The constancy of the C-terminal parts is explicable in terms of binding to the strongly conserved actin molecule and this would suggest that the mechanism for the inhibition of the actomyosin ATPase is the same for each of the three types of striated muscle troponin I. The much greater variability in the N-terminal part of troponin I and in particular in the troponin C binding region is somewhat surprising in view of the conservative nature of troponin C itself and this may reflect subtleties in the interaction of troponin I with troponin C which may only be appreciated from an understanding of the three-dimensional structure of the troponin complex.

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letters to nature

Discovery of an X-ray QSO

WE report here the discovery of an X-ray emitting QSO, the first to be initially identified from X-ray observations. Previously, the only QSO known to be an X-ray source was 3C273 (refs 1 and 2). The new QSO has been found within a 40″ error circle established by the SAS-3 X-ray Observatory. The SAS-3 error circle lies within the Ariel V error box (~0.2 square degrees) for the source 2A 2251-179 (ref. 3). Following the convention for optical QSOs, we have designated the optical object MR2251−178. The X-ray luminosity (2–11 keV) of this object, presently $\sim 5\times 10^{44}$ erg s^{-1}, has been as large as $\sim 1.6\times 10^{45}$ erg s^{-1} (in 1975) and exceeds the optical luminosity by a factor of ~10. Among known compact X-ray sources, only 3C273 has a greater luminosity. Also, in radio observations at 4,885 MHz with the NRAO Very Large Array (VLA), we have discovered a point-like radio source coincident with MR2251−178.

A 12°×12° field near 2A2251−179 was observed with the rotating modulation collimator (RMC) system (ref. 4) on the SAS-3 X-ray Observatory from 11.1 August 1977 to 13.5 August 1977. Data from 36 orbits (effective integration time of 9.7×10^{4} s) have been analysed.

Detection of a source within the error box for 2A2251−179 was achieved in each of the two independent RMC detectors. The statistical significance of the detection was 6.2σ in the 2!3 FWHM detector (2–11 keV) and 5.7σ in the 4!5 FWHM detector (2–11 keV). In Table 1 the results of these two independent detections are given, including spectral data for the two energy channels in each of the two detectors. While the spectral shape cannot be uniquely determined, the data are consistent with a power law having a photon number index of 1.5 ± 0.5 (assuming $E_c \gtrsim 2$ keV; ref. 5). The flux is $2.5\pm 0.4\times 10^{-11}$ erg cm s^{-1} (2–11 keV). If we combine the two independent position determinations according to the technique described by Doxsey *et al.*[4] we obtain the following position for the X-ray source (in subsequent catalogues, the X-ray source will be designated 2S2251−178).

Table 1 X-ray observations of MR2251−178 (2A2251−179) by SAS-3

Collimator f.w.h.m.	Energy band (keV)	Counting rate (s^{-1})
2!3	2–6	0.45 ± 0.08
	6–11	0.14 ± 0.05
4!5	2–6	0.30 ± 0.06
	6–11	0.13 ± 0.05

$$\alpha(1950) = 22\text{ h }51\text{ min }25.4\text{ s},\quad \delta(1950) = -17^\circ\ 50'\ 40''$$

error circle radius (90% confidence): 40″

In Fig. 1, we show the Ariel V error box for 2A2251−179 (0.187 square degrees in area; ref. 3) and the refined SAS-3 error circle reported here. Both are superimposed on a Palomar Observatory Sky Survey (POSS) blue plate. Figure 1 inset shows only the SAS-3 error circle, but with a scale factor twenty times larger. Within the SAS-3 error circle, there are only 2 conspicuous objects ($m_v \gtrsim 20$) visible on the POSS plates. They are denoted '1' and '2' on the inset. Object 1 possibly is a compact elliptical galaxy, whereas Object 2 is starlike. There is no marked difference between the red and blue POSS images of either object. Coordinates for these two objects were measured on POSS glass plates at Kitt Peak National Observatory (KPNO) by S. Kleinmann. Plates from the Tololo–Michigan Objective Prism Survey (previously taken with the 61 cm Curtis Schmidt telescope at Cerro Tololo; refs 6 and 7) were then examined. On these plates, the spectrum of Object 1 is obscured in part by that of Object 2. In the most remarkable spectrum of Object 2, bright emission lines from the following species are evident: Hβ, [OII] λ3727, [NeIII] 3869, Hγ, and probably [NeV]λ3426 and HeII λ4686. Using 4 lines in the 3,500–5,350-Å interval, we determined a redshift of $z = 0.0680\pm 0.003$. This implies a distance of 410 Mpc, assuming $H_0 = 50$ km s^{-1} Mpc^{-1}. Based on the diameter of its POSS image, the apparent magnitude of Object 2 is $B \sim +16$.

