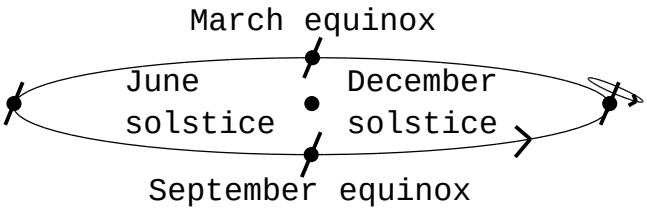
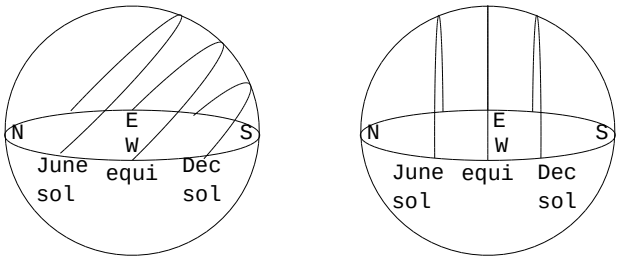
Fake Leap Months in the Chinese Calendar: From the Jesuits to 2033

Helmer Aslaksen
Department of Mathematics
National University of Singapore
aslaksen@math.nus.edu.sg
www.math.nus.edu.sg/aslaksen/calendar/

A Quick Course in Astronomy

The Earth revolves counterclockwise around the sun in an elliptical orbit. The Earth rotates counterclockwise around an axis that is tilted 23.5 degrees.





Beijing Singapore

In the northern hemisphere, the day will be longest at the June solstice and shortest at the December solstice. At the two equinoxes day and night will be equally long.

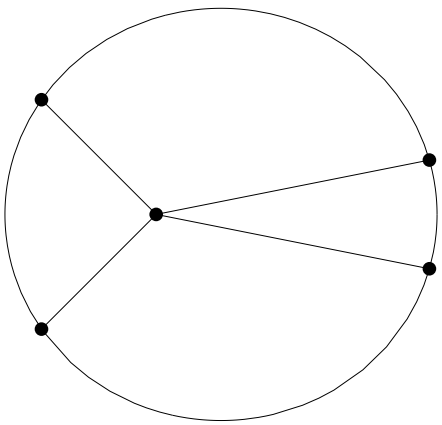
Seasonal Markers

The equinoxes and solstices are called the seasonal markers. The point where the Earth is closest to the sun is called perihelion. The point where the Earth is farthest from the sun is called aphelion.

Approximate dates	
Perihelion	January 4
March equinox	March 21
Aphelion	June 4
June solstice	June 22
September equinox	September 23
December solstice	December 22

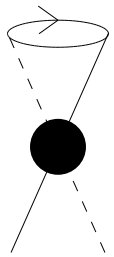
Kepler's Second Law

Kepler's second law says that the radial line sweeps out equal areas in equal time. This means that the Earth moves faster along the orbit in winter near perihelion.



Precession of the Equinoxes

The Earth's axis revolves around in a circle with a period of about 26,000 years. This is called precession of the equinoxes. Because of this, perihelion will shift one day later about every 50 years.



The Year

The tropical year (or solar year) is the time from one March equinox to the next. The mean value is 365.2422 days.

The synodic month is the time from one new Moon to the next. It ranges from 29.27 days to 29.84 days with a mean of 29.53 days.

$12 \times 29.53 = 354.3671$, so a lunar year consisting of 12 lunar months is about 11 days short of a solar year.

The Metonic Cycle

235 mean lunar months equals $235 \times 29.53 = 6939.6884$ days.

Nineteen tropical years is $19 \times 365.2422 = 6939.6018$ days.

The difference is about two hours. This is called the Metonic cycle (432 BCE). It was known in China by about 600 BCE and was called the zhāng (章) cycle.

The Metonic cycle is used in the Jewish calendar, in the computation of Easter, and was used in the Chinese calendar before 104 BCE.

