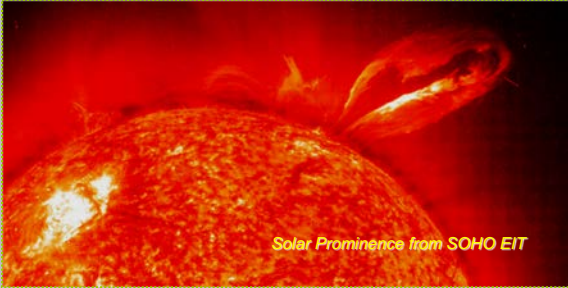


ASTR 1040: Stars & Galaxies



Solar Prominence from SOHO EIT

Prof. Juri Toomre TAs: Max Weiner, Loren Matilsky
Lecture 6 Thur 30 Jan 2020
zeus.colorado.edu/astr1040-toomre

- ### Topics for Today (pre-show)
- 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, HW #1 returned graded
 - Observatory Night #1 tonight, but forecast dubious

Today's NY Times



The Sun's Charming Face
A close-up of the sun's surface, captured by the most detailed view yet, revealing a face of "sunspots" each about the size of Texas. Page A12.

IN RUSH TO ACQUIT, G.O.P. BRUSHES OFF BOLTON'S ACCOUNT

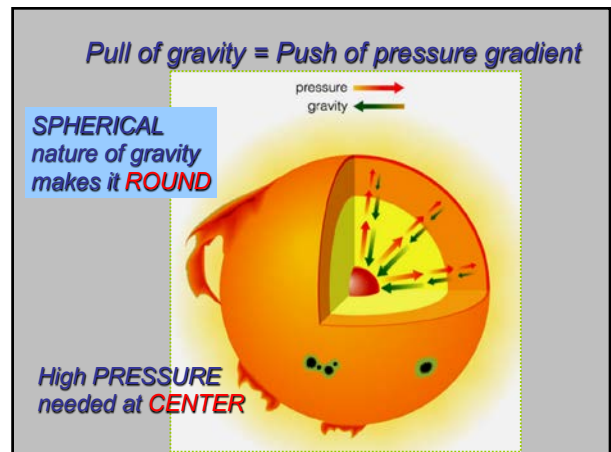
Fear of Flood of Donor Linings Up Votes to Block Witnesses

The New York Times, January 30, 2020

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** ?



Gravitational equilibrium

PRESSURE vs GRAVITY

HOT CENTER

GRAVITATIONAL (HYDROSTATIC) EQUILIBRIUM (15/24)

"HOW A STAR HOLDS ITSELF UP"

NEED VERY HIGH PRESSURE AT CENTER, LOWER PRESSURE OUTSIDE

GAS MOLECULES NEED TO MOVE VERY FAST TO YIELD HIGH PRESSURE = VERY HOT

TO KEEP CENTER HOT: OPERATE A NUCLEAR "FURNACE"!

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

THE SUN: OUR LOCAL NEIGHBORHOOD STAR
A PROTOTYPICAL STAR

OUTER: 30% : CONVECTION ZONE OF ROLLING/BULBING FLOWS (200Mm DEEP)

INNER: 25% : ENERGY SOURCE NUCLEAR BURNING CORE H → He (FUSION)

RADIUS = 700Mm { 1 Mm = 10⁶ = 1000Mm }
 EARTH RADIUS = 6.4Mm
 RADIUS (R₀) = 700,000 Km { ≈ 100 EARTH RADIUS }
 ≈ 1/200 EARTH-SUN DIST.

MASS (M₀) = 2 × 10³⁰ Kg ≈ 300,000 EARTH MASS

COMPOSITION (WHAT IS SUN MADE OF):

(ALL GAS)	"X"	73%	HYDROGEN (BY MASS)
	"Y"	25%	HELIUM
	"Z"	2%	ALL OTHER ELEMENTS "METALS"

SUN IN PROFILE

Vast range in temperature and density

chromosphere

corona

photosphere

CORE

ATMOSPHERE

THE SUN IN PROFILE

AVERAGE DENSITY ~ 1.4 x WATER (1.4 g/cm³)

