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The Paradox of the Planetary Metals

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Abstract—The historical evolution of the traditional correspondences of planets and metals and of knowledge of the planetary arrangements is reviewed. The traditional geocentric sequence of the planets generates not only the sequence of days of the week, whose names are taken from the deities traditionally associated with the planets, but also a ranking by atomic number of the metals traditionally associated with the planets. The probability that this could be coincidental is quite low, about 1/120. Yet this is not a contemporary artifact nor the result of ancient knowledge of unknown provenance. The concept of synchronicity is a possible working hypothesis. Corroboration or refutation of this approach would depend on further research work on other anomalous events, for which the existence of a hidden causal origin is also highly unlikely.

Keywords: planetary metals—meaningful coincidences—synchronicity—astrology—alchemy

Ancient and mediaeval astrology associated the planets with specific metals. The (geocentric) arrangement of the planets in Greek astronomy turns out to match a pattern generated by the ranking by atomic number of the corresponding metals, even though knowledge of such atomic properties came only much later. The probability of such a conjunction is low, less than 1%. One might search for possible relations between some ancient beliefs and scientific knowledge acquired only much later, or one might consider the idea that meaningful interconnections between causally unrelated events may be systematic, as several writers have proposed (Jung, 1973; Kammerer, 1919).

In the following section, the history of the geocentric arrangement of the planets and of the origin of the "planetary week" are reviewed. Then, the history of the assignment of metals to planets is presented, and the correlation of the atomic order of metals with the geocentric distance of the corresponding planets is described. In the last section, the possible implications of these parallel arrangements are discussed.

References to the ancient literature are given in the standard way in square brackets. Most of these texts may be found in recent editions of the "Thesaurus Linguae Graecae" (TLG).

TABLE 1
Ancient Planetary Arrangements

No.	Planetary arrangement	Historical origin
1	Ju Sa Mars Merc Venus	Found in ancient Egyptian texts[a]
2	Ju Venus Sa Merc Mars	Mesopotamian arrangement I[a]
3	Ju Venus Merc Sa Mars	Mesopotamian arrangement II[a]
4	Sa Ju Mars Venus Merc SUN MOON	Attributed to Heraclides of Pontos[b] (4th cent. BC) or Heratosthenes (3rd cent. BC)[b]
5	Sa Ju Mars Merc Venus SUN MOON	No. 5, 6: Archimedean arrangements (3rd cent. BC)[b], 5 was also proposed by Plato (4th cent. BC)[b]
6	Sa Ju Mars SUN Merc Venus MOON	
7	Sa Ju Mars SUN Venus Merc MOON	**The "preponderant arrangement":** Ipparchus (2nd cent. BC), Ptolemy "Planetary Hypotheses" (2nd cent. AD)[b]

Note: Ju = Jupiter; Sa = Saturn; Merc = Mercury.
[a] Arrangement by stellar brightness or according to the order of the corresponding planetary deity.
[b] Arrangement according to supposed geocentric distances.

Geocentric Arrangement of the Planets and the Planetary Week

Ancient Mesopotamian civilizations observed and recorded planetary positions over long periods of time (Neugebauer, 1975). They also developed methods of predicting planetary movements, based on numerical algorithms, and they had an extended system of astrological-religious beliefs (Bouché-Leclercq, 1899; Cumont, 2000; Dicks, 1970). The systematic study of cuneiform texts revealed the existence of several arrangements of the planets, related either to the order of the corresponding planetary deities or simply to their brightness. In Table 1 the first arrangement is Egyptian, the next two are of Mesopotamian origin. There is no indication that the Chaldeans, earlier Mesopotamians or the Egyptians ordered the planets on the basis of (conjectured) geocentric distances (Bouché-Leclercq, 1899: 64). The Mesopotamians had conceived the planetary motions as occurring on the inner surface of the celestial vault. This view was favored by their interest in astrology: if the planetary distances from Earth were unequal, the astrological "aspects" (geocentric angles) could be artifacts.

Greek astronomers, on the other hand—at least those working before the extended syncretism characterizing the Hellenistic period—had developed their spatial models of the "cosmos" under little astrological influence. As shown in Table 1, they sought to use geocentric distance to order the seven planets of the geocentric system, which include the five visible planets (Mercury, Venus, Mars, Jupiter, Saturn) as well as the Sun and Moon.

