'Tidal disruption events: from stellar disruption to accretion (TDE)' Abstracts

Talks

Shock-driven wind in tidal disruption events

Authors

Paola Martire (1)

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Abstract

TDEs observations have already produced tens of light curves, and this number is expected to grow rapidly with the upcoming telescopes. Nevertheless, the origin of the early-time luminosity peak remains unclear, as key processes such as energy dissipation and circularization are not fully understood. Numerical simulations are essential to probe these mechanisms. In my talk, I will present the results from a 3D global simulation of a 10^4 solar mass black hole that self-consistently includes both dynamics and radiation. I will discuss the role of the nozzle shock in driving unbound outflows, and producing near-Eddington emission. Combining numerical and analytical approaches, I will explore the properties of the outflowing material and their implications for the system’s dynamics, polarization, and energy transport.

Revisiting Double Tidal Disruption Events as an Alternative Channel for Extreme Nuclear Transients

Authors

William Stone (1)

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Abstract

A recently discovered subset of luminous, long-lived, nuclear transients has been attributed to accretion events onto supermassive black holes (SMBHs). More specifically, these extreme nuclear transients (ENTs) have been interpreted as the tidal disruption of high-mass stars by massive SMBHs. However, the rare nature of this channel casts doubt on whether it can account for the number of ENT observations thus far. We propose formation channels which could serve as alternative explanations for massive star tidal disruption events (TDEs), such as double TDEs from stellar binaries, tidally induced binary stellar collisions, and high-velocity collisions in the dense nuclear environment.

Focusing on the double TDE channel, we perform a rigorous parameter space study and discuss the conditions for producing either a single or double peaked light curve. Using analytic scalings and physically motivated light curve predictions we comment on how well we can replicate the observational features of ENTs. We also demonstrate how the choice of optical/UV TDE emission model affects the predicted observables from a double TDE and the potential implications for double TDEs as ENT progenitors.

Can Tidal Disruption Events Reliably Weigh Black Holes in the Rubin LSST Era?

Authors

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Abstract

Tidal disruption events (TDEs) offer a unique window onto dormant supermassive black holes, but reliably inferring black hole masses from TDE light curves remains a major challenge. In this talk I will present results from a systematic investigation of current semi-analytic TDE models applied to a sample of spectroscopically confirmed repeating partial TDEs. By modelling multiple flares from the same black hole with independent frameworks (including fallback accretion fits, stream-stream collision scalings, empirical luminosity relations, and cooling-envelope models), we assess both internal model consistency and agreement with host-galaxy mass proxies. While many approaches yield self-consistent black hole masses to within ~0.3–0.5 dex, strong degeneracies in stellar mass and encounter depth highlight limitations in current model grids and stellar prescriptions. Looking forward to the Vera Rubin Observatory's Legacy Survey of Space and Time (LSST), I will discuss how cadence, wavelength coverage, and survey depth will impact TDE parameter recovery, including systematic offsets introduced by sparse sampling and limited rest-frame UV information, and what strategies are needed to maximise scientific return from LSST TDE samples.

White dwarf-intermediate mass black hole tidal disruption events and the promise of GRB 250702B (Invited)

Authors

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Abstract

White dwarf-intermediate mass black hole tidal disruption events (WD-IMBH TDEs) are a particularly elusive class of TDE, with no truly definitive detection over the decades of TDE astronomy. However, GRB 250702B, also detected by Einstein Probe as EP250702a, may represent the best candidate for these transients. Despite its name, its properties of repeating gamma-ray flares, an X-ray precursor that appeared a day earlier and extreme energetics are incompatible with classic models of gamma-ray bursts. Instead, I will show that these properties are entirely consistent with repeated partial disruptions in a WD-IMBH system building to a final complete disruption. I will also discuss the possibility that other objects similar to GRB 250702B may be hidden in archival data or in the parameter space being explored by Einstein Probe, and the implications for other possible WD-IMBH systems.

