

## Nobel Prize in Physics 2002: Riccardo Giacconi

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Although X-rays were used to probe the world of atoms that helped developing the quantum theory of matter, within a few decades of Roentgen's discovery of X-rays, it took around a century before scientists could use X-rays to probe the Universe. One of the recipients of the Nobel Prize this year, Riccardo Giacconi, is a chief architect of this development of opening a new window in astrophysics.

The delay in the beginning of X-ray astronomy was due to the very nature of the radiation. Firstly, an X-ray telescope had to differ from optical telescopes in a fundamental way. X-rays do not reflect off the mirrors as visible light does; they penetrate into the material of the mirror, since they carry much more energy than visible light. Just like bullets hitting a wall. But like bullets, X-rays can be made to graze along a surface, ricochet when they hit the mirror at a grazing angle. X-ray telescopes use this concept to bring the high energy radiation into focus so that the cosmic source that has emitted the X-rays can be imaged (see *Figure 1*). For this reason, X-ray telescopes look more like barrels than the familiar parabolic shapes of optical telescopes.

Secondly, it is impossible to detect X-rays from cosmic sources from the surface of the

Earth, as the atmosphere acts like an absorbing layer. It may sound strange since X-rays easily pass through our body (except the bones). Although the atmosphere is very tenuous compared to our body, the total thickness offered by it is much larger and X-rays suffer considerable absorption in it. This means that X-ray telescopes must be positioned beyond the atmosphere, and this had to wait for the space age.

When the first cosmic X-rays were detected in 1949 from the solar corona, which is the hot outer layer of the Sun, using German V2 rockets, it was found that the Sun was only about a millionth as bright as it is in the visible wavelengths. This had discouraged many physicists and astronomers to undertake bigger projects to develop X-ray observatories atop the atmosphere.

It was largely because of the vision of Riccardo Giacconi that X-ray astronomy could take off amidst all doubts and discouraging notes. He was born in Italy and obtained his doctorate in cosmic ray physics at the University of Milan. He then joined a research firm called American Science & Engineering, in Massachusetts, USA in 1959. He wrote a proposal to NASA to search for cosmic X-ray sources which was rejected. Unfazed by this, Giacconi managed to persuade the Air Force to fund a project of sending rockets with X-ray detectors (which were then essentially sensitive Geiger counters), primarily to look for X-rays from the moon. The first two attempts failed, but the third attempt in 1962 was a glowing success. It found a strong source in



the constellation of Scorpius – the first X-ray source to be discovered outside the solar system – and a rather diffuse background X-ray radiation from all over the sky. Within three years, Giacconi and his team made the first imaging X-ray telescope which was flown on a small rocket and took the first images of X-ray spots in the upper atmosphere of the Sun.

X-ray astronomy got another boost when artificial satellites with X-ray detectors on board could be launched for prolonged observations. Giacconi and his team built *UHURU* (the name, meaning ‘freedom’ in Swahili, paid homage to the large number of African nations which gained independence around that time) that was launched in 1970. No sooner had the telescope begun detecting numerous X-ray objects in the sky, he had started planning for a bigger, follow-up project. This resulted in the *Einstein* observatory launched in 1978. The decade of 1990s then saw several leaps in the development and launching of more and more sensitive X-ray detectors in space, with *ROSAT* (sent by the European Space Agency), *ASCA* (sent by Japan) and others, and culminating in *CHANDRA* and *XMM-Newton* which are orbiting at this moment. In fact *CHANDRA* with its very high resolution X-ray telescope was conceived originally by Giacconi back in 1976 in a proposal letter to NASA. The last four decades have seen a spectacular increase in the sensitivity of X-ray detectors of a hundred million times; a similar increase in sensitivity in optical telescopes took more

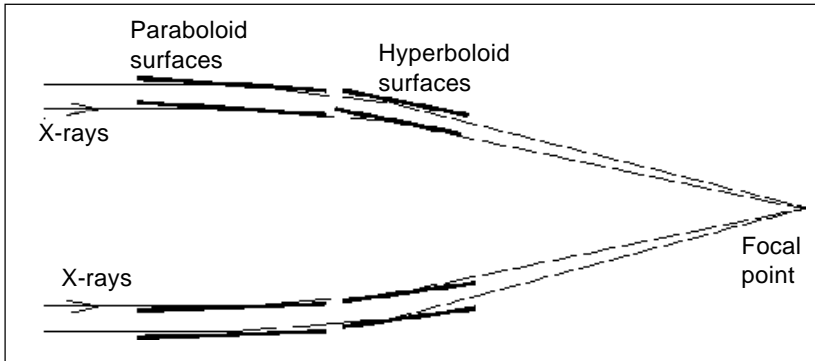
than three centuries.

These X-ray detectors have revealed the violent side of our Universe. The X-ray image of the sky looks remarkably different from the optical image. Since X-ray photons have very high energy, it is easy to understand that they are produced by high energy particles. X-ray sources in the sky therefore denote regions in the cosmos where particles have very high energy, perhaps as a result of strong gravitational field, or catastrophic explosions, or intense magnetic fields. X-rays have been detected from a large variety of sources, from the tenuous gas between galaxies to the vicinity of ultra compact objects like neutron stars and black holes.

First discovered by *UHURU*, one common category of X-ray sources is stars in binary systems, from which strong and rapid (and sometimes periodic) bursts of X-ray are detected. In these systems, gas from a normal star flows towards a compact companion star, falling into its strong gravitational field. Most often the compact star is a neutron star, whose density is so high that electrons have combined with the protons to render the star composed of mostly neutrons. Its strong magnetic field usually funnels the infalling gas into hot spots emitting bursts of X-ray. A few binary systems also have black holes as the compact companion.

X-ray observations also have yielded evidences for the existence of black holes with masses as much as a billion Suns in some galaxies. As gas flows towards these black





holes in the nuclear regions of these galaxies, the gas is accelerated to high energies, producing X-rays and radiation in other wavelengths as well. These galaxies are known as quasars, and they emit from a region with the size of our solar system, as much energy as a normal galaxy as a whole does.

Far away from these monstrous objects, even the tenuous gas between the galaxies are sometimes heated to temperatures in excess of a million degrees, because of the strong gravitational field of unseen dark matter. Detail X-ray observations of this gas give astronomers clues about the distribution of dark matter in the Universe, and therefore, are important observations from the point of view of evolution of the Universe and cosmology. Scientists are yet to come to any firm conclusions about the X-ray background glow of the Universe – which was one of Giacconi's initial discoveries – but it is believed that it was produced about ten billion years ago. When the homogeneously distributed gas in the early Universe formed clumps to collapse into galaxies, the radiation from early quasars and bright nuclei of galaxies could have produced this X-ray glow.

Riccardo Giacconi is not only responsible for the development of X-ray astrophysics, but his efforts have also encouraged astronomers to develop the detectors for even higher energy photons like gamma rays. Gamma ray astronomy is witnessing a spectacular growth at present. The Nobel Prize to Giacconi is commemorative of all these important developments in astrophysics.

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*The stamp issued by Germany in 1999 shows the X-ray picture of the remnants of an exploded star (Supernova remnant).*