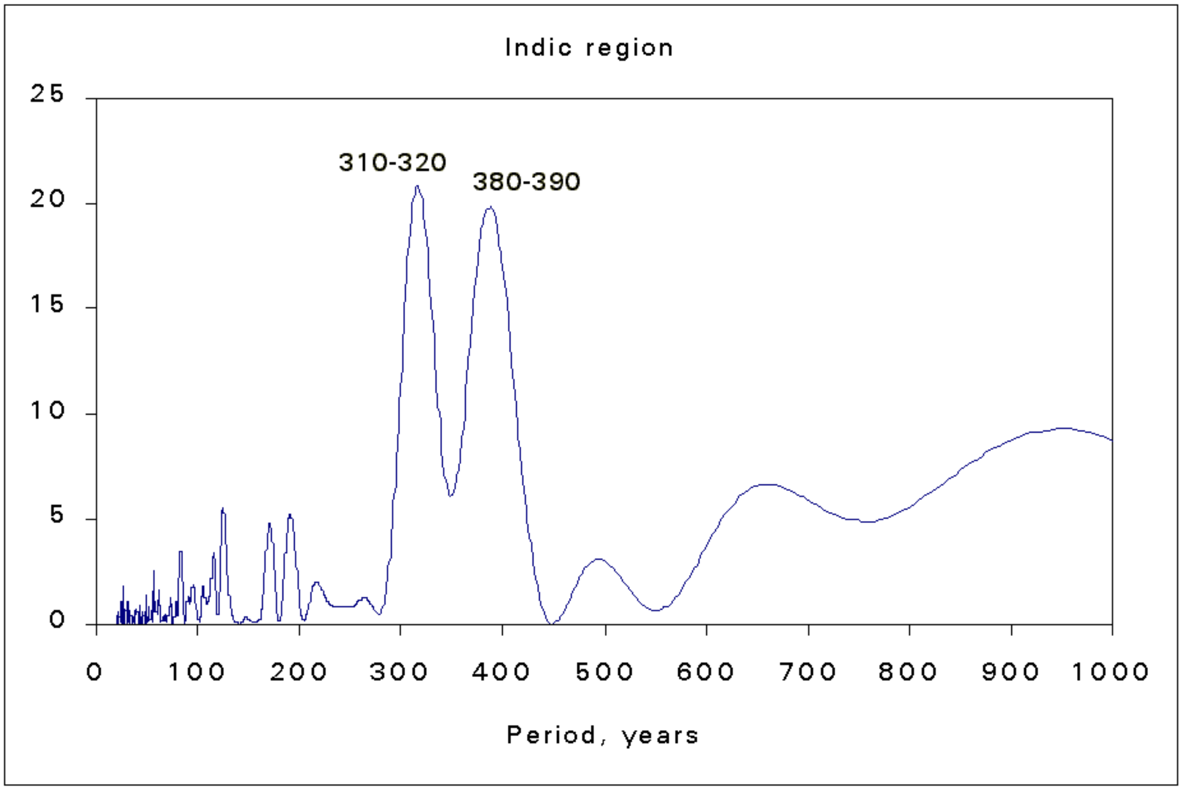

Figure 13. Periodogram of indexes of configuration for the Indic world system

Periodogrammetry. The periodogram, a non-smoothed spectrum, is one of the basic techniques of Fourier spectral analysis. The irregular observational data are decomposed into sines and cosines with various periods. Figure 13 is the periodogram for the index of configuration, as graphed in Figure 1. The horizontal axis of the periodogram shows the various periodicities which are found contribute to the shape of the index of configuration; the height of the periodogram for each periodicity represents the share of the actual contribution which that periodicity makes to the fluctuation of the Indic power configuration. The peaks of the periodogram indicate the most powerful component periodicities.

According to Figure 13, it would appear that the changes in the political configuration of the Indic civilization display only the cycles of 300-400 years which we singled out during the analysis of the duration of the concentration index.

However, this evaluation is inexact. If we analyze not the time series of the index value configuration but the time series of its changes, we get quite a different picture (see Figure 14). We may note that for individuals, and for the various polities that are members of a world system, the changes of the political situation are no less important than the political situation itself.

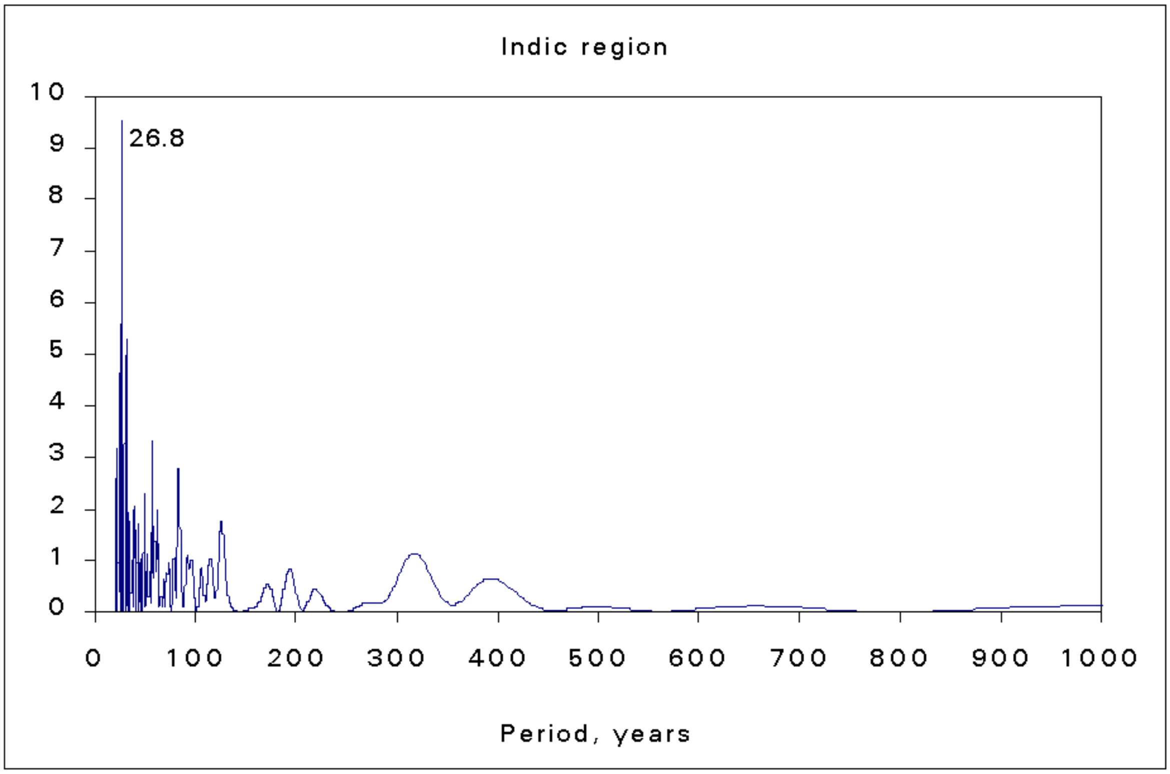

Figure 14. Periodogram of changes of indexes of configuration for the Indic world system

The predominance of short cycles in Figure 14 once more shows the stability of the political process characteristics of the Indic civilization over the two thousand years of its existence--the tempo of the changes of the political configuration during a human life-span changes more drastically than during centuries. In other words, over long intervals of time the speed of change of political configurations varies very little: there is near-zero "acceleration." Rapid accelerations and decelerations of political processes are found only over only short intervals of time, and the most frequent period of changes (between periods of stability and instability) is of a length of a generation, approximately 27 years. (These features of the "acceleration" spectrum in Figure 14 are connected with the character of the attractor which was discussed previously.)

At the same time, Figures 13 and 14 show that the process of change in political configurations is neither a white noise (in white noise, the situation in later periods is independent of the situation in the preceding period), nor a red noise (in red noise, changes of the situation are independent of the preceding situation). Hence, to evaluate the significance of the kind of periodicities it is impossible to use either of the periodograms.

To secure a more adequate evaluation of different cycles' significance from the periodogram transforms, two approaches are possible. The first one, more general, is considered to be a null hypothesis: a complicated process is treated as having no genuine cycles, but rather as consisting of a combination of white and red noises. The characteristics of this process are computed using the method of maximum likelihood. The second approach consists in using the Markov process simulation summarized in Figure 4 as the null hypothesis. The periodograms are then reduced by these two methods. The periodograms so reduced are shown in Figures 15 and 16. Figures 17 and 18 show the portions of short periods of reduced periodograms in more detail.

