When is Chinese New Year?

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1 Introduction

Chinese New Year is the main holiday for more than one quarter of the world's population; very few people, however, know how to compute the date. People who are knowledgeable about science often feel that the Chinese calendar is backwards, while people who care about Chinese culture usually lack the scientific knowledge to understand how it works. For many years, the only reliable source in English was the article by Doggett ([4]), based on unpublished work of Liu and Stephenson ([5]). But thanks to Dershowitz and Reingold ([3]), correct information and computer programs are now available. Among Chinese sources, my favorite is the book by Tang ([9]).

2 Lunisolar Calendars

A solar year (or tropical year) is the time from one spring equinox to the next. (But see [1, 6] for details.) It is on average 365.2422 days. A lunar month (or synodic month) is the time from one new Moon to the next. It is on average 29.53 days. A lunar year consisting of 12 lunar months equals on the average 354.3671 days, which is about 11 days shorter than a solar year. This was a fundamental problem for the ancients. They tried to find a longer resonance cycle and discovered that 235 lunar months is almost the same as 19 tropical years. The difference is only about two hours. This is called the *Metonic cycle* after the Greek astronomer

Meton who used it in 432 BCE, but it was known to the Babylonians by around 500 BCE and to the Chinese around 600 BCE ([2]).

A *lunar* calendar ignores the Sun and the seasons but follows the Moon. The main example is the Muslim calendar. Since 12 lunar months is about 11 days shorter than the tropical year, the Islamic holidays regress through the seasons.

Lunisolar calendars use lunar months to approximate the tropical year. Examples are the Jewish and Chinese calendars. Since 12 months are about 11 days shorter than the tropical year, a leap month (intercalary month) is inserted about every third year to keep the calendar in tune with the seasons. Notice that the Chinese calendar is *not* a lunar calendar! The Chinese name is yīn yáng lì (阴阳历), which means lunisolar calendar.

One method of inserting leap months is to follow nature. An aboriginal tribe in Taiwan would go out to sea with lanterns at the new Moon at the end of the 12th month. If the migrating flying fish appeared, there would be fish for New Year's dinner. If not, they would wait one month.

A more predictable method is to use the Metonic cycle. Since $235 = 19 \times 12 + 7$, it follows that we need to insert 7 leap months in each 19-years period. This is the method used in the Jewish calendar, and was used in the Chinese calendar before 104 BCE.

3 The 24 Jié Qì

In order to understand the rules for the modern Chinese calendar, we must first define the 24 solar terms or jié qì (节气). I will call the solstices and equinoxes the *seasonal markers*. They cut the ecliptic into 4 sections of 90° each. The 24 jié qì cut the ecliptic into 24 sections of 15° each. The even ones are called major solar terms or zhōng qì (中气), while the odd ones are called minor solar terms or jié qì. The word jié qì is used in two ways. It can either refer to the 12 odd ones, or it can refer to all 24. Table 1 gives the names and approximate dates of the jié qì's. The exact dates vary because of leap years in the Gregorian calendar.

The major solar terms Z2, Z5, Z8 and Z11 are simply the Western seasonal markers. The minor solar terms J1, J4, J7 and J10 start the Chinese seasons. Notice that in Western astronomy, spring begins at the March equinox, while in Chinese astronomy, spring begins midway between the December solstice and the March equinox. In Western popular culture this convention is often used, too. The traditional dates for the equinoxes and solstices were March 25, June 24, September 24 and December 25. Shakespeare's "A Midsummer Night's Dream" takes place on June 23, the eve of Midsummer Day on June 24. To Shakespeare, the June solstice was the middle of summer, not the beginning. Midsummer Day on June 24 is one of the four Quarter Days in the Legal Calendar in the UK.

