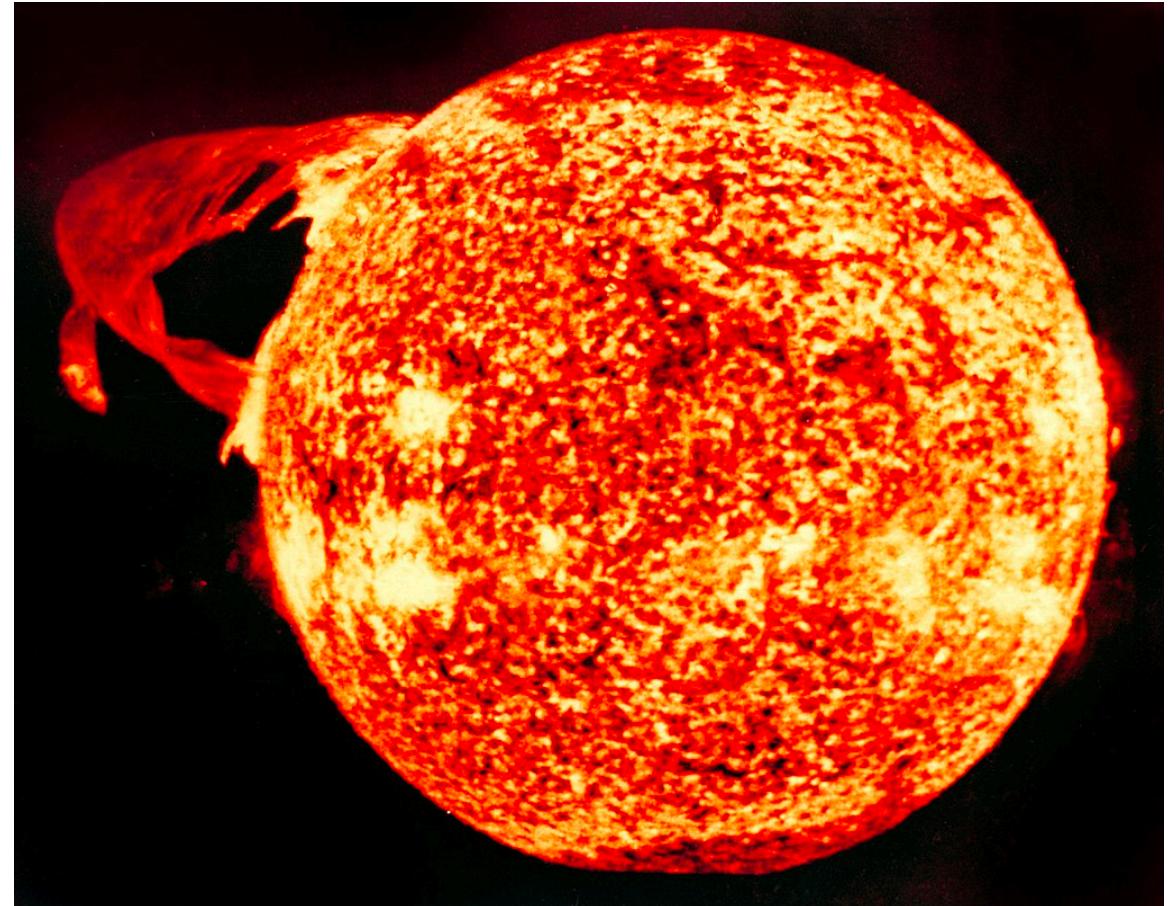


The Sun

Living with a Star

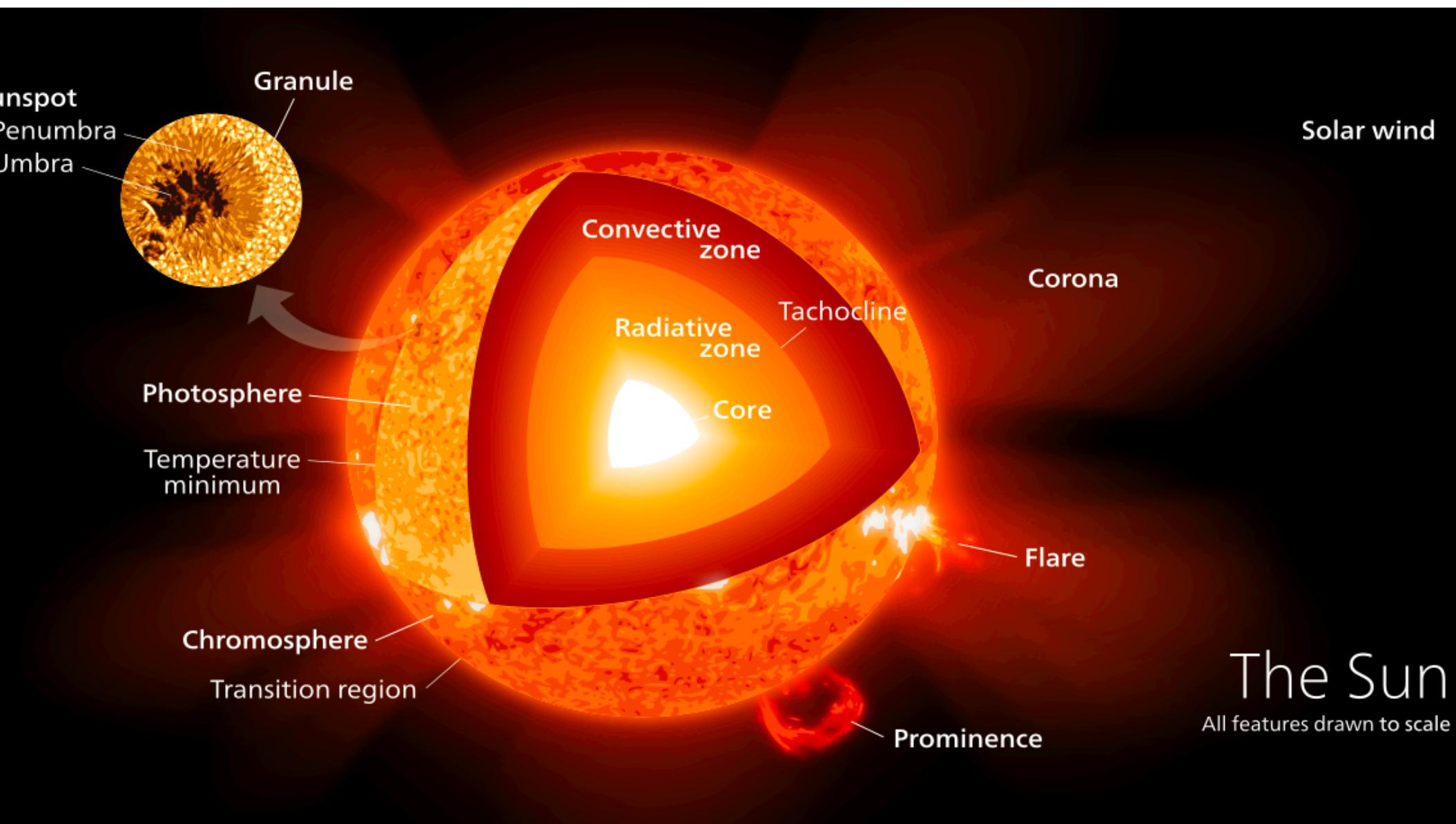


- The sun is big. It's also very bright.
- Distance 1 AU = 150 million km = 93 million miles
- size on the sky is about half a degree
- physical diameter is about 1% of the distance: 1.5 million km.
- Mass is 2×10^{30} kg or about 333,000 earths (1000 jupiters).
- It circles the center of our Galaxy at about 220 km/sec, which takes it 220 million years. The dinosaurs lived on the other side of the Galaxy!
- Temps: surface ~ 5800 Kelvin; center 15 million K; corona 2-5 million K.
 - 5800 K is about 9000 F.

Composition of the Sun

- Cecilia Payne-Gaposchkin showed in her 1925 PhD thesis that the sun & stars are predominantly made of hydrogen. 25% of the mass is helium, around 1% is everything else.
- This was the first PhD granted by the Astronomy Department at Harvard.
- She taught spectroscopy there for many years.



