

Astronomy 150: Killer Skies



Night Obs



This Class (Lecture 17):
The Sun is dangerous today

Next Class:
CME

HW6 due Monday!

Music: *Invisible Sun*– Police

Dates:

- Monday, Oct. 4th ✓
- Tuesday, Oct. 5th ✓
- Wednesday, Oct. 6th ✓
- Thursday, Oct. 7th ✓
- Monday, Oct. 11th
- Tuesday, Oct. 12th
- Wednesday, Oct. 13th
- Thursday, Oct. 14th

Starts at 8pm until 10pm
(expect to spend ~40 mins)

Go to assignment page on
class website for more info.

You **MUST** download
worksheet before you go.

Can be cloudy, so check
webpage before you go.

Question



Outline



Did you go to the Observatory yet?

- Yes, it was okay.
- Yes, it was cool!
- Yes, it was the highlight of my life so far!
- Yes, but it was boring.
- No, but I will do so as soon as I can, I promise. I had other things I had to do, but I really, really want to go and I will make it a **top** priority in my life!

- The Active Sun
- Sunspots and the magnetic Sun

Electron Degeneracy



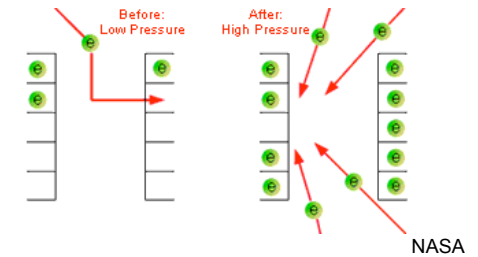
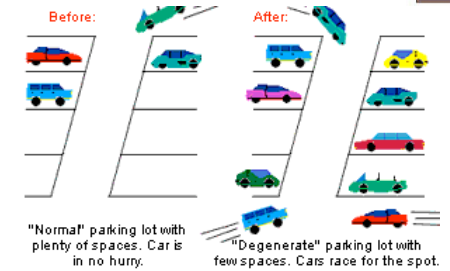
- The electrons get so squashed together that they get pushed into *degenerate states*
 - This creates **pressure** to counteract gravity (Pauli exclusion)
 - Stops contraction



Degeneracy Pressure



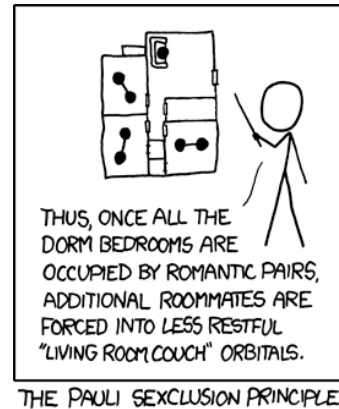
- Electrons are forced into higher energy levels than normal – all of the lower levels are taken
- Effect manifests itself as pressure



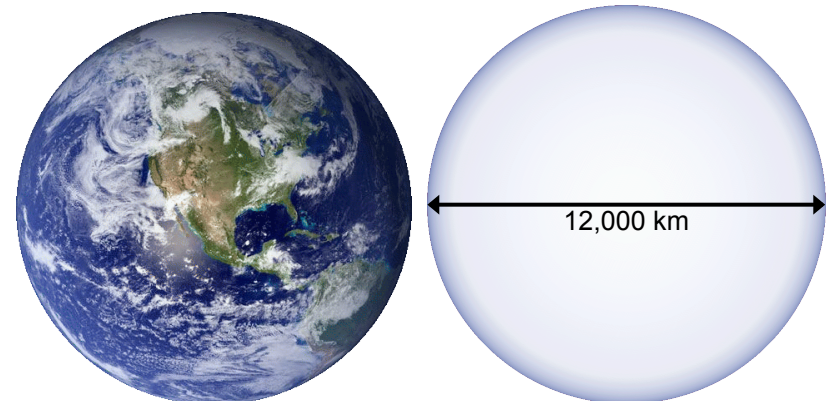
Contraction Junction



- The electrons are limited to what states they can occupy, so they push back.
- Quantum “degeneracy” pressure.
- Need more mass to overcome



Relative Size of White Dwarf



White dwarf– but will usually weigh about 0.6 Solar masses

Question



Why doesn't a white dwarf collapse into a black hole?

