ASTR 1040 Accel Astro: Stars & Galaxies

M 50
star cluster

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Lecture 10 Thurs 14 Feb 08

zeus.colorado.edu/astr1040-toomre

Today +

- *Solar magnetism & effects on Earth*
- *What can we measure in other stars?*
- *How do we begin to classify other stars?*
- *Why O, B, A … such a nutty scheme!*

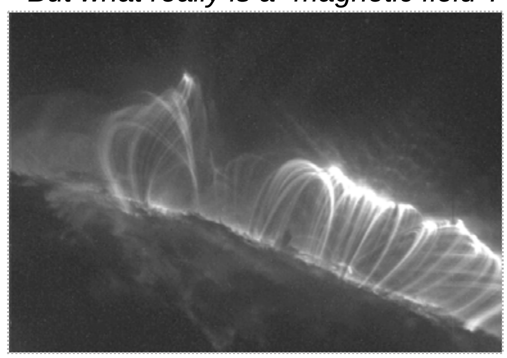
- Read in detail *Chap 15: Surveying the Stars*

- *Review tonight by Kyle in G125 at 7pm, for Mid-Term Exam 1* in recitation Mon Feb 18

Summary Clicker -- Solar Wind E.

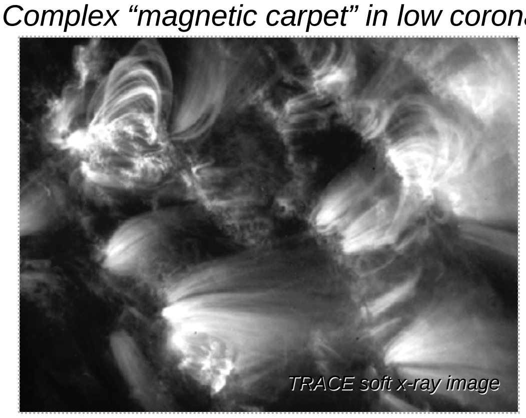
- *What are visible effects of the Earth being "bathed" in the wind of solar particles, especially when wind has strong hiccup?*
- *A.* "Auroral lights" visible at night
- *B.* Electric power grids have problems
- *C.* Short-wave radio talk interrupted
- *D.* Satellites (and beepers) may get fried
- *E.* All of the above

But what really is a "magnetic field"?



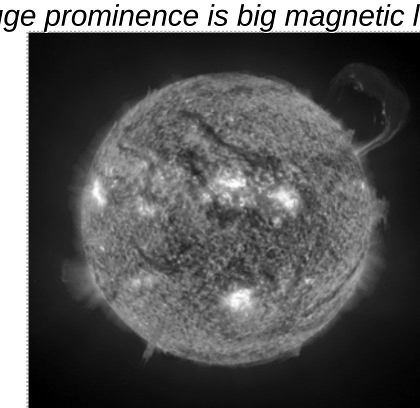
TRACE soft x-ray image: Arcade of magnetic loops on solar limb

Complex "magnetic carpet" in low corona

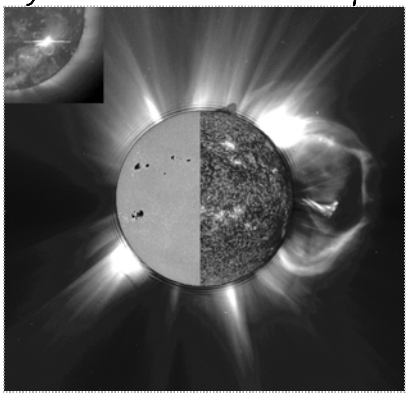


TRACE soft x-ray image

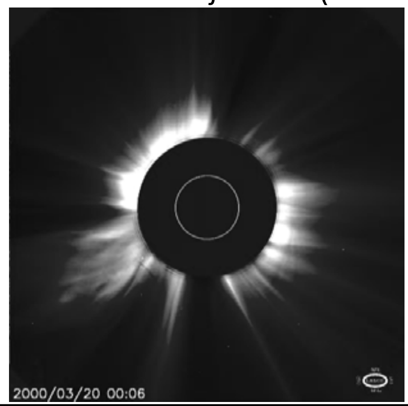
Huge prominence is big magnetic loop



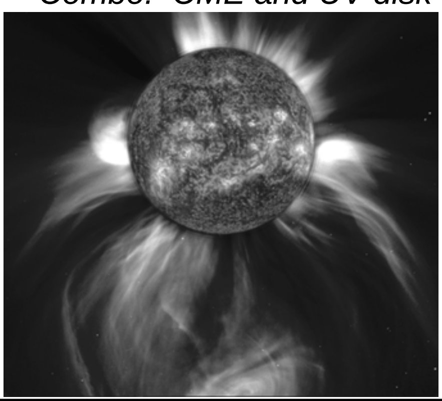
Many Faces of the Sun: Composite



Coronal Mass Ejections (CMEs)



