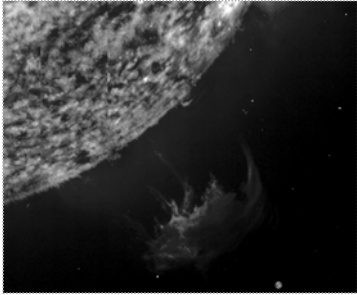


ASTR 1120: Stars & Galaxies



Prof. Juri Toomre TA: Ben Brown
Lecture 11 Fri 4 Feb 05
zeus.colorado.edu/astr1120-toomre

Today

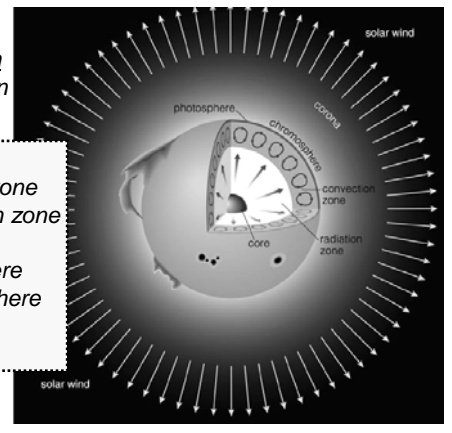
- **Helioseismology** – probing inside the Sun with sound waves
- How the Sun builds (and destroys) its lovely **Magnetic Fields**: sunspots, flares, big loops
- **Homework # 3** due today
- **Observatory Night 3** on Monday Thurs, Feb 5 -- again by sign-up
- **Review Sheet** available today for in-class **Midterm Exam 1** on Fri 11 Feb (review session Wed 9 Feb by Ben Brown)
- **Register on AstronomyPlace by Monday**, or you are out of luck (no more dribbling in!)

Reading Clicker Q **A.**

- What are the solar “layers”, in going from deep inside to outside?
- A. core, radiation zone, convection zone, photosphere, chromosphere, corona
- B. core, radiation zone, convection zone, corona, chromosphere, photosphere
- C. core, corona, radiation zone, convection zone, photosphere, chromosphere

Big System View of Sun

core
radiative zone
convection zone
photosphere
chromosphere
corona
solar wind



SUN IN PROFILE

THE SUN IN PROFILE

AVERAGE DENSITY $\sim 1.4 \times$ WATER (1.4 g/cm^3)

PHOTOSPHERE (SPHERE OF LIGHT): "SURFACE OF STAR"
DENSITY $\sim \frac{1}{5000} \times$ AIR
TEMPERATURE $\sim 5800 \text{ K}$

NUCLEAR BURNING CORE:
CENTRAL DENSITY $\sim 160 \times$ WATER
TEMPERATURE ~ 16 MILLION K

OUTSIDE PHOTOSPHERE:

CHROMOSPHERE (SPHERE OF COLOR)
HOT UPPER ATMOSPHERE ($10^4 - 10^5 \text{ K}$)
PRODUCES SOME EMISSION (BEAD) LINES

CORONA
VERY HOT (2 MILLION K), VERY LOW DENSITY
GRADUALLY BLEATS INTO SOLAR WIND STREAMING AWAY FROM SUN

SURFACE
photosphere

CORE

ATMOSPHERE
chromosphere
corona

Vast range in temperature and density

SUN : SURFACE FEATURES

Complex SURFACE FEATURES

ROTATION: SEEN FROM MOTION OF SUNSPOTS AND PATTERNS

25 DAYS (EQUATOR)
28 DAYS (MID-LATITUDE)
33 DAYS (POLES)
SUN ROTATES "DIFFERENTIALLY"

SUNSPOTS: COOL SPOTS (4000K), STRONGLY MAGNETIZED
EXHIBIT 11-YEAR CYCLES OF "ACTIVITY"

FLARES: INTENSE MAGNETIC STORMS

PROMINENCES (FILAMENTS): EXTENSES OF GAS IN CORONA (ARCHES OF MAGNETIC FIELD)
SICULES (LIKE GRASS)