The development of knowledge about planets and their arrangements, as found in the first Greek texts preceding Hipparchus and Ptolemy, shows the following principal stages. Homer mentions the morning and the evening appearances of Venus [Il. Ψ226, X317], but regards them as two different stars. Demokritus, however, understands that these are two appearances of the same planet. Plato in Timaeus [38d] mentions only Venus and Mercury, while in Epinomis [987b] he gives the complete list of the five visible planets for the first time. We will not consider here the relation between the planets and the gods assigned to them, or the progressive appearance of astrolatry in Greek thought. Much information about this can be found in the cited literature and especially in a related monograph of Cumont (1935). In the Roman period, the names of the Greek deities were replaced by their Latin counterparts.

Diogenes Laertius mentions that Leucippus considered the orbits of the Sun and the Moon to be the outermost and innermost, respectively, while the orbits of the other celestial bodies (not explicitly mentioned) lay between them. Demokritus supposed the Moon to be closest to Earth, then the Sun, and then the other planets (again without further specification) [Hippolitus, Diels-Kranz, 68, A40]. Another source has Demokritus putting the orbit of Venus between Moon and Sun (Dicks, 1970).

These "atomic philosophers" had rejected or simply ignored the advances made by the Pythagoreans (Dicks, 1970), especially knowledge of the sphericity of Earth, which was widely accepted by the end of the 5th century BC (Neugebauer, 1975).

Platonic planetary theory is quite obscure and contradictory. Consequently, several ancient [Macrovius, Comm. I, 19] and contemporary (Bouché-Leclercq, 1899: 106; Taton, 1966: 261) writers have attributed to Plato various other planetary arrangements as well. In the Republic [616–617], Plato has the Moon closest to Earth, then follow the Sun, Venus, Mercury, Mars, Jupiter, and Saturn. In Timaeus [38d,1–7], it is not clear whether the Sun, Venus, and Mercury occupy the same or consecutive orbits.

Eclipses of the Moon show that it is closer to Earth than is the Sun. Hipparchus made the first measurements of these distances in the 2nd century BC. But ancient Greek astronomy could not compute any other planetary distances (Neugebauer, 1975: 647). The ancient Greek writers most familiar with astronomy had agreed on planetary arrangements of the type:

fixed stars Saturn Jupiter Mars ? ? Sun ? ? Moon **Earth**

where the question marks indicate possible locations for Mercury and Venus (the *inner planets*, as they are called today). This framework of possible arrangements was based on the Aristotelian argument that the lower the (angular) velocity of a celestial object, the greater must be its distance from Earth [see, e.g., Aristotle, De Caelo, II, 10]. Almost every one of the possible planetary arrangements, some of which are shown in Table 1, had been proposed by someone.

We do not know exactly when the finally accepted planetary arrangement (Table 1—no. 7) was put forward, or who proposed it. Undoubtedly, its complete dominance from late antiquity on is related in part to the adoption of this arrangement by Ptolemy in his "Planetary Hypotheses". However, even earlier, Cicero [De Divinatione II, 43], Vitruvius [Architecture, IX, 1,5], and

Pliny [Naturalis Historia, II, 8] took it for granted. Ptolemy comments that "the older astronomers" placed Venus and Mercury inside the solar orbit, while the more recent ones placed them outside [Almagest, IX, 1]. He mentions, as an argument put forward against inner position, the absence of transits—the passages of a celestial object in front of the solar disc, as observed from Earth. Only later, in the "Planetary Hypotheses", does he correctly consider the Sun's brightness as a possible cause of the invisibility of transits.

The second part of the first book of Ptolemy's "Planetary Hypotheses" has only recently been found and published (Goldstein, 1967), based on an Arabic translation. There, Ptolemy gives the full argument for his aforementioned choice. Using the absolute terrestrial distances of Moon and Sun and the ratios (eccentricities) of maximum-to-minimum distances from Earth, computed in the Almagest for all planets, Ptolemy realized that the given arrangement (Table 1—no. 7) for the orbits of Mercury and Venus allowed him to "fill" the space between the Lunar and Solar orbits without leaving "empty" space. Extending this principle of completely "filling" the interplanetary space with orbits, beyond the Sun to the outer planets, Ptolemy obtained an estimate for the distance of the sphere of the fixed stars as next to the orbit of Saturn. This picture of a universe consisting of a sequence of nested planetary spheres dominated Islamic and Western mediaeval astronomy, and it remained the guiding principle in Kepler's writings. Interestingly, however, only recently has Goldstein's work found incontrovertible evidence for its origin (for detailed discussion see Neugebauer, 1975: 690–698, 917–922).

