The big bang: model it, graph it, weigh it

Name: Class: Date:

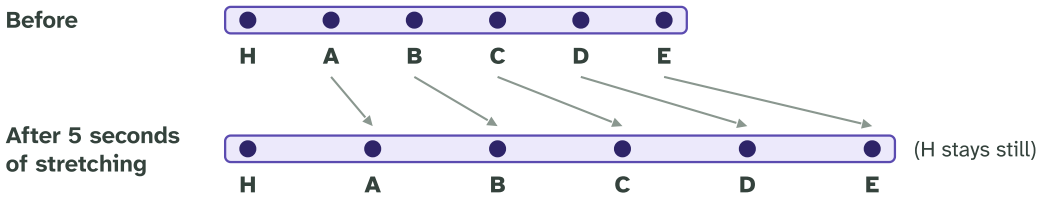
Page 1 models the expanding universe with a strip of elastic. Page 2 graphs Edwin Hubble's 1929 data to estimate the age of the universe. Page 3 is a model-evidence link diagram.

PRACTICAL Model the expansion

Each pair needs: a strip of wide, flat elastic about 30 cm long (or a long rubber band cut open), a ruler, a fine marker and a timer.

> **Safety.** Hold the ends firmly and stretch the elastic gently, below face height, so that it can't flick into anyone's eyes. Wear safety glasses if your school provides them.

1. Lay the elastic flat on the bench without stretching it. Near one end, mark a dot and label it H, for home.
2. Mark five more dots, A to E, at 2, 4, 6, 8 and 10 cm from H. Record each dot's distance from H in the table.
3. Your partner holds the H end still. Stretch the strip steadily for 5 seconds, until dot E is about 15 cm from H, and hold it there.
4. Measure each dot's new distance from H. Work out how far each dot moved, and its speed in centimetres per second (distance moved ÷ 5 s).
5. Let the strip go back. Now make C the home dot: hold the strip at C while your partner stretches both ends for 5 seconds, and measure how far A, B, D and E move away from C.



Before you start: which dot do you think will move away from H fastest? Why?

RECORD Results with H as home

Dot	Distance from H before (cm)	Distance from H after (cm)	Distance moved (cm)	Speed (cm/s)
A				
B				
C				
D				
E				

1. How does a dot's speed depend on its distance from H? Describe the pattern.

2. With C as home, which dots moved away fastest? Did the pattern change when the home dot changed?

3. How is the elastic like the expanding universe on screen 4? Give one way in which it is different.

DATA Hubble's 1929 data

Edwin Hubble published these distances and speeds for 24 galaxies in 1929. His table gave the distances in millions of parsecs. Here they are in millions of light-years (1 parsec = 3.262 light-years). A negative speed means that the galaxy is coming towards us.

