Astronomy

Semester 2

Weeks 11 - 13

Monday / Tuesday (March 23 & 24)

- T: **12D** analyze the origins and effects of space weather, including the solar wind, coronal mass ejections, prominences, flares, and sunspots.

- O: I will be able to understand solar flares

- D: by completing an Actively Learn, taking notes, and completing two Discovery Eds.

- A: solar flare, magnetic field, sunspots
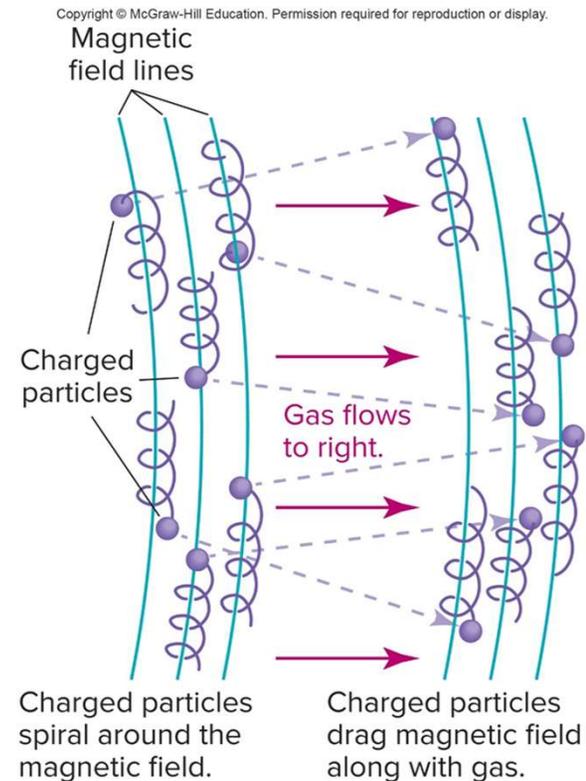
- Y: What causes solar flares?

Solar Magnetic Activity

- Surface waves are but one type of disturbance in the Sun's outer layers.

- A wide class of dramatic and lovely phenomena occur on the Sun and are caused by its magnetic field.

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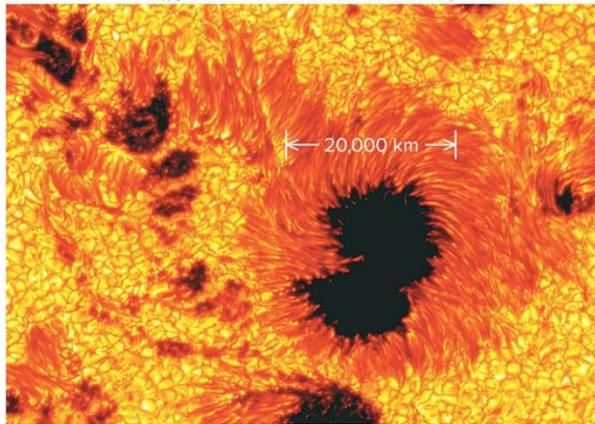
Earth for comparison

- NASA

Interaction of Fields and Particles

- Charged particles tend to spiral along magnetic field lines easier than they drift across them.

- Bulk motion of plasma carries the field along with it.

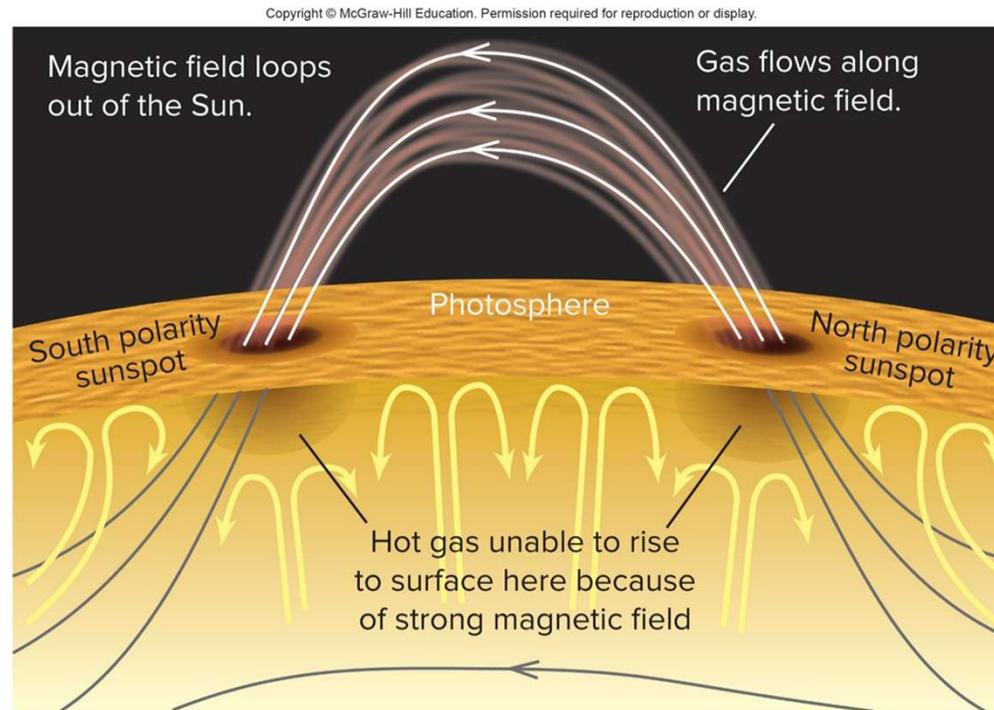- Motion of the field carries particles along with it.