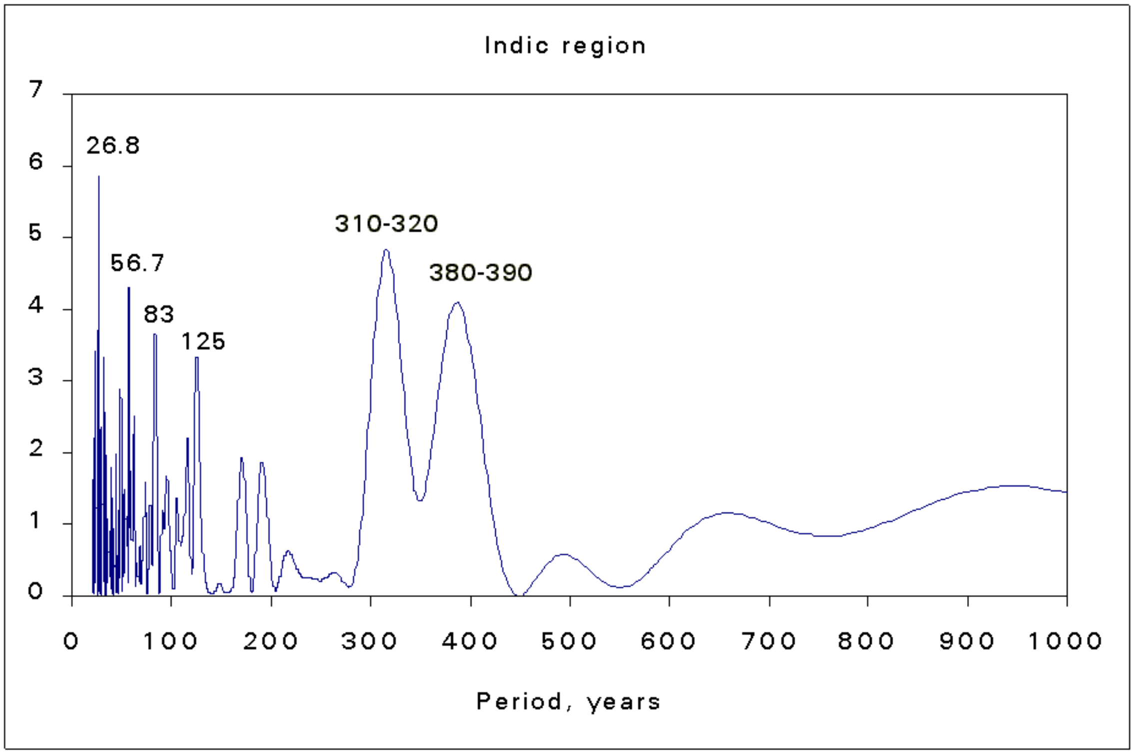

Figure 15. Reduced periodogram (reduced by the sum of white and red noise) of the index of configuration for the Indic world system

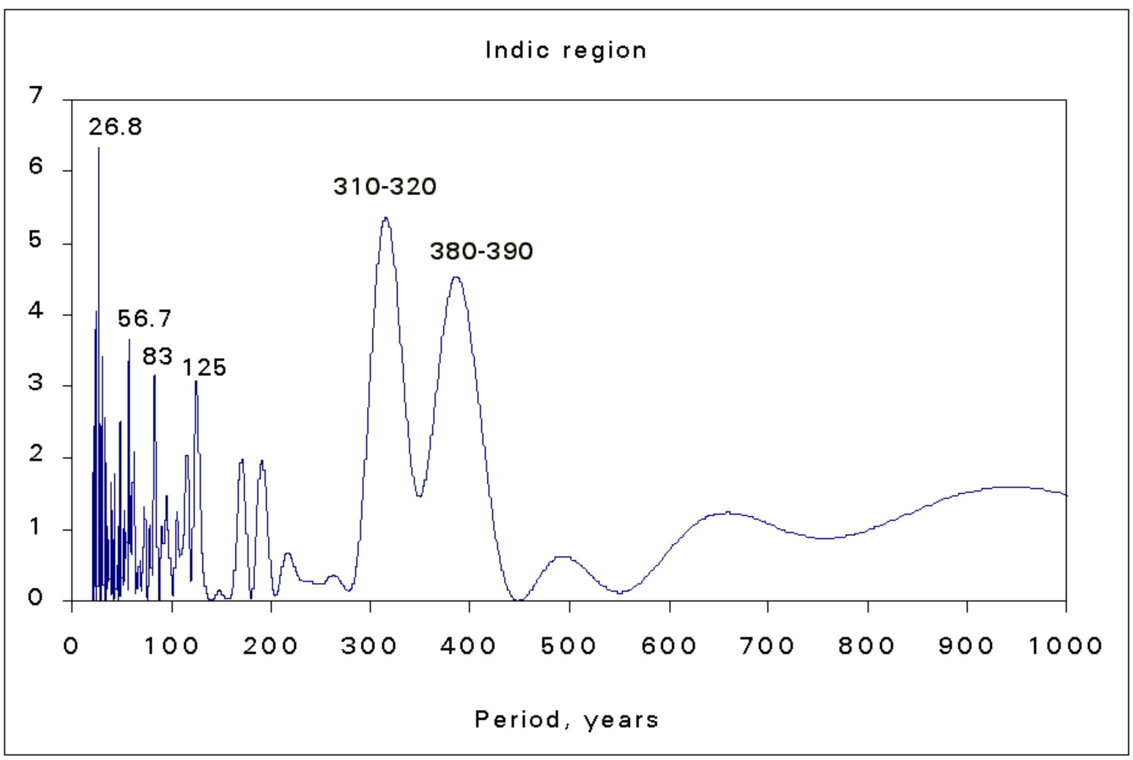

Figure 16. Reduced periodogram (reduced by the simulated Markov process) of the index of configuration for the Indic world system

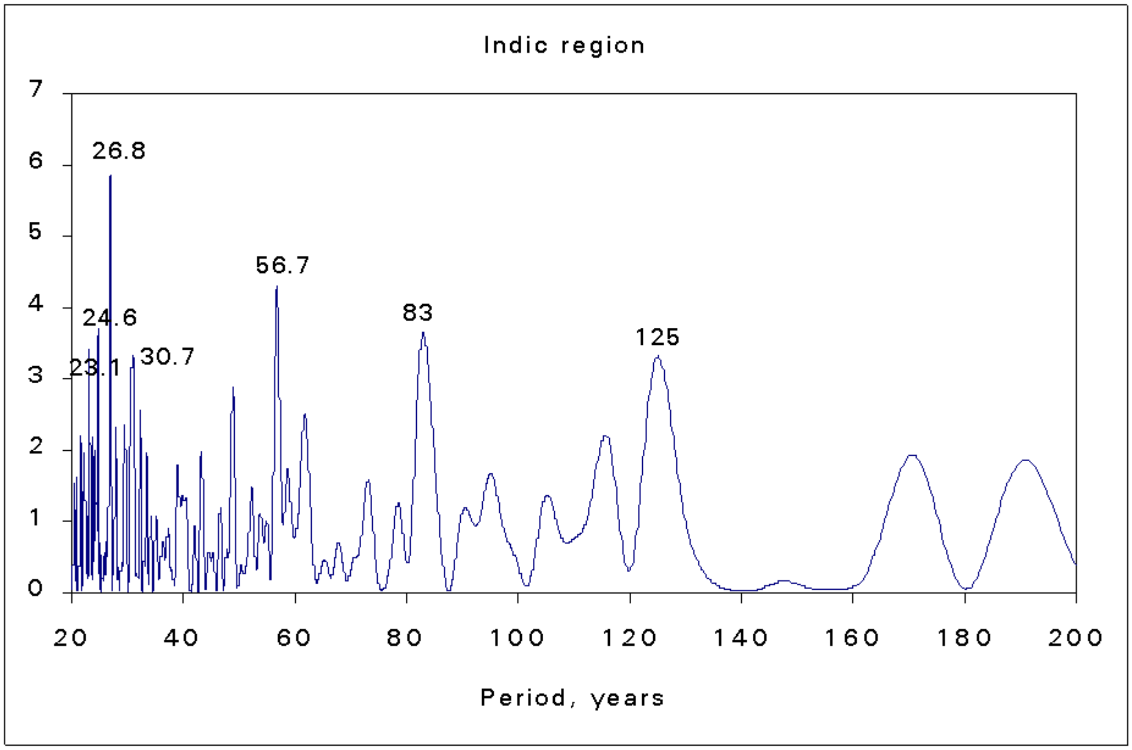

Figure 17. Reduced periodogram (by sum of white and red noise) of index of configuration for the Indic world system (short periods)

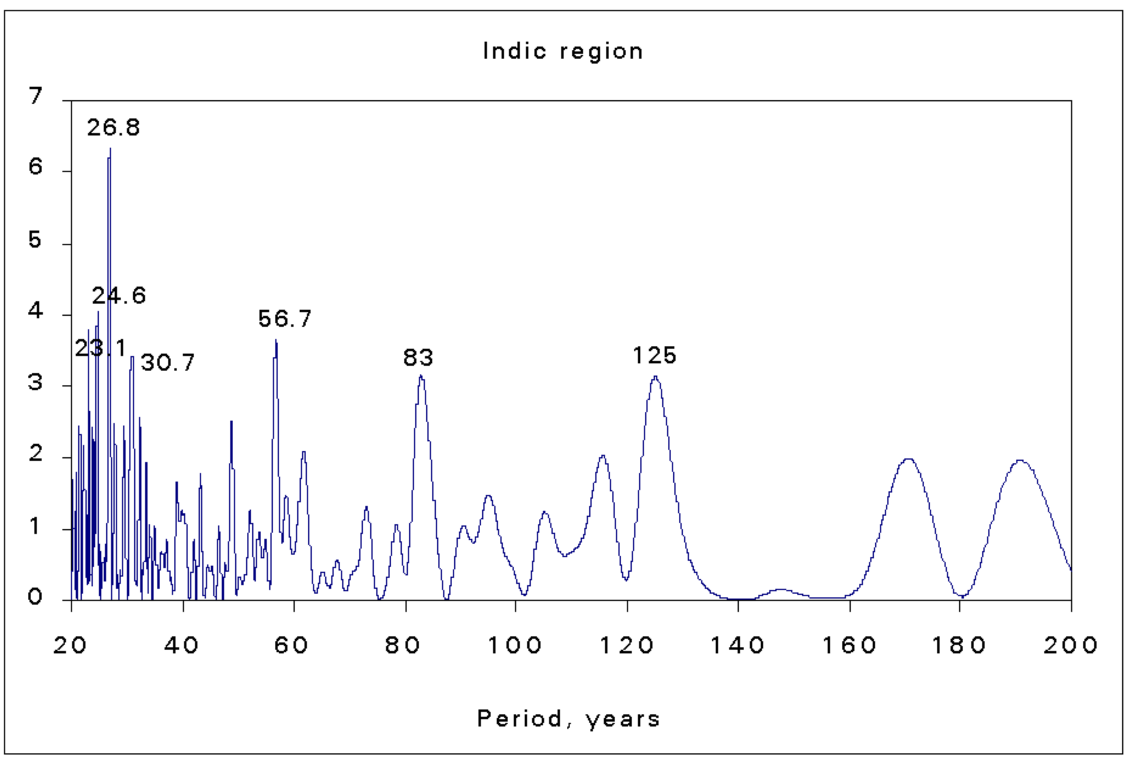

Figure 18. Reduced periodogram (by Markov process) of index of configuration for the Indic world system (short periods)

It is obvious that notwithstanding the fundamental differences in the reduction methods, the obtained periodograms are very much alike. An attentive study of the figures allows us to notice a number of small differences, the most meaningful being a stronger delineation of the main cycles (26.8 and 310-320 years) when using the Markov process.