- a) Electron degeneracy pressure
- b) Heat pressure
- c) Fusion pressure
- d) Proton degeneracy pressure
- e) For the same reason that the Earth doesn't collapse into a black hole.

Chandrasekhar limit



- Maximum mass of a white dwarf.
 - 1.4 solar masses!
- No white dwarf observed is over this.
- If mass is higher, the white dwarf can not support itself with electron degeneracy, and it collapses more!
- Gravity is a harsh mistress!
 - More of this latter.



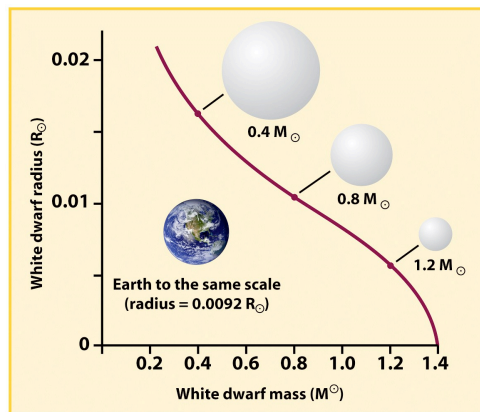
Subrahmanyan Chandrasekhar 1910-1995

White Dwarfs are Weird

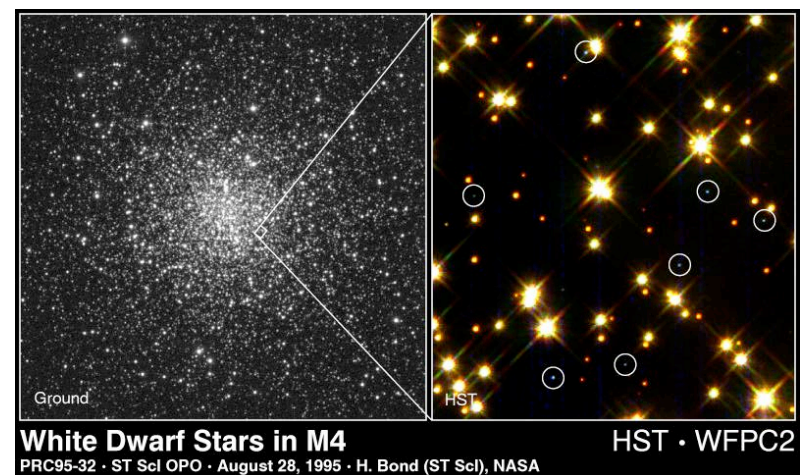


The more massive, the smaller!

Their radius *decreases* with mass!

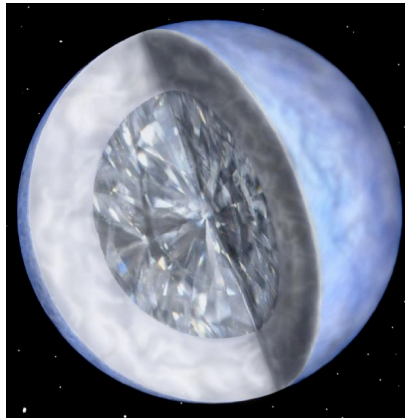


White Dwarves!