J1	Lì chūn	立春	Beginning of spring	February 4
Z1	Yǔ shuǐ	雨水	Rain water	February 19
J2	Jīng zhé	惊蛰	Waking of insects	March 6
Z2	Chūn fēn	春分	March equinox	March 21
J3	Qīng míng	清明	Pure brightness	April 5
Z3	Gǔ yǔ	谷雨	Grain rain	April 20
J4	Lì xià	立夏	Beginning of summer	May 6
Z4	Xiǎo mǎn	小满	Grain full	May 21
J5	Máng zhòng	芒种	Grain in ear	June 6
Z5	Xià zhì	夏至	June solstice	June 22
J6	Xiǎo shǔ	小暑	Slight heat	July 7
Z6	Dà shǔ	大暑	Great heat	July 23
J7	Lì qiū	立秋	Beginning of autumn	August 8
Z7	Chǔ shǔ	处暑	Limit of heat	August 23
J8	Bái lù	白露	White dew	September 8
Z8	Qiū fēn	秋分	September equinox	September 23
J9	Hán lù	寒露	Cold dew	October 8
Z9	Shuāng jiàng	霜降	Descent of frost	October 24
J10	Lì dōng	立冬	Beginning of winter	November 8
Z10	Xiǎo xuě	小雪	Slight snow	November 22
J11	Dà xuě	大雪	Great snow	December 7
Z11	Dōng zhì	冬至	December solstice	December 22
J12	Xiǎo hán	小寒	Slight cold	January 6
Z12	Dà hán	大寒	Great cold	January 20

Table 1: The 24 jié qì

The others are Lady Day (or Annunciation Day) on March 25, Michaelmas on September 29 and Christmas on December 25.

The Chinese beginning of season markers also have their analogies in Western culture. Groundhog Day or Candlemas on February 2 is close to lì chūn (beginning of spring) on February 4. May Day on May 1 and Walpurgisnacht on April 30 are close to lì xià (beginning of summer) on May 6. Lammas on August 1 is close to lì qiū (beginning of autumn) on August 8. Halloween (Hallowmas) on October 31, All Saints' Day on November 1, Guy Fawkes Day on November 5 and Martinmas on November 11 are close to lì dōng (beginning of winter) on November 8. These Christian holidays are related to the Celtic holidays Imbolg, Beltane, Lughnasa and Samhain. These holidays are listed in Table 2.

Two of the jié qì's are Chinese festivals: qīng míng on April 5 and dōng zhì (December solstice) on December 22. All the other Chinese festivals are lunar.

Astronomical	Chinese	Western	Celtic
	lì chūn	Groundhog Day, Candlemas	Imbolg
March equinox	chūn fēn	Lady Day, Annunciation Day	
	lì xià	May Day, Walpurgisnacht	Beltane
June solstice	xià zhì	Midsummer Day	
	lì qiū	Lammas	Lughnasa
September equinox	qiū fēn	Michaelmas	
	lì dōng	Halloween, All Saints', Guy Fawkes, Martinmas	Samhain
December solstice	dōng zhì	Christmas Day	

Table 2: Holidays related to seasonal markers

This is similar to the ecclesiastical calendar, where Christmas Day and Annunciation Day on March 25 are solar holidays, while all the other holidays are tied to Easter and are therefore lunar.

4 The Rules of the Chinese Calendar

We can now state the rules for the modern Chinese calendar.

Rule 1 *Calculations are based on the meridian* 120° *East.*

Before 1929 the computations were based on the meridian in Beijing (116°25′), but in 1928 China adopted a standard time zone based on 120° East. Since 1949 the Purple Mountain Observatory in Nanjing has been responsible for calendrical calculations in China.

Rule 2 *The day on which the new Moon occurs is the first day of the month.*

The length of the months are determined astronomically (Table 3). Suppose a lunar month is 29.5 days, and starts with a new Moon at 13h on May 1. The next new Moon then takes place at 1h on May 31, so the month has 30 days. But if the new Moon occurred at 1h on May 1, then the next new Moon would be at 13h on May 30, so the new month would start one day earlier, and we would only get 29 days in the month.

In the Gregorian calendar all the months (except for February) have the same number of days in different years. This is not the case for the Chinese calendar. A month may have 29 or 30 days in different years. Since the mean lunar month is 29.53 days, a little over half the months are big months, dà yuè (大月), with 30

New Moon	Next new Moon	Length
May 1 13h	May 31 1h	30 days
May 1 1h	May 30 13h	29 days

Table 3: Determining the length of the months

days and a little under half the months are small months, xiǎo yuè (小月), with 29 days. From a naive point of view, we would expect them to more or less alternate, with occasionally two long months, lián dà (连大), in a row. This was the method until the start of the Táng (唐) dynasty in 619, when the mean Moon, píng shuò (平朔), was abandoned in favor of the true Moon, dìng shuò (定朔). Because of Kepler's Second Law, the lunations will be longer in the winter and shorter in the summer. It turns out that it is possible to have up to four big months or three small months in a row. An example of four big months in a row is given in Table 4.

