

Preface

This book presents a theoretical treatment of an exciting problem in astrophysics: the tidal disruption of stars by supermassive black holes (SMBHs). The multiwavelength flares produced by tidal disruption events (TDEs) have supernova-like luminosities, and their associated relativistic jets are visible to cosmological distances. TDEs probe the demography of quiescent SMBHs, and are natural laboratories for jet launching mechanisms and super-Eddington accretion. Although for many years this was an area of purely theoretical research, the first observations of TDEs began in the mid-1990s, and since then the sample of TDE candidates has grown rapidly. Many of the newest observations do not fit easily into the predictions of past TDE models, highlighting the need for renewed theoretical work on the subject.

Much state-of-the-art TDE research is done using numerical simulations, but the large hierarchy of mass, distance, time, and energy scales in tidal disruption means that analytic techniques are in many cases applicable, and often necessary. This book evolved out of my PhD thesis on stellar tidal disruption, and has retained as its central focus the study of TDEs through analytic methods. A majority of the chapters in this book represent my original research on TDEs, and they are interspersed with shorter chapters reviewing general results from the greater literature. These general chapters aim to provide a useful introduction for those new to the field, and to place the results of my thesis work in a greater context. The originality of the work presented in each chapter is covered here, and is also clearly labeled at the start of each chapter.

The first chapter broadly surveys TDE physics, and will be of the most interest to non-experts looking for a general introduction. The second chapter reviews existing literature on TDE rates to provide a formalism for calculating these rates in standard galactic nuclei. This rate calculation sets the stage for two chapters of original research; in the third and fourth chapters, we estimate the TDE rate following gravitational wave (GW) recoil of a SMBH (after a SMBH binary merger). Immediately after GW recoil, the TDE rate increases, sometimes to $\sim 10^{-1}$ TDEs per year. This “burst” of TDE flares can provide an electromagnetic counterpart to low frequency GW signals, localizing sources and measuring cosmological parameters. Millions of years later, recoiled SMBHs wandering through their host galaxies will produce spatially offset TDEs at a rate which is likely detectable with the *LSST*; this is the subject of the fourth chapter.

In the fifth chapter, we present another original research paper, showing that standard estimates for $\Delta\epsilon$, the energy spread of TDE debris, are wrong, sometimes by orders of magnitude. Correcting this error reduces the observability of many TDEs. We introduce a new analytic model for tidal disruption, calculate the dependence of $\Delta\epsilon$ on stellar spin, estimate general relativistic corrections to $\Delta\epsilon$, and quantify the GW signal generated from tidal compression.

The seventh chapter surveys past work on the importance of general relativistic effects for TDEs, describing the ways in which general relativity can modify TDE rates, the tidal disruption process, and the formation of accretion disks. Although this chapter primarily summarizes past research in the literature, it concludes with a brief summary of original, numerical research on how relativity can mediate debris circularization. The eighth chapter introduces the final original work of my thesis. In it we show that TDE light curves can constrain or measure SMBH spins, as Lense-Thirring torques produce quasiperiodic variability in disk emission. Precession of a relativistic jet could also measure SMBH spin, and we apply our model to the relativistic Swift J1644+57 TDE.

Finally, the ninth chapter offers concluding remarks, and thoughts on future directions for theoretical and observational development of this exciting subject.

The Tidal Disruption of Stars by Supermassive Black
Holes

An Analytic Approach

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