This planetary arrangement is reflected in the order of the days of the week that is still in current use. The planetary week is a continuous succession of seven-day time intervals in which every day is dedicated to a planetary deity. It seems to stem from the Hellenistic era, no earlier than the 2nd century BC (Bouché-Leclercq, 1899: 482; Cumont, 2000: 130). The Latin day-names characteristic of the planetary rulers of the days are: *dies Solis/dies Lunae/dies Martis/dies Mercurii/dies Jovis/dies Veneris/dies Saturni*, and they remain very similar in most contemporary languages of Latin origin but are replaced by Teutonic deities in Teutonic languages (Tuesday for Tiu, the Germanic god of war and sky [= Mars]; Wednesday for Woden; Thursday for Thor; Friday for Frida).

There is a clear difference between this "planetary week" and the Chaldean seven-day week that corresponded to one fourth of the Lunar month. Thus, in the Chaldean system, weeks did not succeed one another continuously. There is no clear indication of any planetary association with the days of the Chaldean week. A seven-day week is also met in Genesis.

Ancient Egypt was the cradle of an extended system of assigning time intervals to the domination of deities (chronokrators), but Egyptian chronokrators were not *planetary* gods (Bouché-Leclercq, 1899: 478). These time intervals formed nested hierarchies with chronokrators at all levels, up to the so-called "spirits of hours". This complex system was mainly utilitarian, aiming to determine the most "favored" time for every activity. There is clear evidence that the system of chronokrators was combined with Chaldean astrology more than once during the period of Hellenistic and the Roman syncretism (e.g., in the system of Terms [lat. Termini], see Bouché-Leclercq, 1899: 206–215).

The planetary week seems to be the product of a convergence of three cultural traditions: Chaldean astrology, Egyptian Chronokrators, and Greek astronomy. The result is that the Chaldean planetary deities play the role of "spirits of hours", combined with the order of planets as provided by Greek astronomy. The division of day and night into twenty-four hours is also an Egyptian legacy.

The succession of the planetary names of the days can be produced in two equivalent ways. The first is based on the horary rulers (Cassius Dio, Historiae Romanae, XXXVII, 19): The first hour after sunrise of the first day of the week is under the domination of the Sun, and the same holds for this day as a whole. In the same day, second, third, fourth, and fifth hours are attributed to Venus, Mercury, Moon, and Saturn going over the planets in decreasing geocentric order. After the twelve diurnal and the twelve nocturnal hours of *dies Solis* (Sunday), continuing in the same way, the first hour after sunrise of the next day will be dedicated to the Moon, which will rule the whole day, thus called *dies Lunae* (Monday), and so on until the completion of the entire week. This method of assignment of horary and daily chronokrators is also mentioned by Vettius Valens, Stoic philosopher and astrologer, who called this method "sphaira heptazônos" (seven belt sphere) [Vet.Val. Anthologiarum Libri, IX, 26].

The second way of producing the day-names in the planetary week is pictorial (Bouché-Leclercq, 1899: 482, fig. 43, reproduced here as Figure 1) and again is described by Cassius Dio [Historiae Romanae, XXXVII, 18]. We arrange the seven planets in their traditional geocentric order on the seven vertices of a regular heptagon. Beginning from the Sun and tracing the star-shaped acute-angle regular heptagon generates the sequence of day-rulers of the planetary week.

Obviously, these two methods are equivalent because the residue of the division 24:7 is 3 or, symbolically, $\text{modulo}_7(24) = 3$. Thus, advancing in the planetary arrangement, following the horary rulers' succession, from one day to the other, the increment will always be three steps. Equivalently, the (acute-angle) star-shaped heptagon is produced by connecting every vertex to its third neighbor (clockwise or counter-clockwise).

The Paradox of the Planetary Metals

In the world-view of late antiquity and the Middle Ages, the concepts of *affinity* and *correspondence* were essential. Among the wide variety of such supposed relationships, one of the most venerable and long lasting was that between planets and metals, namely: Saturn ↔ lead (Pb, atomic number 82); Mercury ↔ mercury (Hg, 80); Sun ↔ gold (Au, 79); Jupiter ↔ tin (Sn, 50); Moon ↔ silver (Ag, 47); Venus ↔ copper (Cu, 29); and Mars ↔ iron (Fe, 26).

