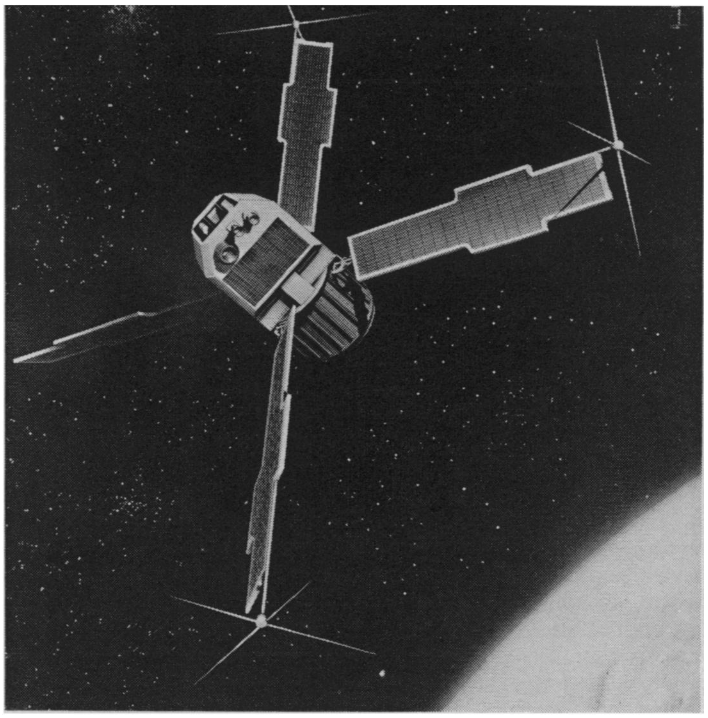
X-ray eyes on the universe



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Uhuru: A notable year for the first X-ray satellite.

A year's results from Uhuru show the value of a steady view from a satellite instead of quick glimpses from rockets

by Dietrick E. Thomsen

X-ray astronomy became possible after high-flying rockets had been invented. For millennia astronomers had looked at the universe in visible light because the human eye receives it and the earth's atmosphere passes it. (The two facts are probably not coincidental.) The earth's atmosphere also passes a wide band of radio wavelengths, and radio astronomers have been exploiting the information these waves bring for almost 40 years. But the atmosphere does not pass X-rays.

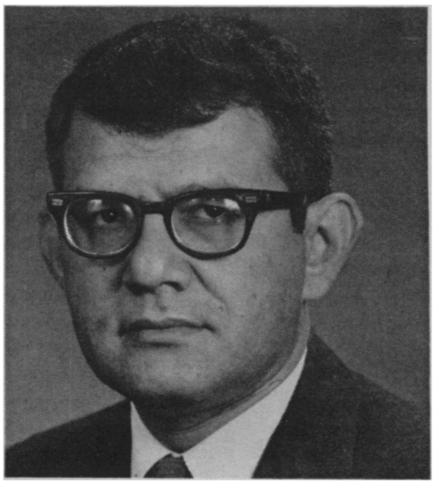
X-ray astronomy began in 1962 with the first X-ray detectors to be lifted far enough to catch X-ray emissions from beyond the earth. In the time between that event and the launching at the end of 1970 of Uhuru, the first all-X-ray artificial satellite, the total of actual X-ray observing time could be counted in minutes. Long-period or continuous observations simply were not possible on rockets that stayed above the atmosphere for at most a minute or two.

Yet the observations of those years, piecemeal and painstaking as they were, showed astronomers a completely new aspect of the universe. The first results were surprising, says Herbert Gursky of American Science and Engineering, Inc. in Cambridge, Mass., "not only because they were generally unexpected by the astronomical community, but also because they revealed that X-ray production was a widespread feature of cosmic objects and appeared at power levels that could not be understood." The intervening years have shown that there are a large number of discrete X-ray sources in our galaxy. There are also extragalactic sources, such as the radio galaxy M87 and the quasar 3C 273. In addition a diffuse background flux of X-rays was discovered.

Having gotten the merest blink of what the universe looks like in X-rays, astronomers were eager for more. The early results demonstrated the potential usefulness of a satellite that would record X-ray emissions.

Uhuru was launched Dec. 12, 1970, from the Italian San Marco range in the Indian Ocean off the coast of Kenya. The date coincided with Kenya's independence day, and the name means freedom in Swahili. The launching was a kind of independence day for X-ray astronomers. At last they could do long-period observations and systematic sweeps of large parts of the sky.

The results have come in a rush. Gursky summarized them at a symposium at the recent meeting of the American Association for the Advancement of Science in Philadelphia. In our galaxy about 75 sources have been found by Uhuru compared with the 40 that were known before the satellite.



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Gursky: X-ray production widespread.

The galactic sources were known to cluster along the spiral arms of the galaxy: The most prominent arm, which contains the sun, runs from the constellation Cygnus to the constellation Centaurus; four X-ray sources had been found in Cygnus and at least six in Centaurus. Uhuru found these and more. It found six in the constellation Serpens, the direction of another, more remote, spiral arm.

Uhuru also provided a means of better locating the sources that are seen in the direction of the galactic center. In that direction many galactic arms lie in the line of sight, and one must know the distances of the sources to locate them in the proper arms, if they belong to arms.

