ASTRONOMICAL MUSICALITY WITHIN MYTHIC NARRATIVES

Richard Heath

I open this paper with a diagram of its structure (figure 1). This purportedly ancient symbol came to light around 1914 as the (nine fold) Enneagram [BLAKE, 1996]: Literary analysis has shown ancient writers using very similar Ring Compositions [DOUGLAS, 2010] as just one of many techniques, often employed within mythic texts to insert hidden structures of meaning.

Figure 1. An Enneagram used as ring composition for this paper to help author and reader understand its narrative structure.

I will be introducing another such technique rediscovered by Ernest McClain [MCCLAIN, 1976, 1978] in which he has “offered a persuasive explanation of crucial passages in texts of world literature—the Bible, the Rig Veda, the Egyptian Book of the Dead, and Plato’s dialogues -- that have defied experts in the concerned disciplines.” —Wikipedia. His work finds harmonic parallelism within texts and finds a purpose for the anomalous often “astronomical” numbers, found within mythic narratives whose meaning is explainable by reconstructing a unique array (a matrix) of whole numbers lesser than the number within the text, numbers evoked purely by consequence of limiting the harmonic generative power to that number. McClain finds that a limit’s matrix, naturally shaped like a mountain, explains the plot elements, events and characters of the narrative, which run parallel to the harmonic concerns found within these mountains. The most significant question emerging from such harmonic parallelism within texts is why the harmonic facts implicit within different limiting numbers were ever thought an important substratum for mythic narrative. What could have made harmonic facts relevant to spiritual tales involving divine worlds and heroic dramas?

Part One: Possible Sources of Astronomical Musicality

Evidence of techniques like ring composition and harmonic parallelism within the narratives of the ancient world throw light on the intellectual world of their authors. Ancient musical knowledge must have come to Just tuning long before Greek music, quite possibly because of two sources of musical information not usually associated with early musical tuning by ear: firstly, the early number field is the original template upon which musical harmony is based [see pages 4-5]; and secondly, the prehistoric geocentric astronomy which preceded the ancient world could compare counted astronomical time-periods, and therefore discovered the rational wholetone and semitone intervals between the lunar year, Jupiter and Saturn [HEATH, 2004, 2007]. This would mean that the cultures preceding the ancient Near East, though lacking an arithmetic, had inherited a metrology which could count numbers as collections of unit lengths and was also able to calibrate geometrical structures with their metrology, as is found within the large built structures of Egypt and Mesopotamia.
The Whole Tone of Jupiter and Half Tone of Saturn

Figure 2. The wholetone and semitone interval between the lunar year and synods of Jupiter and Saturn presented within a right angled triangle as if three musical strings.

In Matrix of Creation [HEATH 2002] I reported astronomical intervals, findable by the megalithic methods of north west France (see below). These express exact musical ratios relative to the lunar year, Jupiter a Pythagorean wholetone (8:9) and Saturn a Just semitone (15:16)\(^1\). These two intervals are only found together in Just tuning. My recent collaboration with musicologist Ernest McClain led to my developing a web application called Harmonic Explorer\(^2\) which enables rapid calculation of and navigation between the harmonic worlds generated by limiting numbers. Through this I discovered that the musical ratios of Jupiter and Saturn require, at least, the Just tuning matrix for the limiting number of 1440 units. Driving this matrix is the synodic comma [ratio 80:81] uniquely arising between the Pythagorean and Just tone sets of Just intonation, but in this case between the Moon’s synodic month and the Earth’s rotation. If realised, deep links could have been forged in the late prehistoric between musicology, astronomy and myth, Later, traditional symbols and narratives could have been crafted to preserve the astronomical and musical realities within creative textual dramas, about planetary gods.

In 2010, my brother and I [HEATH and HEATH, 2010] surveyed a megalithic monument of the fifth millennium BCE which counted the days of at least two different types of year, through accumulating a constant unit of length to form what is then a numerical length. These counts were then juxtaposed (within a monument called the Le Manio Quadrilateral) for comparison of lengths using a right angled triangle.