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Magnetic field lines

Charged particles

Gas flows to right.

Charged particles spiral around the magnetic field.

Charged particles drag magnetic field along with gas.

Sunspots

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20,000 km

- Dark-appearing regions ranging in size from a few hundred to a few thousand kilometers across.

- Last a few days to over a month.

- Darker because they are cooler than their surroundings (4500 K vs 6000 K).

- Cooler due to stronger magnetic fields within them.

- Courtesy of Royal Swedish Academy of Sciences

Origin of Sunspots

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Magnetic field loops out of the Sun.

Gas flows along magnetic field.

Photosphere

South polarity sunspot

North polarity sunspot

Hot gas unable to rise to surface here because of strong magnetic field

- Starved of heat from below, the surface cools where the magnetic fields breach the surface creating a dark sunspot.
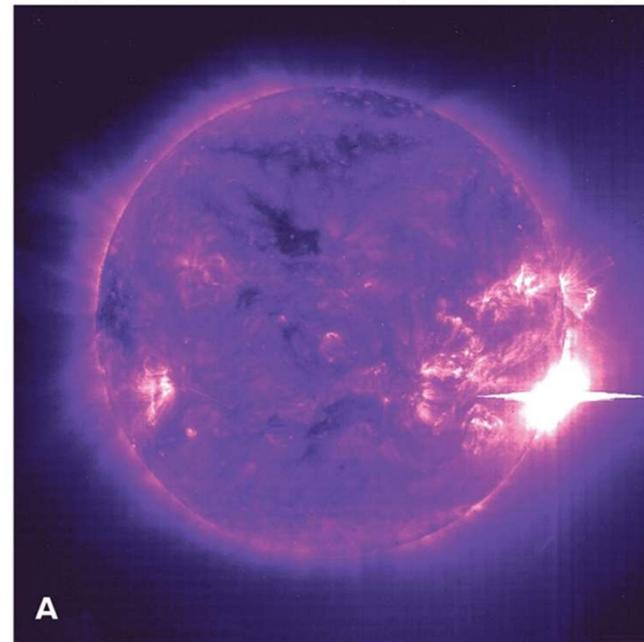
Prominences

- ***Prominences*** are huge glowing gas plumes that jut from the lower chromosphere into the corona.

Earth for comparison

- NASA
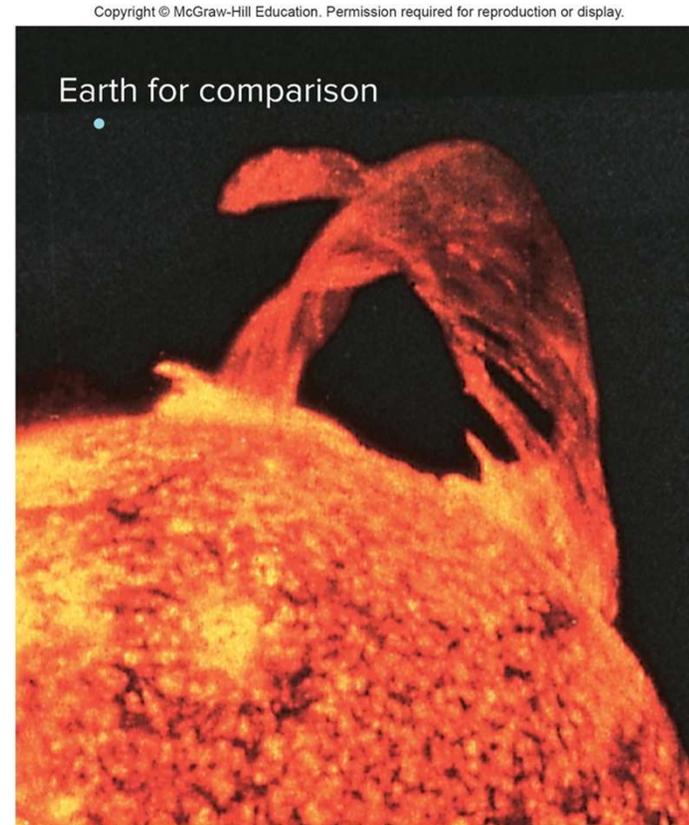
Solar Flares

- Sunspots give birth to *solar flares,* brief but bright eruptions of hot gas in the chromosphere.

