Time, and how we tell it

- Announcements

- LABS started this week.
- You MUST have a yellow lab book and manual.
- Read 4-pg lab manual intro + first 6 pages Lab 1
- Answers to math review are on the web site.
- Readings for Friday:
    - Chapter S1, Sections 2.1- 2.2

Sun's motion defines the seasons

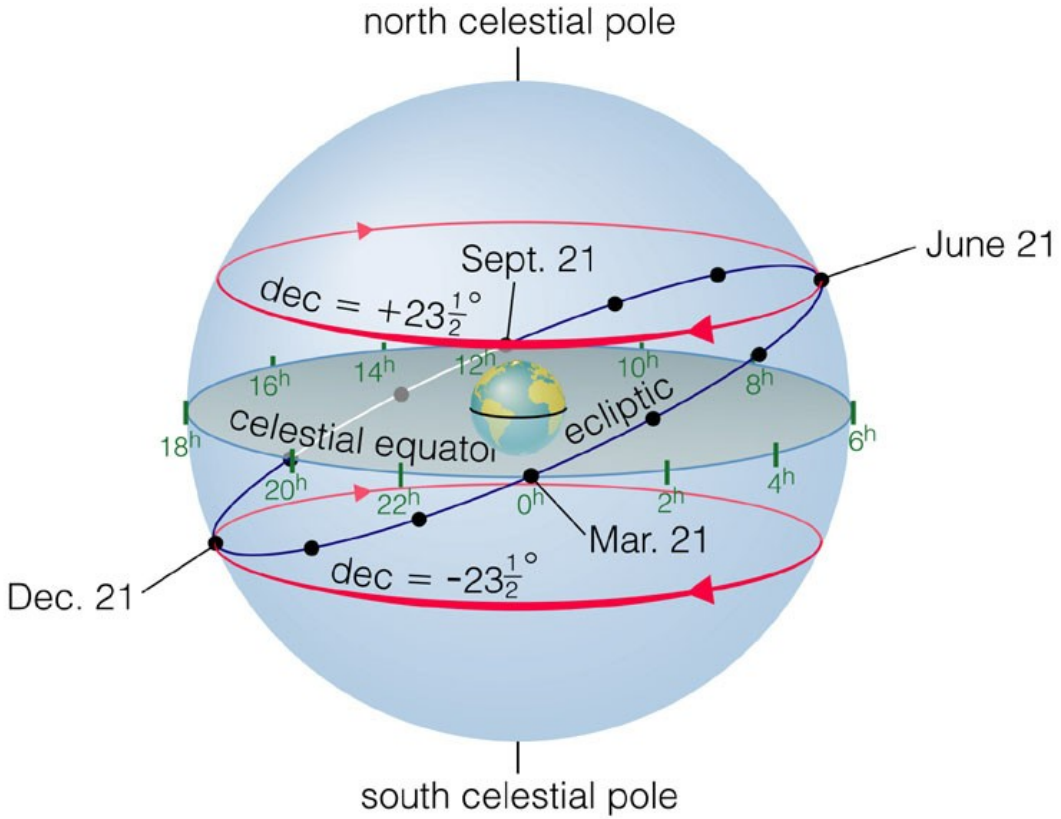


Table S1.1 The Sun's Approximate Celestial Coordinates at 1-Month Intervals

Approximate Date	RA	Dec
Mar. 21 (Spring equinox)	0hr	0°
Apr. 21	2 hr	+12°
May 21	4 hr	+20°
June 21 (Summer solstice)	6 hr	+23½°
July 21	8 hr	+20°
Aug. 21	10 hr	+12°
Sept. 21 (Fall equinox)	12 hr	0°
Oct. 21	14 hr	−12°
Nov. 21	16 hr	−20°
Dec. 21 (Winter solstice)	18 hr	−23½°
Jan. 21	20 hr	−20°
Feb. 21	22 hr	−12°

Origin of time-keeping.

Ancient peoples watched the sky

- They desperately needed to know when they could plant crops.
- Watching the motion of the Sun allows one to predict the seasons, especially the arrival of spring.
- Many cultures built 'sky monitoring stations'

How do these work?