One notes this as being exactly the same principle one might use when comparing two string lengths, where a series of intervals held between string lengths can create a melodic scale, string ratios containing only the three superparticular ratios of Just tuning, two wholetones [8:9 and 9:10] plus a semitone [15:16]. This illustrates the means whereby the harmonic relationships between the Moon, Jupiter and Saturn could have come to be associated with string lengths and how the celestial regions might originally have come to be seen as a “harmony of the spheres”, these anciently thought of as titans and gods, and only then as a fitting implicit subject for the mythic narratives of the ancient world.

Ernest McClain’s matrices could also have developed within the megalithic alongside a pre-arithmetic astronomy using right triangles, which can use the all-important units held as the differences between two counted lengths of time. It is this difference, dividing into two string lengths, which reveals a superparticular ratio uniquely expressive of a given interval which, when harmonic, is a musical interval. We indeed see in the Le Manio Quadrilateral a formation of what was probably the original megalithic yard, being such a differential unit held between day counts for three lunar years and three solar years, a length of 32 and 5/8th day-inches. This simple way of handling numbers and ratios is quite unfamiliar today and this has made what the megalithic were achieving within their monuments obscure. Instead, a common explanation given for these monuments is as providing settings for unspecified sacred rituals, just as a modern religious building might be used. If, however, planets were
being equated in the megalithic with gods and if their planetary time periods exhibited harmonic intervals between one another, then some of these monuments are better explained as technical structures the aim of which became religious only when characterising these planets as important aspects of reality.

Another natural source of harmonic order can be found in the simplest intervals, which exist between the smallest numbers themselves when cumulatively quantified, as the differential ratios containing their products. Quite simply, all of what western music associates with harmony is generated by the differential “size” of the first three prime numbers; two, three and five. Any number with only these numbers as its factors is, so to speak, a harmonic number since it is capable of forming a harmonic interval with any other harmonic number. There is a Nippur List of numbers showing only such harmonic numbers between 1 and 81, indicating how the early numbers were significant by 2,200 BC for Mesopotamian harmonic thought. The non-harmonic gaps between the harmonic numbers separate the latter when viewed as “lengths”, to form harmonic intervals between and the gaps can only be made up of only two species (a) the other harmonic numbers and (b) the non-harmonic numbers (which contain any factor other than 2, 3 and 5).

One needs to see each successive number as having length equal to one unit. The first six numbers 1-6 define the unitary ratios 1:2:3:4:5:6, sometimes called the Senarius or six unit metric, which expresses the octave 1:2, the fifth 2:3, the fourth 3:4, the major third 4:5 and the minor third 5:6. The first non-harmonic number, 7, causes a difference of two between 6:8, which is nothing new being a doubling of the fourth. But the next numbers give the two types of whole tone necessary to Just tuning. The next new species is 15:16, the Just semitone.

Each of the ratios within the ranges 1:2:3:4:5:6, 8:9:10, and 15:16, will be encountered later in the higher number field, when inevitably doubled, tripled, quadrupled and so on. Something seems extraordinary in how these multiples of the harmonic ratios then successively express the familiar order of the modes used within Just tuning.

Figure 4. The early number field is dominated by the first three primes, {2,3,5}, which generate musical octaves, fifths, fourths, major and minor thirds through their successiveness [1:2:3:4:5:6] halted by seven, considered less harmonic. This has a mythic interpretation of being the six days of creation after which God rests, opening the Bible. Two wholetones [8:9:10] and semitone [15:16] completes the components of Just tuning without any resort to a Pythagorean tuning procedure such as the Cycle of Fifths, starting with the unit length 24 [see figure above]. The first sequence is 24:27:30:32:36:40:45:48 describing the mode called Ionian by the Greeks, which starts with the interval 8:9 as 24:27, that is three times (x 3). Then 9:10 is available as 27:30 (x 3), 15:16 as 30:32 (x 2), 8:9 as 32:36 (x 4), 9:10 as 36:40 (x 4), 8:9 as 40:45 (x 5), as can be seen below.

