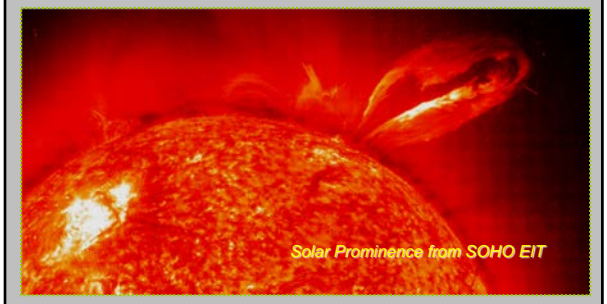
ASTR 1040: Stars & Galaxies



Prof. Juri Toomre TAs: Ryan Horton, Loren Matilsky

Lecture 6 Thur 13 Sept 2018

zeus.colorado.edu/astr1040-toomre

Topics for Today and Tues

- Next Tues Sept 18: go to Fiske Planetarium
- Start with how Sun is put together
- Why is a star spherical, and does not collapse? (Gravitational equilibrium)
- Why does it shine, and must it shine? What is the energy source? (Fusion of H to He)
- Complete detail read Chap 14 (Our Star)
- Read S4.1, S4.2 (quarks, leptons, ..)
- New Homework #3 (The Sun) passed out, HW #2 to be turned in

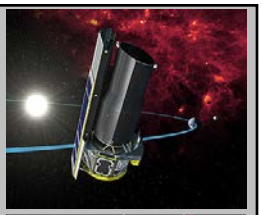
"Nonvisible" Light – X-ray, UV, IR, Radio

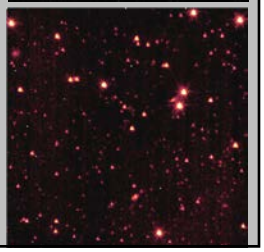
- Most light is invisible to human eye
- Special detectors can record such light
- Digital images built using false-color coding

Chandra X-ray image of center of our Milky Way Galaxy

SPITZER Infrared Telescope

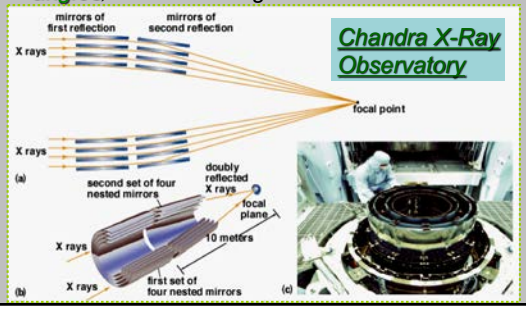
- Launched August 2003
- Trails behind Earth to get away from Earth's thermal spectrum
- 0.85m aperture , T ~ 5.5 K
- Cooled with liquid helium, had 2-5 years worth, now used up (warmer phase)



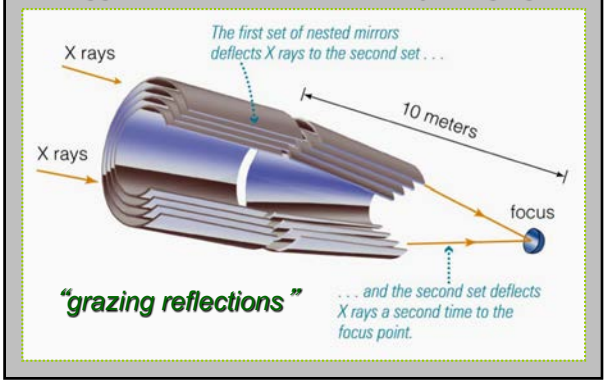


X-Ray Telescopes – do it their own way!