- Set up alignments of rocks that mark the Sun's rising or setting on the horizon on certain days when viewed from the center.

How do you know which day is the summer solstice?

- Many cultures used this as a day of celebration.
- In northern hemisphere, the Sun is highest in the sky (at its northernmost declination) that day.
- This means shadows are shortest at noon.
  - Use of gnomons and obelisks to project a 'straight' shadow.

Some cultures used holes instead of posts

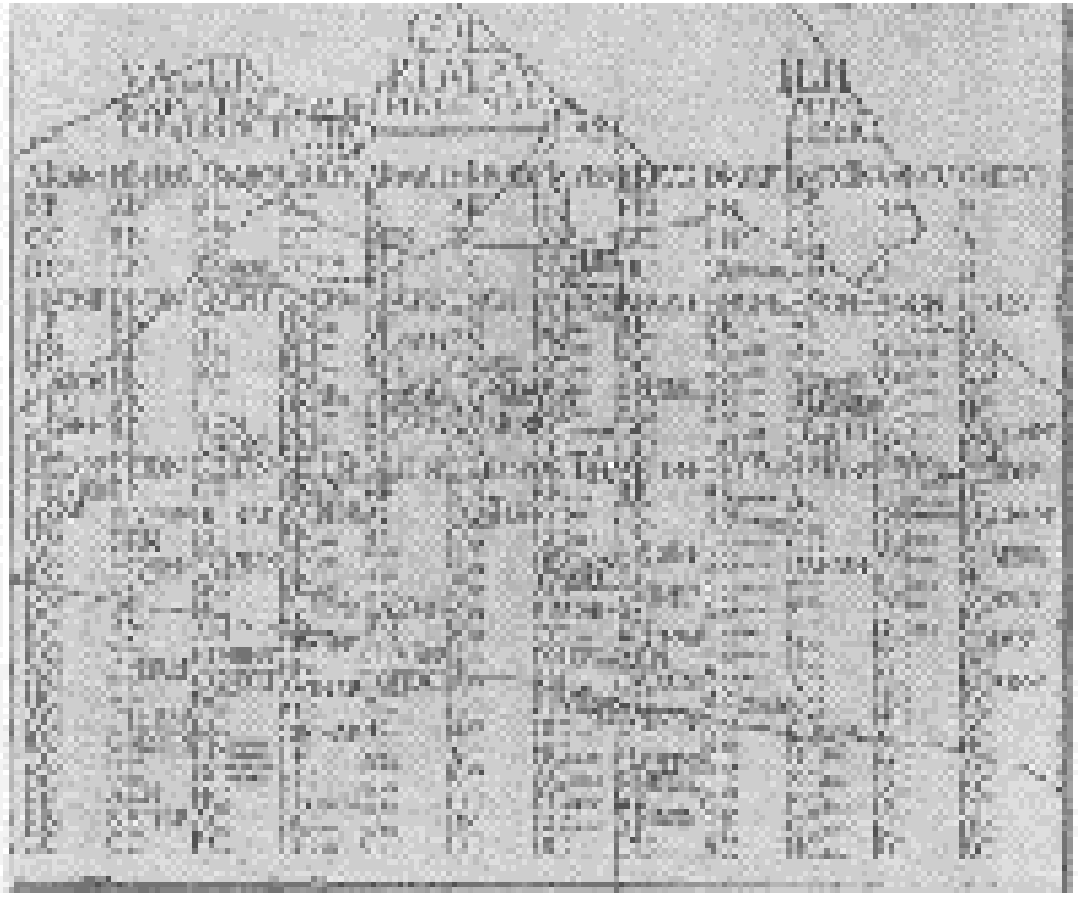
- The passing light gives the 'perfect' straight line.

The Chaco Sun Dagger :

- *Only* at noon on the Summer solstice!