This continues in a seamless way until the interval 9:10 as 72:80 (x 8) which concludes the “last” mode, called Aolian by the Greeks. This is possible because all of the six modal sequences effectively overlap, so that Dorian starts with 9:10 as 27:30 (x 3), Phrygian starts with 15:16 as 30:32 (x 2), Lydian with 8:9 as 32:36 (x 4), Mixolydian with 9:10 as 36:40 (x 4) and Aolian with 8:9 as 40:45 (x 5). This demonstrates an apparent ascendancy of musical harmony (based upon the numbers 2, 3 and 5) in the way harmonic numbers are perfectly packed or structured within the early number field. This extraordinary sequence of modes concludes with the distinctive comma of the Just tuning system, the syntonic comma of 80:81, which separates the Pythagorean from the equivalent Just tone sets, just as the Pythagorean wholetone interval of 8:9 is 81 units long to the Just wholetones 9:10 interval “length” of 80 units. Similarly, the Pythagorean Leimma (or heptatonic semitone) of 243:256 is one syntonic comma of 80:81 less in length than the Just semitone of 15:16.
Figure 5. How the numbers between 20 and 81 create enlarged whole and semi tones to, from 24 to 80, sequence the six modes: Ionian, Dorian, Phrygian, Lydian, Mixolydian and Aolian, using numbers for “strings” found notated in 2800 BC Sumer.

Unlikely as these circumstances (between 1:81) may seem, evidence can be found in the earliest musical “texts” where a scribal description of a harp-like instrument names its strings using exactly the numbers found above in the early number field. This usage of the lowest possible numbers was not restricted to a single modal octave but apparently to a slightly larger range specified as string number 36:40:45:48:54:60:64:72:80. This suggests a knowledge of the derivation given above, of numerical string lengths from first principles, using the harmonic numbers based solely upon the factors of the first three primes, 2, 3 and 5, less than 81. This would be six hundred years earlier than the Nippur tables, where (as already stated) non-harmonic numbers had been eliminated from the early number field.

Identifying string tones by the numerical string lengths is very natural if numbers were being formed as numerical lengths. Therefore, the earliest depictions for early instruments employing harmonic string numbers as initial string lengths, would also have been depicted with tuning knobs to adjust for variations in string properties, due to manufacture, humidity or temperature. The idea of specifying the lengths as: 36:40:45:48:54:60:64:72:80 must have arisen due to a prior arithmetical calculation of harmonic intervals using existing small units for an aural discovery of musical intervals. This could have emerged in the prehistory of the megalithic period, in which numeracy was exactly based upon the suitable geometrical methods employing a metrology of numbers held within lengths which could be strings.

* See Drummond, ICONA 2008, Evidence and Inference in Texts of Theory in the Ancient Near East
Part Two: Theological Implications of Astronomical Musicality

From Part One we gather the following key points:

1. Some significant geocentric time periods stand in harmonic intervals to each other.

2. The prehistoric numeracy, geared to numbers held as metrological lengths, would have been well suited to understanding the numerical origins of harmony.

3. In the 3rd millennium BC ancient Near East texts appear to refer to the unique minimum string length sequence predicated on the lowest possible numbers to achieve just tuning scales, these numbers being less than 81.

4. Ernest McClain [MCCLAIN 1978] has recovered the Classical form of an ancient harmonic system used for a harmonic parallelism within narratives, which used the citing of numbers noting harmonic “landmarks”.