ACTIVE REGIONS OR PLACES (BRIGHT BEACH!): WIDE REGIONS OR PATCHES OF MODERATE MAGNETIC FIELD (MAYBE WITH SUNSPOTS INSIDE)
APPEAR BRIGHT IN HYDROGEN ALPHA (H α) LINE

SUNSPOTS

PROMINENCES

ACTIVE REGIONS

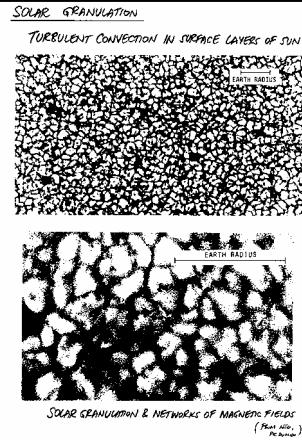
SOLAR ROTATION as viewed with SOHO



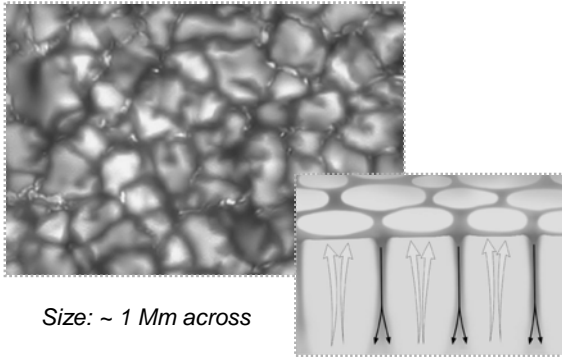
GRANULATION
VISIBLE AT
SURFACE

Smallest scale of
solar convection

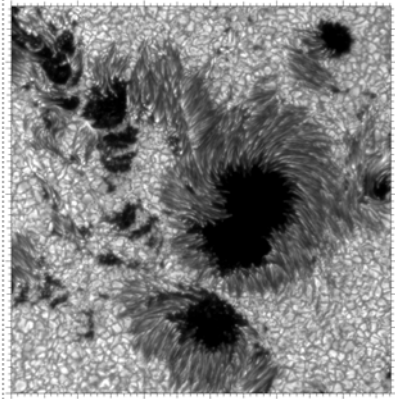
“Roiling and boiling”
at the surface !



Granulation: turbulent convection

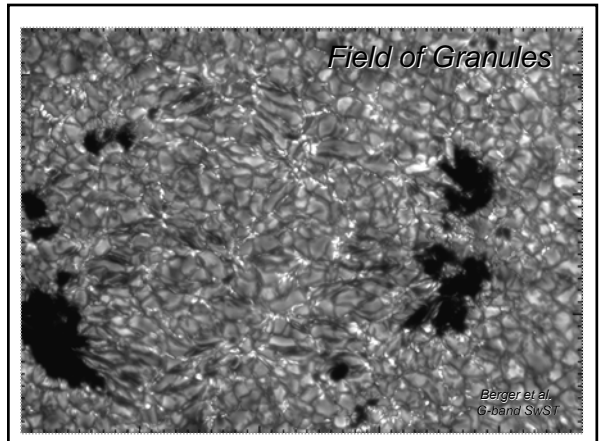
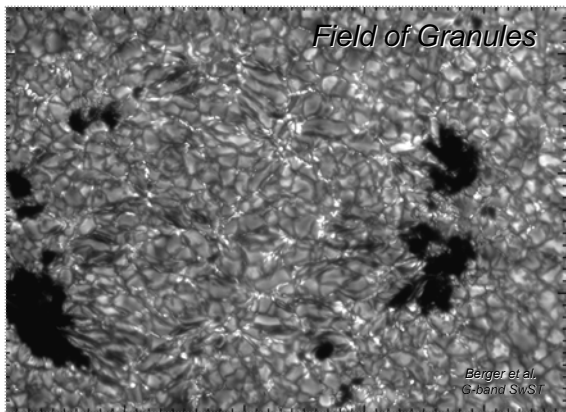