- Hot gas brightens over minutes or hours, but not enough to affect the Sun's total light output.
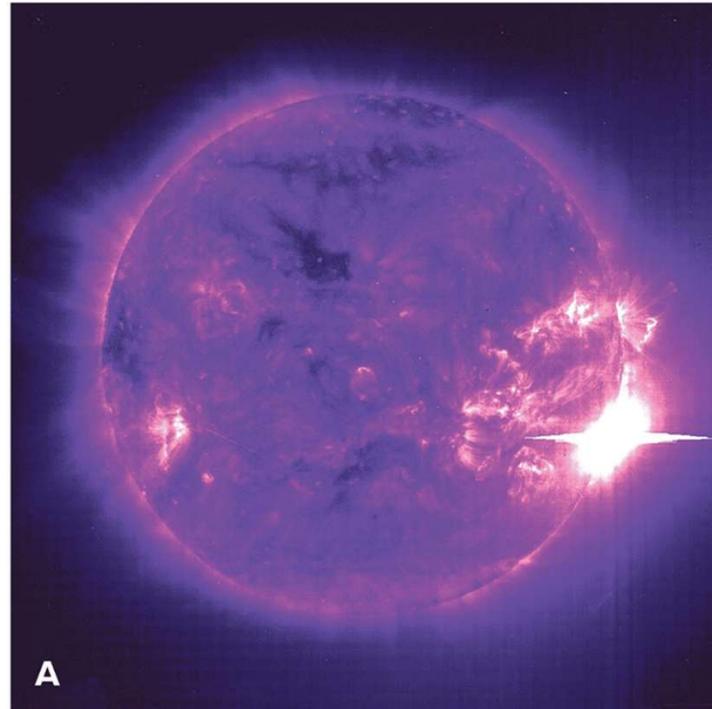
- a: SOHO/EIT Cosortium/ESA/NASA

Source of Flares

- Strong increase in radio and x-ray emissions.

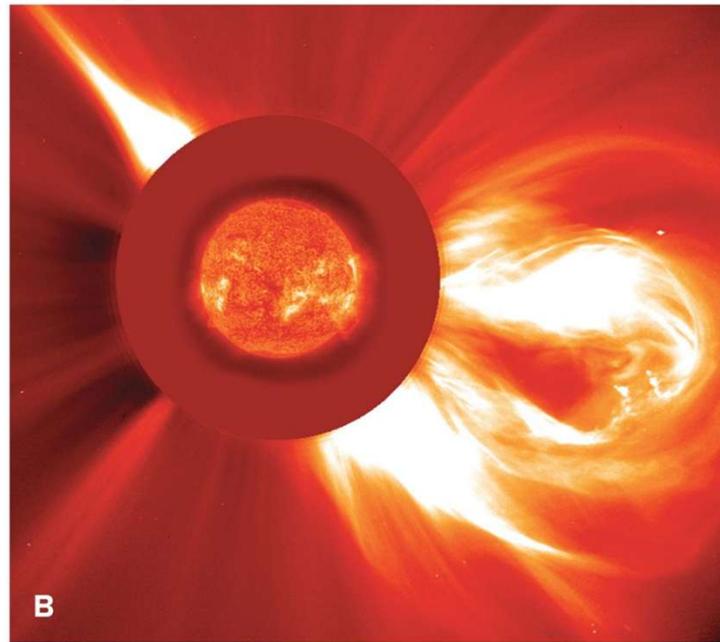- Intense twisting and "breakage" of magnetic field lines is thought to be the source of flares.

- A: SOHO/EIT Consortium/ESA/NASA

Coronal Mass Ejections

- *Coronal mass ejections* can explosively shoot gas across the Solar System and result in spectacular auroral displays.

- b: Courtesy of NOAO/AURA/NSF
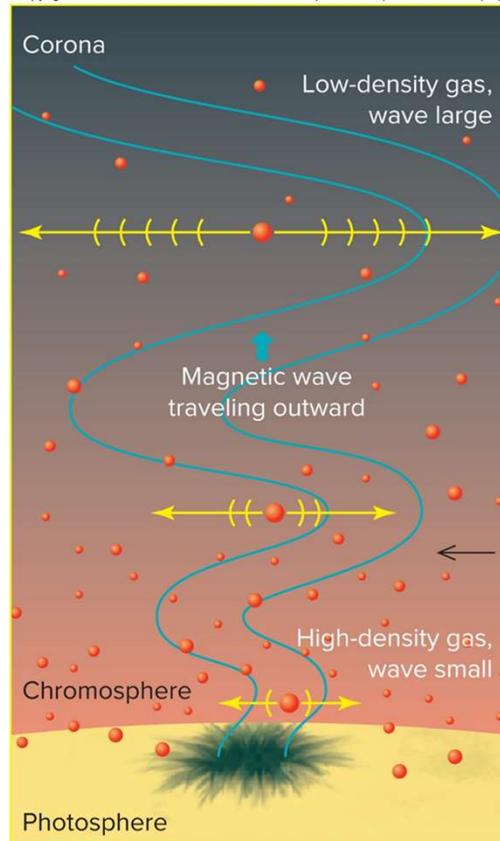
Impact of Solar Flares