McClain’s matrices are made of large integers which on the outside seem related by just two intervals: from left to right the fifth of 2:3; from bottom to diagonally upwards, the major third of 4:5. In fact the mountainous structure of harmonic number “bricks” generates an interval between every pair of bricks throughout the mountain and it is through these that will soon locate the lowest limiting number [1440], where the lunar year, Jupiter synod, Saturn synod and other periodicities can all be placed within such a mountain. Thus, each mountain is a lexicon of distance functions, each of these forming a harmonic interval between its bricks. But why should astronomical musicality fall into such a scheme at all, since celestial mechanics is not thought of as musical? In celestial mechanics, “an orbital resonance occurs when two orbiting bodies exert a regular, periodic gravitational influence on each other, usually due to their orbital periods being related by a ratio of two small integers” but it now seems obvious that the first three harmonic primes will be as dominant in gravitating systems as they are in delivering musical harmonies to our ears.

The tuning view of a limiting mountain is actually misleading since the origin of such a mountain comes directly from the products of three and five found within harmonic numbers. Each place on such a mountain has a root product of the powers of three and five such that its height is exactly due to its powers of five and its own location to the right is exactly how many powers of three it contains. For any given limit there can be only one harmonic tone number in each position on the mountain and these are the invariants found within the octave as defined by the octave between the Limit and its halving. To create a mountain for a given limit requires the creation of a table of the cross multiplications of powers of three and five.
How Holy Mountains are numerically Born,
First by products of 3 and 5
Then by 2 to reach Octave Limit = N
Using ANE Arithmetic and attaining large
relative string lengths numbers

Result: Yantra for N<30
"God on the Mountain"
The Diatonic Scale of
[30 32 36 40 45 48 (50) 54 60]

Step 2: Double to N>30
(Powers of 2)

Step 1: Building Blocks for N<60
(Powers of 3 and 5)

An example of McClain’s more recent work
on the Bible concerns the formation of the
dozen tribes of Israel, illustrating a progression
within numerical limits which has astronomical
as well as harmonic relevance. This concentrates
upon the root number 45 as 3 times the 15 used
(figure 7, left) to develop the limit 60 as 4 times
15. This tripling of a mountains limit causes the
brick for D to move one place to the right. The
only freedom then remaining is to boost a limit by
successive powers of two, to form the sequence
45:90:180:360:720:1440, which appears to offer a
harmonic number near to the solar year as 360 days,
developed by Plato as his “Calendar” progression,
represented below [Timaeus 36c].

Figure 8. The Expansion of an important root limit of 45 = 3²
x 5 into a “calendar number” 360 and beyond, purely through
doubling to generate higher octave limits. The harmonic
numbers can be seen as emanating within a tone circle as
invariants based purely on their factors of three and five,
as found in the computational mechanism of the harmonic
matrices generating these tone numbers (as figure 7).
Whenever a limit contains a single power of five, D will be on the second row of a mountain and this is a very important location for Just tuning, in that the bricks on the rows below and above the limit then provide Just tone alternatives to the Pythagorean cycle of fifths which would also require very large numbers to achieve chromatism. Raising the limit of 9 to the second row, using one power of five to make 45, leads to an improved chromatism, eliminating audible commas and reducing the size of limiting number required to achieve twelve note chromatism. In the case of 45 doubled five times to 1440, twelve tones surround the limit and this appears to have informed the idea of twelve tribes developed through Abram as 243 \([3^5]\), Isaac as 180 \([45 \times 4]\) then Joseph as 125 \([5^3]\) who doubled up to 1,000, as Vizier of Egypt, stands above the three Just registers of 1440, forming a minor diesis to the cornerstone valued at 1024 \([2^{10}]\).

