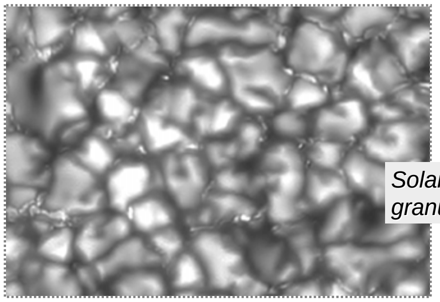
ASTR 1120: Stars & Galaxies



Solar granulation

Prof. Juri Toomre TA: Ben Brown

Lecture 13 Wed 9 Feb 05

zeus.colorado.edu/astr1120-toomre

Today

- Solar dynamo models, effects of solar wind
- What can we *measure* in other stars?
- How do we begin to classify other stars? Why O, B, A … such a nutty scheme!

- *Review Session* given <u>tonight</u> (Wed 9 Feb) by Ben Brown, here in G1B20, 7pm-9pm
- *Review Sheet* still available for in-class *Mid-term Exam 1* this Fri 11 Feb
- *Homework # 3* (graded), plus answer sheet, being returned today

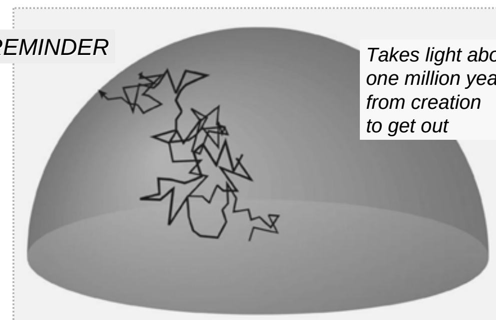
Clicker – Energy is how "old" ? E.

- *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

Meanderings of outbound photons

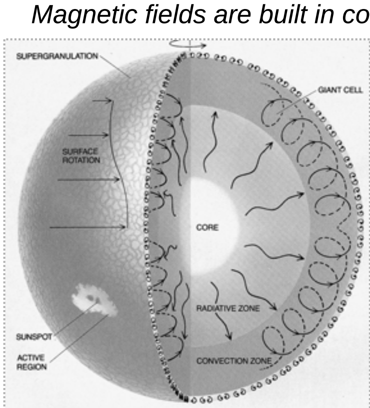
P-P chain makes gamma-ray photons, which "random walk" outwards (getting absorbed, re-emitted), gradually cooling

REMINDER



Takes light about one million years from creation to get out

Magnetic fields are built in convection zone

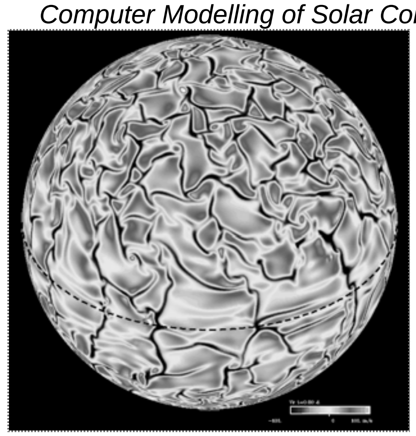


Convection Zone: ROTATING SHELL OF TURBULENT PLASMA

<u>Differential Rotation</u> and <u>Magnetic Dynamo</u> go HAND-IN-HAND

REMINDER

Computer Modelling of Solar Convection

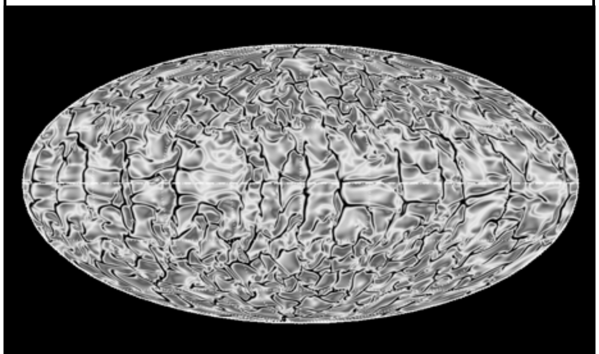


RADIAL VELOCITY NEAR TOP OF LAYER

Large-scale convection "drives the differential rotation"