- X-ray photons can pass right through a mirror
- Such photons can only be reflected at shallow angles, like "skimming stones" off water surface

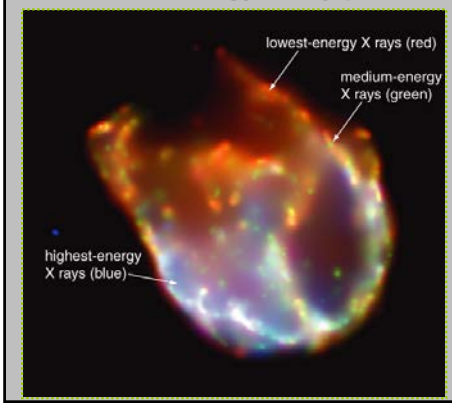


Bigger view of Chandra's X-ray Imaging



Chandra X-ray Observatory (at L_2 Lagrangian)

Multi-energy X-ray picture



Chandra: Supernova Remnant SNR: N132D

Clicker

What does the technique of interferometry allow?

A. … to make astronomical observations without interference from light pollution
B. … the same telescope to make images with both radio waves and visible light
C. ... to determine the chemical composition of stars
D. … multiple telescopes to obtain the angular resolution better than the individual telescopes
E. … multiple telescopes to obtain a total light-collecting area larger than the individual telescope

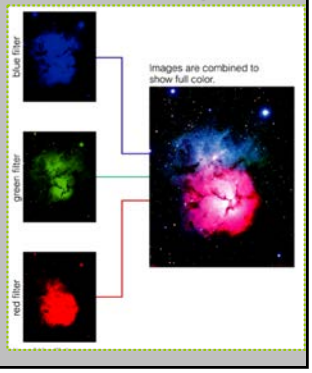
Instruments in the Focal Plane

How astronomers use light collected by a telescope:

1. **Imaging**
   - use camera to take pictures (images)
   - photometry: measure amount and color (with filters) of light from object
2. **Spectroscopy**
   - use spectrograph to separate light in detail into its different wavelengths (colors)
3. **Timing**
   - measure how amount of light changes with time (sometimes in a fraction of a second)

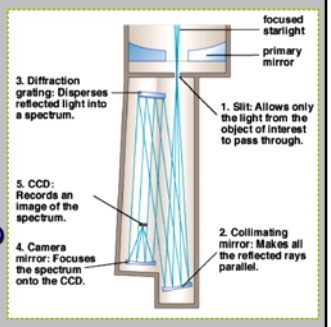
Imaging (Digital with CCDs)

- Filters are placed in front of camera to allow only certain colors to be imaged
- Single color images are superimposed to form "true color" images.

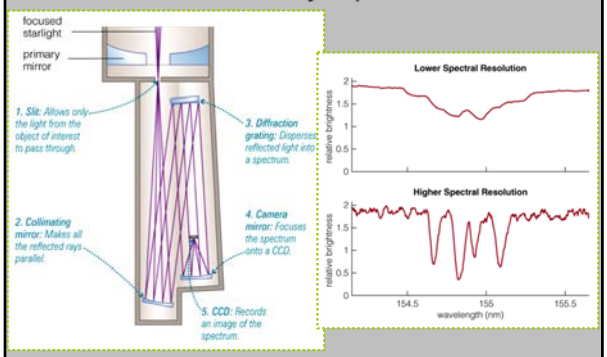


Spectroscopy – analyzing the light

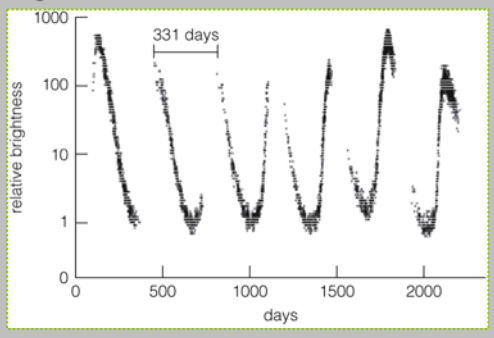
- Spectrograph reflects light off a grating: finely ruled, smooth surface
- Light (by interference) disperses into colors
- This spectrum is recorded by digital CCD detector



Spectral resolution is vital but also "costly in photons"



Light curves: Studying changes with time



Variable star MIRA: period ~331 days

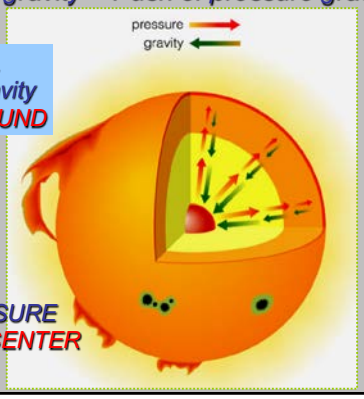
Next to Our Nearest Star Chap 14

Big Qs about the Sun (and any star)

- Why is a star ROUND ?
- What keeps a star from collapsing inward ?
- What keeps it shining ?
- Why does it rotate and have varying magnetic fields ?

