Keeping time

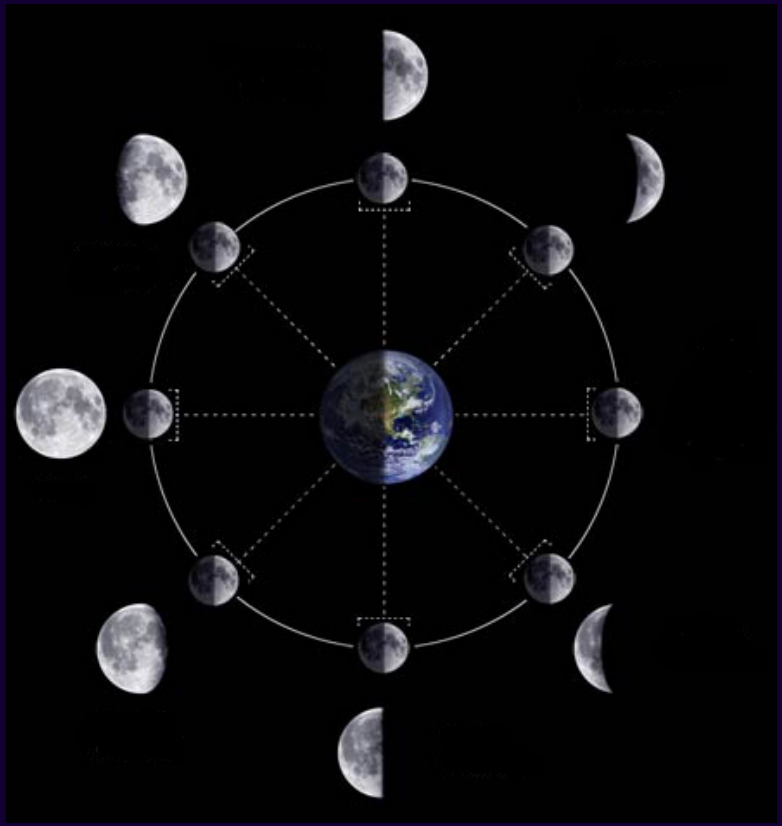
Astronomy 101
Syracuse University, Fall 2020
Walter Freeman

September 15, 2020

Announcements and questions

- Remember, your evaluations for Project 1 are due by midnight tonight (or three days after you received the project from the submitting group, if they were late)
- Project 2 has been written; will be posted today after class
- This will also include updated group rosters

Please make an effort to work with your groupmates as adults. If you're having issues still after Lab 2, we will reassign you.



You can figure all of this out by drawing pictures.

Do this whenever you need to figure something out about the Moon...

Let's make a doodle on the board and see how much we can figure out...

When the full moon is high in the sky, what time of day is it?

What phase of the moon is mostly seen during the day?

When the waxing half moon is just rising over the horizon, what time of day is it?

As seen in the Northern Hemisphere, which part of a waning crescent moon will be lit?

As seen in the Northern Hemisphere, which part of a waning crescent moon will be lit?

What about the Equator?

Keeping time

The predictable cycles in the sky are the basis for the way we keep time.

One day

- What is a *day*? Tell me things about days.

One year

- What is a *year*? Tell me things about years.

Keeping time

The predictable cycles in the sky are the basis for the way we keep time.

One day

- What is a *day*? Tell me things about days.

One year

- What is a *year*? Tell me things about years.

One month

- What is a *month*? Tell me things about months.

Solar and sidereal days

Is one day...

- ... the amount of time it takes Earth to rotate once?
- ... the amount of time between noon one day and noon the next day?
- ... something else!

Solar and sidereal days

Is one day...

- ... the amount of time it takes Earth to rotate once?
- ... the amount of time between noon one day and noon the next day?
- ... something else!

There are *two kinds of day*. Let's see why they are different on the board.

Solar and sidereal days

Is one day...

- ... the amount of time it takes Earth to rotate once?
- ... the amount of time between noon one day and noon the next day?
- ... something else!

There are *two kinds of day.* Let's see why they are different on the board.

- One *solar day:* judged by the apparent motion of the Sun: from noon to noon
- One *sidereal day:* judged by the apparent motion of the stars: Earth, and the celestial sphere, rotate exactly 360°

Which one is more important for our lives?

Two sorts of day

The *sidereal day* is the amount of time it takes the Earth, and thus the celestial sphere, to rotate once.

One sidereal day $\rightarrow$ 360° rotation of the Earth

The *solar day* is the amount of time from solar noon to solar noon.

Since the Earth orbits the Sun, this requires more than 360° rotation:

- 360° plus a little extra, to compensate for the motion of the Earth around the Sun
- In my animation, with the "fast orbit", this is a lot more than 360°
- In the real world, the Earth moves only $1/365 \approx 1°$ around the Sun each day
- ... so in a solar day the Earth rotates:
  - 360° for the stars to rise and set once...
  - ... plus *one more degree* to compensate for the Earth's movement

One solar day $\rightarrow$ 361° rotation of the Earth

Solar day:

- 361° rotation of Earth
- The Sun returns to its same position (east/west)
- A bit more than a sidereal day → the stars move “too far”
- Exactly 24 hours

Sidereal day:

- 360° rotation of Earth
- The stars return to their same positions (exactly)
- A bit less than a solar day → the Sun moves “too little”
- Four minutes less than 24 hours

What about the moonth?

Is a lunar month...

- One complete cycle of phases of the Moon? (new moon to new moon)
- One orbit of the Moon around the Earth?