To proceed from a visual analysis of the graphs to the study of the characteristics of the underlying political process, we have to choose one of three solutions concerning every one of the peaks.

1. The sinusoid whose amplitude shows the given peak is accidental and devoid of meaning as to the historical process.

2. The sinusoid is one of the components of the decomposition into harmonic components of a real cycle (of the same duration or longer).

3. The peak shows a real cycle which approaches in form the sinusoid.

Unfortunately, we cannot choose one of these solutions by mathematics alone. Furthermore, even if we use not only mathematical but historical and political arguments as well, we can obtain only an approximation of the truth, subject to being supported or refuted in the course of further investigation.

The first stage must be the evaluation of the significance of the main periodic components shown in Figures 15-18. By this we, in fact, determine the probability (level of significance) of the randomness of such significant deviations, i.e. we compare solution 1 as against 2 and 3. As a rule, in the study of small samples of events which are a priori possible, the probability of 5-10% is chosen as the critical level of significance. The appropriate computations show that neither of the peaks in Figures 15-18 satisfies this condition. The most pronounced peak, that with a period of 26.8 years, possesses the level of significance equal to 27% in Figure 16 or 18% in Figure 17. Nevertheless, the results of the computations do not disprove the existence of periodicities, and we must look deeper.

Computations with a smoothed periodogram (or spectrum) yield different estimations of the level of significance. Cycles with periods of 27 and 350 years (the latter uniting cycles of 310-320 or 380-390 years of duration) have levels of significance of 5-10% to 10-12% under different weight functions (reflecting different ways of smoothing). This finding increases the persuasiveness of the idea that there are least two cycles. Furthermore, if we evaluate not the greatest peak only, but a group of the greatest peaks, significance improves again. For a group of 2-5 peaks we get levels of significance not of 27% and 18%, but 10-20% and 10-12% respectively. Again we are led toward the idea of the non-randomness of the variations, and toward two cycles.

We may add that the preceding computations were carried out inductively, as if we had no ideas about what periodicities might be found. But it is easy to see that the shortest cyclical peaks that appear on Figures 15 and 16 are approximately equal to the durations of 1, 2 or 3 generations, and one of them is very near to the length of the Kondratieff cycle (ca. 55-60 years). We did not bring these durations in as hypotheses; but in other literatures, they are treated as self-evident or proved. On this ground, their appearance in the Indic data is in no way shocking.

Further discussion of the short cycles will follow later. For now, we may say that we feel some confidence that, for these periods and the c. 350-year period, solution 1 should be rejected. However, the harmonic (sinusoidal) cycles we have located could still turn out to be not independent cycles, but only components of more complicated cycles. The choice between solutions 2 or 3 is very difficult. First, there exists no set rule according to which to distinguish between the components of decomposition (with periods of T/2, T/3 and so on) and independent cycles of the same length. Second, if we do not predetermine the cycle form, then double, threefold etc. time periods are also cycles. Third, there is no accepted mathematical procedure to single out all cycles of random form.

The only existing method to single out all the cycles is the oldest analysis method, that of epoch superposition. In the epoch superposition method, the original diagram (e.g. our Figure 1) is cut into pieces of various lengths (periods) and the pieces (epochs) are then superimposed upon one another. If, for any period, the features of its different epochs fail to complement each other, the periodicity is considered insignificant. On the contrary, if features develop and are boldly shown on the combined diagram the period is considered essential. Epoch superposition analysis has a host of different variants, but we shall use the strictest one which is based on analysis of variance, one-way classification.

Unfortunately, the possibility of singling out random-form cycles leads to some substantial defects of the epoch superposition method, against which we must be on guard even as we use it.

1. As stated above, the method enables us to single out double and threefold cycles. At the same time, in a number of cases, it singles out cycle components with fractional periods – T/2, T/3, etc.

2. It is possible to work out evaluations possessing adequate precision only for time periods which coincide with two-fold, three-fold, n-fold intervals between observations (20, 30, 40 years etc.).

3. The values obtained by epoch superposition will characterize an interval of $T-0.5T^2/N$ up to $T+0.5T^2/N$ (mostly from $T-0.3T^2/N$ up to $T+0.3T^2/N$). (N=2200 years – the total observation time.) For example, the value at the point where T=400 years in fact covers periods of 365 to 435 years (mostly 380-420 years), and the value at the point of 40 years actually covers periods 39.65 to 40.35 years. This constraint means that we cannot observe the majority of possible short periods by epoch superposition. We shall use it only for detecting the longer periodicities.

In Figure 19 is shown the spectrum obtained by the epoch superposition method. Once again, since the investigated process differs drastically from white noise, the process requires reductions to evaluate the level of significance of the peaks found. We shall restrict ourselves to reducing the spectrum by the Markov process (Fig. 20).

The most significant peaks coincide with periods of 380 and 320 years. In addition, there are five peaks of lesser value – 170, 250, 630-640, 750-770 and 940-990 years.

Our main purpose is to separate independent cycles from those formed by doubling or tripling independent cycles, or by superimposing several independent cycles of different duration. Another wording of the same problem is that it is necessary (Figures 15-18) to distinguish genuinely independent cycles from harmonic components obtained by the decomposition of independent cycles.

The main supposition which we use as our starting point in solving this problem is that independent cycles have one maximum and/or one minimum value of the configuration index. In other words, we leave out all cycles during which there are two or more steps in the direction of centralization or decentralization. We consider them to be combinations of shorter periodicities, whether these are obvious or hidden.

Of course, we do not deny that more complicated cycle processes may take place in history during which two or more similar phenomena (“stages”) can be observed in one and the same cycle. For example, there is a hypothesis of a two-step character in the process of a technological phase. This hypothesis proposes that a technological phase passes through two upward waves, the first of which takes place at the start of its life cycle and is connected with the technological breakthrough, as such, while the second occurs at the beginning of the second half of the cycle and is associated with society's nascent readiness to accept and profit from the new technologies. In our view, the characteristics of the political process typical of Indic civilization, considered earlier in this article (i.e. the reversibility of change and the routing of political change through the nodes of Bipolarity and Unipolarity), make the existence of such multi-step political phenomena highly improbable.

Let us consider in this light the main cycles in Figure 20. They are shown in Figure 21, in which the bold blue line shows smoothed curves. It is clear that only those cycles with 320 and 380 years duration wholly satisfy our criterion of a single peak or a single minimum. The remaining cycles in Figure 21 can be divided into two groups. The first one consists of cycles in which it is impossible to single out any "one-humped" form. The group includes the cycles of 250 and 760 years duration. According to the our criterion stated above, we consider them to be combinations of simpler cycles. The second group contains the cycles with periods of 170, 640 and 990 years. These do suggest, beneath many irregularities, the existence of a simple "one humped" form. Conceivably they may contain, and conceal, a simple cycle. However, the significance of all the cycles of the second group exceeds 30%, which does not allow us to consider them as plausible.

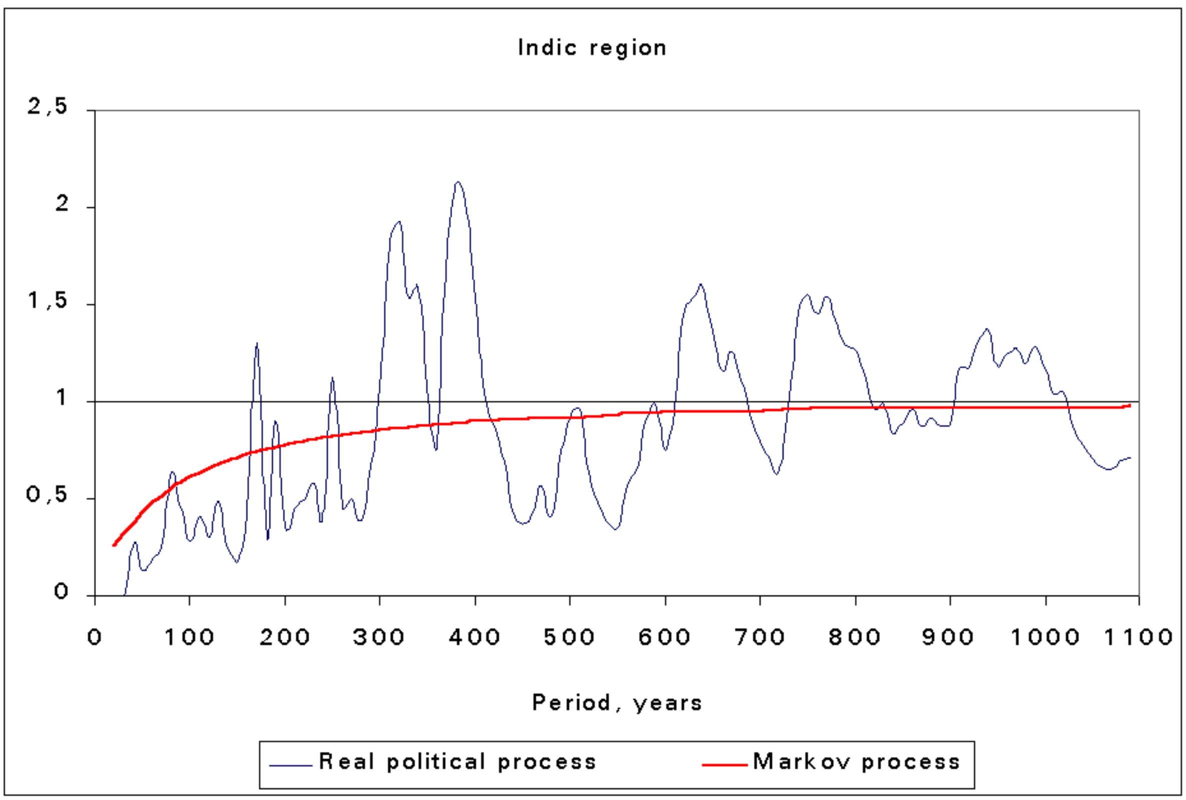

Figure 19. Epoch superposition spectra of index of configuration for the Indic world system

