Are We All in the Grip of a Great Attractor?

The Milky Way and all the other galaxies in the immediate universe may be under the sway of a mass to dwarf the superclusters

In a patch of sky centered roughly on the Southern Cross, astronomers are finding increasing evidence for a "Great Attractor," an enormous accumulation of mass that is perturbing the motion of galaxies for hundreds of millions of light years in every direction. If it is real—and many astronomers are still cautious—the Great Attractor dwarfs every cluster of galaxies known. Indeed, if it is real it puts a severe strain on conventional theories to explain just how such a thing could come to be.

The idea of a Great Attractor first came into prominence in the early part of 1986, when a team of seven British and American astronomers—instantly dubbed "The Seven Samurai" by their colleagues—announced that a routine survey of elliptical galaxies had turned up a decidedly nonroutine result. One of their goals in the survey had been to measure the actual recession velocity of each galaxy, and then to subtract its expected recession velocity due to the overall expansion of the universe. Their presumption was that the resulting "peculiar" motions would show how each galaxy is being influenced by the gravity of its neighbors, and would thus provide a rough indication of how the mass is distributed in the region.

What the seven astronomers found, however, was not the small-scale random motions they had expected, but coherent motion on a vast scale. The Milky Way galaxy itself, the galaxies of our Local Group, the huge Virgo cluster and all the other components of our Local Supercluster, and even some of the nearby superclusters such as Indus and Perseus—all seemed to be streaming at some 700 kilometers per second toward a point in Earth's sky near the Southern Cross. Intriguingly, that point also lay in the general direction of the massive Hydra-Centaurus supercluster about 100 million light years away. The obvious inference was that Hydra-Centaurus was actually causing the streaming motion by the shear magnitude of its gravity—except that Hydra-Centaurus itself was moving even faster in the same direction. So the Great Attractor, if it existed, had to lie somewhere beyond. It also had to have at least an order of magnitude more mass than any other supercluster in the region.

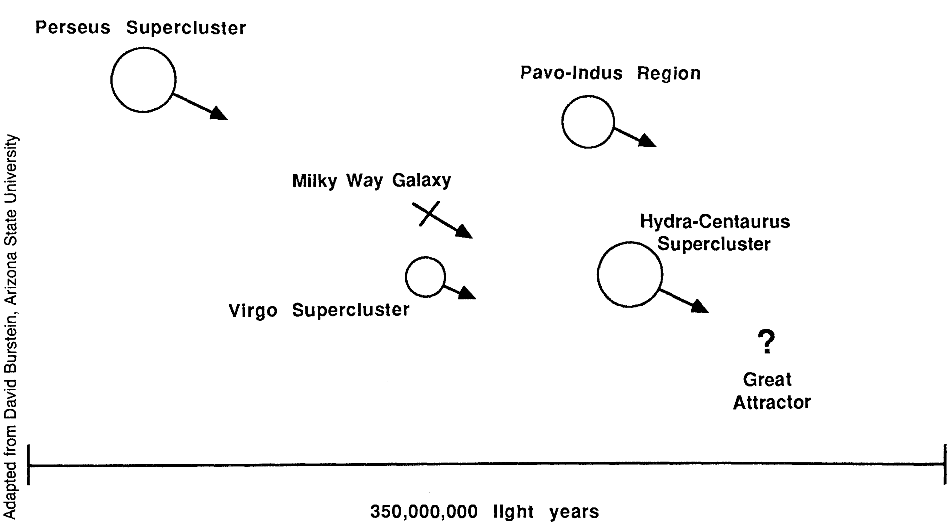
The discovery of the streaming motion caused an understandable sensation in the astronomical community, tempered by an equally understandable wait-and-see skepticism. Now, however, some of that skepticism seems to be fading as new results come in. A prime example is the recently announced work of the late Marc Aaronson of the University of Arizona, Jeremy Mould of the California Institute of Technology, and their colleagues. Working at the Parkes radio telescope in Australia, and using a distance measure known as the Infrared Tully-Fisher relation, the team of British, American, and Australian astronomers found much the same peculiar velocity for Hydra-Centaurus as that found by the Seven Samurai. Moreover, their survey measured the peculiar velocity of spiral galaxies in the region, whereas the previous survey had included only ellipticals. Thus, the confirmation not only comes from a completely independent group, but from a completely independent method.

"If you'd asked me about this a year ago I'd have been *very* skeptical," says John Huchra of the Harvard-Smithsonian Center for Astrophysics. "But the evidence is getting better all the time."

Huchra, who is himself a leader in redshift survey work, and who is widely known in the community as a hard man to convince, is now willing to concede that there is "something peculiar" in the direction of Hydra-Centaurus. Furthermore, he says, we may very well be moving in the direction of that something. "My gut feeling is that it's right," he says. However, he points to at least two major caveats.

First, he says, observers have to rule out the possibility of environmental effects—some peculiarity of galactic evolution or structure that has somehow conspired to befuddle the standard distance indicators in the Hydra-Centaurus region, and that has thereby skewed the surveys into a distribution that only looks like a large-scale flow. The recent work of Aaronson, Mould, and their colleagues is a big step in the right direction. Nonetheless, he says, "In a case like this it's guilty until proven innocent."

Second, advocates of the Great Attractor have to explain why the standard galaxy catalogs show nothing out of the ordinary in that region. Unless the Attractor is some huge agglomeration of invisible "dark matter"—in which case all bets are off, says Huchra—it is presumably a supercluster of galaxies like any other, just bigger. And yet, he says, "you look at the all-sky maps and you see some excess, but not nearly enough." On the other hand, the only available catalog of galaxies in this region of the sky happens to be of notoriously poor quality. So the objection is not yet a fatal one.



