Astronomy 150: Killer Skies
Lecture 13, February 15

Assignments:

- Hour Exam 1 next time, Feb 17, in class
  more later today
- Planetarium: report due Feb 24
  extra show added tomorrow, Thursday Feb 16
  or can go to a public show on “Black Holes” or on “Prairie Skies”

Last time: Impact Mitigation, and a new threat--the Sun

Today: the Sun--stability and energy

Question of Stability

The Sun's size is constant.

- Not expanding or collapsing

  at least on human timescales

But: Sun has huge mass and thus huge gravity

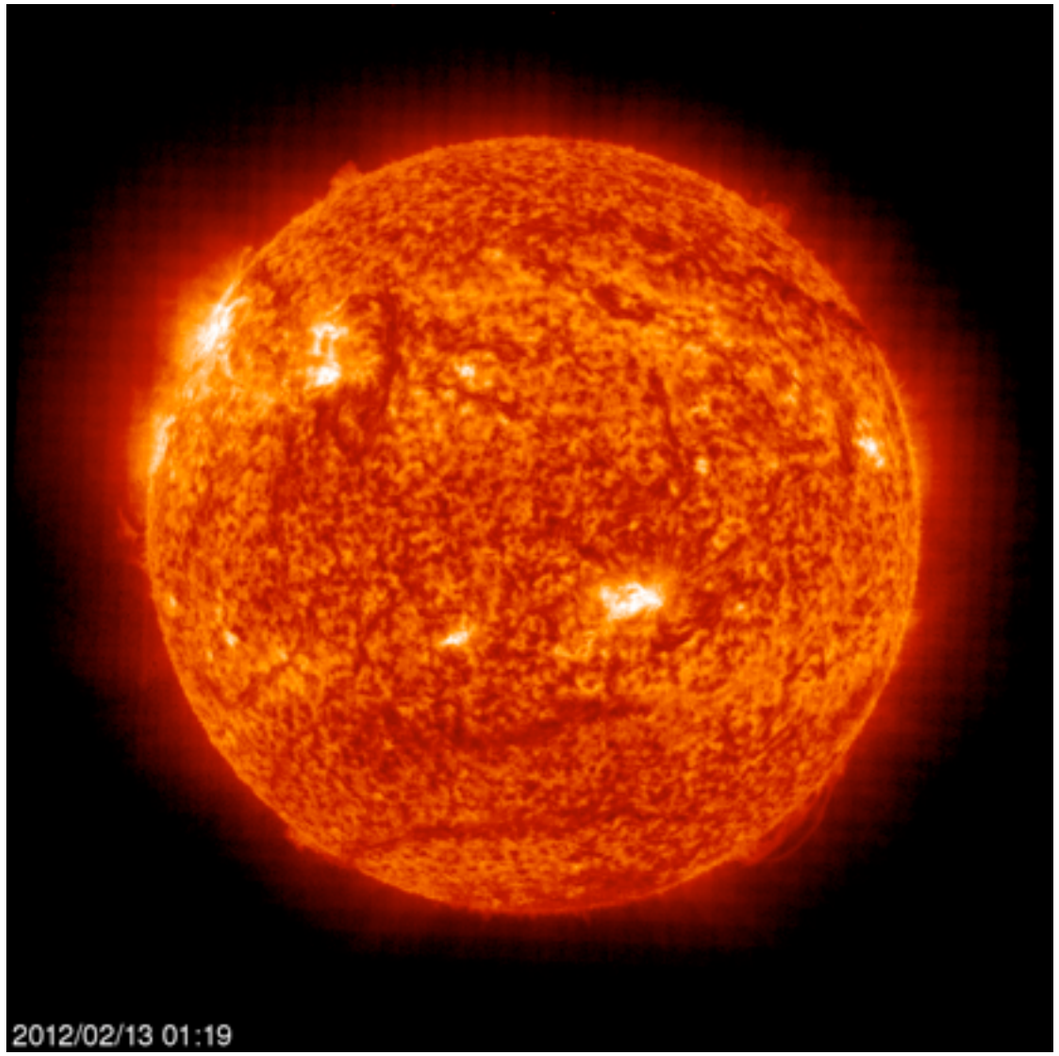
- keeps all planets in orbit
- but also pulls on itself!

