cally, and the same sequence could be repeated at different sites—and so the probes might be finding the same sequence at different places in the Y chromosome from different men.

Evolutionary gumshoe. *Michael Hammer is hot on the trail of Adam.*

Researchers in the field say they need the nucleotide sequence—or at the very least a clear location for the polymorphism—to be able to trace when a particular piece of DNA appeared in human males. By having the site or sequence, geneticists can determine if the genetic material also appears in the same location in the DNA of a comparison group—such as chimpanzees. If it's present in both human males and chimps, it seems likely that it was present in a common ancestor and wasn't a later evolutionary addition.

Having established that a particular sequence was, in fact, present at the beginning of the human species, the researchers working on the Y chromosome could then figure out when and how variants on the sequence came into being in different populations—being added or deleted by mutation or by exchange with other chromosomes. "I think if we want an answer about human evolution, we'll have to do it by sequencing," says Lewontin. "Only sequencing will give us unambiguous information. Once that's done, then we can talk about trees." And some groups, such as Goodfellow's in London, are already doing just that.

But, for evolutionary studies, DNA sequencing means rapid analysis of DNA from hundreds of blood samples from around the world. That kind of work was impossible until a few years ago, when the polymerase chain reaction (PCR) came into use. The availability of PCR jump-started studies of the Y chromosome—and the first Y-specific gene was cloned 3 years ago. And geneticists working in the field say that PCR—and the accompanying innovations in gene cloning and automated nucleotide sequencing—offers the best chance of understanding human evolution through the Y chromosome. "I'll put my money on those taking advantage of the new technology," says Page.

One leader in using sequencing to study the Y is Hammer, who has been analyzing a 3000-base sequence of Y chromosome DNA in populations from Japan, Asia, Europe, the United States, and Africa. Early results identified nucleotide polymorphisms distinguishing Africans and Europeans. Hammer, however, is reluctant to draw any conclusions about a common ancestor until he has sequenced the region in other populations.

Dorit's group at Harvard is also sequencing Y chromosome DNA, and their early results are surprising—but largely for what they did *not* find. In an analysis of an 800-base region of DNA, Dorit complains that he found "no variation at all, zip, nada" between 16 males who were Nigerian, Japanese, Latin American, African, American, and of other ancestry. That has raised a number of questions, which Dorit is trying to answer with hypotheses such as the "Genghis Khan" approach, in which a few warriors swept across wide geographic regions, raping and pillaging and fathering far more than their share of children.

It's just this kind of conflicting data—along with the paucity of known and specifically located polymorphisms—that makes work on the Y chromosome challenging. "Ten thousand scientists working 24 hours a day aren't going to make more variation appear on the Y chromosome," sighs Dorit.

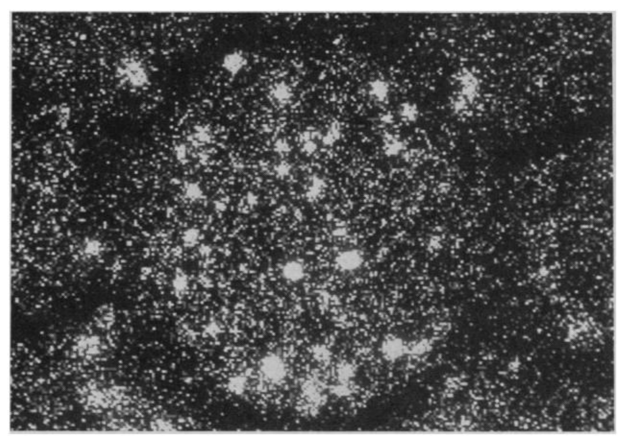
And to build a really convincing case, it will require sequencing many polymorphisms, not just one or two.

Finding those variants—which are like needles hidden in a genetic haystack—will require sampling an array of populations. Several researchers are calling for a cell line repository so that all researchers in the field can work with DNA samples from the Y chromosome, mitochondria, and nuclei of cells from defined populations. Kidd at Yale, along with Luca Cavalli-Sforza at Stanford University, has assembled 800 cell lines. But despite his efforts, Kidd has been unable to secure funding that would enable him to share the cell lines more widely.

