

Spaghettification

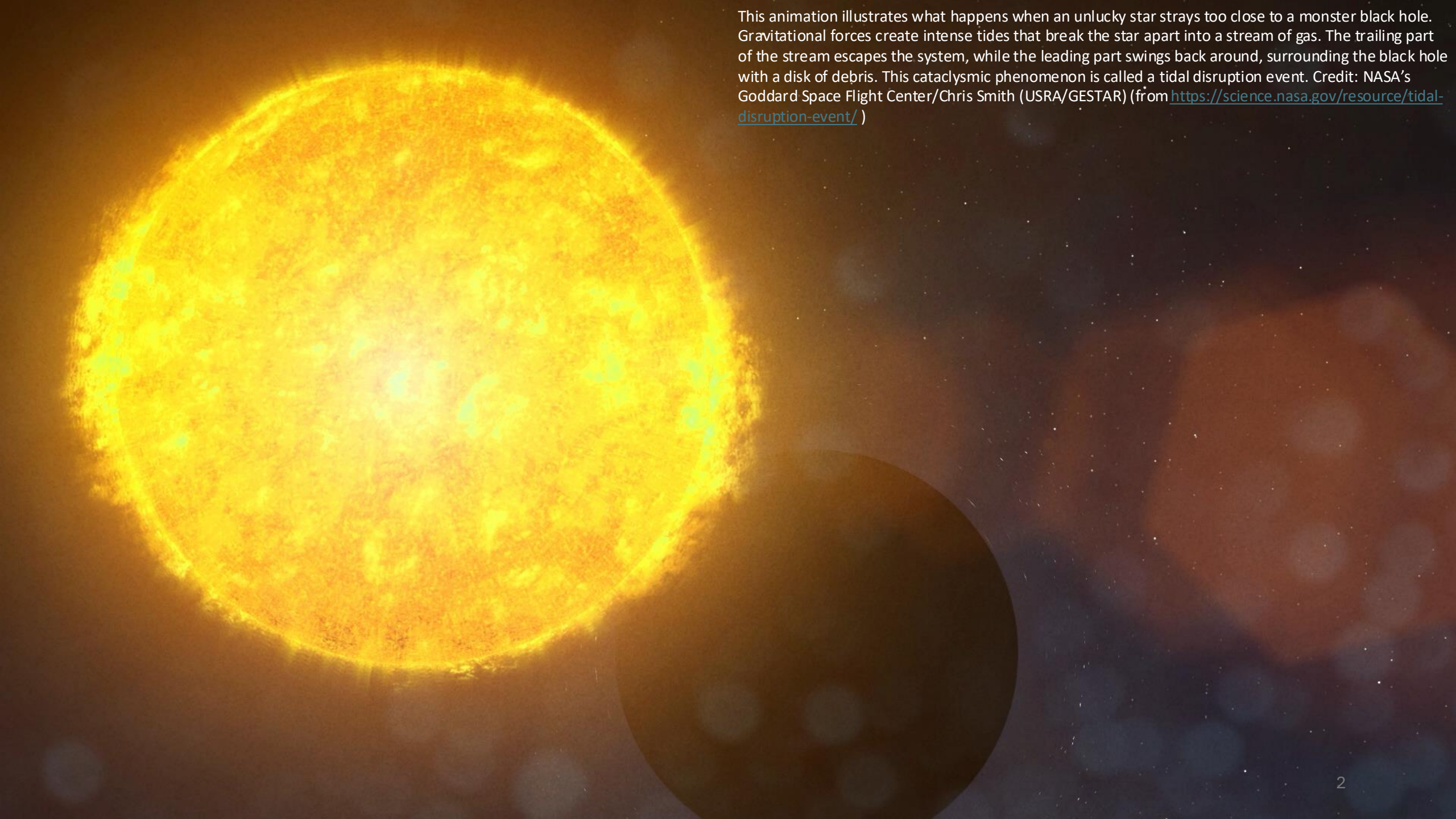
In astrophysics, spaghettification (sometimes referred to as the noodle effect) is the vertical stretching and horizontal compression of objects into long thin shapes (rather like spaghetti) in a very strong, non-homogeneous gravitational field. It is caused by extreme tidal forces. In the most extreme cases, near a black hole, the stretching and compression are so powerful that no object can resist it. Within a small region, the horizontal compression balances the vertical stretching so that a small object being spaghettified experiences no net change in volume.

