EVIDENCE FOR A BLACK HOLE IN LMC X-3

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The best X-ray position (Einstein Observatory HRI - Giacconi et al 1979) for LMC X-3 confirms its identification with the early type star first suggested by Warren and Penfold (1975). Our spectroscopic observations obtained with the CTIO 4-m telescope show the WP star is a slightly reddened B3 V star with $m_V \approx 16.9$. Large radial velocity variations ($\Delta v \approx 500$ km s^{-1}) reveal an orbital period of 1.7049 days. From the orbital elements (Table 1) one can determine the mass function $f(M) = (M_x \sin i)^3/(M_{opt} + M_x)^2 = 2.3\ M_\odot$, which shows without <u>any</u> assumptions about the mass of the optical star, the orbital inclination, or the mass ratio the unseen X-ray object has a mass $>2.3\ M_\odot$. Detailed analysis of the HEAO-1 scanning modulation collimator X-ray data shows that the system does <u>not</u> eclipse, implying that the orbital inclination is $\lesssim 65^o$. Assuming the B star mass lies between 4 and 8 $M_\odot$ (an average mass for a normal B3 V star would be about 6 - 7 $M_\odot$), the mass of the unseen companion must lie between 7 and 13 $M_\odot$ (see Fig. 4a - Hutchings, this volume). Smaller inclinations of course give even higher masses. An important point is that the unseen star must have a mass <u>larger</u> than that of the B star, and thus if it were any kind of normal star it should be easily seen in the spectrum. Thus the X-ray emitting object is a very good candidate for a black hole.

It is important to establish the absolute magnitude of the optical star, as together with the temperature it can be used to determine a radius which can be equated with the Roche radius of the star. This in turn yields the mass ratio in the system and hence another way of deriving the minimum stellar masses. Unfortunately, at present, the M_V of the optical star is uncertain by more than ≈ 0.5 magnitudes for a variety of reasons: The reddening, and hence the extinction, is poorly known. Our spectroscopic observations show all of the absorption lines are about 50% weaker than in standard stars, indicating the probable presence of a luminous accretion disk in the system (as is seen in SMC X-1 and LMC X-4). Finally the overall variability (≈ 0.6 mag) of the system introduces uncertainty into the absolute magnitude. Once M_V is determined, masses can be read from Fig. 4 of Cowley et al (1983). A similar discussion about the mass determination has been made by Paczyn-

S. van den Bergh and K. S. de Boer (eds.), Structure and Evolution of the Magellanic Clouds, 241–242.

https://doi.org/10.1017/S0074180900040316 Published online by Cambridge University Press

ski (1983), although he fails to consider the large range in uncertainty of the absolute magnitude.

Some confirming evidence has been presented to establish further that the orbital period is correctly determined and that a black hole may be present. Van der Klis and van Paradijs (1983) have found photometric variations (ellipsoidal) modulated on the 1.7 day period. The amplitude of these variations is consistent with the mass ratio and orbital inclination range suggested here. Also, White and Marshall (1983) have shown that the exceptionally soft X-ray spectrum of LMC X-3 is similar to that of another black hole candidate, Cyg X-1 in its high state.

Although both the mean radial velocity of the optical star and its luminosity are consistent with LMC X-3 being a member of the Large Cloud, its distance has almost no bearing on the dynamical arguments which imply the probable presence of a black hole.

TABLE 1. Orbital Elements for LMC X-3

$P = 1.70491 \pm 0.00007$ days	T_o = HJD 2445278.45 ± 0.01
$K = 235 \pm 11$ km s^{-1}	$e = 0$ (assumed)
$V_o = 310 \pm 7$ km s^{-1}	$\omega = 0$ (assumed)

REFERENCES

Cowley, A.P., Crampton, D., Hutchings, J.B., Remillard, R., and Penfold, J. E. 1983 Ap. J. 272, in press.
Giacconi, R. et al, 1979 Ap. J. 230, 540.
Paczynski, B. 1983 preprint.
Warren, P. R. and Penfold, J. E. 1975 M.N.R.A.S. 172, 41p.
White, N.E., and Marshall, F.E. 1983 preprint.
van der Klis, M., and van Paradijs, J. 1983 I.A.U. Circ. #3765.

https://doi.org/10.1017/S0074180900040316 Published online by Cambridge University Press