Structure: the rise (and infall) of Dark Matter

Lecture 5 - October 29th, 2011

Today we will discuss how gravity and dark matter worked together to make all the big and wonderful objects -- stars, black holes, galaxies, and planets -- that populate the Universe as we know it. I will also explain what observations have led us to believe that there is six times as much dark matter as there is ordinary matter.

The story of dark matter in cosmology is closely linked to the story of gravitation:

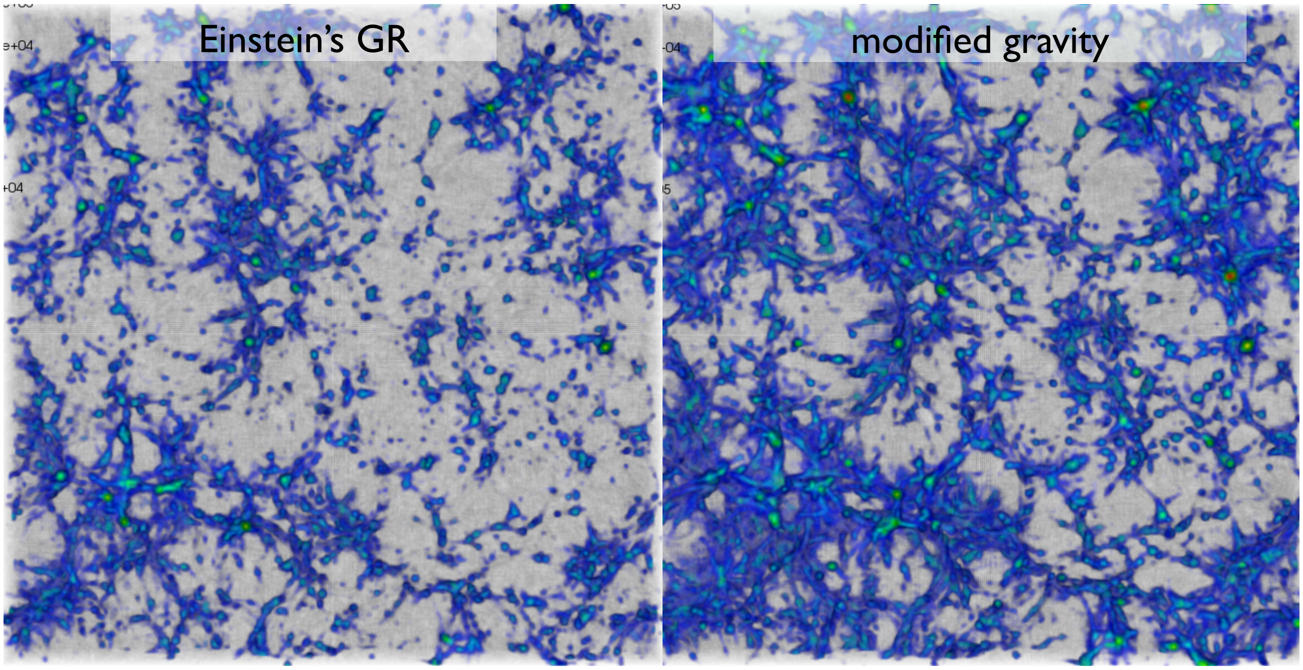
- Gravity caused dark matter to clump together and form dark matter **haloes**
- The dark matter haloes also contain regular matter, which in turn becomes black holes, stars, and galaxies
- We can see dark matter's effect through its gravitational impact on regular matter.

The "Bullet Cluster", the best *direct* evidence we have of the existence of dark matter.

Some of the most important observational techniques used to study dark matter include:

- Galaxy **rotation curves**, which let us see dark matter's gravitational effect on spiral galaxies.
- Gravitational **lensing,** which shows us where dark matter is, even when we can't see it directly. This includes two kinds of lensing:
  - ✦ **Strong** lensing, which happens near the centers of galaxies and clusters of galaxies, when there is so much mass that light is dramatically bent
  - ✦ **Weak** lensing, which happens in the outskirts of galaxies, where light is bent just a little, so that we must do many observations to find the bending. Although this may seem to be an inferior thing to observe, there is so much more space where weak lensing happens that it will, in the long term, be the most important observational use of lensing!
- Galaxy **redshift surveys,** where we use galaxies, which we can see, to infer the properties of the dark matter that we can't directly see. This assumes that galaxies live in the same place as dark matter, which we prove using other means (like those described above)

If time permits, I will also discuss how dark matter observations can give us insights into the nature of gravity, and also what kind of experiments we're doing here on Earth (even right here in Chicago!) to try to find out more about dark matter's true nature.



Images made using computer simulations from my own research, showing the effect of changing the law of gravity on the way that dark matter behaves. The colored regions here show where dark matter is dense and fast moving. Most of the modified gravity models we study make gravity stronger on long length scales than it is on Earth, which is why the "modified gravity" picture has more regions colored -- it makes dark matter move faster.

A series of images from the Hubble Space Telescope used in the research of U Chicago professor Mike Gladdders, one of the world's leading experts on strong gravitational lensing. Each of the elongated rectangles you can see in these pictures is a galaxy from the distant Universe that is magnified and distorted by the force of gravity! Prof. Gladders uses a particularly powerful computer for analyzing his images: the human brain (see lecture for details).