Many Blue Moons

Anton R. (Tom) Peters,
v2.2 2018-Jul-03
v1.0 2009-Sep-10

The meaning and origin of "Blue Moon"

Introduction

  The expression "once in a Blue Moon" has an astronomical and calendric origin that has been the subject of much study in the recent past. Briefly, a Full Moon has been called "Blue Moon" if it is the second Full Moon in a calendar month: this was introduced in a Sky&Telescope article in 1946 (Ref.1)). It was derived from a misunderstanding of a convention in the "Maine Farmers' Almanac" around 1937, to call the third Full Moon in a season that has four Full Moons, a Blue Moon.

  The astronomical and calendrical background is, that usually there are 12 Full Moons in a year (so one in each month), and 3 in a season. These Full Moons have traditional names, like "Harvest Moon". The most important one is the Easter Moon: the first Full Moon in spring; Easter is celebrated on the first Sunday after that.

  A lunation lasts about 29.5 days on average, so 12 lunations count 12*29,5 = 354 days: 11 days short of a year. So it may happen that 13 Full Moons (or any other phase) fall within a calendar year, and 4 in a season of 3 calendar months: this occurs 7 times in 19 years (Metonic cycle). This irregular ominous extra ("embolismic" or "leap") Moon apparently was called the Blue Moon.

  However the first known occurrence of the term is a rhyme in an anti-clerical pamphlet from 1528: "*Yf they say the mone is belewe, we must believe that it is true*" (WorldWideWords site, Ref.2)). The common understanding is that it refers to something absurd, like a blue coloured Moon. The equally absurd notion that it is made of green cheese dates from the following year.

  A more or less definitive account of all this was given in a Sky&Telescope article in 1999 (Ref.3)), on occasion of the occurrence of 2 Blue Moons that year, in January and March. However, later the website of the Maine Farmers' Almanac (Ref.4)) suggested an alternative meaning: "belewe" is said to also be an old-English word for "betray": this extra Full Moon was somehow deceptive. This suggests to me an origin and meaning that I have not seen explained in detail before in the discussions.

Circumstances

Until well into the 20th century, most people in Western Europe (and elsewhere) lived a marginal existence. Their lives were regulated by the seasons. This was beautifully depicted in the late-medieval calendar miniatures in the "*Très Riches Heures du Duc de Berry*", painted around 1414 by the brothers van Limburg and (later) Barthélemy van Eyck and Jean Colombe. There was only a single grain harvest per year, and people had to make do with that (see the calendar miniature for July, link 1)). If you held swine, in autumn you could send them into the forest to fatten themselves on acorns (miniature for November, link 2)).

But if these were exhausted you had no fodder for them until next spring, and you did best to butcher most of them and eat them yourself. If you dried, smoked, pickled the meat, or boiled it as a sausage with a lot of garlic (helps protect against rot), you could keep it for a while. About half way into the winter people had a final feast, in which they ate the last remnants of meat: Carnival (Latin *carne* = meat).

After that, the Lent period of fasting began, until Easter. It became a religious custom in which Christian values like austerity, abstinence – from feasting, fine foods, and sex – , restraint, endurance and perseverance were promoted: but I think its main purpose was to keep up morale in a time of year when fasting was a bitter necessity. Every winter people died of cold and

famine (also see the miniature for February, link 3)). So people really looked forward to the end of Lent. Easter is a Christianized spring festival. March hares (no Easter bunnies!) started to multiply, birds laid eggs that you could search for, and then people had something to eat again.

  Now as we all know, Easter is celebrated on the first Sunday after the first Full Moon of spring. Officially hower, Easter Sunday occurs not after Full Moon, but after the 14th day of the lunar month, which is reckoned to begin when a crescent New Moon becomes first visible after sunset, not with the conjunction of Sun and Moon 1 or 2 days earlier.

