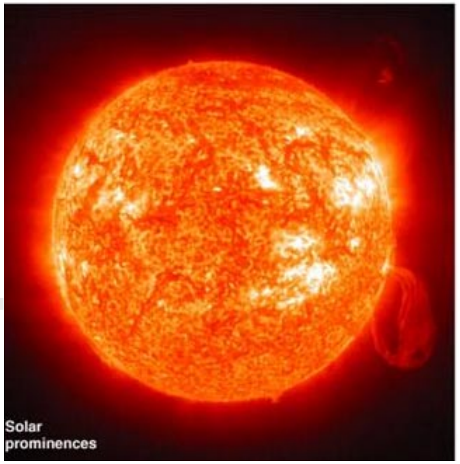
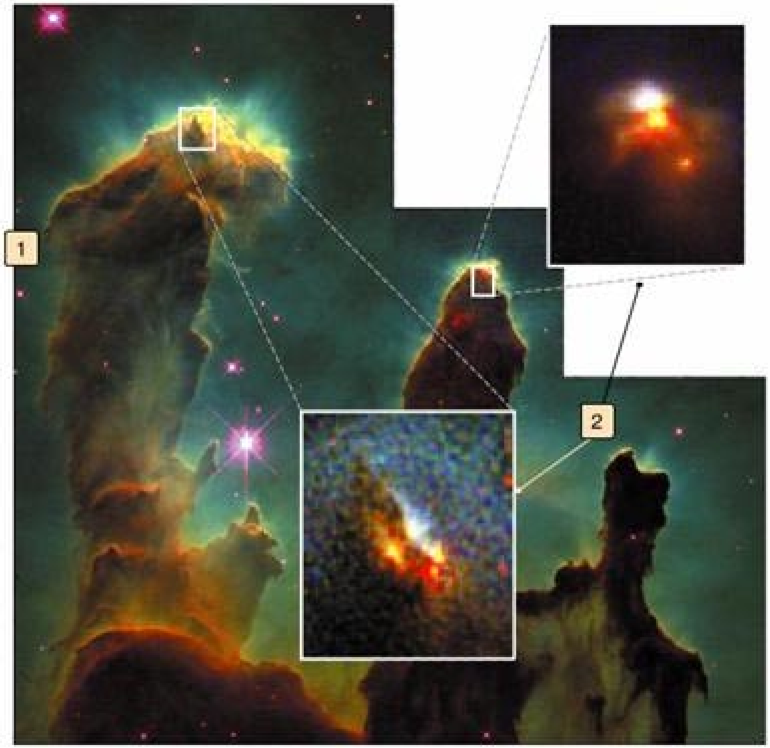
Stellar Formation

October 23, 2002

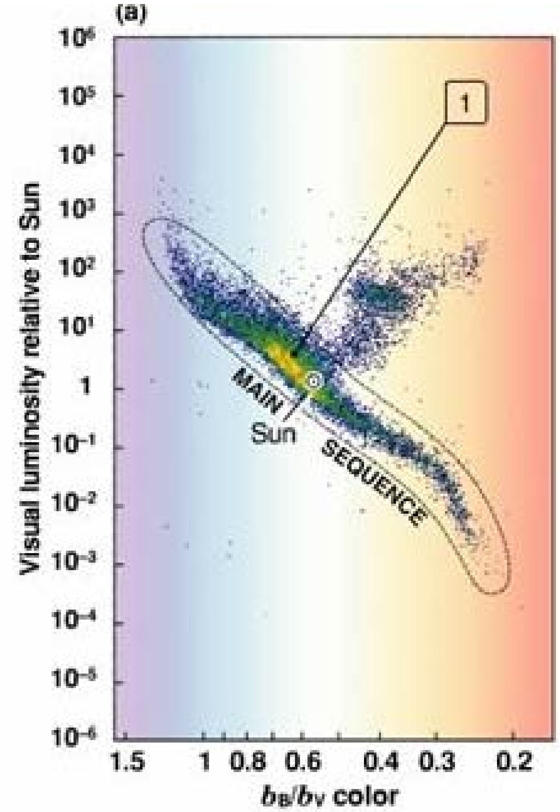


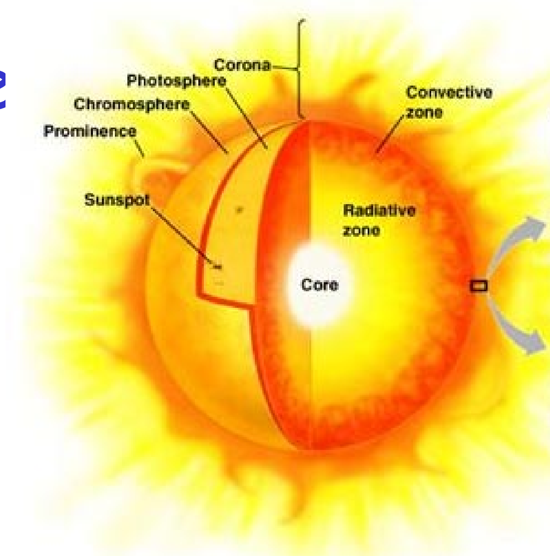
1) Solar Wind/Sunspots
2) Interstellar Medium
3) Protostars
4) A Star is Born



