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Accretion Disks and TDEs

A new paper submitted to the Astrophysical Journal this August contains new findings that strongly suggest accretion disks are always formed during tidal disruption events.

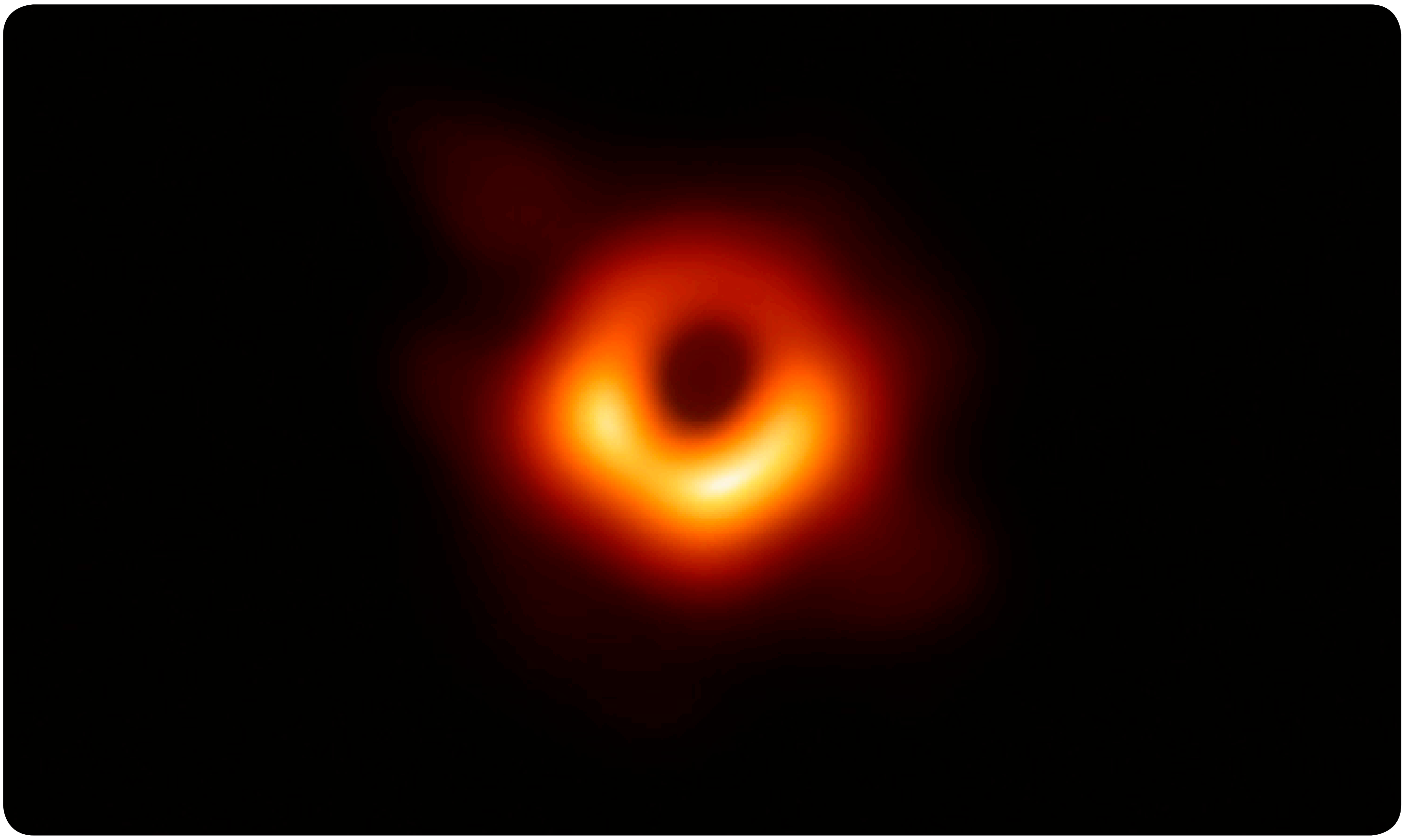
Tidal disruption events (TDEs) are luminous radiation flares caused when a star approaches sufficiently close to a supermassive black hole (SMBH) and is ripped apart by tidal forces. These are forces that occur when there is a considerable difference in gravitational strength, and therefore mass. They cause tides and stretch objects—the larger the difference in mass, the larger the stretching effect. A typical black hole can be between 3 and 10 solar masses, while supermassive black holes are astonishingly heavy and weigh in at millions and billions of solar masses. This is why black holes cause an extreme case of stretching—spaghettification.