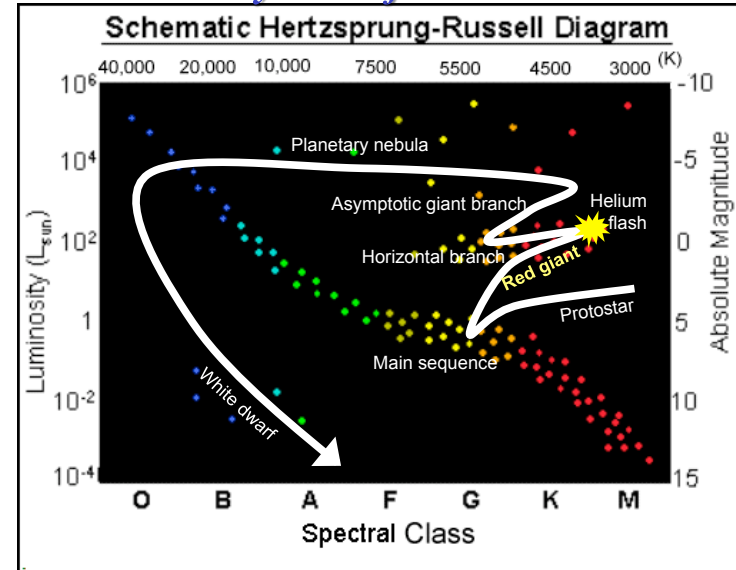


Stellar Diamonds!?!

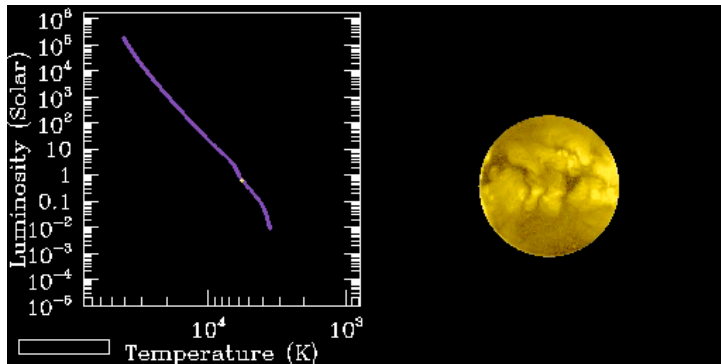
- The interior of the white dwarf crystallizes due to the extreme pressures
- Made mostly of carbon (some oxygen)
- Crystallized carbon = **a diamond**
 - With a blue-green tint from the oxygen
 - 10 billion trillion trillion carats!



Evolutionary Path of a Solar-Mass Star



Evolutionary Path of the Sun



Question

This is the way the Sun ends. This is the way the Sun ends, not with a bang but a

- whimper; it just cools down over time.
- supernova blasting heavy elements into space.
- blackhole.
- planetary nebula and a white dwarf that cools with time.
- a helium flash.

Imagine

- After being dropped into suspended animation in a Pizza accident a billion years ago, you awake to a crazy new world.
- Disregarding the signs warning people to stay underground, you wander outside and see that the Sun is only about 10% more luminous, but it is crazy hot and the oceans are shrinking.
- As you quickly succumb to heat stroke, you wonder what Leslie said about Solar Evolution so many years ago.

Imagine

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space-art.co.uk

- After being transported forward in time after being hit by a spiraling phone booth six billion years ago, you awake to a crazy new world.
- The Sun is Red? And super hot.
- The entire Earth's surface is molten rock during the day, slightly cooling at night.
- As you burn in pain, you wonder what Leslie said about Solar Evolution so many years ago.

But, I Know You're Thinking



But Solar Evolution is so far in the future,
is there anyway that the Sun can kill us
today?

Yes!

Top 10 Ways Astronomy Can Kill you or your Descendents



1. Impacts!
Splat.. Boom... Watch out for space rocks!
2. Solar Evolution.
MS to Red Giant to White Dwarf.
3. Coronal Mass Ejections
The Sun gets angry..

Imagine

- It's winter. It's cold.
- The Sun is unusually active, and you hear NASA is worried about something called Space Weather.
- A huge batch of new sunspots on the Sun's equator are seen..
- A huge coronal mass ejection from the Sun comes screaming toward the Earth.

Approximate size
of earth for

Imagine

- All of our satellites are knocked out.
- Airplanes are left without communication
- Electrical transmission lines overload and melt, causing wildfires.
- Half the planet is without power.
- Thousands die the first night...
- Then, more sunspots...
- And you can't remember what Leslie mentioned about CMEs....