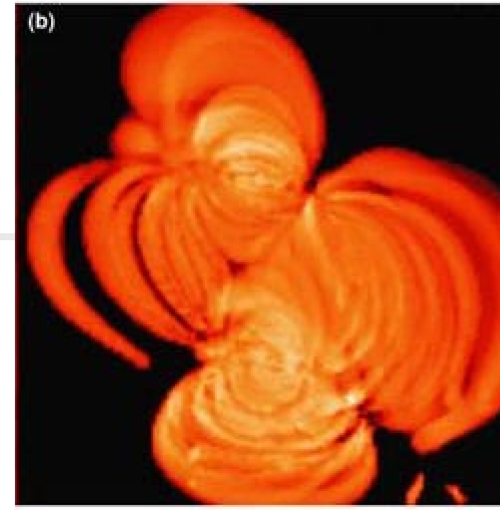
Review

- Stellar compositions
- H-R diagram/main sequence
- Nuclear fusion
- The Sun
  - Interior
  - Surface/atmosphere
  - Neutrinos
  - Magnetic fields



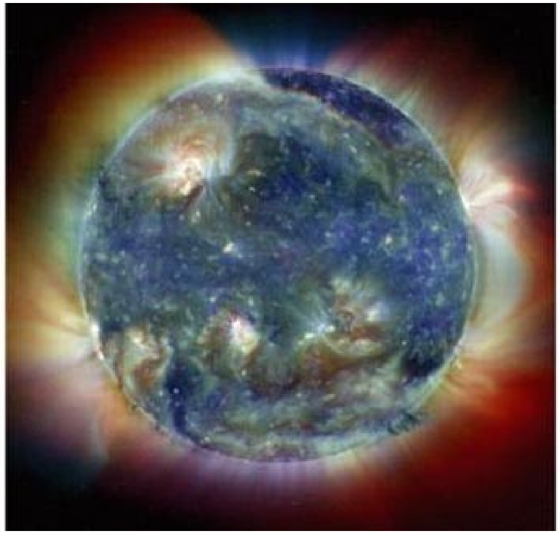


Solar Magnetic Fields

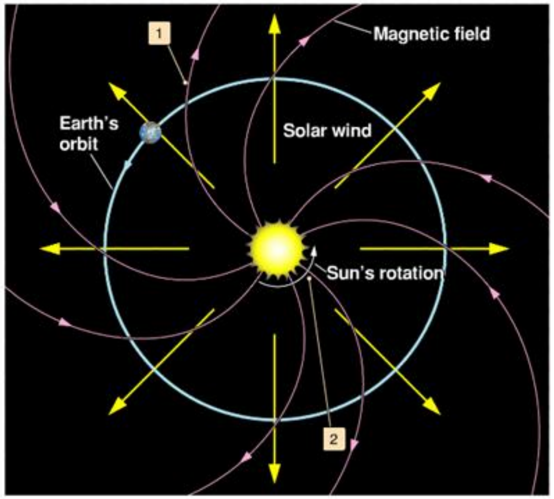


- The Sun's magnetic field is very complicated
- It has magnetic "tubes" through which particles travel
  - like a water hose
  - each end of the tube is connected to the Sun's surface
- Coronal holes
  - where magnetic field points outward and particles escape
- Magnetic field is constantly changing
  - partially due to Sun's rotation
  - occasionally flips direction

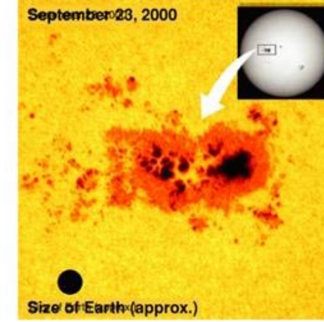
Solar Wind



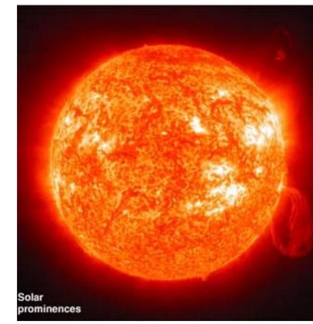
- Particles escape the Sun through coronal holes
  - travel outward from the Sun
  - responsible for comet's tail and for blowing away primary atmospheres of inner planets
  - pushes interstellar dust out of the Solar System
- Solar wind changes as Sun rotates
- Effects Earth
  - satellites
  - Aurora Borealis