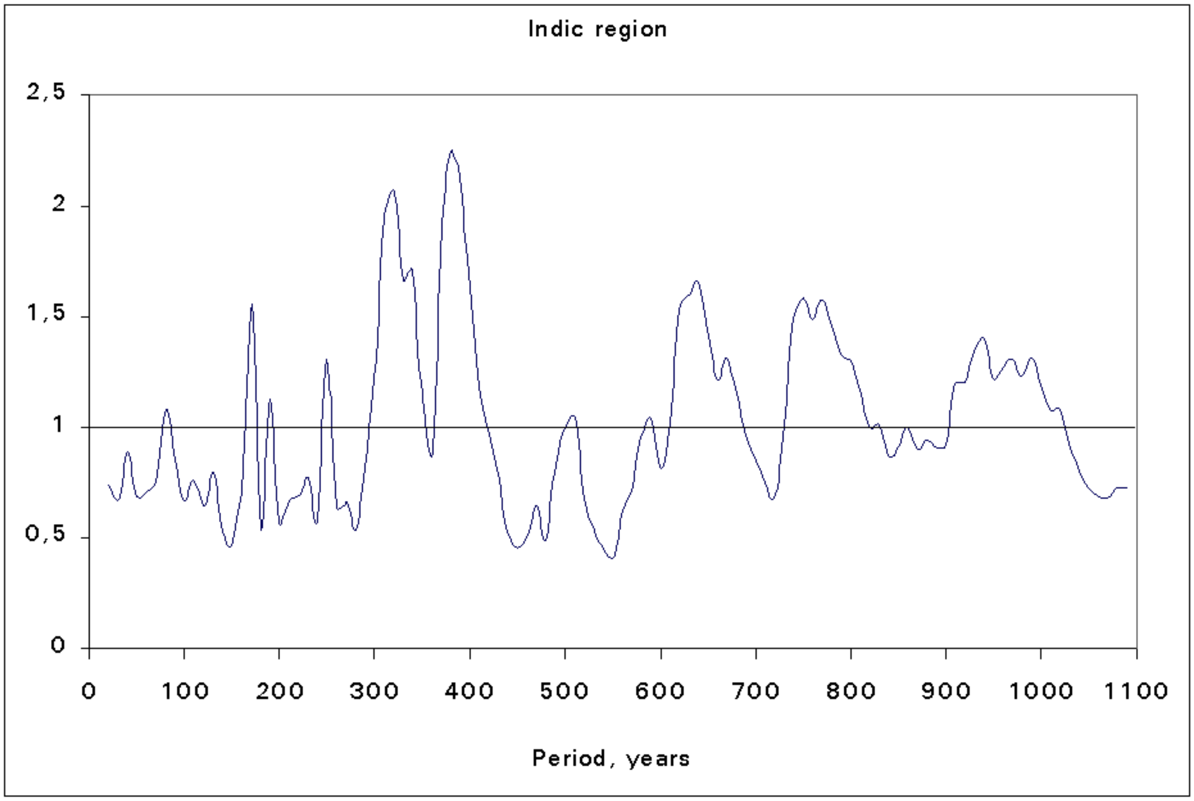

Figure 20. Reduced (by Markov process) epoch superposition spectra of index of configuration for the Indic world system

The 320-year cycle is nearly a sinusoid, hence a second harmonic (component) with a period of T/2=160 years does not appear in the spectra of Figures 17 and 18, while the third harmonic, with a period of T/3~105 years, has a very small amplitude. The 380-year cycle has a form which is not similar to a sinusoid, hence harmonics with periods T/2=190 years, T/3~125 years and even T/6~63 years are clearly shown in the spectra. The discovery of higher harmonics essentially changes the power and significance of cycles.

It will be observed that in Figure 19, by contrast with Figures 14 and 15, the second (380) cycle is more powerful than the first. In Figure 19, the significance of the cycle with a period of 320 years is equal to approximately 8-9% (vs. 18% in Figure 15), whereas the significance of the cycle with a period of 380 years is equal to 15% (vs. 25% in Figure 15). We consider these results the final test of the existence of the approximately 350-year cycle which was first mentioned in the analysis of the index of concentration (Table 13). A more detailed analysis of the nature of these cycles will be carried out later, in the "Discussion." At this point we shall consider the intensities and durations of our cycles during 2200 years of Indic history.

Time-spectral analysis (TSA). Cycles whose intensity varies over time, or which occur only during a part of an entire observation period, may be examined via TSA, time-spectral analysis. Time-spectral analysis is spectral analysis within a sliding time window, such that a number of Fourier spectra are generated, one for each location of the sliding window. Time-spectral analysis produces a TSA-diagram, which appears as a pattern of points. The vertical axis represents the various frequencies or periodicities whose importance in the time-series data is to be investigated. The horizontal axis represents calendar time, and for each point which appears on the diagram, its location on the horizontal axis corresponds to the center of a time window. Each column of points can be matched in one-to-one correspondence with the Fourier amplitude spectrum for the portion of the data trace that falls within the window centered at that moment in time.

Thus each locus on the TSA diagram refers to a particular periodicity (the value at the vertical axis) and a particular moment (the value at the horizontal axis). The more intense the black color on the TSA-diagram at a given locus, the higher the spectral amplitude found for the period in the window centered at that moment, i.e., the more strongly does a cycle of that periodicity appear in that window.

TSA-diagrams may show more or less prolonged dark horizontal stripes, reflecting relatively intense processes at the frequency of the stripes. The beginning and end of such stripes indicates the beginning and ending, therefore the limited lifetime, of such processes. A characteristic interpretation of a TSA-diagram might assert that one or more "components" (oscillations of specific durations) were predominant in the frequency spectrum of the time series under study, either overall (continuous horizontal stripe), or in a particular period (broken stripe), suggesting respectively the presence of a persistent process or a transitory process. Different shadings distinguish pronounced rhythms from less marked or only faintly visible ones.

The width of the window for TSA is chosen on the basis of the accuracy demanded of the investigation, and the frequency-components of interest to the investigator. Narrow windows lose information about weak, low-frequency "long wave" phenomena, but are useful for exploring high-frequency component processes of the composite process under study, i.e. short, powerful cycles. Wide windows detect long waves better, but overlook short-term phenomena. Wide windows are also useful for detecting stable, weak rhythms of any duration. Window sizes of 0.25 to 0.33 the length of the time-series under investigation are standard, and in the Indic case revealing. Figure 22 gives the TSA-diagram for the initial (not the reduced) spectrum of the Indic system with a window size of 25% of the full time series, i.e. a window of 550 years.

A dark horizontal band at a period of 300-400 years, 225 BC to about AD 600, is broken in the period AD 600 to 1200-1400, and then returns more weakly. The band shows a somewhat stable (long-enduring) periodicity of that duration: recall the periodogram's 393 and 325-year rhythms, which here appear locally concentrated. Weaker rhythms with shorter periods of 150-200 years, not strongly shown in the periodogram, appear in the TSA-diagram only during the break. A 600-700 year rhythm is marked only in the 2^{nd} millennium AD.

Figure 23 gives the Indic TSA-diagram for a 33% window, i.e. 733 1/3 years, employed in this case to search for weak but stable cycles.. The shortest cycles (25-30 years), or several cycles with nearly the same period, are shown after AD 300. The cycle closest to the Kondratieff cycle (the period of 55-60 years) is shown after AD 600; before that, a cycle with the unstable period of 75-90 years is found. All these cycles were detected by the periodograms; however, the TSA-diagram localizes them to various time-periods. Thus time-spectral analysis has improved the accuracy of our description of the cycles discovered in the changing pattern of Indic political-power configurations.