The problem with such an explanation appears to be why the authoring individuals should seek to drive the narrative of Genesis using a hidden framework of harmonic facts, here found within limits based upon 45. Is this simply a desire that the text preserve harmonic knowledge in occult form, or is there something more important underlying these mountains, about twelve tribes, or tones, such as the characterisation of a divine world of astronomical musicality? Ernest McClain gives a character explanation of 1440 as being ‘little Adam’ read as Hebrew A.D.M meaning (the number values 1.4.40 as) 1440, justifying 720 as middle of the paired Great and Small double octave, perhaps using 45 to displace Semitic gods, particularly the Assyrian and Babylonian goddess ISHTAR \([= 15]\) as the tonal root of D. We know for instance that the Jews followed a lunar calendar and that there are twelve lunar months within a solar year. The Pentateuch opens with six days of creation (the 1:2:3:4:5:6 of the Senarius) and rests on the seventh day, a non-harmonic prime. The planetary designations of seven days in the week are lacking in semitic usage (unlike the Indo-European equivalent observance of the week) perhaps because it was idolatrous, implying a denial of “other gods” as the planets, who are merely agents of harmony like the demiurge. However, the seven day week has only one astronomical sponsor which is the god of time, Saturn, whose synod is divided perfectly by it (as 378 divided by 7 days is 54 weeks). The synod of Jupiter is similarly commensurate with seven days as 57 weeks, and the two giant planets are then shown to be in ratio as 18:19 when seen through their difference of 21 days or three weeks. Such things were known when people spent time under the skies and counted the time between events.

Figure 9. Joseph is cornerstone to the idea of twelve tribes who will become saviour of the descendants of Isaac = 180 and hence form the twelve tribes, as \(ab = 45/32\). This cornerstone of 128, having no powers of three and five, is raised by the minor diesis \([128:125]\) to 125, then doubled thrice to 1000. The twelve tribes represent a superior Just chromatism whilst the saviour, now 1024, stands opposite the Plato’s tyrant number \([729]\) on the base of the mountain for 1440.
Figure 10. Location of the synods of Jupiter and Saturn as intervals to the Lunar Year of twelve months, within the matrix of 1440 equal to a limit of eighteen lunar months.

It is time to find a reason for there being two intervals [8:9 and 15:16] between the lunar year and the synods of Jupiter and Saturn, respectively. The key lies in dividing the lunar month by 80 parts (each of 0.369 days) after observing that, the next-door-but-one neighbours on McClain’s mountain rows form a whole tone [8:9] (see above figure) and that, in the limit for 1440 above, the left hand brick to 1440 is 960, which is 80 times 12 (a lunar year equalling 12 lunar months). 81 of these units (of 0.369 days) equals 30 revolutions of the earth (relative to ecliptic). That is, the duration of a lunar month (29.53059 days) relative to that of a month of sidereal days (each 0.997283 days long) form the interval called the synodic comma [80:81] generated by Just tuning.

Since next-door-but-one neighbours are 8:9, the Jupiter synod must then be 1080 of these synodic units whilst Saturn becomes the “cornerstone” of the mountain for 1440 as 1024 syntonic units (see next). Hence perhaps, the fuss about Joseph and eventually Jesus as “the stone the builders rejected”. McClain identifies the cornerstone of Isaac’s [180] patriarchal matrix as being Reuben, himself a saviour through saving Joseph from his other brothers, each brother the notional head of twelve future tribes, each created through Joseph’s inspired transition to Egypt, equal to one thousand syntonic units.

The narrative construction is preserving an astronomical matrix relevant to a cornerstone of Saturn [1024], whose designation of the number seven is a prime number that will not mix with the other harmonic numbers, especially in a harmonic context, whilst also being the ancient designation of an extra divine part, greater than ordinary mortals and hence heroic in an age of god-kings and royal cubits of 12/7 feet.

