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Kuhn and the Structure of Scientific Revolutions

How does one describe the process of science as a human endeavor? How does an account of the natural world become widely accepted, be it the motion of planets or the products of a chemical reaction? And why can long held theories be supplanted by new ones that seemingly invalidate the former, such as replacing Newtonian absolute spacetime with Einsteinian relativity or geocentrism with heliocentricism? These are the kinds of questions Thomas Kuhn attempts to answer in his preeminent work *The Structure of Scientific Revolutions*. Published in 1962, Kuhn outlines a compelling vision of scientific inquiry, using prime historical examples to accompany an erudite prose, and elevating ideas such as a 'paradigm shift' into the popular lexicon. The influence of his account is still seen today in mainstream science magazines, though the results are often hyperbole. This essay will describe the Kuhnian model of scientific change and discuss how the model informs how a Discover magazine article presents an alternative theory to dark matter, a major cosmological subject among astrophysicists today.

Before beginning an explanation of this nuanced topic, it is helpful to be aware of some conditions for Kuhn's model. First, the path of scientific progress is not strictly linear. Even in times of wide acceptance for a particular theory, there are people working from different perspectives and on alternate ideas. There are numerous concurrent paths of inquiry at work with many different outcomes; some amounting to nothing, some affirming an existing theory, and some though seldom resulting in revolutions. Signs of linearized and discretized steps are primarily for didactic purposes. Additionally, Kuhn employs certain key words in defining his model, each embodying more of an idea rather than an exacting definition. Being cognizant of the manner in which these terms are used is critical to understanding the Kuhnian model.

A *paradigm* is the central construct Kuhn employs. A paradigm is a framework for investigating and explaining the natural world.[1] A good paradigm has several characteristics. First, it provides satisfactory justification for the basis of its theories that explain observed phenomenon. This avoids having the scientist constantly defend his theory from its core principles, freeing up more time and resources. Second, it outlines certain specific problems or 'puzzles' that might be solved if approached with the paradigm. Thus, the paradigm directs energy and resources towards developing better instruments, mathematics, and/or processes that might help explain the phenomena that are not yet accounted for by the paradigm. In undertaking this investigation, scientists are not actively seeking to develop revolutionary ideas that upend the existing paradigm.

[1] Kuhn, pgs. 10-11, 23

Instead, they are intended to affirm the validity of the existing paradigm.[2] As these explorations become more refined, new phenomena or anomalies may begin being observed. When this occurs, scientists attempt to provide an answer that is consistent with the existing paradigm. The steps described above are all encompassed by what Kuhn calls 'normal science', and the majority of scientists practice this for most of their lives.[3] Normal science is critical to furthering our understanding and paves the way for revolutions to occur. When a new anomaly is discovered and resists initial attempts of explanation, novel explanative ideas surface that do not fit within the existing paradigm. Scientists must look beyond the construct of the existing paradigm because of the failure of the paradigm to explain the anomaly.[4] The budding of an alternative paradigm occurs when one of these novel ideas is formulated to the point where it offers an inceptive explanation for the anomaly. The majority of professionals work to modify the existing paradigm to account for the anomaly, often spawning

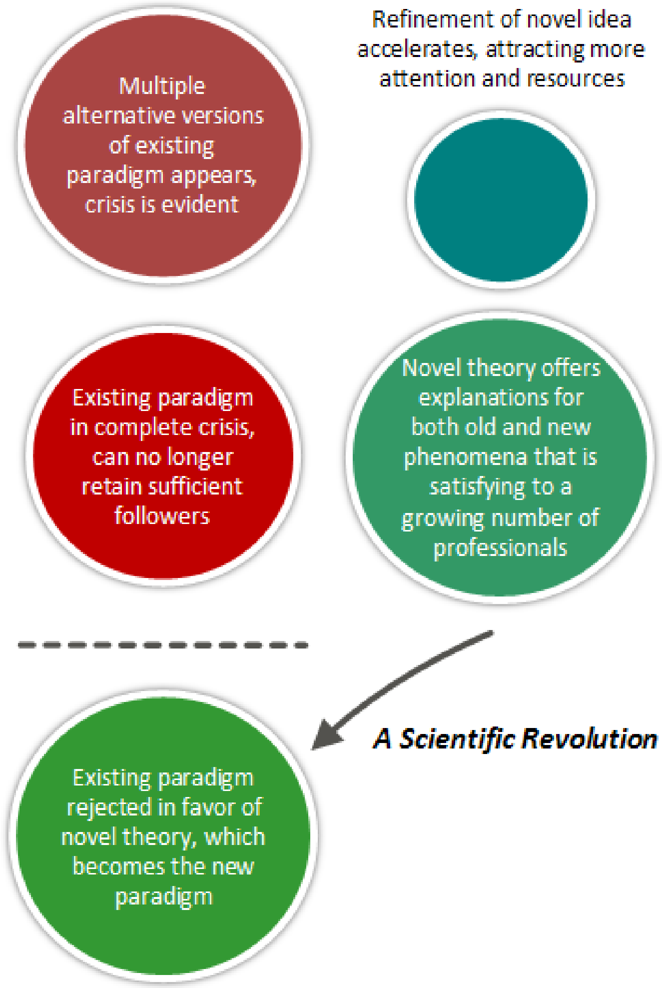

Figure 1 - Kuhnian Model of Scientific Revolution

The colors in this figure represent the overall 'health' of a theory, with red representing crisis mode. The size of the steps relates to the strength of support that a theory has within the scientific community. Note that the existing paradigm is not rejected until the novel theory is a viable alternative.