PHOTOSPHERE (SPHERE OF LIGHT): "SURFACE OF STAR"
 DENSITY ~ 1/1000 x AIR
 TEMPERATURE ~ 5800 K

NUCLEAR BURNING CORE:
 CENTRAL DENSITY ~ 160 x WATER
 TEMPERATURE ~ 16 MILLION K

OUTSIDE PHOTOSPHERE:

CHROMOSPHERE (SPHERE OF COLOR)
 HOT UPPER ATMOSPHERE (10⁴ - 10⁵ K)
 PRODUCE SOME EMISSION (BROAD) LINES

CORONA
 VERY HOT (2 MILLION K), VERY LOW DENSITY
 GRADUALLY ELEVATE INTO SOLAR WIND STREAMING AWAY FROM SUN

Big System View of Sun

core

radiative zone

convection zone

photosphere

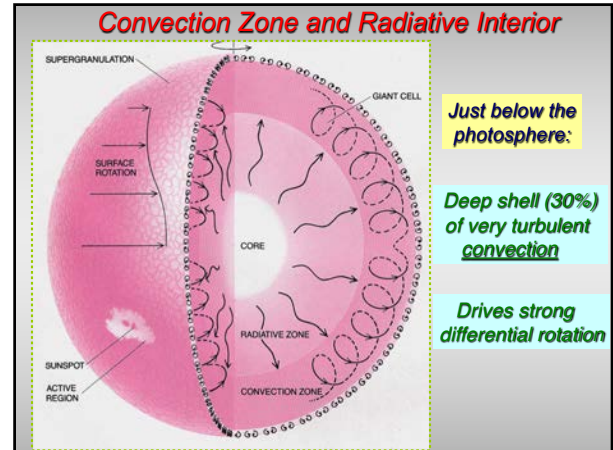
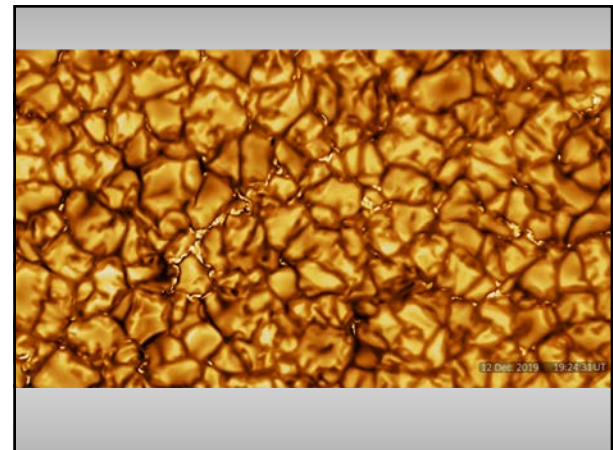
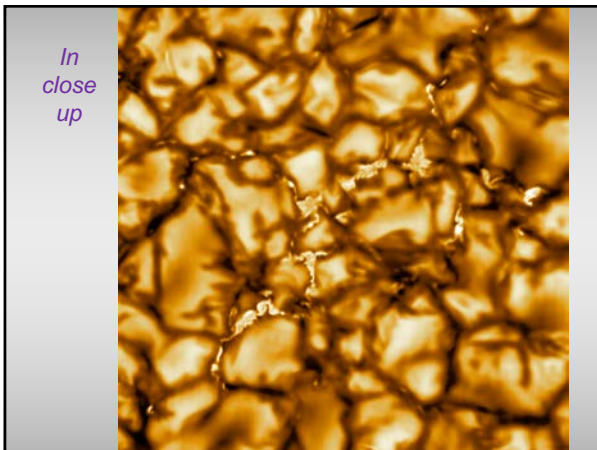
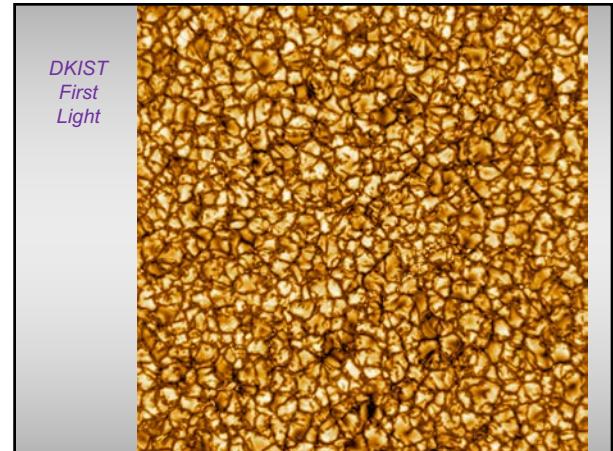
chromosphere

