characteristics that happen to be amalgamated by culture. All too often, though, the decision of what to study is driven by socio-medical politics rather than biological logic.

The study by Caspi *et al.* (*9*) also analyzed a promoter region polymorphism, in this case for the gene encoding monoamine oxidase A (MAOA), an enzyme that breaks down the neurotransmitters serotonin, dopamine, and norepinephrine. Although the MAOA gene had previously been implicated in aggression and impulse control in both humans and rodents (*10*), this transcriptional variant had not been associated with personality traits (*11*). Caspi *et al.* hypothesized that the effect of the gene would be more readily revealed if the environment were explicitly taken into account.

Their study group was a large birth cohort, representative of the male population of New Zealand, whose development had been carefully followed for 26 years. The environmental variable of interest was childhood maltreatment, and the outcome was a composite measure of antisocial behavior. Although the MAOA genotype by itself failed to predict antisocial behavior, there was a significant interaction with childhood history; individuals with both a low-activity genotype and previous maltreatment were by far the most likely to have committed a violent crime and to be diagnosed with conduct disorder. Over 85% of the males who had both "bad genes" and a "bad environment" developed some form of antisocial behavior by the time they were 26. It will now be crucial to repeat this intriguing finding on other populations with documented developmental histories.

The serotonin transporter and MAOA stories nicely illustrate how changes in regulatory rather than coding sequences can influence brain function and behavior. Such variations in gene expression probably play a predominant role in many types of individual differences, but this has been difficult to prove in humans because we are so genetically outbred. Yan and colleagues (*12*) devised an elegant solution to this problem. They measured the expression of different alleles in a single person who was heterozygous for the locus in question, thus avoiding the problems of extraneous differences in genetic background or other factors. Remarkably, even though most of the variations they studied were random single-nucleotide substitutions far from the promoter region, almost half of them were associated with detectable changes in messenger RNA levels. A few of the genes they studied are expressed in the brain, and many more will soon follow.

Although the Hariri, Caspi, and Yan reports provide tantalizing glimpses of how the study of complex traits can be improved, they are still at the primitive stage of examining single genes. This isn't how the brain works. Human behaviors, and the brain circuits that produce them, are undoubtedly the product of intricate networks involving hundreds to thousands of genes working in concert with multiple developmental and environmental events. Further advances in the field will require the development of techniques, such as microarray analysis, that measure the activity of many different genes simultaneously. Only then will the gene hunters have a shot at achieving the promises held out by the past century of classical behavior genetics research.

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PERSPECTIVES: COSMOLOGY

The Cosmic Web of Baryons

Joel N. Bregman

About 80% of the mass in the universe is composed of "dark matter," which can only be detected through its effects on gravity. The nature of this material is entirely unknown. The remaining 20% is the kind of matter that we are all familiar with. Known as baryons, this matter forms the stars and galaxies in the local universe. But all the stars contain less than a tenth of the baryons that existed when the universe was young (*1*, *2*). Four recent papers shed light on the whereabouts of the missing baryons.

A few minutes after the big bang, the first elements—helium, deuterium, and trace amounts of other light elements—were produced. The relative amounts of these isotopes and elements are sensitive to Ω_b, the ratio of the baryon density to the critical density of the universe (*3*). Abundance measurements of primordial deuterium and other isotopes show that $\Omega_b = 0.04$.

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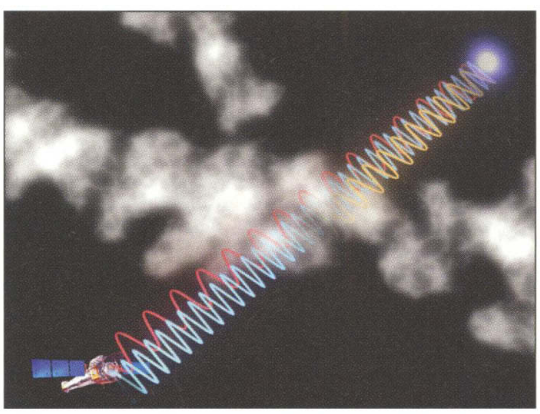
A few billion years later, when the universe was about one-quarter of its current age, active galactic nuclei (enormously luminous objects powered by massive black holes in the centers of galaxies) formed. In their spectra, we see absorption lines from very distant gas distributed across the universe. This gas is either neutral or moderately ionized, with a temperature below ~20,000 K. A veritable forest of absorption lines from hydrogen, the most common element, tells us that at this time, $\Omega_b = 0.04$, the same as shortly after the big bang.



Absorption by intergalactic gas. This artist's impression shows how x-ray emission from a distant active galactic nucleus reaches the Chandra x-ray observatory. Some x-rays are absorbed by gas filaments in the intergalactic space. See chandra.harvard.edu/photo/2002/igm/index.html.

CREDIT: A. HOBART/SAO/CXC

In the present-day universe, this "forest" of gas absorption lines has nearly vanished. At first, the gas was believed to have been incorporated into the galaxies and stars that we see today. However, a mass census of the local universe shows that the baryons in galaxies and cool gas amount to only $\Omega_b = 0.004$. Hence, 90% of the baryons must be located elsewhere.

Gas is still found between galaxies. For example, galaxy-clusters contain a stable hot atmosphere of gas with temperatures of up to 10^8 K and masses as great as, or greater than, those of the galaxies. Yet even including the gas in these clusters (and in less massive groups of galaxies), most of the baryons are still missing.

Theoretical calculations suggest a solution that features "filaments" of matter formed by gravitational collapse. The filaments, which are much larger than galaxy clusters and not nearly as dense, connect the many galaxy clusters and groups in a cosmic "web" of baryons. Theorists predict that the missing baryons in these filaments have high temperatures (10^5 to 10^7 K) but low densities, making them particularly difficult to detect (*4*).