Accretion, literally meaning accumulation, is when diffuse material aggregates into a large object by gravitationally attracting more and more matter. The orange glow in the first ever picture of a black hole that broke international headlines last year is an accretion disk. These disks are structures composed of diffuse material in orbit around a heavy central body. A disk is formed instead of a spherical cloud due to the conservation of angular momentum which causes the cloud to flatten in order to increase the radius of the structure.

Classical theory suggests that stellar debris spirals inwards due to friction and is captured in such a disk around a black hole, which causes a temporary radiation flare as matter in the disk is consumed by the black hole. When this happens, frictional and gravitational forces compress the material and increase its temperature, leading to the emission of electromagnetic radiation. In practice, we know that bright flares like these are TDEs as they have been observed in quiescent galaxies and evolve from supernovae in a distinct manner.

The inner region where hot gas escapes into the black hole is expected to produce x-rays, but for most TDEs, only ultraviolet (100 nm–400 nm) and optical wavelengths (100 nm–1 mm) are seen. Theorists have started to question whether accretion disks can even be formed in an efficient manner, and have considered the possibility of an alternate source of emissions—collisions of stellar stream debris. A stellar stream is a group of stars orbiting certain types of galaxies that have been stretched out by tidal forces.

In their 2018 paper, Jane Dai at the University of Hong Kong, and professor Enrico Ramirez-Ruis at the University of California, Santa Cruz proposed a model that explains the lack of x-ray emission during TDEs despite the formation of accretion disks. They posit that an optically thick wind obscures the



The red ring seen here is an accretion disk

region close to the black hole which is why the x-ray emissions aren't seen, however, optical light from an elliptical accretion disk is. Since 1999, more than 93 TDEs have been observed, and accretion disk formation has been confidently established in the ones with x-ray emissions (less than 10% of the TDEs observed). In optically discovered TDEs, the first event where x-rays have been seen was observed very recently.

A TDE in 2MASS J10065085+0141342, a galaxy 624 million light-years away, named AT 2018hyz, was first detected in November 2018 by ASAS-SN (the All Sky Automated Survey for Supernovae). An unusual spectrum from the TDE was noticed at the Lick Observatory in San Diego in January 2019. The hydrogen line (the line created by changes in the energy state of neutral hydrogen atoms) had a double peak—a result of the Doppler effect.

The Doppler effect is a change in the frequency of waves, like sound or light, that happens as the source and observer move away or towards each other. In the black hole image, one side of the accretion disk is brighter; the rotation of the disk causes the part of the disk towards us to move almost at lightspeed. The difference in brightness is a result of the Doppler effect.

The doubly peaked Balmer emission, which is the emission that occurs in hydrogen atoms when electrons transition from higher states to the state with principal quantum number 2, is interpreted as near-definite proof of the formation of an accretion disk. The line profile of the emissions is well-modelled by a near-circular disk, serving as strong observational evidence for swift circularisation following the disintegration of a star, consistent with classical predictions. Observations were obtained at Lick Observatory, the W. M. Keck Observatory, the Southern Astrophysical Research (SOAR) telescope, and the Las Campanas Observatory.

Single supermassive black holes can be studied under drastically varying conditions through the observation of objects such as AT 2018hyz. Continued study provides the best prospects of truly understanding the full extent of the physics of accretion disks around supermassive black holes. Accretion is ubiquitous—the formation of stars, planets, and galaxies all occur through this process—and there is a good chance that grasping what happens here also enriches our knowledge of what happens everywhere else in the universe.

