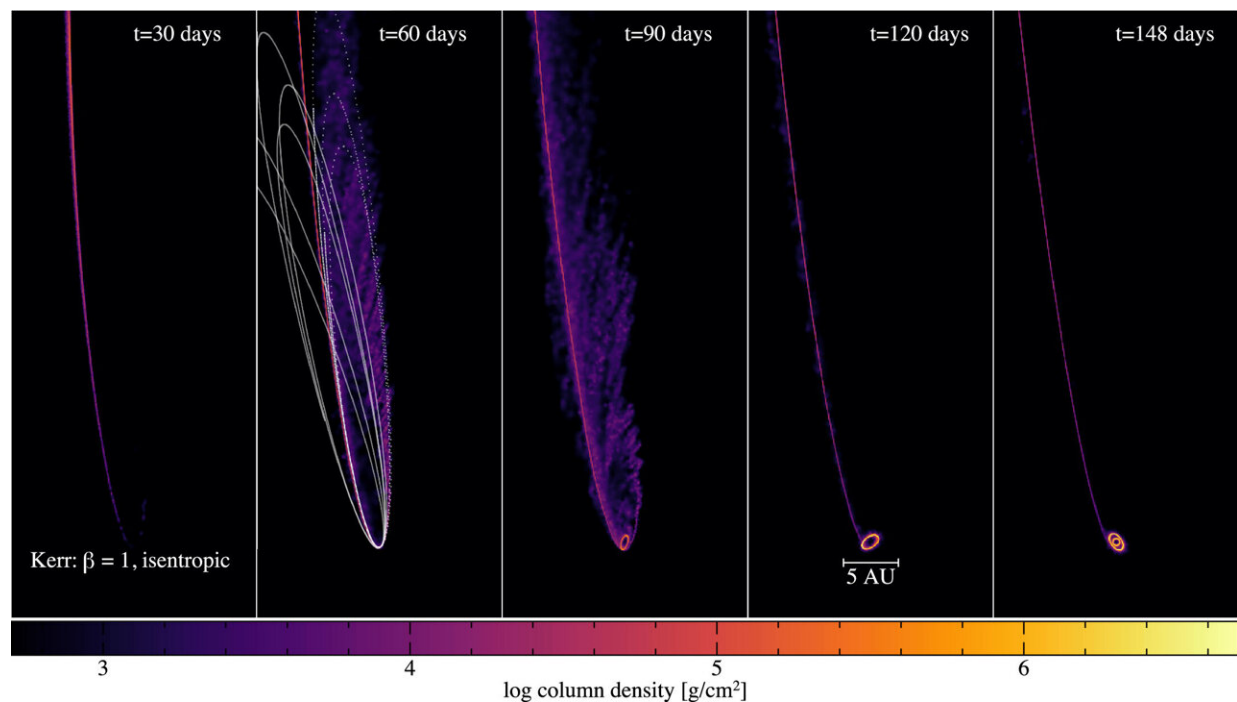


New simulations shed light on stellar destruction by supermassive black holes

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Disk formation in an isentropic simulation (radiatively efficient cooling) with a spinning black hole ($a = 0.99$, $\theta = 60^\circ$). The disk in this case is formed after 90 days and undergoes differential precession, which "tears" the disk into independent rings. Credit: *The Astrophysical Journal Letters* (2024). DOI: 10.3847/2041-8213/ad6862

Monash University astronomers have contributed to a breakthrough in understanding the dramatic fate of stars that wander too close to

supermassive black holes at the centers of galaxies.

Through innovative simulations, an international research team, led by Professor Daniel Price and former student David Liptai from the School of Physics and Astronomy has captured the complex process of how these stars are torn apart and consumed by black holes, providing new insights into the mysterious optical and UV emissions observed during these [catastrophic events](#).

"This is the first self-consistent [simulation](#) of a star being tidally disrupted by a supermassive black hole, followed by the evolution of the resulting debris over the course of a year," Professor Price said.

"Our simulations provide a new perspective on the final moments of stars in the vicinity of [supermassive black holes](#)," he said.