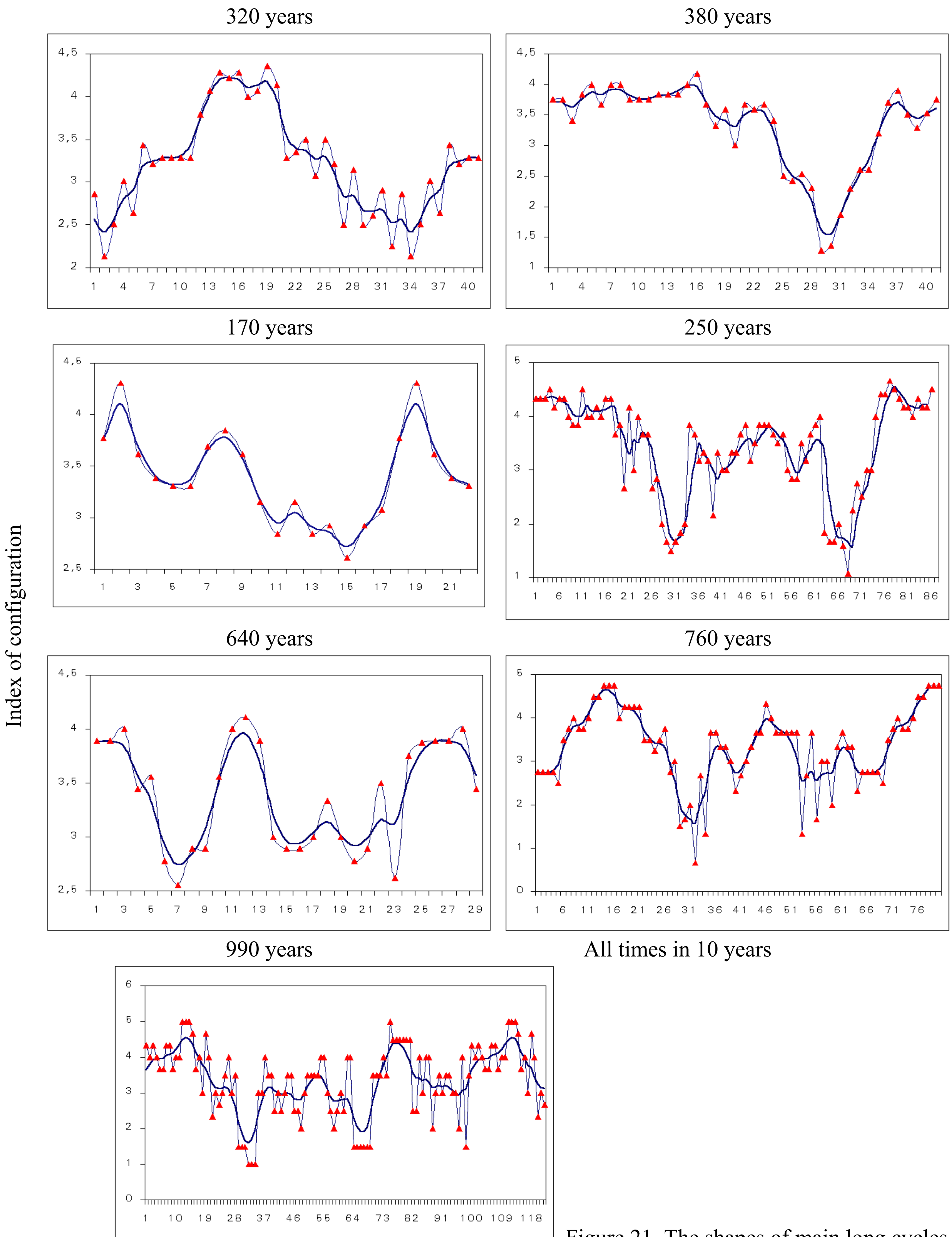

Figure 21. The shapes of main long cycles

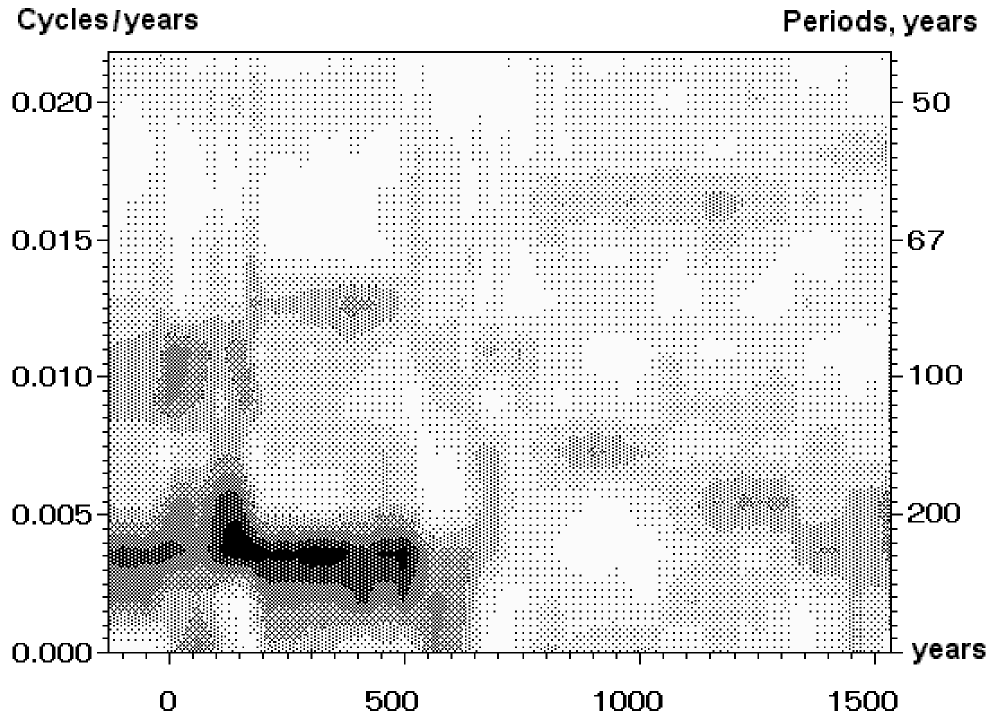

Figure 22. TSA-diagram for the Indic system (the width of the window is 25 % of the entire time series)

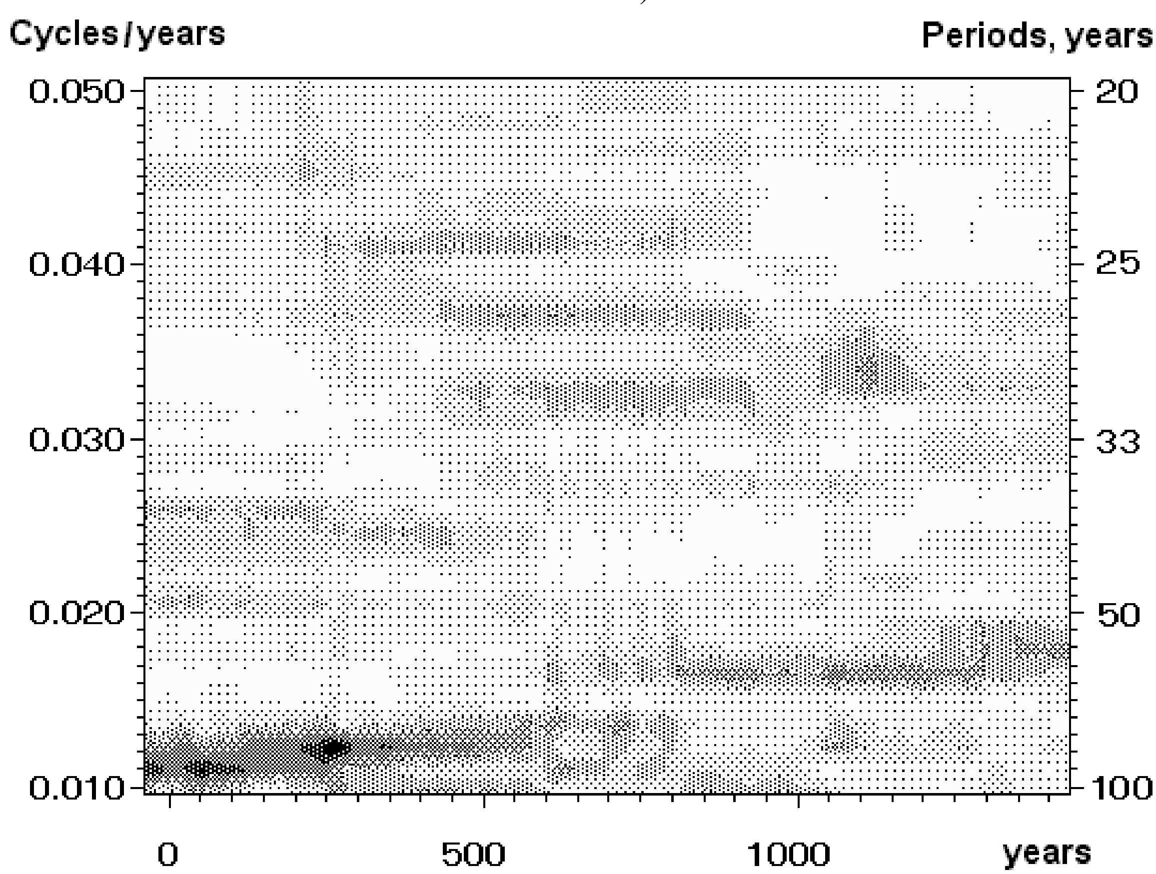

Figure 23. TSA-diagram for Indic region (short periods, ~20-100 years: the width of the window is 33% of the entire time series)

As a check, we have performed an analogous time-spectral analysis using the epoch superposition method. Figure 24 is a TSA-diagram for the Indic system constructed by epoch superposition. It further shows the presence of short cycles of the length of 1-3 generations.