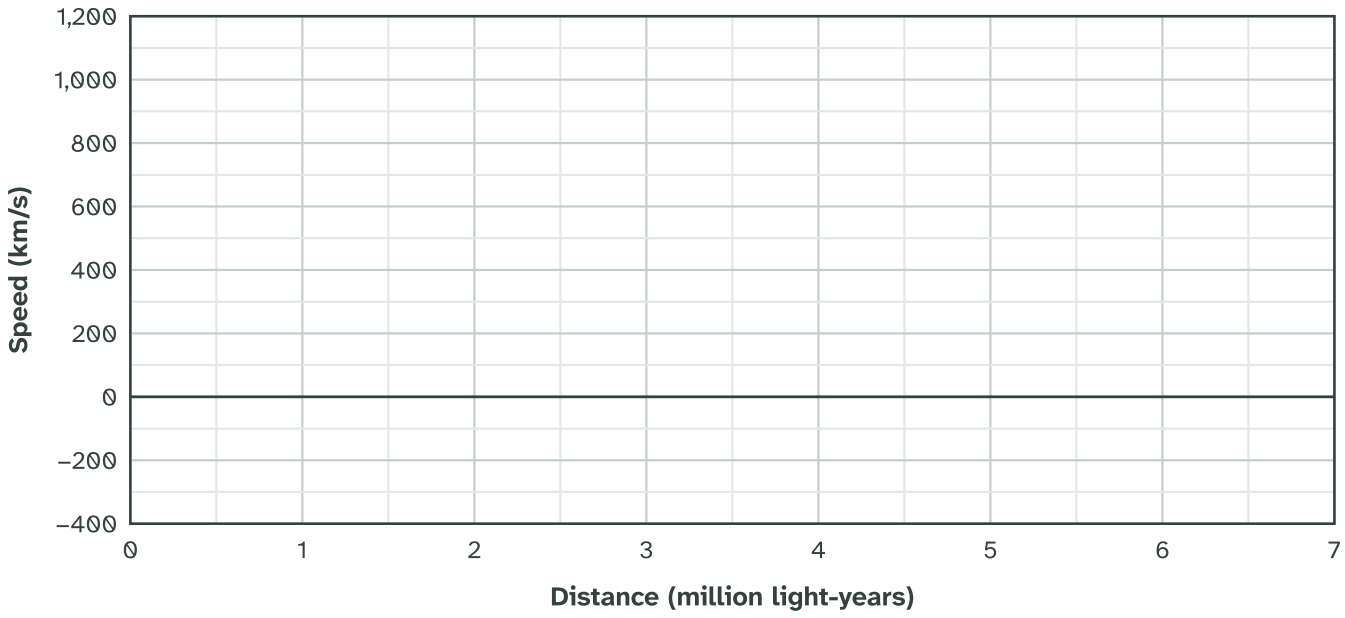
Galaxy	Distance (million ly)	Speed (km/s)
Small Magellanic Cloud	0.10	+170
Large Magellanic Cloud	0.11	+290
NGC 6822	0.70	−130
NGC 598	0.86	−70
NGC 221	0.90	−185
Andromeda Galaxy (NGC 224)	0.90	−220
NGC 5457	1.47	+200
NGC 4736	1.63	+290

Galaxy	Distance (million ly)	Speed (km/s)
NGC 5194	1.63	+270
NGC 4449	2.06	+200
NGC 4214	2.61	+300
NGC 3031	2.94	−30
NGC 3627	2.94	+650
NGC 4826	2.94	+150
NGC 5236	2.94	+500
NGC 1068	3.26	+920

Galaxy	Distance (million ly)	Speed (km/s)
NGC 5055	3.59	+450
NGC 7331	3.59	+500
NGC 4258	4.57	+500
NGC 4151	5.55	+960
NGC 4382	6.52	+500
NGC 4472	6.52	+850
NGC 4486	6.52	+800
NGC 4649	6.52	+1090

GRAPH Plot it and find H

1. Plot each galaxy on the grid.
2. Draw a straight line from (0, 0) through the middle of the points.
3. Pick a point on your line, read off its distance and speed, and work out the slope: H = speed ÷ distance, in km/s per million light-years.
4. Work out the time since the galaxies were together, 1/H: divide 9.461×10^{18} km (a million light-years) by H to get seconds, then divide by 3.156×10^{7} s (a year).



My slope: H = _____ km/s per million light-years. My age, 1/H = _____ billion years.

1. Today's value of H is about 22 km/s per million light-years. Work out 1/H with it.

2. Hubble put the Andromeda Galaxy about 900,000 light-years away. It is a little more than 2 million light-years away. Explain why distances that are too small give an age that is too small.

