# The Dark Energy Crisis

Lecture 6 - November 5th, 2011

The expansion rate of the Universe is accelerating today, and has been for the past few billion years. In terms of the Universe's size, we can say that the expansion rate has been accelerating since the Universe was about half its current size (1/8th its current volume). We call the mysterious something that is making this acceleration happen "dark energy." Today's accelerating expansion is in some ways quite similar to the accelerating expansion that occurred during the epoch of inflation. Nonetheless, the two are distinct, and although joining the two into a single theory is something we all hope for, it is not very easy to do. The main difference is in energy scale: the energy scale of the "vacuum energy" during inflation was tremendous, whereas the energy scale of today's Dark Energy is very small. The only reason that dark energy has taken over as the dominant form of energy density in the Universe now is because the Universe has gotten so large that other forms of energy (matter, radiation) have become very diluted, whereas Dark Energy does not dilute!

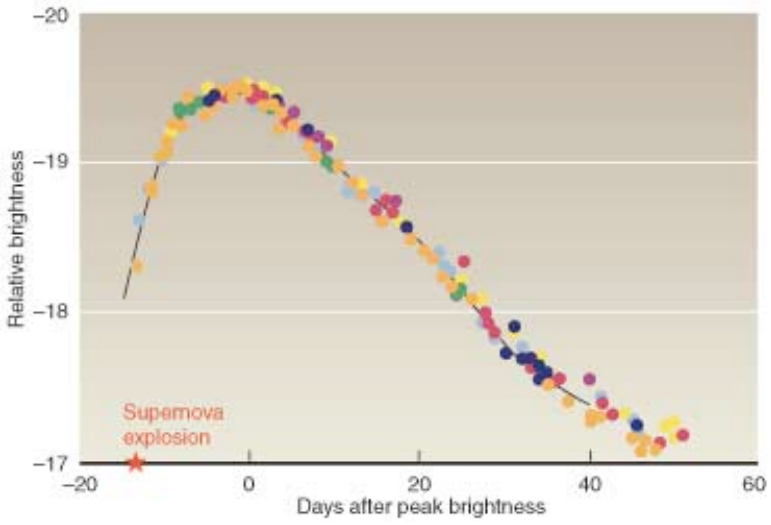
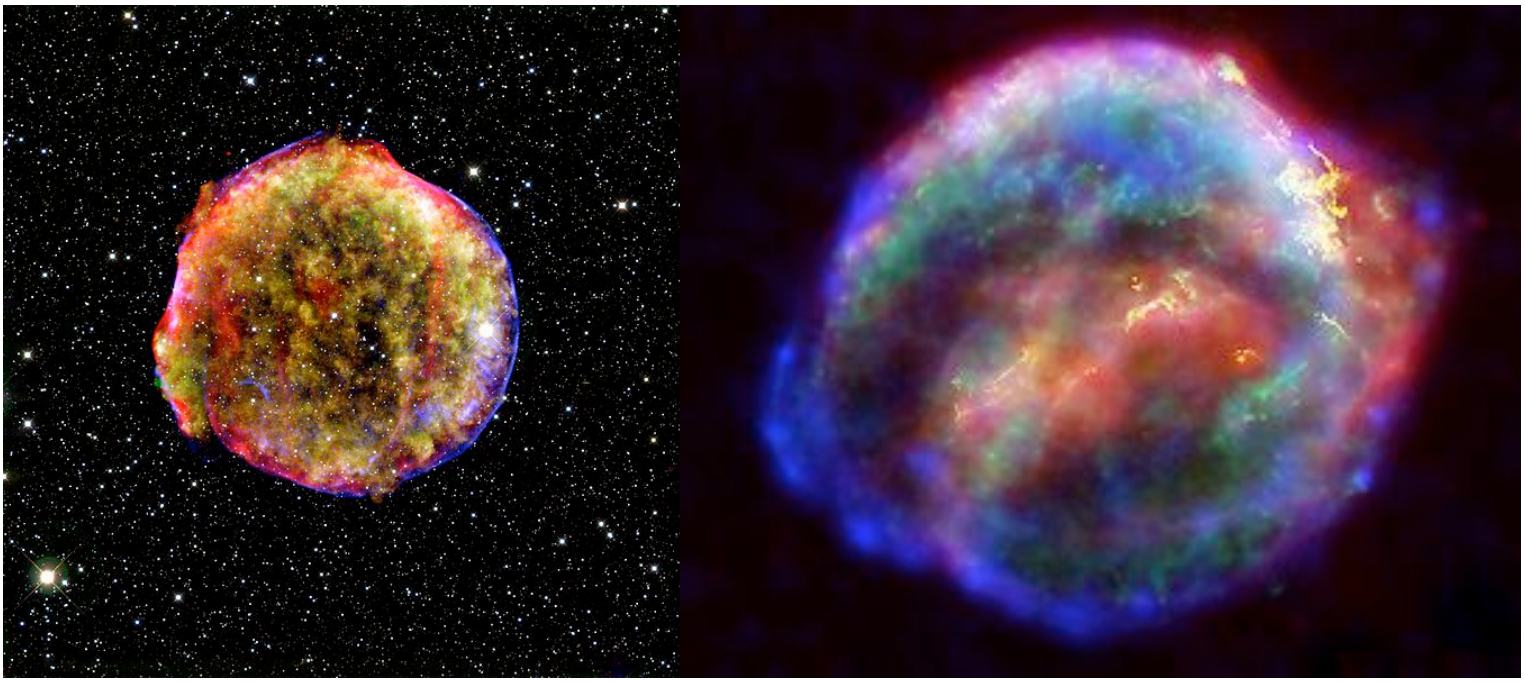



Diagram of brightness versus time for supernovae type Ia, after standardizing corrections are made. The goodness of this fit lets us use SNe for cosmology.

