How black is Cyg X-1?

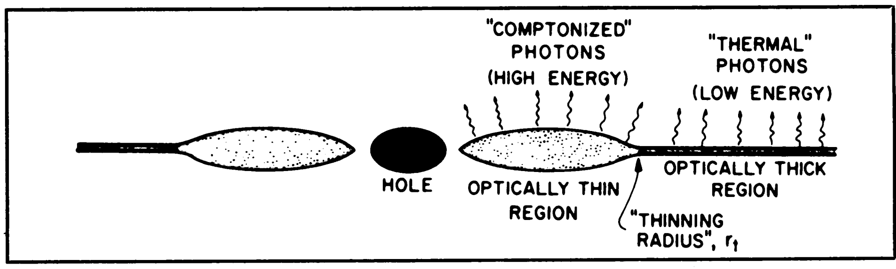
Since astronomers cannot handle nor experiment with what they study, they are always faced with the philosophical problem of how to prove rigorously and to general satisfaction that a celestial object is what they suppose it is. From the evidence that all can see (the spectrum of the object's electromagnetic radiations) to its nature and physics usually involves several steps of reasoning (and sometimes a few flying leaps). Different minds can take different steps. What it all comes to is that the way to convince is to make a detailed comparison with a detailed and self-consistent theory.

The specific object under consideration here is the X-ray source Cygnus X-1. The astrophysical question is whether it is in fact a black hole. If it is, its discovery is one of the most important astronomical events of the century. The latest news is that Kip S. Thorne of the California Institute of Technology and Richard H. Price of the University of Utah have completed such a comparison of observation with a fairly detailed theory, and the result leads Thorne to declare: "I'm about 80 percent convinced that Cygnus X-1 contains a black hole. We are going from the stage in which we were doing gross exploration and the vague idea that Cygnus X-1 might be a black hole to real concrete comparisons between observation and theory."

That underlines the point. Two important things are happening. The theory of binary X-ray sources as black holes is developing and surviving development, and as it does, it compares well with observations of the object.

When Cygnus X-1 was first discovered, it was apparent from fluctuations in the X-ray output that the object was a binary system involving a more or less normal star and a condensed dark companion. A condensed dark companion can be a lot of things: black hole, neutron star, white dwarf. But the people who wanted to see black holes said, suppose the dark companion is a black hole.

Black holes are former stars that have collapsed to such enormous densities that their immense gravitational fields prevent them from emitting anything. Even light, if it should be generated inside them, is infinitely redshifted by the field and so never gets out. But that strong gravity should draw a stream of matter from the normal star, matter that comes and falls down the black hole. The infalling matter should form a disk around the black hole. Collisions of one thing with another in the disk heat it up, and the hot disk is the source of the X-rays.



A black hole is surrounded by a thick-and-thin disk of matter that emits X-rays.

So far it was a nice picture. But the next step is to calculate the dynamics in detail and see if the idea stands. In this process sometimes the nitty gets very gritty, and the detail proves that the basic idea won't hold up. But this theory appears to be doing quite well. The work has been done mainly by Martin Rees and James Pringle of Cambridge University and Rashid Sunyaev and Nikolai Shakura of the Institute of Applied Mathematics in Moscow. Thorne and a graduate student, Don N. Page, altered the theory for general relativistic effects.

The picture now divides the disk of infalling matter into two sections, an inner, optically thin (relatively translucent) region that emits high-energy X-rays and an outer, optically thick region that emits low-energy X-rays. Typically the radius of the black hole should be about 12 kilometers and that of the entire disk 300 kilometers.

The boundary between the thick and thin parts of the disk can vary. In 1971 Cygnus X-1 suffered some kind of cataclysm after which its output of low-energy X-rays declined considerably. This may have been caused by dynamical instabilities in the disk of a sort predicted by Alan Lightman and Douglas Eardley, which result in the expansion of the optically thin region at the expense of the optically thick one.

The theory as it now stands makes predictions regarding maxima and minima and fluctuations in various regions of Cygnus X-1's X-ray spectrum both before and after the cataclysm. These are the comparisons that Thorne and Price made, and it was a difficult job because the X-ray output fluctuates wildly (as theory says it should). Number by number the comparisons are given in ASTROPHYSICAL JOURNAL LETTERS (195:L101).

For the future more theory and more observations, especially at the very high and very low ends of the X-ray spectrum, are needed. Thorne is now about "80 percent convinced." There is still a way to go before he and a majority of astrophysicists are 100 percent convinced. □

Carbon monoxide in two other galaxies

Carbon monoxide is one of the most ubiquitous chemical substances in our galaxy, being found in many of the interstellar clouds. Now there is a finding that it also pervades two other galaxies, M82 and NGC253. The determination was made by Lee J. Rickard and Patrick Palmer of the University of Chicago, Mark Morris of California Institute of Technology, Ben Zuckerman of the University of Maryland and Barry Turner of the National Radio Astronomy Observatory.

The technique is to use a radio telescope to search for characteristic frequencies emitted by a given molecule. It is difficult enough to do within the confines of our own galaxy; distance to other galaxies increases the problems. (Previously molecular hydrogen was reported in some distant galaxies.) The instrument used was NRAO's 36-foot antenna located in the Quinlan Mountains near Tucson, Ariz.

Both M82 and NGC253 are undergoing explosions that push out gas and dust at speeds up to 2 million kilometers per hour. Both are full of dust and have strong infrared sources in their centers. Our galaxy is also pervaded by dust and has a strong infrared source in its center so it too may have suffered an explosion at some time in the past. It begins to seem as if there is some astrophysical connection between being an exploding galaxy and having carbon monoxide. It may be that chemical elements are synthesized in such explosions. □

Exploding M82: A connection with CO?