At these temperatures, oxygen exists with one, two, or three bound electrons (OVIII, OVII, and OVI, respectively). It is the most abundant element that is not fully ionized under these conditions. OVI has strong absorption lines in the ultraviolet, whereas OVII and OVIII absorb and emit at x-ray energies. Recently, researchers have found the first observational evidence for the "missing" baryons by detecting these absorption and emission lines with four different space-based telescopes.

X-ray and far-ultraviolet absorption lines from oxygen can be detected against some extremely bright active galactic nuclei with the Chandra observatory, Far Ultraviolet Spectroscopic Explorer (FUSE), Hubble Space Telescope (HST), and the XMM-Newton telescope. The strongest absorption lines are not redshifted and hence originate near our Milky Way Galaxy (*5*, *6*). Nicastro *et al.* (*7*) argue that absorption does not occur in our galaxy but in a dilute gas that fills, and may extend beyond, our Local Group of galaxies. This interpretation agrees with theoretical expectations. Several other groups of galaxies are known to contain hot gas from their diffuse x-ray emission.

At redshifts beyond the Local Group, absorption lines from the same oxygen species are seen in the spectra of a few active galactic nuclei. Fang *et al.* (*8*) and Mathur *et al.* (*9*) have detected absorption by intervening OVII and OVIII gas, providing evidence for the hot gas predicted by theory. In the far ultraviolet, Savage *et al.* (*10*) have detected OVI along several sightlines, demonstrating that gas at 10^5 to 10^6 K is plentiful.

In a different approach, we (*11*) have detected hot x-ray–emitting gas with a shadowing technique. Hot diffuse baryons produce a faint x-ray glow around the sky, but other sources of diffuse x-ray emission, such as the Milky Way, must be excluded. This is accomplished by using the cold gas in another galaxy, which absorbs the background diffuse x-rays, leading to a shadow in the background emission that we observe.

The detection of hot diffuse baryons (*7–11*) is a major step in our understanding of the present state of the universe. However, the important quantitative work still lies before us. The most rapid progress is likely to come from efforts to study OVI absorption with FUSE and HST in the next few years. OVI emission will be studied by NASA with a Small Explorer named "Spectroscopy and Photometry of the Intergalactic Medium's Diffuse Radiation," scheduled for launch in 2005.

At x-ray energies, additional efforts are planned to detect absorption and emission from the cosmic web with Chandra and XMM-Newton. These studies are limited to a few of the most favorable targets owing to sensitivity limitations. Such limitations will be overcome by the Generation-X telescope planned by NASA.

Collectively, these observations will determine the mass of baryons in the cosmic web along with their spatial structure and temperature distribution. These data are fundamental to understanding the formation and evolution of the structures in our universe.

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PERSPECTIVES: ASTRONOMY

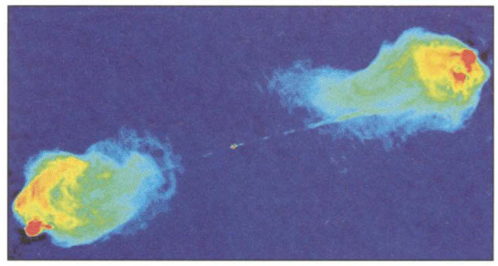
Microquasar Fireworks

Michael P. Rupen

Over the past decade, astronomers have discovered several transient, highly relativistic jet sources associated with stellar-mass black hole binary systems in our galaxy (*1*). These are called microquasars, by analogy to the much more powerful relativistic jets found in radio galaxies at moderate distances, and to quasars at the edge of the known Universe.

In radio galaxies and quasars, the jets are powered by accretion onto massive black holes. They are surprisingly efficient at transporting the resulting energy out to large distances, often well beyond the edge of the host galaxy (*2*, *3*). There the jet may collide with the intergalactic medium, releasing its bulk kinetic energy in a terminal shock, from which the material flows back to inflate huge radio lobes (see the figure).

Enhanced online at www.sciencemag.org/cgi/content/full/298/5591/73



The radio galaxy Cygnus A. A narrow, highly collimated jet links the central core to the outer lobes. The lobes extend to ~195,000 light years from the center—double the optical radius of the host galaxy. The very bright "hot spots" at the ends of the jets are thought to be the areas where the jet hits the surrounding intergalactic medium; the resulting shock produces high-energy particles and fields, and the splashback creates the huge radio lobes. In most microquasars, the inner part of the jet is seen but the interaction region is missing. Original data from (*8*).

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The jets in microquasars seem very similar in terms of speed, power source, and collimation. One would therefore expect similar fireworks when they hit the interstellar medium. A few unusually steady and long-lived sources (*4*) show signs of such collisions, but most microquasars do not; in fact, there is little evidence that these short-lived jets interact at all with their surroundings. This is not too disturbing for any individual source: Some jets remain collimated but fade as they move out, and others may expand and get lost in the background. But some microquasars must surely interact with the interstellar medium at some point. On page 196 of this issue, Corbel *et al.* (*5*) report evidence that they do.

Like most other microquasars, XTE J1550-564 was discovered when it underwent a strong x-ray flare. Such flares are usually interpreted as the result of runaway accretion in a black hole binary star system. Observations with very long baseline interferometry (*6*) resolved the associated radio emission into three emission "blobs" roughly oriented along an east-west line. The system thus bore the hallmarks of a typical microquasar radio jet.

Transient microquasars' jets usually move out with roughly constant velocity and rapidly fade below detectability. But XTE

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