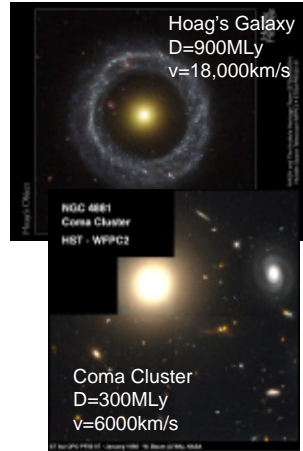


## Hubble's Law—6 April

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



## Hoag's Galaxy



## NGC4881, central galaxy in Coma Cluster



## Milky Way Galaxy



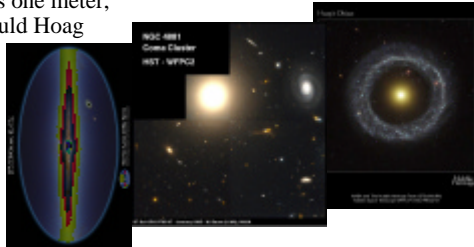
## Hubble's Law

- 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

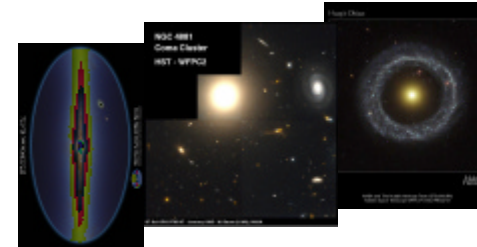


## Hubble's Law

- Velocity  $V$  is proportional to distance  $D$ 
  - $V = H \times D$
- 2. Hoag is 3 times as far as Coma. Is this still true in the future? Was this true in the past?

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

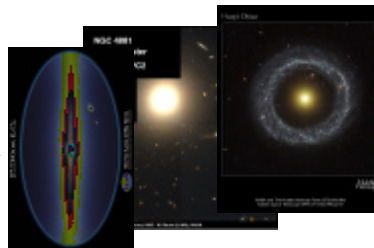
- a. YY
- b. YN
- c. NY
- d. NN



## 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.

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

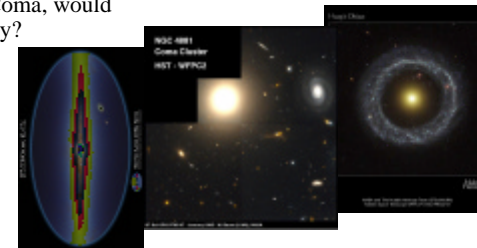


## Hubble's Law

- $V = H \times D$
- 3. If we are in Coma, would H's Law apply? (All guesses count as correct.)
- 4. If we are in Coma, would H's Law apply?

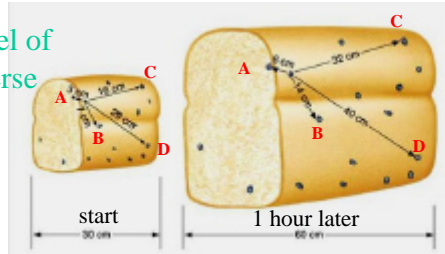
	Speed	Dist
Milky Way	0 km/s	0 MLy
Coma	6,000 km/s	300MLy
Hoag's Object	18,000 km/s	900MLy

- a. Y
- b. N



## 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?
- Space pushes galaxies.
  - Big Bang set proto-galaxies in motion. Gravity slows (or accelerates) motion.



Galaxy	$d_{\text{start}}$	$d_{\text{end}}$	$d_{\text{end}} - d_{\text{start}}$	velocity
A	3 cm	6 cm	3 cm	30 cm/hr
B	7	14	7	7
C	16	32	16	16
D	20	40	20	20

Looks same from any raisin