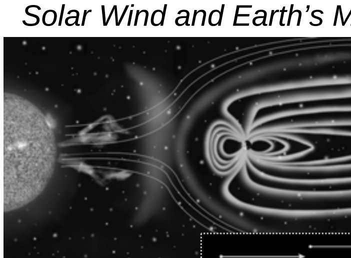
Combo: CME and UV disk



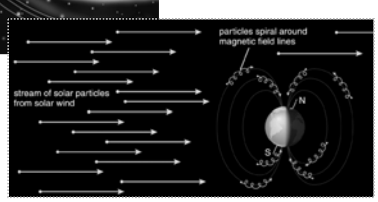
Clicker – Energy is how "old" ? E.

- *Light radiated from Sun's surface reaches us in about 8 minutes, but the energy of that light was released by fusion in the solar core about …*
- *A.* one year ago
- *B.* ten years ago
- *C.* a hundred years ago
- *D.* a thousand years ago
- *E.* a million years ago

Solar Wind and Earth's Magnetosphere



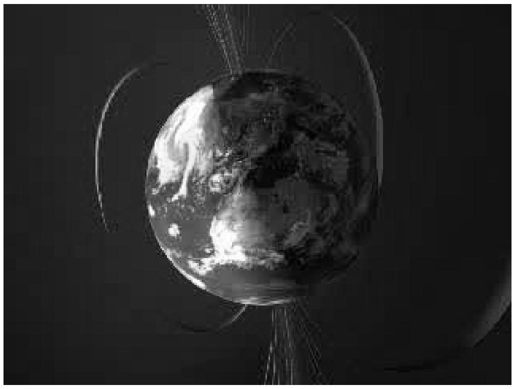
Earth's Magnetic Field Is Shaped by Solar Wind



Discussion

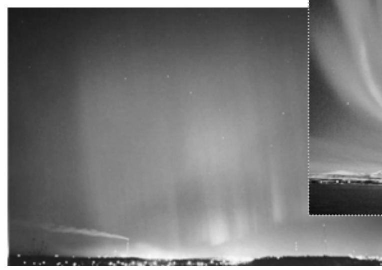
What are effects of solar activity on our technological society?

Solar Wind and Aurorae

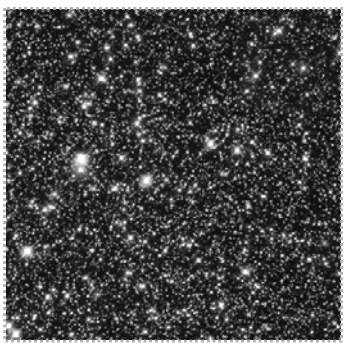


Northern Lights

(Aurora Borealis)



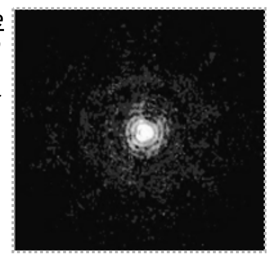
Now onward to measuring other stars: Chap 15 – SURVEYING THE STARS



- *Measuring stellar luminosities*
- *Measuring distances*
- *Measuring temperatures*

Often only seeing a point of light

- *Stars are so small compared to their distance that we almost never have the resolution to see their sizes and details directly – "point sources"*
- *We deduce everything by measuring the amount of light (brightness) at different wavelengths (color, spectra)*



So what can we find out about other stars?

APPARENT BRIGHTNESS

POSITION

SPECTRUM

WHAT CAN WE MEASURE IN OTHER STARS?

1. APPARENT BRIGHTNESS (OR INTENSITY)
   MEASURED IN FUNNY UNITS CALLED "MAGNITUDES"
   ⇒ LUMINOSITY, IF KNOW DISTANCE
   RECALL INVERSE SQUARE LAW ...
   $$\text{BRIGHTNESS OF POINT SOURCE} \sim \frac{1}{(\text{DISTANCE})^2}$$
2. POSITION (AND CHANGES OF IT WITH TIME)
   - PARALLAX ⇒ DISTANCE
   - PROPER MOTION
3. SPECTRUM (MEASURE ITS SHAPE & SPECTRAL LINES)
   ⇒ TEMPERATURE OF SURFACE
   ⇒ COMPOSITION (WHICH ELEMENTS CAN BE SEEN)
   VIA DOPPLER SHIFT OF LINES: RADIAL VELOCITY, ROTATION
   VIA ZEEMAN SPLITTING OF LINES: MAGNETIC FIELDS

