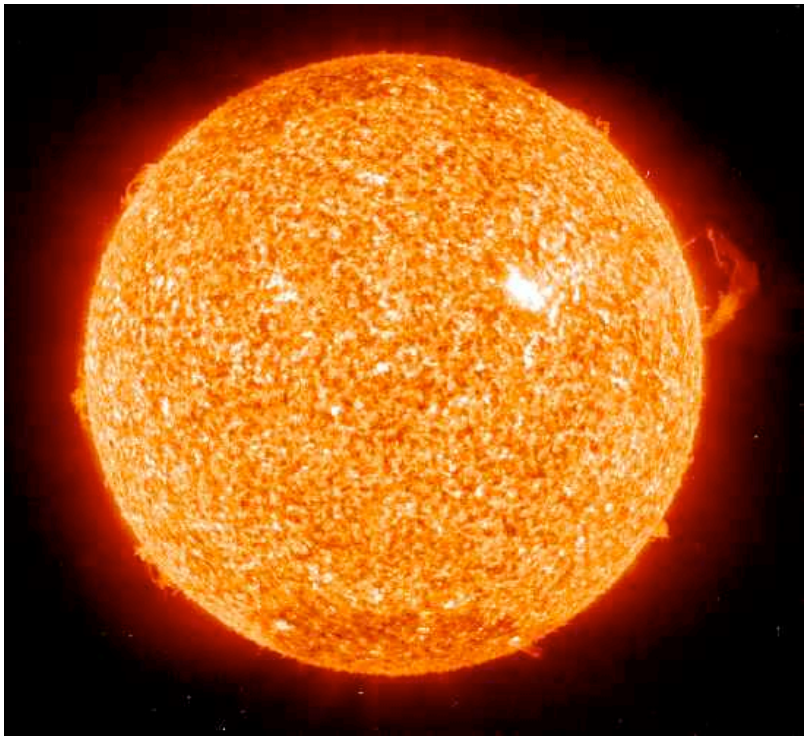
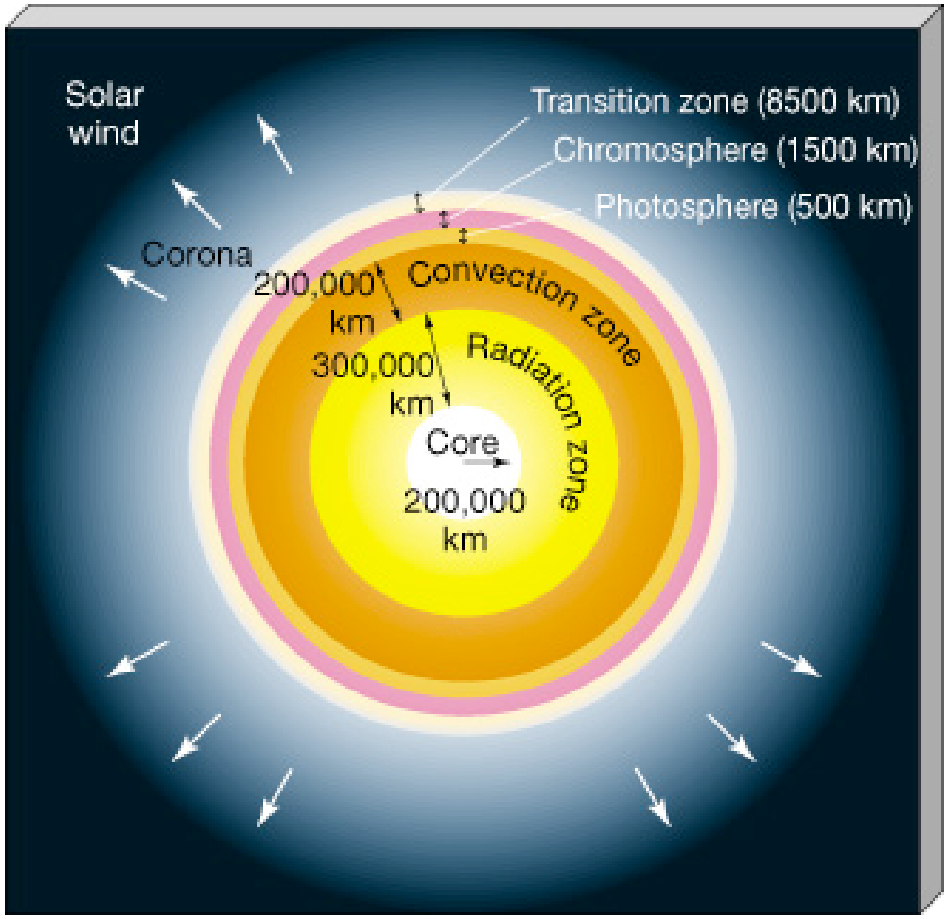
The Sun: Our nearest star



Property	Value
Surface T	5500K
Central T	15×10^6 K
Luminosity	2×10^{33} ergs
Mass	4×10^{33} grams
Lifetime (ms)	10 billion years

Solar Structure



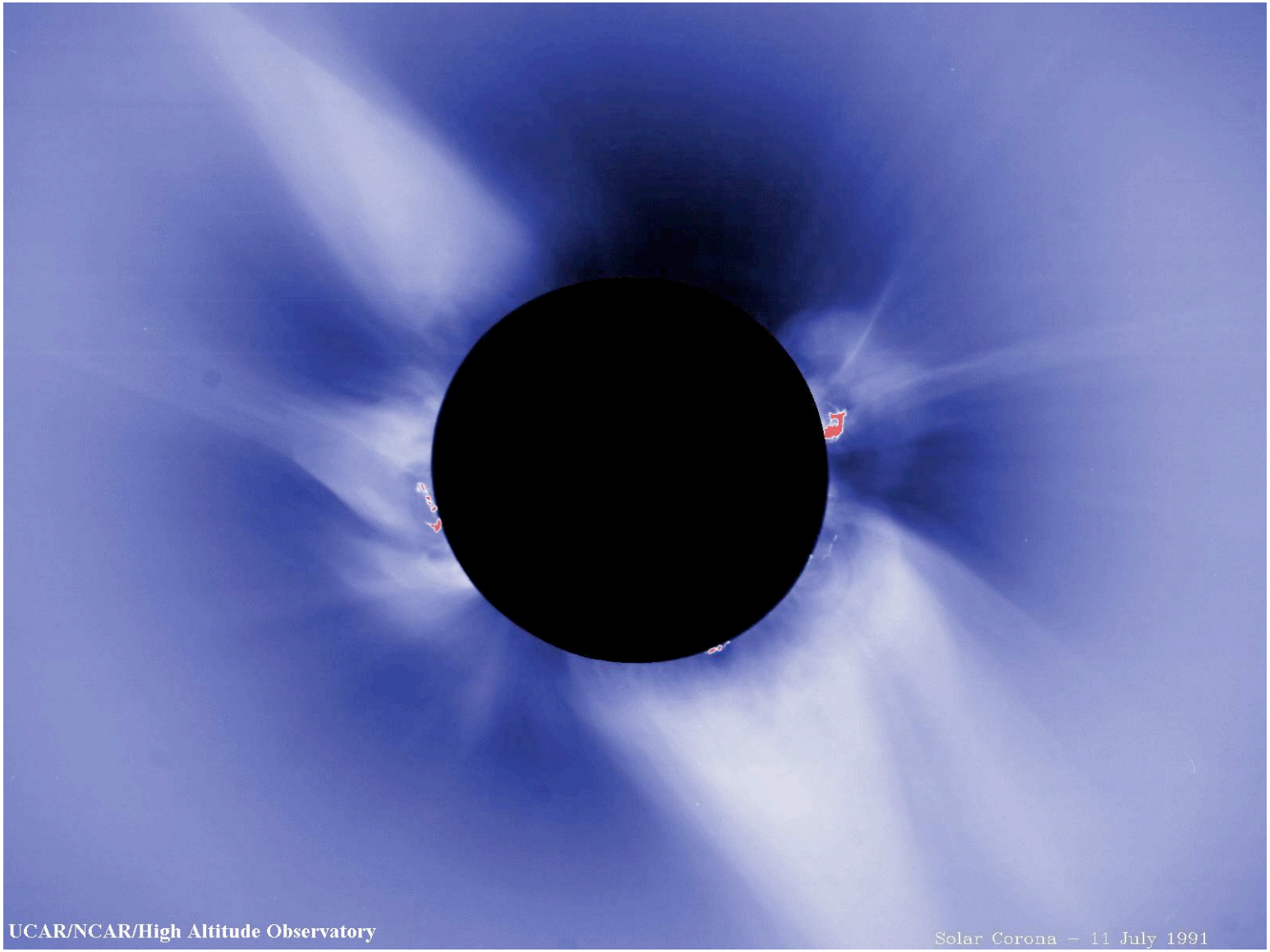
- Build a model and find the central part of the Sun has the right conditions for H fusion to He.
- Energy released in the form of gamma rays in the core is very quickly absorbed then reemitted and absorbed and …
- It takes about 180 thousand years for the energy released in H fusion to leave the surface of the Sun