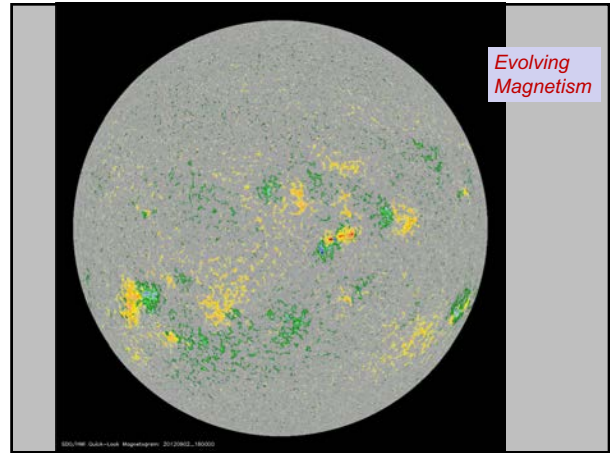
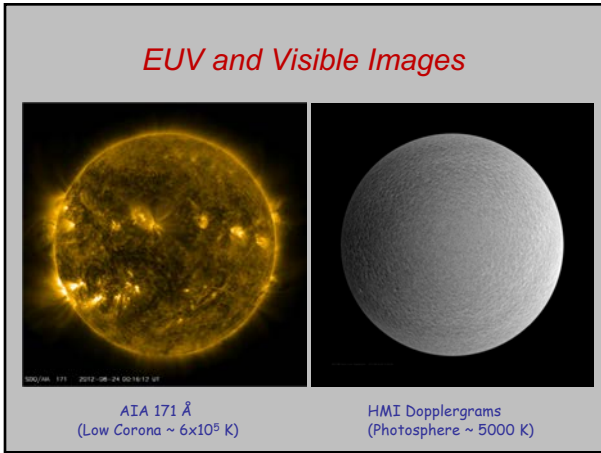
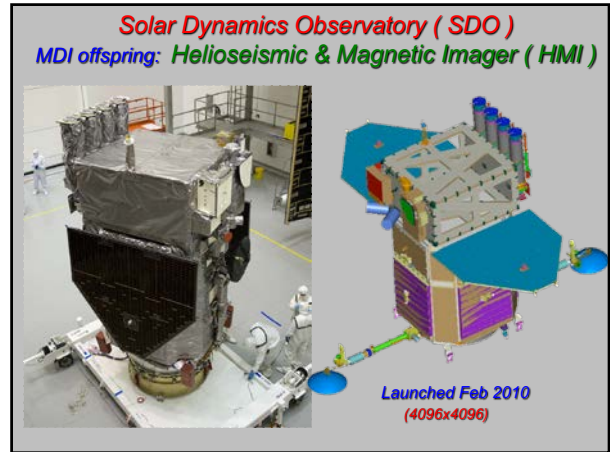
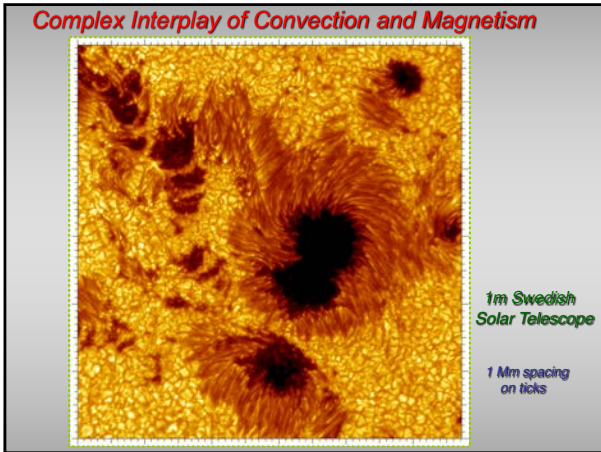
corona

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



NOW TO PLANETARIUM SKY

with full-dome flythrough to our location within the spiral arm of our galaxy, visit to M51 for reality check on star-birth regions in spiral arms, visiting splendid images of nebulosities and explicit star-birth regions including Orion in different wavelength bands

and then turn to full-dome Lucas production

“Solar Superstorms”