Topics: More on the Newtonian Friedmann equation, equivalence principle, cosmic geometry

Reading:

- Read section 3 of Ch. 23 (pp. 536-543).

Summary of work to submit:

- Nothing to hand in for Thursday's class.

Overview:

We'll have to touch on general relativity is we want to understand the implications of the Friedmann equation. Gravity is really (according to GR) the manifestation of curved spacetime. And spacetime is curved by the mass in it. Since gravity from this mass also slows the expansion of the universe, it's not surprising that the geometry of the universe is connected to its fate. ...at least until we consider the cosmological constant (which we don't do in this reading, but will soon).

Commentary on the reading, viewing, and other preparation:

The equivalence principle is the idea that underlies general relativity: acceleration and gravity are indistinguishable – equivalent, actually. And gravitational and inertial mass are equivalent. Think hard about what these two kinds of mass are – they are so different. The fact that they are equal to each other experimentally (it's why acceleration of gravity is 9.8 m/s on the Earth's surface for everything regardless of its mass) motivated Einstein to hypothesize that gravity is not really a force, but just a manifestation of curved space. Note that this implies that photons (not just matter) will take curved paths through space when that space is curved – we'll see this gravitational lensing soon.

Note as you read about the geometry that (a) the analogies shown are two dimensional (flat, sphere's surface,...) but our space is three dimensional; and (b) in 3-D, these three geometries are the only ones that obey the cosmological principle. Space is curved locally near massive objects but overall, on cosmological scales, it can only be curved in one of three ways (spherical, flat, hyperbolic). And that curvature is due to the density of mass (and energy) and that includes everything – photons, neutrinos, dark matter and even dark energy.

The examples of geometry's effect on measured angles are interesting – the most useful and important one is shown in Fig 23.9. Think about the angle-distance-size relationship in spherical geometry (easier than hyperbolic) – imagine standing on the north pole of a globe. Two neighboring lines of longitude radiate from the pole and they are separated by some angle. The biggest object that subtends that angle from your point of view would have to be placed at the equator. As you look beyond/below the equator, the lines of longitude converge – that's very different than how Euclidean space behaves.