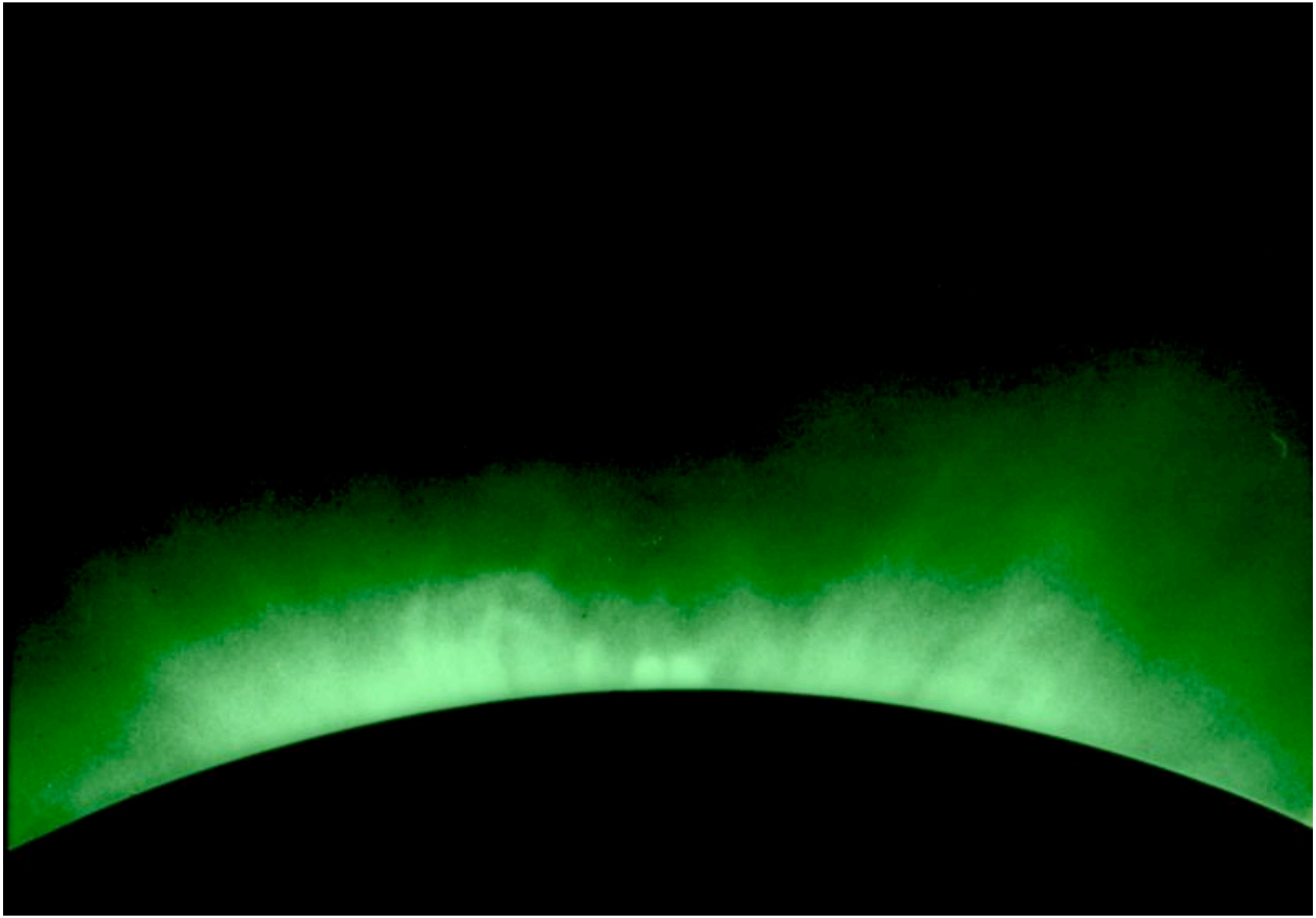
Solar Structure

- Above the core is the Radiative Zone where the photons carry all the energy outward
- Next comes the Convection Zone where the Sun becomes convectively unstable and bulk motions help to carry the energy outward.
- On top of this is the Photosphere -- this is the region where photons from below are last absorbed and the next reemited photons stream off into space.