Sun made of very hot gasses

- but gasses can flow, be compressed

Why doesn't the massive Sun collapse under its own gravity?

Why doesn't the superhot Sun explode?



http://sohowww.nascom.nasa.gov/data/realtime/eit_304/512/

iClicker Poll: Forces in the Sun

Consider a shell of matter (gas) in the Sun

Sun constant size:

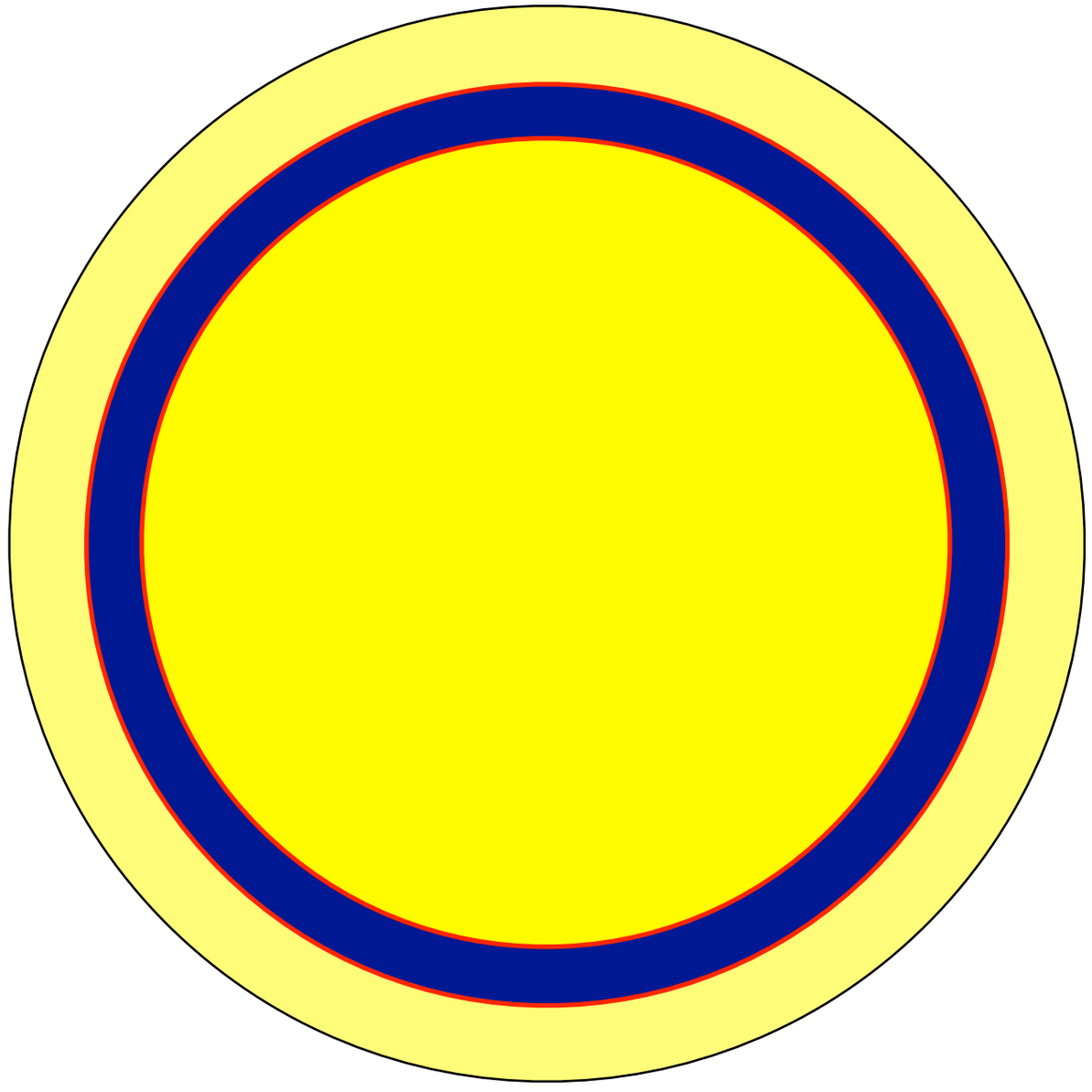
shell is at rest--does not move inward or outward

How many forces act on this shell?