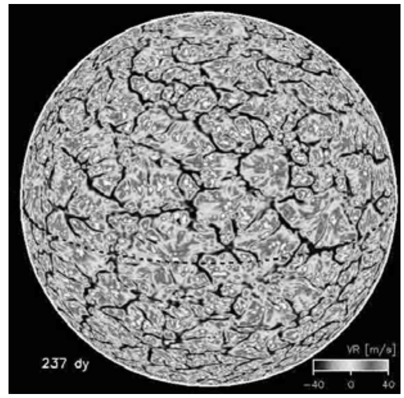
Case E Brun, Miesch & Toomre

Global View of Velocities in Simulations



Different Patterns Near Equator and Near Poles

Modelling Convection Close to Surface

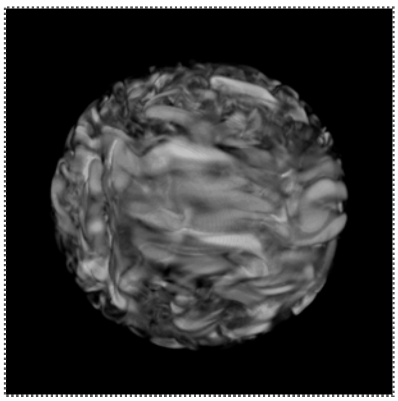


THIN SHELL
STUDIES OF
SUPERGRANULATION
AND NEAR-SURFACE
SHEAR LAYER

Smaller scales of convection driven near the solar surface

DeRosa, Gilman & Toomre

Computer Model: Toroidal Magnetic Fields

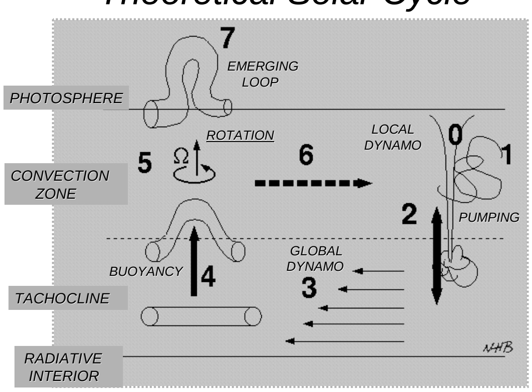


Dynamo action by global-scale convection

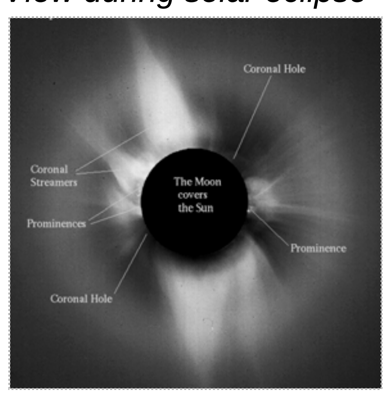
Case M3
Brun et al

Radial Magnetic Fields in Computer Model

Theoretical Solar Cycle



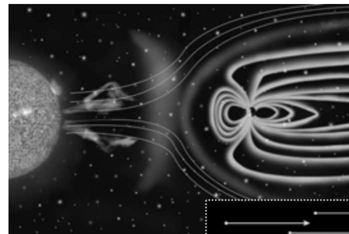
View during solar eclipse



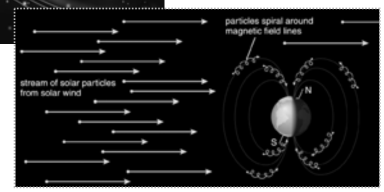
Reading Clicker -- Solar Wind E.

