The Science of Science

By Nicholas Astete

"If I have seen further it is by standing on the shoulders of Giants."

Isaac Newton, who in 1676 wrote this sentence to colleague Robert Hooke, has himself become a giant in the eyes of the scientific community. With keen intellectual insight, Newton made huge advances in the sciences—particularly by developing the particle theory of light and discovering the laws of physical motion and universal gravitation. Alan Gross, however, would object to Newton's "insight," contesting his purported "discovery." While discovery implies apprehending the objective workings of nature, Gross in "Rhetorical Analysis" argues that "the claims of science are solely the products of persuasion" (389). Newton is a giant, he would say, because of his eloquent yet *invented* arguments. However, the act of rendering all scientific endeavors to rhetoric and persuasion is not something uncontroversial. Though science is certainly linked with argumentation, this doesn't give it license for speculation. A scientific theory is not a stick man supported solely by its proponents' glib tongues. Rather, even the most beautifully constructed theories must cede to experimental data because science at its core demands rigor and specific, testable claims.

The *raison d'être* for scientific theories is explaining the world around us. Measurements themselves are not enough. The luminosity of a distant star or the interference patterns on a photosensitive screen *per se* tell nothing further. As Gross notes, "the 'brute facts' themselves mean nothing; only statements [*about* the facts] have meaning ..." (390). This is where a theory steps in, incorporating many measured facts into a coherent framework.

Theories always make some logical leap because they are inductive rather than deductive processes.[1] However, this epistemological limit does not characterize science as "essentially rhetorical" (Gross 390) because theories make definite, verifiable predictions about reality. Any theory, no matter how elegant or wonderfully inventive, *must* ultimately live or die based on experimental data. "As Thomas Huxley wrote, 'The great tragedy of science—the slaying of a beautiful hypothesis by an ugly fact' " (Lederman 14).

Professor Mordehai Milgrom's article "Does Dark Matter Really Exist?" which appeared recently in *Scientific American* displays the rigor that distinguishes science from rhetoric. Cosmologists use Newtonian equations[2] to determine a galaxy's minimum required mass from measuring its rotational velocity. As there is a large discrepancy between the required mass and what

[1] Some philosophies of science recognize, in David Hume's fashion, these innate limits of our knowledge and consequently re-evaluate the scope of science (while still maintaining that it is distinct from rhetoric). Cosmologist and theoretical physicist Dr. Stephen Hawking details one such philosophy:

> According to [Karl Popper's positivist] way of thinking, a scientific theory is a mathematical model that describes and codifies the observations we make. A good theory will describe a large range of phenomena on the basis of a few simple postulates and will make definite predictions that can be tested. If the predictions agree with the observations, the theory survives that test, though it can never be proved correct. On the other hand, if the observations disagree with the predictions, one has to discard or modify the theory…. (Hawking 31)

[2] It is a common misconception that Newton was completely superceded by Einstein. Einstein's theories of relativity expanded the scope of Newtonian mechanics to very high velocities, rather than eliminating Newton. Lederman writes, "Einstein's theory of gravity also went beyond Newton's to include the dynamics of the universe ... yet when Einstein's equations are aimed at the Newtonian world, they give Newtonian results" (196). This is yet another example of how science advances on the shoulders of giants. As it is, the rotational velocity of galaxies is far from the speed of light, so Newton's equations may safely be used.

we observe, scientists have postulated that something unseen must be adding a gravitational pull to keep the observed galaxies held together—so-called "dark matter." The existence of dark matter is accepted by most cosmologists, but Milgrom proposes an iconoclastic theory called MOND, which modifies Newtonian dynamics at very low velocities and hence eliminates the need for dark matter**.** He does not speculate when addressing the vexing mystery of dark matter but instead grounds MOND with definite predictions and supporting experimental data: "Orbital velocities in spiral galaxies, instead of declining with increasing distance from the galactic center, flatten out to a constant value, as predicted by MOND .... Another success concerns the shape of galactic rotation curves ... and the correspondence with MOND is remarkable" (Milgrom 45-46). Science uses rhetoric to supplement theories by giving them some semantic meaning, by enriching gathered information with explanations. Rhetoric never comes to the forefront, though, because a theory's fit to the data is vital. For instance, Milgrom points outs that two scientists who had developed an elegant explanation to counter MOND had based their work on "crude approximations that disagree with observed dark matter halos and with detailed numerical simulations of dark matter behavior" (Milgrom 52)—and as such, their graceful yet flawed counter-theory could not sustain itself.