[2] Kuhn, pgs. 24, 35
[3] Kuhn, pg. 34
[4] Kuhn, pg. 68, 74-75

in turn a multiplicity of versions that are dissatisfying[5]. The qualities that previously made the paradigm favored no longer bear currency. During this time, the novel idea continues to be refined, gaining adherents and attracting the attention of more and more scientists from the existing paradigm. The novel idea soon begins to offer cogent explanations for both old and new phenomena. In contrast, the inability of the existing paradigm, in any of its forms, to confront the problem marks a true 'crisis' in its status. This concept is critical because Kuhn posits that an existing paradigm, however fractured it might be, will not be rejected until a viable alternative exists.[6] When the novel idea reaches this point, it replaces the existing paradigm and a 'scientific revolution' is said to have occurred. Sometimes, though seldom, such as with Copernican revolution[7], the novel idea emerges very early on, before the existing paradigm is demonstrated to be significantly lacking.

Kuhn emphasizes that paradigms are not easily or often overturned, particularly broad ones such as Newtonian dynamics or Darwinian evolution. Furthermore, what some narrow discipline might consider a paradigm shift may be inconsequential to another discipline. Overall, the endeavor of normal science has proven extraordinarily effective for scientific progress. Despite this, mainstream reporting of the science tends to be overly sympathetic to theories that purportedly threaten (hyped by the media) to upend fundamental paradigms. Such accounts can, however, feature elements of the Kuhnian model. An August 2006 issue of *Discover* magazine features an article by Adam Frank titled 'Gravity's Gadfly', which discusses a novel approach to arguably the most perplexing cosmological phenomena facing the astrophysics community. The problem is that observations about the growth and structure of the universe and the motions of galaxies are not consistent with our current understanding of gravity. Scientists have not seen

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[5] Kuhn, 68-69
[6] Kuhn, pgs. 66, **77**, 79
[7] Kuhn, pg. 75

enough matter in the universe to generate the gravitational forces needed to explain astronomical observations. The leading theory to solve this proposes 'dark matter', matter which does not emit light but still has mass. Frank introduces his protagonist, Dr. Mordehai Milgrom, as a heretic for not accepting the existence of dark matter. Instead of using dark matter to explain puzzling observations of galactic rotation curves, Dr. Milgrom introduced a modification to Newtonian dynamics (MOND) that explains the data at the very low gravitational forces in effect on this scale.[8] Today, the vast majority of astrophysics is behind the dark matter theory while MOND attracts only a handful of interested scientists. Let us frame this situation from a Kuhnian perspective. Dark matter theory is the existing paradigm – it has proven adept at explaining phenomena, and has directed the efforts of hundreds of physicists into discovering how dark matter can explain other phenomena. The predictions it offered concerning the cosmic microwave background radiation were confirmed[9] with satellite probes, and scientists are enthused about its continuing robustness. Dr. Milgrom's novel idea, as the Frank describes, has offered an initial explanation to a key anomaly that hold well. And, after years of refinement, MOND (actually a variant called TeVeS) has taken the next important step in accounting for gravitational lensing, a phenomenon that Einstein's general theory of relativity was the first to coherently explain. But has it become a viable alternative which would give credence to Frank's dubious claim that MOND could "tear up our whole picture of how the universe is put together"[10]? No. First, it has not attracted the significant support needed to be a worthy alternative. With just a handful of adherents, MOND has not attracted the resources or attention to be explored in detailed, leaving the theory stunted. And more importantly, MOND has yet to expose any significant fracture within the dark matter paradigm. The crisis, that interminable

[8] Frank, pg. 35.
[9] Frank, pg. 36
[10] Frank, pg. 33

problem confounds any paradigm vulnerable to rejection, does not exist. Dr. Milgrom began his novel idea because he could not accept the grounds for dark matter.[11] But the introduction of an unexplained force or particle is not new in scientific progress, and so MOND remains one of several clever ideas, not a threat to existing paradigms.

While promises of scientific revolution and upheaval by a lone scientist make for publicity and sales, it has little to do with the actual practice of science as a social endeavor. Indeed, it appears that even Dr. Milgrom is quite candid about the status of his theory, as a good scientist would be. What is remarkable about Kuhn's thesis is that is appeals both to the scientist's mandate of disinterested analysis as well as the innately human love for inspiring narrative.

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[11] Frank, 35.

Works Cited

Frank, Adam. "Gravity's Gadfly." *Discover* 27 (August, 2006): 33-37.

Kuhn, Thomas S. *The Structure of Scientific Revolutions*. 3rd Edition. The University of Chicago Press; Chicago, IL. © 1996 (1st edition © 1962).