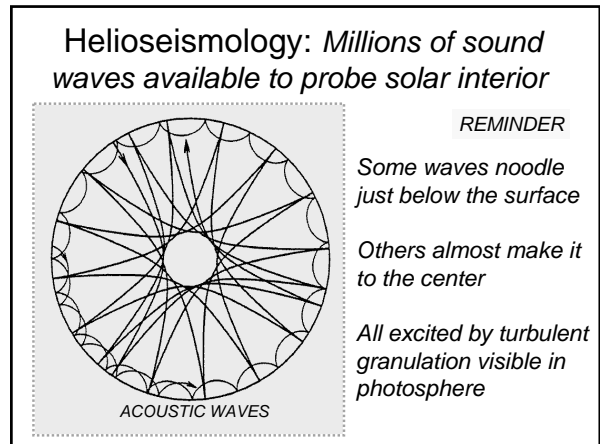
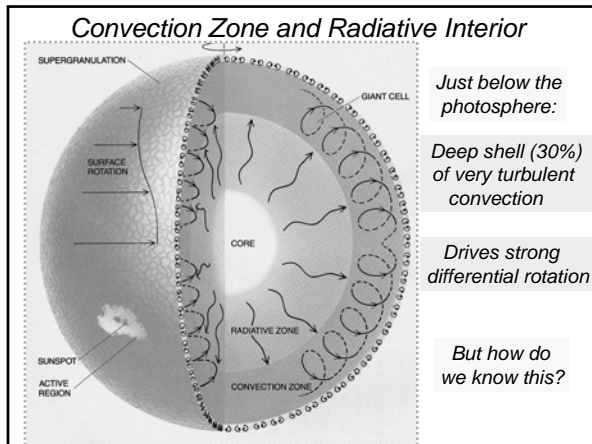
Complex Interplay of Convection and Magnetism



SUNSPOTS
amid field of
GRANULES

1 Mm spacing
on ticks





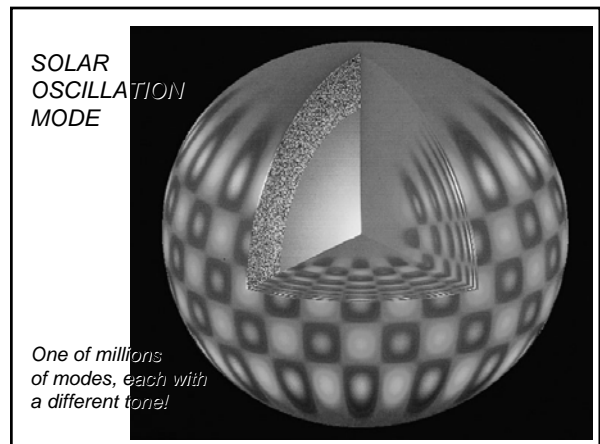
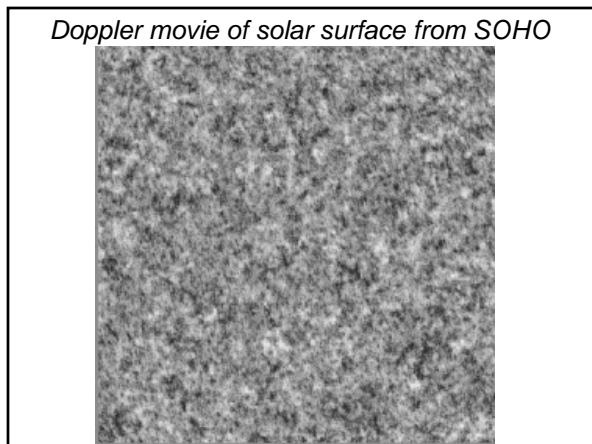
Tools of Imaging Helioseismology