  Anyhow people really looked out for that Spring Moon. Therefore it was hard to swallow if 4 Full Moons fall within the winter season: you think that the fourth is the Easter Moon announcing springtime, but then it becomes apparent that you will have to fast for another full month!
  Moreover, this rule of thumb was not valid according to the church. The church does not do astronomical observations, but uses a reckoning (called the *Computus*) to establish the holidays. This was based on the Julian calendar for the solar year, and the cycle of Meton that distributes 235 lunations over 19 years. The table they used had been introduced in the early Middle Ages, in 525 *A.D.* by Dionysius Exiguus (links 6),7),8)). Meton's cycle is imperfect however, and accumulates a systematic error of about 1 day in 3 centuries. Moreover the average Julian calendar year is somewhat longer than the so-called tropical year which follows the seasons: every 131 years the beginning of spring (Sun in the spring aequinox, the first point of the zoodiacal sign of Aries), falls 1 day earlier in the Julian calendar.
  By the 16th century, the ecclesiastic Moon was already about 3 days behind the real Moon that everyone could see in the sky. Moreover the spring aequinox fell already on 10 or 11 March in the Julian calendar, but the church kept the start of spring fixed on 21 March which used to be the date in late Roman times when they established the rules. So people could see, smell, and feel that spring was beginning, and see that the Moon was full: but the church told them that it was a "betrayer" Moon, and that they had to wait for another month before the fasting of the Lent period was over and they could celebrate Easter. Lent starts 40 days before Easter as the church reckons it: but the winter season of course had started already in early December, especially at that time when the Little Ice Age was going on, so the winter season would have been made unnecessarily long in the experience of people.

Interpretation

Table 1

Year	Golden Number	Solstice	FM 1	FM 2	FM 3	Aequinox	Belewe Moon ?	real Easter Moon	church Easter Moon
1520	1	12 Dec –	04 Jan	03 Feb	04 Mar	10 Mar		03 Apr	05 Apr
1521	2	12 Dec –	24 Dec –	22 Jan	21 Feb	11 Mar		23 Mar	25 Mar
1522	3	12 Dec –	13 Dec –	12 Jan	10 Feb	11 Mar	12 Mar	10 Apr	13 Apr
1523	4	12 Dec –	01 Jan	31 Jan	01 Mar	11 Mar		31 Mar	02 Apr
1524	5	12 Dec –	22 Dec –	21 Jan	19 Feb	10 Mar	19 Mar	19 Mar	22 Mar
1525	6	11 Dec –	09 Jan	08 Feb	09 Mar	11 Mar		07 Apr	10 Apr
1526	7	12 Dec –	29 Dec –	28 Jan	27 Feb	11 Mar		28 Mar	30 Mar
1527	8	12 Dec –	18 Dec –	17 Jan	16 Feb	11 Mar	18 Mar	16 Apr	18 Apr
1528	9	12 Dec –	06 Jan	05 Feb	06 Mar	10 Mar		04 Apr	07 Apr
1529	10	11 Dec –	25 Dec –	24 Jan	23 Feb	11 Mar		24 Mar	27 Mar
1530	11	12 Dec –	15 Dec –	13 Jan	12 Feb	11 Mar	13 Mar	12 Apr	15 Apr
1531	12	12 Dec –	03 Jan	01 Feb	03 Mar	11 Mar		01 Apr	04 Apr
1532	13	12 Dec –	23 Dec –	22 Jan	20 Feb	10 Mar		21 Mar	24 Mar
1533	14	11 Dec –	12 Dec –	11 Jan	09 Feb	11 Mar	10 Mar	09 Apr	12 Apr
1534	15	12 Dec –	31 Dec –	30 Jan	28 Feb	11 Mar		29 Mar	01 Apr
1535	16	12 Dec –	20 Dec –	19 Jan	18 Feb	11 Mar	19 Mar	19 Mar	21 Mar
1536	17	12 Dec –	08 Jan	07 Feb	07 Mar	10 Mar		06 Apr	09 Apr
1537	18	11 Dec –	27 Dec –	26 Jan	25 Feb	11 Mar		26 Mar	29 Mar
1538	19	12 Dec –	16 Dec –	15 Jan	14 Feb	11 Mar	15 Mar	14 Apr	17 Apr

Dates followed by a ´-´ refer to the year preceding the one listed in the first column.
"FM" is Full Moon. Red dates fall between the actual winter solstice and 21 December; blue dates fall between the actual spring aequinox and 21 March: these are the original "Blue Moons". In 1524 and 1535, the real Full Moon fell on 19 March, also between the actual aequinox and 21 March: but the church computed them on 22 and 21 March and thus accepted them as Easter Full Moons, and there was no delay of Easter, so these were not "betrayer" Moons. In 1533 the real Full Moon fell on 10 March, before the aequinox on 11 March, so was a genuine 4th Full Moon in winter.

