major conclusion is that a Hot Big Bang must have occurred; densities and temperatures must have risen at least to high enough energies that quantum fields were significant, at something like the GUT (Grand Unified Theory) energy. The universe must have reached those extreme temperatures and energies at which classical theory breaks down." (emphasis in original).

Ellis is saying that even though we can't observe the universe at that time when it was so small and temperatures were so high that quantum properties would have been significant, we can infer that this was the case theoretically, that is to say that there was a "Hot Big Bang" at the beginning of the universe with extremely high temperatures (energies) and an extremely small volume.

Thus, given the contracting size of the universe as one goes back to the origin, there will be a time such that quantum effects must come into play. However, there are some basic limitations to using quantum mechanics as a theory for the origin of the universe. As Ellis points out: "The attempt to develop a fully adequate quantum gravity approach to cosmology is of course hampered by the lack of a fully adequate theory of quantum gravity, as well as by the problems at the foundation of quantum theory (the measurement problem, collapse of the wave function, etc.)"

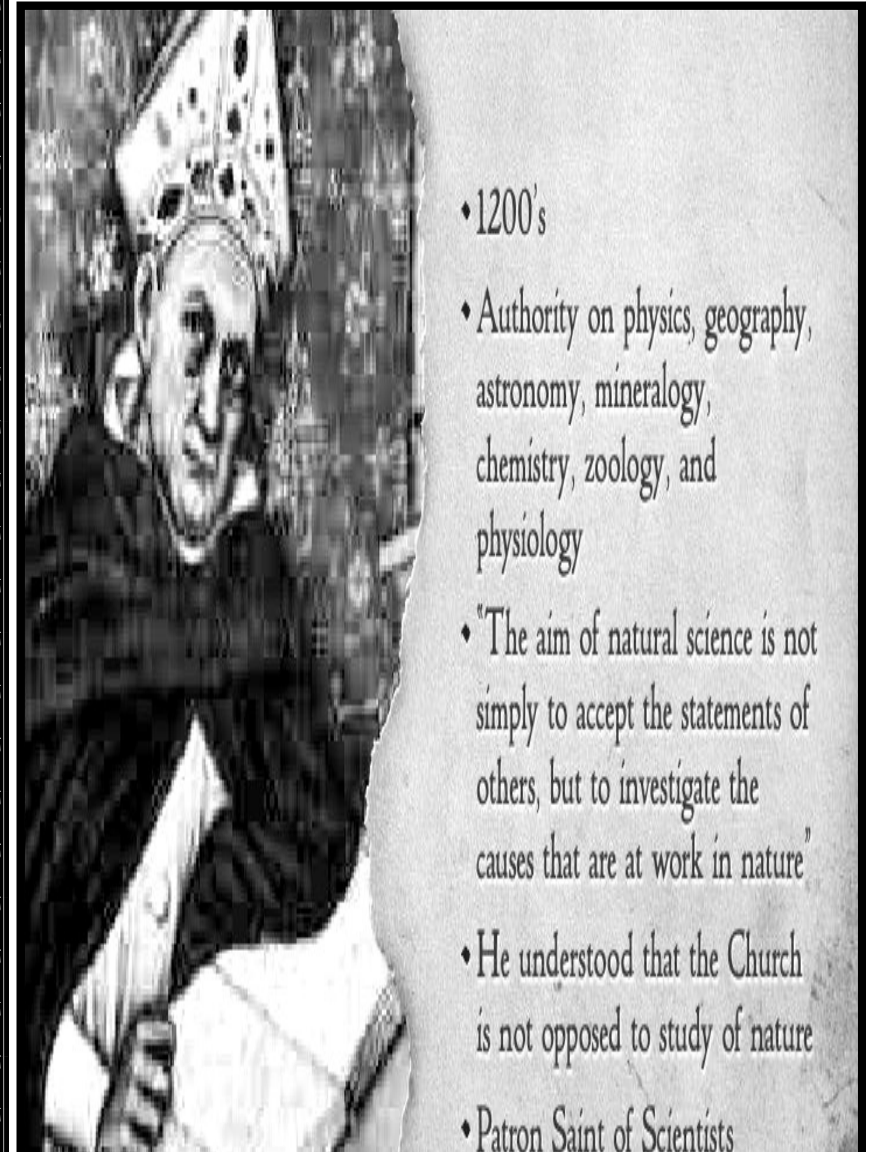
(Added later: The Hawking-Penrose Theorems shows that a class of solutions to the General Relativity equations have a singularity in the solution. Also, the Borde-Guth-Vilenkin Theorem shows that under conditions of universe average expansion, there is a beginning point. Since all such solutions are non-applicable at the singularity because quantum gravity enters the picture, the relevance of such theorems is perhaps questionable.)