Approximate size
of earth for

Top 10 Ways Astronomy Can Kill you or your Descendents



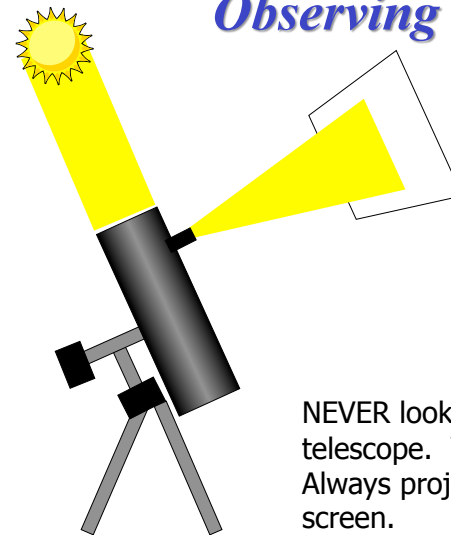
2. Coronal Mass Ejections, CMEs !

The Sun is a star! The Sun seems the same every day, but it isn't. It changes. The Sun is a huge vast mighty furiously seething cauldron of mass and energy! The Sun can get mean!

I mean rock impacts may never happen, and Solar Evolution is so far away, but CMEs can kill today.

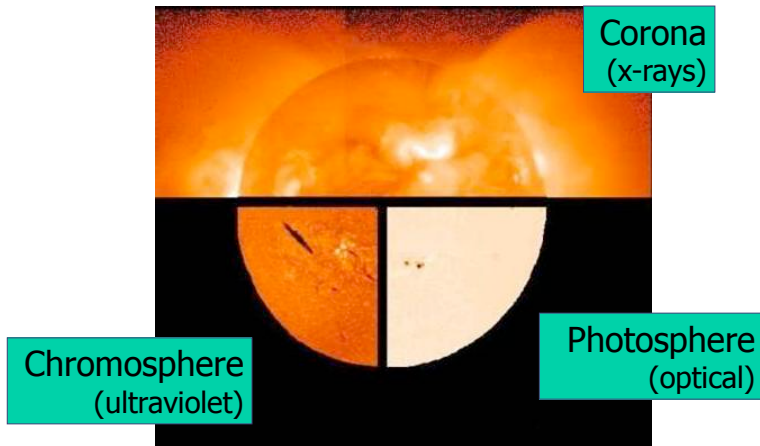
<http://www.youtube.com/watch?v=Pfkz-uMkafY>

Observing the Sun

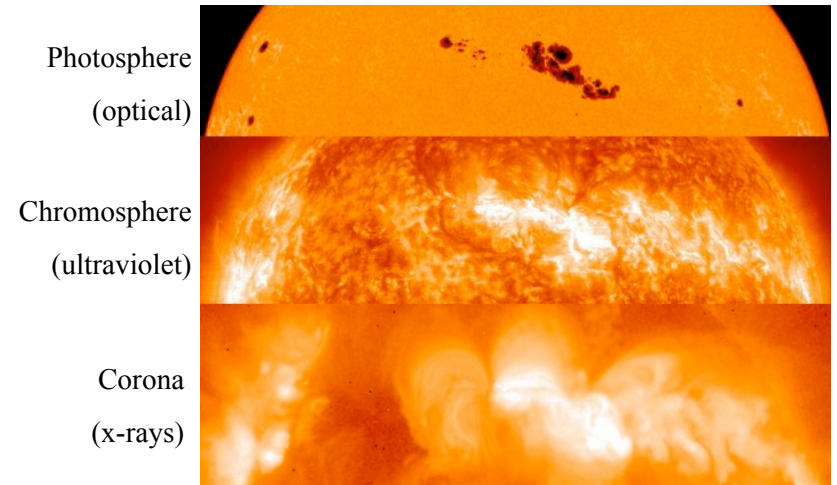


NEVER look at the Sun through a telescope. You will damage your eyes! Always project the Sun's image onto a screen.