What about the moonth?

Is a lunar month...

- One complete cycle of phases of the Moon? (new moon to new moon)
- One orbit of the Moon around the Earth?

Same deal:

- Synodic month: One complete cycle of phases of the Moon (29.5 days)
- Sidereal month: One orbit of the Moon ("Moon in Capricorn $\rightarrow$ Moon in Capricorn" – 27.3 days)

What about the year?

Is a year...

- ... from winter solstice to winter solstice?
- ... One orbit of the Earth around the Sun? ("Sun in Sagittarius $\rightarrow$ Sun in Sagittarius")

What about the year?

Is a year...

- ... from winter solstice to winter solstice?
- ... One orbit of the Earth around the Sun? ("Sun in Sagittarius → Sun in Sagittarius")

What would have to happen for them to be different?

What about the year?

Is a year...

- ... from winter solstice to winter solstice?
- ... One orbit of the Earth around the Sun? ("Sun in Sagittarius → Sun in Sagittarius")

What would have to happen for them to be different?

The orientation of the Earth's tilt makes one rotation every 26,000 years.

Same deal:

- Tropical (seasonal) year: solstice to solstice
- Sidereal year: one orbit around the Sun; 1/26,000 less than a seasonal year

Now what do we have?

The year

Sidereal year

- One Earth orbit around Sun
- 365.26 24-hour days (1/26,000 *more* than a seasonal year)
- Sun returns to same place relative to stars

The day

Sidereal day

- One Earth rotation
- 23 hours 56 minutes (1/365 *less* than a solar day)
- Stars return to the same places in the sky

The moonth

Sidereal moonth

- One Moon orbit around Earth
- 27.3 days (about 1/12 *less* than a synodic moonth)
- Moon returns to same place relative to stars

Now what do we have?

The year

Sidereal year

- One Earth orbit around Sun
- 365.26 24-hour days (1/26,000 *more* than a seasonal year)
- Sun returns to same place relative to stars

Seasonal year

- One cycle of the seasons (solstice to solstice)
- 365.24 24-hour days (1/26,000 *less* than a sidereal year)
- Sun does not quite return to same place relative to stars!

The day

Sidereal day

- One Earth rotation
- 23 hours 56 minutes (1/365 *less* than a solar day)
- Stars return to the same places in the sky

Solar day

- Noon to noon / midnight to midnight
- 24 hours (1/365 *more* than a sidereal day)
- Stars do not return to the same places in the sky

The moonth

Sidereal moonth

- One Moon orbit around Earth
- 27.3 days (about 1/12 *less* than a synodic moonth)
- Moon returns to same place relative to stars

Synodic moonth

- One cycle of the Moon phases
- 29.5 days (about 1/12 *more* than a sidereal moonth)
- Moon returns to same place relative to stars

Now what do we have?

The year

Sidereal year

- One Earth orbit around Sun
- 365.26 24-hour days
- Sun returns to same place relative to stars

Seasonal year

- One cycle of the seasons (solstice to solstice)
- 365.24 24-hour days
- Sun does not quite return to same place relative to stars!

Difference caused by wobble of Earth's axis; seasonal year about 1/26,000 shorter

The day

Sidereal day

- One Earth rotation
- 23 hours 56 minutes
- Stars return to the same places in the sky

Solar day

- Noon to noon / midnight to midnight
- 24 hours
- Stars do not return to the same places in the sky

Difference caused by motion of Earth around Sun: solar day about 1/365 longer

The moonth

Sidereal moonth

- One Moon orbit around Earth
- 27.3 days
- Moon returns to same place relative to stars

Synodic moonth

- One cycle of the Moon phases
- 29.5 days
- Moon returns to same place relative to stars

Difference caused by motion of Earth and Moon around Sun: synodic moonth about 1/12 longer

Keeping time

How many solar days are in a seasonal year?

Keeping time

How many solar days are in a seasonal year?

How many synodic moonths are in a seasonal year?

Keeping time

How many solar days are in a seasonal year?

How many synodic moonths are in a seasonal year?

How many solar days are in a moonth?

Building a calendar

How many solar days are in a seasonal year?
365.24 (ack, doesn't come out even)

Building a calendar

How many solar days are in a seasonal year?
365.24 (ack, doesn't come out even)

How many synodic moonths are in a seasonal year?
364.24 / 29.5 = 12.35 (also doesn't come out even)

Building a calendar

How many solar days are in a seasonal year?
365.24 (ack, doesn't come out even)

How many synodic moonths are in a seasonal year?
364.24 / 29.5 = 12.35 (also doesn't come out even)

How many solar days are in a moonth?
29.5 (ack, doesn't come out even)

... what do we do?

Building a calendar

How many solar days are in a seasonal year?
365.24 (ack, doesn't come out even)

How many synodic moonths are in a seasonal year?
364.24 / 29.5 = 12.35 (also doesn't come out even)

How many solar days are in a moonth?
29.5 (ack, doesn't come out even)

... what do we do? Two choices:

- Don't worry about it (Gregorian months aren't lined up with the moonths)

Building a calendar

How many solar days are in a seasonal year?
365.24 (ack, doesn't come out even)

How many synodic moonths are in a seasonal year?
364.24 / 29.5 = 12.35 (also doesn't come out even)

How many solar days are in a moonth?
29.5 (ack, doesn't come out even)

... what do we do? Two choices:

- Don't worry about it (Gregorian months aren't lined up with the moonths)
- Intercalation: add extras (about one in four years is a leap year)