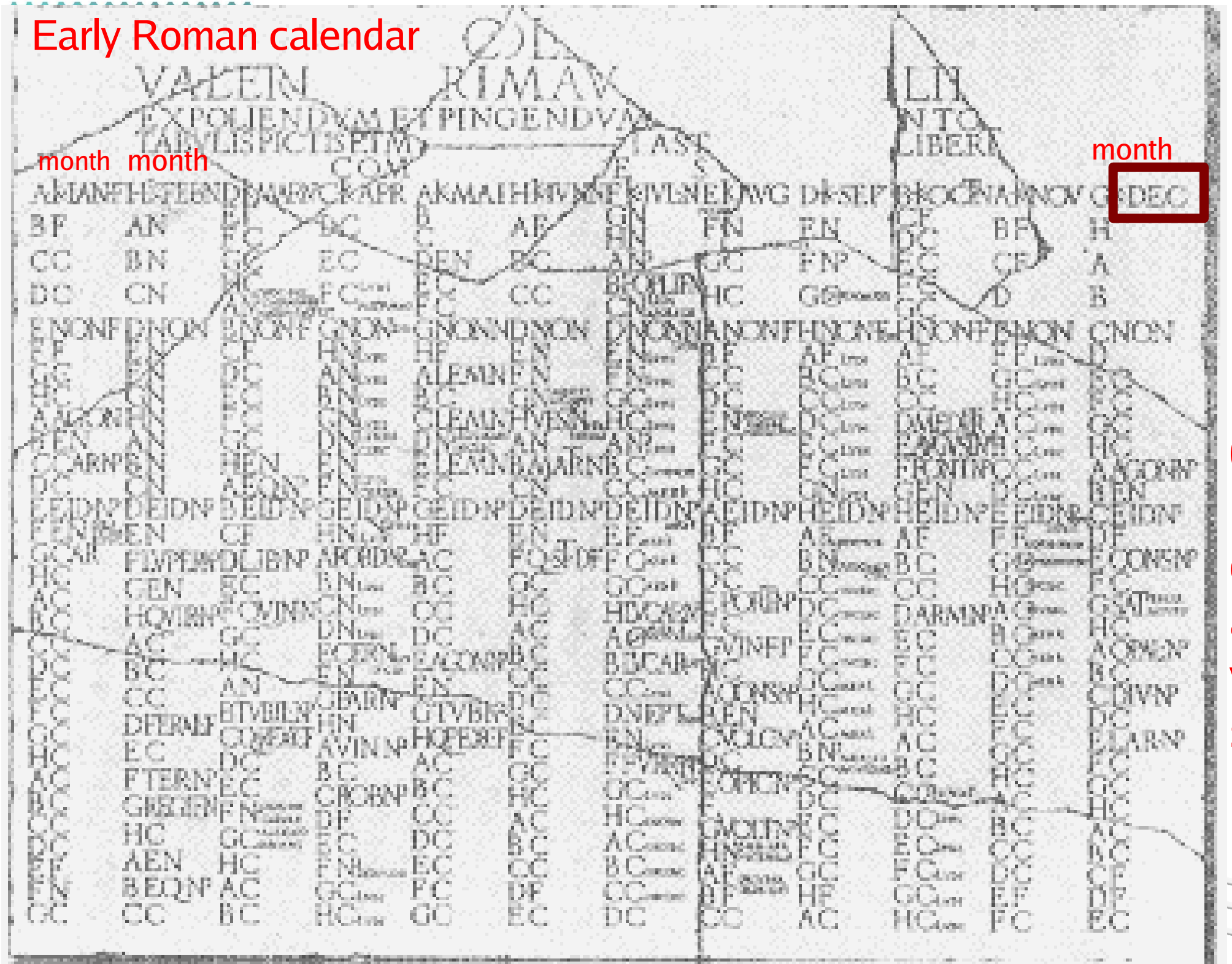
- *Surely* this must be evidence for aliens, no? Could primitive cultures do the complex necessary calculations?