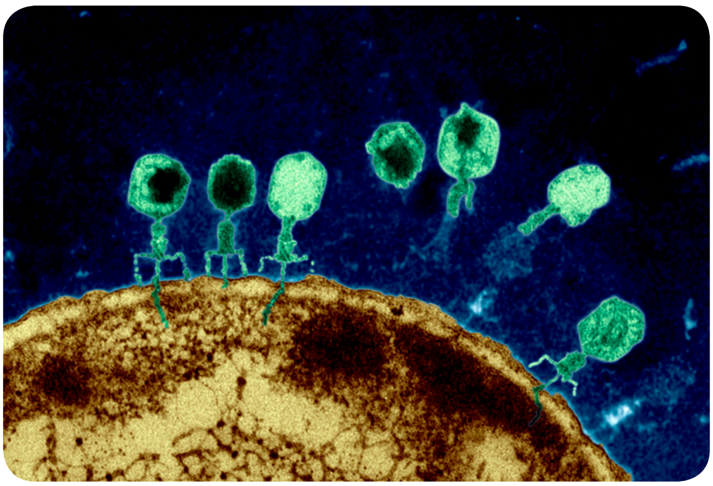
—Rithika Ganesan, B '19
References: [1], [2]

Phage Therapy

The rise of antibiotic-resistant 'superbugs' is detrimental to human healthcare. The overuse and improper disposal of chemicals such as antibiotics has led to more and more bacteria acquiring antibiotic resistance. Therefore, it is only predictable for antibiotic resistance to be seen in bacterial infections like tuberculosis, gonorrhoea etc., making their treatment extremely difficult. In this scenario, strange as it may sound, viruses might be a possible alternative to antibiotics in what is called phage therapy.

Bacteriophages, or phages, are viruses that can infect bacteria. Phage therapy makes use of genetically engineered bacteriophages to attack the bacteria that cause infections. They act by recognizing certain receptors on the surface of bacteria and entering the cell. Once inside, the virus can either incorporate its genetic material into the host genome and stay dormant, in what is called the lysogenic cycle, or use the host cell machinery to make more viruses and break free from the host cell by lysis, in what is called the lytic cycle. In phage therapy, viruses are engineered to follow the lytic cycle so that the host bacteria is lysed and killed immediately.

Phages tend to be strain and species-specific and are harmless to the host, unlike broad spectrum antibiotics which may attack essential gut bacteria. Since bacteriophages are highly specific, there is a need to administer phage cocktails to increase the chances of success, especially in the case of infected burn victims who may be infected by more than one type of bacteria. Other major advantages that phages have over antibiotics include self-amplification, biofilm degradation and low toxicity to humans.



Bacteriophages on a bacterial cell wall

This method was successfully used to treat 15-year-old Isabelle Carnell-Holdaway, who was suffering from cystic fibrosis caused by an antibiotic-resistant strain of *Mycobacterium abscessus.* She was not cured but the therapy helped put her condition under control.

Although bacteria have evolved mechanisms to resist viral infection, such as altering their surface receptors and using defence strategies like CRISPR, viruses have also evolved to break through these defences using equally remarkable methods like identifying the altered receptors and anti-CRISPR genes. We have essentially pitted a virus against a bacterium and there is a kind of competitive evolution happening where each tries to defeat the other. This is not possible for a chemical compound such as an antibiotic.

Although phage therapy was founded before antibiotics, it was abandoned due to lack of full knowledge of phages, and logistical and technical difficulties. However, with more research, this strategy has the potential to transcend antibiotic resistance in a post-antibiotic era.

—Annu Mariyam Joseph, B '17
Source

Event 201: An Eerie Premonition

On 31st December 2019, the WHO China Country Office was informed of a pneumonia of unknown cause detected in the city of Wuhan in the Hubei province, China. On 11th February 2020, this disease was finally christened COVID-19. A few months earlier, in October 2019, a group of people met in New York to take part in a pandemic preparedness simulation called Event 201.