The Outer Layers of the Sun



The Various Layers

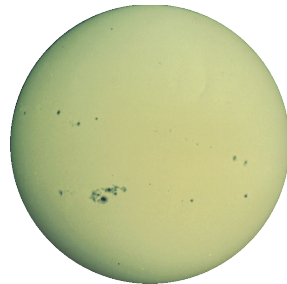


<http://antwrp.gsfc.nasa.gov/apod/ap010419.html>

The Photosphere



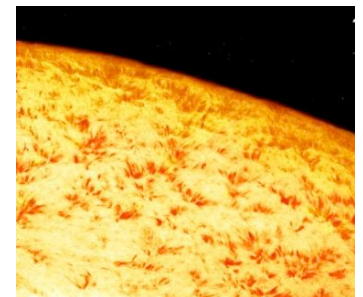
- Apparent “surface” of the Sun
 - Ionized atoms make the gas highly opaque
- Most of the Sun’s light we see comes from the photosphere
- Temperature, about 5800 K
 - Hotter as you go deeper into the Sun



The Chromosphere



- Very sparse layer of gas above the photosphere
- Hot – Over 10,000 K
- Produces very little radiation – too sparse
- Only seen during eclipse or with special instruments
- Helium was first discovered in the chromosphere
- Heated by magnetic and acoustic energy



The Corona



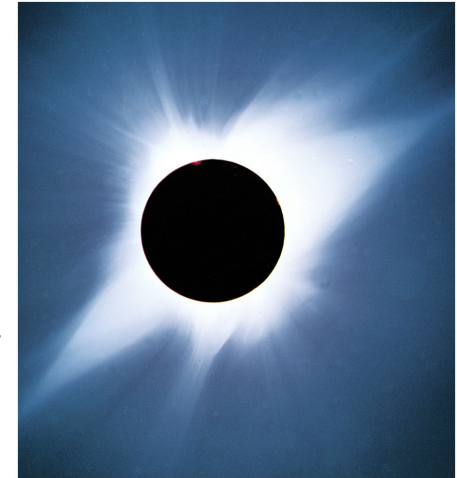
- Sun's outer atmosphere
- Visible only by blocking light from photosphere
- Heated by magnetic and acoustic energy
- Temperatures about 2 million K
- Hot enough to produce X-rays!



The Corona



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Question



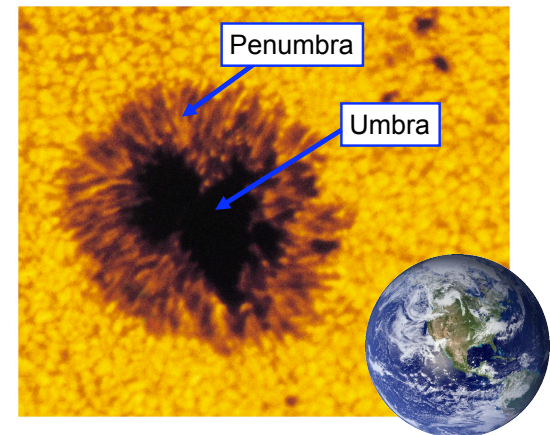
Which of the following is not a layer of the Sun?

- Stratosphere
- Corona
- Chromosphere
- Photosphere
- Core

Why are Sunspots Dark?



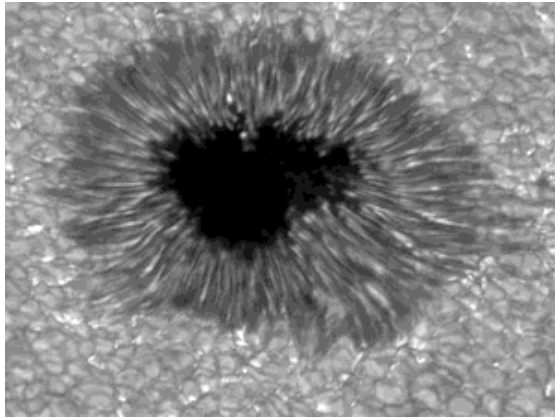
- Dark spots on the Sun.
- Slightly cooler than their surroundings: 4000 K vs. 5800 K
- Since brightness depends on temperature like the 4th power, they are only 30% dimmer.