Adapted from David Burstein, Arizona State University

The large-scale streaming motion. *An observer at rest with respect to the 2.7 K microwave background radiation would see all the nearby superclusters moving at about 700 kilometers per second toward the Great Attractor—if it really exists.*

Indeed, a new observation by Alan Dressler of the Mount Wilson and Las Campanas observatories, one of the original Seven Samurai, suggests that the trans-Hydra-Centaurus region may be richer than it seems. In a recent nine-night observing run he obtained redshifts for some 600 galaxies in this part of the sky. Plotting the data along with 300 redshifts already available in the literature, he found that the distribution had two peaks. One, as expected, was at the distance of Hydra-Centaurus. But the other was 50% further away, at roughly 150 million light years. Moreover, it contained just as many points as the first.

Dressler, for one, argues that this second peak is exactly what it seems to be: the Great Attractor. To begin with, he says, galaxies are fainter when they are farther away, and we therefore see fewer of them. Correcting for that effect, one can argue that the second peak actually represents about four times as many galaxies as the first. Next, he says, one can convert the estimated number density of galaxies into an estimated mass density, and thereby come out with a mass for the region as a whole. The result works out to about ten times the mass of the Local Supercluster—which is just about what is needed for the Great Attractor.

Dressler's argument is clearly intriguing. But it is hardly proof—especially considering that it depends upon a series of assumptions about numbers and masses that other observers may want to question. Moreover, as Dressler himself points out, "to prove that the overdensity is doing the pulling you have to study other nearby mass distributions to make sure they aren't equally massive," he says. "Also, you have to study the velocities within this cluster to make sure *it* isn't moving." Nonetheless, he says, finding a major group of galaxies sitting in roughly the right place is an important step.

Assuming for the sake of argument that the Great Attractor does exist, then astronomers have to face a final question: how could such a thing form? It may not be an easy question to answer. The uniformity of the 2.7 K microwave background radiation implies that the universe was quite homogeneous when the radiation was emitted, about 100,000 years after the Big Bang. And yet, as observers have mapped our present-day universe on larger and larger scales, they have continued to find that matter is clustered on larger and larger scales. The theorists have been having enough trouble trying to explain the formation of clusters and superclusters of galaxies. The existence of structure on the scale of the Great Attractor may only make the challenge that much tougher. ■

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Causality, Structure, and Common Sense

Ordinary common sense turns out to be far too subtle for conventional theories of logic; at a minimum it demands a much better accounting of such everyday notions as causality

IN their efforts to teach computers how to show "common sense," artificial intelligence (AI) researchers in recent years have found themselves paying more and more attention to such everyday notions as causality, structure, process, and time. These are the notions that underlie our intuitive understanding of the world. They seem easy and straightforward. And yet they turn out to be surprisingly difficult to pin down in any theoretical sense. Indeed, the struggle to capture these concepts in a computer-usable form proved to be one of the strongest undercurrents in the work presented at the recent annual meeting of the American Association for Artificial Intelligence (AAAI), which was held this July in Seattle. The very profusion of names for this research—qualitative process theory, naïve physics, and temporal logic, to mention just a few—was a testament to just how broad-ranging, how pervasive, and how unsettled the problem really is.

Two survey talks presented at the meeting gave some of the flavor of these efforts. The first, which addressed the critical role of causality in common sense reasoning, was given by Judea Pearl of the Cognitive Systems Laboratory at the University of California, Los Angeles (UCLA).

Consider the following situation, said Pearl: you go outside in the morning and you notice that the grass is wet. The obvious inference is that it rained during the night. In fact, you are almost sure that it rained. However, suppose that you now learn that someone left the lawn sprinkler on during the night. Suddenly, said Pearl, your confidence in the rain goes down considerably. In other words, upon receiving a new fact, you withdraw your original conclusion.

This kind of logical flip-flop, which is known in the AI community as "nonmonotonic" reasoning, is the epitome of common sense. Unfortunately, it is also a blatant violation of the conventional theory of logic, which is the first and most obvious place that one might look for a theory of automated computer reasoning. As formulated by generations of philosophers and mathematicians, the standard formalism of logic does offer an elegant way to represent facts about the world—as axioms—and it does provide a well-defined method for drawing conclusions from those facts: state each conclusion as a theorem and then prove that theorem. Indeed, it is for precisely this reason that AI researchers have spent so much time devising fast and powerful algorithms for computer theorem-proving. However, the standard theory of logic also implies that a new axiom (a new fact) can never change the validity of a previously proved theorem (a previous conclusion); the most it can do is allow the computer to prove new theorems that it could not prove before. In a word, conventional logic is "monotonic."

Clearly, then, something more flexible is needed for common sense reasoning. The question is what? Fool around with the rules of logical inference and it is all too easy to prove that grass is simultaneously green and purple.

This question of nonmonotonic reasoning has become something of a cause célèbre in the AI community during the past decade, and not only because of its deep theoretical significance. Those same 10 years have also seen a sharp rise of commercial interest in the so-called expert systems, which are programs that are supposed to give expert-level advice in fields such as medical diagnosis or tax planning. The expertise in these systems is ultimately provided by human specialists in consultation with the programmers. But because the knowledge is often uncertain ("If the patient has symptoms X, Y, and Z, then he *most likely* has disease D"), the program will almost always arrive at conclusions that are tentative—just as the human experts do. And for that very reason, expert systems have to be able to revise their conclusions ("The patient's nausea is caused by something she ate") on the basis of new evidence ("The patient is pregnant"). In other words, some approximation of common sense is absolutely critical.

To get a feel for the difficulty, said Pearl, consider the aforementioned lawn: after