Constraining massive black hole properties using repeating partial TDEs

Authors

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Abstract

Recent observations have revealed an increasing diversity of non-standard tidal disruption events (TDEs) exhibiting complex optical light-curve morphologies, such as precursor emission and double peaks. These observations suggest that the population of TDE progenitors in the dense nuclear environments of massive black holes extends beyond single stars on plunging parabolic orbits.

Stars on bound orbits can undergo repeated partial TDEs (rpTDEs), which will be the focus of this talk. The partial stripping of a star leaves behind a surviving core and generates a fresh debris stream at each pericentre passage. Using kinematic simulations, I will characterise the dynamics and energy dissipation of multiple stream–stream collisions arising from these successive stripping events, including both standard stream self-intersections and (unique to rpTDEs) stream collisions from distinct stripping events. I will describe how the latter interactions produce precursor emission before the main repeated flare, and show how they offer a new way to constrain black hole spin. I also note how repeating partial TDEs can mimic double-TDE light curves. Finally, I will discuss prospects for time-domain surveys and rapid multi-wavelength follow-up.

First optical polarimetry of ambiguous nuclear transients: probing the geometry of extreme accretion

Authors

Phil Wiseman (1)

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Abstract

Ambiguous Nuclear Transients (ANTs) occupy a poorly understood territory between tidal disruption events (TDEs) and AGN variability, exhibiting smooth, large-amplitude flares on timescales of hundreds to thousands of days and luminosities that can challenge both paradigms. ANTs are highly heterogeneous and likely span several physical phenomena, including the full or partial disruptions of massive and evolved stars; TDEs in pre-existing AGN disks; disruptions of dense clouds originating in circumnuclear dust structures, or other extreme scenarios. A key open question is the geometry of the UV-optical emission region: does the light originate from a structured accretion disk, shock interaction with circumnuclear material, or scattering by a dusty torus? Optical polarimetry offers a uniquely direct probe of emission geometry, yet no systematic polarimetric study of ANTs has previously existed.

We present the first imaging polarimetry of a sample of seven ANTs obtained with VLT/FORS2. Several events show significant polarization detections, most strikingly AT2021lwx, the most energetic transient ever discovered, which reaches up to 2.5%. This strongly implies an aspherical emission geometry or scattering by structured circumnuclear material. The wavelength dependence of the polarization in our multi-band targets provides additional constraints on the distribution and grain properties of the dust responsible for the ubiquitous mid-infrared echoes seen in ANTs.

Not all events are polarized, however, and the non-detections are themselves informative: they place meaningful upper limits on photospheric asymmetry and suggest that ANTs do not form a geometrically homogeneous class. This diversity from null polarization to a 2.5% signal mirrors the heterogeneity already seen in ANT light curves and spectra, and raises the question of whether ANTs represent a single physical mechanism or a population unified only by observational appearance. We discuss what these first polarimetric constraints tell us about the nature of ANTs and their relationship to the broader TDE and AGN families.

Establishing the role of relativistic precession on tidal disruption events

Authors

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Abstract

The tidal field of a black hole can turn a star into a gas stream whose orbit can precess, especially if the a black hole is rapidly spinning. In this work, we investigate the impact of precession on both light curves and mass fallback rates of tidal disruption events (TDE). To do so, we perform two-dimensional radiation hydrodynamic simulations of the interaction of the TDE wind and luminosity with the precessed stream wrapped around the black hole. Our results show that in events with black holes of ~10^6 Msun and no orbit-spin inclination, the line of sight has little effect on the light curves, since the stream covers a small fraction of the solid angle as the precession is confined to the orbital plane. In the case of black holes of >10^7 Msun and high inclination (i ~ 90º), the light curve peaks can be delayed by ~100 days due to presence of the precessed stream blocking the radiation in the early phase of the event. Additionally, we present our new tool for performing hydrodynamic modelling of stellar disruptions in Kerr spacetime. We discuss the results of our first set of simulations of tidal disruptions with (non-)spinning black holes studying the impact of the depth on the mass fallback rates.