Sunspots



- Usually last a few days to few weeks, sometimes months.
- Sunspots change over time
 - Grow, shrink, merge, rotate



<http://antwrp.gsfc.nasa.gov/apod/ap000223.html>

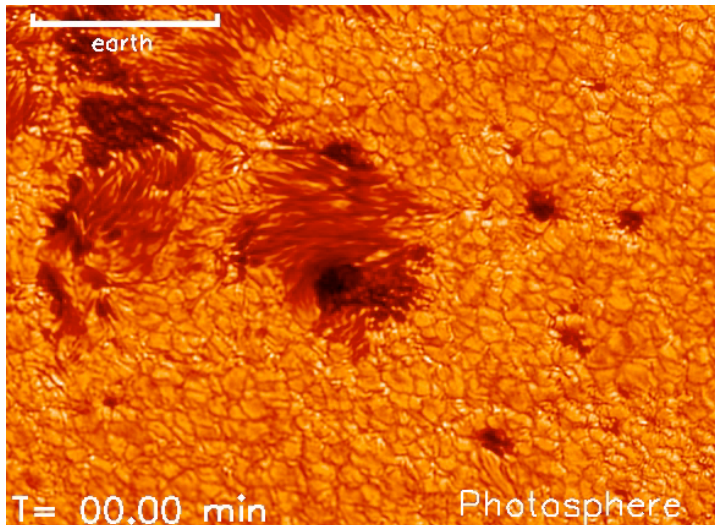
Sunspot Motion



- Sunspots' motion reveals the Sun's rotation!
- The Sun spins about once every 25 days at the equator
- At the poles, it spins once every 30 days
- Called **differential rotation**



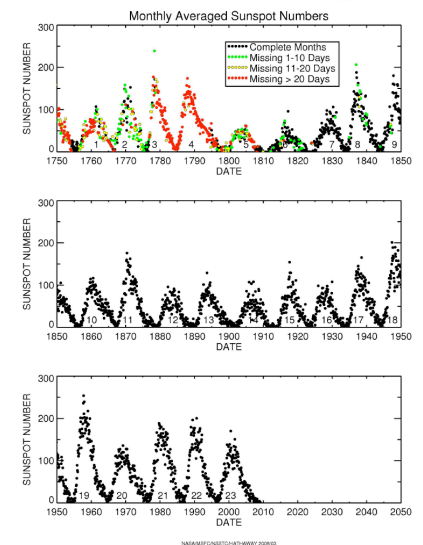
Sunspots



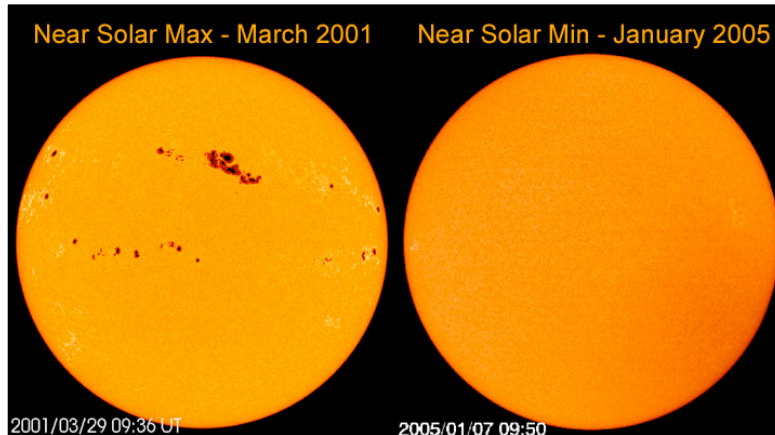
Sunspot Cycles



- Start near 30°N/S, migrate toward equator
- More numerous every 11 years (**solar maximum**)
- 2008/2009 the least number of sunspots since 1950s
- Next maximum is May 2013 with expected below average count



