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Editorial to the Topical Collection: The Tidal Disruption of Stars by Massive Black Holes

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For several decades, astronomers have speculated that a hapless star could wander too close to a super massive black hole (SMBH) and be torn apart by tidal forces. It is only with the recent advent of numerous wide-field transient surveys that such events have been detected in the form of giant-amplitude, luminous flares of electromagnetic radiation from the centers of otherwise quiescent galaxies. These discoveries span the entire electromagnetic spectrum, from γ-rays through X-rays, ultra-violet, optical, infrared, and radio. A small number of events launch relativistic jets. These tidal disruption events (TDEs) have caused widespread excitement as they can be used to study the properties of quiescent, otherwise undetectable, SMBHs; the populations and dynamics of stars in galactic nuclei; the physics of black hole accretion including the potential to detect relativistic effects near the SMBH; and the physics of (radio) jet formation and evolution in a pristine environment. For scientific questions concerning quiescent SMBHs, TDEs are unique probes beyond the local universe. TDEs can also occur around active galactic nuclei (AGNs), although uniquely identifying such an event on top of a bright AGN is difficult.

Whereas AGNs (such as quasars) host SMBHs that are supplied by steady streams of fuel for thousands to even millions of years, TDEs offer a unique opportunity to study individual SMBHs with accretion rates that change by orders of magnitude on human timescales of

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days to months or sometimes years. In addition, because the rate of TDEs can be substantially enhanced in binary black hole systems, TDEs could point us to galaxies that are likely to host so far elusive compact binary SMBHs. Gaining knowledge on their presence and properties is of paramount importance for the ESA-led mission LISA, that will detect gravitational waves from the binary's final stages of coalescence. After the merger, a recoil kick imparted on the newly formed SMBH can cause a second wave of enhanced rate of TDEs, which can potentially be located off-centre with respect to the nucleus of the host galaxy.

Currently, the diverse emission properties of flares associated with TDEs is not fully understood. This challenge is being addressed by a sharp increase in observational work and theoretical modelling. Over the next few years, the largest growth areas will likely be in the greatly expanded surveys of the transient sky, and in new numerical modeling techniques. Together these will reveal how SMBHs shine by ripping apart orbiting stars and swallowing the stellar debris.

In light of this foreseen growth, many new researchers are expected to enter the field. Therefore, the time was deemed ripe to compose a comprehensive overview of the state of the art in this rapidly-evolving field. This topical collection was planned and launched at a workshop held at the International Space Science Institute (ISSI) in Bern on 8–12 October, 2018.

The topical collection starts off with a description of the observational properties of TDEs. Saxton et al. discuss the multi-wavelength properties and rates of those TDEs and TDE candidates selected via X-ray observations, and van Velzen et al. for those discovered in the optical and ultra-violet part of the spectrum. Alexander et al. present the radio properties of TDEs and show that only a small fraction of TDEs launches radio-luminous, mildly relativistic jets. A second van Velzen et al. contribution delves into cross-wavelength correlations, as well as echoes and reverberation from TDEs. Maguire et al. review the properties of TDEs from white dwarfs including the prospects for their detection across different wavelengths. Zabludoff et al. discuss how to distinguish TDEs from possible impostors such as supernovae, AGN flares, and gamma-ray bursts. These authors also discuss several candidate TDEs whose nature is still contended. Finally, French et al. summarize the host galaxy properties of known TDEs, and what can be learned from them, including the prospects for using host galaxy classification to assist in identifying TDEs in upcoming large transient surveys.

The collection then turns to the theory behind TDEs and the emission mechanisms at play. Stone et al. present the theory that determines the rate of tidal disruptions, and overview theoretical TDE rate estimates. Rossi et al. describe the analytic theory of the tidal disruption process itself, followed by a presentation of existing numerical hydrodynamics simulations of stellar tidal disruption. Although the theory of the disruption process is reasonably well-understood, subsequent aspects of a TDE are substantially more uncertain. Bonnerot & Stone describe a particularly unsettled aspect of TDE physics: the dissipational processes by which highly eccentric stellar debris streams lose orbital energy before settling into some type of accretion flow. Next, Dai et al. describe the physics of more fully circularized TDE discs, where the accretion rates may be highly super- or sub-Eddington. Many stages of TDE evolution present problems in 3D hydrodynamics that can only be modeled precisely with numerical simulations. Lodato et al. review the numerical techniques and results that have been used so far in the literature. Roth et al. then review existing theories of radiative emission processes in TDEs, focusing on the current debates regarding the origin of optical/ultra-violet light in TDEs. Coughlin et al. present the unique features – both dynamical and hydrodynamical – of TDEs occuring in *binary* SMBH systems. Finally, Krolik et al. overview future prospects for simulations of TDEs, emphasizing both existing physical challenges and possible computational advances that may overcome them.

While there is a loose ordering of topics, observational articles are presented in the rough order that different wavelengths or other observational aspects of TDEs entered the literature, and theoretical articles are mostly presented in a temporal sequence following the disruption process and its aftermath. Nevertheless, each article in this collection has been designed as a stand-alone review, with appropriate references to the other papers, where more details on a specific topic may be found. As such, there is no single "correct" order in which to proceed, and the reader should feel free to flip directly to the topics of greatest interest to them.

The editors would like to thank all authors and coordinators for their hard work in creating this collection, the staff at ISSI for their friendly and generous support, and the future readers of this topical collection who will no doubt answer many of the TDE puzzles that so far remain unresolved.

Due to an error, the name of the editor Nicholas C. Stone was inadvertently left out of the list of editors for this collection.