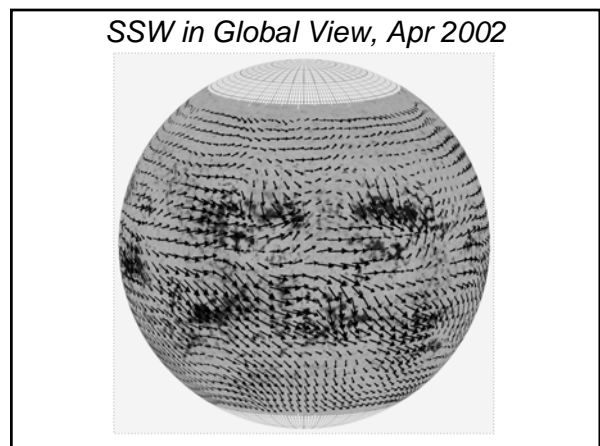
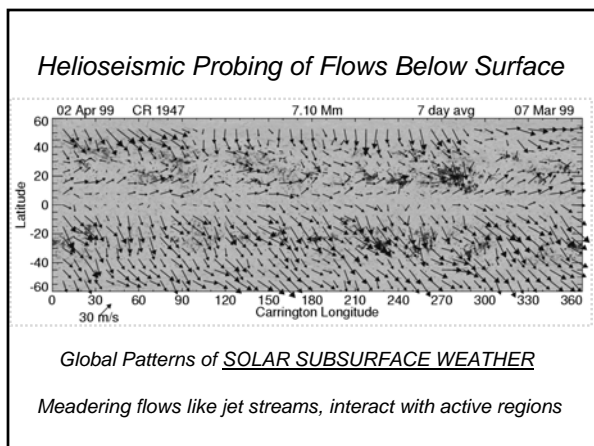
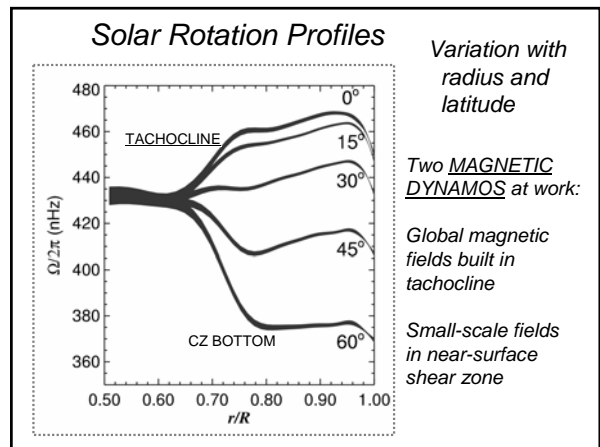
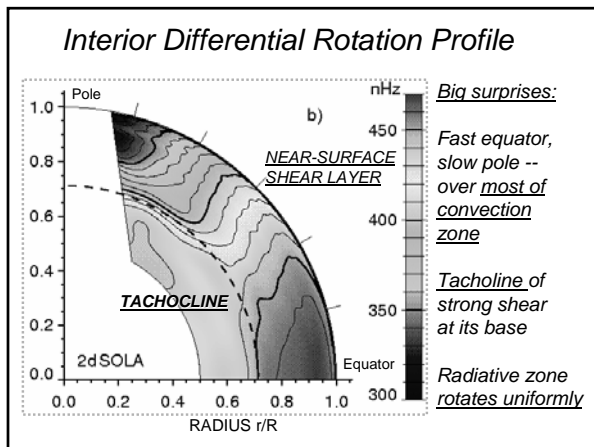
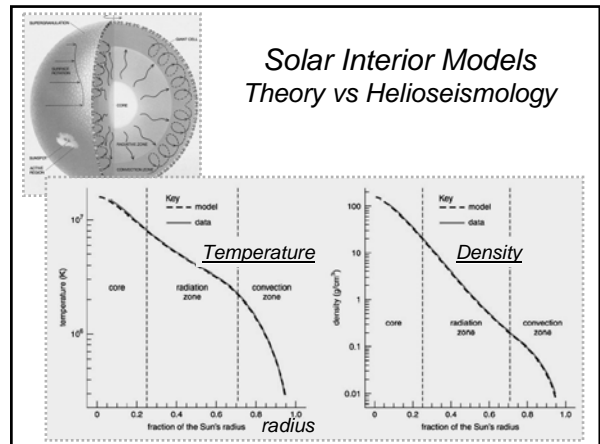
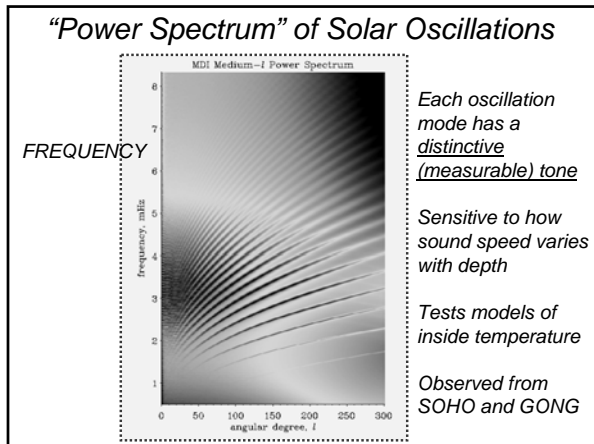
SOHO Spacecraft
Michelson Doppler Imager (MDI)