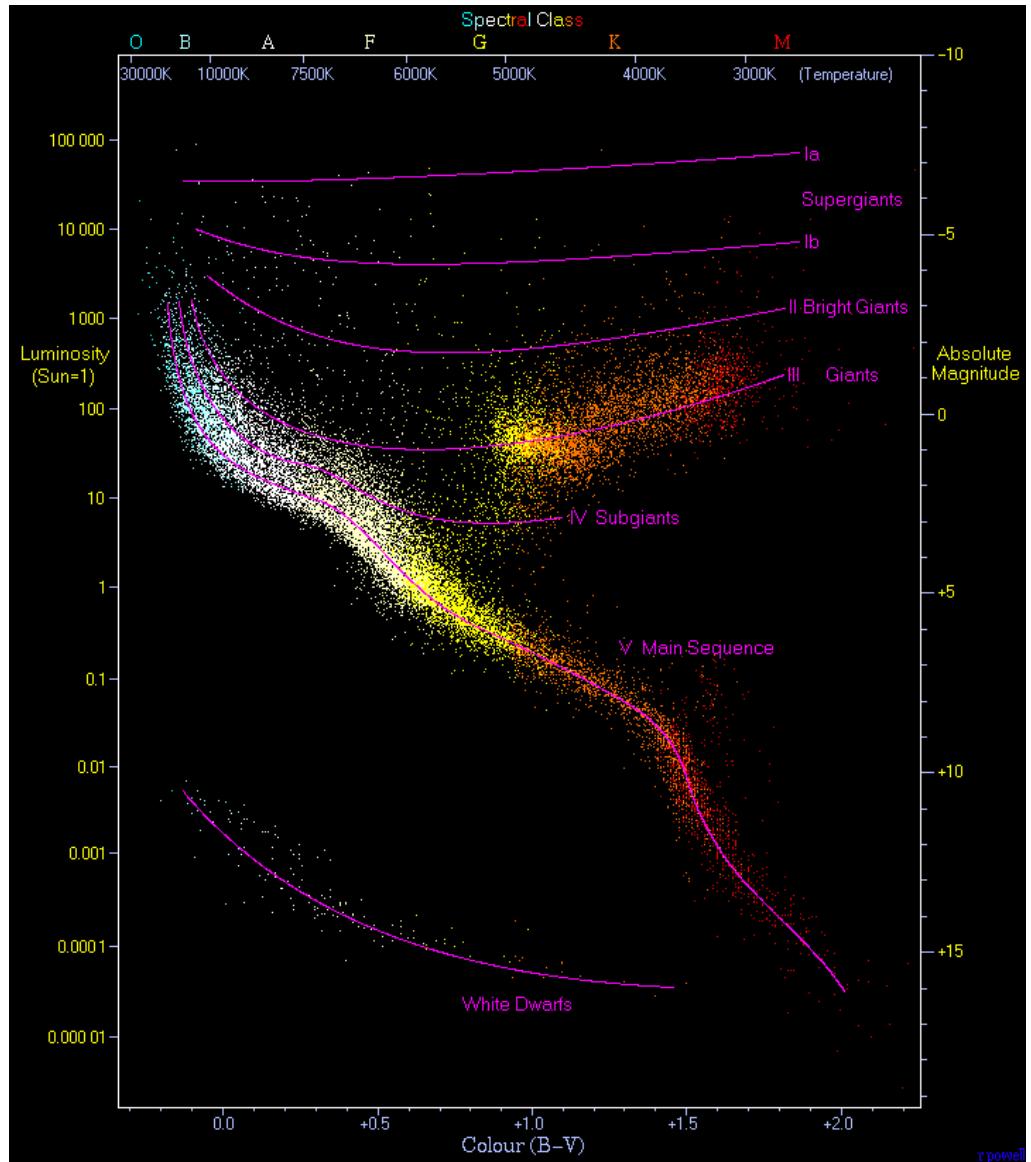


- When you stuff together large amounts of material, it's a gas (plasma) that's denser and hotter in the interior. It's bound by gravity.
- If there's more than about 8% of the sun's mass around, the core of the star will be hot enough to make nuclear reactions happen, with the net reaction



