An unusual object in Australia's skies

CSIRO's 64-m radio-telescope dish at Parkes, N.S.W.

Deep in the southern sky, not far from Alpha and Beta Centauri — the two bright stars that point to the Southern Cross — is the small and little-known constellation of Circinus, the compass.

Unlike the Southern Cross, Circinus is not an arrangement of bright stars likely to attract the attention of anybody casually gazing up at the night sky. In fact, it comprises three rather dim stars and not much else that you can see. But, although visually undistinguished, this area of the sky holds some intriguing objects, including a pulsating source of X-rays.

Because X-rays are absorbed by the atmosphere, astronomical objects that give them off remained unknown to astronomers until the advent of high-flying rockets. The Circinus X-ray source, dubbed Circinus X-1, was first detected in 1977 by a satellite operated by the Jet Propulsion Laboratory in California, and is one of the brightest X-ray objects in the sky.

In the same year, Dr Jim Caswell of the CSIRO Division of Radiophysics and Dr David Clark of the University of Sydney suggested that a point source of radio emission on one of their sky maps could perhaps be associated with the newly discovered X-ray object. About a year later, Circinus X-1 was again observed by radio-astronomers on the ground, but radiating in another waveband. Together with Dr Caswell, Dr Raymond Haynes and Dr Lloyd Simons, also of the Division of Radiophysics, were mapping the galaxy, using the Parkes radio-telescope in New South Wales.

They were looking for the faint remnants of those cataclysmic events called supernovae, when, for a brief time, one star can shine as brightly as a whole galaxy as it 'kills itself' in a gigantic explosion. Following this burst of activity and the loss of much of its mass, the remainder of the original star is thought to continue as a very compact, dense object — a pulsating neutron star, or pulsar, which radiates at radio wavelengths as well as optically.

The CSIRO scientists' work involved thorough and methodical searching throughout the southern sky. By chance, two radio pictures taken only a day apart showed an object that had increased in radio brightness fivefold in that short time. Intrigued, Dr Haynes considered that further detailed observations were in order. Over time, he noticed that this object, which later turned out to be Circinus X-1, didn't shine steadily as a radio source; instead, the energy it emitted fluctuated, increasing dramatically every 16·59 days, and it was this sudden burst that the team had fortuitously observed originally.

Further work showed that, as well as producing X-rays and radio waves, Circinus X-1 was also radiating, and pulsating, at optical and infra-red wavelengths. Dr Haynes and his colleagues, Dr Ian Lerche of the Division and Dr Paul Murdin of the Anglo-Australian Telescope, have constructed the following theoretical model to account for its behaviour.

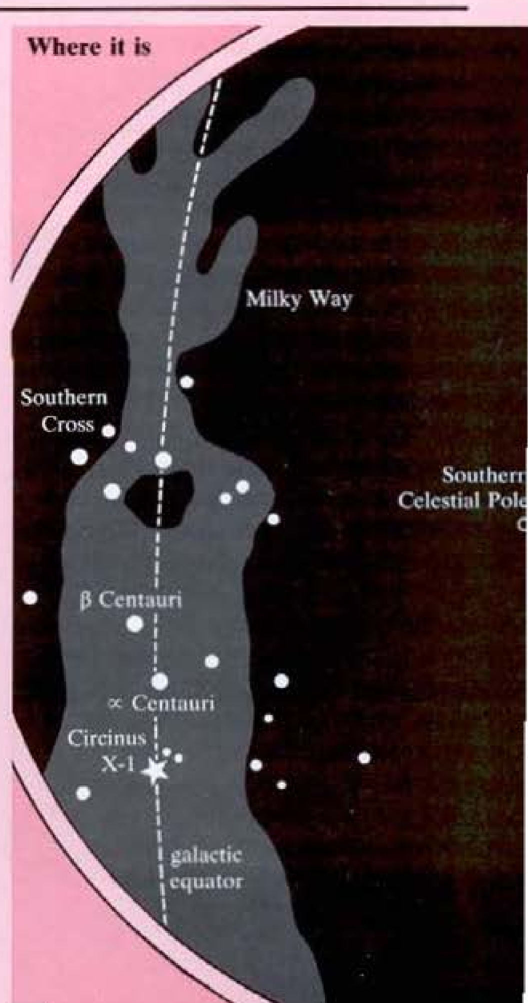
A double star system must be involved, with the two stars very different. One, the primary star, must be large both in its physical dimensions and in its mass, which should be about 10–20 times the mass of our sun. The secondary object must be very small — perhaps only 10–20 kilometres across — but nonetheless about three times more massive than our sun. Such a vast quantity of matter compressed into such a small volume will give rise to an immensely dense object — either a neutron star or a black hole.