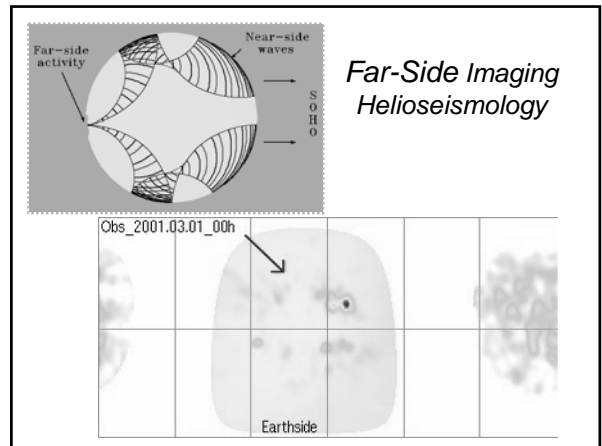
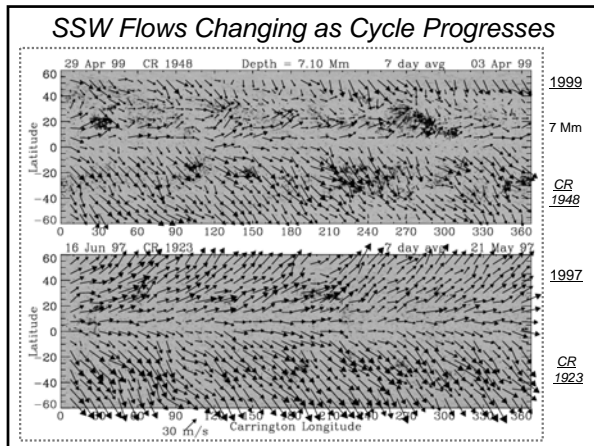
Global Oscillation Network Group (GONG)

How Sound Makes A Surface Bounce

- Sound waves inside Sun cause the photosphere to move up and down, with "five-minute oscillations"
- Can detect these with Doppler imaging of gas at solar surface ("see" the sound)







