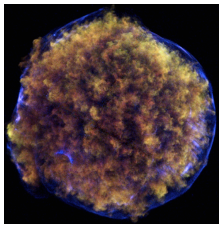


Type Ia Supernovae and the Expansion of the Universe

Edwin Hubble was the first to measure that distant galaxies are all moving away from us, showing that the universe has been expanding since its origin in the Big Bang. However, the universe is only expected to expand at the **constant** rate predicted by **Hubble's Law** if it is empty, and contains no mass. Any mass will cause the expansion to slow (a deceleration) due to the gravity from this mass.

In a decelerating (matter-dominated) universe, the expansion rate today (as measured by **Hubble's constant**) will be **less** than the expansion rate at very early times. More distant galaxies will thus be moving away from us **faster** than a simple application of Hubble's law would predict. In fact, we don't actually expect Hubble's "constant" to be a constant at all— it should change with the age of the universe!

To measure this, it is necessary to observe objects at extreme distances, and such objects need to be very bright in order for us to detect them! We also have to be able to measure their distance. The constant brightness of Type Ia supernovae makes them perfect for this task: they are bright beacons that can be used as standard candles to determine distance. By observing these supernovae in galaxies, astronomers have measured the expansion rate of the universe as a function of distance, further out in the universe than ever before.

- **STEP 1: Plot the data in the table on Page 2 on the graph on Page 3**
- **STEP 2: Use this plot to answer the questions at the end**

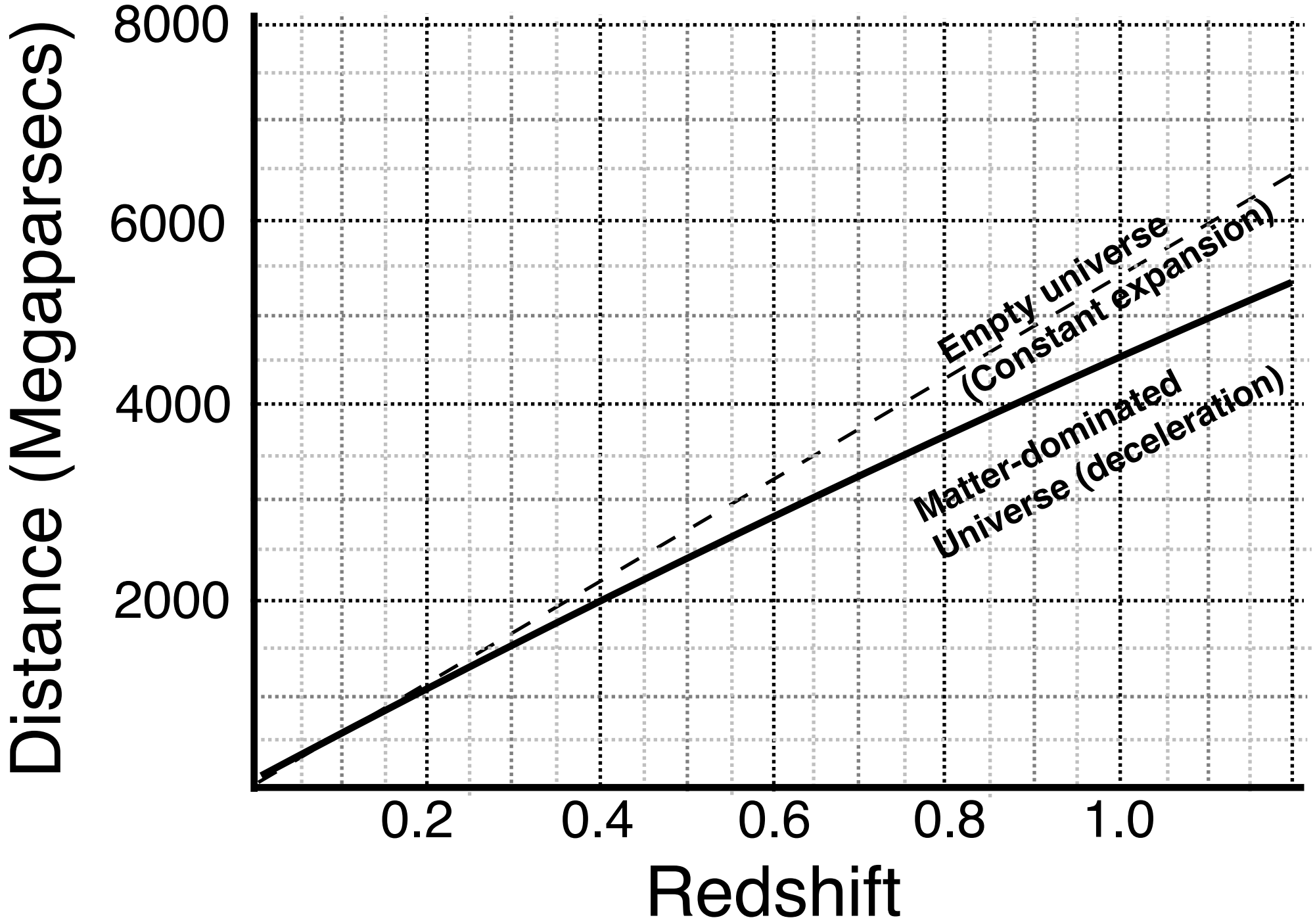
Supernova Data

Supernova Name	Redshift	Distance (Megaparsecs)
1990af	0.05	220
1992aq	0.1	460
1992bs	0.08	390
1995K	0.48	3100
1996ab	0.12	660
1996C	0.03	150
1996H	0.62	4000
1996I	0.57	3700
1996J	0.3	1600
1996K	0.38	2800
1996U	0.43	2900
1997cj	0.5	3500
1997ck	0.97	7200

1 **Megaparsec** = 1 million parsecs

1 **parsec** = 3.3 lightyears

Redshift is a type of Doppler Shift: it is a change in the color of the light we detect from an object moving away from us


Distance (Megaparsecs)
8000
6000
4000
2000
0.2
0.4
0.6
0.8
1.0
Redshift
Empty universe
(Constant expansion)
Matter-dominated
Universe (deceleration)

1. Where are the most distant galaxies located on your plot compared to the lines representing the two models of the universe (constant vs. decelerating expansion)? How does this compare to our knowledge of the makeup of the universe?

2. For each model, does this mean that the most distant galaxies are moving away from us faster or slower than the model would predict?

3. How would the expansion rate of the universe have to behave in order to match these observations? What could cause this to happen? Can we explain it with any forces we have discussed in class?