The need for a Calendar



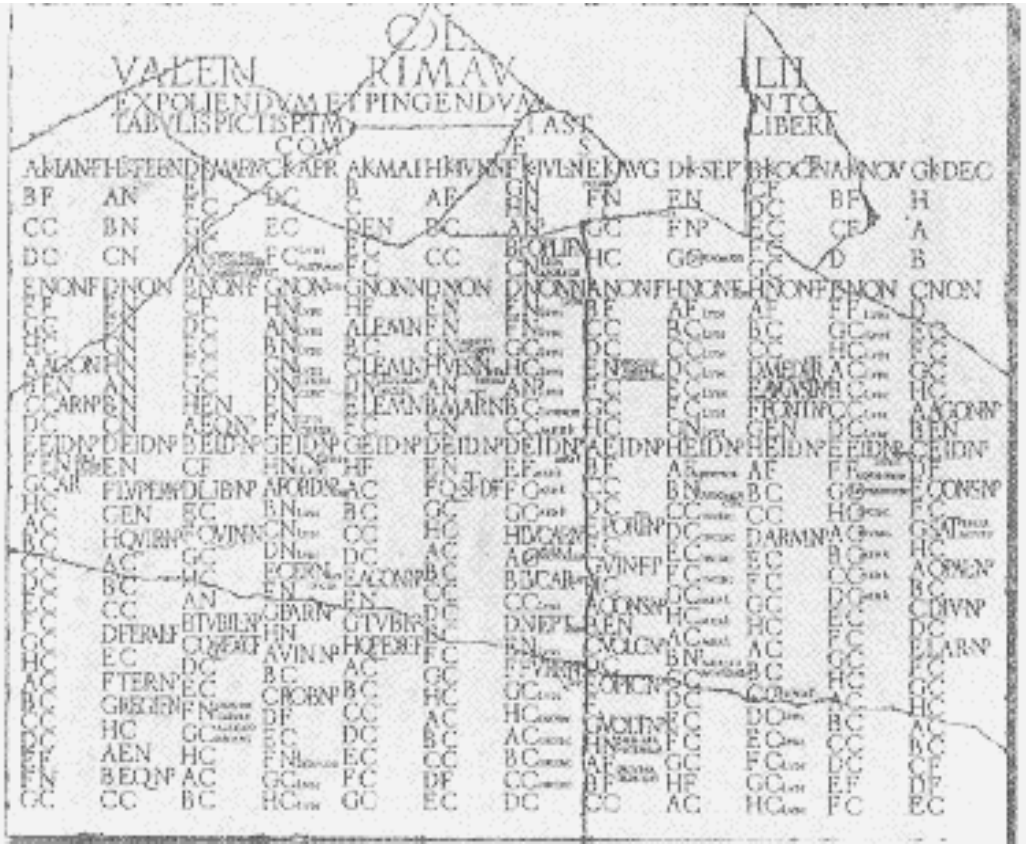
- Why do you need one?
  - Agriculture
  - Commerce
  - Holidays
  - Religious festivals
  - Parties!
- For agriculture, want the calender based on the seasons (Sun)

Early Roman calendar



Early Calendars: What's a year?

- Ahem...wait a sec...
  - 12 months. 30 days each
  - 360 days!
  - Causes seasons to drift
- Roman priests 'added' days, but were bad at it!