Pull of gravity = Push of pressure gradient

SPHERICAL nature of gravity makes it ROUND

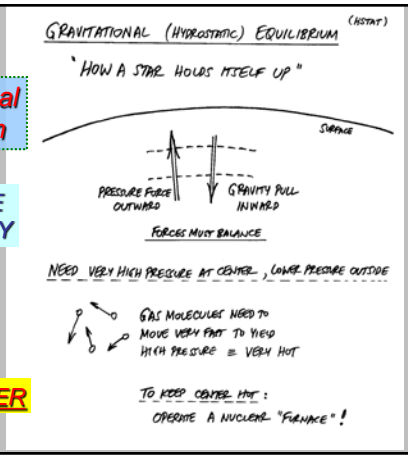


High PRESSURE needed at CENTER

Gravitational equilibrium

PRESSURE vs GRAVITY

HOT CENTER



How to get high central pressure?

In gases, plasmas, "equation of state" is roughly

PRESSURE = DENSITY x TEMPERATURE

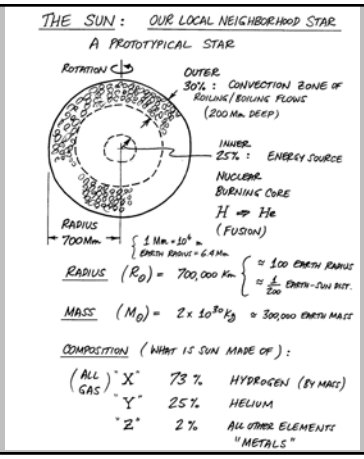
1. Making the CENTER HOT yields high pressure that keeps star from collapsing
2. If really hot, NUCLEAR BURNING can supply the energy that always leaks away from hot places

