Seasons from the Sun

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*This is a series about calendar makers from history.*

The first two articles discussed *phases*, days when the Moon is lit up the most (*poornima*) and least (*amavasya*). We saw that 12 lunar months gives 12 months times 29.5 days/month = 354 days. There is a 11 days gap to match the lunar calendar with the seasonal year, when Sun-Earth-stars come back to the same relative positions.

*Solstices* are days when we have the most and least daylight in the year, from sunrise to sunset. As sunrises and sunsets (the position of the Sun) move in the sky from day to day, the Sun's position in the sky was marked by *rashis*, which are some constellations of stars. The Sun's movement from one rashi to another is called a sankranti.

**Intercalary calendars track both Moon and Sun**

The Greek observer and engineer **Meton** is known for his study of counting, a subject that mathematicians call *combinatorics*. The Greek new year began with **summer solstice**. Meton observed where summer and winter sunrises and sunsets happened on the hills around Athens, where he lived. The foundations of his observatory can still be seen in Athens (see photo). Meton is also said to have built a public sundial. He was popular enough to be a character in a play by Greek playwright **Aristophanes**, appearing on stage to solve a geometrical problem.

Based on his dating of solstices, in 432 BCE Meton made a suggestion. The same phase of the Moon occurs on the same day of the year, once every 19 years, which Meton counted as 6940 days. This matches modern data since 19 seasonal years = 6939.60 days and 235 lunar months = 6939.55 days.

The gap with lunar months would be 19 years times 11 days/year = 209 days. Of course, 19 years would be expected to have 19 years times 12 months/year = 228 months.

As 12 years times 12 months/year + 7 years times 13 months/year = 235 months, Meton's suggestion was to add 7 **intercalary** (*adhika*) months every 19 years, 6 having 30 days each and 1 with 29 days. Seven months over 19 years works out to 2.71 years/month. Therefore these adhika months have to be introduced every 2 or 3 years.

The idea of intercalary months was known much earlier. Sumerian calendars used them in the 21st century BCE. Adhika months were introduced when the months seeemed to be going off course with the seasons. But as we said, these were decided and announced by kings.

In Meton's system, followed by the Hebrew calendar of **Moses ben Maimon** (12th century CE), adhika months are during the 3rd, 5th, 8th, 11th, 14th, 16th, 19th of a 19-year cycle, so that the calendar has 235 months in 19 years. This is simple enough to be a popular school project. It is said Meton's system was earlier in use by the Persians of today's Iran.

**Solstices keep changing**

Makara rashi sankranti (the date when the Sun appears to enter the Makara rashi in the sky) coincides with the festival of **uttarayana**, Karka rashi sankranti with **dakshinayana**. These days winter solstice (least daylight) happens on 21 December, but the festival of uttarayana is celebrated on 14 January. Summer solstice (most daylight) is on 21 June, dakshinayana is celebrated on 16 July. Why this disparity?

Very precise observations of bright stars, such as *Chitra* (Spica), were recorded by Egyptian observer **Timocharis** around 290 BCE. Egyptians had been observing the stars at least since the 25th century BCE. After Greek emperor **Alexander** conquered Egypt, the Greek empire absorbed a lot of their knowledge. Most likely Timocharis worked in the library in the Egyptian city of Alexandria, named after the former emperor. A 19th century rendering of the library, based on archaeological evidence, is shown in the picture.

**Eratosthenes** of Shahhat, Libya, lived later in the 3rd century BCE. Libya was ruled by Greece and the Greek empire had schools (a school was called a *gymnasium*). Eratosthenes studied and later became chief librarian at Alexandria. He became famous for measuring the circumference of Earth. A 17th century painting of him teaching in Alexandria is shown in the picture.

Eratosthenes pointed out another disparity in the Greek calendar of 365 days, that the seasons kept shifting. This shift was estimated at 1 day every 4 years. You may remember that Greeks used to have the Olympic games every 4 years since at least 7th century BCE.

So you leapt ahead to Eratosthenes's idea? Priests under the Egyptian ruler of that time, **Ptolemy III**, announced that every 4 years an *intercalary* day would be added to the year. But the Greek emperors may not have agreed and the idea was lost.

Then around 130 BCE, Greek astronomer **Hipparcos** compared position of star *Chitra* (Spica) with that recorded by **Timocharis** 160 years before him on the same date, and exactly measured how the relationship of seasons with the stars changes. So he scientifically demonstrated that seasons keep shifting. Today we know that the rotation of Earth *precesses*, like a top whose axis keeps shifting slightly as it spins. Hipparcos lived in today's Turkey which was conquered by **Alexander**. The mathematical subject *trigonometry* of measuring angles in a triangle is attributed to him.

**A seasonal calendar**

It still took several centuries before the idea of a **leap year** of 366 days every four years was adopted. From 45 BCE, the Italian emperor **Julius Caesar** abandoned traditional intercalary lunar calendars and moved to a calendar based on seasons. It is attributed to the Egyptian astronomer **Sosigenes** of Alexandria. The year 46 BCE had 445 days to correct for all the errors which had crept in from earlier calendars. Today's space missions still use the Julian calendar.

The seasonal “months” January to June are named after European deities. July is named after Julius Caesar and August after another Italian emperor. The celebration of January 1st as new year also comes from the Roman empire.

In four years the fraction 0.2422 in 365.2422 days that Earth takes to go around the Sun adds up to an extra 0.9688 days, nearly 1 day. A leap day (29th February) is introduced every 4 years to make up this extra day. So we have 1461 days in 4 years, an average of 365.25 days per year.

When an extra day is thrown in every four years, 48 lunar months would have a total of 354+354+354+355 = 1417 days, 354.25 days on the average. A lunar month would have 29.52 days on the average. A more sophisticated calendar would now have to match lunar months with solar years. The scene now shifts to India and its panchangas. The next issue of *JM* talks about them.