Weighing the Universe—18 Apr

- Fill out SIRS; then get 3 bonus clicker points an angel.
  - 18-29 April
- Dear Students:

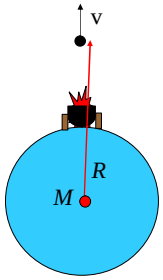
  As Director of Integrative Studies- Science, your opinions of ISP and ISB are very important to me. Comments from previous students have made a difference and yours may also. Therefore, I hope you'll take a few minutes and go to https://sirs.natsci.msu.edu/ and fill in the SIRS questionnaire. I look at the results for every class, and I read every comment.

  If you would rather write me directly, please email me at sibley@msu.edu. I'll write back.Thank you, and good luck on your finals.

  Dr. Duncan Sibley, Director
  Center for Integrative Studies in General Science

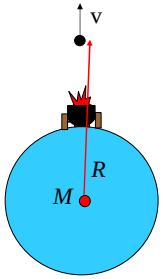
- Weighing the earth with a cannonball
  - What is the fate of the cannonball? Will it fall back to earth?
  - What is the mass of the earth? Is there mass that we cannot see?
- Weighing the universe
  - What is the fate of the universe? Will it expand forever or fall back on itself?
  - What is the universe made of? Is there mass that we cannot see?
- Key parameter: PE/KE

A Cannon Ball



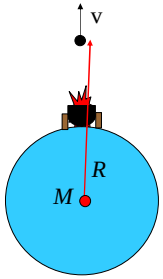
- Cannonball is shot out of cannon at speed v. Cannonball has mass=1kg.
  - Kinetic energy is ½ v^2.
- Gravity pulls on cannonball to slow the motion.
  - Potential energy of gravity is
    - G M /R
    - M is entire mass enclosed by sphere of radius R!
    - Mass outside of R does not count if spherically symmetric.
    - Distance is R between cannonball and center of sphere!

A Cannon Ball



- Cannonball is shot out of cannon at speed v. Cannonball has mass=1kg.
  - Kinetic energy is KE= ½ v^2.
- Gravity pulls on cannonball to slow the motion.
  - Potential energy of gravity is
    - PE = G M /R
- Cannonball will escape if
  - KE ≥ PE
  - Shot faster than gravity can hold
- Define "Density parameter"
  - Ω = PE/KE = 2 G M / (R v^2)

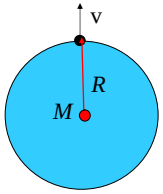
A Cannon Ball



- Kinetic energy is KE= ½ v^2.
- Potential energy of gravity is
  - PE = G M /R
- Cannonball will escape if
  - KE ≥ PE
  - Shot faster than what gravity can hold
- Define "Density parameter"
  - Ω = PE/KE = 2 G M / (R v^2)

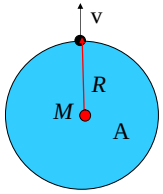
1. A cannonball is shot with Ω=0.7. Will the cannonball escape? Same question for Ω=1.1.

A Galaxy



- Hoag's object is moving from us at speed v. Galaxy has mass=1kg.
  - Kinetic energy is ½ v^2.
- Gravity pulls on galaxy to slow the motion.
  - Potential energy of gravity is
    - G M /R
    - M is entire mass enclosed by sphere of radius R!
    - Mass outside of R does not count if spherically symmetric.
    - Distance is R between cannonball and center of sphere!

A Galaxy

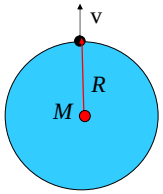


B

- Hoag's object is moving from us at speed v. Galaxy has mass=1kg.
  - Kinetic energy is ½ v^2.
- Gravity pulls on galaxy to slow the motion.
  - Potential energy of gravity is
    - G M /R

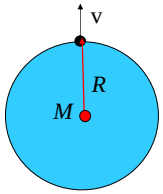
2. Galaxies are distributed uniformly in space. Do galaxies at A affect motion of H's object? Same question for galaxies at B.
   a. NN
   b. NY
   c. YN
   d. NN

A Galaxy



- Hoag's object is moving b/c big bang. Use Hubble's Law v= H R
  - Kinetic energy is ½ v^2= ½ H^2R^2.
- Potential energy of gravity is
  - G M /R
- Define "Density parameter"
  - Ω = PE/KE = 2 G M / ($R v^2$)
  - Ω = PE/KE = 2 G M / (R^3H^2)
- Mass/volume is mass density ρ
  - Ω = PE/KE = 8π G ρ / H^2
- Does not depend on particular galaxy

A Galaxy



- Density parameter
  - Ω = PE/KE = 8π G ρ / H^2

3. Ω=0.7. Will the universe expand forever? Same question for Ω=1.
   a. YY
   b. YN
   c. NY
   d. NN