New Moon	Length
1990 Oct.~18 23h 36m	29d 17h 29m
1990 Nov.~17 17h 5m	29d 19h 17m
1990 Dec.~17 12h 22m	29d 19h 28m
1991 Jan.~16 7h 50m	29d 17h 42m
1991 Feb.~15 1h 32m	

Table 4: Four big months in a row

Notice that the new Moon "takes" the whole day, no matter what time of the day it occurs. So if a zhōng qì occurred in the early morning, it is considered part of the new month, even though it may have occurred almost 24 hours before the new Moon.

5 The Chinese Year

It is important to understand that the Chinese calendar is a combination of two calendars, a solar calendar and a lunisolar calendar. The solar calendar starts at the December solstice and follows the 24 jié qì. This is traditionally called the farmer's calendar (农历). The lunisolar calendar starts at Chinese New Year and consists of 12 or 13 months. This is what most people think of as the Chinese calendar, and the term farmer's calendar has come to refer to the lunisolar calendar, even though it is not suitable for farmers.

There are therefore two different years in the Chinese calendar, the suì (岁) and the nián (年). A *suì* is the solar year from one December solstice to the next. A *nián* is the Chinese year from one Chinese New Year to the next. The length of a nián can be 353, 354 or 355 days in case of a normal year and 383, 384 or 385 days in case of a leap year. Just as we think of the Gregorian year as an approximation to the tropical year, we can think of the nián as an approximation to the suì. Table 5 gives the distribution of the length of the years between 1911 and 2110.

353 days	354 days	355 days	383 days	384 days	385 days
1	84	41	5	66	3

Table 5: The length of Chinese years between 1911 and 2110

The tropical year tracks the return of the Sun to the same tropic. In Western astronomy it used to be defined as the mean time between two March equinoxes. It is a good exercise to see why this is not the same as the Chinese solstice year ([1, 6])! The modern definition is the time it takes the Sun's mean longitude to increase by 360°. It is currently 365.2422 days. I will feel free to use the term solar year or tropical year for either the value derived from the mean longitude, the March equinox year or the December solstice year.

In modern Chinese, the word suì is only used when talking about a person's age. Traditionally, Chinese people count their age from the December solstice, but many instead count from Chinese New Year or the seventh day of the new year (人日). Using the word suì when talking about a person's age is maybe related to this custom.

When I say that 2033 is a leap year, it means that the nián 2033 contains 13 months. I will now define a leap suì. The suì can be divided into 12 whole months and about 11 days, or 11 whole months and about 40 days. Table 6 gives two examples.

365 days		
5 days	354 days (12 months)	6 days
13 days	325 days (11 months)	27 days

Table 6: Determining the number of months in a suì

Rule 3 *The December solstice falls in month 11. A suì is a leap suì if there are 12 complete months between the two 11th months at the beginning and end of the suì.*

If there is a new Moon on the day after the December solstice or within about 11 days, the suì is a leap suì. If there is a new Moon on the same day as the December solstice or the first new Moon after the December solstice is more than about 12 days later, it is a normal year. Notice that the leap year test applies to suì's and not to nián's.

Because of Kepler's Second Law, the speed of the (apparent) motion of the Sun across the ecliptic is not constant, so the time between the zhōng qì's is not constant. This was known to Chinese astronomers since the 7th century, but it was not until the last calendar reform in 1645 that they started using the true Sun, dìng qì (定气), in their computations of the jié qì. Before that, they had used the mean Sun, píng qì (平气).

Under the mean Sun system, the length between two zhōng qì's is always about 30.44 days, which is a little bit longer than the lunar month. Hence it is possible to have two new Moons between two zhōng qì's or equivalently, a month without any zhōng qì. Under the true Sun system, the zhōng qì's are closer together during the winter. The time between two zhōng qì's ranges from 29.44 days to 31.44 days. So under the modern system it is also possible to get a month with two zhōng qì's.