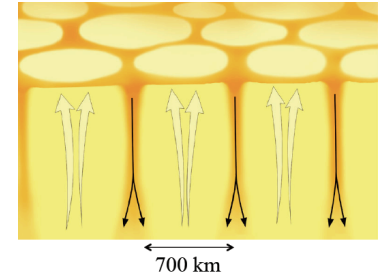
Sunspot Cycles



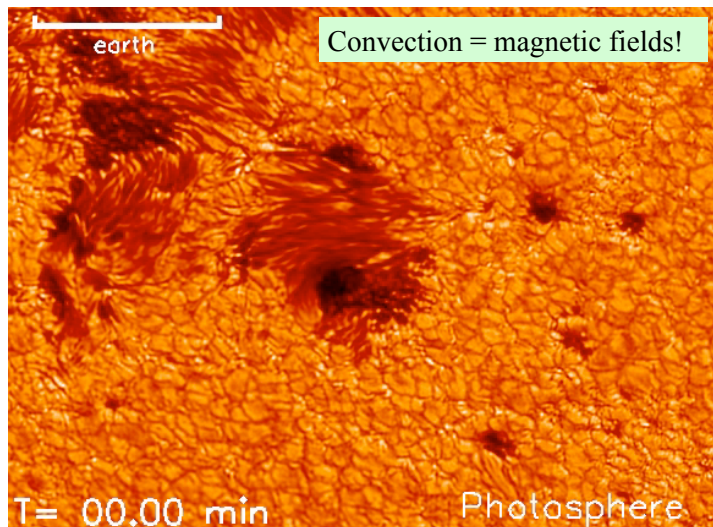
The Solar Surface: Boiling Soup



- The Solar surface is a cauldron of bubbling and noise.
- In the Sun's upper layers, hot gas rises to the surface, cools, and falls back into the Sun
- This **convection** is primary means of transporting energy to the surface.



Sunspots



The Magnetic Cycle



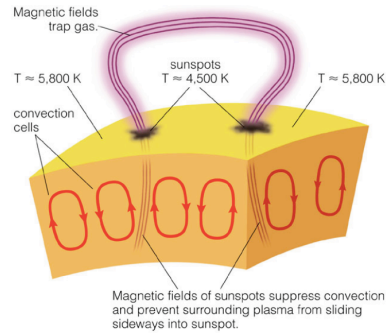
- Sun's magnetic field comes from its surface
- Convection and differential rotation twist and wrap magnetic field lines
- When field lines get too twisted, they pop through the surface
– Makes sunspots!



What Causes Sunspots?



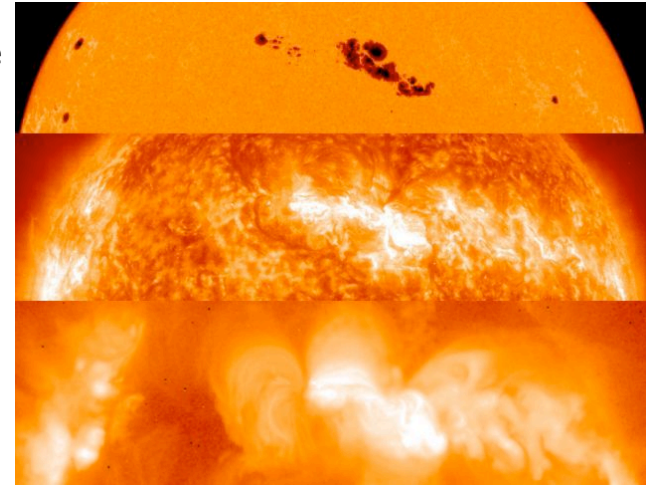
- Magnetic field “loops” popping through the photosphere
- Powerful magnetic activity shuts down convection
 - 5,000 times stronger than the Earth’s field
- Gas cools off (4000 K)
- Appears darker than the rest of the photosphere