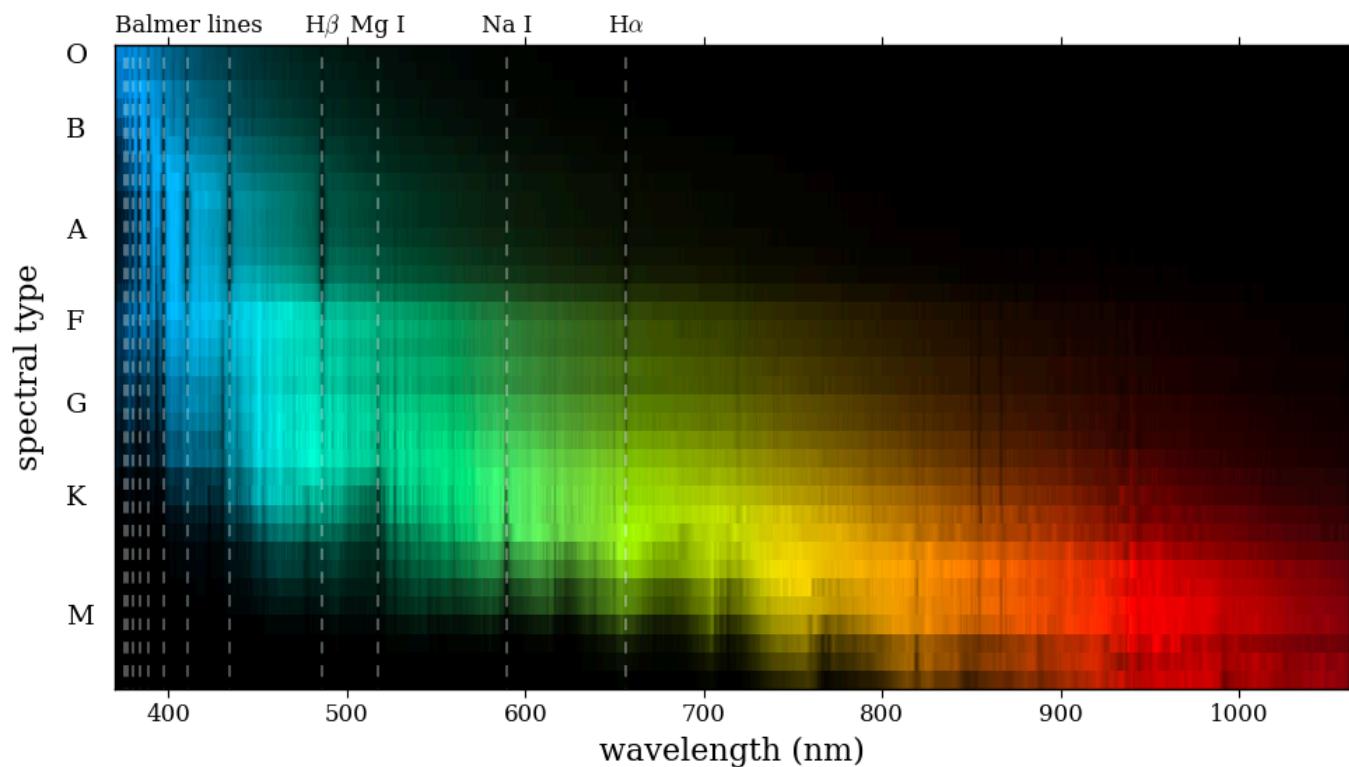
- plus some energy.
- A star is an uneasy balance between gravity compressing it, and the nuclear energy release from the core, holding it up.
- Transporting energy out of the core helps support the overlying layers.
- The hydrogen fuel eventually runs out and interesting things happen.

- The Hertzprung-Russell diagram
- The sun is near the middle in the yellow part of the diagram @ Luminosity = 1 sun, temp 5800K
- As the sun ages it'll get brighter, go up to the Giant branch, expand to eat the inner planets, and get redder.
- The sun is middle aged at 4.5 billion years old. It'll last about that much longer.
- Hot stars burn their fuel much faster (down to 3 million year lifetimes!)