Tidal encounters of white dwarf binaries with intermediate mass black holes

Authors

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Abstract

When a stellar binary comes close to a black hole, tidal forces can lead to a range of distinct outcomes. Here, using smoothed particle hydrodynamics, we perform a suite of numerical simulations of tidal disruption events for a close binary system consisting of two low-mass white dwarfs due to an intermediate mass black hole. The black hole and the binary components are considered to be detached and on the same plane. Our results quantify how the outcomes of these events depend crucially on the positional configuration of the binary components at the orbital pericenter, and we also show how distinctive behaviour for non identical mass binaries arise, as compared to identical ones. We highlight these differences on observables such as mass fallback rates and gravitational waves. Within the ambit of the Hills mechanism, we find that the observable outcomes can be modified due to interactions between the tidal debris of the individual stars, and may also be altered by repeated tidal disruptions. Our results should serve as indicative benchmarks in the observational aspects of tidal interactions between close white dwarf binaries and intermediate mass black holes.

Posters

Planets orbiting SMBHs

Authors

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Abstract

The traditional paradigm of planetary formation is confined to the gaseous disks of young stars; however, the extreme environments surrounding Supermassive Black Holes (SMBHs) provide a radical new frontier for the birth of "Blanets." This research explores the gravitational and thermal dynamics of planetary bodies orbiting within the decoupled, cold outer regions of Active Galactic Nuclei (AGN) accretion disks. By applying modified core-accretion models to the unique pressure gradients of Kerr black holes, we demonstrate that dust coagulation can bypass fragmentation barriers to form Earth-to-Neptune mass bodies at distances of several parsecs. We further analyze the orbital stability of these systems, accounting for Lense-Thirring precession and relativistic perturbations, while evaluating the potential for atmospheric retention under the intense high-energy radiation of the central engine. This study redefines the limits of planetary demographics, suggesting that the most massive gravitational sinks in the universe may also host the most exotic planetary systems in existence.

ANTEATER: First Results for the Discovery of Candidate Exotic TDEs with LSST and 4MOST

Authors

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Abstract

The discovery of AT2021lwx established a new paradigm in transient astronomy, setting new records for both the highest luminosity and total radiated energy of a non-quasar optical transient. Perhaps most striking about this event is the ambiguity of its source: the single slow rise, slow decline of the light curve resembles a slowly decaying TDE, yet around 2 dex brighter than canonical luminosities. The spectrum is similarly non-standard, missing standard AGN lines like [OIII] and having far narrower Balmer emission than expected for TDEs. Therefore, AT2021lwx became a poster child for the emerging class of ambiguous nuclear transients (ANTs).

Before and since, a further handful of similarly ultra-luminous, long duration and un-assignable ANTs have been added to the sample, yet the group remains largely heterogeneous apart from ubiquitous MIR dust echoes. A favoured hypothesis is that ANTs represent an exotic class of TDEs: perhaps the disruption of a high mass star (with interaction with an AGN?) but the likelihood of such massive stars existing long enough to migrate and undergo tidal disruption is difficult to reconcile with the observed rate. Understanding extreme TDE behaviour could serve to constrain more general TDE models and with the upcoming industrialisation of transient astronomy using LSST, it is critical to leverage this tidal wave of data to maximise the detection of new ANTs. Based on current ANT rates, this should swell the sample by at least an order of magnitude.

Ideally, these ANTs should be detected early in their rise; the long, slow evolution of ANTs allows for a uniquely resolved glimpse into the process of SMBH accretion (and perhaps debris stream self-interactions) if full time series spectral follow-up can be arranged. TiDES, part of the 4MOST survey, will be crucial for this, with a guaranteed 250 thousand fibre-hours in an era where spectroscopic follow-up will be massively oversubscribed. Determining the difference between strange AGN behaviour and true positive ANT signatures becomes more difficult at earlier times, so obtaining early spectra will both boost the purity of our photometric ANT sample and further support the inference of the astrophysical origins of ANTs.