In the technical vocabulary of Alexandrian "chemists" and their successors,

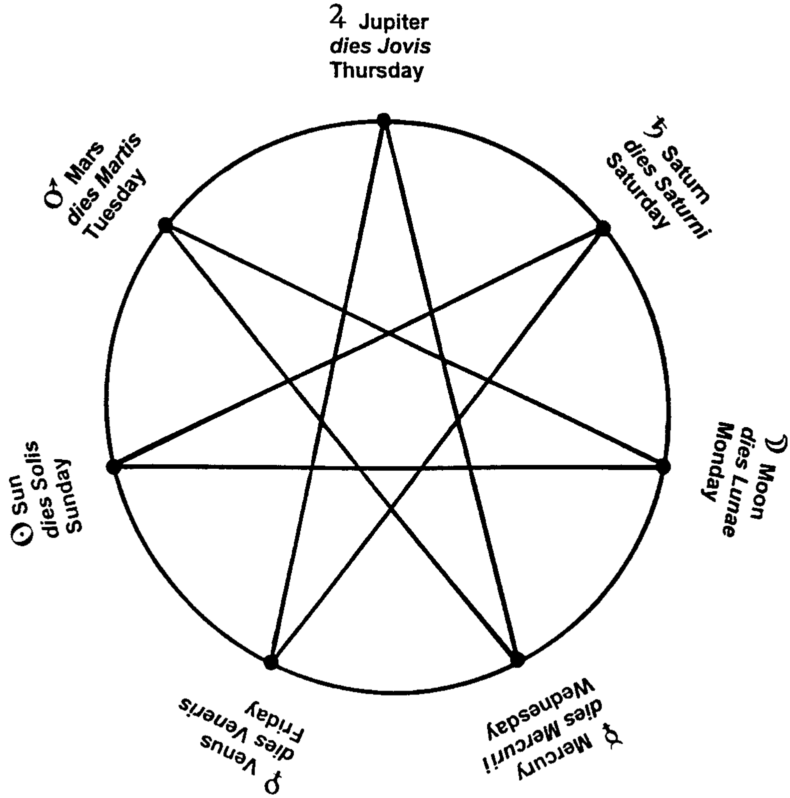

Fig. 1. The succession of the day-names in the planetary week, as derived by the geocentric arrangement of the planets.

metals were often named after their planetary counterparts (Leicester, 1956: 46), and it was thought that they were formed in the depths of the Earth as materializations of the corresponding planetary influences. The alchemists believed that there were equal numbers of metals and planets, though miners knew of several other metals as well. Zinc, cobalt, and bismuth were first discussed in the works of metallurgical writers (Leicester, 1956: 95). However, the dogma of the seven metals remained largely dominant until the 16th century.

The first clear mention of correspondence between the seven planets and metals is found in an Alexandrian commentary on Pindare [Pindari Opera, ed. Boeckh, vol. II, p. 540, 1819]. Commenting on the poet's claim of correspondence between gold and the Sun, the document gives the following additional correspondences: Moon–silver, Mars–iron, Saturn–lead, Jupiter–electrum (alloy of gold and silver), Mercury–tin, and Venus–copper.

In the 2nd century AD, in a passage of Celsus preserved by Origenes [Contra Celsum, VI, 22], there is testimony to a quite different correspondence related to

Mithraic initiation rites. During these ceremonies there was used, as a symbol of the passage of the psyche through the celestial (planetary) spheres, a ladder named "klimax heptapylos" (seven-gate ladder). The successive "gates" consist of different metals corresponding to the planetary orbits as follows: lead–Saturn, tin–Venus, bronze–Jupiter, iron–Mercury, coin alloy–Mars, silver–Moon, and gold–Sun. Correspondences similar to this have been found sporadically in manuscripts, mainly of astrological nature.

Proclus, neo-platonic philosopher of the 5th century AD, includes in his comment on Timaeus [in Platonis Timaeum Commentaria, ed. Diehl, p. 43, 1728] the correspondences Sun–gold, Moon–silver, Saturn–lead, and Mars–iron. Another neo-platonic philosopher of the 6th century AD, Olympiodorus, also mentioned this correspondence.