Where to find the X-ray star

If you don't have access to a radio-telescope or an X-ray satellite, you're unlikely to be able to 'see' Circinus X-1 clearly. However, this little star map should show you where it is.

Possibly a very good optical telescope (with an aperture of at least 25 cm) may enable dedicated amateur astronomers to glimpse Circinus X-1 with their eyes. (Of course the radio nebula will be invisible.) But don't expect much; although the primary star is large and bright, it and its small companion are unbelievably far away — at least 25 000 light years.

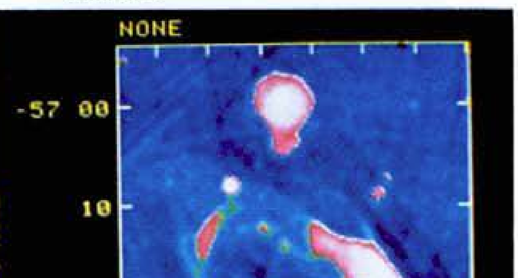
The pair appear as a single dull red star of magnitude about 15, which brightens to 14·5 when it flares on cue every 16 days or so. (Magnitude is a logarithmic measure of brightness; the brightest stars and planets may have 0 or negative magnitudes, while the faintest the human eye can see under the best conditions is magnitude 6.) Because the object's radiation only reaches the red end of the visible spectrum, it may still not be visible without an infra-red detector. And you thought Halley's was a tricky proposition!



An artist's impression of mass transfer taking place between two interacting stars in a binary system, like Circinus X-1.

All binary stars rotate about their common centre of gravity. In this case that would be located near the centre of the more massive star, which means, in effect, that the dense star swings around that one.

A false colour map of the Circinus X-1 region (made with Sydney University's Molonglo Observatory Synthesis Radio-telescope). Circinus X-1 itself — the presumed binary star — is the bright object at top. The other bright regions form the roughly spherical shell of a supernova remnant.



Dr Haynes and his colleagues have suggested that the orbit is very elliptical or, to use the technical term, eccentric. The small dense star's orbit swings it in towards its large partner every 16 days. When this happens, it pulls off some of the outer gas of the primary star. The material is then sucked in by the huge gravity of the neutron star or black hole. These violent events result in a burst of X-ray and other radiation, which we detect.

New findings

In 1986, using the Molonglo Observatory Synthesis Radio-telescope (run by the University of Sydney), Dr Haynes and his co-workers made an exciting new discovery: Circinus X-1 is part of something much larger. It is embedded in a radio nebula. Nebulae are large but tenuous clouds of dust and gas that often radiate light and heat, either due to their own gravitational contraction (in which case they may be on the way to forming stars), or because somewhere within them lie one or more stars or protostars, whose emitted energy makes the nebula shine.

Nebulae are common in our galaxy (and are visible in other nearby galaxies such as the Magellanic Clouds). An example well known to amateur astronomers is the nebula in the 'sword' of the constellation Orion. Another famous example is the Crab nebula in Taurus, which is the expanding gaseous remnant of a colossal supernova explosion in our own galaxy that was seen in the Middle Ages.