If we consider the first December solstice and the first 11th month as part of the suì, but not the second December solstice and 11th month, then a leap suì contains 13 months and 12 zhōng qì's. Hence there must be at least one month without a zhōng qì. Notice that in extreme cases, there may also be a month with two zhōng qì's, and hence two months without a zhōng qì. This will lead to "fake leap months" ([1]).

Rule 4 *In a leap suì, the first month that doesn't contain a zhōng qì is the leap month, rùn yuè* (闰月)*. The leap month takes the same number as the previous month.*

Let me illustrate this idea. On one of my training runs I run up a gentle hill with small steps that are far apart. The distance between the steps is a little bit more than the length of my running stride. On most strides I climb to the next step, but once in a while, I land near the edge, and I have to take a "resting" stride on the same level. If you think of the steps as the zhōng qì's, and my stride as the lunar months, you get a nice analogy with the leap month rule in the Chinese calendar. Another way is to say that whenever the lunar months have gotten too far ahead of the zhōng qì's, they need to take a pause (leap month) to let the zhōng qì's catch up.

Some people say that when a Gregorian calendar month contains two full Moons, then the second is called a "blue Moon" ([7]). This concept is somewhat similar to the system of Chinese leap months.

Notice that *any* month can have a leap month. Some Chinese astronomers claim that there can be no leap month after the 11th, 12th or 1st month. This is true in the sense that it hasn't happened since the last calendar reform in 1645. But because of the precession of the equinoxes ([1]) it is clear that in the future there will be many such leap months. In 2033 there will be a leap month after the 11th month. This was an error in Chinese calendar until about 1990 ([1, 5]). I believe that in 2262 there will be a leap month after the 1st month, and in 3358 a leap month after the 12th ([1]).

I would also like to mention that some astrological sources use a year running from lì chūn to lì chūn, and claim that your Chinese zodiac animal should be based on this. In 1960, Chinese New Year fell on January 28 while lì chūn fell on February 5. If you were born on February 1, you would not be a rat, but a pig!

6 What is the Date of Chinese New Year?

The exact date of Chinese New Year follows from the above rules. Table 7 shows that the possible dates of Chinese New Year between 1645 and 2644 are between January 21 and February 21.

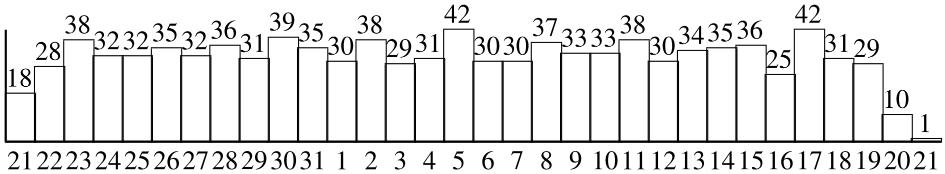

Table 7: Dates of Chinese New Year between 1645 and 2644

Chinese New Year moves backwards by 11 days (or 10 or 12) once or twice, but if a step would take it before (or in some cases, close to) January 21, it jumps forward by 19 (or 18 or 20) days as in Table 8. There are also two simple rules of thumb.

1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
7/2	28/1	16/2	5/2	24/1	12/2	1/2	22/1	9/2	29/1	18/2
-10	+19	-11	-12	+19	-11	-10	+18	-11	+20	

Table 8: The movement of the dates of Chinese New Year

Rule of thumb 1 *Chinese New Year falls on the day of the second new Moon after the December solstice.*

Since the December solstice falls in the 11th month, this rule of thumb is correct provided there is no leap month after the 11th or 12th month. In that case, Chinese New Year falls on the third new Moon after the December solstice. It can be shown ([1]) that there can only be a leap month between the December solstice and Chinese New Year if there is a new Moon very soon after (but not on the same day as) the December solstice, so the second new Moon will then be around January 21 and the third around February 21.

Rule of thumb 2 *Chinese New Year falls on the day of the new Moon closest to lì chūn* (立春)*, "beginning of spring" (approximately February 4).*

This rule of thumb explains why Chinese New Year is called the Spring Festival, chūn jié (春节). But it is hard to determine which new Moon is closest if we have a very early or a very late Chinese New Year. The rule fails 31 times between 1645 and 2644.