A. zero

B. one

C. more than one



Forces in the Sun

Shell has mass:

- feels gravity force=has weight
- pulled toward Sun's center

Newton II: F = ma

- if net force, then acceleration

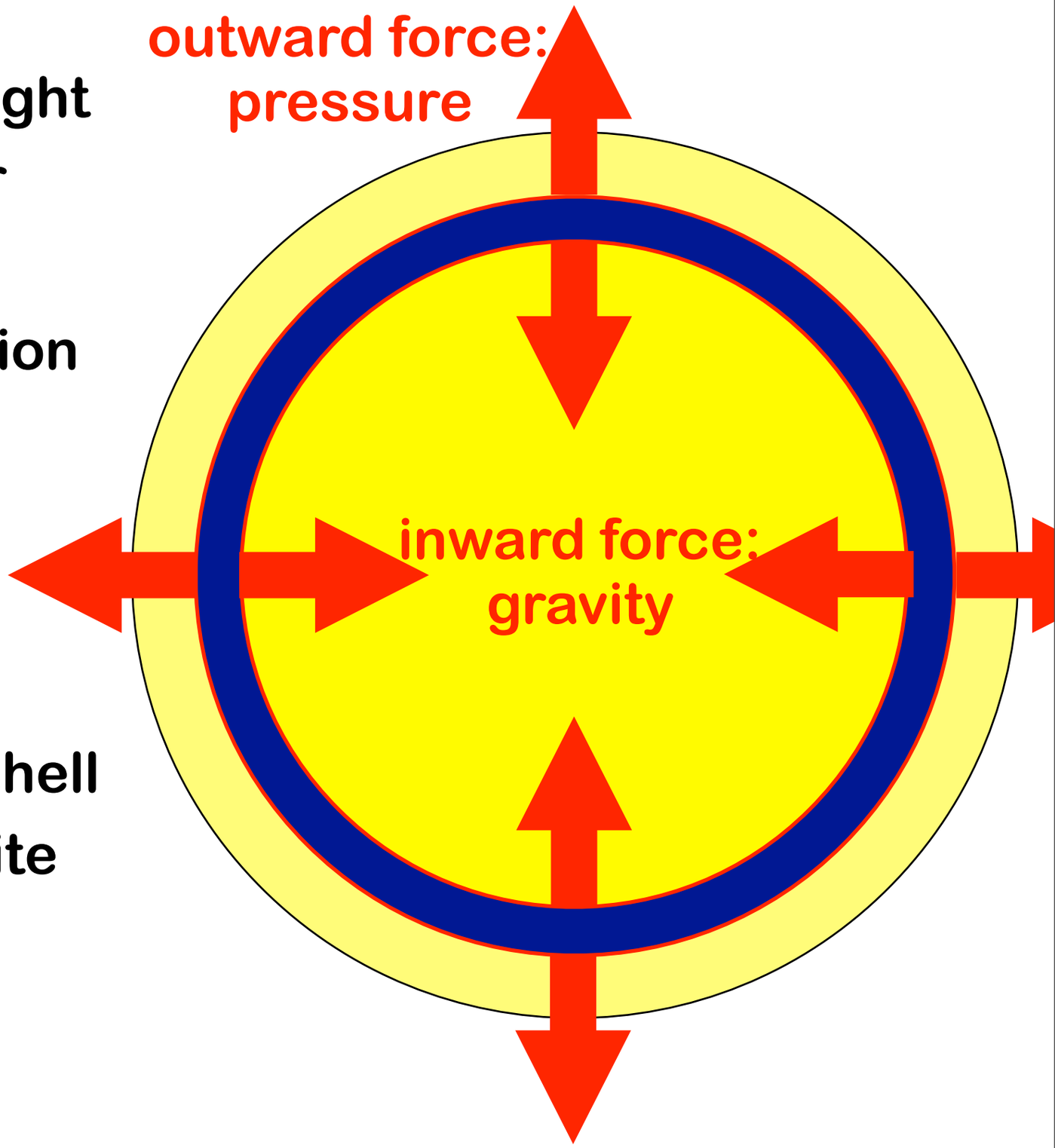
But shell at rest:

- no acceleration: a=0
- so F=0: no net force!

