Puzzling accretion onto a black hole in the ultraluminous X-ray source M 101 ULX-1

With the support by the National Natural Science Foundation of China (Grant Nos. 11273028 and 11333004), Dr. Liu Jifeng at the Key Laboratory of Optical Astronomy, National Astronomical Observatories, Chinese Academy of Sciences, reported dynamical measurements of a black hole in the ultraluminous X-ray source M 101 ULX-1, which was published in *Nature* (**2013**, 503 (7477): 500 — 503).

There are two proposed explanations for ultraluminous X-ray sources with luminosities in excess of 10^{39} erg s^{-1}. They could be intermediate-mass black holes (more than 100—1,000 solar masses, $M_{\odot}$) radiating at sub-maximal (sub-Eddington) rates, which are thought as the seeds of the super-mass black holes ($\sim 10^{6}$ $M_{\odot}$) harboured at centres of galaxies. Alternatively, they could be stellar-mass black holes radiating at Eddington or super-Eddington rates. On its discovery, M 101 ULX-1 had a luminosity of 3×10^{39} erg s^{-1} and a supersoft thermal disk spectrum with an exceptionally low temperature, consistent with the expected appearance of an accreting intermediate-mass black hole. A series of Gemini spectra have led to the discovery of the black hole donor star. The motion of the companion star in M 101 ULX-1 has been measured with the 4686 Angstrom helium emission line, which provided the first well-constrained and direct estimate for the primary mass in a ULX. A minimum mass of 5 $M_{\odot}$, and more probably a mass of 20 $M_{\odot}$ ~30 $M_{\odot}$, is found, and it is extremely unlikely to be an intermediate-mass black hole. This finding urges us to rebuild the understanding of intermediate-mass black holes and their connections to super-mass black holes. In addition, because of its exceptionally soft spectra at high Eddington ratios, the theory of accretion onto stellar-mass black holes needs to be readjusted.

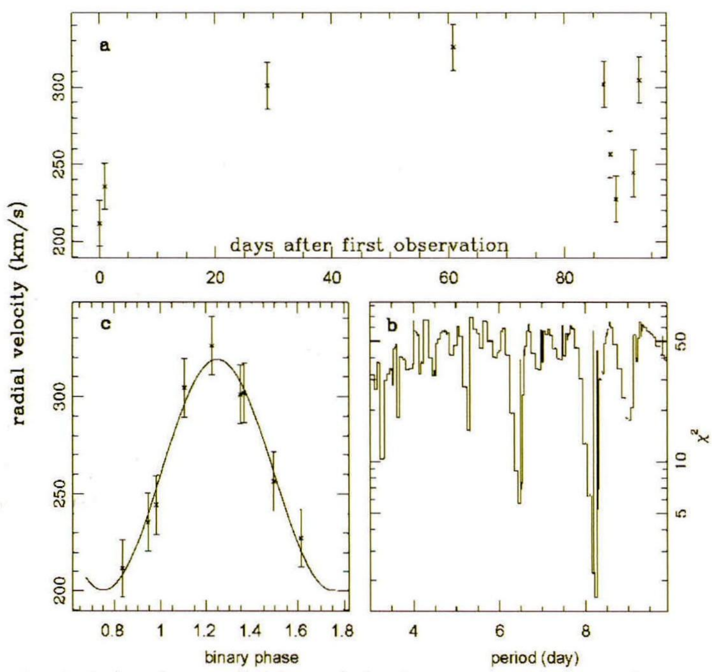

Figure An orbital period of ~8.2 days is revealed by radial velocity measurements taken over three months for M 101 ULX-1. a, Radial velocities measured from the 4686 Angstrom helium emission line. b, The chisquared value obtained when fitting circular orbits of different periods to the data, demonstrating that the best-fitting orbital period is 8.2 days. c, The measured radial velocities folded over the inferred orbital period.