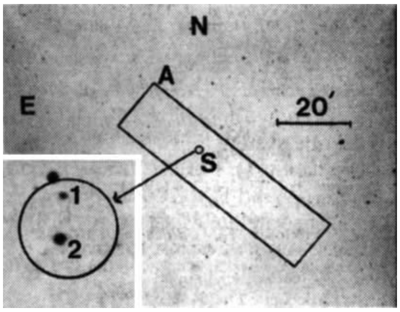

Fig. 1 The QSO MR2251−178 and the X-ray source 2A2251−179. 'A' and 'S' denote the Ariel V error box and the SAS-3 error circle, respectively. The inset shows the SAS-3 error circle enlarged by a factor of 20. Object 2 is MR2251−178. Photographs are taken from the Palomar Sky Survey Plates National Geographic Society).

The B luminosity of the object is then $\sim 5\times10^{43}$ erg s^{-1}, while the X-ray luminosity is $\sim 5\times10^{44}$ erg s^{-1} (2–11 keV). The position of the optical object (designated MR2251−178) is

$$\alpha(1950) = 22\text{ h }51\text{ min }25.89\text{ s}\pm0.03\text{s},\quad \delta(1950) = -17^\circ\,50'\,54''.2\pm0''.5$$

The coordinates of the centroid of Object 1 were also measured at KPNO. They are

$$\alpha(1950) = 22\text{ h }51\text{ min }25.82\text{ s}\pm0.03\text{ s},\quad \delta(1950) = -17^\circ\,50'\,15.3''\pm0.5''$$

A search for radio emission from MR2251-178 was carried out at a frequency of 4,885 MHz using 6 antennas of the NRAO Very Large Array (VLA) in New Mexico. Operating with 50 MHz bandwidth and system temperatures of roughly 60 K, the six 25-m antennas form an aperture synthesis system capable of easily detecting 1 mJy sources in a 5′ field in 1 h. With the six antennas arranged in a linear array, 7.7 km in length, the resolution of the system is <1 arc s. Aperture synthesis maps of the field containing MR2251−178 made with 1.8 and 2.4 h of data on 4 and 6 October, 1977, independently show the presence of a dominant 3.2 ± 0.3 mJy point source at a position of

$$\alpha(1950) = 22\text{ h }51\text{ min }25.90\text{ s}\pm0.04\text{ s},\quad \delta(1950) = -17^\circ\,50'\,53.5''\pm1''$$

No variability was noted between the two dates and the source was <1 arc s in extent.

In the field containing MR2251−178, there is also an extended radio source of very low surface brightness at

$$\alpha(1950) = 22\text{ h }51\text{ min }25.8\text{ s}\pm0.8\text{ s},\quad \delta(1950) = -17^\circ\,50'\,20''\pm10''$$

This source has a size of the order of 30″ and contains at least 10 mJy of radio flux at 4,885 MHz. Because of the elongation of the synthesised beam, it is not possible at the present time to discuss the detailed structure of this extended source; however, considering its position and size, it is very likely associated with Object 1 in Fig. 1.

Based on the positional coincidence ($\sim$40 arc s), we regard the identification of the X-ray source 2A2251−179 with the optical object MR2251−178 as virtually certain. The association of the VLA radio point source with MR2251−178 is certain ($\sim$1 arc s positional coincidence). The classification of MR2251−178 as a QSO is based upon its stellar appearance on POSS plates, its redshift, and its high luminosity. It is possible that it could be an extreme Seyfert galaxy. This, however, would require that its luminosity be greater than that of any known X ray-emitting Seyfert galaxy (refs 8 and 9). 2A2251−179 is reported to vary by a factor of $\sim$10 in the 2A catalogue (ref. 3). At the maximum brightness reported, the 2-11 keV luminosity would be $\sim 1.6\times10^{45}$ erg s^{-1}. This exceeds the maximum value reported for the Seyfert galaxy of highest reported X-ray luminosity, 3C390.3 (refs 10 and 11).