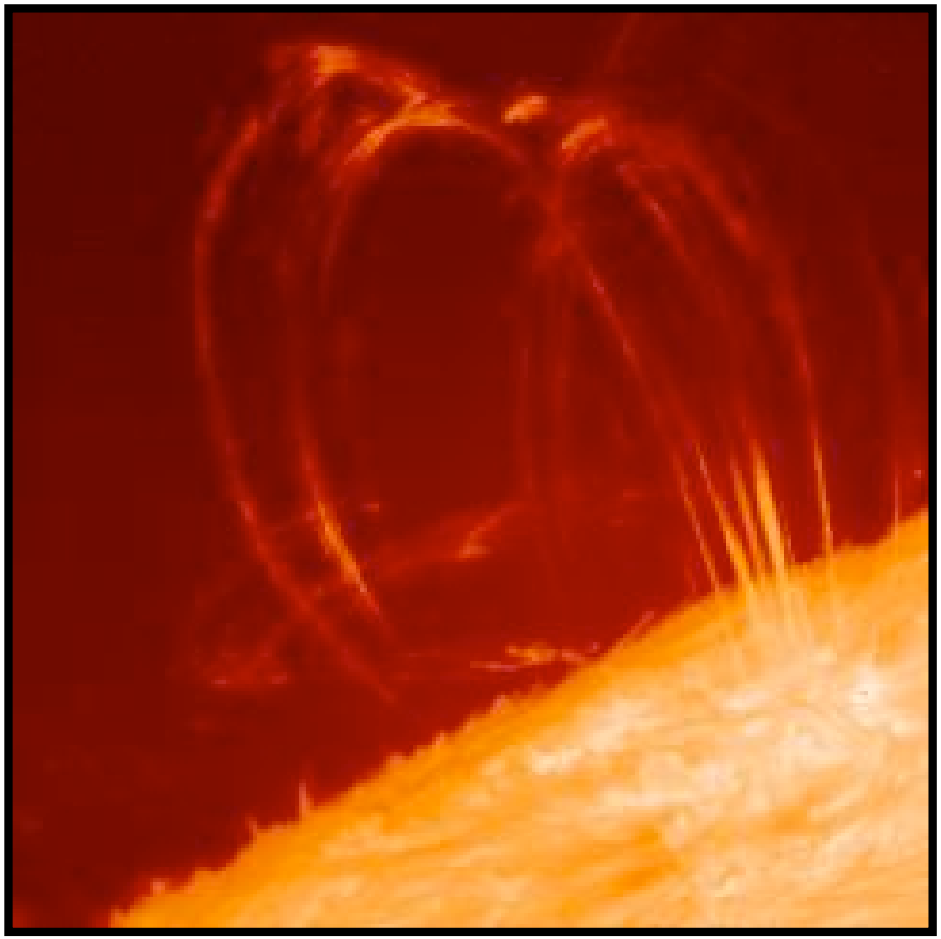
Outer Solar Structure

- The Sun's temperature reaches a minimum in the photosphere, then increases in the chromosphere and increases again into the million K regime in the corona.