SUN : SURFACE FEATURES

SURFACE FEATURES

Now on to **SOLAR MAGNETISM**

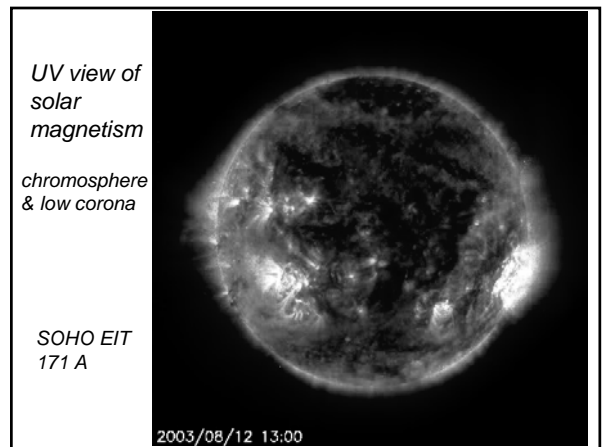
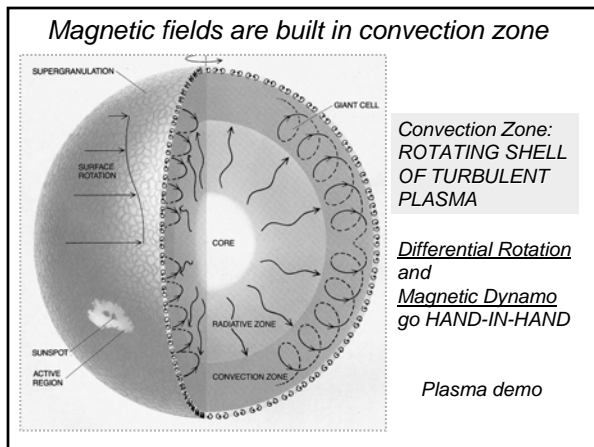
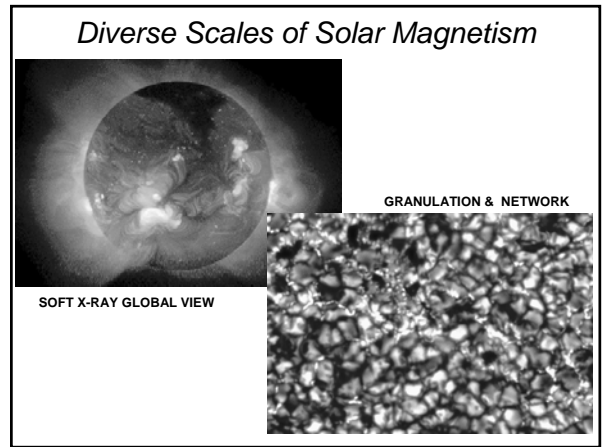
ROTATION : SEEN FROM MOTION OF SUNSPOTS, AND DOPPLER SHIFTS
 25 DAYS (EQUATOR)
 28 DAYS (MID-LATITUDE)
 33 DAYS (POLES)
 SUN ROTATES "DIFFERENTIALLY"