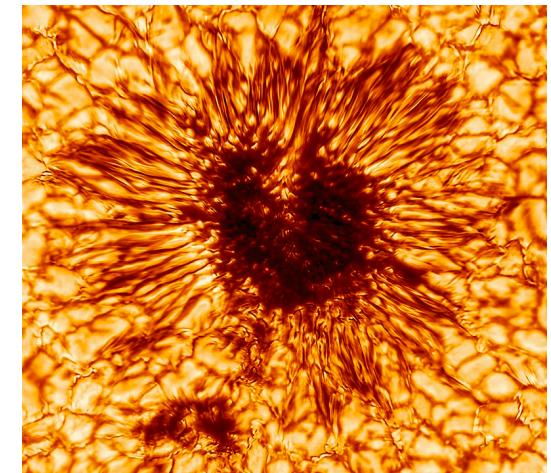
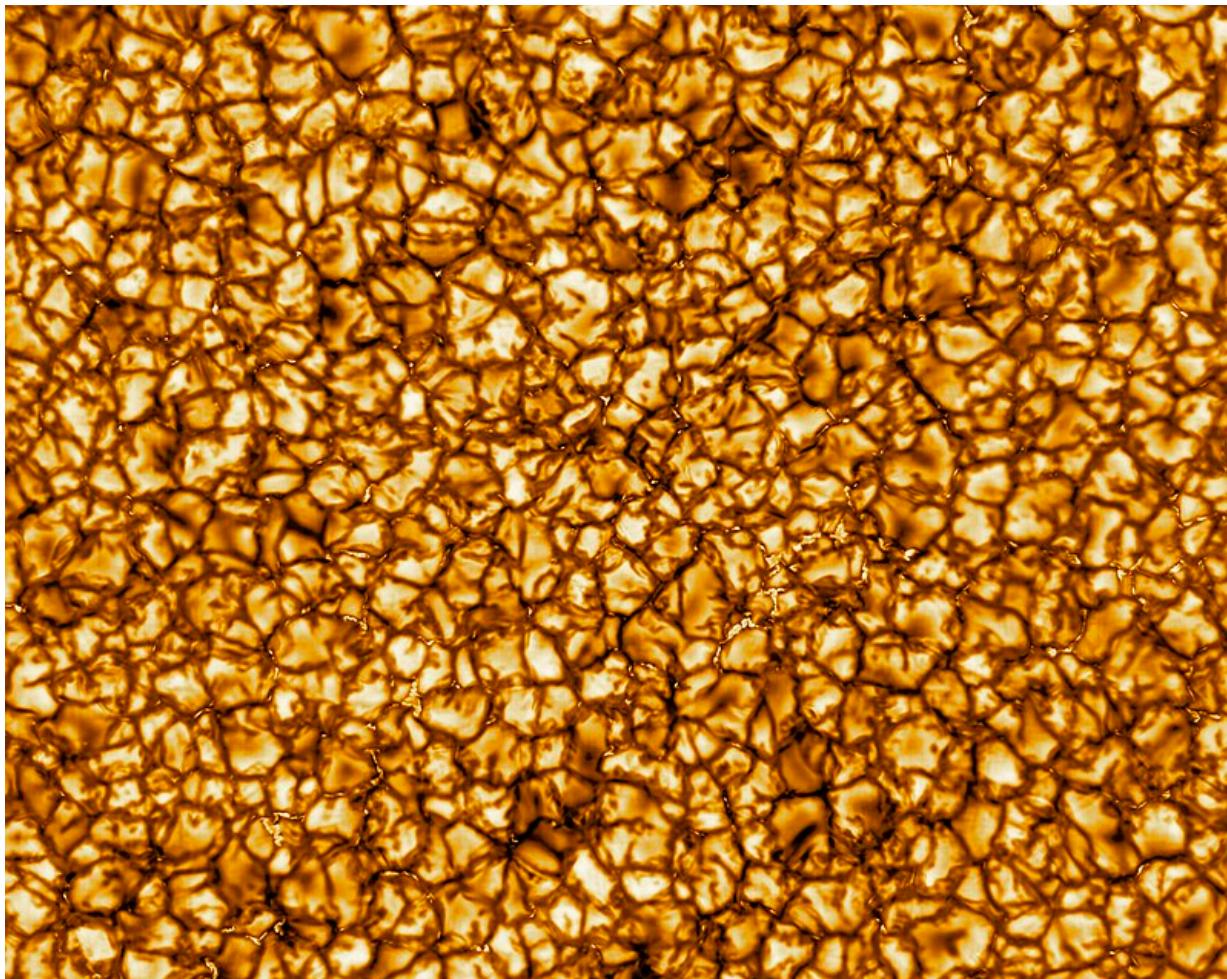


- The sun is 75th percentile by mass.
- If you observe bunches of stars (with known distances) and make a scatter plot of brightness against color, they fall into groups.
- The “Main Sequence” turns out to be hydrogen-burning stars of various masses. Heavier stars are hotter and brighter (and shorter-lived).
- The red giants in the upper right have used up their core hydrogen, some burn helium to C, N, O, ... in fits and starts.
- Burnt-out low-mass stars are across the bottom (White Dwarfs), fading and cooling.

- This stack of stellar spectra shows how dramatically the colors change with temperature/mass/etc.
- Sun is class “G”

