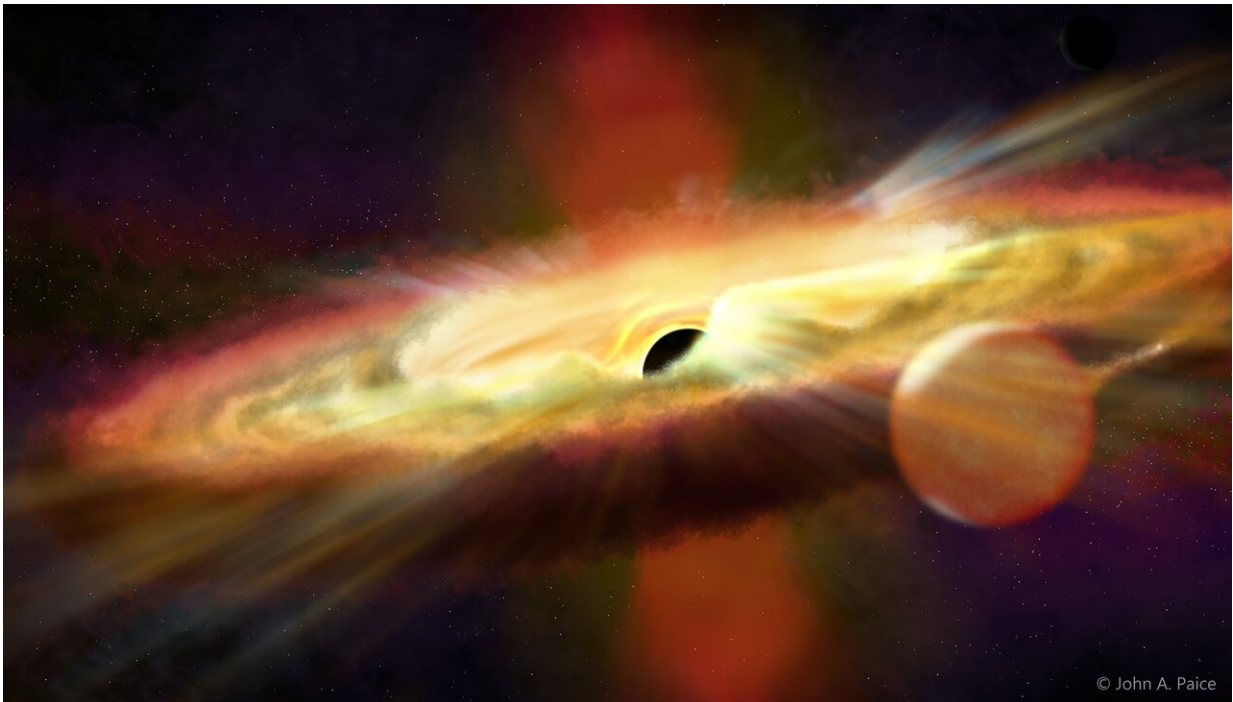


Repeating outflows of hot wind found close to black hole

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Credit: John Paice/University of Southampton/Inter-University Centre for Astronomy

An international team of astrophysicists from Southampton, Oxford and South Africa have detected a very hot, dense outflowing wind close to a black hole at least 25,000 light-years from Earth.

Lead researcher Professor Phil Charles from the University of

Southampton explained that the gas (ionised helium and hydrogen) was emitted in bursts which repeated every 8 minutes, the first time this behaviour has been seen around a black hole. The findings have been published in the journal *Monthly Notices of the Royal Astronomical Society*.

The object Professor Charles's team studied was Swift J1357.2-0933 which was first discovered as an X-ray transient—a system that exhibits violent outbursts—in 2011. These transients all consist of a low-mass star, similar to our Sun and a compact object, which can be a white dwarf, neutron star or black hole. In this case, Swift J1357.2-0933 has a black hole compact object which is at least 6 times the mass of our Sun.

