

Prospects for detecting stellar tidal disruptions with LOFAR

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A star that passes too close to a super-massive black hole is shredded and an electromagnetic flare is emitted as the bound fraction of the stellar debris falls back onto the black hole. Candidate examples of such accretion flares have been observed at optical to X-ray frequencies. If a jet is launched from the accretion disk, tidal flares might be detectable at radio frequencies too. Here we estimate the luminosity of this jet using the observed properties of a sample of (candidate) tidal flares that have been found in SDSS and GALEX data. The scaling between disk and jet luminosity as observed for radio-loud quasars is used to predict a jet flux of ~ 0.1 mJy. This flux is well observable with LOFAR and other radio telescopes.

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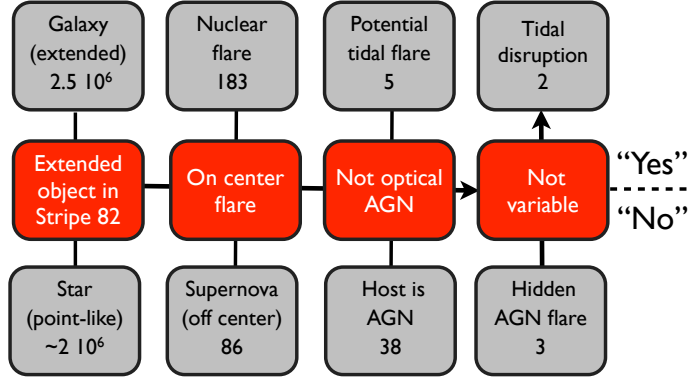


Figure 1: Flow chart summarizing the successful search for tidal disruption flares in SDSS multi-epoch imaging data (Stripe 82) [1].

1. Introduction

When a star passes too close to a super-massive black hole, the tidal pull exceeds the self-gravity, and the star is disrupted. For black holes with mass $\lesssim 10^8 M_\odot$, the tidal disruption radius lies outside the Schwarzschild radius and an electromagnetic flare can be observed as the debris falls back onto the black hole [2, 3]. These flares are an important probe to black holes in quiescent galaxies; a large sample will enable a census of black holes including otherwise undetectable mass ranges.

A number of (candidate) examples of tidal disruption events (TDE) have been identified in UV and X-ray surveys [4, 5, 6, 7, 8]. Recently, two TDEs have been identified using optical data [1]. In the following section we will briefly summarize this work. In section 3 we use the observed properties of these flares to estimate the luminosity of jets from tidal disruptions.

2. Tidal disruption flares found in optical data

Two TDE have been found in $\sim 300 \text{ deg}^2$ of multi-epoch imaging data of the Sloan Digital Sky Survey (SDSS), also known as “Stripe 82” [10, 11]. This dataset contains over 2 million galaxies, each observed about 70 times over a nine year baseline. This rather large sample of galaxies, with many having spectra, enables flares to be classified into well-defined categories. Supernovae are identified by being significantly off-center from their host. Flares from active galactic nuclei

ID	T ($\times 10^4 K$)	L_g ($\times 10^{43} \text{ erg}$)	L_{BB} ($\times 10^{43} \text{ erg}$)	z
TDE1	2.4	0.5	3	0.138
TDE2	1.8	4.1	10	0.252
D1-9	5	0.2	14	0.326

Table 1: Observed properties of TDE1,2 identified in SDSS data [1]. We also show D1-9, a (candidate) TDE discovered in *GALEX* [9]. Columns list temperature, g -band luminosity, black body luminosity and redshift.

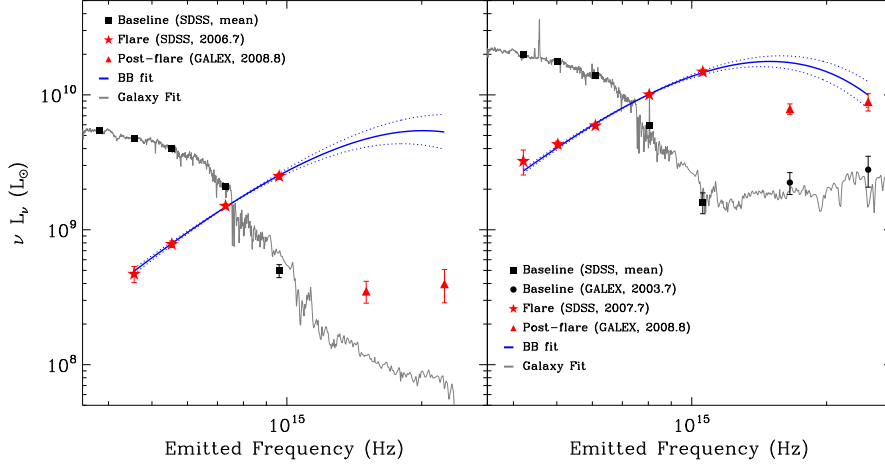


Figure 2: The SED of the two tidal flares discovered in SDSS data [1]. The optical baseline flux of the host is shown (black squares) with the best-fit combination of eigen spectra (grey line) [12]. The flux of the flare in the difference image (red stars) is well-fit by a black body (blue, with dotted lines indicating the 1- σ uncertainty)

(AGN) can be identified by the additional variability they display in the seasons beyond the main flare. The search pipeline of [1] is summarized in Fig. 1. The spectral energy distributions (SED) of the two TDE (dubbed “TDE1” and “TDE2”) are shown in Fig. 2. In Table 1 we summarize the observed properties of TDE1,2.

3. Jet prediction

As the debris of the disrupted star is accreted, a jet may be launched. To estimate the luminosity of this jet, we use the jet-disk relation that has been observed for radio-loud and radio-quiet quasars [13]. Here we take the expected radio flux of the radio cores of radio-loud quasar jets, which is applicable to at least 10% of the black holes. The assumed radio core spectrum we take is flat and steady and we note that individual flares might be more luminous and show peaked radio spectra that travel through frequency. We conservatively obtain the disk luminosity from the black body (BB) luminosity of the three TDE presented in Table 1. We find that for these three flares, the predicted jet flux is about 0.4 mJy. For comparison we also consider a “maximal” scenario for the

	based on observed BB luminosity	maximal
F_{jet}	0.4 mJy	1–7 mJy
$t_{\text{obs}}(\tau = 1)$	0.5–1 yr	2 yr
$t_{\text{int}}(3\sigma)$	3 h	1–20 min

Table 2: Predicted jet properties of the three TDE considered (Table 1) for two different scenarios (see section 3). These results were calculated using an angle between the jet and observer of 30deg and a jet Lorentz factor of 5. The first row lists the observed flux of the jet, the second row lists the time the jet becomes optically thick at 120 MHz, and the last row lists the integration time for a 3- σ detection with LOFAR.

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disk luminosity. We assume that $0.5 M_{\odot}$, the bound material from the disruption, is accreted in one year and the disk radiates at 1% efficiency. In this case, the jet luminosity equals $3 \times 10^{30} \text{ erg s}^{-1}$ for any TDE and the observed flux depends on the distance only. In Table 2 these findings are summarized.

4. Discussion

We have presented an estimate of the jet flux from known tidal flares of $\sim 0.1 \text{ mJy}$. This flux is easily accessible for most radio observatories; follow-up observations of TDE at radio frequencies will allow us to test the hypothesis that jets are launched during the accretion of the disrupted star. The potential for detecting TDE in a multi-epoch radio survey without higher frequencies serving as a trigger will be discussed elsewhere.

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