- Courtesy of Eugene Lauria

Heating of the Chromosphere and Corona

- While the Sun's magnetic field cools sunspots and prominences, it heats the chromosphere and corona.

- Heating is caused by magnetic waves generated in the relatively dense photosphere.

- These waves move up into the thinning atmospheric gases, grow in magnitude, and "whip" the charged particles found there to higher speeds and hence higher temperatures.

- Origin of waves may be from rising bubbles in convection zone.

Magnetic Waves

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Corona

Low-density gas, wave large

Magnetic wave traveling outward

High-density gas, wave small

Chromosphere

Photosphere

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The Solar Wind

- The corona's high temperature gives its atoms enough energy to exceed the escape velocity of the Sun.

- As these atoms stream into space, they form the **solar wind,** a tenuous gas of hydrogen and helium that sweeps across the entire Solar System.

- The amount of material lost from the Sun via the Solar Wind is insignificant.

- Typical values at Earth's orbit: a few atoms per cm^3

  - and a speed of about 500 km/sec.

- At some point, the solar wind merges with interstellar space.

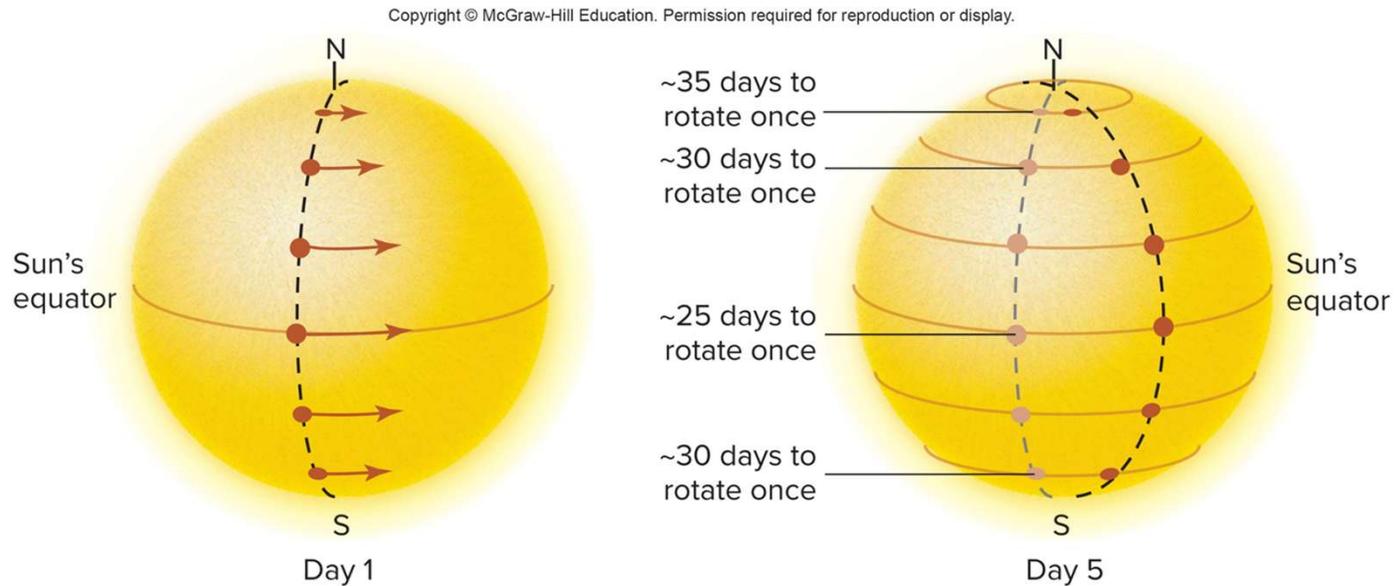# Wednesday / Thursday (March 25 & 26)

- T: **12C** describe the eleven-year solar cycle and the significance of sunspots; and
- O: I will be able to determine the reason for sunspots and calculate the rotation of the sun
- D: by taking notes, participating in a class discussion, and completing an assignment in Canvas.
- A: sunspots
- Y: How can sunspots be used to determine the rotation of the sun?