Hosted by the Johns Hopkins Centre for Health Security, the World Economic Forum, and Bill & Melinda Gates Foundation, Event 201 was a simulation exercise. The participants included scientists, public health experts, government officials and business owners. The scenario briefing for Event 201 reads: 'Event 201 simulates an outbreak of a novel zoonotic coronavirus transmitted from bats to pigs to people that eventually becomes efficiently transmissible from person to person, leading to a severe pandemic. The pathogen, and the disease it causes, are modelled largely on SARS, but it is more transmissible in the community setting by people with mild symptoms.' To us in 2020, this sounds eerily like what we are going through right now. The exercise consisted of pre-recorded newscasts and briefings where the participants were given information about this new fictional disease that was causing widespread illness and death. In this model of the pandemic, half of all patients develop mild illness (I_m) and the other half develop severe illness (I_s). Patients with a severe infection either die (D) or recover (R) at rate α. Those with a mild infection move to the recovered compartment at rate δ. The objective of such an exercise was to bring together people from different sectors and present them with a difficult situation, in this case a pandemic, to identify improvements the world's disaster preparedness. It highlighted the need for quick response and co-operation between different sectors. Their recommendations included enhancing stockpiles of medical supplies, finding ways to maintain trade and travel safety, ramping up manufacturing of diagnostics equipment, vaccines and therapeutics, and minimising the economic impact of the pandemic.

The outcome of Event 201 was very grim; the scenario ends at the 18-month point, with 65 million deaths. However, this shouldn't be fuel for conspiracy theories or panic about COVID-19. The team behind the exercise has categorically stated that these predictions should not be used to make assumptions about how COVID-19 will pan out. Instead, they want the knowledge gained through this exercise to inform the actions of all stakeholders to minimise the damage caused by a pandemic.

—Ira Zibbu, B '19
Read more

The Younger Dryas Period

History is full of mystery through the lens of a scientist. It is interesting to note that human civilization has changed so much in the past 300 years that it is impossible to guess what's going to happen in the next 300 years. History has had its own roller coaster ride in terms of its temperature, life forms, civilization etc. Although our knowledge of history begins to fade as we move beyond 5,000 years ago, we have managed to uncover some truly fascinating details about what happened around 12,800 years BP.

Earth was at the end of the late Pleistocene Epoch (which lasted from 2.6 million to 11,700 BP) and was slowly rising through the ice age. Before long, a sudden climatic change prompted the atmospheric temperatures to drop to extremely low levels again. The planet saw a dip of almost 7°C. Keep in mind that the atmosphere had an average temperature increase of 0.7°C per decade since 1880.

This harsh period of almost -50°C continued for about 1200 years, with fluctuations in temperature, before a resurgent spike in temperatures altered the atmospheric temperature to -37°C. This mysterious period is called the Younger Dryas (YD), which led to the beginning of Holocene Epoch (11,700 years ago to the present) and Earth's modern climate.

The graph (see figure) was a product of two important research projects: the Greenland Ice Sheet Project (1971–81,1988–93) and the Greenland Ice Core Project (1989–95). The timing of past climatic fluctuations has been determined by measuring the ratio of two oxygen isotopes, oxygen-18 and oxygen-16, present in bubbles of air trapped in different layers of the ice, which was taken from the Greenland Ice Sheet. The isotope data suggests that Greenland was approximately 15°C colder during the YD than it is today and that the sudden warming that ended the YD took about 40 to 50 years. The total warming at the end of the YD was about 10∓4°C.

Earth, as a whole, experienced massive floods and wildfire across its face. This led to many extinctions of flora and fauna, including Pygmy Mammoths (*Mammuthus exilis*). The supposed start of human civilization started right after the end of YD. This comes as a surprise since the climate would have been extremely harsh during the YD. Scientists are still working on how these people adapted and survived the climate.

Revealing the truth behind this event is a monumental task for archaeologists and geologists as any leftover evidence is scarce and scattered everywhere. Despite this, scientists have plausible explanations. The best, recent evidence suggests a flood into the Arctic Ocean through western Canada. This used to be the driving theory until a massive crater was found by Kurt Kjæ under Hiawatha, Greenland. The Hiawatha crater is a 31-kilometre-wide, circular bedrock depression beneath up to a kilometre of ice. This led to the formulation of what's known as the Impact Hypothesis. The theory suggests that an extra-terrestrial comet (maybe many) flew into the atmosphere and resulted in the beginning of YD. Although controversial and far-fetched, this theory is backed by relevant evidence. Many scientists believe that the Hiawatha Crater would date right back to the YD period, but the accurate date is still unknown. Strong evidence for the theory is the discovery of shock-synthesized hexagonal diamonds in the YD boundary sediments which could only form under tremendously high temperature.