To this end, I present ANTEATER: the Ambiguous Nuclear Transient EArly Time ExtractoR, a machine learning classifier trained on simulated LSST NT light curves and designed to predict the classification based on the first 100 days of data. This is the first and only tool to have supervised training on a large sample of synthetic ANT light curves. ANTEATER will be used in conjunction with LSST brokers to annotate sources as they arrive, providing the community with predictions for non-standard nuclear transients of interest. In my talk I will outline the workings of ANTEATER and focus on its performance on early LSST data. I will present a first look at TiDES spectra for LSST-discovered ANT candidates and discuss the outlook for future discoveries.

Optimising Photometric TDE Classification - Results from the MALLORN Classification Challenge

Authors

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Abstract

The Vera C. Rubin Observatory's 10-year Legacy Survey of Space and Time (LSST) is expected to increase the number of TDEs discovered by two orders of magnitude, with an estimated 35000-80000 discoveries across the duration of the survey. However, even with dedicated follow-up surveys such as TiDES, we have insufficient spectroscopic resources to classify all of the detections from LSST. To maximise the scientific potential of this avalanche of data, it is necessary to be able to prioritise objects for follow-up or select them for large sample studies based purely on their photometry.

To assist with this, I created the Many Artificial LSST Light curves based on Observations of Real Nuclear transients (MALLORN) data set. MALLORN consists of over 10000 simulated LSST light curves generated from Zwicky Transient Facility (ZTF) photometry, Gaussian processes, machine learning approaches, SNCosmo SED simulations and the Rubin Survey Simulator. By grounding the simulated light curves in real ZTF observations, this approach produces a realistic and representative LSST training set with minimal assumptions about the underlying physics of the light curves. This novel approach is highly reproducible and can be used to create simulated data for any future photometric survey, provided that there is an estimate of the detection limits and cadence of the survey.

The MALLORN data set was shared as a classification challenge for photometrically identifying TDEs from 15/10/25 to 30/01/26, attracting ~13000 submissions from ~1000 participants. I will discuss the insights gained from this classification challenge, including which machine learning methods are most successful at photometrically identifying TDEs, what features are most important for their selection and what the most common contaminants will be in our search for TDEs with LSST.

These results provide a foundation for constructing large, high-purity photometric samples of TDEs in the LSST era. Such samples are essential for enhancing our physical understanding of TDEs – allowing us to better probe the diversity of TDE light curves and connect observed emission properties to the underlying physical processes.

Dragon Slaying: Removing active galactic nuclei from tidal disruption event samples

Authors

Peter Clark (1)

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Abstract

The contamination of tidal disruption event (TDE) samples by variable active galactic nuclei (AGNs) has been a persistent problem in the compilation of pure TDE samples for population studies.

With the number of TDE candidates published across literature now reaching approximately 500, it is of growing importance to improve overall sample purity to prevent the introduction of significant biases into our growing understanding of TDEs and their host galaxies.

Here I will present a method leveraging the distinct mid-infrared properties of TDE outbursts as observed by the Wide-field Infrared Survey Explorer (WISE) that allows for a pure sample of TDEs occurring in galaxies with dense nuclear environments to be isolated from other forms of nuclear activity (e.g., variable AGNs and ambiguous nuclear transients). I will outline the properties of this sample and how its properties relate to, and differ from, the established population of TDEs and other nuclear transients more generally. Whilst a powerful tool for archival studies, following the end of its operations WISE can no longer offer new transient discovery or follow-up observations.

Thankfully all is not lost, with NASA's recent launch of the Spectro-Photometer for the History of the Universe, Epoch of Reionization and Ices Explorer (SPHEREx) which provides all-sky NIR through MIR spectrophotometry.

I will show how SPHEREx provides both a new discovery engine for transients that may be otherwise missed in optical searches, as well as powerful tool for exploring the NIR and MIR evolution of nuclear transients on a scale not previously possible.