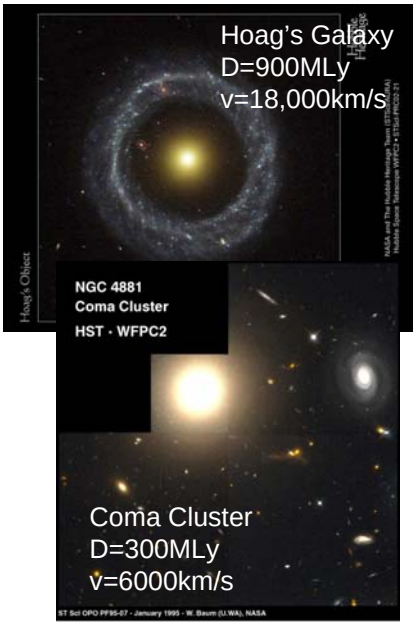
Hubble's Law

- Hubble's Law: More distant galaxies are moving away faster.
  Speed = H × Distance
- Universe is expanding
- Universe started with a Big Bang
- How Hubble discovered Hubble's Law



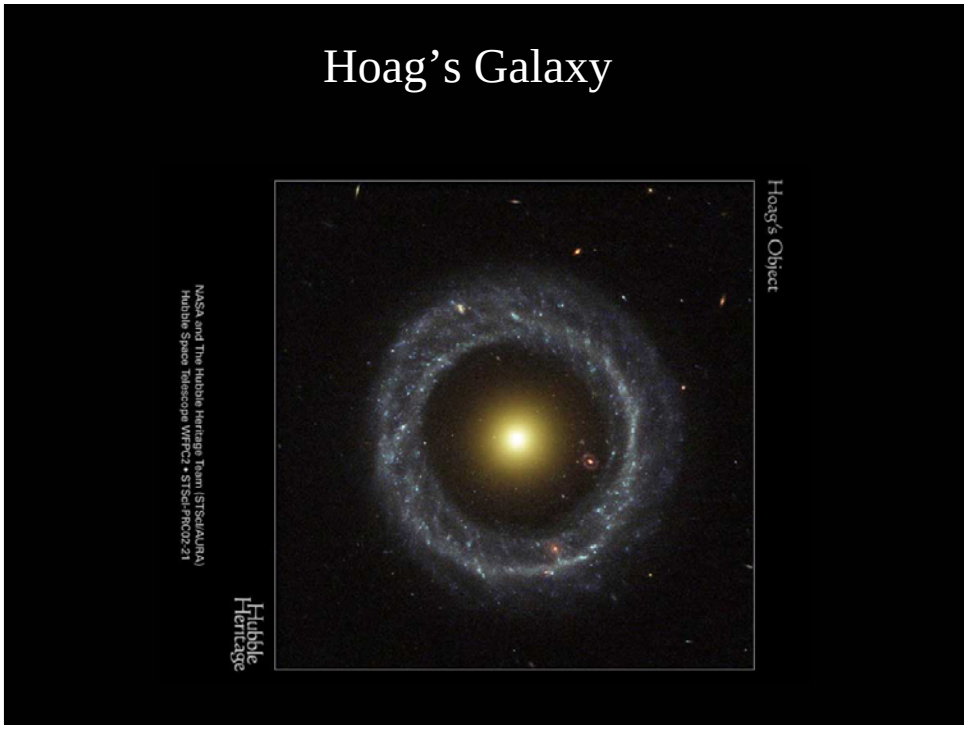
- Reorder topics
- Hubble's Law, expansion of the universe
- Quasars & active galaxies

- Astronomical Horizons Public Talks
  - First Light for the Spartan Infrared Camera
    - Ed Loh
    - Abrams Planetarium
    - Thursday at 7:30pm

OBAFKGM winners

- **O**uch! **B**illy, **a** **f**at **g**oat **k**icked **m**e! — Marissa Burns
- Odd blue armadillos fight green killer mice. — Brian Nekic
- Only babies are fun giggling kissing machines. — Garrison Warr
- Obama blasted AIG for getting kooky with money. — Hayley Lynch
- Oh bummer! A fire grounded Kevin's mission. — Lisa Hagen
- Our basketball and football guys kill Michigan. — Brandon Bailey
- Only bored astronomers find gratification knowing mnemonics. — Sarah Harris
- One bright astronomer finally grasped kinetic motion. — Megan Fleming
- Obama beat a fatigued gentleman known-as McCain. — Andrea Goossens
- Other Bigten athletes fear gigantic killer Michganstaters. — Madeline Morrison
- One black afternoon Freddie got killed mysteriously. — Jessica Prentice
- Only boys accepting Feminism get kissed meaningfully. — Morgan Martens
- Olivia Brown astonished funny Germans knowing microeconomics. — Brent Wilson
- Officially, Bill always felt guilty kissing Monica. — Rachael McKenney

Hoag's Galaxy



NGC4881, central galaxy in Coma Cluster

Milky Way Galaxy

Hubble's Law

- Velocity V is proportional to distance D
  - $V = H \times D$
- Demo: Let Coma & Hoag's Galaxy move according to Hubble's Law

	Speed	Dist
Milky Way	0 km/s	0 MLy
Coma	6,000 km/s	300MLy
Hoag's Object	18,000 km/s	900MLy

1. If Coma moves one meter, how much should Hoag move?
   a. 1 m
   b. 3 m
   c. 1/3 m
   d. 9 m
   e. 1/9 m

Hubble's Law

- Velocity V is proportional to distance D
  - $V = H \times D$

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Milky Way	0 km/s	0 MLy
Coma	6,000 km/s	300MLy
Hoag's Object	18,000 km/s	900MLy

