Blackhole with warped accretion disc discovered

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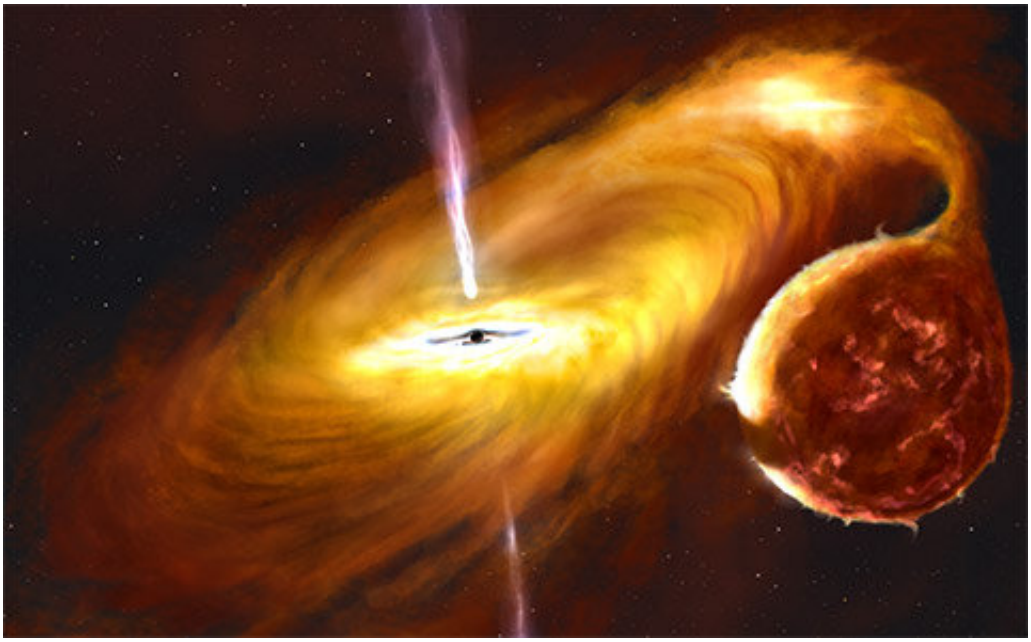

Black hole with warped disc. Credit: John Paice

An international team of astrophysicists from South Africa, the UK, France and the US have found large variations in the brightness of light seen from around one of the closest black holes in our Galaxy, 9,600 light-years from Earth, which they conclude is caused by a huge warp in its accretion disc.

This object, MAXI J1820+070, erupted as a new X-ray transient in March 2018 and was discovered by a Japanese X-ray telescope onboard

the International Space Station. These transients, systems that exhibit violent outbursts, are binary stars, consisting of a low-mass star, similar to our Sun and a much more compact object, which can be a white dwarf, neutron star or black hole. In this case, MAXI J1820+070 contains a black hole that is at least 8 times the mass of our Sun.

The first findings have now been accepted for publication in the journal *Monthly Notices of the Royal Astronomical Society*. The lead author is Dr. Jessymol Thomas, a Postdoctoral Research Fellow at the South African Astronomical Observatory (SAAO).

The discovery presented in the paper was made from an extensive and detailed light-curve obtained over almost a year by dedicated amateurs around the globe who are part of the AAVSO (American Association of Variable Star Observers). MAXI J1820+070 is one of the three brightest X-ray transients ever observed, a consequence of both its proximity to Earth and being outside of the obscuring plane of our Milky Way Galaxy. Because it remained bright for many months, this made it possible to be followed by so many amateurs.

Professor Phil Charles, researcher at the University of Southampton and member of the research team explained, "material from the normal star is pulled by the compact object into its surrounding accretion disc of spiraling gas. Massive outbursts occur when the material in the disc becomes hot and unstable, accretes onto the black hole and releases copious amounts of energy before traversing the event horizon. This process is chaotic and highly variable, varying on timescales from milliseconds to months."

The research team have produced a visualization of the system, showing how a huge X-ray output emanates from very close to the black hole, and then irradiates the surrounding matter, especially the accretion disc, heating it up to a temperature of around 10,000K, which is seen as the

visual light emitted. That is why, as the X-ray outburst declines, so does the optical light.

But something unexpected happened almost 3 months after the outburst began when the optical light curve started a huge modulation—a bit like turning a dimmer switch up and down and almost doubling in brightness at its peak—on a period of about 17 hours. Yet there was no change whatsoever in the X-ray output, which remained steady. While small, quasi-periodic visible modulations had been seen in the past during other X-ray transient outbursts, nothing on this scale had ever been seen before.

What was causing this extraordinary behavior? "With the angle of view of the system as shown in the pictorial, we could quite quickly rule out the usual explanation that the X-rays were illuminating the inner face of the donor star because the brightening was occurring at the wrong time", said Prof. Charles. Nor could it be due to varying light from where the mass transfer stream hits the disc as the modulation gradually moved relative to the orbit.

This left only one possible explanation, the huge X-ray flux was irradiating the disc and causing it to warp, as shown in the picture. The warp provides a huge increase in the area of the disc that could be illuminated, thereby making the visual light output increase dramatically when viewed at the right time. Such behavior had been seen in X-ray binaries with more massive donors, but never in a black-hole transient with a low mass donor like this. It opens a completely new avenue for studying the structure and properties of warped accretion discs.

Prof Charles continued, "This object has remarkable properties amongst an already interesting group of objects that have much to teach us about the end-points of stellar evolution and the formation of compact objects. We already know of a couple of dozen black hole binary systems in our

Galaxy, which all have masses in the 5—15 solar mass range. They all grow by the accretion of matter that we have witnessed so spectacularly here."

Starting some 5 years ago, a major science program on the Southern African Large Telescope (SALT) to study transient objects has made a number of important observations of compact binaries, including black hole systems like MAXI J1820+070. As the Principal Investigator for this program, Prof. Buckley, states "SALT is a perfect tool to study the changing behavior of these X-ray binaries during their outbursts, which it can monitor regularly over periods of weeks to months and can be coordinated with observations from other telescopes, including space-based ones."

More information: Jessymol K Thomas et al, Large optical modulations during 2018 outburst of MAXI J1820+070 reveal evolution of warped accretion disc through X-ray state change, *Monthly Notices of the Royal Astronomical Society* (2021). DOI: 10.1093/mnras/stab3033

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