Extreme Phenomena Abound

Tales of a single-note black hole symphony, cannonball pulsars, and electrons clinging for dear life.

by Christopher Wanjek

After searching for a unifying theme that would have tied together belching black holes, flying pulsars, and dwindling physical constants (I was shamefully toying with a U.S. economy analogy), I decided to lay out a month's worth of exciting results one by one. This will spare the reader any forced segues.

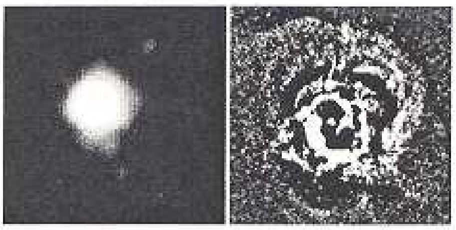
Let's begin with the closest. Using the European Space Agency's XMM-Newton observatory, scientists captured an X-ray image of the Geminga pulsar flying through space at mach 20 (22,000 kilometers per hour), with fiery twin tails of X-ray light stretching nearly 3 billion kilometers from this tiny, dense sphere.

Featured in the September 5 *Science*, this is the first clear image of a pulsar's X-ray bow shock, tracking Geminga's flight in 3D. Geminga, at 500 light-years, is the closest known pulsar to Earth. The image provides the first *in situ* measurement of the density of the interstellar "ocean" that Geminga is plowing through. Scientists hope to soon ascertain independent measurements of key pulsar properties now estimated with optical data: mass, radius, magnetic field strength, and the speed at which such pulsars are "kicked" when born in supernovae.

Considerably deeper in the cosmos, a black hole in the Perseus galaxy cluster appears to be bellowing a B-flat. How can there be sound in space, you ask? It is true that there is no sound in a vacuum. Sound waves travel by compressing a medium, such as the air on Earth. But space isn't a complete vacuum.

The sound from Perseus, detected by NASA's Chandra X-ray Observatory, is a result of pressure waves emanating from outbursts in the accretion disk of the supermassive black hole at the center of the giant galaxy Perseus A. The sound waves churn through the hot gas in the Perseus cluster, some 250 million light-years across. Each wave is about 30,000 light-years across with a 10-million-year period of oscillation. Humans cannot hear sound with a period lower than 0.05 second. The inaudible black hole is 57 octaves below middle C, which is even lower than the smooth baritone of the late, great Barry White.

But this finding is about X rays, not sound. The sound was "seen" as ripples in the abundant X-ray-hot gas in between galaxies. Most of the visible matter in the Perseus cluster resides as hot gas between galaxies, not in the thousands of galaxies that make up the cluster. Scientists have long wondered why cluster gas is so hot, and now they have one possible answer: black holes might be energizing the region with pressure waves.



Left: XMM-Newton captures the bow shock and an X-ray tail of the pulsar Geminga as it plows through interstellar space at mach 20. Courtesy of ESA/XMM-Newton/Patrizia Caraveo, et al. Right: Special image-processing techniques from a 53-hour Chandra observation reveal what appears to be sound waves emanating from the supermassive black hole in galaxy Perseus A. The black hole is the white spot in the middle. Courtesy of NASA/CXC/IoA/Andrew Fabian, et al.

Journeying deeper yet into space, two scientists have found one possible reason why, in this topsy-turvy world of changing trends and stormy alliances, even the fundamental constants of nature don't seem constant anymore.

The bond between electrons and protons, called the fine structure constant, or alpha, may not be constant and may have been 0.0005% weaker about 10 billion years ago. That might not sound like a big deal, but if it is true, it messes up a lot of our current thinking about the universe. If correct, this result implies that the spectral signature of light varies through the ages. Thus, scientists over the past decades might not have been correctly reading the spikes in spectrographs that signify the identity, temperature and velocity of specific atoms emitting the light — particularly distant quasar light.

The change in alpha, announced in 2001, is still hotly debated (see "Are the Physical Constants Constant?" Nov/Dec 2001). Luis Anchordoqui and Haim Goldberg of Northeastern University took an "all right, what if" approach. In a paper in *Physical Review D*, they said the apparent tiny shift in alpha through the years may mirror the apparent accelerating expansion rate of the universe, as if electrons and protons clung ever more tightly together as the universe began to fly apart.

They find that alpha may be coupled to "quintessence." This theory of dark energy, one of many, says a mysterious universal repulsive field, once weaker long ago, now dominates over the force of gravity and is causing the universe to fly apart at an ever-expanding rate (see "Decoding Dark Energy," Sep/Oct 2003). So, alpha was measurably weaker 10 billion years ago, but as quintessence assumed dominance about 8 billion years ago, the force between electrons and protons became stronger and "more constant." The strength of the electron-proton bond from any atoms created anytime within the last several billion years is essentially indistinguishable from one another. This rectifies why scientists have detected no change in alpha in most starlight.

A changing alpha departs from the standard model of physics and may point to modifications introduced by string theory, the modern Theory of Everything that attempts to unify the 4 fundamental forces in nature. More power to these scientists. I had a tough time just unifying these results in a simple column.

CHRISTOPHER WANJEK of NASA/SP Systems prefers the B-flat featured on Miles Davis' Kind of Blue.