Stephen Hawking described the flight of a fictional astronaut who, passing within a black hole's event horizon, is "stretched like spaghetti" by the gravitational gradient (difference in gravitational force) from head to toe. The reason this happens would be that the gravitational force exerted by the singularity would be much stronger at one end of the body than the other. If one were to fall into a black hole feet first, the gravity at their feet would be much stronger than at their head, causing the person to be vertically stretched. Along with that, the right side of the body will be pulled to the left, and the left side of the body will be pulled to the right, horizontally compressing the person.

(from Wikipedia, <https://en.wikipedia.org/wiki/Spaghettification>)



This animation illustrates what happens when an unlucky star strays too close to a monster black hole. Gravitational forces create intense tides that break the star apart into a stream of gas. The trailing part of the stream escapes the system, while the leading part swings back around, surrounding the black hole with a disk of debris. This cataclysmic phenomenon is called a tidal disruption event. Credit: NASA's Goddard Space Flight Center/Chris Smith (USRA/GESTAR) (from <https://science.nasa.gov/resource/tidal-disruption-event/>)



Eddington luminosity

(simplified calculation from a note by Ilya Mandel)

- Spherically symmetric accretion and spherically symmetric radiative energy outflow
- Hydrostatic equilibrium of thin spherical shells (gravitational pull = radiation pressure force)

$$F_G = \frac{GMdm}{r^2} = F_\gamma = \frac{L}{c} \frac{\kappa dm}{4\pi r^2}$$

mass of gas shell

luminosity (W m^{-2})

opacity of the whole shell (m^2kg^{-1})

radiative momentum per unit time

fraction of photons interacting with the shell

Eddington luminosity

(simplified calculation from a note by Ilya Mandel)

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- Hydrostatic equilibrium of thin spherical shells (gravitational pull = radiation pressure force)

$$F_G = \frac{GMdm}{r^2} = F_\gamma = \frac{L}{c} \frac{\kappa dm}{4\pi r^2}$$

Solving for the luminosity L we find

$$L_{\text{Eddington}} = \frac{4\pi Gc}{\kappa} M$$



Eddington Envelopes: The Fate of Stars on Parabolic Orbits Tidally Disrupted by Supermassive Black Holes