UCAR/NCAR/High Altitude Observatory
Solar Corona – 11 July 1991

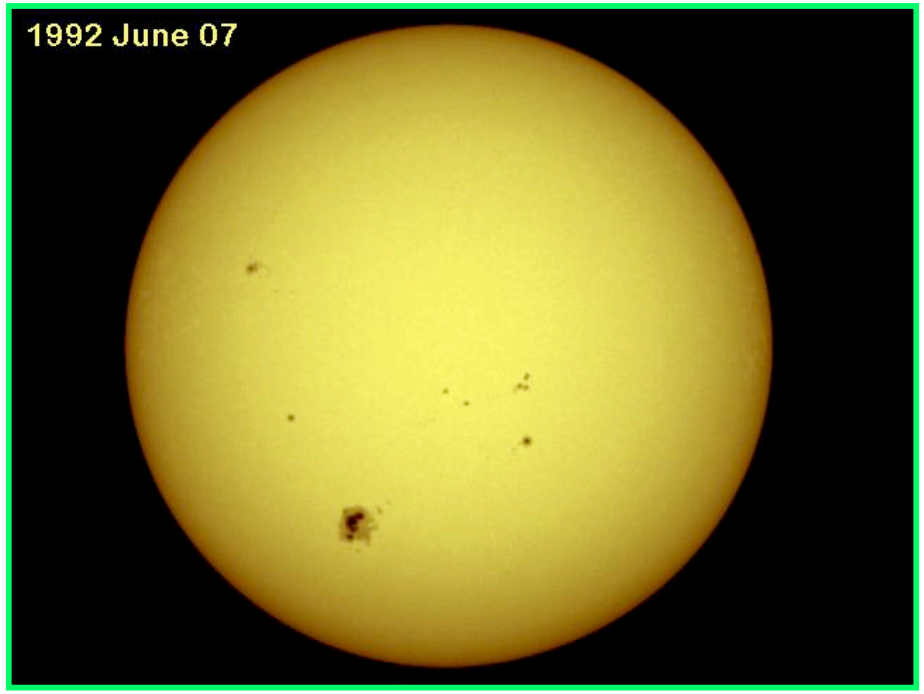


Solar Wind

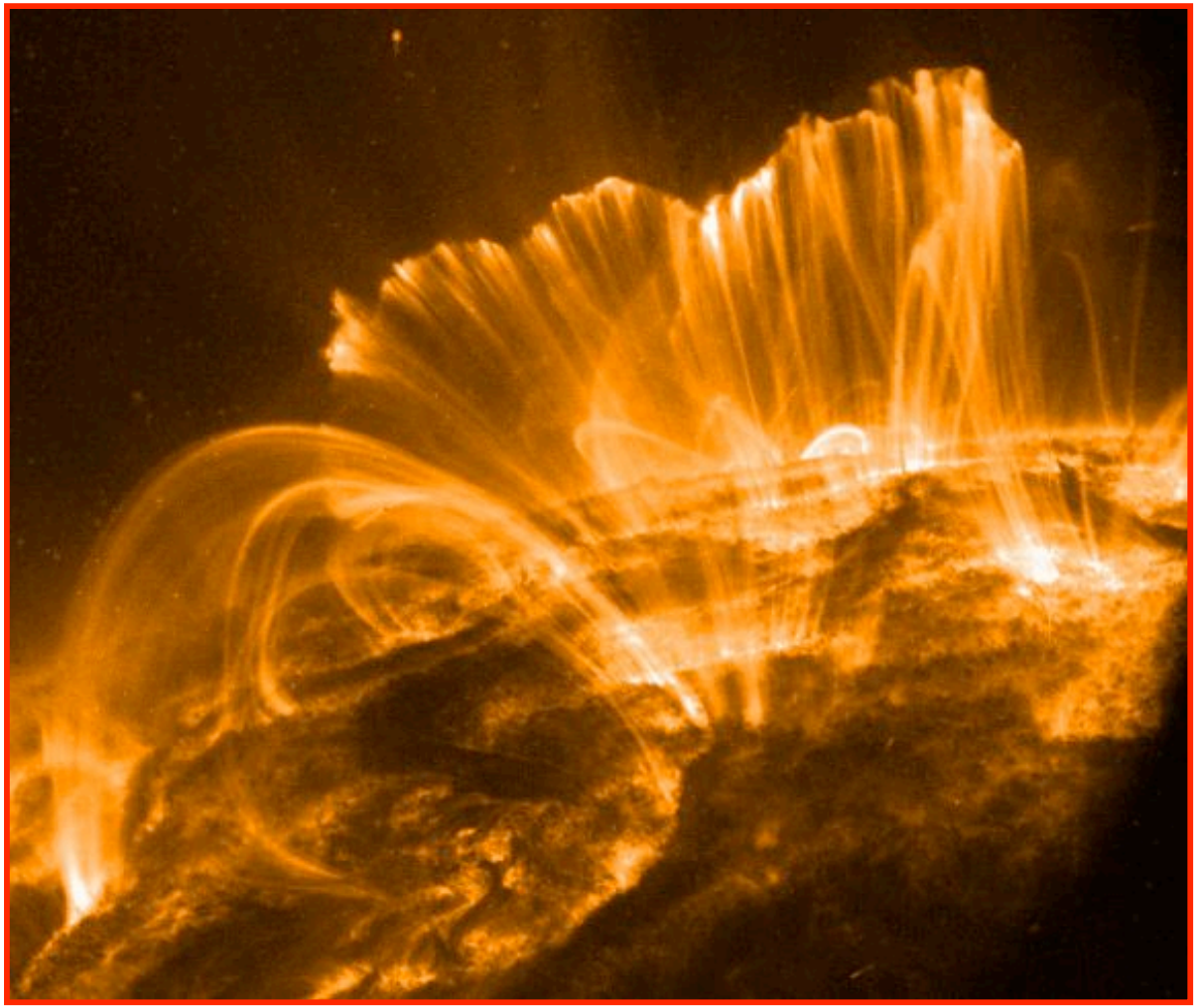


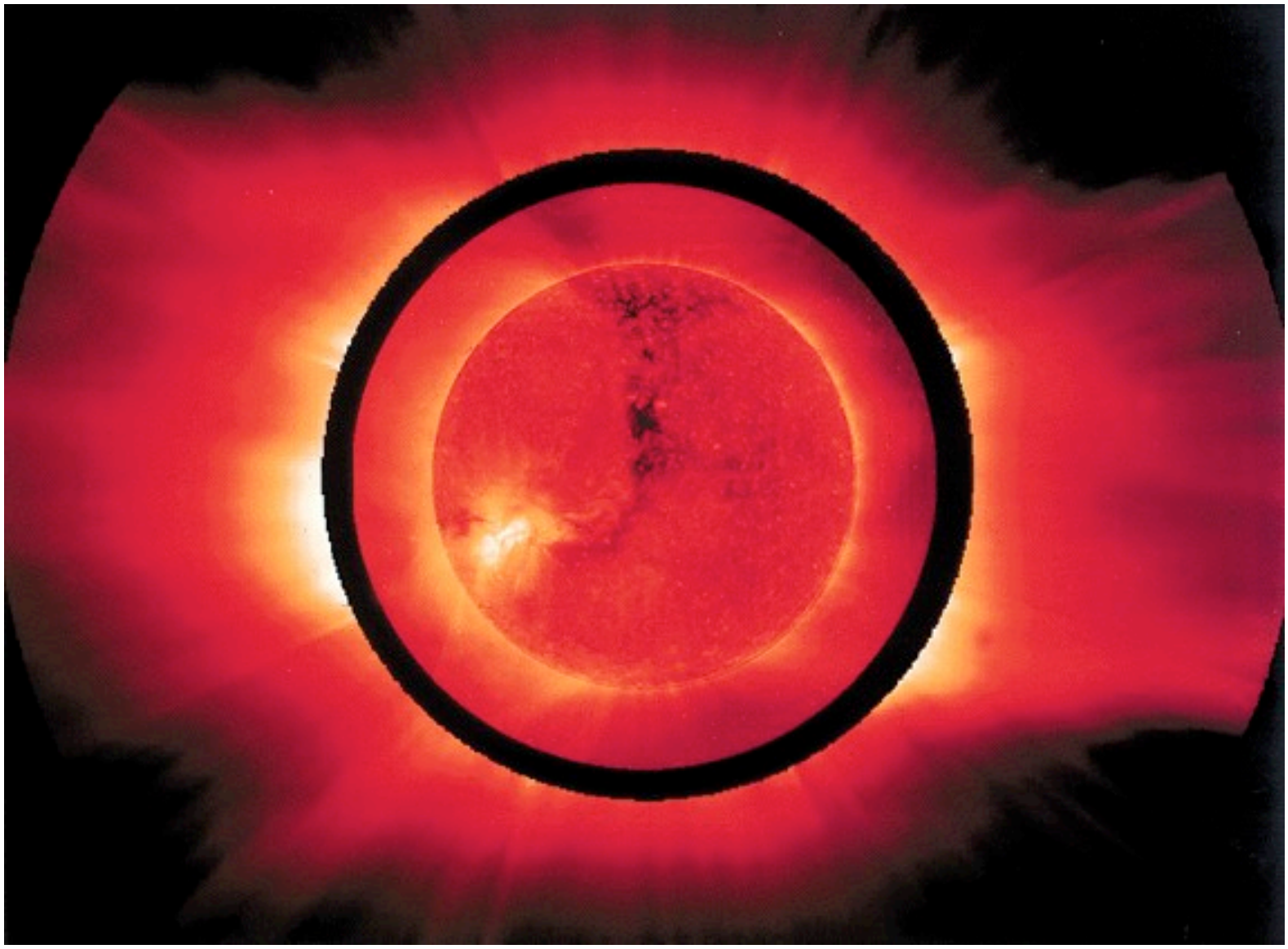
- There is one last solar phenomenon to talk about.
- Hot charged particles (mostly p+ and e-) evaporate from the Sun and stream into the Solar System.
- About 1 million tons/second stream away at 1 million mph.