Therefore:

- must be another force on shell
- must be equal to an opposite to gravity!

Key: Sun made of hot gas: pressurized!



Atoms, Pressure, and Temperature

Microscopic, small-scale, view of matter:

- **Richard Feynman:** http://www.youtube.com/watch?v=v3pYRn5j7oI

matter made of tiny atoms in constant motion

in gasses:

- **atoms widely separated, travel as free bodies until collide with each other**
- **collisions "scramble"/randomize motion direction**
- **and tend to "equalize" particle energy**
- http://comp.uark.edu/~jgeabana/mol_dyn/KinThI.html

if gas enclosed:

- **atoms bombard walls, exert force!**
- http://mutuslab.cs.uwindsor.ca/schurko/animations/idealgas/idealGas.htm

Macroscopic, large-scale picture

average atom speeds ⟺ temperature

- **faster atoms ⟷ hotter; slower atoms ⟷ colder**

bombardment & collision forces ⟺ pressure

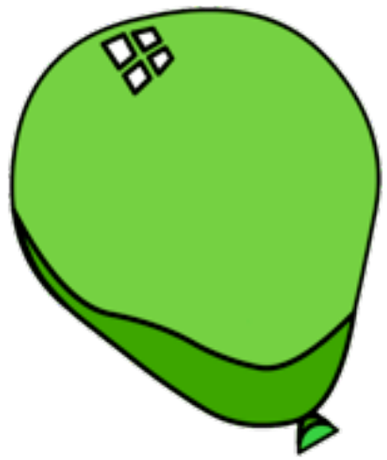
- **faster atoms = hotter = more violent collisions = more pressure**
- **cram in more atoms = more density = more collisions = more pressure**
- **pressure force (ideal gas law!)** $\text{pressure} \propto \text{density} \times \text{temperature}$

Pressure Stable

What is pressure?