2. Hoag is 3 times as far as Coma. Is this still true in the future? Was this true in the past?
   a. YY
   b. YN
   c. NY
   d. NN

Hubble's Law

- $V = H \times D$

2. The proto Milky Way and the proto Coma were very close together at one time. Was the proto Hoag's Object close the proto Milky Way at the same time or a different time?
   A. Same
   B. Different

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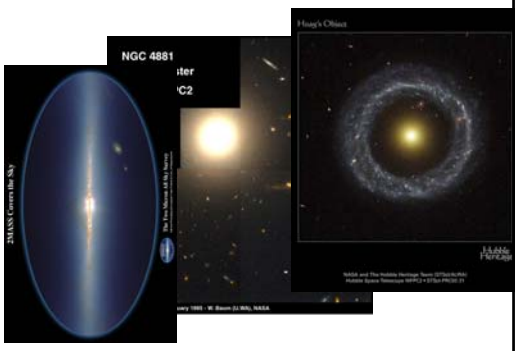

Hubble's Law

- $V = H \times D$

2. Hoag is 3 times as far as Coma. Is this still true in the future? Was this true in the past? YY.
- H's Law => Universe began in a Big Bang
  - Universe was very dense
  - What became Milky Way was very close to what became Coma & Hoag's Galaxy.
- Current physics can explain universe 10^{-10}s after Big Bang, when proto-Coma was 1 mm from proto-us.

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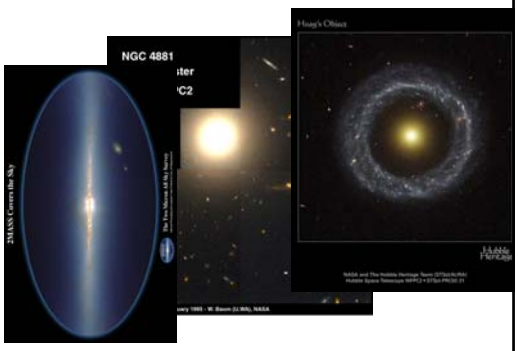

Hubble's Law

- $V = H \times D$

3. If we are in Coma, would H's Law still apply? (All guesses count as correct.)
   a. Y
   b. N

- Do the demo.

3. If we are in Coma, would H's Law still apply?
   a. Y
   b. N

	Speed	Dist
Milky Way	0 km/s	0 MLy
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Hubble's Law

1. I am asleep at a basketball game. I wake up and see a b'ball moving toward the basket (and away from K Lucas). Why is the b'ball moving?
   A. Space pushes b'balls away from b'ball players.
   B. K Lucas shot the ball.
2. We see Coma moving away from us. Why does Coma moving?
   2. Space pushes on Coma.
   3. The Big Bang set proto-galaxies in motion.

- What would have to happen for Coma's distance to change? For Coma's speed to change?

3. Which quantity changes the most and which quantity changes the least? Coma' speed, Coma's distance.
   A. Coma's distance. Coma' speed.
   B. Both change about the same.

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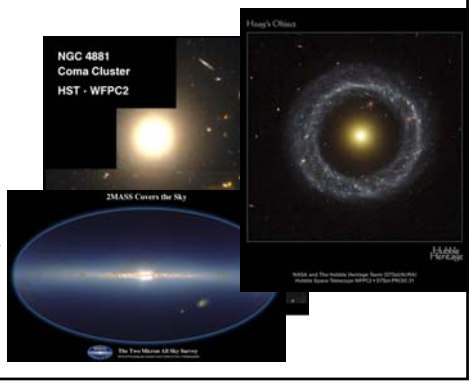

The universe expands

- The universe expands.
- The distance between the Milky Way and Coma increases, because they remember the motion set in place by the Big Bang.

1. Does a piece of wood expand? Does the distance between the Earth & Sun expand?
   A. YY.
   B. YN.
   C. NY.
   D. NN.

	Speed	Dist
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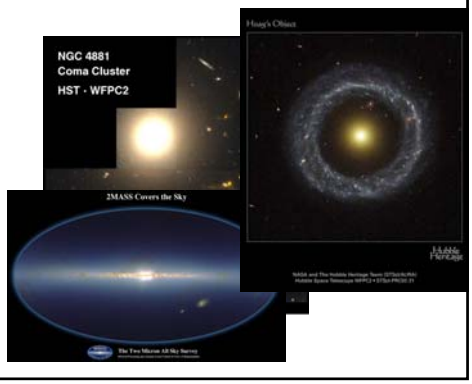
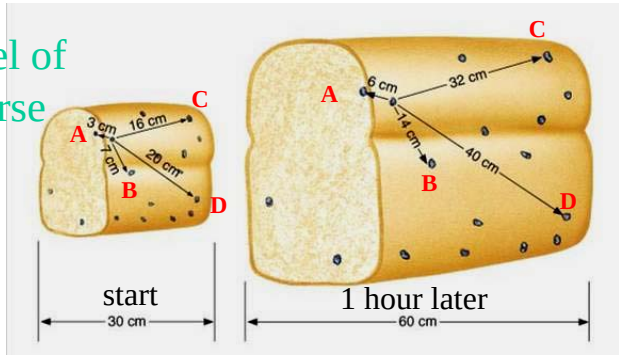


Raisin Bread Model of Expanding Universe

- Raisin-bread model shows V=H D
- Why do raisins move? Bread pushes them.

5. Why are galaxies moving?
   a. Space pushes galaxies.
   b. Big Bang set proto-galaxies in motion. Gravity slows (or accelerates) motion.



Galaxy	d_{start}	d_{end}	$d_{end} - d_{start}$	velocity
A	3 cm	6 cm	3 cm	3 cm/hr
B	7	14	7	7
C	16	32	16	16
D	20	40	20	20

Looks same from any raisin