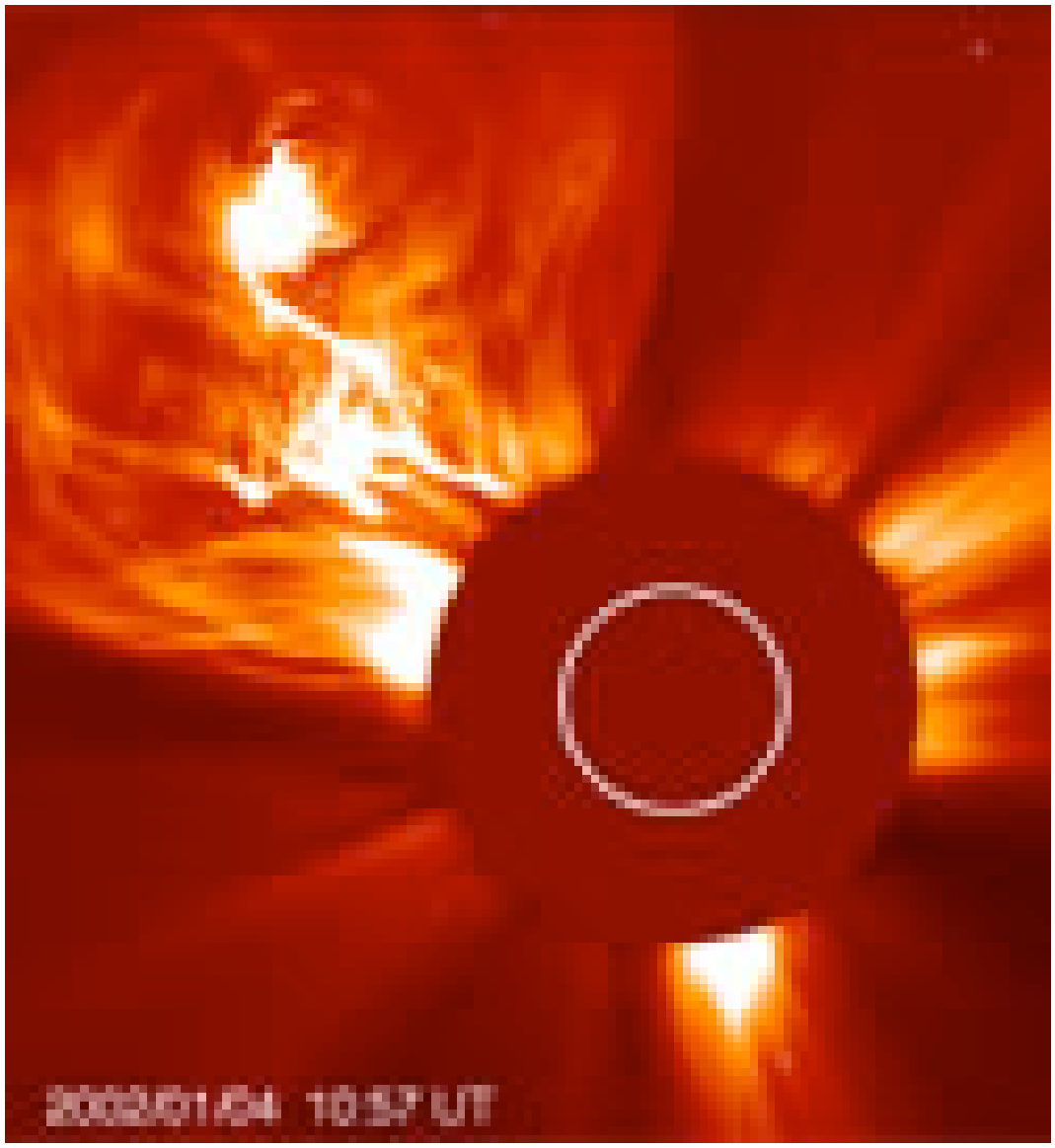
Solar Wind

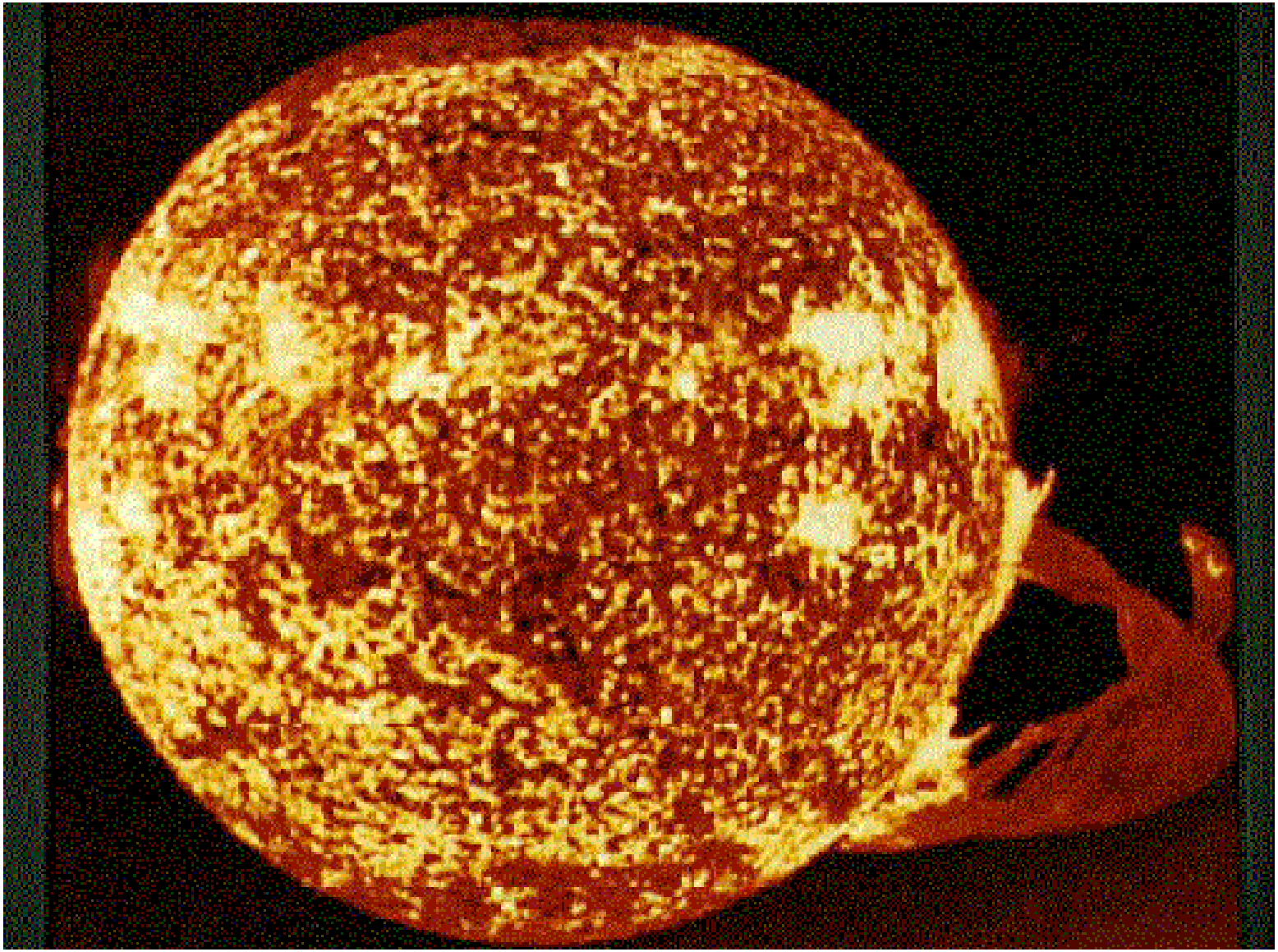


- The solar wind increases in times of solar surface activity (flares) which in turn are correlated with sunspot activity.
- Solar wind `storms' can have powerful effects on the Earth.



