ASTROPHYSICS AND THE PROBLEM OF SAMPLE SIZE

submitted by:

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Anyone familiar with the problem of induction has reason to worry about our theories of the origins of the universe. After all, the universe is unimaginably large and unimaginably old. Comparatively speaking, the part we occupy is exceedingly small and the time we have been observing it is exceedingly short. Yet some of us claim to know what happened when the universe was 10^{-35} of a second old.

According to these people, our discovery of these events is among the most astonishing achievements of our species. Incredible as it seems, we have developed a technology that enables us to observe events in galaxies billions of light years away. The Big Bang Theory is based on these observations. So is our knowledge of what the universe was like in the first 10^{-35} second of its existence. We accept that theory because it makes more sense of observed celestial phenomena than its competitors.

But how confident can we really be that our instruments are accurate at these distances? Our confidence is grounded largely in our acceptance of laws and theories that are based on observations we have made rather close to home. The problem, then, is this: how do we know that these laws and theories which hold in our immediate surroundings, in our drop in the celestial ocean, hold for every other part of that ocean as well? This is especially worrisome since the occupants of some of these parts are not well understood (e.g., black holes).

The answer is that we do not know. We assume. In particular, we assume that our sample is representative, i.e., that the laws of nature we have discovered here, in our sector of the universe, hold everywhere. As an operating assumption, this makes perfectly good sense. We should accept this as a working hypothesis, at least until we have reason to believe otherwise. After all, our goal is to discover the most general laws governing the universe and that is the only way to do it. But the fact that it is reasonable for us to act on this assumption does not mean that this assumption is true, or even likely to be true. The possibility of ever discovering such laws may be extremely remote.

Suppose the universe were like a river. Rivers have calm spots and rapids, eddies and whirlpools, backwaters and back currents, bends and falls. In the spring they are high and fast; in the summer slow and dry; in the winter partly frozen. Suppose that the universe had areas that were as different from one another as the parts of a river and that it goes through cycles in the same sense that rivers do. In that case, inhabitants of any given area might develop a science that explained how the universe behaved in their particular sector and develop instruments for “observing” other areas based on that science. How adequate would instruments based on theories of how “rapids” operate during "low water" periods be for observing “back waters” during “high water” periods? More exactly, to what extent could we trust interpretations based on what such instruments detected? After all, these interpretations of our observations would be based on laws and theories that explained the behavior of "rapids" during “low water” periods.

This analogy does not assume that there are no general laws governing the universe. After all, there are laws governing the behavior of rivers. We have studied rivers and we know why there are bends, rapids, falls, whirlpools, and back currents and so forth. It may also be that there is one set of general laws governing the behavior of matter in the universe. But if so, can we assume that we have now discovered them or that we are anywhere close to doing so? If the universe really is diverse the way that rivers are diverse, we may be trying to understand the whole in terms of laws and theories that hold for a very minute part.

Of course, the river analogy merely suggests a possibility. We don’t know that the universe is diverse in this way. But we don’t know that it isn't either.

What we do know is that current astrophysical theories about the history of the universe are plagued by controversy and inconsistency. To begin with, there is all that “dark matter”. Dark matter is defined negatively, i.e., it is matter not made from quarks (protons or neutrons). Otherwise it is not understood. It is posited because we need the mass that it provides to explain the rate of expansion of the universe. According to some astrophysicists there is ten times as much mass tied up in dark matter as there is in ordinary forms of matter. According to others, the figure is as low as 29%. These differences are related to different estimates of the age of the universe. Estimates here range from 8 to 20 billion years. These differences are related to differences in estimates of the Hubble Constant (the expansion rate of the universe). According to one of the two major studies, the rate is 50km/s/mpc; according to the other it is 100km/s/mpc. Many of the differences, moreover, arise from applying different methods of calculation to the observational data at hand (methods based on different, but accepted laws and theories).

Of course, this doesn’t prove that the universe is like a river. But it is certainly consistent with that understanding. If the universe is like a river, we can expect more such anomalies. In fact, the more we “discover”, the more mysterious the universe might come to seem.

Imagine societies of appropriately minute, appropriate short lived rational beings dwelling on pebbles in or along the banks of a river. It is not impossible that the rapid dwellers could develop theories that explained not only how things work in the rapids but also how they worked in other parts of the river. On the basis of these theories, it is also possible that they could come to understand that the river originated in underground springs high in a neighboring mountain. But it is clear that they will not be able to do so if they assume that the laws that apply to the rapids apply to every other part of the river.

This is not a complaint against astrophysicists in general. Many of astrophysicists acknowledge that certain celestial phenomena are or may be subject to laws we do not now understand; laws that may not be operating in our part of the universe (because, e.g., our gravity is so much weaker). Rather it is directed against the popular conception that astrophysics (as a whole) is scientific in the popular sense, i.e., that it delivers trustworthy results based on reliable observations. This conception is promoted by even the most responsible newspapers and popular science publications when they report new “discoveries” about events billions of light years away. It is also encouraged by some of our more arrogant and/or fund seeking astrophysicists.

It may be that astrophysical theories deserve this status in relation to theories about relatively local phenomena. But it is clear that it does not deserve it in relation to the relatively distant ones. Consider a comparison to medical research. Suppose we were trying to determine the cause of a disease. We suspected a certain virus but, according to known theories, there had to be ten times more of that virus than we actually found in our blood samples (e.g., to overcome the body’s immune response). Do we reject one or more of our theories leading to this prediction or do we call a press conference to announce the discovery of a new and mysterious phenomenon, “the dark virus”, and dream of a Nobel Prize for inaugurating this exciting new field of discovery.