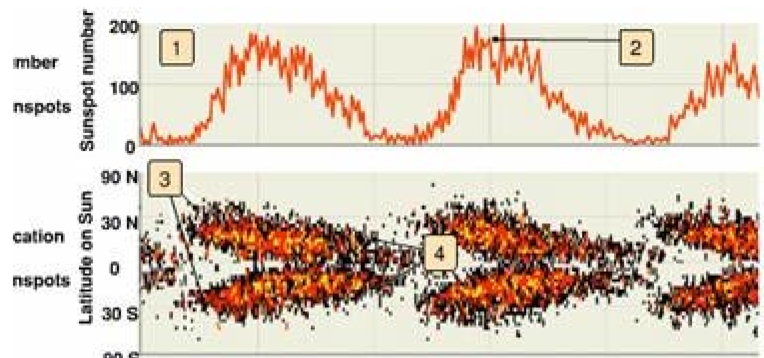
Sunspots



- Sunspots are cooler parts of the solar surface
  - most visible solar "structure"



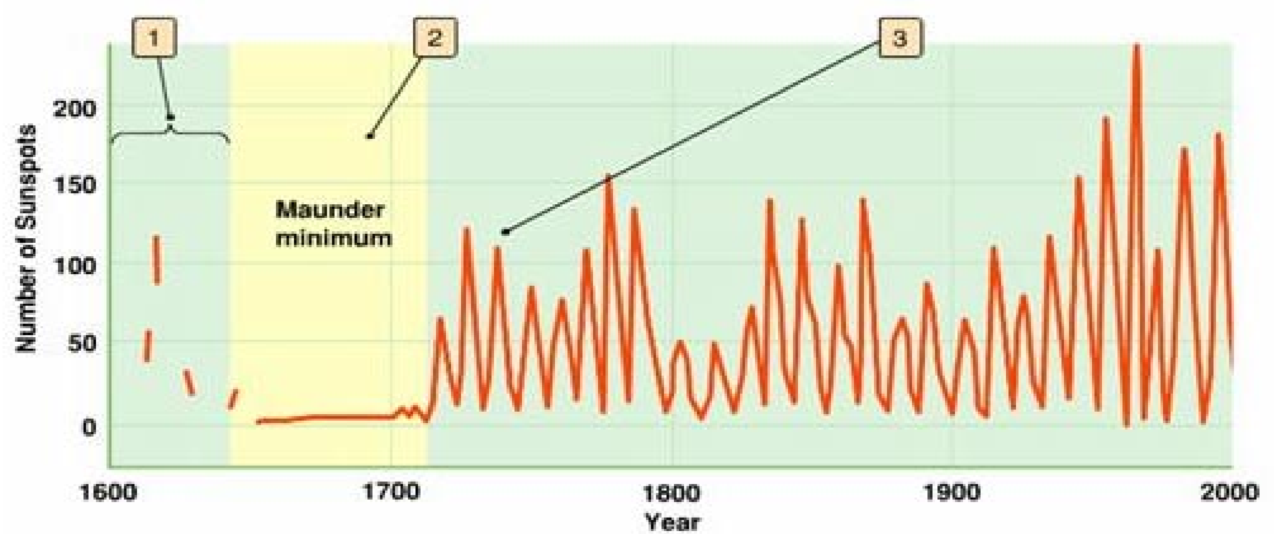
- Caused by magnetic field loops
  - found in pairs
  - shift around with field



- Sunspot cycle
  - Sunspots follow an 11-year period
    - magnetic field changes over 11 years and then flips over

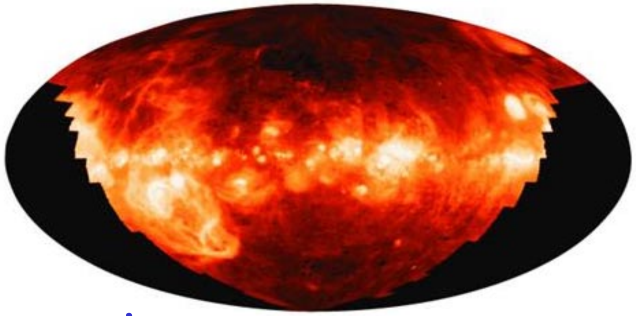
Variations in the Sunspot Cycle

- The sunspot cycle varies
  - sometimes more intense than others
  - some long periods with almost no sunspots
    - Maunder minimum – 1645-1715
    - cooler than normal in Europe