Classification of Calendars

solar Gregorian calendar. Basic unit is day. Approximates the tropical year by adding leap days. Ignores the Moon.

lunar Islamic calendar. Basic unit is lunar month. Ignores the sun

lunisolar Chinese and Jewish calendars. Basic unit is lunar month. Approximates the tropical year by adding leap months.

The Chinese calendar is NOT a lunar calendar!

Alternative Classification of Calendars

arithmetical Gregorian, Indian and Jewish calendars. Based on arithmetical formulas. Prediction and conversion between different arithmetical calendars is simple.

astronomical Islamic, Indian and Chinese calendars. Based on astronomical data. Prediction and conversion is hard.

The Chinese Calendar

The goal is to approximate the solar year by adding leap months. Sine 12 lunar months are 11 days too short we will need to add a leap month a little bit more than every third year. In ancient times, this was done by observing nature.

Since $235 = 19 \times 12 + 7$, we can use the Metonic cycle and get a decent lunisolar calendar by having 7 leap years in every 19-year cycle.

The 24 Jié Qì

A fundamental concept in the Chinese calendar is the 24 solar terms or jié qì (节气). They are a generalization of the solstices and equinoxes. The even ones are called major solar terms or zhōng qì (中气).

A useful rule of thumb is that Chinese New Year is the new Moon closest to lì chūn (立春), the beginning of spring. This rule is correct most of the time, but it failed in 1985 and will fail again in 2015. Since lì chūn falls around Feb. 4, this helps explain why Chinese New Year will always fall between Jan. 21 and Feb. 21. It also helps explain why Chinese New Year is called the spring festival.

In Western astronomy, spring begins at spring equinox. In Chinese astronomy, spring begins midway between winter solstice and spring equinox.

The 24 Jié Qì

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	Spring 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	Summer 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	处署	Limit of heat	August 23
J8	Bái lù	白露	White dew	September 8
Z8	Qiū fēn	秋分	Autumnal 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	Winter solstice	December 22
J12	Xiǎo hán	小寒	Slight cold	January 6
Z12	Dà hán	大寒	Great cold	January 20

The Chinese Solar Calendar

It is important to understand that the Chinese calendar is a combination of two calendars, the usual lunisolar calendar and a solar calendar that follows the 24 jié qì. The solar calendar is traditionally called the farmer's calendar (农历). Unfortunately the term farmer's calendar has come to include the lunisolar calendar. The Chinese solar calendar follows the tropical year closely, so it is perfect for farming purposes, but the lunisolar calendar is not at all suitable for farmers.

There are two Chinese holidays that are determined by the solar calendar, namely qīng míng (清明) around Apr. 5 and winter solstice dōng zhì (冬至) around Dec. 22.

Notice that lunar dates can fall within a range of about one month in the solar calendar and conversely. Chinese New Year can fall between Jan. 21 and Feb. 21, while qīng míng can fall between the 13th day of the 2nd month and the 17th day of the 3rd month.

The Chinese Year

There are several years in the Chinese calendar. The most important are the suì (岁) and the nián (年).

A suì is the solstice year from one winter solstice to the next. This is the same as the tropical year.

A nián is the Chinese year from one Chinese New Year to the next. Since a Chinese year can contain 12 or 13 lunar months, and they can have 29 or 30 days, it can be shown that the length of a nián can be 353, 354, 355, 383, 384 or 385 days long.

Just like we can think of the Gregorian year as an approximation to the tropical year, we can think of the nián as an approximation to the suì.

The Chinese astrological year runs from lì chūn, the beginning of spring about Feb. 5, not from Chinese New Year.

The Chinese Meridian

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.

The Length of a Chinese Month

RULE 2:The day on which a new Moon occurs is the first day of the new month.

The length of the months are determined astronomically. The lunar month can vary between about 29.25 and 29.75 with a mean of 29.53. Suppose a month is 29.5 days.

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

There can be four long months or three short months in a row.

Mid-Autumn Festival

If the 1st month marks the beginning of spring, autumn should start with the 7th month. This explains why the Mid-Autumn Festival is celebrated on the 15th day of the 8th month.