Most Basic Problem in Astronomy

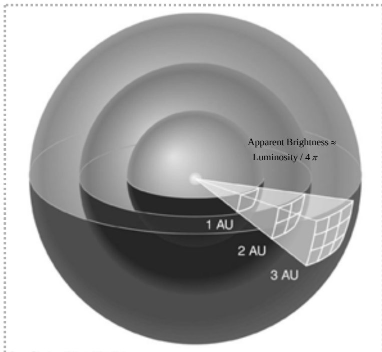
Star of given APPARENT BRIGHTNESS could be either

A. very luminous star far away

B. low luminosity star closer by

Need to know the DISTANCE to the star

Inverse Square Law of Brightness



Apparent Brightness ≈ L_o / (distance)^2

Clicker – Dimming with distance ?

- If you quadruple (x4) your distance to a light and look again, how much dimmer does it appear?

D.

- A. one-half as bright as originally
- B. one-fourth as bright
- C. one-eight as bright
- D. one-sixteenth as bright
- E. unchanged, since really same light

Stellar Luminosity

- What we measure: APPARENT BRIGHTNESS

  or how bright it appears to us here on Earth

- What we want to know: (absolute) LUMINOSITY

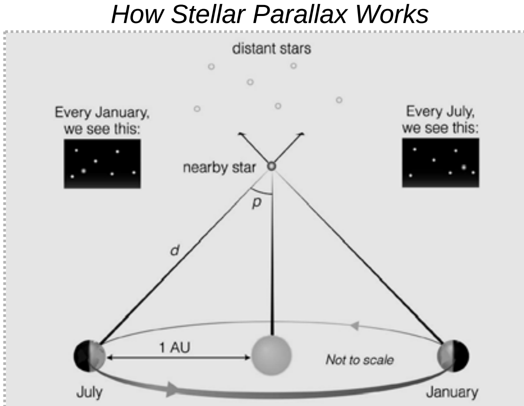
  or how much energy is emitted (joules/sec or watts)

- Need to know DISTANCE to the star

Parallax – to determine distance

- Measure the apparent movement of stars over a year
- Movement is caused by Earth's movement around the Sun
- Closer objects will move more than farther objects

How Stellar Parallax Works



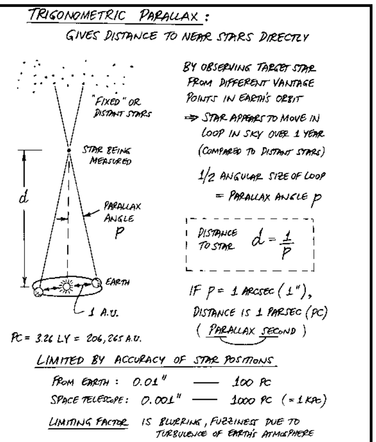
Class self-demo of parallax

- Your nose is the Sun
- Your left eye is the Earth in January
- Your right eye is the Earth in June

Watch the apparent motion of your thumb against a distant reference point (repeat at arm's length)

Which "move" more -- closer or farther objects?

Stellar Parallax: *measuring nearby distances*

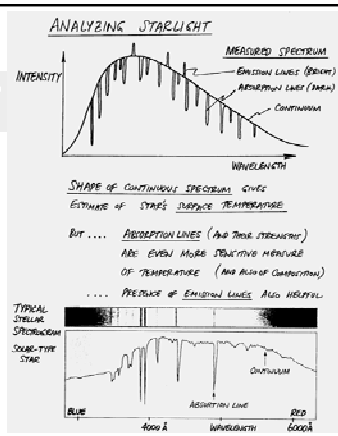


Best parallax measurer: Hipparcos satellite 1989-1993

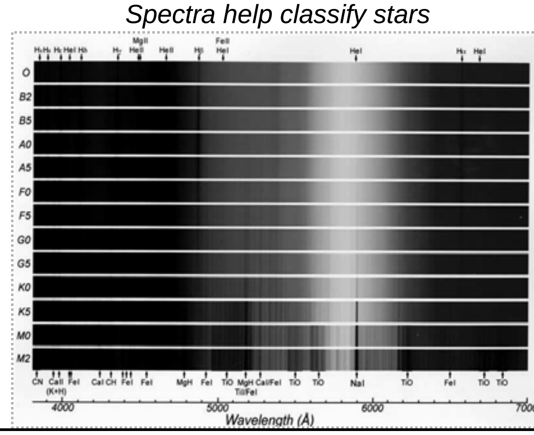
- *Space measurements not affected by atmosphere*
- *Measurement made many times until accurate to 0.001 arcsec (→3300 light years)*
- *100,000 stars mapped*
- *(2.5 million to slightly lesser accuracy)*