In the astronomical version of 1440, Joseph as 1000 units would be the synod of the planet Uranus of 369.66 days, an outer planet invisible to the naked eye and with a period notable rather for its ability as 1000 to make all the bricks of the matrix “read” like decimals in place notation without any ancient ability to use aggregates in a fractional notation. Joseph stands at the same harmonic distance [25:27] to the Jupiter synod, as the lunar orbit does to the lunar month. Astronomically it is Uranus that is related to the Saturn synod as the minor diesis [128:125], as is the eclipse year (shown black and an illegal fraction [937.5 units] in this context, as half of a yet to appear 1875) now related to the lunar year. Saturn, Joseph and the eclipse year stand outside the twelve tonal tribes surrounding ADM as 14.4.0, whilst the lunar year and Jupiter synod are each one of the twelve tribal bricks, merely actors manifesting God’s harmony. Only cornerstone Saturn can provide the 12th note within the tone circle [right of figure 10], though 1024 is not symmetrical relative to both high and low D but, being an approximation to octave’s geometrical mean [the square root of two] opposes D in the logarithmic world of tone perception to give the twelfth tone of a-flat, if and when required.

It seems significant that the two main aspects of the moon, the eclipse year and the lunar year, are shown here related to three rows of a practical pentatonic musicality, having twelve symmetrical tones and chromatic options via Just and Pythagorean alternatives for the same tones and with the Saturnine 13th tone. McClain’s story may be substantiated by resorting to the definite astronomical correspondences to harmonic intervals, based as it is on a relatively small number set [1440], similar in scale to four years of day counting [1461 days]. However, the idea that celestial mechanics could ever have cooperated with such astronomical arrangements might seem implausible to a modern scientist who prefers only natural solutions to mechanical problems, hence based upon physical forces with no design or
designer. (Giving significance back to geocentric and synodic time periods perhaps grates with the momentous move to heliocentric dynamics, responsible for so much scientific progress.)

However there is in principle no difficulty here for, in celestial mechanics, the solution of the n-body problem (which gravitating systems like our earth, sun, moon and planets present, from multiple centres,) can often reduce to various special cases that are solvable (that is integrable) to yield interval ratios between the astronomical periodicities, these based upon “small whole number ratios”, providing certain conditions prevail between the bodies such as repeated points of symmetry in the configuration of celestial bodies. The ancient tuning matrices proposed by McClain do express a perfect symmetry between their tone sets, using small harmonic numbers. Symmetry in tones could represent the mutual gravitational influences between celestial bodies. It may also be true that modern celestial mechanics fails to see the considerable power given to harmonic numbers within the early number field, and so fails to report it. One reason for filtering out celestial harmonics might be the long-standing belief in a “harmony of the spheres”, prevalent in the pre-scientific thinking from Plato to Kepler: has modern astronomy become “harmony averse”?

**Summary**

We have seen that harmonic intervals exist between celestial time periods and that these intervals could have inspired a characterisation of the planetary world as being ruled by harmony, hence the enduring notion of a harmony of the spheres, that is of the planetary periods.

The ideal circumstance for this step to have been taken is the megalithic period of the 5th and 4th millennia BC, when monuments were built in which (a) time periods were counted as lengths and (b) lengths were compared using right triangles. Such triangles could reveal the invariant interval between time periods in their slope angle and via dividing by their differential length to obtain the superparticular (nn+1) ratio for the interval, the megalithic yard being one such differential length, obtained over a three year count. Once we allow for the development of such a pre-arithmetic form of what is nonetheless calculation, as being performed in prehistory, one can see that astronomy, a study of number and or musical intervals, could have preceded the 3rd millennium’s own contributions to these subjects in the ancient Near East.

Perhaps the greatest contribution of the ancient world has been literary in the form of mythic narratives. Ernest McClain has used his understanding of Plato’s system of harmonic

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**Figure 11.** Just as the early number field offers a syntonic comma of 80/81, so also does the moon provide an 80th part of its synodic month as a new unit which enables an astronomic musicality to appear within the limit of 1440, overseen by 1000 but also, though invisibly, the eclipse year [1875/2] and another minor diesis [128:125], this time to the lunar year.
analysis to see parallels being made through mention of definite numbers within such texts. Numbers can generate entire harmonic matrices (or holy mountains) and these then used by ancient authors to ensure that their stories reflected a harmonic world evidently considered sacred or “higher”.