The electrum of the Greeks and Romans was known to the Egyptians under the name of "asem", considered to be a discrete metal. Only after the Roman period did it progressively disappear from the list of metals, and the correspondence between planets and metals took the final form that remained unchanged from the early Middle Ages until the decline of alchemy. Mercury metal (quicksilver) was not widely known to ancient Mediterranean civilizations; there are only vague references to it in early Greek literature. Nevertheless, owing to the fact that mercury can sometimes be found in nature in its pure metallic form, it has been found occasionally in graves of the 16th and 15th centuries BC (Leicester, 1956: 43).

The final list of the correspondences between metals and planets, as above, first appeared in a manuscript of a work of Stephanus of Alexandria (library of Paris, 2327, folio 73 verso): Saturn/lead, Jupiter/tin, Mars/iron, Sun/gold, Venus/copper, Mercury/quicksilver, Moon/silver. Berthelot (1888, vol. 1: 94–95) has followed systematically the progressive modifications of the chemical symbols of the metals as they were taking their final correspondence with the planets.

Chaucer (14th century), in "The Canon's Yeoman's Tale" from his *Canterbury Tales,* describes this correspondence in the following lines:

The bodies sevene eek lo! hem heer anoon:
Sol gold is, and Luna silver we thrape,
Mars yren, Mercurie quik-silver we clepe,
Saturnus leed, and Jupiter is tin,
And Venus coper, by my fader kin!

It was often remarked that several properties of these metals are closely related to mythological characteristics of the Greek gods associated with the corresponding planets (Berthelot, 1888; Bouché-Leclercq, 1899; Read, 1995). The only uncertain coupling is **Jupiter** and tin, where the only basis is a parallelism between thunder, governed by Jupiter, and the noise accompanying the bending of a tin plate (unusual for a metal) that alchemists called "the tin cry". **Saturn**, god of old age and of time, corresponds with its characteristic gray tint to the slowest of the planets and to the heaviness of lead—the ancients could not, of course, know that lead is the final product of radioactive degradation of all the naturally occurring radioactive elements, which is a nuclear-physics analogue of ageing. **Sun** and **Moon** correspond, respectively, to gold and silver, an almost self-explanatory association. (The color of the Sun is characteristically seen as gold even though it is a source *par excellence* of white light.) **Venus**—Cypris is connected both by her name and by her origin to copper (cuprum), which in antiquity was produced in large amounts in mines on the island of Cyprus; also, she is related to this metal through the mirror (the most typical emblem of the goddess), which in antiquity was usually made of polished copper; and, moreover, the shape of the mirror has given to the planet Venus its astrological symbol. Iron is assigned to **Mars**, whose astrological symbol is an abstraction of the form of the ancient Greek hoplite, with the spear and the shield; the red color of iron rust was associated with the red planet and with the red of blood as well. Mercury (quicksilver) is correlated to the planet and to the god **Mercury** because of its agility and its tendency to slip and escape.

An astrology book of the end of the 19th century (Sepharial, 1981) mentions the following feature of planetary metals: Let us arrange the planets on the vertices of a regular heptagon in their traditional geocentric order (as in Figure 1). If we connect these points following the order of increasing atomic weights of the metals associated with the planets, we form a star-shaped obtuse-angle regular heptagon (Figure 2). (Sepharial wrote before Moseley's identification of atomic numbers, which constitutes the most relevant number for the identification of an element, and which in general parallels atomic weights.) None of the physical or chemical properties of metals known in antiquity (density, hardness, facility to be oxidized, brightness) could serve to arrange the metals in the same order as the one produced when the atomic weight or the atomic number is used.

An "*Acausal Connecting Principle*": Is That Search Possible on Quantitative Grounds?

Notwithstanding the strong sensation of symmetry and non-randomness given by Figure 2, a fundamental question arises: How probable is it for these properties of the observed pattern to result from pure chance?

Consider the seven planets at the vertices of a heptagon, following their traditional geocentric order, as in Figures 1 and 2. By connecting in sequence any two vertices chosen at random, a large number of patterns can be generated. Figure 3 shows one such (random) pattern. The number of all the permutations of seven objects is $7! = 1 \times 2 \times 3 \times 4 \times 5 \times 6 \times 7 = 5040$. In other words, there are 5040 ways to arrange sequentially seven different objects. However, as we will point out in the next paragraphs, there is a much smaller number of patterns (closed graphs) corresponding to these 7! permutations.