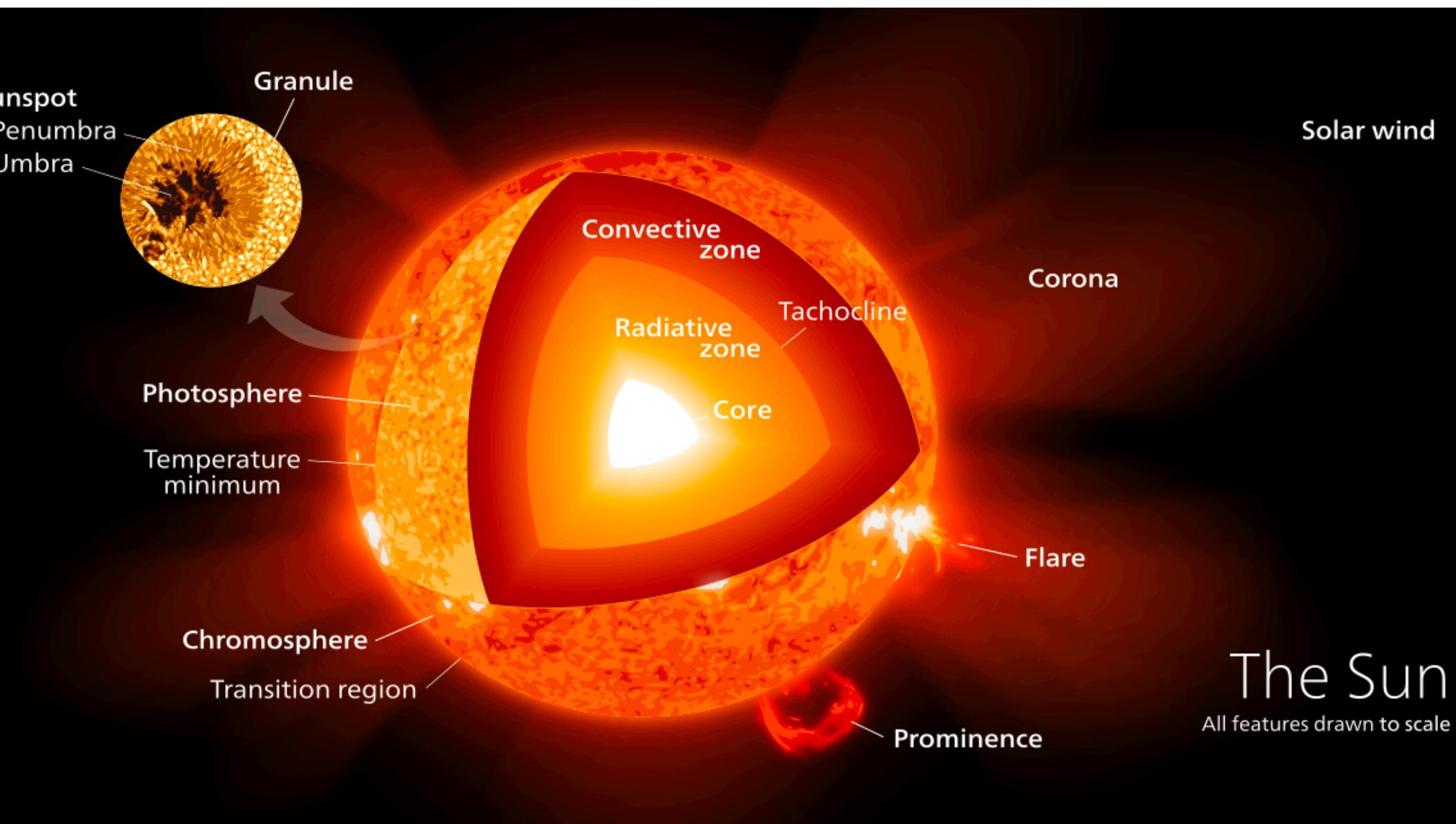






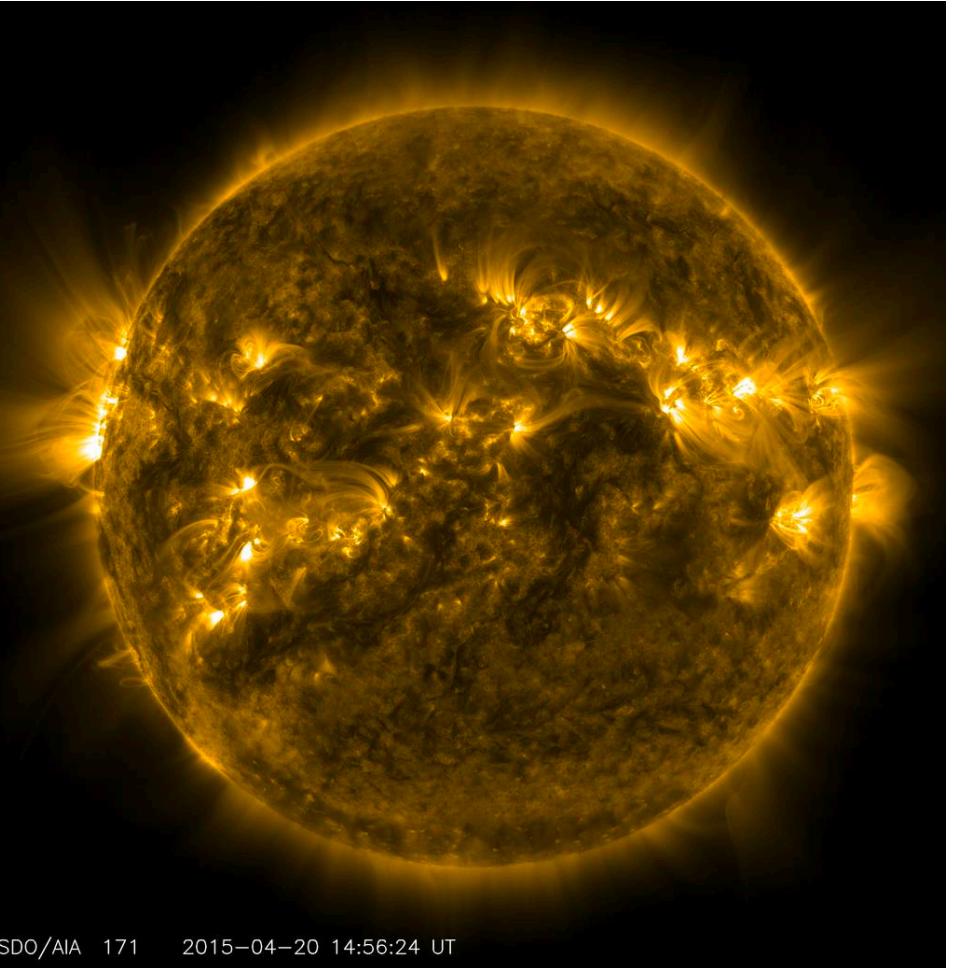
- Hi-res images from the Daniel K Inoue Solar Telescope (DKIST) in Hawaii
- Convection cells!
Sunspots!

- Energy transport in the sun is radiative in the core and envelope.
- It's convective from about 75% of the solar radius up to near the surface.
- We can see the tops of the convective cells, with hot gas rising in the centers of the granules, cooling by radiating away their heat, and then sinking around the edges.
- This process is very noisy, and we can "hear" the resulting ringing of the entire sun by observing the total brightness as it changes on few-minute timescales. The changes are small, but help constrain the models of the solar interior.
- The atmosphere of the sun is about 5800 K or a bit cooler and then the temp rises dramatically to a few million. The reasons are hotly (!) debated.