- *What are visible effects of the Earth being "bathed" in the wind of solar particles, especially when wind has <u>strong hiccup</u>?*
- *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

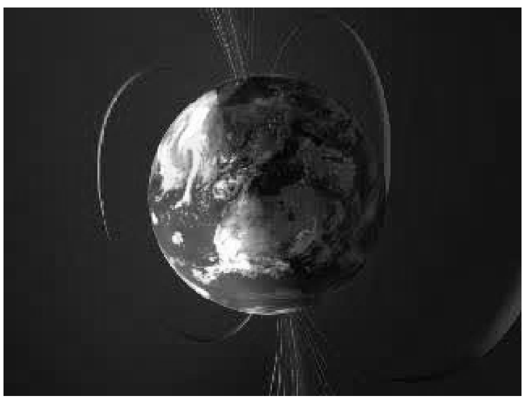
Solar Wind and Earth's Magnetosphere



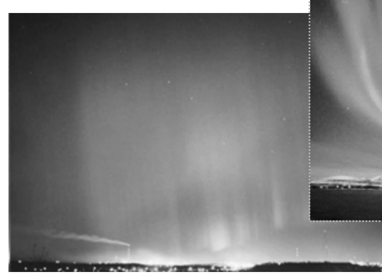
Earth's Magnetic Field Is Shaped by Solar Wind



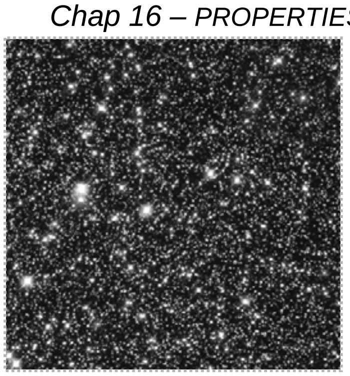
Solar Wind and Aurorae



Northern Lights
(Aurora Borealis)



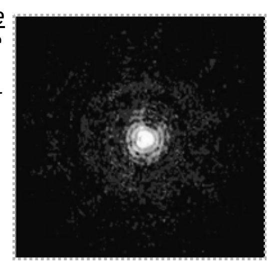
Now onward to measuring other stars: Chap 16 – PROPERTIES OF STARS



- *Measuring stellar <u>luminosities</u>*
- *Measuring <u>distances</u>*
- *Measuring <u>temperatures</u>*

Often only seeing a point of light

- *Stars are <u>so small compared to their distance</u> that we almost never have the resolution to see their sizes and details directly – "<u>point sources"</u>*
- *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

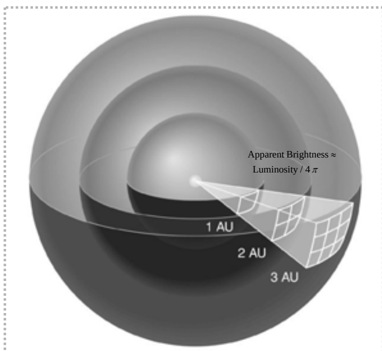
Star of given APPARENT BRIGHTNESS could be either

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 $\approx L_o / (\text{distance})^2$

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*

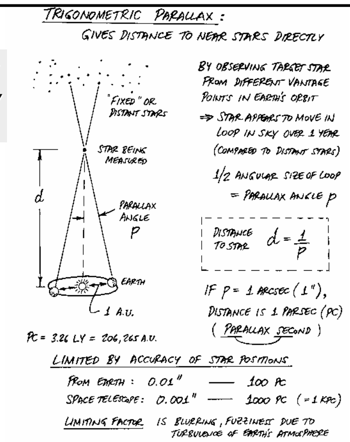
  or how bright it appears to us here on Earth
- *What we want to know: (absolute) LUMINOSITY*

  or how much energy is emitted (Joules/sec or watts)
- *Need to know DISTANCE to the star*

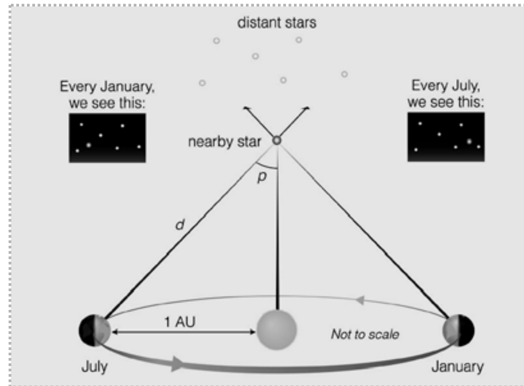
Parallax – to determine distance

- 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

Stellar Parallax: measuring nearby distances



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?

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)