"By capturing the full evolution of the debris, we can try to connect simulations to the growing number of observed star-shredding events identified with telescope surveys"

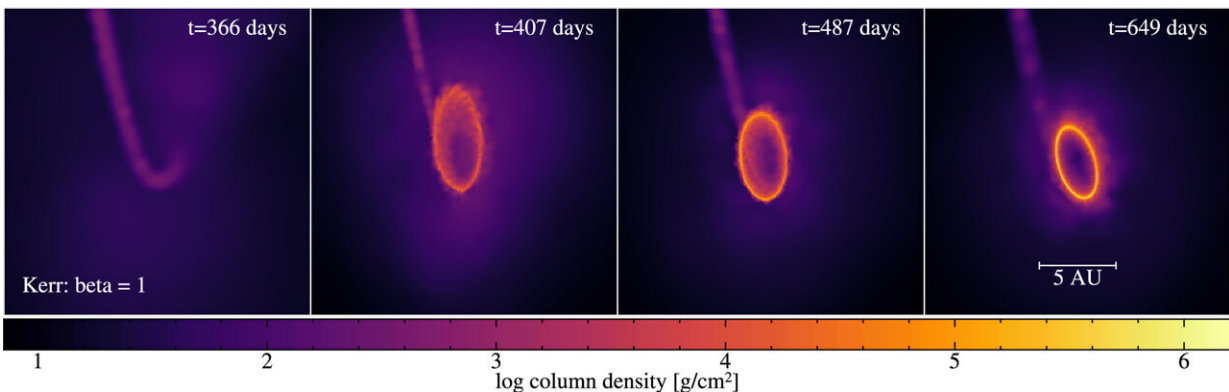
The study, [published](#) in *The Astrophysical Journal Letters*, is a significant step forward in astrophysics, opening new avenues for research into the behavior of matter in extreme gravitational fields and the life cycles of stars and black holes.

When a star passes too close to a supermassive black hole, the intense gravitational forces pull it apart in a process known as a tidal disruption event (TDE). The debris from the star forms a stream that eventually feeds the black hole. The debris from the star forms a swirling disk around the black hole, which emits intense radiation across the electromagnetic spectrum. However, many aspects of TDEs remain poorly understood.

The new simulations show that this debris forms an asymmetric bubble around the black hole, reprocessing the energy and producing the observed light curves with [lower temperatures](#), fainter luminosities, and gas velocities of 10,000–20,000 km/s.

"The study helps to explain several puzzling properties of observed TDEs," Professor Price said. "A good analogy is the [human body](#): when we eat lunch, our body temperature does not change much. This is because we reprocess the energy from lunch into infrared wavelengths.

"A TDE is similar, we mostly do not see the black hole stomach eating gas, because it is smothered by material that reemits at optical wavelengths. Our simulations show how this smothering occurs."



Disk formation in the core of the envelope when an adiabatic simulation is continued with radiatively efficient cooling. We resumed an adiabatic calculation 1 yr after disruption assuming isentropic evolution. Credit: *The Astrophysical Journal Letters* (2024). DOI: 10.3847/2041-8213/ad6862

Other mysteries explained by the new simulations include:

- Why tidal disruption events are observed at optical rather than X-ray wavelengths, where X-rays would be expected from accretion onto a supermassive black hole.
- Why the temperatures observed are consistent with the photosphere of a star rather than the expected hot accretion disk.
- Why observed star-shredding events are fainter than expected from models of black holes efficiently eating material.
- Why the spectra of observed events find material expanding towards us at a few percent of the speed of light (10–20,000 km/s).

The research team used the advanced smoothed particle hydrodynamics code Phantom, incorporating general relativistic effects to simulate the dynamics of the star and the [debris](#) accurately. This level of detail is crucial for capturing the [complex interactions](#) and energy dissipation processes that occur during and after the star's disruption.

"The findings confirm the theoretical existence of Eddington envelopes, which act as a reprocessing layer for the emitted energy, explaining the optical and ultraviolet emission observed during TDEs," Professor Price said.

"This model also offers a potential explanation for the observed differences in X-ray and optical lightcurves from these events, suggesting that varying viewing angles might account for these discrepancies."

More information: Daniel J. Price et al, Eddington Envelopes: The Fate of Stars on Parabolic Orbits Tidally Disrupted by Supermassive Black Holes, *The Astrophysical Journal Letters* (2024). [DOI: 10.3847/2041-8213/ad6862](https://doi.org/10.3847/2041-8213/ad6862)

Provided by Monash University

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