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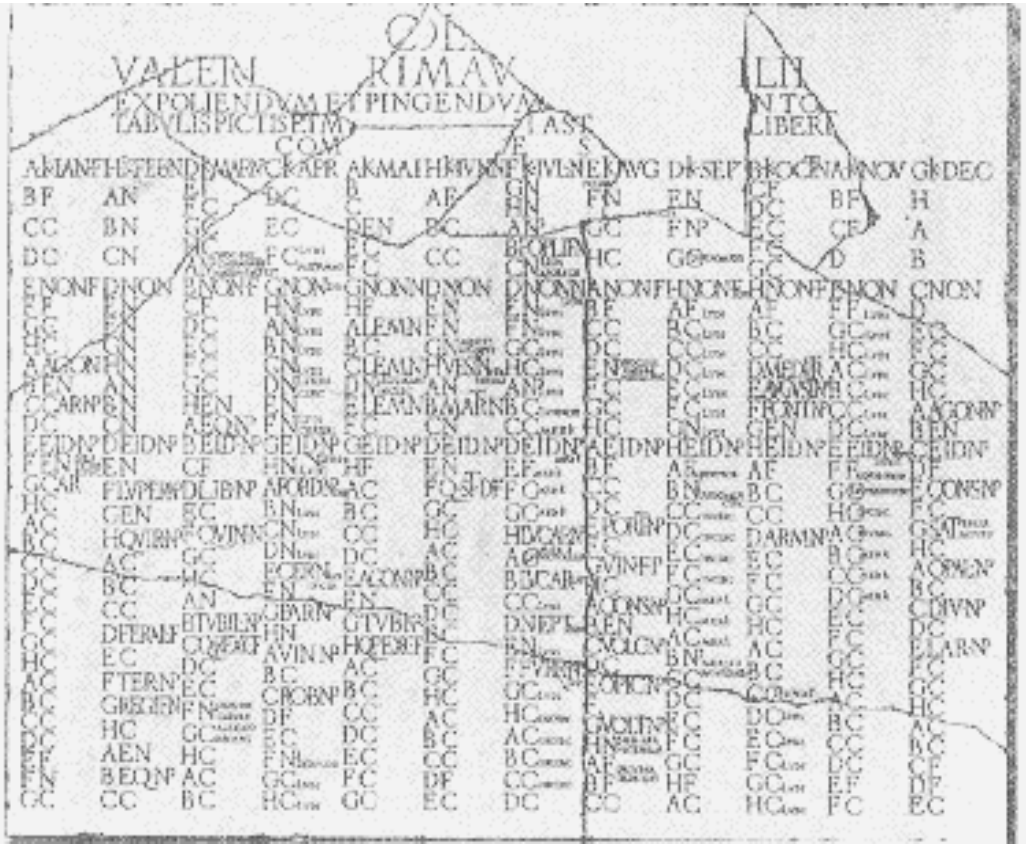


- Julius Caesar fixed this in the 'year of confusion', 46 BC, when two whole months were temporarily added to re-align seasons and get correct # of days. But what IS the correct number of days?

How many days in a year?

- 365, right?
- Well, 365 and a quarter, right?
- No
- 365 days, 5 hours, 48 minutes, 46 sec