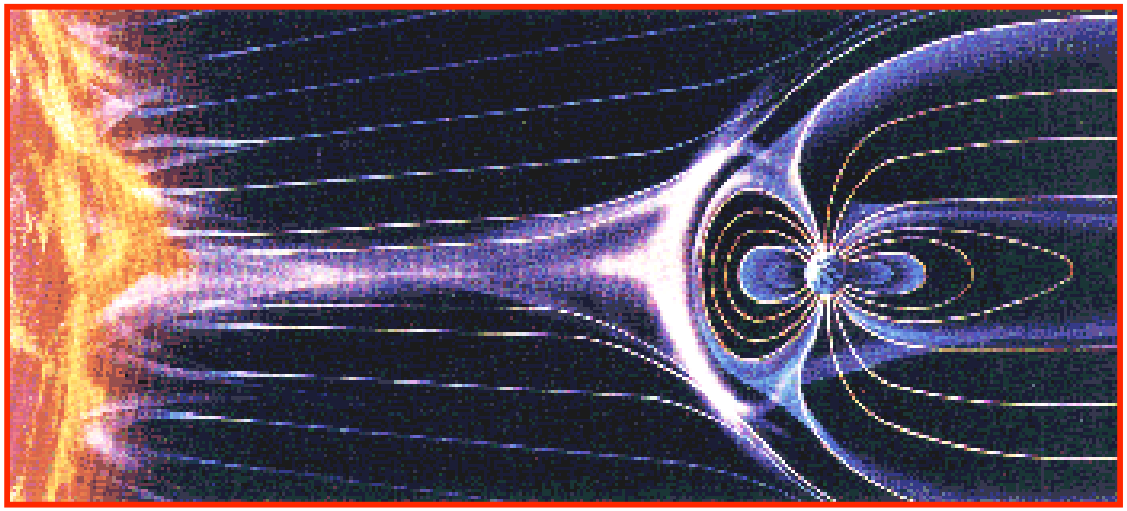



2002/01/04 10:57 UT



Solar Wind

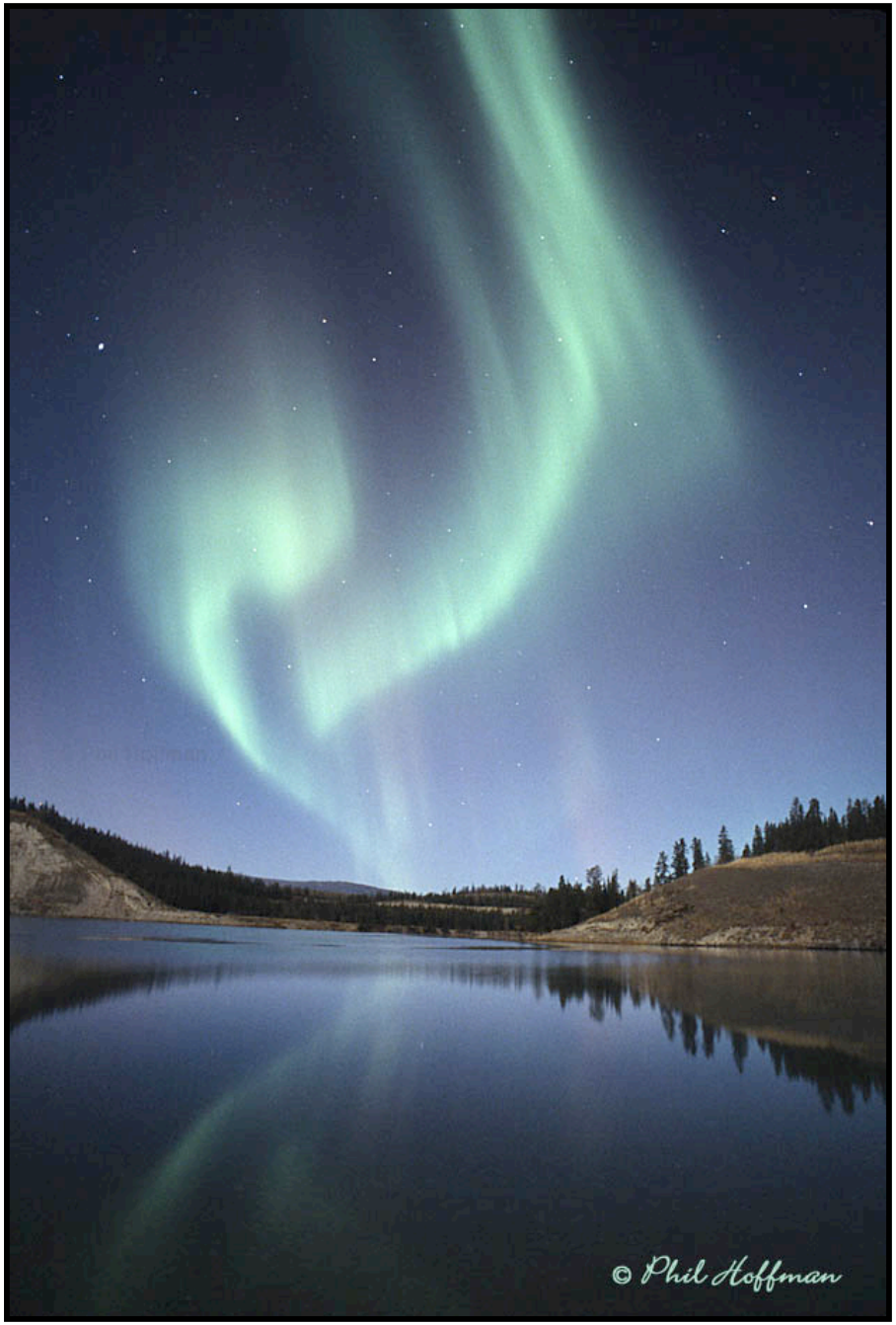
- The Solar wind (very high energy charged particles) would be very dangerous.
- Fortunately, we are protected by the Earth's magnetic field.



Solar Wind

- Moving charged particles spiral along magnetic field lines. The Solar Wind particles get funneled to the Earth's magnetic poles and stored in the `Van Allen Radiation Belts'.
- The solar wind particles crashing into atoms (mostly oxygen) in the upper atmosphere at the poles is the source of the northern and southern lights.


© Sigurður H. Stefnisson


© Phil Hoffman

Solar Wind

- Although biological organisms are pretty well protected from the solar wind, solar storms can have serious consequences.

  (1) The Earth's atmosphere expands

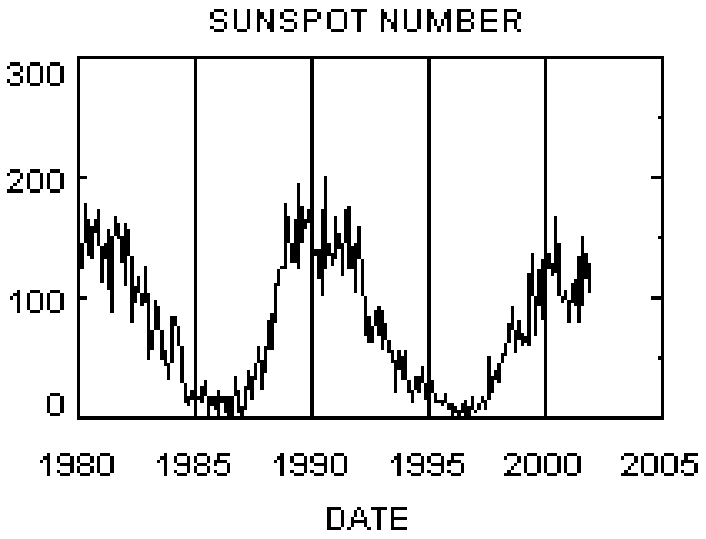
  -Certain types of communications are disrupted