Ultimately, researchers say they will have to share samples and analyze them with a variety of methods to build a convincing case that their data really are giving them a glimpse into the past. "I think all the systems being studied—mitochondrial, nuclear genes, and the Y chromosome—will be important for finding the answer," says Hammer. "It won't be just one person saying, "Aha! I found the answer. It's a large task for lots of labs to be involved in." And the way the field is growing, it probably won't be too long before more labs are involved. ■ ANN GIBBONS

The Cosmic Eye of Rosat

Philadelphia—For half a decade now, cosmologists have been increasingly confounded by their discovery that galaxies are clustering on scales much larger than the current theories of galaxy formation can explain. But now the researchers may be getting some help from a new eye in the sky, the German–British–U.S. Roentgen satellite (Rosat).



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The glow of cosmic x-rays. *Made by a British team, this Rosat image is much like the one discussed by Hasinger; it shows dozens of quasars amidst the x-ray background.*

The first inkling of this came at the American Astronomical Society meeting here, where Rosat team member Günther Hasinger of the Max Planck Institute for Extraterrestrial Physics in Garching bei München, Germany, presented a long exposure x-ray image showing what may be evidence for the earliest galactic clustering ever seen. Since this is a phenomenon that nobody understands very well yet (*Science*, 18 January, p. 272), astronomers such as George Blumenthal, a leading theorist on galaxy formation at the University of California, Santa Cruz, see it as "potentially a very exciting result." In principle, he added, "This could give us a direct measure of when galaxy clustering begins."

The image in question was something of a target of opportunity, Hasinger told meeting attendees. In the months since Rosat was launched in June 1990, it has spent the bulk of its time systematically scanning the sky to complete its initial objective: an all-sky survey of x-ray sources that will have better angular resolution and more than 100 times better sensitivity than the landmark examination of x-ray sources carried out in the late 1970s by

NASA's Einstein satellite. The Rosat survey will be completed on 7 February. Only then, said Hasinger, will mission scientists start pointing Rosat at specific targets for more detailed study.

In the meantime, however, as a kind of preview of coming attractions, Hasinger and his colleagues have generated a prototype exposure by digitally combining many images from the north ecliptic pole, a point in the sky where Rosat's survey scans overlap. The result, the equivalent of a single 8-hour exposure, covers an area about the size of the full moon and looks out farther into the universe than any x-ray image before it.

Qualitatively, the image is similar to week-long exposures made 10 years ago by NASA's Einstein x-ray satellite. Like the Einstein images, said Hasinger, it shows dozens of bright, compact blobs, most of which are quasars roughly 10 billion light-years away. Assuming that this area is typical, such numbers correspond to roughly 4 million quasars in the whole sky.

If nothing else, Hasinger said, this shows that x-ray scans are "the most efficient way of discovering quasars." Astronomical x-rays are generally produced by very hot sources, where temperatures reach into the millions of degrees. And quasars are among the hottest. They are thought to be otherwise normal galaxies that have somehow formed a black hole in the center with a mass about one billion times that of our own sun. The extraordinary luminosity of quasars is presumably the result of gas and stars spiraling inward and releasing one last, thermonuclear burst of energy before disappearing into the hole forever.

In addition to the quasars, however, the Rosat image also shows something even more intriguing: a light sprinkling of data points that seems to cover everything in the focal plane, as if the satellite had been caught out in a gentle rain of x-ray photons coming from every direction in the universe. This is the diffuse x-ray background, which has baffled astronomers since it was discovered in 1962. It doesn't seem to come from anywhere within our own solar system, or from hot gas drifting between the galaxies, or from anything else in the immediate cosmic vicinity.