  Now Table 1 shows the situation in the years that the pamphlet was written. A moon phase falls on the same calendar date after 19 years (cycle of Meton), so based on the sequence number of the year in cycle – the so-called **Golden Number** (see second column) – people can predict the Moon's phases.
 We see that within a 19-year cycle, it occurred 4 times (blue dates) that there were 4 Full Moons between the winter solstice and 21 March, in which the fourth Full Moon occurred after the actual spring aequinox – so should be regarded as the first Full Moon of spring – but that the church computation would designate only the next Full Moon as the Easter Moon. So this supposedly "betrayer" (= blue) Full Moon is the real first Full Moon in spring, but was reckoned by the church to still fall in winter because it fell before 21 March and could not be the Paschal Moon.

  It is not clear when the winter season was supposed to have started in the (ecclesiastic) calendar: maybe on 21 December, maybe on the 22nd (when the solstice occurs in most years of the Gregorian calendar that we now use), maybe with Christmas on the 25th. In any case these "Blue Moons" as listed in the table were the third in the winter season according to the calendar.

  After the Gregorian reform (1582) had fixed the lunar calendar and synchronized the year with the seasons again, there would still occasionally be 4 Full Moons in a season, as is inherent in the

19-year cycle. Folklore in North America and elsewhere would have 12 traditional names for the Full Moons according to the season, but people would start using the term "Blue Moon" for any extra Full Moon. If they kept the traditional names for the Full Moons on either side of the turn of the season (*e.g.* "Lent Moon" the last Full Moon in winter, and "Easter Moon" the first in spring), then the third Full Moon in a season which has four would be counted as the extra "Blue Moon" - just as the "betrayer Moon" was the third in winter according to the old Julian calendar, and this convention was continued in the Famers' Almanac.

Reading the *tympanes* in the *Très Riches Heures*
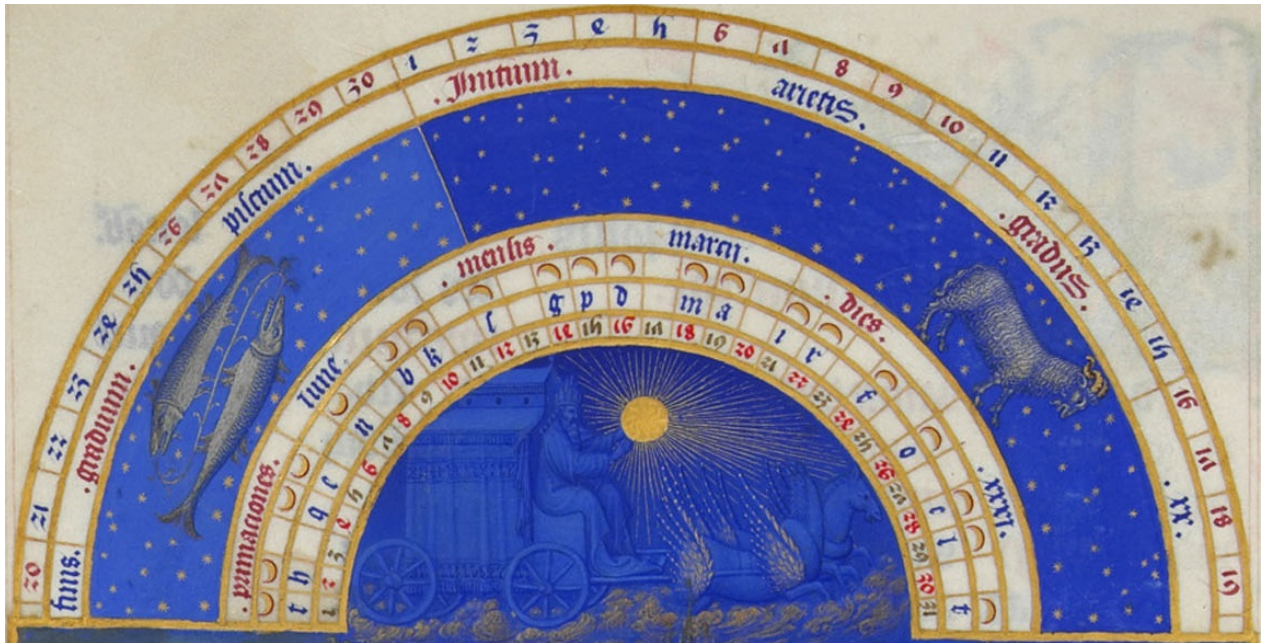
Consider the calendar miniature for March (link 4)). The semicircle ("*tympane*") on top (shown above) contains an astronomical almanac.