The Solar Cycle

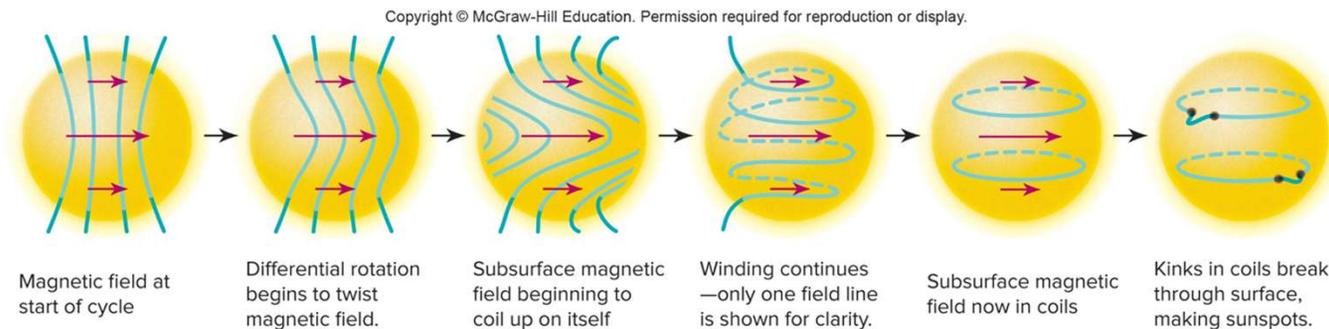Copyright © McGraw-Hill Education. Permission required for reproduction or display.
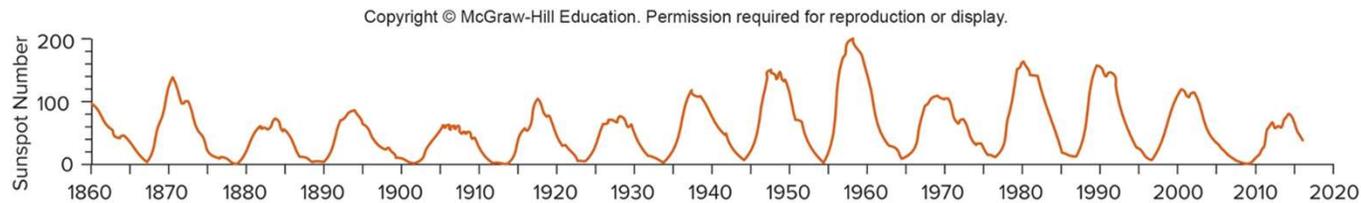
- Discovered by a pharmacist, Samuel Heinrich Schwabe, who was hunting for a planet closer to the sun than Mercury.

- Sunspot, flare, and prominence activity change yearly in a pattern called the *solar cycle.*

- Over the last 140 years or so, sunspots peak in number with a cycle lasting as short as 7 years to as long as 16 years, usually 10 to 12 years.

- Climate patterns on Earth may also follow the solar cycle.

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Differential Rotation

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~35 days to rotate once
~30 days to rotate once
~25 days to rotate once
~30 days to rotate once

Sun's equator

Sun's equator

Day 1

Day 5

- The Sun undergoes differential rotation: 25 days at the equator and 30 at the poles.

Cause of the Solar Cycle

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Magnetic field at start of cycle

Differential rotation begins to twist magnetic field.

Subsurface magnetic field beginning to coil up on itself

Winding continues —only one field line is shown for clarity.

Subsurface magnetic field now in coils

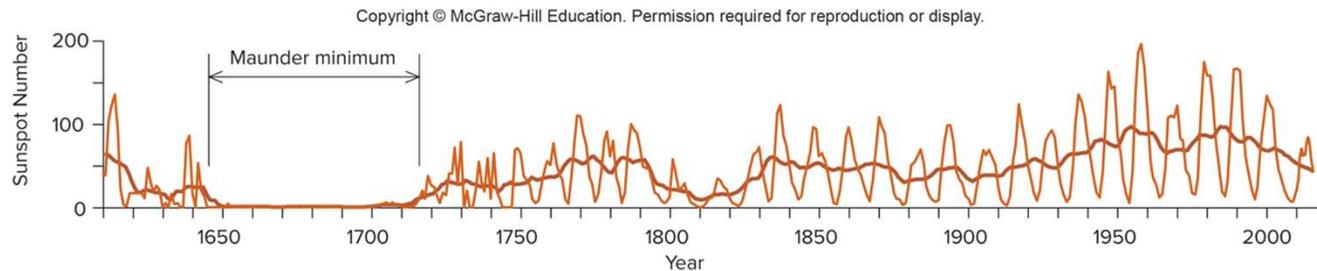Kinks in coils break through surface, making sunspots.

- This rotation causes the Sun's magnetic field to "wind up," increasing solar activity (magnetic field "kinks" that break through the surface).

- The cycle ends when the field twists too "tightly" and collapses – the process then repeats.