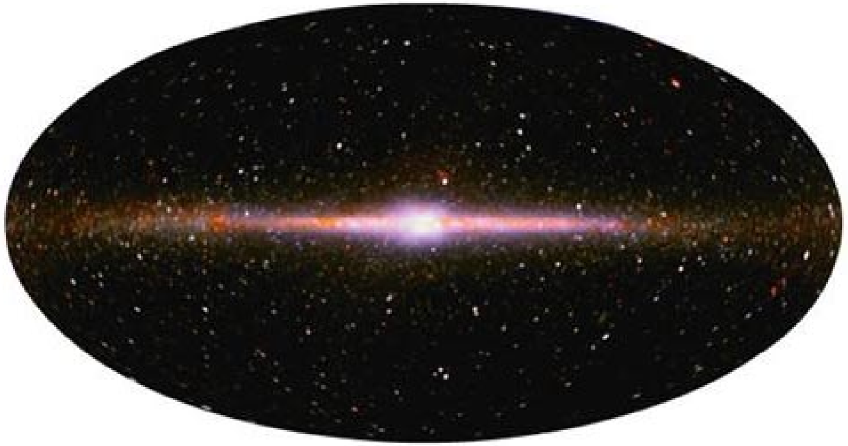


Interstellar Gases/Dust

- Composition
  - 90% hydrogen, 10% helium, 0.1% other
- VERY low density – 1 atom/cm^3
  - air is 2.5×10^{19} molecules/cm^3
- Interstellar dust
  - very small particles of "heavy" materials
- Interstellar clouds
  - large collections of interstellar gas
  - about ½ the interstellar gas occupies 2% of the volume
- Intercloud gas
  - remaining 50% of gas spread over 98% of the Universe



Dust and Light



- Light absorption
  - dust absorbs light
  - efficient at absorbing short wavelength light
  - lets longer wavelengths through
  - light passing through dust becomes "redder"
    - less blue
  - also, atoms and molecules absorb specific wavelengths through excitation
    - create spectral lines
- "glows" in the infrared – blackbody radiation
  - wavelength depends upon temperature
    - far-infrared to x

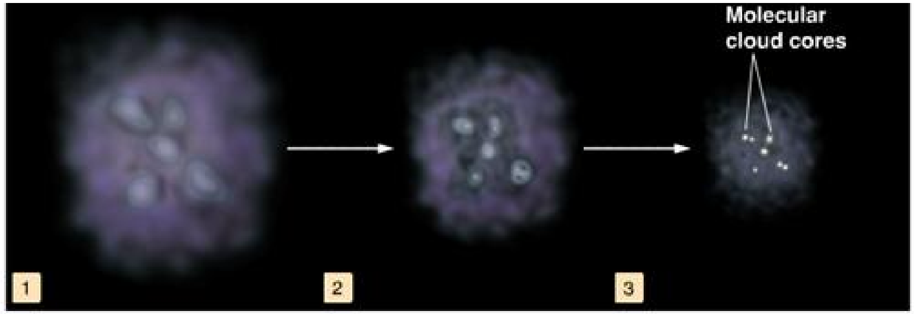
Hot Intercloud Gas

- Some gases are very hot
  - some million Kelvin temperatures
    - we are in a bubble of hot gas
  - most around 8,000 K
- Atoms in warm regions are ionized
- H II regions
  - ionized hydrogen recombines and gives off photons in the hydrogen spectrum
  - ex. “Great Nebula” and 30 Doradus
  - home to formation of hot (O class) stars

Molecular Clouds

- Molecular clouds
  - cooler (~100 K) and denser (100x) than hot interstellar gas
  - surrounding dust absorbs energetic light
  - atoms and molecules can form
- Giant molecular clouds
  - 100s to 1000s of lightyears across
  - 4,000 of them in our Galaxy
- Birthplace of Stars

Cloud Collapse



- Pressure, angular momentum and magnetic fields keep a cloud large
- Gravity wants to pull it in
- In dense molecular clouds gravity eventually wins
  - some areas denser than others
  - cloud cores form around these
- Cloud cores collapse
  - inner region collapses giving up support for outer region
  - outer regions collapse inward
  - form an accretion disk and a protostar! (remember Chapter 5?)