  -Satellites can be dragged out of orbit

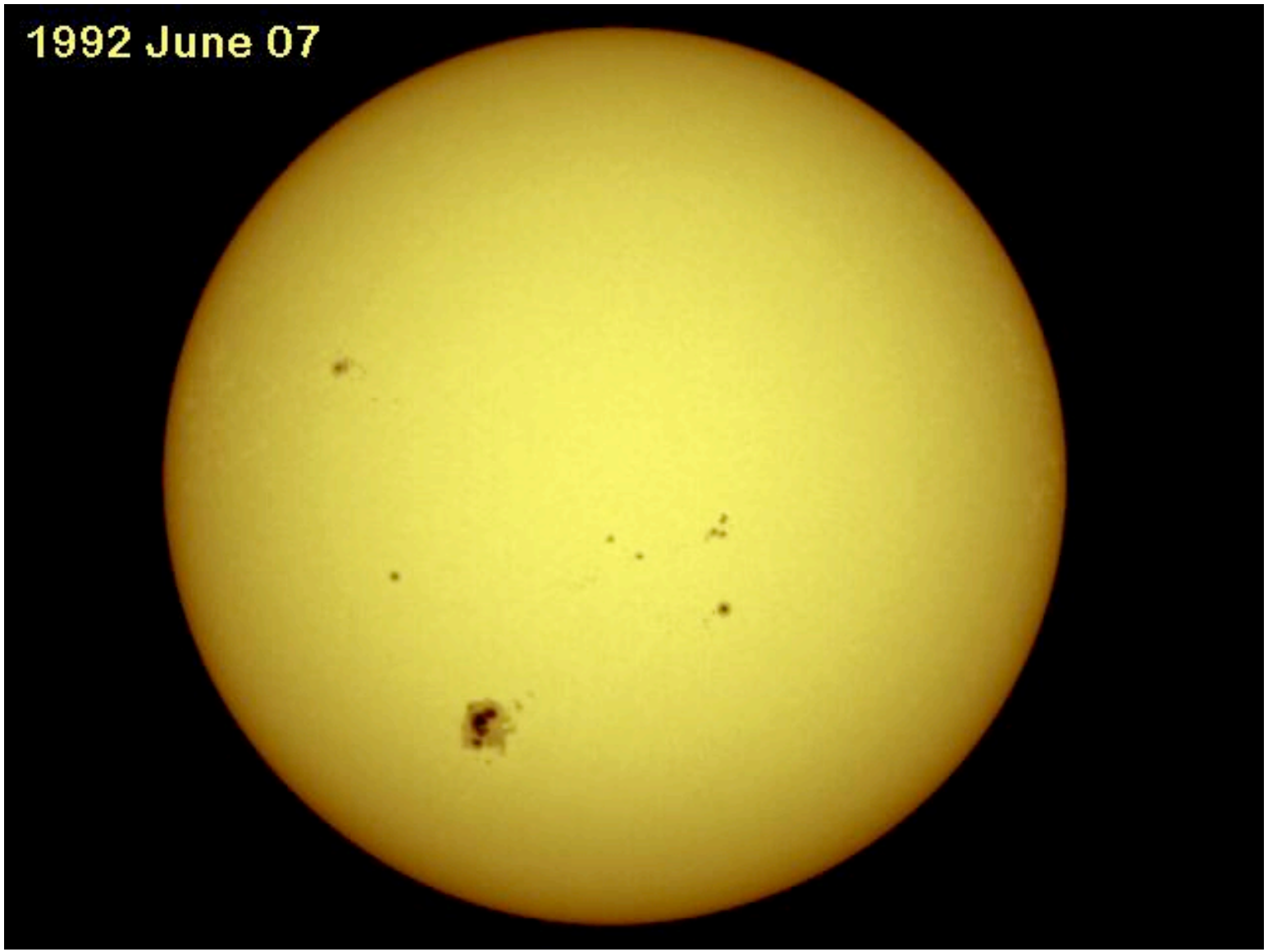
  (2) Large currents can get induced in power grids

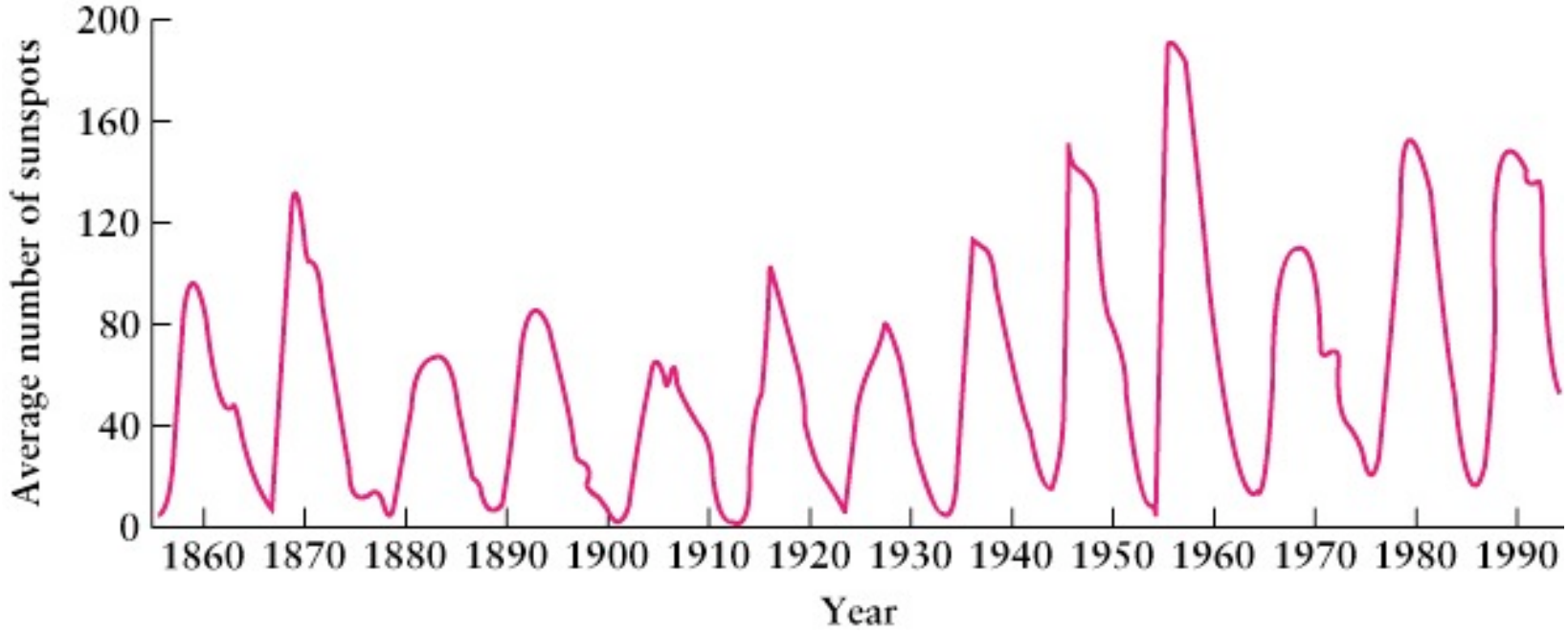
  (3) There is a mysterious connection with solar activity and the Earth's weather.

Solar Activity-Earth



- There is an 11-year cycle of solar activity.
- People have claimed correlations of the solar cycle with droughts, cold weather and the like.
- Maunder Minimum from 1650 - 1700 coincides with the only mini-ice age in recorded history.