First, note that any pair of mutually inverse arrangements corresponds to the same pattern, reducing the number of closed graphs from 7! to 7!/2 (= 2520). Next, take into account that all the seven "circular permutations" of a given planetary arrangement correspond to the same closed graph: a, b, c, d, e, f, g

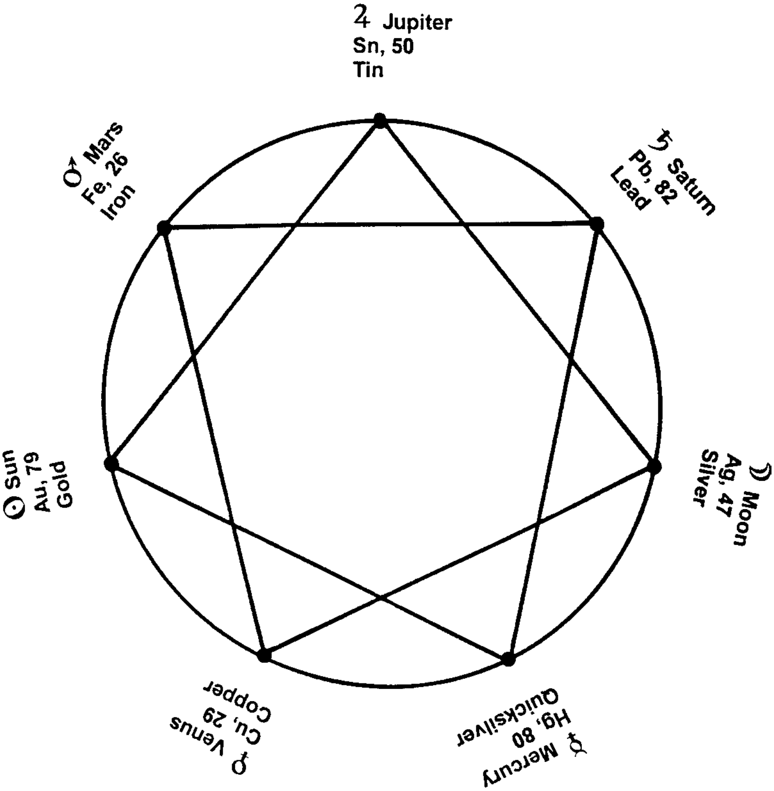

Fig. 2. "The paradox of planetary metals". The combination of the geocentric arrangement of the planets with the atomic numbers of the planetary metals leads to the formation of this star-shaped heptagon.

results in the same geometric pattern as (say) d, e, f, g a, b, c. Thus, the number of possible closed graphs is further reduced by a factor of 7 to 360.

But what is striking about these patterns is their symmetry. Of the 360 patterns corresponding to all possible planetary arrangements, only three are highly symmetrical: the simple regular heptagon and the two star-shaped regular heptagons (technically speaking, characterized by a rotation-symmetry axis of seventh order). Any one of these three symmetric geometries would seem striking. The probability of obtaining the planetary-metals paradox, the correct quantification for the "strangeness" of the phenomenon under consideration, is therefore not 1/360 but 3/360 = 1/120.

In addition, however, there is the oddity that a symmetric pattern is also obtained when connecting the planets/days in sequence, as in Figure 1. Moreover, in that figure, the last day of the week corresponds to the furthest planet, Saturn; and similarly, in Figure 2, the highest value of atomic number (lead, 82) corresponds again to Saturn.

