The Dark Side of the Universe

ASTRO-PARTICLE PHYSICS:
The cosmos is a very beautiful, structured and dynamical environment!
**Hubble Expansion of the Universe**

**The doppler effect:**

- Approaching = blue-shift
- Resting
- Receding = red-shift
about 15Gyr ago: Hot Big Bang
$10^{-43}$ seconds

$10^{32}$ degrees
3 minutes

$10^9$ degrees
1 thousand million years

18 degrees
15 thousand million years M0V 3 degrees
The big Bang
Is the picture complete?

Have we seen all components of the universe?

NO! 95% is missing!

-> dark matter & dark energy

How do we know?
Historical method to find new planets
> compare observed and calculated paths of known planets
Galactic rotation curves $\leftrightarrow$ visible matter distribution
Explanation: A halo of "dark matter"
• essentially all galactic rotation curves require DM
• the same observation on larger scales (clusters)
• search for conventional (baryonic) DM
• ==> by far not enough
• ==> exotic new type of matter!
• Other ways to arrive at same conclusion
• ==> supernova of type Ia
• ==> CMB, BBN, .....
Supernovae of Type Ia
Perlmutter, et al. (1998)

Supernova Cosmology Project

Calan/Tololo
(Hamuy et al., A.J. 1996)

$\left(\Omega_M, \Omega_\Lambda\right) =
(0, 1)
(0.5, 0.5)
(1, 0)
(1.5, -0.5)
(2, 0)

$\Lambda = 0$

MORE REDSHIFT
(More total expansion of universe since the supernova explosion)
Another method: Gravitational lensing
-> indirect information about matter distribution
What is the Universe made of?

The final accounting seems to be:

- 5% Ordinary Matter
- 25% Dark Matter
- 70% Dark Energy
"you want proof? i'll give you proof!"