British science-journalist Graham Hancock, along with American geologist Randall Carlson, has been tracking the events of YD for almost two decades now. They are perhaps the most famous proponents of the Impact Hypothesis. To add their own flavour to the mix, they propose the existence of an advanced human civilization that was wiped out as a result of YD. Gobekli Tepe is one of the many pieces of evidence they're using to fuel their claim.

Despite the fact that Graham and Randall receive heavy criticism, they seem to be confident with the large amount of evidence they have. I highly recommend Graham's books, *The Fingerprints of the Gods* and *The Magicians of the Gods*, which heavily outline his theory along with hard scientific facts. The past is just waiting patiently to be revealed.

—Praveen Murali, B '18
References: [1], [2], [3], [4]

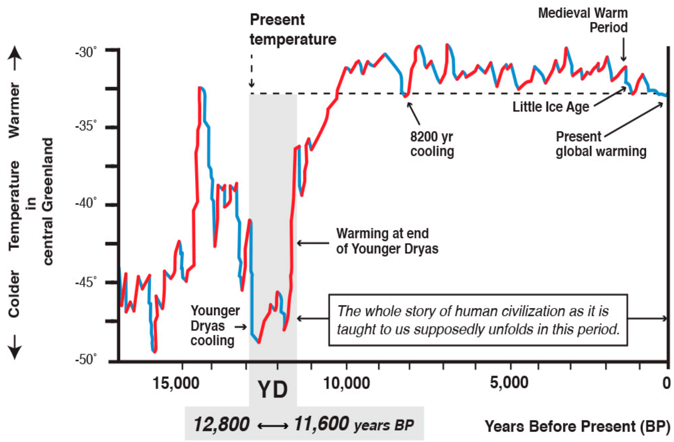


Figure: The History of Temperature Change in Greenland

The Father of Digital Vision

When was the most recent event where you got frustrated in front of a screen that showed unaesthetic blocks in place of smooth lines and gradients? Well, if it's any consolation, the creator himself laments this decision: 'Squares was the logical thing to do,' he told the magazine *Wired* in 2010. 'Of course, the logical thing was not the only possibility but we used squares. It was something very foolish that everyone in the world has been suffering from ever since.'

Twenty-two-year-old Russell Kirsch joined the National Bureau of Standards in 1951 as a part of the team that ran the Standards Eastern Automatic Computer (SEAC), the US's first stored-program computer. Six years later, his group developed a digital image scanner to trace the variation of intensity over the surface of photographs. The scanner was composed of a rotating drum and a photomultiplier, which sensed reflections from a small image mounted on the drum. A mask was used to dissect the image into smaller elements in the shape of—you guessed it—squares. They tested multiple algorithms and plugged the SEAC to a staticiser which allowed the image to be displayed on a cathode ray tube. The black and white image (which had no greyscale) showed them the limitations of binary representation. To overcome this, they scanned the image multiple times at different thresholds and superimposed them, and using time-varying thresholds for pulse density modulation, multiple grey levels were achieved.

The fruit of this arduous labour is the picture shown below. The 176 x 176 array image scaling 5 cm x 5 cm of Walden Kirsch, Russell's three-month-old son, is one of the first-ever digitally scanned images. The image was later ranked among the '100 photographs that changed the world' by *Life* magazine. The word for these squares—pixels—was coined in 1965, a combination of the words picture (pics–pix) and elements (el).