A ProtoStar Shrinks

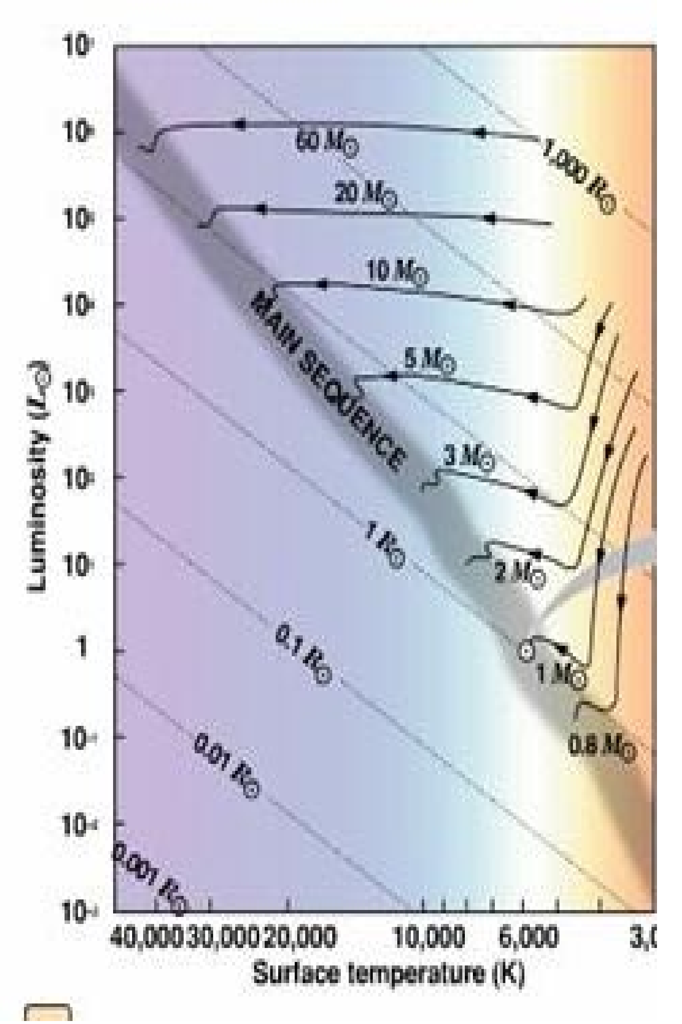
- Pressure and gravity must balance
  - starts off very large (100s x radius of our Sun)
- But the situation is changing
  - additional mass is being pulled in by gravity
  - energy is being radiated away
    - infrared
- These cause the protostar to shrink
- As it shrinks, it gets denser = higher pressure
- As pressure rises, so does temperature
  - more collisions

Protostar Ignition

- When a protostar gets hot enough, fusion begins
  - requires 0.08 solar mass to ignite
- Brown dwarf
  - cloud core with less than 0.08 solar mass
  - does not burn hydrogen
  - emits light from heat
    - blackbody radiation
    - gravitational energy converted to heat
  - between gas giant and star

Getting on the Main Sequence

- The H-R diagram tells us what happens to a star
- The mass determines how the star behaves
  - More mass, faster ignition
    - ~10 million years as a protostar for the Sun
  - but we don't fully understand what determines the mass of a star



The Pleiades

- Stars often form in clusters
  - from same molecular cloud
  - stars in clusters were formed at the same time with same material
- Great for comparisons
- The Pleiades
  - the Seven Daughters
  - in the constellation Taurus
  - visible in the northern hemisphere in the winter

Stellar Adulthood

- A star spends a lot of time on the main sequence
- Main sequence stars burn hydrogen
  - keep burning until it runs out of hydrogen
- Stellar lifetime depends upon
  - amount of hydrogen
    - bigger star means more hydrogen
  - rate of burning
    - bigger star is hotter $\Rightarrow$hydrogen burns faster
- Larger stars have shorter lifetimes
  - rate of burning wins over amount of hydrogen

Calculating Lifetime

$$\tau_{MS} = 1\text{x}10^{10}\text{ (years) x } \frac{\text{amount of hydrogen (solar mass)}}{\text{rate of hydrogen burning (luminosity)}}$$

- τ_{MS} = star lifetime in years
- amount of fuel is listing in solar masses (M)
- rate of burning is measured from star's luminosity (L)

- Our Sun has M = 1, L = 1
  - $\tau_{Sun} = 1.0 \times 10^{10}$ years (10 billion years)
- O5 star
  - mass is 60 times our Sun
  - luminosity is 794,000 times our Sun

$$\tau_{MS} = 1x10^{10}\,\frac{60}{794{,}000} = 8\text{x}10^{5}\text{ years}$$