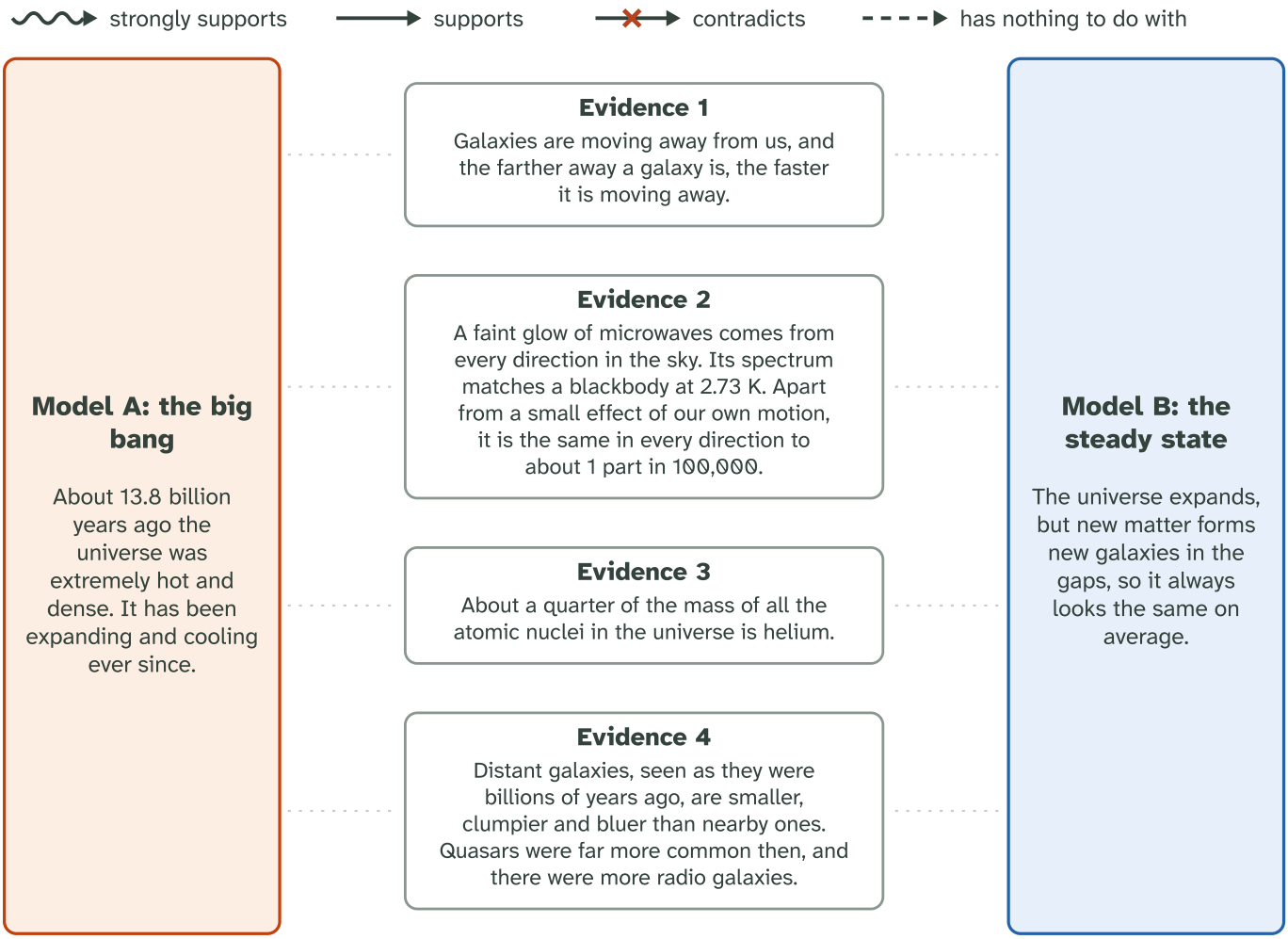
WEIGH IT Model-evidence link diagram

Rate each model before you start. Then draw two arrows from each line of evidence, one to each model, using the key. When all eight arrows are drawn, rate the models again.

Before: how plausible is each model?

Model A: the big bang	1	2	3	4	5	6	7	8	9	10
Model B: the steady state	1	2	3	4	5	6	7	8	9	10

1 means greatly implausible or even impossible, and 10 means highly plausible.



After: how plausible is each model now?

Model A: the big bang	1	2	3	4	5	6	7	8	9	10
Model B: the steady state	1	2	3	4	5	6	7	8	9	10

1. Choose two of your arrows. For each one, say which evidence and which model it joins, what kind of arrow it is, and why you chose it.