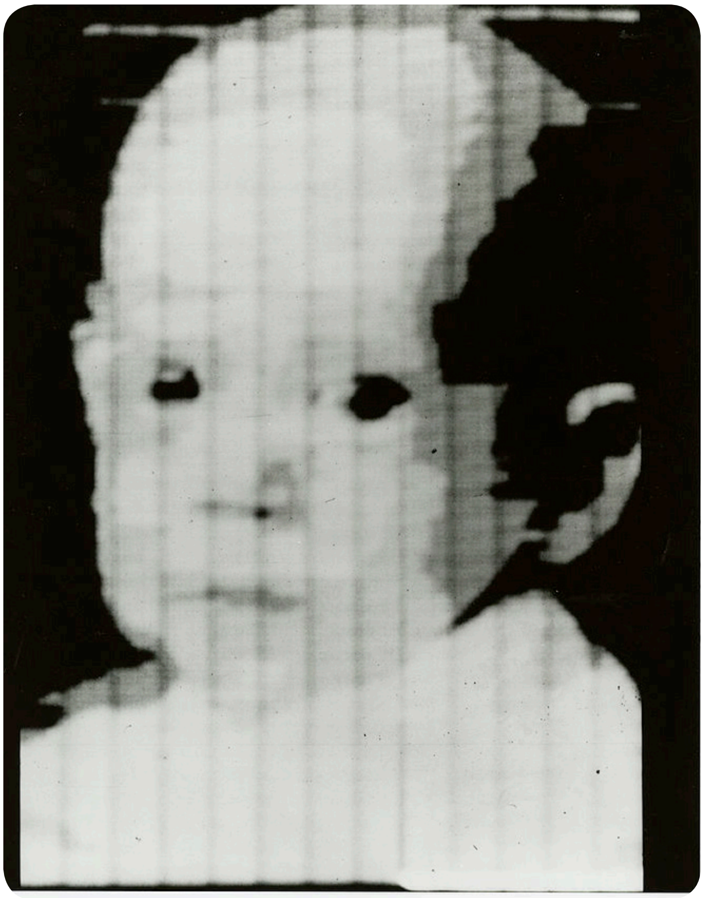
Digital imaging is now an integral part of nearly every walk of life. Pixels have become the priority, prominence and pride of almost everyone with a screen, and 'pixelated' became one of their most dreaded words. Born in Manhattan in 1929 to Jewish immigrants, Russell Kirsch received his education from Bronx High School of Science, NYU, Harvard and MIT. He later worked for five decades as a research scientist at the National Bureau of Standards. NIST statistician and Russell's colleague, Jim Filliben, describes him as a 'computer scientist before there was such a thing as computer science.' He continued to work on variable shaped pixels to replace the squares well into his senescence.

One of the best personal pictures of Russell Kirsch is painted by Joel Runyon, a blogger he met at a coffee shop. In his account of the encounter, he recounts Russell's words: 'I guess, I've always believed that nothing is withheld from us what we have conceived to do. Most people think the opposite, that all things are withheld from them which they have conceived to do, and they end up doing nothing.'

Russell Kirsch passed away on 11th August 2020. He is survived by his wife, four children and four grandchildren.

—Yashas R., B '16

Recommended reading



One of The First Ever Digitally Scanned Images

ESI Species of the Month: Copperpod (*Peltophorum pterocarpum*)

It's September and the copperpod tree, named after its bright copper-red pod cases, is about to flower, exploding with colour, and knowing a bit about it would help us better appreciate its beauty. You'd be hard-pressed to not notice these vibrant yellow-colored flowers carpeting avenues all across the country. The copperpod tree is native to South East Asia, Malaysia and Northern Australia, and is naturalised in many other tropical places. The copperpod tree is also known as *Peela gulmohar* (Hindi), *Charakonna* (Malayalam), *Perunkondrai* (Tamil), *Haladi gulmohar* (Kannada) and *Radhachura* (Bengali).

Description:
It is a deciduous tree species that belongs to the family of Leguminosae. It has bi-pinnate leaves, which bear a resemblance to the Gulmohar tree's leaves. The bright yellow, mildly scented flower clusters adorn the tips of branches. Copperpod generally starts flowering towards the end of August in India. The fruit is a pod which has a copper-red case that blackens upon maturing and each pod bears 2-4 seeds, which are used for propagation.

Uses:
The wood is used for making cabinets, and the leaves are a source of fodder. Decorations in Telangana state's Batukamma festival make good use of Copperpod flowers. These trees when planted alternatively with the Gulmohar tree give a beautiful yellow-red effect in summer.

—Article by Vishwathiga J., B '19
Art by Nikitha S., B '17
Source

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