How do we know about this Dark Energy?

- Primarily from **Type Ia Supernovae**, which we will discuss in some detail today. These are a special class of supernovae that come from **white dwarf stars**.
- Type Ia supernovae are what we call **standardizable candles**. What this means is that we can figure out the intrinsic brightness of the explosion by studying other properties of the explosion, in this case the rate at which the explosion dims with time.
- Although the first evidence for Dark Energy came from supernovae, we now have lots of different streams of evidence (the CMB, observations from the Hubble Space Telescope) observations from galaxy surveys, and others) all pointing to the same conclusion: that in the Universe today **about 73% of the total energy density is in the form of Dark Energy**.
- This year's Nobel Prize in Physics was given to Saul Perlmutter, Brian Schmidt, and Adam Riess for their use of type Ia supernovae to discover the accelerated expansion and dark energy.

Although the discovery of Dark Energy is very exciting for cosmology, it also presents us with a very difficult puzzle: what IS the dark energy? We simply don't know yet, and our theoretical understanding of the subject is still very confused. We call this utter confusion the "dark energy crisis" or the "cosmological constant problem."



Astronomy is an old subject now: each of these supernovae nebulae are modern pictures of supernova explosions seen by historical astronomers: Tycho Brahe (left) -- SN 1572; and Johannes Kepler (right) -- SN 1604. Each was a type Ia supernova, the kind we use now to infer the existence of Dark Energy.

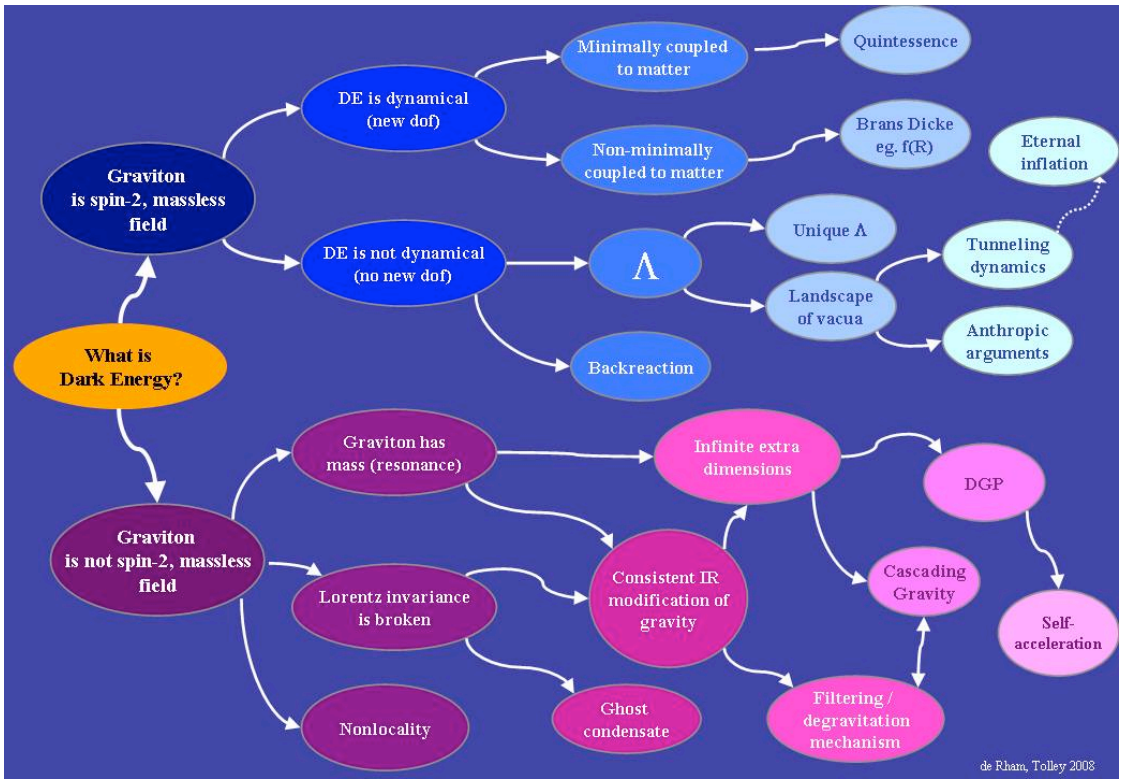



Diagram of the possible solutions to the cosmological constant problem / dark energy crisis. The abundance of possibilities is rather disheartening!