If new Moon happens near midnight, it can be difficult to determine the beginning of the new month correctly. In 1978, most calendars in Hong Kong and Taiwan were based on old imperial calendars that had the seventh month as a short month, while the modern calendar in China had the seventh month as a long month. Because of this, the Mid-Autumn festival was celebrated on different days.

The full Moon will normally fall on the 15th or 16th day, but it can also fall on the 14th or 17th.

Which Years are Leap Years?

RULE 3: A suì is a leap suì if it contains 12 complete months.

The 365 days can be divided into 12 whole months and 11 days, or 11 whole months and 40 days.

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

The True Jie Qi's

The average length between to zhōng qì's is 30.44 days, which is a little bit longer than the lunar months. Before 1645, the Chinese used mean values for the motion of the Sun (mean Sun), so the distance between the zhōng qì's were the same. After 1645, they have used the true Sun. The zhōng qì's are closer together during the winter.

Important: If a zhōng qì and a new Moon fall on the same day, we will consider the zhōng qì as falling in the new month, even though it may have occured earlier in the day than the new Moon.

Which Month Will be the Leap Month?

In the Chinese calendar, *any* month can have a leap month.

If there are 11 full months in a suì, there will usually be one zhōng qì in each month, and the month takes it's number from the number of the zhōng qì. In extreme cases, there may be two zhōng qì's in one month, and no zhōng qì in a nearby month.

If there are 12 full months in a suì, there must be at least one month without a zhōng qì.

RULE 4: In a leap suì, i.e., a suì with 12 full month, the first month that doesn't contain a zhōng qì is the leap month, rùn yuè (闰月). It takes the same number as the previous month.

RULE 5: Winter solstice falls in month 11. This determines the numbering of the months in a normal suì. In a leap suì, the leap month takes the same number as the previous month.

Rules of Thumb for Chinese New Year

Rule of thumb 1: CNY falls 11 days (sometimes 10 or 12) earlier than the previous year, but if that would take us outside of the CNY range of Jan. 21 to Feb. 21, we must add a leap month, so CNY jumps 19 days (sometimes 18) later.

This rule is clearly an approximation, and can be problematic near the edges of the CNY interval.

1998	1999	2000	2001	2002	2003
28/1	16/2	5/2	24/1	12/2	1/2
	19	11	12	19	11

	2004	2005	2006	2007	2008	2009
	22/1	9/2	29/1	18/2	7/2	26/1
10	18	11	20	11	12	

The Lì Chūn Rule

Rule of thumb 2: CNY is the new Moon closest to lì chūn, the beginning of spring.

This rule is correct most of the time, but it can be complicated to determine which new Moon is closest. It failed in 1985 and will fail again in 2015. Since lì chūn falls about Feb. 4, this helps explain why CNY will always fall between Jan. 21 and Feb. 21. It also helps explain why CNY is called the spring festival.

The 2nd New Moon Rule

Rule of thumb 3: Chinese New Year is the second new Moon after winter solstice.

This rule is correct, provided there are no leap months after months 11 or 12.

Fake Leap Months

A month with no zhōng qì will happen about every third year. In rare cases, there can be a month with two zhōng qì's. In that case there will be a month nearby without any zhōng qì, but where that is caused not by a shift of the months, but by one month being "greedy" and grabbing two of them. Such a month without any zhōng qì which is not a leap month is called a fake leap month.

What Happens in 2033?

The suì 2033 has only 12 months, but the suì 2034 has 13 months. Hence the 7th month does not have a leap month. This was an error in all Chinese calendars up until the early 1990's.

Notice that the nián 2033 is a leap suì, but the suì 2033 is not!

Since 1804, fake leap months have only happened in 1851, 1870, 1984 and 2033.

2033 in also exceptional in that it has "double spring, double rain", i.e., the nián contains both lì chūn and yǔ shuǐ (雨水). Since 1804, this has only happened in 1832, 1851, 1984 and 2033.