The inner circle lists the days of the month of March (1..31, using an early form of our "arabic" numerals); the outer circle lists the degrees of the zoodiacal signs that fall within the calendar month: 20..30 of Pisces, and 1..19 of Aries. These animals are also depicted in the blue segments in the middle. Now note that the first point of Aries, that of the spring aequinox, has been set at 12 March (in the Julian calendar).

There is also a semi-circle with 20 crescents, and inside of this, for the same days, the so-called martyrological letters 'a' to 't'. These count the years of the 19-year cycle (the letter 'j' is omitted - remember "*Indiana Jones and the Last Crusade*"?). Look for the next letter 10 to 12 days before the previous one. These letters work as Golden Numbers, and for a certain year in the cycle they indicate on which date a New Moon occurs.

This is also listed in the *Kalendarium* on the pages opposite the calendar miniatures in the manuscript (link 5)): see the fragment shown above.

The last column "*Nu(meru)s aure(us) nov(us)*" shows in roman numerals the Golden Numbers (in gold!) corresponding to the martyrological letters in the tympane. These "new" Golden Numbers show that the almanac in the *Très Riches Heures* was already updated to the astronomical reality of around 1400. The first column however lists the traditional Golden Numbers still actually used in the *Computus* for Easter (the second column lists the Sunday letters used to find Sundays, in particular Easter Sunday).

Now note that for the last year in the cycle, with the letter 't' and Golden Number *xix* (19), the new Golden Numbers indicate a New Moon on 1 and on 31 March. The 14th day ("Full Moon") then occurs on 14 March, and since in the new reckoning the Sun was in the first point of Aries on 12 March, this is the first Full Moon of spring, and therefore should be the Easter Moon.

But the Roman Church still used the old Golden Numbers in the first column: here the number *xix* is assigned to the 5th day of March, so this was computed to be the first day of a lunar month in the 19th year of the cycle. The 14th day would then be 18 March: before 21 March which the church used as the canonical date for the begin of spring, so the Full Moon that was computed to occur on 18 March was not an Easter Moon. As we see in Table 1, 17 April would have the Easter Moon according to the church (the New Moon was computed to occur on 4 April, running 4 days behind the real New Moon at 31 March).

The *Très Riches Heures* demonstrate that it was a well-known problem at the time that the Easter *Computus* was obsolete (Ref. 5)). It is therefore understandable that people in the 16th century were angry with the church and started to resist. The incompetence of the Roman Catholic Church to get the calendar in order may have been a factor in the success of the Protestant Reformation. The Gregorian Calendar reform came only in 1582 . This reform modified not only the leap day scheme of the Solar calendar to keep the beginning of spring closer to 21 March: but more importantly it introduced a better Lunar calendar that in the long term keeps in pace with the real Moon, such that Easter will fall in the proper season.

The Super Blue Blood Moon

The Super Blue Blood Moon of 31 Jan. 2018 setting in Arizona. APOD 1-Feb-2018, (c) Fred Espenak.

As mentioned before, from a misinterpretation of the tradition (Ref.1)), since 1946 the second Full Moon in a calendar month has been called "Blue Moon". The history of this has been discussed extensively at the occurrence of a double "Blue Moon" in 1999 (Ref.3)). One 19-year cycle later, in 2018 there was much media interest in the "super blue bloodmoon" of 31 January, and the story was retold. Besides being a "Blue Moon", this was also a "Super Moon" and a "Blood Moon".

   The latter term refers to a total lunar eclipse, when the Moon turns orange to brown red as it passes through the shadow of the Earth: only light refracted by Earth's atmosphere reaches the Moon, but short-wave blue light is scattered and mostly red light remains to illuminate the Moon.