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

OVERVIEW of the Sun

Sun is round, rotates, burns H to He

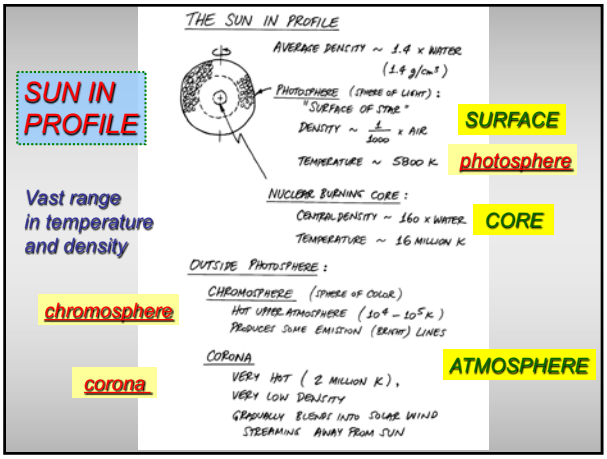


SUN IN PROFILE

Vast range in temperature and density

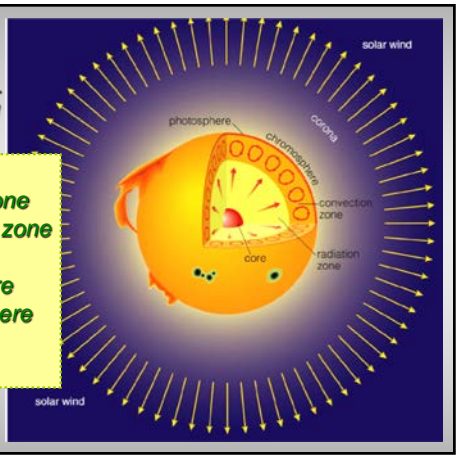
chromosphere

corona



Big System View of Sun

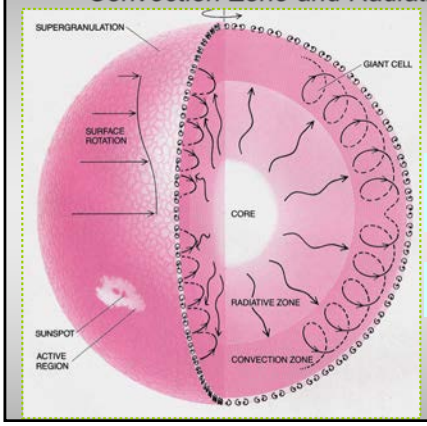
core
radiative zone
convection zone
- - - - -
photosphere
chromosphere
corona
solar wind



Sun is a big ball of "plasma"

- Hydrogen and helium are ionized by the high temperature throughout most of star
- Such electrically-conducting GAS is called a PLASMA
- Movement of plasma has currents flowing, builds magnetic fields and electric fields

Convection Zone and Radiative Interior

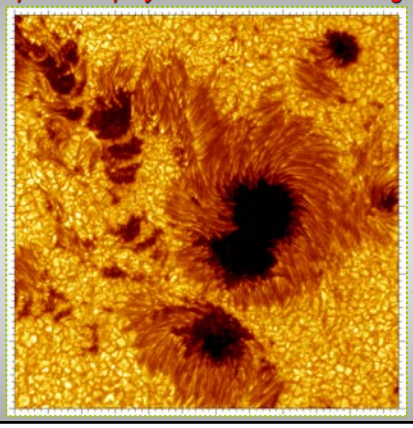


Just below the photosphere:

Deep shell (30%) of very turbulent convection

Drives strong differential rotation

Complex Interplay of Convection and Magnetism

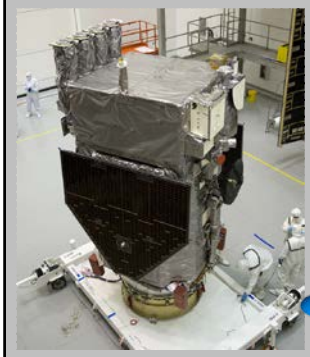


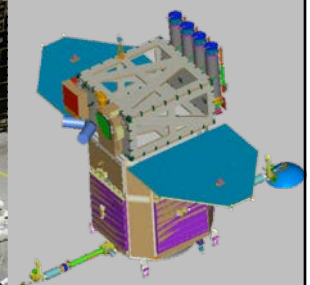
1m Swedish Solar Telescope

1 Mm spacing on ticks

Solar Dynamics Observatory (SDO)

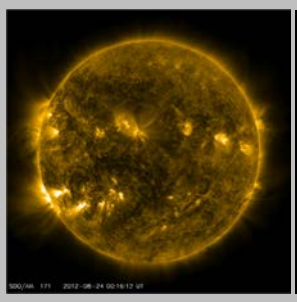
MDI offspring: Helioseismic & Magnetic Imager (HMI)

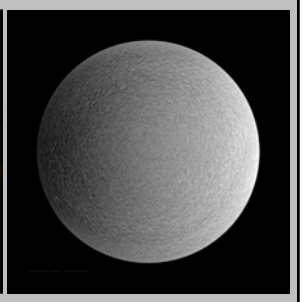




Launched Feb 2010
(4096x4096)

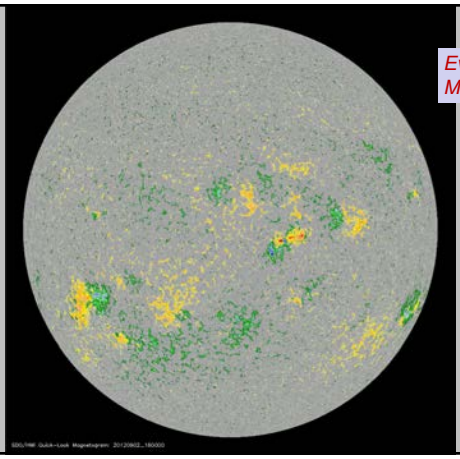
EUV and Visible Images





AIA 171 Å
(Low Corona ~ 6×10^5 K)