Notice also that if Chinese New Year is at the beginning of spring, then the middle of spring should be in the middle of the 2nd month. This explains why the Mid-Autumn Festival, zhōng qiū jié (中秋节), is celebrated on the 15th day of the 8th month.

7 The Jesuits and the Chinese Calendar

The Chinese emperor based his authority on being the "Son of Heaven", so it was important that the calendar was in harmony with the heavens. Unfortunately, with a lunar or lunisolar calendar, errors are much more obvious than with a solar calendar. Only astronomers would notice if a solar calendar was off by a week. But if a lunar calendar has an error of just a couple of days, everybody would each month see that the new Moon was visible near the end of the old month or that the old Moon was visible in the new month.

Because of the importance the Chinese rulers placed on calendars, they were willing to incorporate foreign ideas into the calendars. The last three main calendar reforms were all implemented with the aid of foreigners. The Táng (唐) dynasty calendar reform in 619 switched to following the true Moon. This was inspired by Indian Buddhist astronomers. The Yuán (元) dynasty reform in 1280 was inspired by Muslim astronomers. It was the most accurate calendar in the world at that time. The last calendar reform came in 1645 during the Qīng dynasty (清) and was implemented by Jesuit missionaries. In 1582, the first Jesuit missionary Matteo Ricci came to China. At that time, the Chinese calendar was no longer accurate. Positions in the Bureau of Astronomy had become hereditary, and the astronomers no longer understood the principles behind the old calendar.

When they made an error of more than half an hour in computing a solar eclipse on December 15, 1610, it caused serious embarrassment. Finally, in 1629 Xǔ Guāng Qǐ (徐光启), an official who was a Christian convert, was asked to revise the calendar, and he asked the Chinese and Muslim astronomers in the Bureau and the Jesuits to make predictions for an upcoming solar eclipse on June 21, 1629. The Jesuits had the best prediction, and when Xu was made director of the Bureau, he appointed the Italian Terrentius and another Jesuit as members. Terrentius had been a member of the Cesi Academy with Galileo, and wrote him repeatedly for help. The Pope had forbidden Galileo to promote his views, and even though Terrentius promised that he would keep any help secret, Galileo was not very eager to help the Jesuits. Finally, in 1623 Terrentius wrote to Kepler. It took more than four years before Kepler received the letter! This was in the middle of the Thirty Years War, but even though Kepler was a Protestant, he did not hesitate to help the Jesuits. As a thank you, the Jesuits sent him some data about old Chinese eclipse observations.

In 1644, the German Adam Schall went to the new Qīng rulers and presented his calculations for an upcoming solar eclipse. Again the Jesuits' calculations were best. Schall was appointed director of the Bureau and he formulated the current rules for the Chinese calendar.

However, a Chinese official, Yáng Guāng Xiān (杨光先), wrote that it was "better to have a wrong calendar than to have foreigners in China". He managed to have Schall and the Belgian Ferdinand Verbiest arrested in 1664. A solar eclipse was coming up and while in prison, the Jesuits predicted it would occur at 3 pm, Yáng predicted 2.15 pm, and the Muslim Wú Míng Xuǎn (吴明炫) predicted 2.30 pm. On the day of the eclipse, the Jesuits were brought into the palace in chains, and everybody watched as the eclipse occurred exactly as the Jesuits had predicted! Unfortunately, the regents were not impressed and the Jesuits were sentenced to death. However, the next day a strong earthquake struck Beijing. This was taken as a sign from Heaven that the sentence was unjust, and it was first converted to flogging and eventually to house arrest. In 1666, Schall died in house arrest.

In 1668, the Kāng Xī (康熙) emperor took over. The emperor ordered Verbiest, Yáng and Wú to compute the length of the shadow of a pole and the position of the Sun at noon on a certain day. They were to leave their instruments pointing towards the predicted spot in the emperor's garden two weeks in advance. Verbiest easily won, and was appointed director of the Bureau, while Yáng and Wú were arrested. Jesuits remained as directors of the Bureau until 1746 and it was run by other Westerners until 1826.

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