- **Pressure** $= \frac{Force}{Area}$

Pressure of Earth's atmosphere is 14.7 pounds per square inch

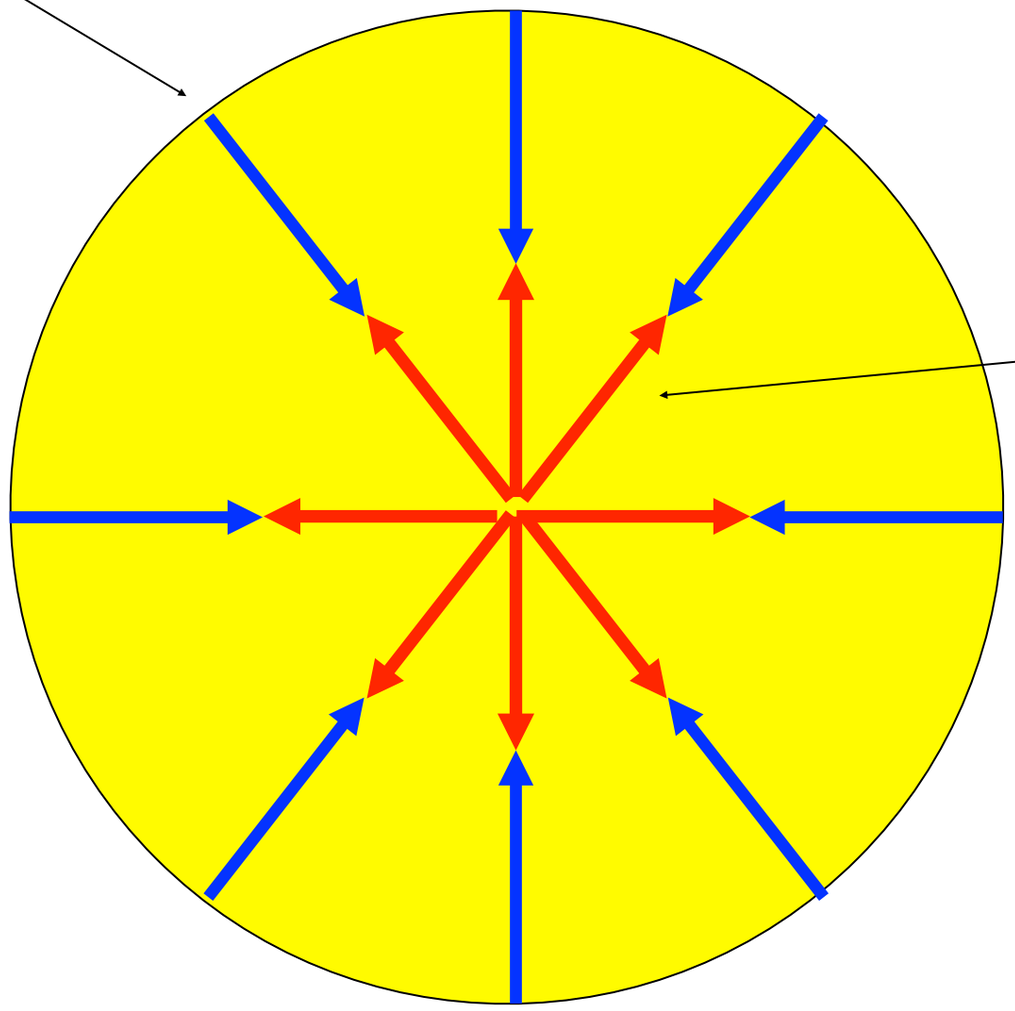


Explain blowing up a balloon? Forces?

http://www.phy.ntnu.edu.tw/java/idealGas/idealGas.html

The Battle of The Solar Titans
Gravity vs Pressure

Gravity pushes in



pressure from hot gasses pushes out

This battle long ago fought to standoff:

- gravity compressed Sun -- raised density and temperature
- which raised outward pressure
- until the forces balance!

pressure vs gravity balance: “hydrostatic equilibrium”

iClicker Question

Imagine drastically lowering the temperature of a balloon

...without popping it

What would happen?

A. balloon gets smaller

B. balloon gets larger

C. balloon stays same size

How could we do this experiment?

Experiment:
Balloon vs Liquid Nitrogen

Nitrogen:

most abundant element in the air you are breathing

- a gas at room temperature

If cool down enough:

condenses to liquid nitrogen

- same idea as water vapor cools to liquid water
- transition temperature: boiling point
- liquid nitrogen boiling point: -321 ^{o}F = -196 ^{o}C=77 K
- boils at room temperature!

to liquify, have to make very cold

- and then store in high-quality “thermos”--a dewar

Experiment: pour liquid nitrogen on balloon

Why’d that happen?

- Reduce temperature = reduce pressure = balloon collapses

So wait…what was the point? Why did we do this?

Astro-Lesson?

- the Sun’s gotta stay hot to remain stable!
- if loses heat source: lose pressure! shrinkage! collapse!

The Facts of Life for the Sun

Fact: the sun constantly radiates energy into space

- and at a huge rate!
- the Sun: a lightbulb with wattage ("luminosity") of 4×10^{26} Watts!