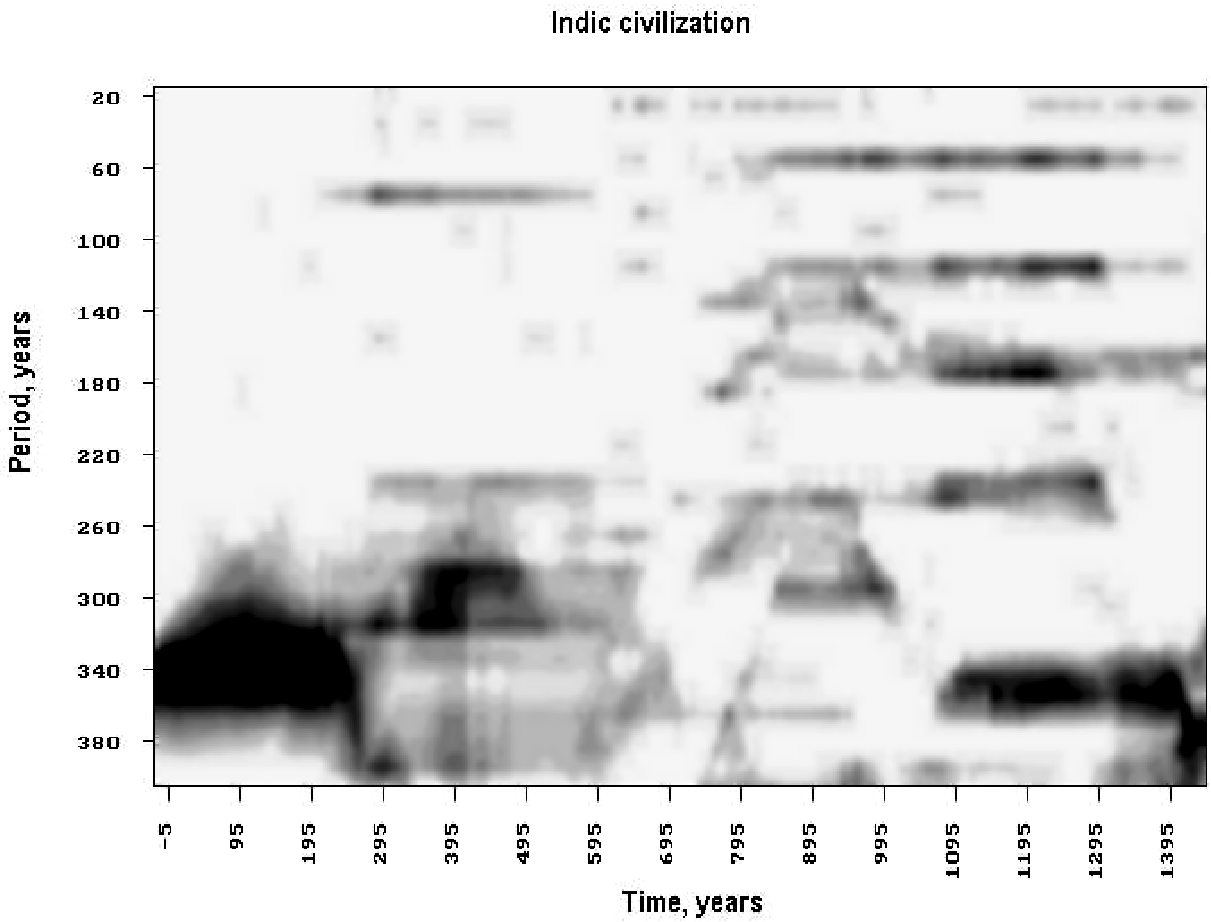

Figure 24. Epoch superposition TSA-diagram for the Indic world system

Discussion. We have located a number of apparent cycles of change in the political configurations of Indic world-system. But what is their significance?

The apparent significance of inductively-located cycles is less than that of hypothesized cycles tested for. We began with no hypotheses; but theories exist which would provide such. Are any of interest? Let us first consider the relations between long cycles alleged in various literatures, and the long cycles possibly significant in the Indic data, i.e. those of 300-400 years, 170 years, 900-1000 years and 600-700 years.

The most pronounced discovered long cycle, that of 300-400 years, is reminiscent of 150-300 year demographic and dynastic cycles located in other world-systems, but it exceeds them in its duration. This cycle is most evident in variations in the index of concentration, whose is 0 during diffused-power Multipolar and Nonpolar periods, and 1 during Tripolarity or any greater concentration of power. According to Indian mythology, 360 years equal a year for the Gods; alas, no empirical connection seems to connect deity with concentration. We shall have to try to construct an explanatory mechanism.

The cycle we have found has two forms and two periods. The more powerful cycle form structure with a period of 380-390 years means approximately 300 years of presence of poles of force and 50-100 years of their absence. The less powerful cycle form structure with a period of 310-320 years reflects sinusoid oscillations of the political configuration among unipolarity, bipolarity and tripolarity. The analysis of separate intervals of time shows existence only one of these periods at any given moment, i.e., they do not exist simultaneously (see Figures 5 and 24): short cycles (310-320 and less years) are found only in the middle of the observation set (in the first millennium AD), while longer cycles (350-400 years) are found only early or late in the observations. For there to exist two truly independent periods of almost equal length which by chance never coexist seems too hard to believe for real history, where all the phenomena are interconnected.

Accordingly, in spite of the differences between them, we think that these two are simply variants of one and the same cycle. We propose that the differences between these two variants can be explained by two linked causes, which embody two peculiar features of the Indic system: its preference for unipolarity and bipolarity; and the loose linkage between the Indic states and Indic society. First, part of the cycle is precisely constituted by the peculiarly Indic oscillations between unipolarity, bipolarity or, more seldom, tripolarity; the duration of the cycle of concentration is then determined by the duration of the most stable pole or poles of force. Second, the considerable self-dependence of communities allowed for preserving the way of everyday life even during the periods when poles of force were being destroyed, which in turn promoted the continuity of the process of the formation of poles of force.

The shorter and weaker cycle of 170 years, judging by the form and values of the configuration index, is in our opinion of the same nature. Its duration corresponds to the duration of demographic and dynastic cycles located in other world-systems. But, in contrast to such, in the Indic world-system this cycle is expressed in a weaker form, so much so that we have no reliable grounds to prove its regular character.

What of the 900-1000 year cycle? The happy Biblical millennium (Revelation, XX, 2-7) has an apt length, but does not otherwise seem to fit the Indic case. Nor does Spengler's (1926) full life-cycle of pre-Culture, Culture and Civilization, a 1900 to 2200-year progression from folk to feudality, aristocracy, nation-state, revolution, bourgeois money-power, Caesarism, bureaucratic empire, and ossification. Some of Spengler's other numbers, such as his "ideal" duration of one millennium per culture--actually 800 to 900 years in the Cultures he inspects--and his 300-year ideal duration--actually 300-350 years--of the state-form of "Late Culture"; the 50-year rhythm of giant wars—have periods close to those we have seen in the Indic system, but no obvious relevance to the actual history of that system (which Spengler indeed does not anatomize politically: see 1926:101 and his tables II and III). We would propose that in Indic history a thousand-year cycle (if it really exists—we lack sufficient probative evidence to assert its existence with confidence) is a cycle of short bursts of domination rupturing the oscillations between unipolarity, bipolarity and nonpolarity.

What of the intermediate long cycle of 600-700 years which appears in Figures 12, 13, 15, 16, 19, 20, 21, and late in Figure 22? It is reminiscent of the proposal of Iberall and Wilkinson (1987) of 200-1200 years, with approximately a 500-year (logarithmic) mean, as "the major scale for macrosocial and macropolitical change" (1987: 36-37), more specifically for enculturation and deculturation, formation and loss of social coherence, cultural turnover (1991: 92-94). The period of 600-700 years is close to the average value of this time lag. The empirical cycle is one in which the system acquires and loses a central control, alternating between central domination and local autonomy; not a total misfit to the theory, but not entirely illustrative of it either. An alternative explanation is that this apparent rhythm is actually a composite artifact made up, on the one hand, of a shortened unity cycle in the second millennium AD, and on the other hand, of a doubled and intensified cycle of concentration.

Let us next consider the relation of the apparent short Indic cycles (27, 57 and 83 years) to existing literatures. The three short periods correspond, approximately, to 1, 2, and 3 generations. It would seem at first glance as though generations could hardly be relevant at the world-system scale: although the process of generational replacement in every separate family is clearly cyclic, in great communities the replacement occurs as a continuous process. However, from the point of view of history (and demography), great historical events proverbially impart cyclic characteristics to systemwide generational replacement. Great systemwide events (wars, revolutions, economic crises etc.) form discrete "generations of consciousness" who possess their own historical memories, principles, habits and characteristics.

The phenomenon of discrete generations has a number of manifestations. Spengler (1926: 110n) is not the only one to allege that the generations of grandparents and grandchildren are usually more similar than those of parents and children. American third-generation immigrants are stereotyped to take a greater interest in their first-generation roots than the second generation. Easterlin (1980) documents and analyzes the alternation of numerous and scanty generations in the history of the USA. Turchin (2003) proposes an approximately 50 year cycle in the intensity of internal wars; we have mentioned Spengler's use of the same period for systemic wars. Similar periodicities have been noted in the history of technological revolutions (e.g. Schumpeter, 1939 affirmed the utility of the near-60 year Kondratieff cycle), and quite possibly the phenomenon of "social generations" lies at the root of Kondratieff waves too.

In the political history of the Indic civilization the 25-30 year rhythm is more noticeable then that of 50-60 years. In Figures 17-18 it is the most powerful cycle. A noteworthy one-generational rhythm is proposed for the USA by Schlesinger (1986), an alternation of public purpose and private interest, which involves a jostling back and forth between rivals who persist and are not ousted nor absorbed. Iberall and Wilkinson (1987) identified the 1-generation social timescale as 20-30 years, likely reflecting near-complete turnover in the command-control positions in society. The existence of several peaks (23.1, 24.6, 26.7 and 30.7 years) may be due either to the actual differences of the time of generations' appearance or simply to the inexactitude of our estimations (the interval between observations is equal to 10 years).

One of the most important mechanisms producing shortened waves is determined by the status of a side which suffered defeat. In many cases this side (state, social stratum etc.) does not play any further role in history, being assimilated by the victorious side, exiled or exterminated. But if the defeated side remains historically important, then it is this side which forms the shortened cycle--children avenge the parents (literally or allegorically). It is of interest that there seems a certain "softness" in the Indic history of political struggle, as compared to that of other civilizations: perhaps one should view the Indic short cycles as involving more "jostling" than "avenging." Perhaps in America the softness of political struggle leads to the above mentioned Schlesinger cycles, whereas the severity of economic competition leads to the near 60-year Kondratieff cycle.

