Astronomy

First X-ray-ionized nebula

from A.C. Fabian

THE hottest objects in a galaxy, the binary X-ray sources, should produce the most highly ionized nebulae. Despite extensive calculations of the ionization state of gas around X-ray sources (McCray, R. *et al.* *Astrophys. J. Lett.* **311**, L29; 1977), no such nebula had been found until M.W. Pakull and L.P. Angebault studied the Large Magellanic Cloud carefully, as they describe elsewhere in this issue (*Nature* **322,** 511; 1986).

Spiral and irregular galaxies are dotted with nebulae excited by hot stars. The H II regions are ionized by the ultraviolet radiation from massive main-sequence stars and glow mainly through recombination-line radiation. The even hotter cores of evolved stars that have recently ejected their outer envelopes, the planetary nebulae, ionize substantial amounts of helium as well. Visible radiation from planetary nebulae give an estimate of the ultraviolet radiation field, and thus surface temperature, of hot stars. In principle, this is a relatively simple deduction if it is assumed that all the photons capable of ionizing gases such as hydrogen do so, and that the resulting photon luminosity in some recombination line can be estimated from the observations.

The major problem in the search for nebulae around X-ray sources is that they tend not to be in dense gas environments, so the luminosity of the nebulae is very low. Massive main-sequence stars, by contrast, are young and embedded in dense star-forming clouds. Moreover, planetary nebulae create their own dense surroundings in the ejected stellar envelope.

The X-ray ionized nebula discovered by Pakull and Angebault, LMC X−1, was the first X-ray source found in the Large Magellanic Cloud and is securely identified by them with an O7 III–V star. The star appears to be surrounded by a nebula of radius 5 pc that emits visible lines of hydrogen and ionized helium as well as of doubly ionized oxygen. The He II emission is simply explained by the recombination of He III ionized by extreme ultraviolet photons of energy greater than 54 eV. These photons imply a much harder spectrum than any normal star and are consistent with the X-ray source. The centring of the emission on the O7 star identifies it, or rather its binary companion, as the X-ray source.

The extreme ultraviolet spectrum of LMC X−1 is of particular interest because the source is a black-hole candidate. Pakull and Angebault estimate that the spectrum is flat below the X-ray observed photon energies of ~1 keV down through the otherwise invisible extreme ultraviolet to the ultraviolet. This could be the thermal black-body emission from an accretion disk. The spatial extent of the surrounding He III zone is ~10 light years and so presumably indicates that the source has maintained that spectrum and luminosity for at least the past 10 years.

LMC X−1 is an unusual black-hole candidate as it seems to be stuck in a 'high-state' (White, N.E. & Marshall, F.E. *Astrophys. J.* **281**, 349; 1984). The other black-hole candidates such as Cygnus X−1 switch between 'high'- and 'low'-states for about a month every year or so. (A high-state is characterized by a higher luminosity and steeper (softer) X-ray spectrum and a low state by the opposite.) An X-ray nebula around Cygnus X−1 should then appear as a set of rings around the source marking the past few high-states. Unfortunately, the other black-hole candidates seem to be in low density regions and the He II nebula more or less undetectable at present. Indeed, it is curious that LMC X−1 is in a high-density region. The formation of the compact object in a binary X-ray source is expected to impart a substantial velocity to the system by momentum conservation. LMC X−1 should then be a long way away from the region of its birth. Perhaps it just happens to be passing through a dense region.

Pakull and Angebault remark that the LMC X−1 He III region is similar to the narrow-line region of a Seyfert galaxy. We can expect more investigations of the narrow-line region of LMC X−1 to explore this similarity as well as more searches around other black-hole candidates and X-ray sources. Such investigations have already revealed a high-excitation emission-line region around another LMC binary, LHG83. ☐

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Palaeoanthropology

Human phylogeny revised again

from Eric Delson

A newly recovered cranium of one of the early human species called robust australopithecines may well force palaeoanthropologists to reconsider the evolutionary relationships among all *Australopithecus* forms. On page 517 of this issue[1], Walker and colleagues describe two specimens (a partial lower jaw and a skull lacking most of the teeth and part of the skull roof) found in sediments on the west side of Lake Turkana, Kenya, dated about 2.5 million years (Myr) old. Many of those who have had the opportunity to study a replica of the skull feel that it is the most exciting fossil hominid found since 'Lucy' in 1974 (ref. 2).

The record of early humans (upright bipeds with small canines and apparently already partly expanded brains in comparison to body size) begins about 4–5 Myr ago in eastern Africa. The first well-preserved remains are those from Laetoli (about 3.7 Myr) and Hadar (3.3–3.0 Myr) generally termed *A. afarensis*. This species is often thought to be close to the base of the radiation of Plio–Pleistocene humans, but opinions differ widely on details. Later australopithecine species include the 'gracile' *A. africanus* of South Africa, 3.0–2.3 Myr in age; 'robust' *A. robustus* (and perhaps a distinct *A. crassidens*) from 1.9–1.6-Myr-old caves in South Africa; and the hyper-robust *A. boisei* from eastern Africa, well known between about 2 and 1.3 Myr ago. Based on his identification of isolated teeth and the revision of Omo chronology by Brown *et al.*[3], Grine[4] has argued that *A. boisei* may occur as early as 2.5 Myr ago in Lake Turkana basin. The earliest *Homo* fossils appear about 2 Myr ago in both eastern and southern Africa.

Although there is no consensus, most probably agree with the interpretation of Rak[5] and of Kimbel and colleagues[6] that *A. afarensis* is close to the common ancestor of two main lineages of early humans, one leading to *Homo* but unknown in the 2–3 Myr interval, the other passing through a 'gracile' stage to terminate in several robust species (of which the South African form is most like the common ancestor).

Others, especially Olson[7], have suggested that *A. afarensis* is a mixture of two species, with most of the cranial and dental material being an early robust form based on shared features that are considered derived for the robust lineage, whereas Lucy and other less complete remains are like gracile forms and later *Homo*. Skelton *et al.*[8] conclude that a third option is best: deriving both *Homo* and robust forms from *A. africanus*, with *A. afarensis* as an earlier ancestral stage.

The new robust fossils add to this already confusing picture. Walker *et al.*[1] make two main points in their analysis.