Spacetime Geometry of the Universe

Relativistic cosmology represents the spacetime geometry of the universe at the largest scales with simple expanding universe models (also called the FLRW models). These models are essential to modern cosmology. To what extent can cosmologists make an observational case in favor of using them? The main aim of the talk is to explain two reasons why the answer to this question is surprisingly subtle. First, as with many other cases in physics, we cannot straightforwardly establish that these models fit with the observed universe without employing some assumptions of the models along the way. Observers moving along geodesices in an FLRW model see the universe as homogeneous and isotropic on slices of constant proper time. But we are not fundamental observers, so comparing what we in fact observe to what a fundamental observer would see, to determine whether it is compatible with homogeneity and isotropy, requires further calculations. But these calculations proceed on the assumption that the FLRW models hold, at least approximately. Far from being able to make a clear case for the FLRW models from the data, we almost always use aspects of these models in interpreting the data. Second, the FLRW models ignore the lumpiness of the real universe, describing instead a completely smooth, uniform distribution of matter. What does it mean to say, then, that the FLRW models "fit" the data: above what length scale do we require homogeneity to hold? How can we make sense of "averaging" the actual distribution to determine whether it is sufficiently smooth?

Such considerations lead me to argue that the FLRW models cannot be established straightforwardly from the data, but should be regarded as a working hypothesis. The models themselves are essential in interpreting cosmological observations. Contrary to some skeptics, however, this is neither unusual nor deeply problematic. Accepting the models as a framework for interpreting a wide variety of observations does not guarantee that a consistent assignment of cosmological parameters is possible. In that sense the FLRW models can still be subject to substantive evaluation. I will also assess arguments in favor of the models based on the Copernican principle. I will conclude by briefly contrasting the case for spacetime geometry at the scale of the Hubble volume, and claims regarding the spacetime geometry at much larger scales.