HMI Dopplergrams
(Photosphere ~ 5000 K)

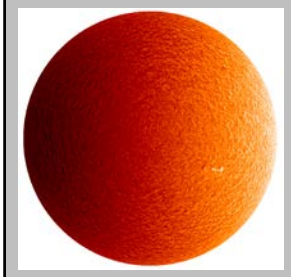


Evolving Magnetism

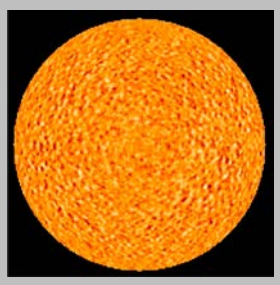
The largest optical telescopes are designed to have

- *A.* high magnification, large collecting area, and high angular resolution
- *B.* high magnification, large collecting area, and low angular resolution
- *C.* low magnification, large collecting area, and low angular resolution
- *D.* large collecting area and high angular resolution - the magnification is of secondary importance
- *E.* large collecting area and low angular resolution - the magnification is of secondary importance
- *(high angular resolution = small angle)*

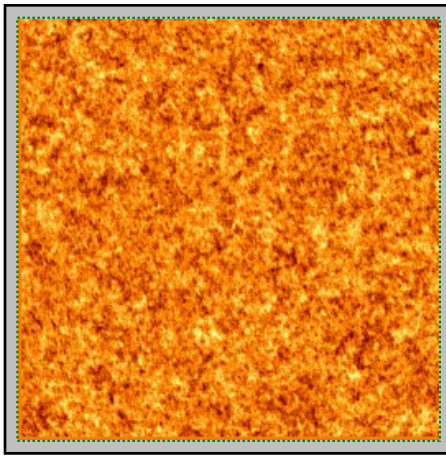
Dopplergrams



Dopplergram of the Sun



Dopplergram sequence with Rotation removed



Radial Velocity
from Michelson Doppler Imager

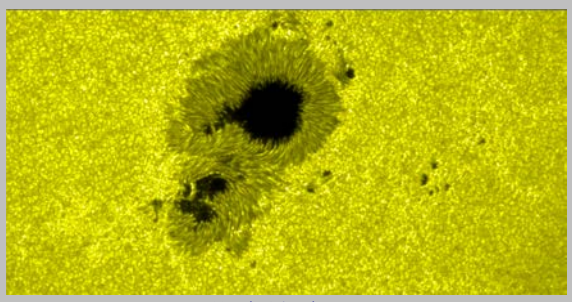
Close-up view

Doppler: ~1000 m/s rms

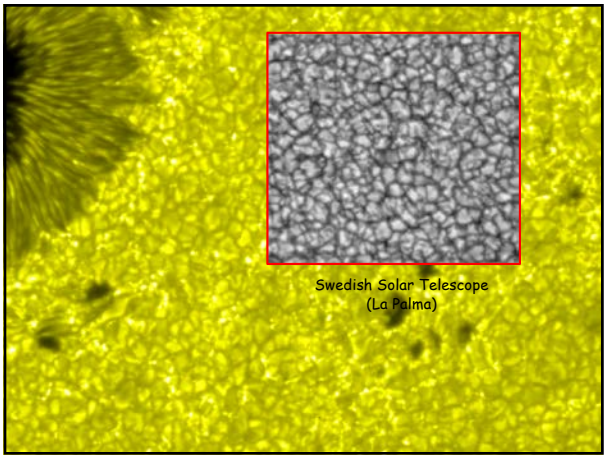
~ 20° across

Excitation of Acoustic Waves

Solar convection in the form of granulation drives broad range of acoustic (sound) waves



Hinode G-band image



Swedish Solar Telescope (La Palma)

UV view of solar magnetism

SOHO EIT 195 A