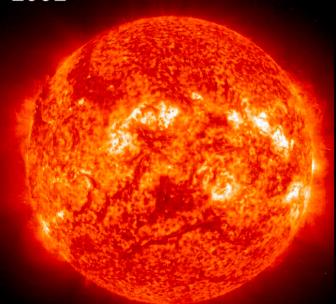


- Looking at the sun in the extreme ultraviolet reveals the hot parts of the solar corona.
- Active regions are associated with sunspots on the visible-light surface. They're magnetic storms, often lifting hot plasma high above the solar surface.
- Some sunspots/active regions erupt and eject plasma into space.
- If it hits the earth's magnetosphere, havoc can result. Also radiation can damage satellites.

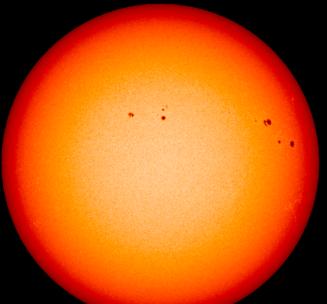


SDO/AIA 171 2015-04-20 14:56:24 UT

2002

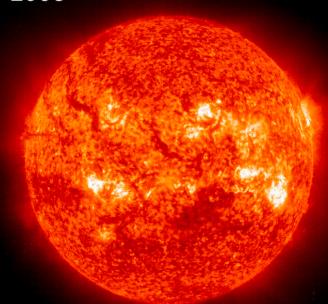


Ultraviolet Light

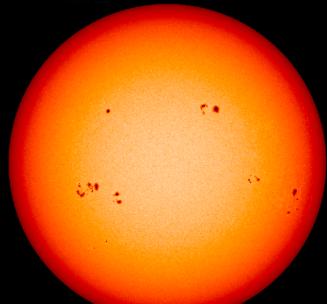


Sunspots

2003

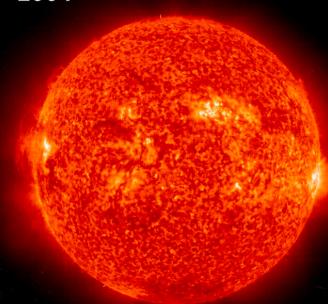


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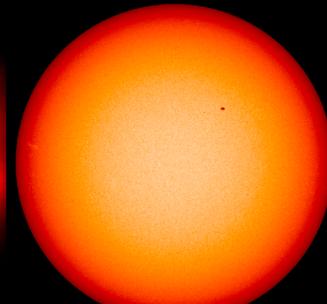