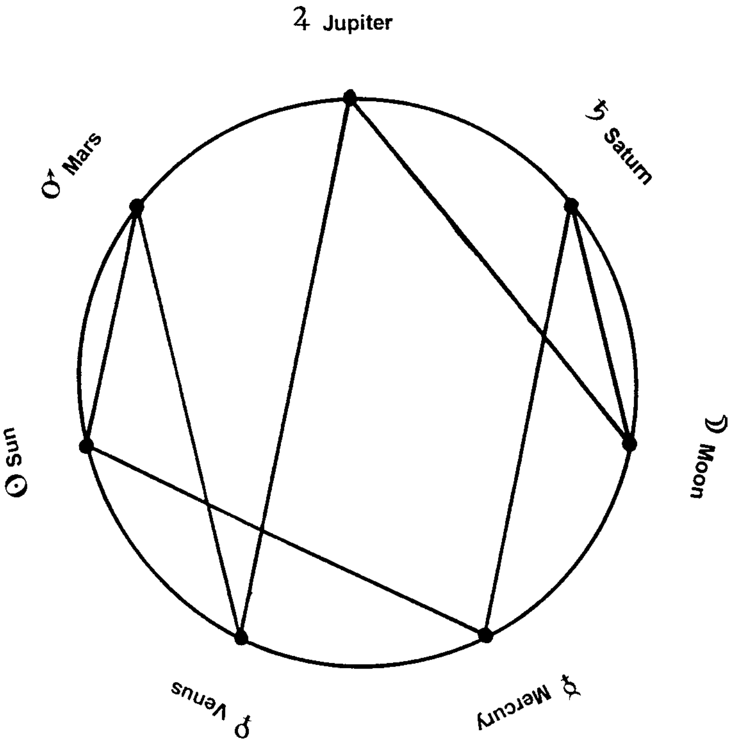

Fig. 3. One of the 357 more or less irregular patterns, which are formed if we combine one random planetary arrangement to the traditional geocentric arrangement of the planets depicted around the cycle. This is the one corresponding to the planetary arrangement R = [Mercury, Saturn, Moon, Jupiter, Venus, Mars, Sun], to its inversion and to all their cyclic permutations (for more details see the text).

It is important to keep in mind, of course, that nature does not guarantee that events will never surprise us. Probability theory teaches that the total absence of improbable events is just as unlikely as their overrepresentation (see, e.g., Peterson, 1998).

We cannot reasonably suggest that these symmetries represent residual knowledge originating from some ancestral civilization, since the planetary sequence reached final form only in the Hellenistic period, and the correspondences of metals to planets dates to about the 6th century, with the assignment of quicksilver to Mercury and tin to Jupiter.

Here is the crux of the issue:

1. The planetary arrangement and the correspondence of metals and planets precede the acquisition of any knowledge about atomic quantities, yet atomic numbers generate the same pattern as traditional correspondences do.
2. The planetary arrangement and planet–metal correspondences leading to

the symmetrical pattern of Figure 2 were dominant in the European and Mediterranean world for a very long period of time (1000 years or more).

3. Our well-established knowledge of the evolution of the beliefs about the planetary arrangement and the planet–metal correspondences, before reaching their final forms, excludes the possibility of their derivation from residual fragmentary ancestral scientific knowledge.

One might conclude that mere coincidence is the only remaining explanation. However, the idea that "coincidences" involving *events meaningfully connected* in space and time occur more often than normally expected has a long history. In traditional civilizations, it was widely accepted that events are fundamentally interconnected because of "affinities" and "correspondences" rather than because of cause-and-effect relationships. The principle of causality has evolved, and in its present form dates only from the Scientific Revolution. In even the recent past, several investigators were driven to the hypothesis of the existence of other ways than causality of meaningful interconnections of events. The Austrian zoologist Paul Kammerer (1919) formulated a "law of series", that similar events succeed one another (i.e., they are clustered in time) more often than expected, even where causal explanations for such a clustering are excluded. Later, Jung and Pauli (Jung, 1973) introduced the *principle of synchronicity* to describe the tendency of events to coincide meaningfully in space and time. Koestler (1972), Peat (1987), and others have presented these ideas systematically. Taking a clearly opposite attitude, other writers (e.g., Dawkins, 1999; Gardner, 1957; Sagan, 1995) maintain that such attempts are equivalent to a reformulation of old beliefs about magic or may suggest the occurrence of clairvoyance or telepathy, and they consider any such claim unsustainable. To the contrary, we believe that the investigation of unusual phenomena, including matters in the classical literature as in the present study, might contribute to our understanding of crucial aspects of reality.

The paradox of the planetary metals cannot be understood on the basis of causal relationships. It brings together physical factors—the geocentric angular speed of celestial bodies, physical properties of planets, physical and chemical properties of metals—with *beliefs*: myths related to gods of the ancient Middle East, astrological traditions of those civilizations, the geocentric concept itself. Only nowadays, with a knowledge of atomic quantities, is the paradox evident. It is either meaningful and synchronistic, or it is sheer coincidence.

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