Changes in the Solar Cycle

Cycle 1	Cycle 2	Cycle 3

N S   N S

S N   S N

1969

S N   S N

N S   N S

1980

N S   N S

S N   S N

1991
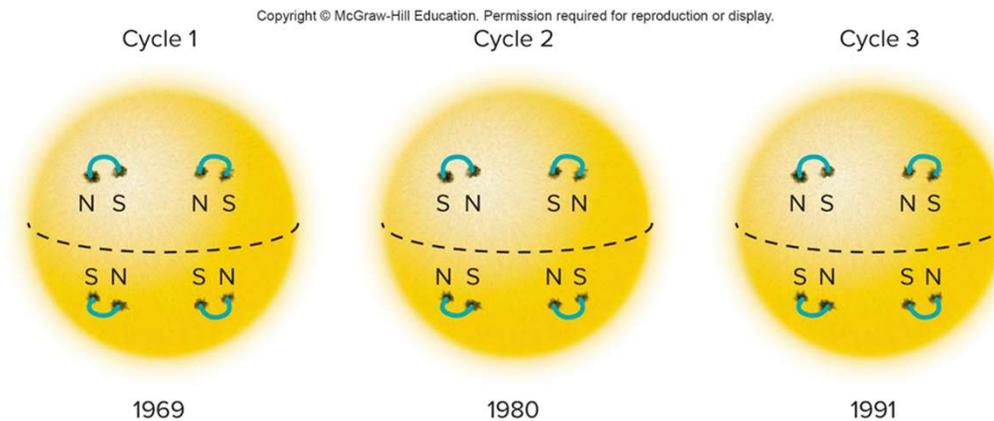
- The cycle may vary from 6 to 16 years.

- Considering the polarity direction of the sunspots, the cycle is 22 years, because the Sun's field reverses at the end of each 11-year cycle.

- Leading spots in one hemisphere have the same polarity, while in the other hemisphere, the opposite polarity leads.

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Solar Cycle and Climate

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- Midwestern United States and Canada experience a 22-year drought cycle.

- Few sunspots existed from 1645 to 1715, the **Maunder Minimum,** the same time of the "little ice age" in Europe and North America.

- Number of sunspots correlates with change in ocean temperatures: more sunspots = brighter sun.

Friday (March 27)

- C-day

Monday / Tuesday (March 30 & 31)

- Test Review (SmartBook)

Wednesday / Thursday (April 1 & 2)

- Test: The Sun

Friday (April 3)

- NO SCHOOL
- Good Friday

Monday (April 6)

- NO SCHOOL
- Purposeful Planning

Tuesday / Friday (April 7 & 10)

- Triangulation Lab

- T: 13 (G) illustrate how astronomers use geometric parallax to determine stellar distances and intrinsic luminosities; and

- (H) describe how stellar distances are determined by comparing apparent brightness and intrinsic luminosity when using spectroscopic parallax and the Leavitt relation for variable stars.

- O: I will be able to determine the distance an object is located from a fixed point

- D: by using the concepts of parallax and geometry to calculate the distance.

- A: parallax

- Y: How do we determine the distance of stars from our sun?
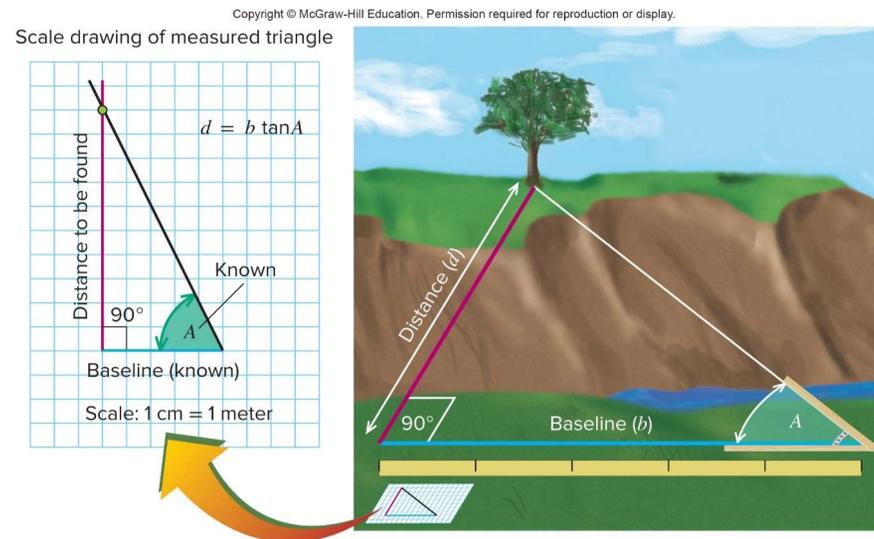
Measuring the Properties of Stars

- Courtesy of Johannes Schedler/Panther Observatory

The Family of Stars

- Those tiny glints of light in the night sky are in reality huge, dazzling balls of gas, many of which are vastly larger and brighter than the Sun.