Measuring Surface TEMPERATURE

Shape of spectrum good … but <u>spectral lines</u> much better



Spectra help classify stars



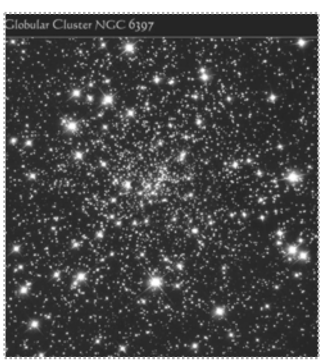
OBAFGKM ?!?

- *<u>Spectral (color) classification</u>*

O *= bluest, hottest*

G *= yellow (Sun)*

M *= reddest, coolest*



A bit of history: <u>Classifying Stars</u>

World War I, Harvard College observatory

Women were hired by Pickering as "calculators" to help with a new survey of the Milky Way

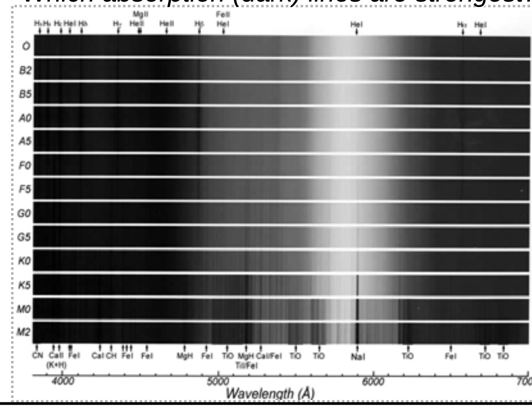
Most had studied astronomy, but were not allowed to work as scientists

Devising the strange temperature code

- *Original classification of spectra (1890) was:*
  A = strongest hydrogen feature
  B = less strong hydrogen …C, D, etc.
- *Annie Jump Cannon realized that a different sequence made more sense (~1910)*

→ O B A F G K M !!

Which absorption (dark) lines are strongest?



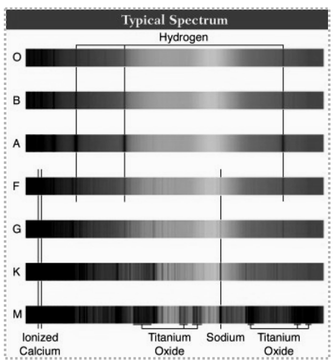
Spectral Classification: O B A F G K M

Hottest stars: O B
ionized helium only

Hot stars: A F helium, hydrogen

Cooler stars: G hydrogen, heavier atoms

Coolest stars: M molecules, (complex absorption bands)



Stars and their spectral classification

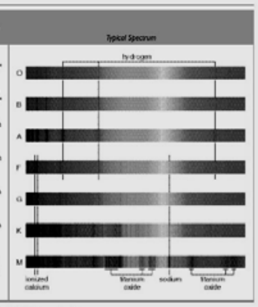


Table 16.1 The Spectral Sequence

Spectral Type	Example(s)	Temperature Range	Key Absorption Line Features	Brightest Wavelength (color)	Typical Spectrum
O	Stars of Orion's Belt	>30,000 K	Lines of ionized helium, weak hydrogen lines	<97 nm (ultraviolet)*	
B	Rigel	30,000 K–10,000 K	Lines of neutral helium, moderate hydrogen lines	97–290 nm (ultraviolet)*	
A	Sirius	10,000 K–7,500 K	Very strong hydrogen lines	290–390 nm (violet)*	
F	Polaris	7,500 K–6,000 K	Moderate hydrogen lines, moderate lines of ionized calcium	390–480 nm (blue)*	
G	Sun, Alpha Centauri A	6,000 K–5,000 K	Weak hydrogen lines, strong lines of ionized calcium	480–580 nm (yellow)	
K	Arcturus	5,000 K–3,500 K	Lines of neutral and singly ionized metals, some molecules	580–830 nm (red)	
M	Betelgeuse, Proxima Centauri	<3,500 K	Molecular lines strong	>830 nm (infrared)	

*All stars above 6,000 K look more or less white to the human eye because they emit plenty of radiation at all visible wavelengths.