Uhuru discovered discrete X-ray sources in two external galaxies, the Magellanic Clouds (SN: 10/2/71, p. 232). The distances to the Magellanic Clouds are known. Therefore it is possible to calculate the intrinsic luminosity of the X-ray sources there to be in the range of 10^{38} ergs per second. If the X-ray sources in the direction of the center of our own galaxy are similar to these, then they are not in the spiral arms, but associated with the center itself. They are also ten times as powerful as anyone expected them to be and one hundred thousand times as powerful as the average star (10^{33} ergs per second, nearly all of it in visible light).

Uhuru's ability to observe particular sources over a span of time has revealed fluctuations, some periodic, some irregular, in the output of some sources. The regular ones have been called X-ray pulsars. Centaurus XR-3 is the most famous of these. Gursky suggests it may be a white dwarf or a neutron star. A few weeks ago some theorists suggested it might be a wobbly neutron star, in which the wobble causes the periodicity of the output (SN: 1/15/72, p. 43).

Uhuru has also increased knowledge of sources outside our galaxy and its immediate neighborhood. Several X-ray galaxies have been found. So far the highest flux comes from the quasar 3C 273, which appears to radiate at 10^{45} ergs per second in X-rays (not counting its optical and radio output). But the surprising extragalactic sources, says Gursky, are the ones associated with the clusters of galaxies in the constellations Virgo, Coma and Perseus. The extent of these sources is quite large; they are on the order of 500,000 parsecs across (1.6 million light-years). It has been suggested that these sources indicate the existence of intergalactic matter in those clusters and that this has an important bearing on cosmology (SN: 10/30/71, p. 291).

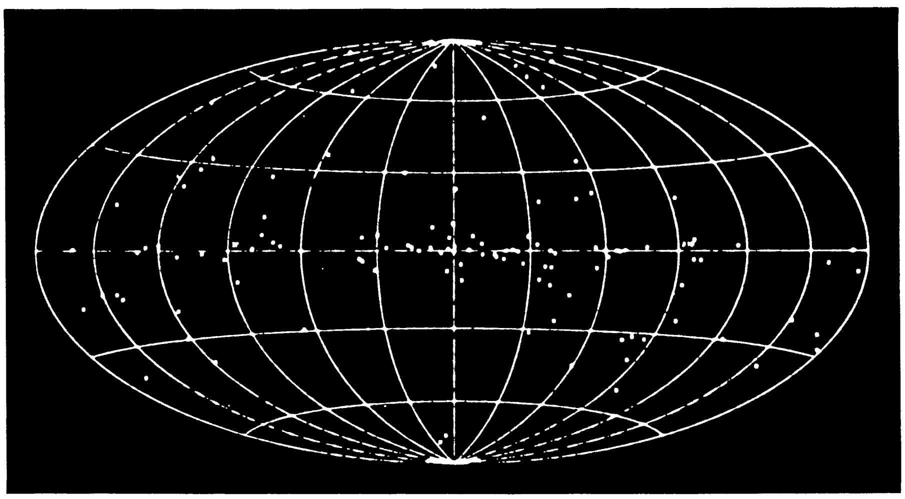
Astrophysicists are far from having detailed pictures of the physics of objects that put out such great fluxes of X-rays. According to Laurence E. Peterson of the University of California at San Diego, the continuous, lineless nature of the spectra so far observed could come from one or more of several possible processes: bremsstrahlung, synchrotron radiation, Compton scattering and collision of cosmic rays with interstellar matter.

Bremsstrahlung could occur in a hot plasma in which atomic nuclei and their electrons are separated from each other. As the plasma particles fly around they suffer collisions and near collisions that decelerate them. Energy lost in the deceleration comes off as X-rays. Synchrotron radiation could occur in a similar plasma if there were a magnetic field present. The magnetic field would force the electrically charged particles to move in spirals, and as they did, they would emit X-rays. Compton scattering occurs when photons of frequencies outside the X-ray range collide with electrons. In the collisions the photons can gain or lose energy and so come off at X-ray frequencies.

In all these cases, the energy of the emitted photons (and therefore their frequencies) can be anything at all within a fairly wide range, and the spectra they produce are continuous over a wide range. X-ray line spectra, in which certain single frequencies appear instead of a continuum, are produced by discrete (quantized) energy changes inside atoms (in the inner electrons or the nucleus). Line spectra have so far not been found in the celestial sources, but they continue to be looked for.

Even more varied and detailed X-ray data are expected from the High Energy Astronomical Observatory, which is scheduled for launch in 1975. It will carry not only X-ray counters, which count X-rays as if they were particles (photons), but also a reflecting telescope for X-rays.

It is almost impossible to make a mirror for X-rays. X-rays striking a solid substance head on go right through. But a certain range of soft (low-frequency) X-rays will be reflected if they strike certain substances at grazing incidence. By working very carefully it is possible to make a mirror in the shape of a collar or plate or a series of collars or plates around the X-ray beam. Grazing reflection off the collars causes the X-rays to converge gradually to a focus. This is called a Baez-type telescope, and it is expected to be both very sensitive and very good at pinpointing the directions of sources that radiate in its range. □



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Uhuru has added 75 X-ray sources to the 40 known in our galaxy previously.