- They look dim because of their vast distances.

- Astronomers cannot probe stars directly, and consequently must devise indirect methods to ascertain their intrinsic properties.

- Measuring distances to stars and galaxies is not easy.

- Distance is <u>very</u> important for determining the intrinsic properties of astronomical objects.
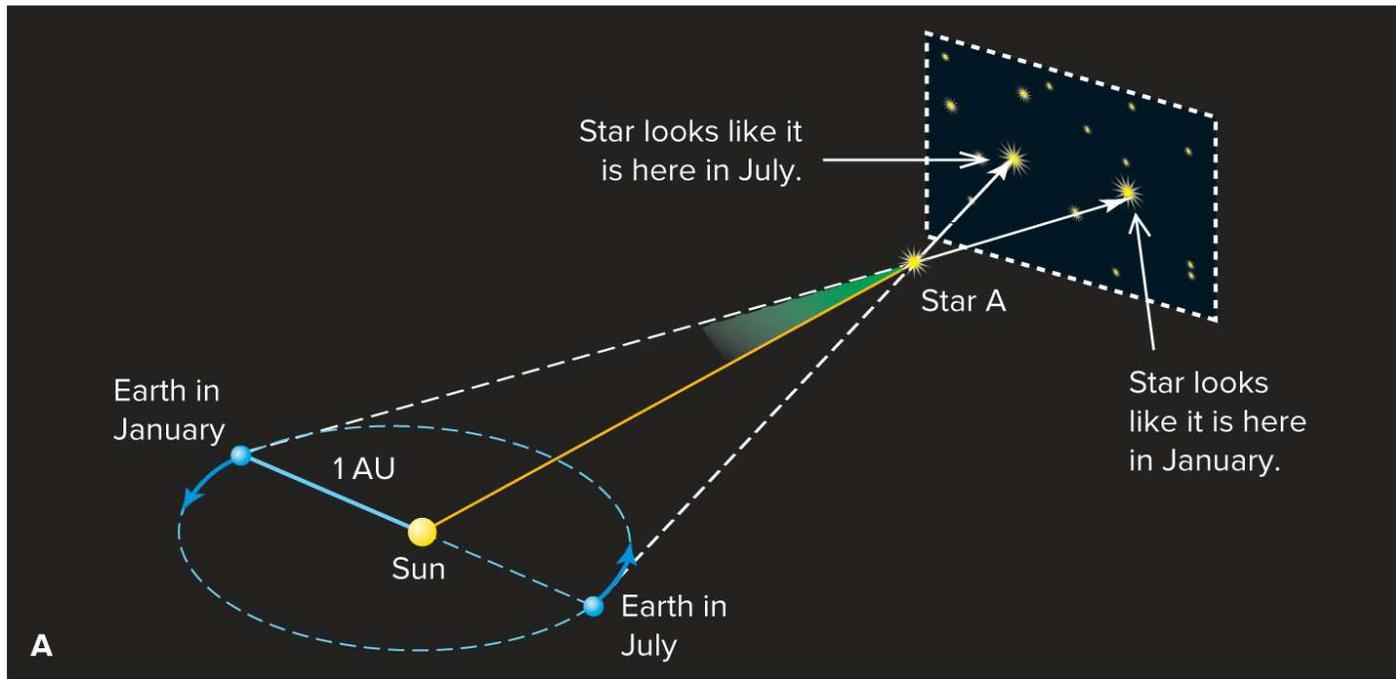
Triangulation

Scale drawing of measured triangle

$d = b \tan A$

Distance to be found

Known

90°

A

Baseline (known)

Scale: 1 cm = 1 meter

Distance (d)

90°

Baseline (b)

A

- Fundamental method for measuring distances to nearby stars is *triangulation:*

- Measure length of a triangle's "baseline" and the angles from the ends of this baseline to a distant object.

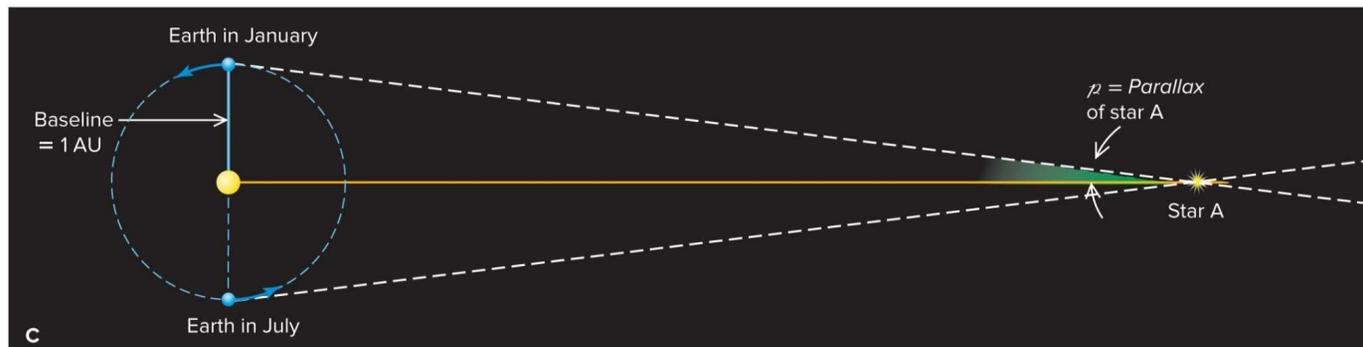- Use trigonometry or a scaled drawing to determine distance to object.