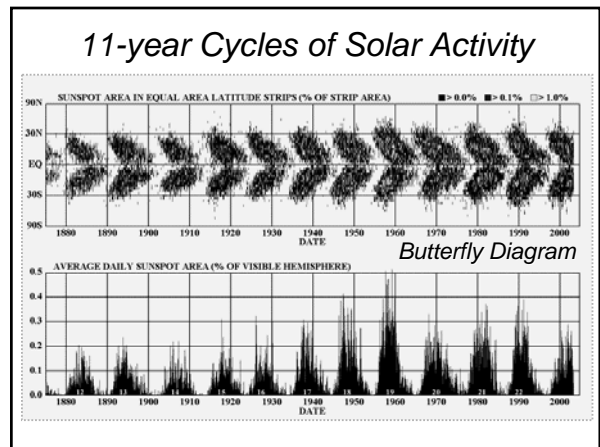
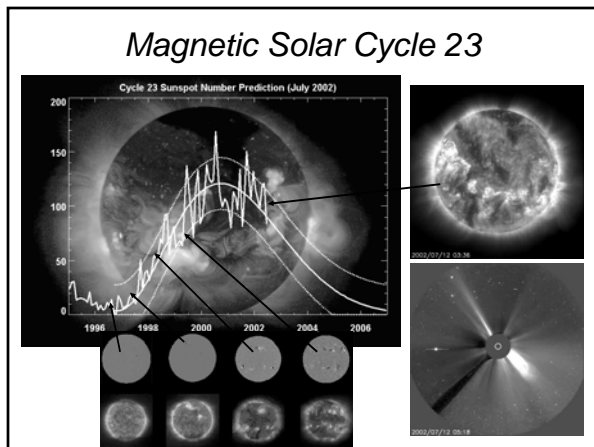
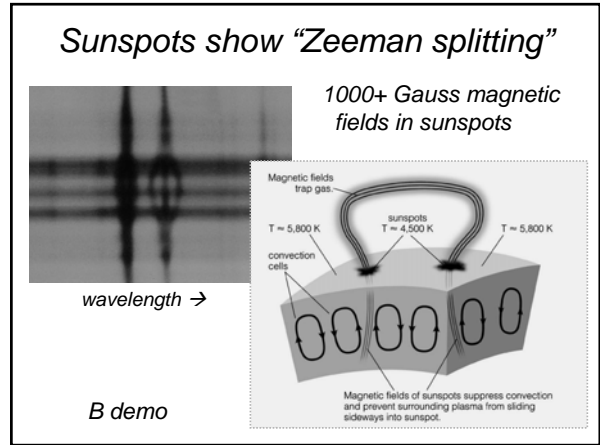
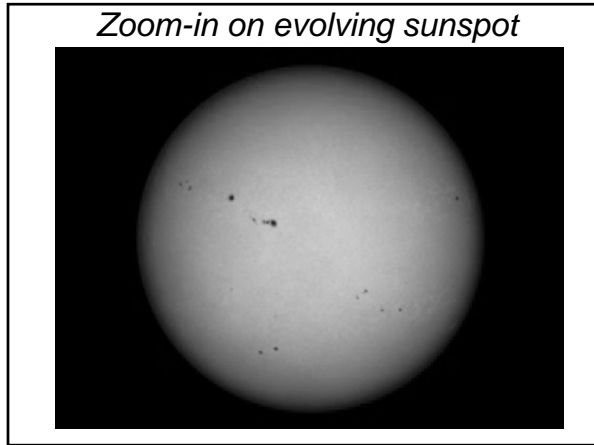
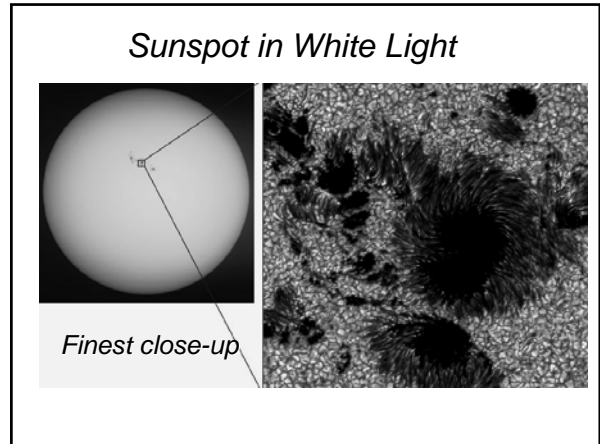
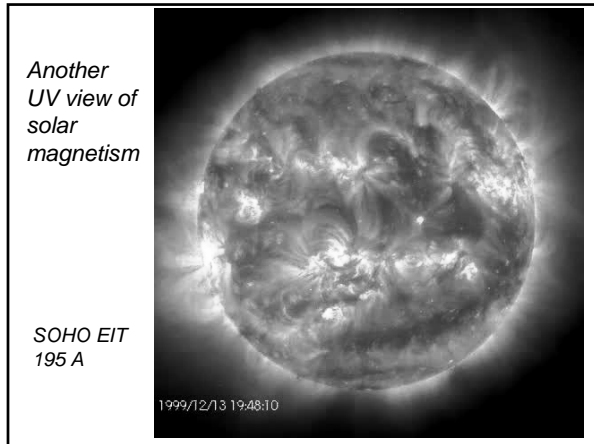
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 LIMS
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 APPEAR BRIGHT IN HYDROGEN ALPHA (H α) LINE





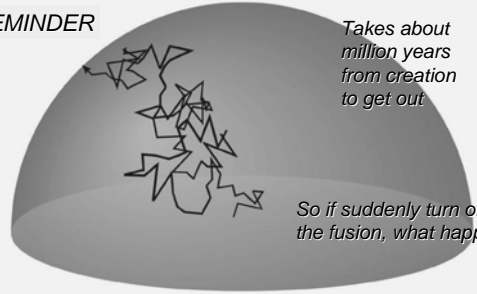
Clicker – Energy is how “old” ? **E.**

- 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 about million years from creation to get out

So if suddenly turn off the fusion, what happens?

Reading Clicker Q **D.**

- What is the composition (by mass) of the Sun ?
- A. 100% hydrogen (H) and helium (He)
- B. 50% H, 25% He, 25% other elements
- C. 70% He, 28% H, 2% other
- D. 70% H, 28% He, 2% other
- E. 98% H, 2% He and other