- Hipparchus (130 BC) had:
  - 365d 5h 55m, not bad (+6 min)
- Julius Caesar : 365 d, 6 h (+11 min)

Wait a minute...what IS a year? For that matter, what's a day? Or a month, or a second?

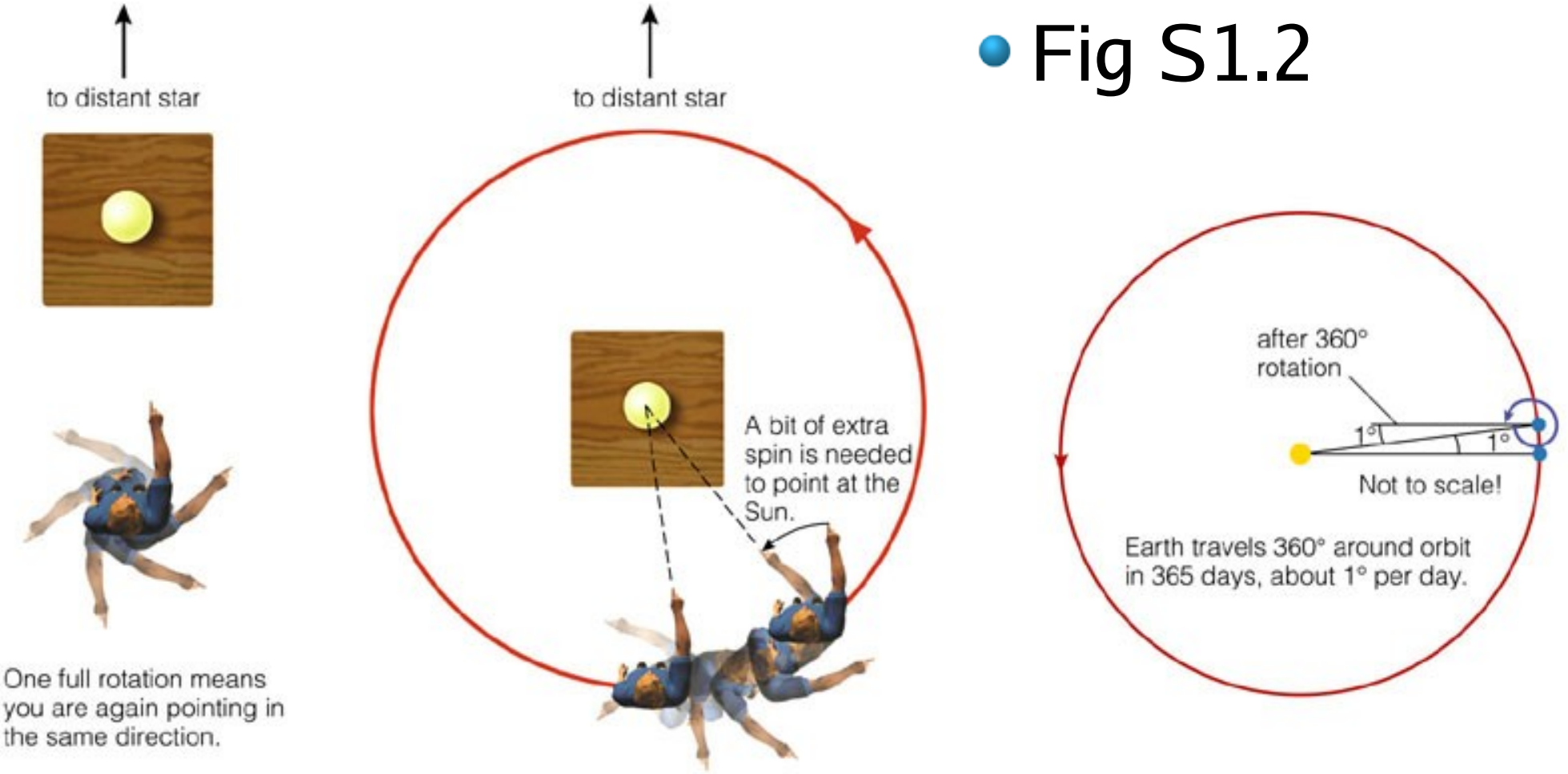
- Most people haven't thought about this in detail.
- A day should be pretty obvious, it's the time for the Earth to turn once, but with respect to what???