See "Philosophic Issues in Cosmology 3: Mathematical Metaphysics--Quantum Mechanical Theories in Cosmology, for the ways physicists apply quantum mechanics to deal with theories of origin (or non-origin) of the universe.

Please Visit the Website: www.pamphletstoinspire.com

Catholic Physics - Reflections of a Catholic Scientist - Part 28

Philosophic Issues in Cosmology 2: Relativistic Theories for the Origin of the Universe



Philosophic Issues in Cosmology 2: Relativistic Theories for the Origin of the Universe

There was a young lady named Bright,Whose speed was far faster than light;She started one day In a relative way, And returned on the previous night. A.H.R. Buller, Punch

This is the second of seven posts, that attempts to summarize George Ellis's fine article, Issues in the Philosophy of Cosmology.

The usual exposition of Einstein's General Relativity Field Equations is very forbidding, full of Greek subscripts and tensor notation; a clear, simplified version has been given on the web by John Baez, and is appropriate for considering the Big Bang. The standard general relativity model for cosmology is that given by Friedmann-Le Maitre -Robertson- Walker, usually designated by FLRW. The FLRW model proceeds from the following simplifying assumptions: a) the universe is isotropic (looks the same in every direction, from every point in space); b) there is a constant amount of matter in the universe; c) on a large scale (hundreds of times the distance between galaxies) the universe has a homogeneous matter density (matter is spread evenly throughout space); d) the effects of "pressure" (from radiation or the vacuum) can be neglected.

With these simplifying assumptions, the equation for the "size" of the universe, its radius R, becomes simple, and looks just like the equation of motion for a particle traveling under an inverse square law, like that of gravity. (Note: this is not to say the size of the universe is really given by some value R; the universe might possibly be infinite—more about that later—but to show how space is expanding.) The universe might expand and then contract in a "Big Crunch" (like a ball falling back to earth), corresponding to positively curved spacetime (like a sphere); it might expand with a constant velocity of expansion (like a projectile going into orbit), corresponding to flat space-time (like a plane); or it might expand with an accelerating velocity of expansion (like a projectile achieving escape velocity), corresponding to a saddle-shaped curvature of space-time. It should also be emphasized that the FLRW solution to the Einstein General Relativity equations is by no means unique, nor is it the only solution with a singularity. It is a model, however, that is in accord with measured data (red shift, COBE microwave background radiation).

The assumptions stated above do not apply rigorously. Observations have shown a filament or bubble-like structure to the universe with clusters and meta-clusters of galaxies. (A theoretical picture for this filament structure has been proposed.) In the early stages of the universe radiation pressure was very likely significant. More recently, measurements have shown that the expansion rate is increasing, which is presumed due to "dark energy", possibly a pressure due to vacuum energy. Moreover, at some point in the expansion the scale of the universe gets so small that classical physics does not apply and quantum mechanics has to be used for theory. Unfortunately quantum mechanics and general relativity have not yet been reconciled into one general theory, so there is a fundamental difficulty with this melding of the two theories.

The simple solution above for FLRW models gives an acceleration of R proportional to 1/R^2, which signifies that there is a singularity at R=0, that is to say, if you try to plug in R=0 you'll get infinity. This would be the same as the infinity at the source for other forces proportional to 1/R^2, coulomb attraction or gravity. Ellis has this to say about the significance and existence of the FLRW singularity:

"the universe starts at a space-time singularity ...This is not merely a start to matter — it is a start to space, to time, to physics itself. It is the most dramatic event in the history of the universe: it is the start of existence of everything. The underlying physical feature is the non-linear nature of the EFE (Einstein Field Equation): going back into the past, the more the universe contracts, the higher the active gravitational density, causing it to contract even more....a