1992 June 07

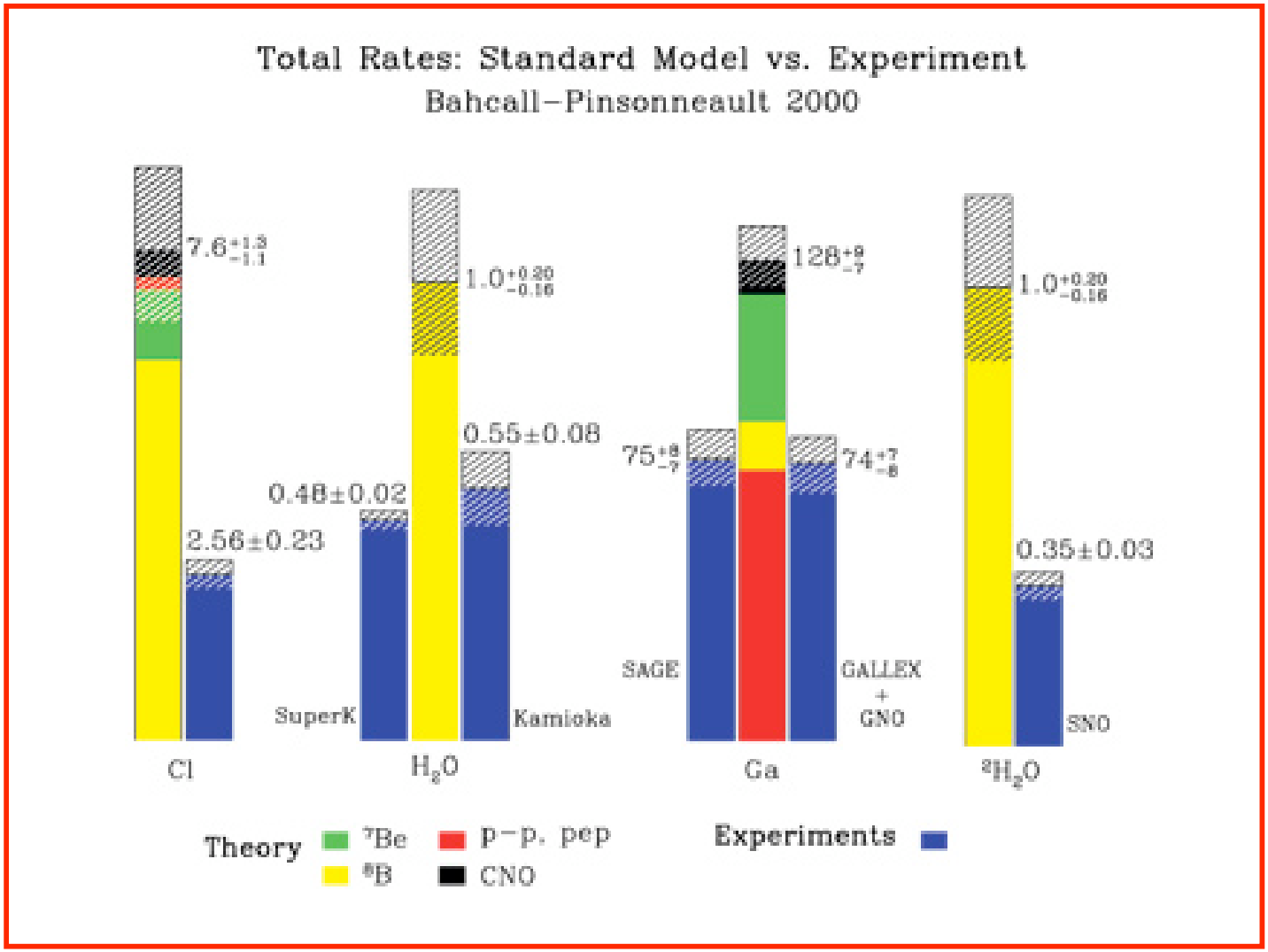

Average number of sunspots
200
160
120
80
40
0
1860 1870 1880 1890 1900 1910 1920 1930 1940 1950 1960 1970 1980 1990
Year

Solar Neutrinos

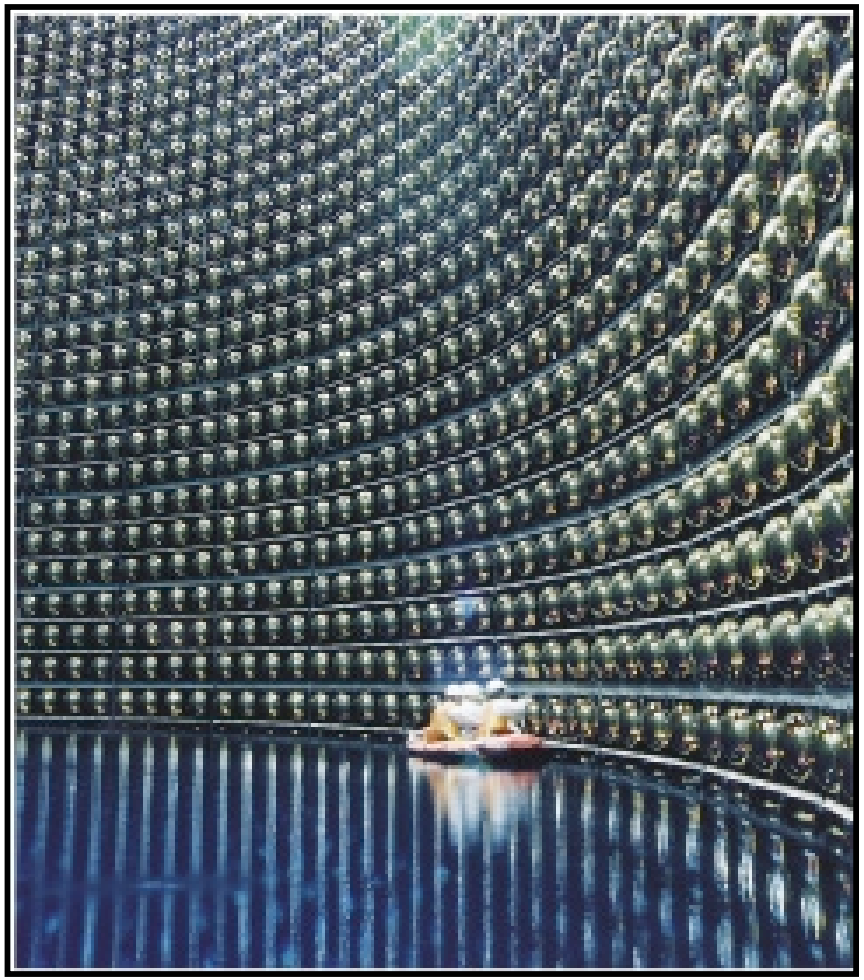
- Final solar issue. Neutrinos.
- Because they zoom straight from the center of the Sun where they are produced, neutrinos give us a picture of the center of the Sun.
- Even though they are hard to catch, seemed worthwhile to attempt to count the Solar neutrinos and verify the solar models.

Solar Neutrinos

- In the 1960s an experiment was set up to count solar neutrinos -- 1 out of every 10^{16} neutrinos that flow through a tank with 100,000 gallons of cleaning fluid turned a chlorine atom into an argon atom. Started counting and they came up short by about a factor of three.
- This was the great Solar Neutrino Problem.


Total Rates: Standard Model vs. Experiment
Bahcall-Pinsonneault 2000
7.6 +1.3 −1.1
2.56±0.23
Cl
0.48±0.02
1.0 +0.20 −0.16
0.55±0.08
SuperK
Kamioka
H2O
75 +8 −7
128 +9 −7
74 +7 −8
SAGE
GALLEX + GNO
Ga
1.0 +0.20 −0.16
0.35±0.03
SNO
2H2O
Theory
7Be
8B
p-p, pep
CNO
Experiments

Solar Neutrino Problem



- Additional experiments started up and the deficiency of solar neutrinos has been verified.
- This caused some consternation about our knowledge of the Sun, but has turned out to be a property of neutrinos and a triumph for astrophysics.

The Main Sequence

- Once the energy source of stars has been identified, it is easy to understand the main sequence in the H-R Diagram.

  (1) More massive stars require higher central temperatures (hydrostatic eqm.)

  (2) The P-P fusion rate and luminosity is proportional to T^4

Therefore, more massive stars will have higher central temperature and higher Luminosity. This is what is seen along the H-R Diagram main sequence.

Theoretical Main Sequence

- When you build careful models and try to quantitatively match the observed main sequence with P-P chain energy as a source it works very well for stars below $2M_o$.
- To explain the upper main sequence other versions of the P-P chain are required (and are well understood).

Philosophical Side Trip

- There is an interesting implication of our understanding of how the Sun and other stars produce energy:

The Universe is changing: H ->He