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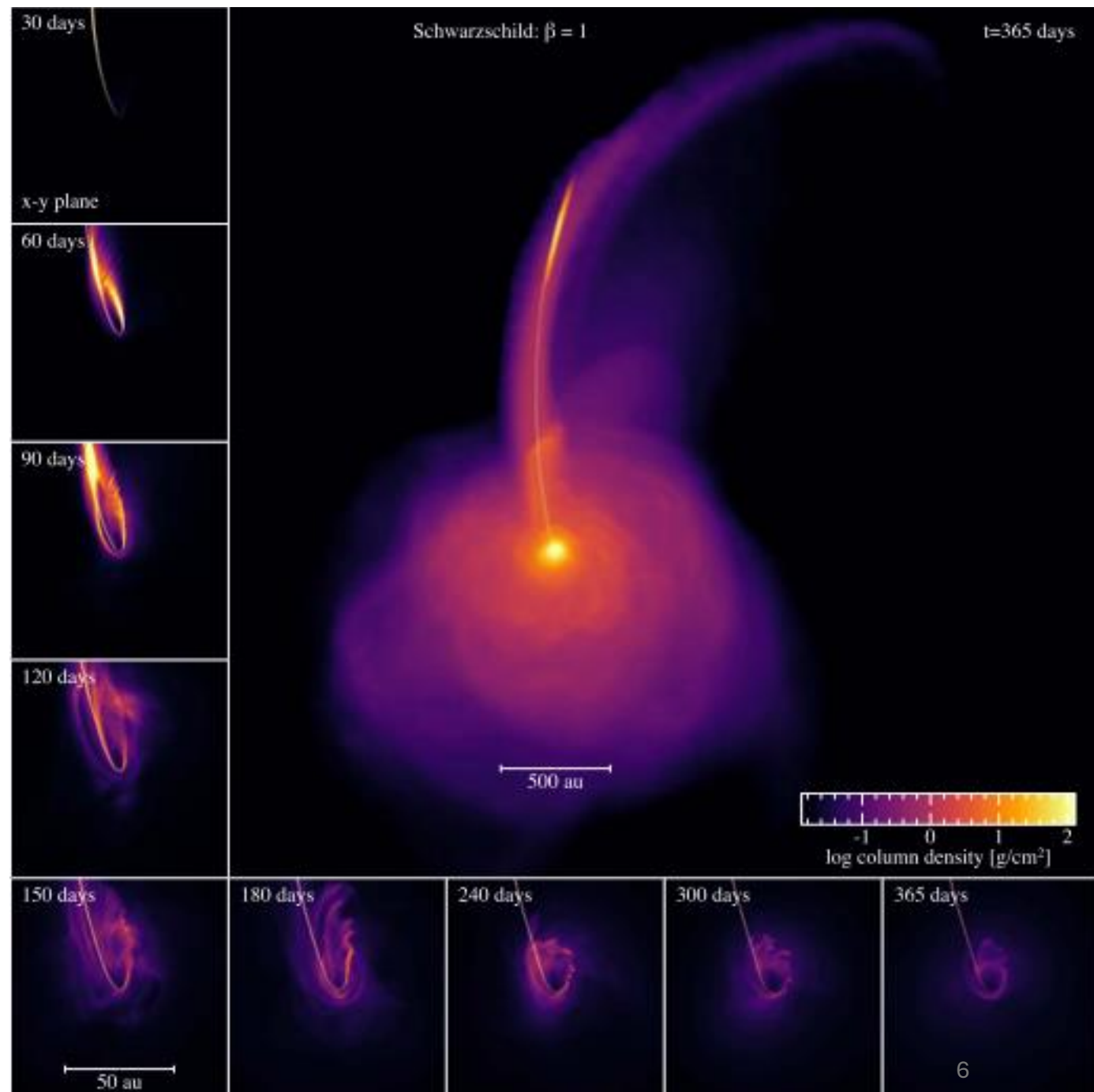
Abstract

Stars falling too close to massive black holes in the centers of galaxies can be torn apart by the strong tidal forces. Simulating the subsequent feeding of the black hole with disrupted material has proved challenging because of the range of timescales involved. Here we report a set of simulations that capture the relativistic disruption of the star, followed by 1 yr of evolution of the returning debris stream. These reveal the formation of an expanding asymmetric bubble of material extending to hundreds of au—an outflowing Eddington envelope with an optically thick inner region. Such outflows have been hypothesized as the reprocessing layer needed to explain optical/UV emission in tidal disruption events but never produced self-consistently in a simulation. Our model broadly matches the observed light curves with low temperatures, faint luminosities, and line widths of 10,000–20,000 km s⁻¹.

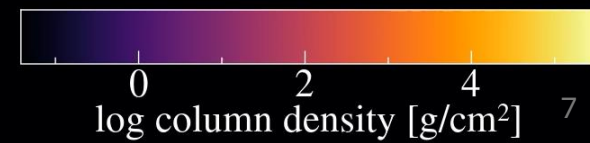
Unified Astronomy Thesaurus concepts: Tidal disruption (1696); Transient sources (1851); X-ray transient sources (1852); Supermassive black holes (1663); Black hole physics (159); Ultraviolet transient sources (1854); Active galactic nuclei (16); High energy astrophysics (739); General relativity (641)

A year in the life of a TDE. We show snapshots of column density in the simulation of a 1 solar mass star on a parabolic orbit with $\beta = 1$, disrupted by a 10^6 solar masses black hole, using 4×10^6 SPH particles in the Schwarzschild metric.

The main panel shows the large-scale outflows after 365 days projected in the x–y plane with log scale. Inset panels show the stream evolution on small scales (100×100 au), showing snapshots of column density projected in the x–y plane on a linear scale from 0 to 1500 g cm^{-2} (colors are allowed to saturate). The animation runs from 0 to 366 days. The real-time duration is 160 s.



