Intergalactic space: Something's making X-rays

Where galaxies associate in clusters, X-ray sources appear to inhabit the space between them. Theorists are perplexed.

by Dietrick E. Thomsen

The emptiest space of all is supposed to stretch between the galaxies. The space within galaxies, astronomers have learned lately, is far from empty. In spite of what old textbooks used to say, intragalactic space is full of gas and dust clouds.

Still it seemed that there was nothing outside the galaxies. Pure emptiness, the absolute vacuum our schoolbooks talked about, ought to reign there. Today astronomers are not so sure. The X-ray satellite Uhuru has been observing and recording celestial X-ray sources for more than a year. It has given evidence that there is something in the space between galaxies, at least between galaxies that associate in clusters, something that emanates X-rays.

Uhuru first reported extended sources of X-rays in the galaxy clusters in the constellations Virgo, Perseus and Coma (SN: 1/29/72, p. 76). Now the second Uhuru catalogue of X-ray sources has been compiled, and it seems to show that those cases are far from unique. In the May 1 ASTROPHYSICAL JOURNAL LETTERS a group of the X-ray astronomers who work with Uhuru (Herbert Gursky, Al Solinger, E. M. Kellogg, Steven Murray, Harvey Tananbaum and Riccardo Giacconi of American Science and Engineering in Cambridge, Mass., and A. Cavaliere of the European Space Research Institute in Frascati, Italy), report that there are dozens of sources that appear to be galactic clusters.

They conclude that most if not all of what they call rich clusters include diffuse regions of X-ray emission. Such regions are of large physical size: The ones in Coma and Perseus are at least 0.9 megaparsecs across (about 3 million light-years); the Virgo one about 0.2 megaparsecs (650,000 light-years). Their X-ray output is also quite bright: in excess of 10^{44} ergs per second for Coma and Perseus.

Theorists are receiving this information with avid interest. With his usual ebullience Geoffrey R. Burbidge of the University of California at San Diego told the recent Washington meeting of the American Physical Society, "The theoretician is in very good shape. Most of the things we'd like to know, we don't know." The subject is thus open for suggestions and speculations, and Burbidge proceeded to review the principal ones, "the three mechanisms everyone talks in terms of."

The three possibilities are synchrotron radiation emitted by electrons orbiting in magnetic fields at relativistic speeds; Compton radiation, in which photons of non-X-ray wavelengths collide with electrons and are shifted to the X-ray range; and thermal bremsstrahlung radiation from hot gas.

Synchrotron radiation appears to be an important source of radio and optical emanations from the same clusters, and one might suspect that it was at work in the X-ray part of the spectrum too. But, Burbidge points out, X-ray synchrotron emission requires much higher energy electrons and stronger magnetic fields than synchrotron emission at longer wavelengths. For X-rays of 10 kilo-electron-volts energy (about one angstrom wavelength), which is roughly the area in question, a magnetic field of a thousandth of a gauss and electrons of 50,000 billion electron-volts (50,000 GeV) are required.

Assuming that there is some mechanism to accelerate electrons to such fantastic energies and eject them from galaxies, they would last only a few weeks before they were degraded to energy levels at which they would no longer radiate X-rays. For continuous X-ray emission from an extended region, the electrons have to be periodically reaccelerated in the intergalactic space. It is hard to imagine a mechanism that could do the job and yet remain invisible.

The case could be saved for synchrotron radiation, says Burbidge, if the sources could be resolved into small regions in the neighborhoods of active galactic nuclei. This is possible in the case of some extragalactic X-ray sources, but those in galactic clusters are shown to have large linear sizes. For these, says Burbidge, "you can leave out the synchrotron process."

The idea of bremsstrahlung from a hot gas is attractive to many, for one reason, because it puts gas into intergalactic space. If there is enough gas between the galaxies, it could explain how the clusters stay gravitationally bound together when there is not enough mass in the observed galaxies to do the binding. [But George B. Field of the University of California at Berkeley has already calculated from the reported X-ray brightness of the Coma and Virgo sources that if there is gas, it is probably not enough (SN: 2/26/72, p. 140).]

Burbidge reminds his colleagues that there is no evidence from optical or radio observations of any intergalactic gas in the clusters. This would mean that the only emanation of such gas would have to be the X-rays. The circumstance is rather unlikely.

Nevertheless, says Burbidge, it is likely that there is some gas in clusters of galaxies. "Whether you believe there is a large amount depends on how you believe galaxies were formed and the universe began. A case can be made that there is gas in Perseus." There is also some correlation between the X-ray luminosity and the fourth power of the root-mean-square random motion of the galaxies in a cluster, and this circumstance would argue some connection between the X-ray emission and the dynamics of the cluster. This would certainly be the case if the X-rays came from gas clouds because the gas would have to be intimately connected with the motions of the galaxies.

The third possibility, Compton scattering, depends on the existence of the microwave background radiation, the supposed three-degree blackbody radiation that pervades the universe and is believed to be left over from the original big bang. Electrons proceeding at relativistic speeds through the intergalactic space could collide with microwave photons and transfer to them enough energy to turn them into X-rays. There are two conditions necessary for this explanation according to Burbidge: The X-ray power from these sources must be greater than the radio, and the magnetic fields in them must be weak.

The ASE-Frascati group mention both the bremsstrahlung and Compton scattering as possibilities. They also point out that it is conceivable that the extended sources are sums of small numbers of very luminous X-ray-emitting galaxies. In that case it would no longer be necessary to explain them with processes taking place in the space between the galaxies.

"The paucity of observational data makes the field wide open," says Burbidge. Information about the detailed spectra of the sources could help make some choices and so could better resolution of their sizes and structure. The question is likely to get more complex before it gets simpler. As Burbidge puts it: "The X-ray astronomers can give us the kind of information we want to confuse the situation further." □