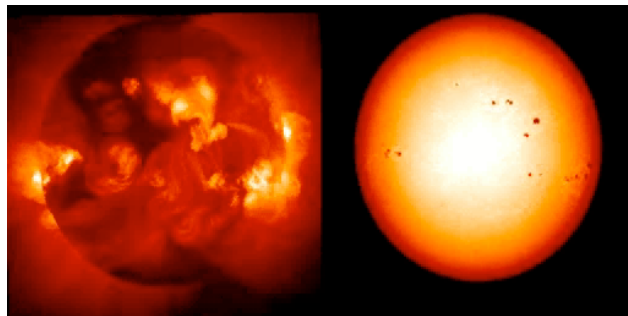
Sunspots and the Outer Layers



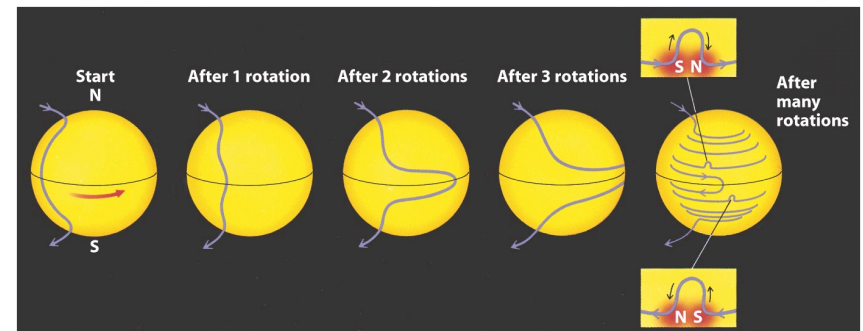
- Photosphere (optical)
- Chromosphere (ultraviolet)
- Corona (x-rays)



Sunspots and the Outer Layers

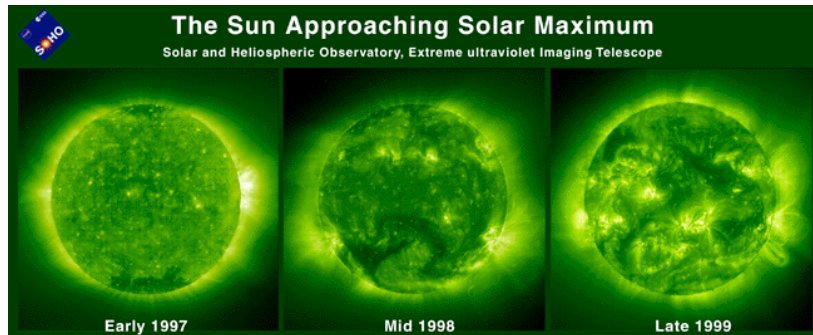


The Magnetic Cycle = Solar Cycle

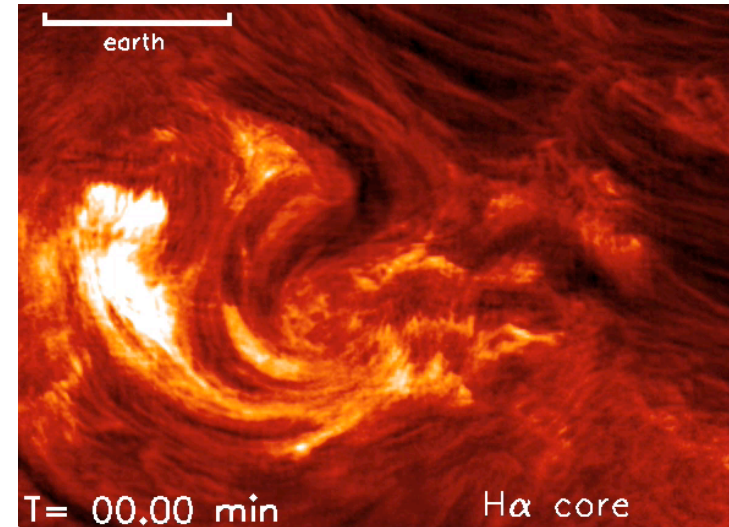


- Every 11 years, the field breaks apart and reorders itself
 - North and south magnetic poles flip!

Magnetic Activity on the Sun



Sunspot and Magnetic Fields



Question



What causes Sunspots?

- a) It is a natural feature of a young Sun. It should clean up as it ages.
- b) Magnetic fields.
- c) Thermonuclear explosions.
- d) Granulation
- e) Greasy food.