But well-known nebulae shine predominantly in visible light; the nebula Dr Haynes has found 'broadcasts' steadily at a radio frequency of 843 MHz. It is a vast region, extending over tens of light years, and its centre, as determined by the strength of its emission, coincides closely with Circinus X-1. The possibility of such an alignment being due to chance is about 1 in 3000, so it's most likely that the nebula is physically associated with the binary system.

The next question is, where did the nebula come from? And what is, or was, its source of energy? Dr Haynes and his team suggest that it formed from an accumulation of the highly energetic particles given off during the flaring of the primary star when the compact object rips off its outer material. These particles are losing some of their energy as radio waves.

'Stop press'

Just as this issue goes to the printers, all eyes — and radio-telescopes — are turned towards the supernova that erupted suddenly at the end of February in the nearby galaxy, the Large Magellanic Cloud. The star involved, a blue supergiant of about 10 solar masses, blew up about 170 000 years ago, but its light has just reached us. Its visual magnitude has risen from 12·4 to 4, and its catastrophe is also broadcast in all the other regions of the electromagnetic spectrum.

The peaks in energy emission throughout the different bands of the spectrum do not occur simultaneously. The star brightened in the ultraviolet early on in the explosion, and a massive radio outburst may follow (if our slender previous experience of supernovae is reliable) about 20 days after the optical flash. The event is only visible from the Southern Hemisphere, so Dr Haynes and his colleagues are busy monitoring the progress of the outburst with the radio-telescopes at Parkes and Tidbinbilla.

This is the first 'close' and naked-eye-visible supernova since 1604, when Kepler observed one occurring in our own galaxy. We now know that this was about 13 000 light years away, and appeared for a time brighter than any other star in our sky. For a few days a supernova can emit more energy than an entire galaxy of thousands of millions of stars. Most stars do not die in such an ostentatious manner — and perhaps it is just as well. Although fascinating for astronomers to observe from a distance, a nearby supernova — within tens of light years, or 100–1000 million million kilometres — could well be quite disruptive to life on earth.

However, it could be that a supernova spawned the mighty cloud. The remnants of one lie a short distance — as we see it — to the south. Astronomers think that, if this is so, the explosion took place about 100 000 years ago. The speed of movement of the matter thrown out of the explosion in the relevant direction would have to be about 500 km per second, which is greater than that of any other supernovae remnants so far studied. Furthermore, the nebula's brightness is rather low for a typical remnant. Another possibility is that the binary system itself, rather than the nebula, was ejected from a supernova.

If a supernova really were the source of the nebula, we might expect to see some continued expansion — that is, movement of the cloud away from the supernova remnant. (This is the case with the Crab nebula.) Also, a bright edge around a nebula is common.

Dr Haynes hopes to answer some of these questions by looking at the nebula in greater detail, using a larger radio-telescope. To do this he will link the dishes at the Australian National Radio Astronomy Observatory operated by CSIRO at Parkes, N.S.W., with the one at the NASA tracking station in Tidbinbilla, A.C.T. Effectively he is then creating one enormous telescope equal in size to the distance between the stations — about 270 km. This set-up will enable him to 'see' down to 1 arc-second. (One degree of arc in the sky comprises 3600 seconds: the moon's diameter is about half of one degree.)

Another goal is to get some idea of the binary system's age. We can estimate that by careful measurement of the slight slow-down in the period of variation. This is caused by the compact object's irregular orbit steadily being 'tamed' by the primary's gravitational attraction, and slowly becoming circular. Extrapolation of the process backwards and forwards in time would give an approximate age, and an estimate of how long the flaring will continue.

In fact Circinus X-1 may no longer be flaring. We can't know the situation there at present. All the information we receive from it — radiating outwards at about 300 000 km per second — is about 25 000 years out of date!

Roger Beckmann

More about the topic

A radio nebula associated with Circinus X-1. R.F. Haynes, M.M. Komesaroff, A.G. Little, D.L. Jauncey, J.L. Caswell, D.K. Milne, M.J. Kesteven, K.J. Wellington, and R.A. Preston. *Nature*, 1986, **324**, 233–5.