   A lunar eclipse occurs when the Moon passes through the shadow that the Earth casts in the light of the Sun: *i.e.* when the Moon is in opposition to the Sun as seen from the Earth, *i.e.* at Full Moon. For an eclipse to occur the alignment must be near perfect, so this only happens when both the Moon and the Sun appear near to the intersection of their orbits: the *nodes*. The Moon passes the nodes twice every 27.21 days (draconitic month), the Sun twice every 346.62 days (eclipse year): so there is an occasion for a lunar eclipse at Full Moon about every 173.3 days. Eclipses recur after a period of 223 lunations (called a saros), which is 18 years and 11 days. Within a saros period there are 26 partial or total lunar eclipses.

   A "Super Moon" is a Full Moon that appears extra big and bright because it occurs when the Moon is near its perigee (the point closest to Earth in its elliptic orbit). At perigee the Moon is 11% closer and 23% brighter than at apogee (farthest from Earth). The period of its elliptic orbit (anomalistic month) is 27.55 days. The beat period with the synodic month of 29.53 days is 411.78 days, which is about 14 lunations and 15 anomalistic months: so every 14th Full Moon is a "Super Moon".

   Blue Moons in the calendar sense occur 8 times in 19 years. If there is no Full Moon in February, then there must be one at the end of January and at the begin of March. But these months have 31 days, while a lunation only lasts between 29.26 and 29.80 days, so there also must be a Full Moon at the beginning of January and at the end of March. So both of these months have a Blue Moon in years when there is no Full Moon in February. Therefore there are not 7 but 8 calendar Blue Moons in the 19-year cycle. The double Blue Moon occurred in 2018, and before in 1999, and again in 2037.

   The coincidence of all three cycles is of course more rare: the previous occasion was in 1866 (with a total lunar eclipse on 31 March close to perigee). On 31 January 2037 there will also be a total lunar eclipse, but not close to perigee.

External material

References

1) James Hugh Pruett: "Once in a Blue Moon". *Sky&Telescope* **V**(5), March 1946, pp.3..4
2) Michael Quinion: "Blue Moon". http://www.worldwidewords.org/topicalwords/tw-blu2.htm
3) Roger W. Sinnott, Donald W. Olson, and Richard Tresch Fienberg: "What's a Blue Moon?" *Sky&Telescope*, May 1999, pp.36..38 .
http://www.skyandtelescope.com/observing/objects/moon/3304131.html?page=1&c=y
4) *Farmers´Almanac*: What is a "Blue Moon"? http://www.farmersalmanac.com/what-is-a-blue-moon
5) C. Philippe E. Nothaft: "The Astronomical Data in the Très Riches Heures and their Fourteenth-Century Source". *J.Hist.Astron*. **46**(2), 1 May 2015, pp.113..129 .
http://journals.sagepub.com/doi/abs/10.1177/0021828615579371

Links

1) Calendar miniature for July from the *Très Riches Heures*:
https://commons.wikimedia.org/wiki/File:Les_Tr%C3%A8s_Riches_Heures_du_duc_de_Berry_juillet.jpg
2) Calendar miniature for November from the *Très Riches Heures*:
https://commons.wikimedia.org/wiki/File:Les_Tr%C3%A8s_Riches_Heures_du_duc_de_Berry_novembre.jpg
3) Calendar miniature for February from the *Très Riches Heures*:
https://commons.wikimedia.org/wiki/File:Les_Tr%C3%A8s_Riches_Heures_du_duc_de_Berry_f%C3%A9vrier.jpg
4) Calendar miniature for March from the *Très Riches Heures*:
https://commons.wikimedia.org/wiki/File:Les_Tr%C3%A8s_Riches_Heures_du_duc_de_Berry_mars.jpg
5) Kalendarium page for March from the *Tres Riches Heures*:
https://commons.wikimedia.org/wiki/File:011_MS_65_F4.jpg
6) Computus in Wikipedia: https://en.wikipedia.org/wiki/Computus#Julian_calendar
7) *Liber de Paschate* of Dionysius Exiguus (525 A.D.): http://henk-reints.nl/cal/audette/denys.html
8) Explanation of the old Computus (in French): http://henk-reints.nl/cal/audette/calgreg.html#elements
9) Moonset Eclipse: https://apod.nasa.gov/apod/ap180201.html