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Tidal disruption events from different kinds of astrophysical objects: a preliminary analysis

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Abstract. Tidal disruption events are a powerful tool to study quiescent massive black holes residing in the centre of galaxies. Occasionally, astrophysical objects such as stars, planets and smaller bodies are captured and tidally disrupted by the massive black hole, giving rise to a luminous flare. A detailed study of disruption parameters and the emitted radiation can give important insights on the black hole and its surroundings.

Keywords. black hole physics, Galaxy: nucleus, methods: numerical

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1. Introduction

Tidal disruption events (TDEs) are useful tools to study quiescent massive black holes (MBHs). In the last two decades, the interest for these astrophysical phenomena has grown due to the availability of more observational data (for a recent review see Komossa 2015). Furthermore, with the growing power of computers, hydrodynamical simulations of TDEs are accessible, providing new means to test theoretical models and to model observational data. Even though a lot of work has been done on TDEs, there are important aspects which are not yet fully understood, for example, the main mechanisms governing the circularization process of tidal debris, how is energy released and where are the radio, optical/UV and X-ray radiations produced (for a review on recent developments see Lodato *et al.* 2015; Krolik *et al.* 2016).

MBHs can be found in the centre of galaxies. The nearest MBH is the one residing in our Galactic Centre (GC), which, thanks to its proximity, provides us the possibility to study the MBH environment in detail. In addition, the GC environment harbours a variety of astrophysical objects (Alexander 2005). While the study of the bound debris of a TDE can give us direct information regarding the disrupted object and the MBH, the unbound debris can provide us data about the surrounding environment. In this respect, we're investigating possible outcomes of the tidal disruption of stars, planets and asteroids. The main goal is to highlight the different physical parameters governing the tidal disruptions and obtain a better understanding of the MBH in the GC.

2. Theory and motivation

A star is disrupted when it is brought too close to a MBH: when the tidal forces overcome the star's self-gravity, the star is torn apart. In the process, about half of the stellar material is unbound and expelled, while the other half is bound and returns to the MBH as a debris stream (Rees 1988). The latter then accretes and produces a luminous flare, which carries information on the MBH and stellar properties. TDEs are particularly useful in the study of otherwise quiescent MBHs.

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Specific conditions need to be satisfied in order to tidally disrupt an object. In the Newtonian picture, if a star of mass m_* and radius r_* orbits a MBH of mass m_{BH} with orbital pericentre r_p smaller than the tidal radius $r_t = r_*(m_{BH}/m_*)^{1/3}$, we may expect the tidal disruption of the star. However, there is a critical mass of the BH above which the star crosses the horizon before being disrupted: for example, a white dwarf can be disrupted by a $\sim 10^3 M_\odot$ BH, but is swallowed by a $\sim 10^6 M_\odot$ BH, which instead can disrupt solar-type stars. In the relativistic picture, also the BH spin, which affects the radius of the innermost stable circular orbit, must be taken into account.

The study of the tidal disruption of objects by a MBH can provide information about the BH itself and the surroundings. For instance, it has been shown that the final accretion of dense objects with mass of the order of 10^{20} g onto the Sgr A* BH can explain the flares detected at various wavelengths, which are characterised by short duration and quasi periodic oscillations (Kostić *et al.* 2009). Furthermore, there is a debate regarding the nature of the object called G2 (i.e. a gas cloud, a planetary embryo). In this respect, it has been considered that planets initially bound to S-stars could be captured on eccentric orbits by the MBH and their orbital properties may be compatible with those of G2 (Trani *et al.* 2016). With these considerations in mind, we want to investigate the tidal disruption parameters of different astrophysical objects such as stars, planets and asteroids.

3. On going work and future perspectives

We are performing simulations using a smoothed particle hydrodynamics (SPH) code, where an object is represented by a set of particles. When considering a star, the initial conditions are obtained by placing the SPH particles within a close packing sphere configuration according to a polytropic model. A similar procedure is used for a planet. After checking the stability of the object, it is set on an orbit which brings it within the tidal radius of the BH in order to be disrupted.

We start investigating the tidal disruption parameters of relatively simple objects. We plan to follow the evolution of their debris and to build the expected light curves using ray tracing codes. We will then extend the study to include increasingly detailed objects. For example, given $m_{BH} = 10^6 M_\odot$, we can study first the disruption of solar-type stars with hydrodynamics, then the evolution of the star's magnetic field during the disruptive process with magnetohydrodynamics (Guillochon *et al.* 2016); for planets we have to take into account the mantle+core structure, and the possibility that they are still bound to the parent star. In addition, we can consider relativistic effects affecting the disruption due to a spinning MBH. This work's first aim is to shed light on the dynamics and the evolution of the objects near the MBH in the GC.

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