Among the known compact X-ray sources, only 3C273 has a maximum luminosity greater than MR2251−178 (ref. 10). The ratio of X-ray to optical emission we have observed for MR2251−178 is $\sim$10:1 compared to a ratio of $\sim$1:1 in 3C273 and typical X-ray Seyferts (ref. 10). Thus, judging from available data, the energy budget of MR2251−178 is dominated by its X-ray emission. Accurate assessments of its bolometric luminosity must await infrared and high energy (>10 keV) X-ray measurements.

The redshift of MR2251−178 would place it among the closer QSOs. In all, there are only 5 (out of 633) QSOs in the list of Burbidge, Crown, and Smith (ref. 12) which have smaller redshifts. At the redshift distance of MR2251−178, the projected separation between it and Object 1 is $\sim$75 kpc.

The presence of the extended radio source near Object 1 may suggest a possible link to MR2251−178. A redshift measurement of Object 1 would clarify this possibility.

The optical and radio properties of MR2251−178 are such that it is unlikely that it would have been detected in pre-Tololo surveys. In the optical, it would likely have been passed over as an uninteresting field star, while in the radio, it is too faint to have been detected in any standard survey to date. Thus, there could be many such sources. Even if their number density were as great as that of Seyfert galaxies ($\sim$0.5% of all galaxies; ref. 13), they could have been overlooked in optical searches, since the objects would be $\sim$2.5 mag fainter for a given X-ray luminosity than are the Type 1 Seyfert galaxies studied by Ariel V (ref. 8), of which the optically faintest was $m_v \sim 14.5$. In view of the hard spectrum of MR2251−178 in the X-ray region (comparable in index to the diffuse X-ray background; ref. 14), the general population of such objects could make a substantial contribution to the X-ray background.

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Observation of X-ray eclipses from LMC X-4

THERE are six known X-ray sources in the Magellanic Clouds: five in the Large Cloud and one in the Small Cloud[1,2]. Until recently, only SMC X-1 was known to be in a binary system[3]. Chevalier and Ilovaisky[4] have now shown that the optical emission of the suggested counterpart of LMC X-4 (ref. 5) exhibits ellipsoidal light variations with an inferred binary period of 1.408 d. Previous X-ray observations have indicated that LMC X-4 is highly variable on time scales from minutes to months[2,6–8]. We report here the detection of several eclipses of LMC X-4, which confirms it as the second known extragalactic X-ray binary. We also discuss briefly the inferred value of the mass of the compact X-ray star.

LMC X-4 was observed on four occasions with the X-ray detectors on SAS-3. The first observation[6] was made with the Rotation Modulation Collimator system (RMC) during 20.5–26.4 February 1976 (UT). During the interval 15.8–17.6 October 1976 (UT), LMC X-4 was scanned twice per satellite orbit with the Right Slat detector system[9,10]. The Y-axis detectors[9,10] were then pointed continuously at LMC X-4 during the intervals 22.2–23.2 and 23.99–24.32 May 1977 (UT). During the first of these pointed observations, SAS-3 was operated with a special telemetry mode whereby the data from the 6–12 keV channel of the Horizontal Tube system[9,10] were recorded with a temporal resolution of 8 ms (ref. 11). For the second pointed observation, as well as the scanning and RMC observations, the normal 0.83 s time resolution of the satellite was used.

LMC X-4 was extremely weak compared to the non-X-ray background during most of our observations. We were, therefore, unable to obtain accurate intensities for the source. Instead, we assigned a qualitative description to the observed intensities as follows: 1 when the intensity was at least 3σ above the background, 0 when it was less than 1σ above the background and 1/2 when we could not determine definitively whether the source was 'on' or not. We then compiled a list of these intensity states, one for each scan during the scanning observation and one for every satellite orbit during the other observations. The results are presented in Table 1.