In his quote, Newton meant that science progresses through the effort of many people, that even great figures work from atop an intellectual edifice that spans the accomplishments of their predecessors. Gross, however, claims that this edifice is more of an ivory tower because "to become a scientific authority is to submit for an extended period to existing authorities" (399).[3]

[3] A common argument for the rigidity of science references Galileo's coercion by the Church into revoking his geocentric claim. However true this is, Galileo lived almost four centuries ago! Science since has matured significantly, and now refuses to be tossed aside when someone objects to a controversial claim. Consider the remarkable resilience in the scientific establishment of both the theory of evolution and the big bang theory, despite the howls of many Christian fundamentalist groups (though the theories' success in the classroom is a different matter).

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Yet if there *is* a tendency, it is not dogmatic but because scientists feel the current model accurately describes the surrounding world. MOND's reference to Mach's principle, which attributes an object's inertia to its interaction with the universe, suggests that science's calls to authority are not just leaps of faith. Milgrom demonstrates how Mach's principle might arise from MOND's framework due to a particle's interactions with the vacuum of space (Milgrom 52). In doing so, he does not blithely submit to the principle's authority but instead shows how it is logically associated with MOND. No rigid status quo is apparent. Further, the very existence of "Does Dark Matter Really Exist?"—a controversial article appearing as the cover story in a respected magazine, even evaluated for its merits and flaws in an accompanying article by scientist Anthony Aguirre (51)—challenges the notion of science as a static institution. Milgrom even opposes any sort of complacent reliance on his own theory, highlighting MOND's possible shortcomings (50) and concluding that "although people are right to be skeptical about MOND, until definite evidence arrives for dark matter or for one of its alternatives, we should keep our minds open" (52).

Further, scientists are very aware of the flaws of currently accepted theories, and they work toward effecting change. Nobel laureate Leon Lederman describes why change occurs:

> How does a revolution happen? During any period of intellectual tranquility ... there is always a set of phenomena that are "not yet explained." The experimental scientists hope their observations will kill the reigning theory. Then a better theory will take place .... Since there are always three possibilities—(1) wrong data, (2) old theory resilient, and (3) need new theory—experiment makes science a lively métier. (Lederman 198)

Granted, the scientific establishment does not claim to be perfect, nor are scientists purely rational. Mitchell Feigenbaum, one of the leading figures in the development of chaos theory, was scorned for his "brazen" claims. After he would teach, others would respond with "wickedly pointed talk[s] that listeners later described as ... 'antifeigenbaum lecture[s]'" (Gleick 183). Similarly, many astrophysicists held an uncharitable view of MOND during its infancy. But MOND, like Feigenbaum, eventually received serious consideration: "In recent years ... outright rejection has become much less tenable [because] MOND's myriad predictions have been confirmed. Many of these studies have been performed by those critical of, or neutral toward, Milgrom's hypothesis" (Aguirre 51). The fact that MOND's *opponents* have ended up demonstrating its resilience shows that primarily, theories rely on a good fit with the data. So while science is not flawless and perfectly oiled, its structure advances change rather than stagnation, and it operates on more than just rhetoric.

Gross's real objection seems to be that science portrays itself as having *exalted* knowledge when it doesn't. This is a valid complaint because scientists may try to bludgeon others with their supposed "superiority," to the exclusion of all other disciplines. All this really goes to show is that scientists, too, are human, but this doesn't reflect on the validity of science itself. Ultimately, Gross relies on manipulating epistemology, the fact that there is no direct and absolutely uncontestable link between observed data and scientific theories. And while this limit is important to recognize (and indeed, science hasn't ignored it), Gross fails to show conclusively that factually science is "beside, but not above, philosophy, literary criticism, history, and rhetoric itself" (Gross 389). While there is always imprecision in measurements, science *does* have a more objective stance on reality than these softer disciplines. Lamarckian inheritance, a pseudo-evolutionary theory in which the physical changes of one generation are passed onto the next (Dawkins 274), was disproved by much negative evidence, Einstein was vindicated—though his theory can never be completely proved—by the measurements of the sun bending light (Greene 75), but the question of whether humans have a tripartite soul or how society functions will never be answered as definitively. In science, intra-disciplinary standards are used to see if measurements support or maim a theory,[4] but these safeguards are *quantitative* and therefore more

[4] For instance, quantum theory's prediction of an electron's g-factor is verified to *twelve* decimal places, and this is so precise that this "spectacular agreement of theory and experiment" (Lederman 143) is self-evident. Likewise, when Newtonian physics is applied to the problem of calculating the total electromagnetic energy in an ordinary oven, the theoretical result is infinity—which obviously clashes with experience (Greene 88). These are extreme

factual. Over two millennia ago, the Greek philosopher Democritus, using reason and logic, proposed that matter might be made of tiny, unsplittable components—"atoms." But science later came along and bolstered his claim by making it specific and testable, thereby giving us a less speculative mode for questioning the world around us.

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examples, but they show that science gets along well enough using common sense as a judgment tool, but that it also measures a reality independent of common sense.