This new image certainly doesn't solve the mystery, said Hasinger. But because of the improved quality of the Rosat instrumentation, it does offer a clue. For the first time, he said, it shows hints that the x-ray background may not be perfectly uniform. It seems to be slightly broken up into clumps, which are statistically non-random. Moreover, the clumps seem to have an x-ray spectrum quite similar to that of the quasars in the image—as if the clumps consisted of groups of quasars just a little too far away for Rosat to resolve. If so, said Hasinger—and he stresses that this interpretation has not yet been verified—then distant quasars could account for as much as 50% of the x-ray background. The remaining 50% (see accompanying box) may be due to newborn galaxies.

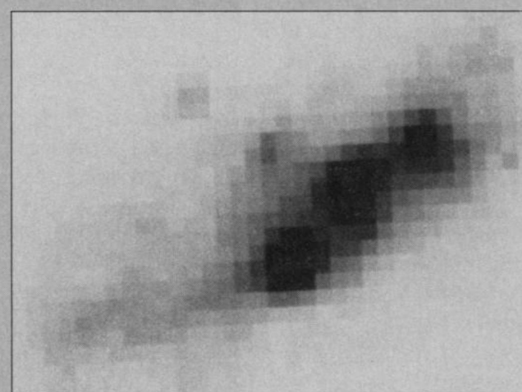
Furthermore, said Hasinger, these clumps would also represent the clustering of galaxies—or at least quasar-bearing galaxies—as they were some 10 billion years ago, when the light emitted by the quasars began its journey to Earth. That's what has Santa Cruz' Blumenthal so excited: If real, the quasar clusters would be almost ten times older than the clusters of visible galaxies. They might therefore help cosmologists understand the origin of structures such as the recently discovered "Great Wall," a vast membrane of galaxies stretching through the nearby universe for hundreds of millions of light-years. Supporting this interpretation is the fact that the clumps, if they are indeed at the distance of the quasars in the image, are about the size of a modern-day supercluster of galaxies.

Hasinger is the first to warn that this is an awful lot of extrapolation from one image. Confirming the existence of these quasar clusters is going to need a lot more observation by Rosat and by other telescopes at other wavelengths. But then, says Hasinger, that is certainly going to be among the Rosat researchers' earliest priorities when the satellite begins its new phase of targeted observing on 7 February.

■ M. Mitchell Waldrop

Looking for the Hard Background

Even if half the x-ray background can be explained by the emissions from millions of distant quasars, as suggested by the recent Rosat results (see story), that still leaves the problem of explaining the other half. But veteran x-ray astronomer Richard Griffiths of the Space Telescope Science Institute in Baltimore told the recent American Astronomical Society meeting in Philadelphia that the answer to that part of the mystery may also be in hand. He and his colleagues at the institute have recently obtained evidence that much of the background consists of energetic x-rays from millions or billions of very young and very distant "starburst" galaxies, which are ablaze with their first massive waves of star formation.



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Starburst. *Rapid star formation in this galaxy is generating lots of hard x-rays.*

Astronomers have known for more than a decade that quasars can't be responsible for all the x-ray background, explains Griffiths, because the spectra don't match. Many of the x-ray background photons have energies running as high as 40 Kiloelectron volts, too "hard" to be emitted by quasars. In fact, says Griffiths, the only astronomical objects that do emit such hard x-rays in significant quantities are the x-ray binaries, in which a tiny, incredibly dense neutron star is siphoning gas from an otherwise normal companion star and pulling the material down onto its surface with thermonuclear force.

And that's where the starburst galaxies come in: "If you make lots of massive young stars all at once," says Griffiths, "you should also get fair numbers of massive young x-ray binaries." Griffiths and his colleagues have now confirmed this idea by carrying out a systematic survey of nearby galaxies that are undergoing bursts of star formation because of disturbances or collisions. These starburst galaxies are indeed copious sources of hard x-rays.

But are there actually enough such starburst galaxies at very large distances to account for all the x-ray background not due to quasars? Quite possibly, says Griffiths. Using very long exposures at visible wavelengths, other astronomers have shown that every piece of "empty" sky is actually covered with a dense patchwork of faint, distant objects whose bluish color is highly suggestive of their being hot, young starburst galaxies. "I don't say that the mystery of the x-ray background is completely solved," he says. "But we've come a long way."

■ M. M. W.