In addition to the low-frequency quasi-periodic oscillations (0.2-15 Hz; QPOs), three confirmed stellar-mass black holes exhibit high-frequency QPO pairs (100-450 Hz) in a frequency ratio of 3:2 (see power spectra on the right). These frequencies are fast, comparable to their Keplerian orbital values in the inner few gravitational radii of the accretion disk and appear to be frequency-invariant when the sources change their luminosities. Such stable, general relativity induced oscillations should scale inversely with the black hole mass if they arise from orbital motion near the innermost stable circular orbit in the accretion disk and there is observational support that they do for stellar-mass black holes.

M82 X-1's high luminosity\(^6\) and the identification of its 30-200 mHz X-ray QPOs as the analogs of the low-frequency QPOs of stellar-mass black holes suggests that it may contain an intermediate-mass black hole with mass in the range of 25-1300 solar masses\(^4\). But, there were two uncertainties with such scaling: first, it was unclear—until now—whether these mHz QPOs are indeed the low-frequency analogs of stellar-mass systems\(^3,4\) and, second, both the low-frequency and the mHz oscillations are variable, resulting in a large dispersion in the measured mass. The simultaneous detection of a stable, 3:2-ratio, high-frequency periodicity and low-frequency mHz oscillations allows one to set the overall frequency scale of the power spectrum and has been proposed to be the smoking gun evidence for an intermediate-mass black hole in a ULX\(^5\).

The discovery of two stable peaks at frequencies with a ratio of 3:2 (3.2 and 5.0 mHz), with the mass increasing as the low-frequency oscillation frequency increases. (b) Contours of M82 X-1's mass as a function of the radius of the origin of these oscillations (in units of rg = GM/c\(^2\), where G, M and c are the gravitational constant, the black hole mass and the speed of light, respectively). In (a) and (b), the vertical lines (solid, solution; dashed, upper and lower limits) represent M82 X-1's mass estimates assuming a simple inverse-mass scaling for the high-frequency QPOs. The three contours correspond to scalings using the masses of the microquasars GRO J1655-40\(^3\) (green), XTE J1550-64\(^4\) (blue) and GRS 1915+105\(^5\) (black).

The discovery of two stable peaks at frequencies with a ratio of 3:2 (3.2 and 5.5 Hz) in the power spectrum of X-ray emission from the brightest X-ray source in galaxy M82 suggests that, if the relationship between frequency and mass that holds for stellar-mass black holes can be extended to intermediate-masses, the black hole believed to be the source of the emission has a mass approximately 400 times that of the Sun.

This work will be published online 17th August 2014 and can be found using its digital object identifier (DOI) at http://dx.doi.org/10.1038/nature13710

For additional details see http://www.astro.umd.edu/~dheeraj/