	June	July	August
19			
20			
21	Z5		
22			M7
23		Z6 M6	Z7
24	M5-leap		

	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr
18							Z1		
19							M1		
20						z12 M12		Z2 M2	Z3
21					Z11				M3
22				Z10 M11	M11-leap				
23	Z7	Z8 M9	Z9 M10						
24									
25	M8								

Month	Number of zhōng qì's
2033 M7	1
2033 M8	0
2033 M9	1
2033 M10	1
2033 M11	2
2033 M11-leap	0
2033 M12	2
2034 M1	0
2034 M2	1

Can Any Month Have a Leap Month?

Chinese astronomers claim that months 12 and 1 can never be repeated, and that month 11 is only rarely repeated. The 11th month has a leap month in 2033.

According to my computations, the 1st month should have had a leap month in 1651. This will happen again in 2262. A leap month after the 12th month will not happen until 3358.

In 11,000 years time, most leap months will fall during the winter.

Notice that there can only be a leap month between winter solstice and Chinese New Year if there is a new Moon very soon after winter solstice, so the second new Moon would be around Jan. 21 and the third around Feb. 21.

The 19-Year Cycle From 1805 to 2050

1805–7	1808–5	1811–3		1814–2	1816–6	1819–4	1822–3
1824	1827	1830–4	1832–9		1835	1838	1841
1843	1846	1849	1851–8		1854–7	1857–5	1860
1862–8	1865	1868	1870–10		1873–6	1876	1879
1881–7	1884	1887		1890–2	1892	1895	1898
1900–8	1903	1906		1909	1911	1914	1917–2
1919–7	1922	1925		1928	1930	1933	1936–3
1938	1941–6	1944		1947	1949–7	1952	1955
1957–8	1960	1963		1966–3	1968	1971	1974–4
1976	1979	1982	1984-10		1987–6	1990	1993–3
1995	1998–5	2001		2004–2	2006–7	2009	2012–4
2014–9	2017–6	2020		2023	2025–6	2028	2031–3
2033–11	2036	2039–5		2042	2044–7	2047	2050

Why Was the Calendar Important?

With a lunar or lunisolar calendar, errors are much more obvious than with a solar calendar. A solar calendar can be off by a couple of weeks without anybody noticing. The reason why the Catholic church had to reform the Julian calendar was because the rules for computing Easter had frozen the March equinox to be March 21. That meant that Easter was drifting noticeably towards summer. Otherwise, few would have cared about the drift of the March equinox. But with a lunar calendar, an error of even a couple of days is a serious problem. Every peasant could each month see that the new Moon was visible near the end of the previous month or that the old Moon was visible in the next month.

Because of the importance the Chinese rulers placed on calendars, they were surprisingly open to incorporate foreign ideas into the making of calendars. The last three main calendar reforms have all been associated with foreign impulses.

The Main Calendar Reforms

Before 621 BCE, the start of the month was based on visibility of the crescent Moon. During the Zhōu (周) dynasty, the Metonic cycle was used for determining leap months and the leap months were always placed at the end of the year. After the Tài Chū (太初) calendar reform in 104 BCE, the "no zhōng qì" (无中气) rule was used for determining leap months, and the month containing the December solstice was fixed to be the 11th month.

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. It used the true Sun.

The Jesuits

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

The Trial of the Jesuits

A Chinese official, Yáng Guāng Xiān (杨光先), had as his slogan that it was "better to have a wrong calendar than to have foreigners in China". Yáng managed to have the Jesuits 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 at 3pm sharp! 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 the sentence of the Jesuits was first converted to flogging and eventually to just house arrest.

The Kang Xi Emperor

In 1668, the Kāng Xī (康熙) emperor took over from the regents. The emperor ordered the Belgian Verbiest, Yáng and Wú to compute the length of the shadow of a pole on a certain day 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. Verbiest became personal tutor to the Kāng Xī emperor, and even learned Manchu. Jesuits remained as directors of the Bureau until 1746 and it was run by other Westerners until 1826.