Sunspots

2004

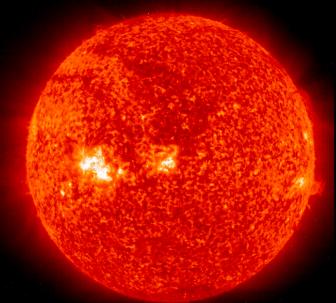


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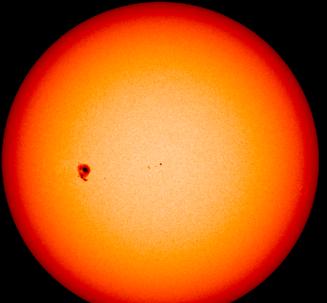


Sunspots

2005

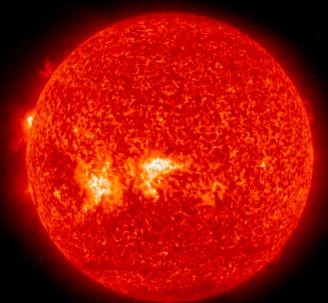


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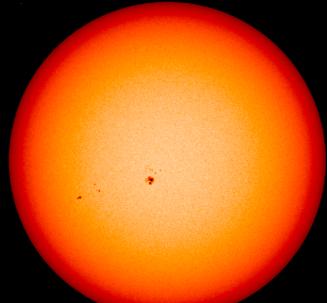


Sunspots

2006

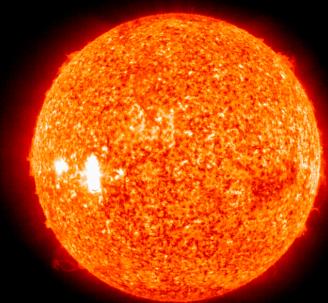


Ultraviolet Light

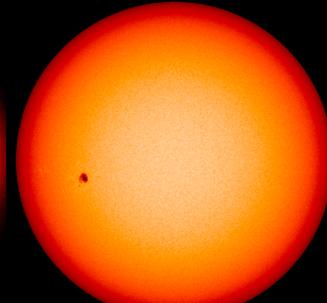


Sunspots

2007



Ultraviolet Light

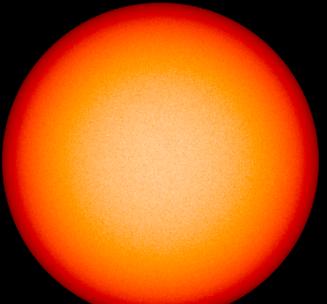


Sunspots

2008

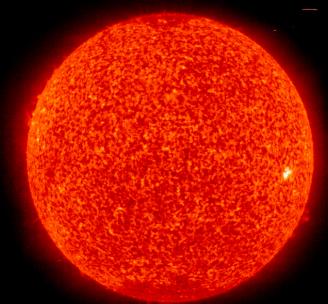


Ultraviolet Light

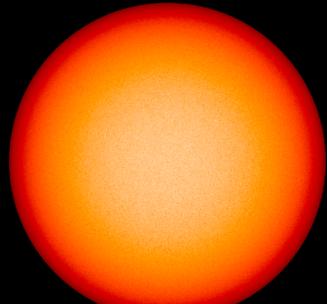


Sunspots

2009

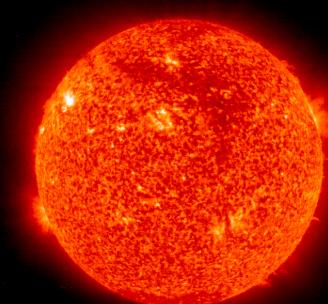


Ultraviolet Light

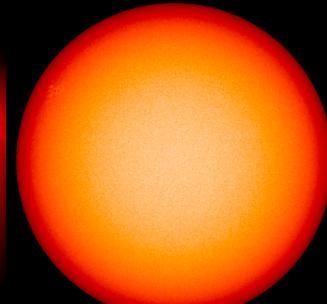


Sunspots

2010



Ultraviolet Light



Sunspots