Table 1 Observed intensities for LMC X-4

Time*	Intensity† state	Time	Intensity state	Time	Intensity state
28.952	1	33.747	0	268.708	0
29.410	1	33.811	1/2	268.823	1
29.477	1	33.878	1	268.839	1
29.607	1	33.942	1	268.888	1
29.871	1	34.009	0	268.954	1
29.937	0	34.073	0	269.020	1
30.132	1	34.140	0	269.035	1
30.198	1	34.207	0	269.085	1
30.265	1	34.271	0	269.151	1
30.331	1	34.338	0	269.167	1
30.395	1	267.375	1	269.216	0
30.463	1	267.398	1	269.232	1
30.527	1	267.440	1/2	269.282	0
30.593	1	267.538	0	269.560	1
30.791	1	267.561	0	269.576	1
31.053	1	267.635	1	269.695	1
31.120	1	267.658	1	269.761	1
31.184	1	267.725	1	269.826	1
31.251	0	267.835	1	269.871	1
31.315	0	267.857	0	269.937	1
31.382	0	267.900	1/2	270.002	1/2
31.514	0	267.923	0	270.021	1
31.654	1	268.034	0	270.068	1
31.711	1	268.051	1/2	485.773	1
31.775	1	268.100	0	485.839	1
31.842	1	268.117	0	485.970	1
31.906	1	268.165	1	486.101	1
31.973	1/2	268.182	1	486.167	1
32.105	1	268.231	1	486.298	0
32.169	0	268.248	1	486.364	0
32.236	1	268.297	1	486.429	0
32.301	1	268.314	1	486.495	1
32.367	1	268.362	1/2	486.626	1
32.433	1/2	268.379	1/2	486.757	1
32.497	1	268.428	1	487.552	1
32.760	0	268.445	0	487.618	0
32.827	0	268.493	1	487.683	0
32.891	0	268.511	1	487.749	0
33.549	1	268.576	1	487.814	1
33.616	0	268.625	1		
33.680	1	268.642	0		

*JD−2442800.0
†See text for definition.

It is evident from Table 1 that LMC X-4 was 'off' for $\gtrsim$ 5 h on six separate occasions. This behaviour is similar to the eclipses observed in other eclipsing X-ray binaries[12]. Furthermore, the last two 'off' states occurred very close to the times when the unseen secondary was predicted to be behind the primary[4]. Unfortunately, the orbital period determined from the optical data is not sufficiently accurate to determine whether the earlier X-ray 'off' states occurred at a predicted eclipse time also.

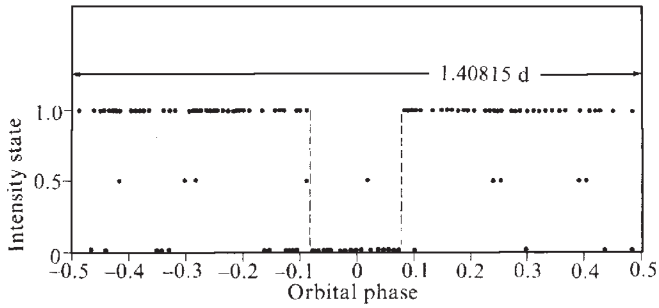

Fig. 1 Orbital X-ray light curve for LMC X-4. The 'digitised' X-ray intensities for LMC X-4, given in Table 1, are folded modulo, the trial orbital period 1.40815 d. The apparent eclipse of the X-ray source has a duration of 0.23 ± 0.02 d and is centred at JD 2443068.01 ± 0.02.

The X-ray 'intensities' from all four observations were folded modulo trail binary orbital periods between 1.404 d and 1.412 d in steps of 0.0001 d. The period range is chosen to be within two standard deviations of the optical period[4]. Figure 1 displays the 'light' curve for the trial orbital period of 1.40815 d. An eclipse is clearly discernible with a width of 0.23 ± 0.02 d. (It is difficult to assign a formal confidence to the errors quoted in this paragraph; however, we regard these errors as conservative limits.) When the data were folded at periods different from 1.40815 d by more than 0.00020 d, the resulting 'eclipses' were significantly shorter and eventually disappeared. We conclude that we have observed an X-ray eclipsing phenomenon with the above binary period, and with an eclipse centre at JD 2443068.01 ± 0.02. This confirms the proposed optical identification of LMC X-4.

A search for X-ray pulsations in the data taken with 8 ms and 0.83 s time resolution was carried out. No significant peaks in the Fourier power density spectrum were observed. From these studies we place an upper limit to pulsing of ~ 25% of the steady flux with pulse periods ranging from ~ 16 ms to 400 s. We note that if LMC X-4 had a pulsation fraction and pulse shape similar to that of SMC X-1 (refs 13, 14) it would have been only marginally detectable as a pulsar.