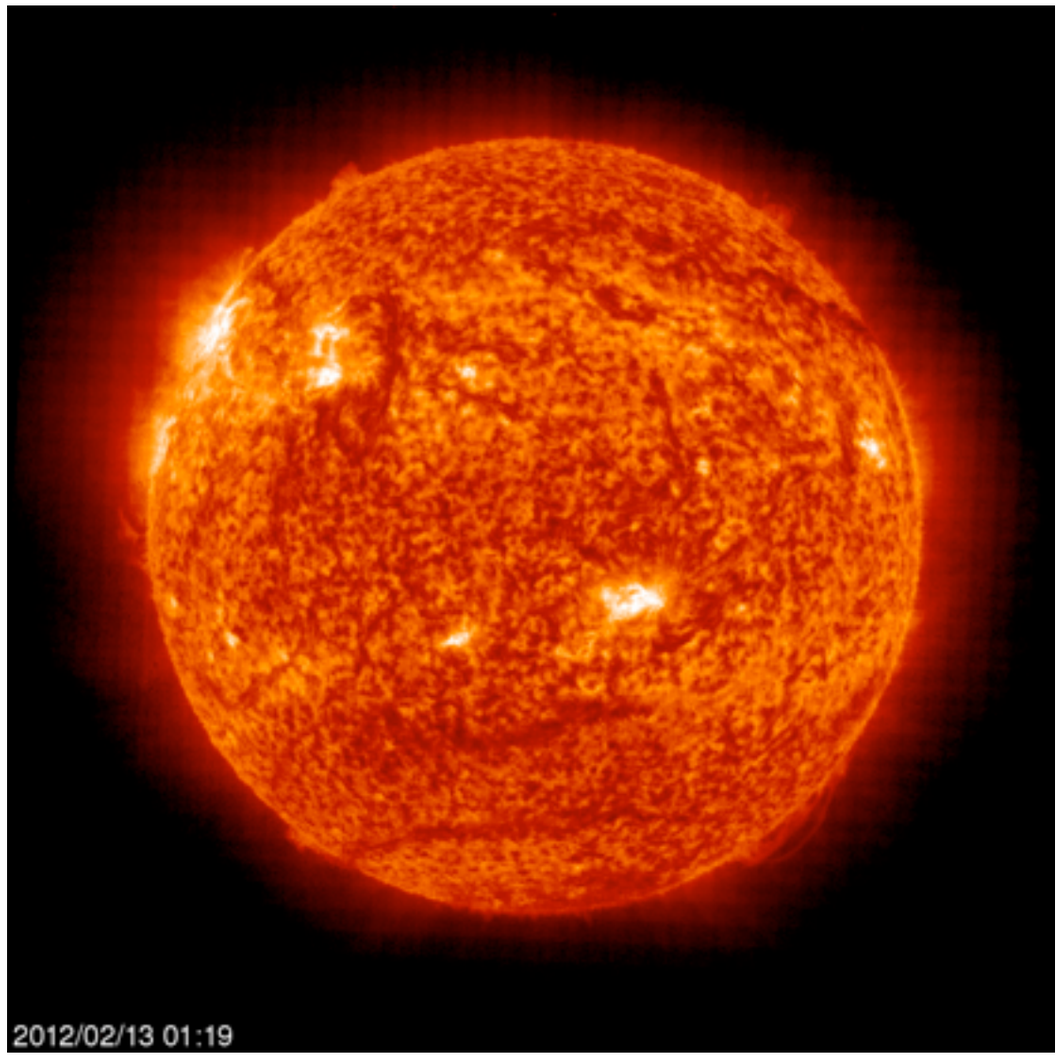
Fact: the Sun has a finite (not infinite) mass

- and thus a finite fuel supply
  (whatever that fuel may be)

Fact: Energy is conserved

- cannot be created or destroyed
- only converted from one form to another
- no free lunch!

Q: therefore?



Consequences of Energy Conservation
The Doomed Stars

the Sun and all stars:

- are constantly releasing energy to the rest of the universe, and
- require fuel, and are unable to "refuel" out of nothing, and
- thus must eventually run of out fuel

Thus:

- all stars – including the Sun – must eventually "burn out"
- = run out of energy = run out of fuel:
- the Sun all stars are doomed to die

Q: important followup question?

the Sun cannot live forever!

But the Sun and other stars are alive today, so...?

- stars alive today were not alive forever
- all stars must be born as well as die
- the Sun and stars have life cycles
- stellar mortality also implies possibility of rebirth!