The mechanism of the early, unstable 75-90 year long cycle is hard to theorize. Iberall and Wilkinson (1987) identified a 70-90 year timescale with a near-complete turnover in the social population; perhaps the loss of experience and social memory of prior configurations reduces resistance to their return. Alternatively, it may be an artifact, composed of a random (or not quite random) alternation of full cycles (2 generations) and shortened cycles (1 generation).

A fourth relatively short cycle of 125 years was seen in Figures 15-18, and late in Figure 24. In our opinion, this is, first of all, the third harmonic of the 380 year cycle and so has no importance of its own.

The presence of short cycles (at least the 1 and 2-generation cycles) is more pronounced in the Indic data in more recent times. This peculiarity can either be treated as the real consequence of an acceleration of historical processes, leading to more distinct differences between generations, or it may be ascribed to our lack of information on the short processes of ancient times.

To the extent that we consider the compatibility of the inductively-discovered patterns with existing theories, we may take a bolder approach to the estimation of the significance levels of the patterns. If we were to suppose that we have not found new maxima in the spectra, but have tested previously chosen periods, then to calculate the significance level of the findings it is possible to use not the formula of Walker (1914), but those of Schuster (1898) or Fisher (1929). Such an approach would drastically change the estimations of our cycles' reliability (Table 14).

Table 14. Recalculated significance of apparent Indic cycles

<table>
<tr><th colspan="3">Period, years</th><th>950 - 1000</th><th>630-640</th><th>380-390</th><th>310-320</th><th>170</th><th>83</th><th>57</th><th>27</th></tr>
<tr><td rowspan="3">Significance level</td><td rowspan="2">Spectral analysis</td><td>Reduced by white and red noise</td><td>.20</td><td>.30</td><td>.017</td><td>.008</td><td>.15</td><td>.02</td><td>.015</td><td>.003</td></tr>
<tr><td>Reduced by Markov process</td><td>.20</td><td>.30</td><td>.011</td><td>.005</td><td>.15</td><td>.04</td><td>.025</td><td>.002</td></tr>
<tr><td colspan="2">Epoch superposition</td><td>(.01-.02)</td><td>(.01-.02)</td><td>.002</td><td>.00025</td><td>(.07-.08)</td><td>-</td><td>-</td><td>-</td></tr>
</table>

The values of the cycles of complicated form found when using the method of epoch superposition are given in parentheses as they include variations due to shorter cycles. The real values must be nearer to those obtained by means of spectral analysis. At the same time, the recalculated significances grow so substantially that our choice between the original and the recalculated significances becomes a very complex question (partly psychological !): here we merely note that the Indic cycles may be quite significant.

Conclusions: unipolarity-bipolarity. The Indic political system is unusual in having been predominantly in either a bipolar or a unipolar power configuration. The dominance of unipolar and bipolar configurations in the Indic case is unique, unmatched in any of 3 other civilizations/world systems thus far studied: the Far Eastern, Egyptian/Northeast African, and Mesopotamian/Southwest Asian (Wilkinson, 1999, 2001, 2004).

Balance-of-power theory, beloved of diplomats, statesmen, and Western international relations theorists, posits multipolarity as a systemic political norm, with occasional deviations toward unipolarity more or less quickly and automatically rectified. The distribution of Indic configurations shown in Table 1 implies failure for any hypothesis that a multipolar power configuration (8 / 221 ≈ 3.5 % of all observations) can have been the Indic norm. The prevalent Indic configurations were bipolarity and unipolarity (143 / 221 ≈ 65 % of all observations), a circumstance which no extant theory of world politics expects. Western international relations theorists have perhaps too confidently assumed the normality of a multipolar states system, with ~5 great powers. In the political configurations of Indic civilization, unipolar and bipolar power structures have been far more prominent, while even tripolar and nonpolar structures have been more frequent, than **"classic"** multipolarity. For the Indic system, at least, a plurality of more or less **"normal"** phases (such as are posited generally for all **"international systems"** by Kaplan, 1957) must be admitted, and provided for by appropriate theory. None such now exists; one must accordingly be constructed.

What might explain the bipolar-unipolar predominance? Since it is unique, we ought to look for individualities of the Indic system. There are many well-known, special features of Indic civilization—the friability of most Indic states, the presence of non-state polities, the importance of castes, communities, and associations of communities in maintaining order and carrying out other functions elsewhere more commonly in the purview of the state — but none of these would self-evidently imply a unipolar-bipolar configuration. Rather they would seem to tend toward nonpolarity. Nonpolar configurations are indeed significantly present in the Indic configuration set, and more so than in any other thus far studied — but only at a rate of 17/221 ≈ 8 %. Of course, we must take notice that Indic power-bipolarity and unipolarity were likely less important in the daily lives of people than would have been the case, say, in China, where the state tended to regulate all human activity: everyday life under Indic unipolarity might thus have resembled everyday life under Sinic nonpolarity, even while, at the level of high politics, matters would have been dramatically dissimilar. (Cf. Bozeman, 1960:120-121, 429; Thapar, 1978.)

We suspect that another special feature of the Indic world system should be called on to account for its equal bias toward bipolarity and unipolarity. The Indic world system, like all others, inhabited a geographically distinctive region. It is equally commonplace to speak of the India as a whole and to assert the distinctiveness of North and South. Perhaps this reflects an approximately equal geopolitical and geocultural capacity for political unification at the Indic system level, and for North vs. South political fracturing with political unification only at the regional level, over and above the local community level of social organization. The individuality of the Indic world system is then in the coexistence of two regions, each relatively welcoming to a preponderant power, with an interregional barrier impeding, but not entirely preventing, the attainment of systemwide preponderance. Alternatively, the bipolar-unipolar predominance might reflect the coexistence, competition and changing influence of different religions-- Hinduism (Brahmanism) vs. Buddhism in the first millennium AD, Hinduism vs. Islam in the second millennium AD.

Conclusions: Poisson vs. Markov process. Research has shown that, in first approximation, the sequence of the change of political power configurations of the Indic world system closely resembles a Poisson process, i.e. the probability of every configuration change is nearly independent of the longevity of its existence. This statement makes rather dubious the validity of well-known theories on the stages of political development, at least as applied to Indic civilization. On the other hand, it agrees rather well with independent findings concerning war durations.

However, a more detailed analysis shows that some substantial departures from the Poisson process have also been registered in the Indic system. The various Indic configurations are unequally durable. This fact suggests the need for a Markov analysis; and in fact, a first-order Markov process is found to have been operating in the Indic system, following rules invariable over two millennia. Almost every transition is to, from, or between Bipolarity and Unipolarity. Furthermore, the transition pattern of the Indic system is nearly symmetrical: rather than progressive or (at this timescale) cyclic: the Indic power transition process is a continuous gaining and losing of bipolarity and unipolarity.

What is the reason for such unexpected properties of Indic world-system history? We believe that the answer is twofold.

1. Historical matches to the Poisson process are not so alien to real history as one might imagine, nor are they restricted to Indic history: Poisson-like onsets, terminations and durations of wars were found in 19th and early 20th century data for the entire globe (Richardson 1960). This kind of history very likely constitutes the background against which rise, develop and disappear other, more remarkable--and therefore better known--structures, events and phenomena. It seems to reflect a historical persistency of probability which could be called an alternative "longue durée" to that of Braudel; for while Braudel was interested first of all in very slow rhythms, waves so long in varying that they functioned like structures to short-lived human beings, this is more like the "longue durée" of a medieval chronicler who thoroughly noted all political events, the varying intervals between the deaths of kings, the falls of empires, the comings of plagues and fires and famines, always possible, eventually occurring, but never on schedule.

2. A second reason for the persistence of patterning without much short-term political memory is however linked to the above mentioned peculiarities of Indic civilization--weak states, with a great social role for religion and communities. Indic great powers and even superpowers fought, to a considerable degree, not against other poles of power, but against adjacent small states, inner disruptive forces, and their own weakness. When a superpower crashed, in its place were found not ruins (the case of the Roman Empire), but quite viable principalities. On the other hand, when these were united into a great power or a superpower, political unification did not lead (in the majority of cases) to drastic changes of their inner way of life. Certainly, there seem to be a number of exceptions to this rule, first of all the Islamic and Mughal conquests, yet these little change the statistics of the whole picture, and the conquerors may have been "Indicized" in the same way that conquerors of China have been "Sinicized." Furthermore, these Indic peculiarities may have been unusual only in their extreme duration—we think they can be found (perhaps to a lesser degree) in the medieval history of Europe, and in the history of Russia between the Kiev princedom and the Moscow kingdom. The idea of a system history that is only weakly "politicized" seems worth further analysis, probably by civilizationists.

Conclusions: spectral analysis and cycles. A more detailed spectral analysis shows that there are some significant elements to the Indic system's behavior which are not captured by first-order Markov process analysis. There is at least sufficient evidence to suspect, and to search historico-archaeologically for, the existence of periodic processes driving political-structural change in the Indic world system at several periodicities. One long and three short cycles stand out most clearly.

1. The most pronounced is a long-wave process (~300-400 years), present especially before AD 600 and after ~AD 1300. This cycle has two form - (a) the system maintains a high degree of concentration of power in a few centers for a substantial period (~300 years) and then briefly (10-100 years) loses structure before regaining it; (b) the system executes oscillations between unipolarity, bipolarity or, more seldom, tripolarity

2abc. There are three short-wave processes, approximately 1, 2 and 3 generations long respectively, in which change in the system structure may be driven, again respectively, by actual generational demographic processes, subjective (generation-consciousness) and/or objective (political elite turnover, capital stock turnover, and population turnover).