t=0 days



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This is a video animation of a tidal disruption event (TDE), an intense flash of radiation caused by a supermassive black hole eating a star. The video begins by zooming into a galaxy located 600 million light-years away. We fly into the galaxy's starry population. Up ahead is a one million solar mass black hole. The black hole is only slightly visible due to the way it distorts light from background stars, through a phenomenon called gravitational lensing. A wayward star is swept up in the black hole's intense gravitational pull and is stretched like taffy as it falls toward the black hole. There is an incredible burst of radiation. Seen from afar, the TDE momentarily outshines the entire galaxy as a brilliant pinpoint of light. (from <https://science.nasa.gov/asset/hubble/black-hole-tidal-disruption-event/>)



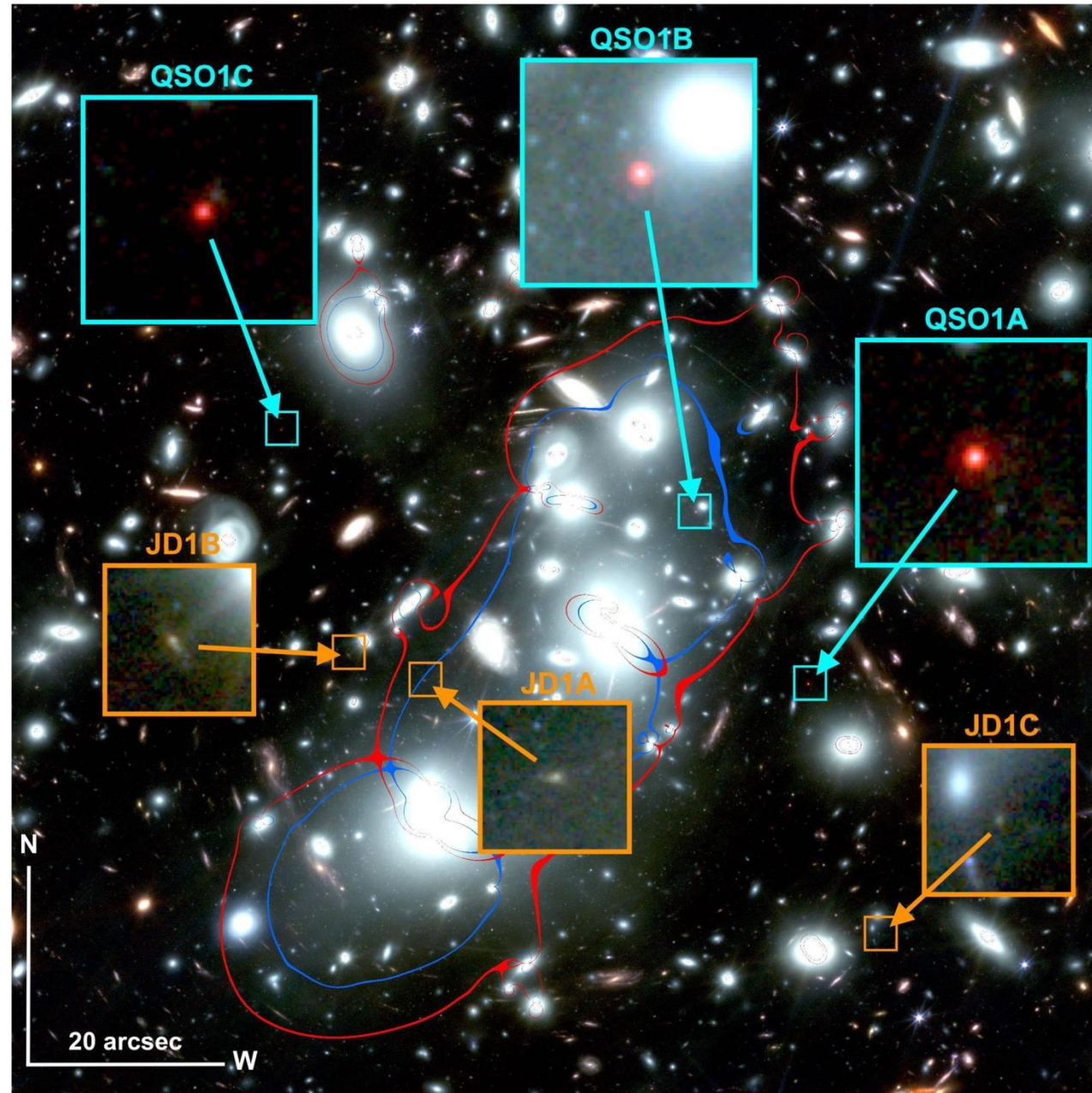
JWST UNCOVER: Extremely Red and Compact Object at $z_{\text{phot}} \simeq 7.6$ Triply Imaged by A2744