Hour Exam 1

Hour Exam 1 next time, Feb 17, in class

information on course website

Most useful study materials

- class notes
- homework questions
- iClicker questions

Focus on concepts, main ideas

Key questions

- What causes the: day, month, year, Seasons, and phases of the Moon?
- What are Newton's laws?
  - what is mass? force? speed? velocity? acceleration?
- What is gravity?
  - what are sources of gravity
  - what attracts what?
  - how does gravity depend on distance?
- What are Kepler's laws?
  - how do planets move around the Sun
  - how does their speed change?
  - how are period and semi-major axis related?

Key questions

- What is a meteor? Shooting star?
  - Why does it shine?
  - Where does it come from?
  - What is the typical size?
  - When is the best time to see them?
- What is a meteor shower?
  - What causes them?
- What is the difference between a meteor and a fireball?

Sample Question

Asteroid Beyonce was discovered exactly 8 years ago, and has a semi-major axis of exactly 8 AU.

How many orbits around the Sun has asteroid Beyonce made since it was discovered?

A. exactly one

B. less than one

C. more than one

Key questions

- What is a meteorite?
  - What are the three types?
  - What are the differences in number?
  - How do we determine the age?
  - How do we know that they're from outer space?
- How do the planets orbit the Sun?
- What is the Oort cloud?
- What is the Kuiper belt?
- What is a meteoroid?
- What is the difference between a comet and asteroid?

Key questions

- What is the asteroid belt?
  - How much mass? How dense?
- What are the properties of Near Earth Asteroids?
  - Where do they come from?
  - How long do they last in near Earth orbit?
- What is the stuff between the stars?
- What is the solar nebula theory?

Key questions

What are molecular clouds made from?
Where are stars born?
How are stars born?
Explain gravitational collapse?
What is the effect of spin on a collapsing cloud?
How does small interstellar space dust become planets?
What is a protostellar jet or outflow?
What causes the differences between the planets?

Sample Question

Which of these has a composition most similar (elements in the most similar proportions) to that of the nebula that gave rise to the solar system?

A. (a) the Earth

B. (b) Jupiter

C. (c) a stony meteorite

D. (d) an iron meteorite

E. (e) the nucleus of a typical comet

Key questions

What is terminal velocity and how does it affect impactors? Large ones, small ones?

What is the temperature of small meteorites when they impact?

- What does the surface look like?
- Why do they hurt so?
- What property plays main role in amount of energy that they have when they impact?

Sample Question

Which of these will cause the most damage?

Hint: compare the kinetic energies.

A. an impactor of mass = M, which impacts with speed = V

B. an impactor of mass = 2M, which impacts with speed = V/2

C. both (A) and (B) have have the same kinetic energy

Key questions

How did the Moon form?

Explain the conditions of the Earth during the first billion years with respect to impactors.

What are typical speeds of objects entering our atmosphere?

What does gravity do to dropped objects? How do they react?

If you drop a hammer and a feather, what happens on the Earth or the Moon?

Key questions

What is a crater?

What are the differences between the two main types?

Why are craters mostly round?

Why so few craters on the Earth?

What happened 65 million years ago?

What is the KT boundary?

Proof of impactor?

What happened in Siberia ~100 years ago?

- How often do we expect such impacts?
- Why not more deaths from such events in the past?

Key questions

What happened to Jupiter in 1994?

What happened to the comet?

What happened at the impact sites?

Why does the impact of Jupiter serve as a wake-up call?

What are the consequences of a large impact?

So far, what has NASA done about 1km sized asteroids?

What is NASA going to do with ~100 meter asteroids?

Key questions

What is the Torino Scale?

What is Apophis?

- How close will it get in 2029?
- What is a keyhole? Why is earlier detection better for impact mitigation?

What are some problems with blowing up a large impactor?

Explain the options for delaying an impactor.

Sample Question

Of the potentially hazardous asteroids we have discovered orbiting the Sun, how many are certain to hit the Earth in the next 10 years?

A. zero

B. 1

C. 2

D. 5

E. more than 5