Trigonometric Parallax

Calculating Distance Using Parallax

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Earth in January

Baseline = 1 AU

p = Parallax of star A

Star A

Earth in July

- A method of triangulation used by astronomers is called *parallax:*

- Baseline is Earth's orbit radius (1 AU).

- Angles measured with respect to very distant stars.

The parsec (parallax-second)

Earth in January

Baseline = 1 AU

p = Parallax of star A
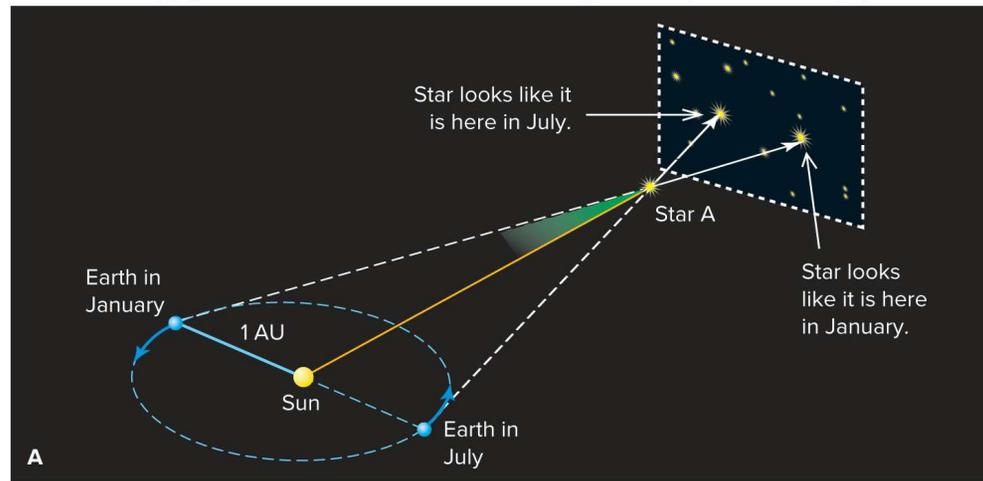
Star A

c

Earth in July
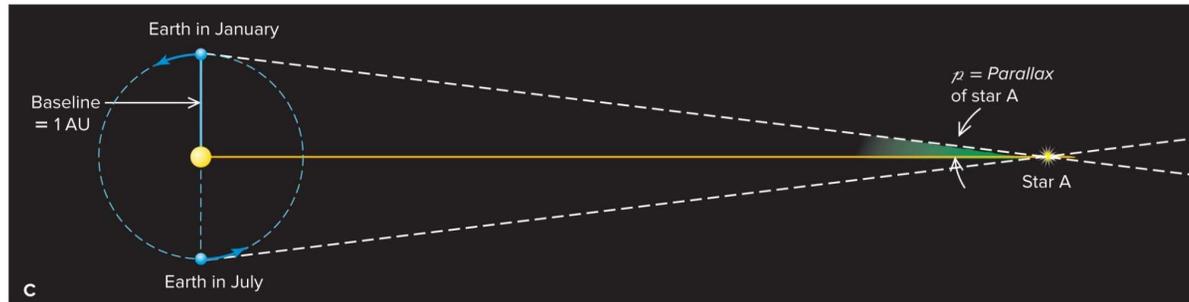
- The shift of nearby stars is small, so angles are measured in arc seconds.

- The parallax angle, p, is half the angular shift of the nearby star, and its distance in parsecs is given by:

$$d_{pc} = 1/parc_{sec\,onds}$$

- A **parsec** is 3.26 light-years $\left(3.09 \times 10^{13}\,\text{km}\right)$.

- Useful only to distances of about 250 parsecs.

Example: Distance to Sirius

Star looks like it is here in July.

Star A

Star looks like it is here in January.

Earth in January

1 AU

Sun

Earth in July

A

- Measured parallax angle for Sirius is 0.377 arc second.
- From the formula,

$$d_{pc} = 1/0.377 = 2.65 \, \text{parsecs} = 8.6 \, \text{light-years}$$

Wednesday / Thursday (April 8 & 9)

- Shutdown Days