The phenomenon we call Just tuning can be seen as implicit within the early number field and explicit in the synods of Jupiter and Saturn relative to the lunar year whose twelfth part, the synodic month, provides the syntonic comma \([80:81]\) relative to thirty earth rotations, within the matrix limit 1440, Plato’s calendar octave limit.

This journey of possible origins, from harmonic parallelism within myth to an actual celestial harmonics, is explainable through celestial dynamics which, under certain special cases (of balanced forces) reduces chaotic n-body situations to develop regular periodically between the gravitating bodies. Whether the resulting harmonics are divinely ordained is not relevant to the question of whether the ancient world saw such celestial harmonies as expressive of a divine principle when forming their related cosmogonies and theologies.

Notes

1 Note that Hesiod’s Cosmogony has Saturn as Cronos, being deposed by Jupiter as Zeus and relegated to a “small island”, parallel perhaps to his Just semitone status as opposed to Jupiter’s Pythagorean whole tone with respect to the Moon, which is then a dominating control over the Moon by Jupiter, the nearest and largest gas giant.

2 Available at http://harmonicexplorer.org

3 The Le Manio triangle, divided by its differential length, would have yielded the superparticular ratio of \([32.6:33.6]\).

4 “Numerous examples exist of mathematical cuneiform tablets from the scribal schools of nineteenth and eighteenth century Larsa, Ur and Nippur, which contain thirty standard pairs of numbers with their reciprocals, encompassing all the sexagesimally regular numbers from 2-81. It was the musicologist, Ernest McClain21 who first suggested that these numbers, all in the form \([2^p3^q5^r]\) seem ‘perfectly engineered to fit the specific needs of mathematical harmonics’”. NEW LIGHT ON THE BABYLONIAN TONAL SYSTEM by Leon Crickmore, ICONEA 2008

5 Quoted from Wikipedia on orbital resonance

6 In this passage Plato cites a Pythagorean equivalent involving whole tones of 8:9 and semitones “bent around” into a tone circle an idea which McClain then blends into Plato’s Just intonation, from other dialogues.

7 It takes three major thirds to generate the minor diesis of 128:125, but that would span four rows of the mountain, beyond the range of the symmetrical twins of a D on the second row.
## Appendix 1: Astronomical Periods and their Matrix Equivalents

<table>
<thead>
<tr>
<th>Planetary Period</th>
<th>Practical Definition</th>
<th>Period in days</th>
<th>in matrix units ideal:actual:error</th>
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<tbody>
<tr>
<td>Lunar Month</td>
<td>Cycle of phases, full-to-full</td>
<td>29.53059</td>
<td>80; 80; n/a</td>
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<tr>
<td>30 Sidereal Days</td>
<td>A sidereal month</td>
<td>29.9185</td>
<td>81; 81.05; 1/76</td>
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<tr>
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<td>Rotation of the earth relative to the ecliptic</td>
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<td>2.7; 2.702; 1/1584</td>
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<td>18 lunar months</td>
<td>Limit for the 1440 matrix</td>
<td>0.997283</td>
<td>1440; 1440; n/a</td>
</tr>
<tr>
<td>Lunar Year</td>
<td>Twelve lunar months between thirteen full moons</td>
<td>354.367</td>
<td>960; 960; n/a</td>
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<tr>
<td>Jupiter Synod</td>
<td>Time between retrograde loops</td>
<td>398.88</td>
<td>1080; 1080.58; 1/1837</td>
</tr>
<tr>
<td>Saturn Synod</td>
<td>Time between retrograde loops</td>
<td>378.09</td>
<td>1024; 1024.27; 1/3840</td>
</tr>
<tr>
<td>Uranus Synod</td>
<td>Invisible to naked eye astronomy</td>
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<td>1000; 1001.43; 1/700</td>
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<tr>
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<td>Time between eclipses of the moon at same node</td>
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<td>937.5; 939.01; 1/620</td>
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