The Solar Day, and sidereal day

- The MEAN solar day: time from noon to noon
- The SIDEREAL day: time for a star on the local meridian to rotate once on the celestial sphere and return to the meridian.
- Sidereal day differs by 3m56s. Longer or shorter?

Solar vs sidereal day

- Fig S1.2



Ratio of the solar day to the year

- The year: One circuit of the Sun around ecliptic.
  - Usually: Time from one spring equinox to next
    - CALLED THE *TROPICAL* YEAR
  - 365 d 5 h 48 m 45 s
- RATS. Not an integer multiple of days
  - Wouldn't that be convenient?...
- Julius Caesar adjusts the Roman Calender to 365 days, with leap years, alternating 30- and 31- day months. At this time March was the 1st month and February the last (with 29)
- Augustus and Sextilus. 30 days hath September...

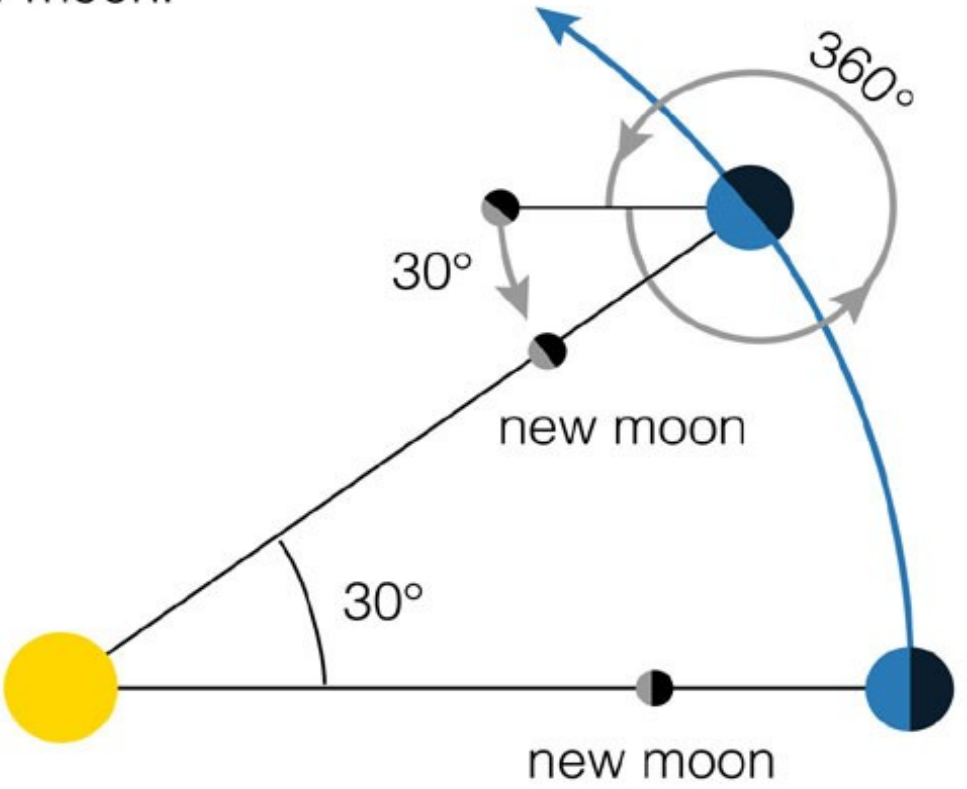
Couldn't we just use another clock?

- Is there another obvious bright object that we could use?
- How about the Moon?
- Monthly cycles all set for us.
- In fact, many cultures used lunar calendars
- But...what's a month?

Sidereal vs synodic month

- Sidereal month: about 27.3 days
- Synodic month (new to new) is 29.5306 days
- So a *lunar year* of 12 synodic months is 354.3672 days
- vs.: 365.2422 d Whoops...

Earth travels about 30° per month around the Sun, so the Moon must orbit around Earth about 360° + 30° = 390° from new moon to new moon.



So, back to the solar calendar

- Tropical year was 365 d 5h 48m 45 s
- Caesar's calendar drifted by 11m 15s every 400 years (do you see why?)
- So the actual day of the equinox moves earlier
- This piled up until by the late 1500s, the spring equinox was occurring on March 11!
- Why was this important? Who cared? (It WAS the Dark ages and all...!)

The Christian church

- The church desperately needed an accurate calendar.
- Why?

Why did the catholic church need the calendar?

A)To know the date of Easter.

B)Development of continental commerce needed a clear system of dates for orders and billing, etc.

C)To know when Christmas was for that holiday

D)To know which day the many Saints holidays were on, because everyone had a patron saint.

Why did the catholic church need the calendar?

A)To know the date of Easter.

- What determines the day that Easter falls in any given year?
- The first Sunday after the first full moon after the spring equinox of the year.
- Yikes! Need to understand the lunar calendar AND the solar calendar...!
- One reason astronomy progressed in Europe...

Pope Gregory fixed this, in 1582

- Signed a decree that made 1582 the last Julian year (using Caeser's calendar)
- Did this by eliminating Oct 5 – 14, 1582. Oct 4 was followed by October 15
- This caused serious consternation!
- For political and religious partisan reasons, many countries ignored the change
- This caused serious confusion!
- Now adopted almost worldwide.

The Gregorian Calendar

- Ignored leap years on the century years
  - (eg. 1700, 1800, 1900, 2100, 2200, 2300)
- EXCEPT when century is divisible by 400
  - Example, 2000 WAS a leap year, and 2400 will be.
- This makes the number of days every 400 years be almost precisely 400 x (365.242199 days) = 146096.88 days, not 146097 days.
  - So 0.12 days in 400 years is a drift of 26 seconds per year for the Gregorian calendar.
  - Accumulated ~3h since 1582. Will be 1d in 4909.

So, that's the Calendar. I can tell you what day it is, but what about what time it is?

- Apparent solar time can be told with a sundial (or a stick!)
- Relies on sun's motion
- Rate can vary.
- Is only LOCAL; why?
- Effect of longitude.

- When it's noon Vancouver, what apparent solar time is it in Kelowna? Or Victoria?

Modern solution is TIME ZONES

- If politics didn't intervene, how many degrees of longitude/time zone?