A Deep, Archival Search for Tidal Disruption Events and Rate Constraints

SURF Interim Report I

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Background and Motivation

Tidal Disruption Events (TDEs) are astronomical phenomena in which a star gets shredded and torn due the tidal forces exerted by a supermassive black hole (SMBH) due to the star getting closer to it than the tidal radius. The resulting multiwavelength radiation causes flares lasting months to years on the time-domain[1]. These flares help detect, observe and study quiescent black holes in distant galaxies.

However, there are several unanswered questions regarding TDEs. The rates of TDEs are yet to be constrained. Also correlations with host galaxy properties, and the factors driving TDEs are also yet to be studied. On top of these, the difficulty in observing TDEs, especially the low luminous ones, suggests that several TDEs might not have been detected in the past[2, 3].

An observed flare could have its origin in an Active Galactic Nucleus (AGN) or a quiescent blackhole. In a quiescent blackhole, the cause is most likely a TDE, however, in an AGN there are several other explanations: supernovae, microlensing, blackhole mergers. Also, AGN light curves tend to exhibit intrinsic baseline variability, as compared to the almost unchanging baselines of a quiescent blackhole. This suggests that TDEs occurring in AGN are less likely to be detected and that there is a possibility that the AGN flares detected in the past could be attributed to TDEs. Therefore it is necessary to study flares of all types in general to get a full understanding of TDEs and their flares.

In this project we aim to address these problems by using re-processed archival data from the Zwicky Transient Facility (ZTF). Utilizing methods used in the past along with our novel approach towards the problem, we are currently working on developing software that can detect and classify flares purely from light curves. At its completion, we aim to use the software to build a catalog of flares, regardless of whether they are due to a TDE or not, from the ZTF data. We will constrain parameters, obtained from distributions of the catalog and those from previous studies, so as to segregate TDE flares from the catalog to obtain a large collection of TDEs, including the faintest detected ones, and study them in depth to further understand the physics surrounding TDEs. The detailed explanations of the work done so far are discussed below.

Approach

The aim for the first quarter of the project is to develop a software to reliably detect flares utilizing light curves from ZTF. The steps we have implemented so far are explained below in detail, along with the specifics of the implementation and the problems solved.

1. Interpolation of light-curves

Due to the irregularities in the cadence in the archival data, it was necessary to interpolate missing data points. This would assist in obtaining a contiguous set of predicted data points with which we can make decisions about the light-curve. Based on several previous papers[4], we decided to implement Gaussian process regression[5] to interpolate the light-curves. We implemented it with the 3/2-Matern kernel, and obtained predictions with a cadence of 2 days. This resulted in convincing continuous light-curves, along with predicted errors.

2. Characterization of flares

It is necessary to define ‘flares’ before we detect them from light-curves. The definition adopted by several papers in the past vary, depending on the context[2,4,6]. The characterization majorly depends on the type of flares expected to be detected (AGN, quasars, TDEs). As per our goals for the first part of the project, to include all flares regardless of their nature, we aim to derive a more inclusive characterization of flares. We have decided to use the following parameters of light-curves for the classification of flares.

1. No. of data points contributing to the flare.
2. Time period: duration of flare, duration of rising, duration of falling.
3. Peak magnitudes.
4. Peak and median amplitudes above the baseline activity.
5. Post peak change in colors.
6. Confidence levels defined by a running average function.

We are yet to finalize the constraints on these parameters. However, we have implemented functionalities in the software to be able to measure these parameters from the given light-curve and its Gaussian progress regression. We have planned to finalize the numbers based on previous work and visual inspection in the following weeks.

3. Software implementation

We are developing a Python software to process the raw data obtained from ZTF. As of now, the program is capable of:

1. Reading and parsing ZTF data to produce the corresponding light-curve data
2. Implement Gaussian process regression on the data to interpolate between missing data points and to predict on a 2-day cadence with errors.
3. Implement confidence level based running average function and detect the rise and fall of a flare for a specified threshold confidence level.
4. Find the parameters of a flare mentioned in the ‘characterization of flares’ section.
5. Make and store plots of light curves indicating flares detected from (3).

Challenges

A technical challenge faced so far is the high time consumption for processing data and to implement regression on them. As we move forward, we plan to store processed data as separate files for easy access in the future. Also with the completion of software, it might be required to use a high-powered computer to process higher volumes of data.

Another challenge is deciding on parameter ranges for flare selection. As explained in the previous section, we are yet to finalize these numbers and make sure that they are as inclusive as possible. We plan to refer to previous work and visually inspect several samples to derive the final sets of parameters.

References

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