Much more tentatively, three more long cycles can be distinguished:

3. A long-wave, weak process (~900-1000 years) of oscillation between on the one hand, a world politics that revolves around one single chief actor and its relations with the rest of the system., and, on the other hand, a more pluralistic and regionalistic systemic politics.

4. A second long-wave process (~650 years), which we suspect may be a combination of a shortened type (1) and a doubled type (2) long-wave, in which the system acquires and loses a central control, alternating between central domination and local autonomy.

5. A third long-wave process (~170 years), possibly associated with a dynastic cycle, but more likely a shortened variant of the 300-400 year process.

Though the long cycle types (1), (3) and (4) all fall within the expected bounds of cultural turnover times, there is likely some other or additional driving process. Plausible suspects might be a demographic cycle, an ecological/climatological cycle, a war cycle, or some combination of these. It may be noted in this connection that several types and epochs of demographic decline have been noted for Indic civilization (Chandler 1987; Wilkinson, 1995b): there were declines in the number of large Indic cities in the intervals AD 100 → 361 → 500, AD 622 → 800, and AD 900 → 1000 → 1100 → 1200; declines in the size of the largest Indic city in the intervals 200 BC → AD 100, AD 361 → 500, AD 622 → 800, and AD 1100 → 1200. In AD 100 → 361 → 500, there was a very high replacement (turnover) rate in the list of the largest Indic cities. The same occurred AD 900 → 1000 → 1100 → 1200; and there was a major decline in the total Indic urban population AD 1100 → 1200. One may say that there was, overall, clearly a long demographic crisis in the Indic system in the period AD 100-500, and another AD 900-1200. The first of these was linked to a broader Old World crisis, what Gills and Frank (1996) call a “B phase” of a long economic cycle; the second was confined to India. The relations between these long economic-demographic phenomena and the longer political rhythms seem worth further investigation. In our opinion, the use of wavelet analysis should be the next main method for a finer analysis of the cycle structure. And it should be worthwhile to reinspect the underlying history in search of causes that might account for the most marked processes (~300-400 years and the three short cycles).

Appendix

The data series resulting from our coding of Schwartzberg is given below, with a date, a configuration code, the associated name of the power configuration as of that date, and (except for nonpolar moments) the names of the polar states.

DATE	CODE	POWER CONFIGURATION	POLAR STATE(S)
550 BC	4	Unipolar	Kashi
500	4	"	Kosala
450	3	Bipolar	Magadha, Avanti
400	5	Hegemonic	Magadha
390	5	"	"
380	5	"	"
370	5	"	"
360	5	"	"
350	5	"	"
340	5	"	"
330	5	"	"
320	4	Unipolar	"
310	4	"	"
300	4	"	"
290	6	Empire	"
280	6	"	"
270	6	"	"
260	6	"	"
250	6	"	"
240	6	"	"
230	6	"	"
220	6	"	"
210	4	Unipolar	"
200	4	"	"
190	4	"	"
180	3	Bipolar	Magadha, Bactria
170	4	Unipolar	Magadha
160	3	Bipolar	Magadha, Bactria
150	4	Unipolar	Magadha
140	3	Bipolar	Magadha, Gandhara
130	4	Unipolar	Magadha
120	0	Nonpolar	--
110	0	"	--
100	0	"	--
90	0	"	--
80	0	"	--
70	0	"	--
60	4	Unipolar	Indo-Parthians
50	4	"	"
40	4	"	"
30	3	Bipolar	Indo-Parthians, Mulaka
20	3	"	"
10	2	Tripolar	Indo-Parthians, Mulaka, Kalinga
AD/BC	3	Bipolar	Indo-Parthians, Mulaka
AD 10	3	"	"
20	3	"	"
30	3	"	"
40	3	"	"
50	4	Unipolar	Mulaka
60	4	"	"

70	3	Bipolar	Mulaka; Kushanas
80	3	"	"
90	4	Unipolar	Gandhara
100	4	"	"
110	4	"	"
120	4	"	"
130	4	"	"
140	4	"	"
150	2	Tripolar	Gandhara, Surashtra, Mulaka
160	2	"	"
170	2	"	"
180	3	Bipolar	Gandhara, Mulaka
190	3	"	"
200	3	"	"
210	4	Unipolar	Gandhara
220	4	"	"
230	0	Nonpolar	--
240	0	"	--
250	0	"	--
260	0	"	--
270	0	"	--
280	0	"	--
290	4	Unipolar	Bidar
300	4	"	"
310	3	Bipolar	Bidar, Guptas
320	3	"	"
330	3	"	"
340	3	"	Magadha, Tondai
350	5	Hegemonic	Magadha
360	5	"	"
370	5	"	"
380	5	"	"
390	5	"	"
400	5	"	"
410	5	"	"
420	5	"	"
430	5	"	"
440	5	"	"
450	5	"	"
460	5	"	"
470	3	Bipolar	Magadha, Bidar
480	3	"	"
490	3	"	"
500	3	"	"
510	4	Unipolar	Southern Hunas
520	3	Bipolar	Magadha, S. Hunas
530	3	"	"
540	3	"	Magadha, Malwa
550	0	Nonpolar	--
560	4	Unipolar	Kanyakubja
570	0	Nonpolar	--
580	4	Unipolar	Kanyakubja
590	4	"	"
600	3	Bipolar	Kanyakubja, Anupa
610	4	Unipolar	Anupa
620	3	Bipolar	Thaneswar, Karnata
630	2	Tripolar	Thaneswar, Karnata, Sind

640	2	"	"
650	3	Bipolar	Sind, Tondai
660	3	"	Sind, Karnata
670	3	"	"
680	4	Unipolar	Karnata
690	4	"	"
700	4	"	"
710	4	"	"
720	4	"	"
730	3	Bipolar	Karnata, Kanyakubja
740	3	"	Karnata, Kashmir
750	3	"	"
760	0	Nonpolar	--
770	4	Unipolar	Maharashtra
780	4	"	"
790	2	Tripolar	Maharashtra, Bengal, Malwa
800	4	Unipolar	Maharashtra
810	4	"	"
820	3	Bipolar	Maharashtra, Malwa
830	3	"	"
840	3	"	Maharashtra, Kanyakubja
850	3	"	"
860	3	"	"
870	3	"	"
880	3	"	"
890	3	"	"
900	2	Tripolar	Maharashtra, Kanyakubja, Gandhara
910	2	"	"
920	2	"	"
930	2	"	"
940	2	"	"
950	4	Unipolar	Maharashtra
960	4	"	"
970	4	"	Gandhara
980	3	Bipolar	Gandhara, Malwa
990	3	"	" "
1000	2	Tripolar	Gandhara, Malwa, Ghazni
1010	3	Bipolar	Malwa, Ghazni
1020	4	Unipolar	Ghazni
1030	4	"	"
1040	1	Multipolar	Ghazni, Malwa, Dahala, Chola
1050	1	"	Ghazni, Dahala, Chola, Karnata
1060	1	"	"
1070	3	Bipolar	Ghazni, Karnata
1080	3	"	"
1090	3	"	"
1100	3	"	"
1110	3	"	"
1120	4	Unipolar	Karnata
1130	4	"	"
1140	4	"	Gujarat
1150	3	Bipolar	Gujarat, Kashi
1160	2	Tripolar	Gujarat, Kashi, Rajputana
1170	2	"	"
1180	3	Bipolar	Kashi, Rajputana

1190	2	Tripolar	Kashi, Rajputana, Ghur
1200	4	Unipolar	Ghur
1210	4	"	Delhi
1220	3	Bipolar	Delhi, Maharashtra
1230	3	"	"
1240	3	"	"
1250	3	"	"
1260	3	"	"
1270	3	"	"
1280	3	"	"
1290	3	"	" "
1300	4	Unipolar	Delhi
1310	5	Hegemonic	"
1320	4	Unipolar	"
1330	5	Hegemonic	"
1340	4	Unipolar	"
1350	4	"	"
1360	4	"	"
1370	4	"	"
1380	4	"	"
1390	4	"	"
1400	0	Nonpolar	--
1410	0	"	--
1420	3	Bipolar	Delhi, Vijayanagar
1430	1	Multipolar	Delhi, Vijayanagar, Orissa, Bidar
1440	3	Bipolar	Vijayanagar, Bidar
1450	3	"	Malwa, Bidar
1460	1	Multipolar	Malwa, Bidar, Jaunpur, Orissa
1470	3	Bipolar	Bidar, Jaunpur
1480	4	Unipolar	Delhi
1490	3	Bipolar	Delhi, Orissa
1500	3	"	"
1510	4	Unipolar	Delhi
1520	3	Bipolar	Rajputana, Vijayanagar
1530	3	"	Delhi, Gujarat
1540	4	Unipolar	Delhi
1550	4	"	Vijayanagar
1560	3	Bipolar	Vijayanagar, Delhi
1570	3	"	Delhi, Bijapur
1580	4	Unipolar	Delhi
1590	4	"	"
1600	4	"	"
1610	4	"	"
1620	4	"	"
1630	4	"	"
1640	5	Hegemonic	"
1650	5	"	"
1660	4	Unipolar	"
1670	4	"	"
1680	4	"	"
1690	5	Hegemonic	"
1700	5	"	"
1710	5	"	"
1720	5	"	"
1730	2	Tripolar	Delhi, Marathas, Hyderabad

1740	3	Bipolar	Marathas, Hyderabad
1750	3	"	"
1760	4	Unipolar	Marathas
1770	4	"	"
1780	1	Multipolar (7)	Afghanistan, Sindhia, Bhonsle/Nagpur, Holkar, British, Marathas, Mysore
1790	1	"	Afghanistan, Sindhia, Nepal, British, Marathas, Bhonsle/Nagpur, Mysore
1800	1	Multipolar (6)	Afghanistan, Sindhia, British, Nepal, Marathas, Bhonsle/Nagpur

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