Material from the normal star is pulled by the compact object into a disc in between the two. Massive outbursts occur when the material in the disc becomes hot and unstable and it releases copious amounts of energy.

Professor Charles said: "What was particularly unusual about this system was that ground-based telescopes had revealed that its optical brightness displayed periodic dips in its output and that the period of these dips slowly changed from around two minutes to about 10 minutes as the outburst evolved. Such strange behaviour has never been seen in any other object.

"The cause of these remarkable, fast dips has been a hot topic of scientific debate ever since their discovery. So it was with great excitement that astronomers greeted the second outburst of this object in mid-2017, presenting an opportunity to study this strange behaviour in greater detail."

Professor Charles and his team recognised that key to getting the answer was to obtain optical spectra a number of times during each dip cycle, essentially studying how their colour changed with time. But with the

object about 10,000 times fainter than the faintest star visible to the naked eye and the dip period of only around 8 minutes, a very big telescope had to be used.

So, they used SALT, the Southern African Large Telescope, the largest optical telescope in the southern hemisphere.

The University of Southampton is one of the founding UK partners in SALT, and together with their South African collaborators, are part of a multi-partner Large Science Programme to study transients of all types. Not only does SALT have the necessary huge collecting area (it has a 10m diameter mirror), but it is operated in a 100 percent queue-scheduled way by resident staff astronomers, meaning that it can readily respond to unpredictable transient events. This was perfect for Swift J1357.2-0933, and SALT obtained more than an hour of spectra, with one taken every 100 seconds.

"Our timely observations of this fascinating system demonstrates how the quick response of SALT, through its flexible queue-scheduled operation, makes it an ideal facility for follow-up studies of transient objects," said Dr. David Buckley, the Principal Investigator of the SALT transient programme, based at the South African Astronomical Observatory, who also added, "With the instantaneous availability of a number of different instruments on SALT, we can also dynamically modify our observing plans to suit the science goals and react to results, almost in real-time"

Professor Charles added: "The results from these spectra were stunning. They showed ionised helium in absorption, which had never been seen in such systems before. This indicated that it must be both dense and hot—around 40,000 degrees. More remarkably, the spectral features were blue-shifted (due to the Doppler effect), indicating that they were blowing towards us at about 600km/s. But what really astonished us was

the discovery that these spectral features were visible only during the optical dips in the light-curve. We have interpreted this quite unique property as due to a warp or ripple in the inner accretion disc that orbits the black hole on the dipping timescale. This warp is very close to the black hole at just one tenth the radius of the disc."

What is driving this matter away from the black hole? It is almost certainly the radiation pressure of the intense X-rays generated close to the black hole. But it has to be much brighter than we see directly, suggesting that the material falling on to the black hole obscures it from direct view, like clouds obscuring the Sun. This occurs because we happen to be viewing the binary system from a vantage point where the disc appears edge-on, as depicted in the schematic illustration, and rotating blobs in this disc obscure our view of the central black hole.

Interestingly there are no eclipses by the companion star seen in either the optical or X-ray as might be expected. This is explained by it being very small, and constantly in the shadow of the disc. This inference comes from detailed theoretical modelling of winds being blown off accretion discs that was undertaken by one of the team, James Matthews at the University of Oxford, using supercomputer calculations.

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, and the single black hole at our Galactic Centre is around 4 million solar masses. They all grow by the accretion of matter that we have witnessed so spectacularly in this object. We also know that a substantial fraction of the accreting material is being blown away. When that happens from the supermassive [black holes](#) at the centres of galaxies, those powerful winds and jets can have a huge impact on the rest of the galaxy.

Professor Charles concluded: "These short-period binary versions are a perfect way to study this physics in action."

More information: Hot, dense HeII outflows during the 2017 outburst of the X-ray transient Swift J1357.2-0933 *Monthly Notices of the Royal Astronomical Society*: Letters, slz120, doi.org/10.1093/mnrasl/slz120

Provided by University of Southampton

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