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Abstract

Recent JWST/NIRCam imaging taken for the ultra-deep UNCOVER program reveals a very red dropout object at $z_{\text{phot}} \simeq 7.6$, triply imaged by the galaxy cluster A2744 ($z_d = 0.308$). All three images are very compact, i.e., unresolved, with a deconvolved size upper limit of $r_e \lesssim 35$ pc. The images have apparent magnitudes of $m_{\text{F444W}} \sim 25\text{--}26$ AB, and the magnification-corrected absolute UV magnitude of the source is $M_{\text{UV},1450} = -16.81 \pm 0.09$. From the sum of observed fluxes and from a spectral energy distribution (SED) analysis, we obtain estimates of the bolometric luminosities of the source of $L_{\text{bol}} \gtrsim 10^{43}$ erg s⁻¹ and $L_{\text{bol}} \sim 10^{44}\text{--}10^{46}$ erg s⁻¹, respectively. Based on its compact, point-like appearance, its position in color-color space, and the SED analysis, we tentatively conclude that this object is a UV-faint dust-obscured quasar-like object, i.e., an active galactic nucleus at high redshift. We also discuss other alternative origins for the object's emission features, including a massive star cluster, Population III, supermassive, or dark stars, or a direct-collapse black hole. Although populations of red galaxies at similar photometric redshifts have been detected with JWST, this object is unique in that its high-redshift nature is corroborated geometrically by lensing, that it is unresolved despite being magnified—and thus intrinsically even more compact—and that it occupies notably distinct regions in both size-luminosity and color-color space. Planned UNCOVER JWST/NIRSpec observations, scheduled in Cycle 1, will enable a more detailed analysis of this object.

Unified Astronomy Thesaurus concepts: [High-redshift galaxies \(734\)](#); [Low-luminosity active galactic nuclei \(2033\)](#); [Reionization \(1383\)](#); [Strong gravitational lensing \(1643\)](#)



A remarkable ruby: Absorption in dense gas, rather than evolved stars, drives the extreme Balmer break of a little red dot at $z = 3.5$

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ABSTRACT

The origin of the rest-optical emission of compact, red, high-redshift sources known as little red dots (LRDs) poses a major puzzle. If interpreted as starlight, it would imply that LRDs constitute the densest stellar systems in the Universe. However, alternative models suggest active galactic nuclei (AGN) may instead power the rest-optical continuum. Here, we present JWST/NIRSpec, NIRCam, and MIRI observations from the RUBIES and PRIMER programs of *The Cliff*: a bright LRD at $z = 3.55$ with an exceptional Balmer break, twice as strong as that of any high-redshift source previously observed. The spectra also reveal broad hydrogen (H α FWHM ~ 1500 km s $^{-1}$) and He I emission, but no significant metal lines. We demonstrate that massive evolved stellar populations cannot explain the observed spectrum, even when considering unusually steep and strong dust attenuation or reasonable variations in the initial mass function. Moreover, the formally best-fit stellar mass and compact size ($M_* \sim 10^{10.5} M_\odot$, $r_e \sim 40$ pc) would imply densities at which near-monthly stellar collisions might lead to significant X-ray emission. We argue that the Balmer break, emission lines, and H α absorption line are instead most plausibly explained by a black hole star (BH*) scenario, in which dense gas surrounds a powerful ionising source. In contrast to recently proposed BH* models of dust-reddened AGN, we show that spectral fits in the rest UV to near-infrared favour an intrinsically redder continuum over strong dust reddening. This may point to a super-Eddington accreting massive black hole or, possibly, the presence of (super)massive stars in a nuclear star cluster. *The Cliff* is the clearest evidence to date that at least some LRDs are not ultra-dense massive galaxies, and are instead powered by a central ionising source embedded in dense, absorbing gas.

Key words. galaxies: active – galaxies: evolution – galaxies: kinematics and dynamics – galaxies: stellar content

An illustration of a black hole star — a potentially new class of cosmic object with a feeding black hole at its center, and a dense cocoon of turbulent gas surrounding it like a star. (Image credit: MPA/HdA/T. Müller/A. de Graaff)

